DEEP WELL DRILLING

The Principles and Practices of Deep Well Drilling and a Hand Book of Useful Information for the Well Driller

By

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To the drillers of the United States and of Canada, the men who have developed modern practices of well drilling at home and abroad, this volume is respectfully dedicated.

PREFACE

Well drilling is an ancient craft, although comparatively a modern industry. Deep well drilling as practiced today began with the drilling of Drake's first oil well at Titusville, Pa., in 1859. The business of drilling deep wells for petroleum, stimulated by the wonderful development of the internal combustion engine, has since spread to many parts of the world and has developed into one of the foremost industries of the United States, requiring the services of an army of experienced drillers. The search for petroleum is destined to lead the driller to the uttermost parts of the earth. These men learn both the theory and the practice of their craft by working in the derrick. Several schools now offer courses in petroleum technology and the University of California has a course in well drilling methods. It is to be hoped that some of our universities and technical schools may add to their curricula a complete course in deep well engineering. For the drilling of a well 5,000 feet deep, or drilling in a foreign country where the geological formations may not be known are both engineering undertakings. Although rule of thumb methods have, to a large degree, been followed by the well driller, yet his work is beset by many difficulties and unforeseen obstacles that are often overcome only by his own ingenuity and resourcefulness.

There are several valuable technical works covering, in a general way, the different branches of the petroleum industry or descriptive of drilling practices in certain localities, also during the past few years the U. S. Bureau of Mines has performed an admirable service in studying the problems of the driller and at frequent intervals publishing technical papers covering various phases of the subject. However, so few books have appeared that describe in detail modern well drilling practices, that the author was led to attempt this work.

The different well drilling methods include the cable, or percussion, pole tool, hydraulic rotary, core drill and hydraulic jetting. In some localities the combination cable and hydraulic rotary system is employed.

Geology plays an important part in well drilling and a study of the rock formation and stratification, in the locality where the well is to be drilled, is necessary to determine the type of drilling outfit best adapted to the purpose. For drilling hard sandstones and limestones the cable tool outfit is suitable equipment, while soft formations are more successfully penetrated with the rotary outfit. In localities where soft formations and hard rock alternate, a combination cable and hydraulic rotary outfit may be the best equipment. The author has undertaken in this volume to cover the processes of drilling wells by the two methods now most generally used: the cable tool and the hydraulic rotary, including the building of the derrick, drilling, handling casing, fishing for lost tools and the completion of the well according to the best practice of present day expert drillers.

Specifications here shown of material for building the several types of derricks and for complete outfits of drilling tools have been carefully worked out and are believed to be accurate according to modern practice.

Different fields present their own drilling problems. It is obviously impossible within the limits of a single volume to treat in detail the drilling peculiarities of every field, but it has been the aim of the author to cover the whole subject as completely as possible in a general way.

The author hopes that this book, the work at odd moments of many years, may find a place both as a guide to the student or the inexperienced and as a handbook of information and reference for the practical driller, and he asks the reader's indulgence for any errors or omissions.

WALTER H. JEFFERY.

Toledo, Ohio, March 3, 1921.

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CHAPTER I

GEOLOGY — ORIGIN OF PETROLEUM AND NATURAL GAS—BIBLIOGRAPHY

Petroleum, natural gas and artesian water occur in many of the stratified rocks forming the earth's crust. The thickness of these strata varies in different localities. In California the sedimentary rocks from the Quaternary to the granites and metamorphics lie in massive beds, aggregating a thickness of more than 25,000 feet. In Northern Ohio, where the more recent formations are absent, the Trenton limestone, lying at nearly the base of the one hundred or more producing formations, is reached at depths of 1,200 to 1,500 feet from the surface. A glance at the accompanying chart of producing horizons in North America will illustrate this.

The older the formation, for example the Trenton limestone of the Ordovician age, the harder will the rocks be found. Hard limestones, while they cannot be drilled rapidly, present few drilling difficulties. The rocks of later periods, as the shales and sandstone of Wyoming and California of Cretaceous and Tertiary age, are usually soft and caving and must be drilled by a process of under-reaming. The more recent alluvial deposits of the Gulf Coastal Plain and some parts of California and Mexico can only be successfully penetrated by the rotary system. Thus a study of the geological formations in the locality to be drilled is essential to determine the type of drilling outfit best suited to the work.

The United States Geological Survey and the Canadian Geological Survey have studied and reported upon large areas of the North American Continent, and in the United States many of the state geologists have much valuable data upon the stratified rocks of their respective states. When, therefore, it is desired to drill in localities where doubt may exist regarding the nature of the formations to be penetrated, it would be well to consult the geological publications reporting on the region to be prospected. The authorities are usually glad to furnish such information if it is a matter of record, otherwise to offer valuable suggestions.

Surface indications of oil or gas occur in but few localities. In broken or mountainous regions, as in Wyoming, an occasional oil seepage is found, and in California there are many such seepages. In Mexico asphalt springs occur, and in the Island of Trinidad we have the famous pitch lake. Along the Athabasca River in Northern Alberta for a distance of several miles the so-called tar sands crop out and asphalt oil seeps from them. At one point on this river, where it flows over a fault line, escaping natural gas forms many bubbles on the surface of the water. Yet considerable drilling has been done in that locality without developing a paying oil field. Oil sands sometimes are located where they crop out or are exposed, due to erosion, the folding of the structure, or to mountain uplift. Oil and gas fields usually are located by searching for geological structures favorable for the accumulation of these deposits.

ANTICLINAL THEORY FOR ACCUMULATION OF OIL AND GAS

The basis of the anticlinal theory is that oil and gas, being lighter than water, naturally find their way to the highest point in the water bearing stratum in which they may be present. Thus in drilling along the axis of an anticline or on the crest of a dome, gas may be found but no oil. Lower down on the dome or on the flanks of the anticline, oil may occur and little or no gas, while near the base of the anticline or dome, or in the syncline (the reverse structure of the anticline), water may be encountered, with usually no trace of oil or gas.

The anticline is an arch or fold in the stratified rocks that form the earth's crust, (See Fig. No. 1. There are several types of the arch or fold, the most common of which are the anticline, the dome and the anticlinal dome. The anticline is a long fold with the dips of its sides inclining away from a line called the axis. Thus in describing an anticline geologists use the terms "strike" and "dip"; the strike being the general direction along the crest or axis and the dip the sloping away on either side from the axis. The dome is, as its name implies, a domelike uplift in the stratum,

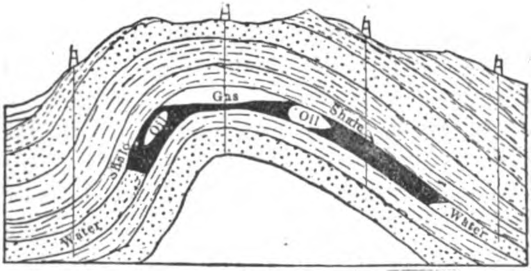


Fig. 1. Anticline *

standing alone, with the dip sloping away on all sides from the crest. Anticlinal domes sometimes occur at intervals along the top of a main anticlinal fold. Such domes are common in Oklahoma, Wyoming and California.

Syncline.—The syncline is the reverse of the anticline and, while usually unfavorable for the accumulation of oil, yet oil has been found in them.

Synclines, that are productive of oil, usually are not water bear-

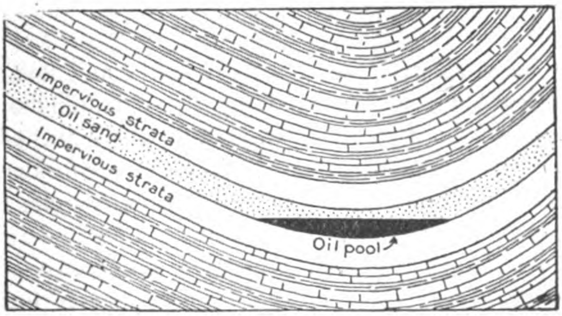


Fig 2. Syncline

ing and, due to the absence of water pressure, the direction of the oil is reversed from that in the anticline and by gravity it has drained into the lowest point or trough of the structure. Oil has

* Illustration after Dorsey Hager.

been found on the flanks of a syncline where the basin is filled with water.

Oil in commercial quantity has beeen found in synclines in shale formations above the regular oil bearing formation, probably forced there through fissures in the rocks. This condition has been developed in the syncline outside the structure of the Salt Creek field of Wyoming. In the Coalinga, California, oil field, oil occurs in both the syncline and the anticline.

Monocline.—The monocline is a structure whose dip is in one direction and where the oil bearing formation may rise to the surface. Oil occurring in commercial quantity in monoclines

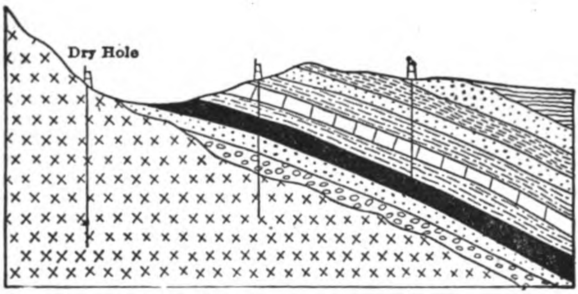


Fig. 3. Monocline *

where the oil sands crop out is usually heavy and forms asphalt beds that seal the outcrop, confining the remaining oil. Light paraffine oil would in most cases escape where the oil bearing sand was exposed, thus draining the sand for a considerable area in proximity to the outcrop. The well location should, therefore, be at a distance from the outcrop.

Near Barranquilla, Colombia, there are numerous seepages of oil and natural gas. One of these seepages has formed a large mound of asphalt, locally named the "big Volcan," yet several wells drilled within a few miles of this surface showing failed to find oil in paying quantity.

Terrace.—Commercially profitable oil pools are sometimes found on terraces. The terrace may be a horizontal bench, ex-

* Illustration after Dorsey Hager.

tending along a gentle slope, or a locality where the dip of an anticline becomes more nearly flat.

In addition to the structures above described, oil is often found

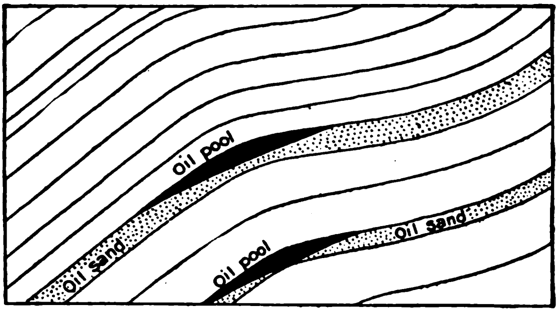


Fig. 4. Terrace

around volcanic necks or chimneys and in saline domes. The top, or on the flank near the top, of an anticline or a dome, however, is the best location for a test well.

The anticline and the dome are sometimes found in close proximity to each other. The accompanying plate * illustrates this condition where the Lamb anticline and the Torchlight dome occur in the Big Horn Basin of Wyoming. The anticline in this instance is a small one, extending over only a few sections. There are many long anticlines; for example, the Preston anticline along the Red River, crossing Grayson and Fannin Counties, Texas, and Bryan and Marshall Counties, Oklahoma, and extending for a distance of over forty miles. The dome usually is a small round structure, as shown on the chart.

The sub-surface contour lines on this chart show numbers indicating the distance at that point to the top of the Greybull sand, above or below sea level. In other words, if it were possible for one to follow any one of these contour lines on the ground, he would always be at exactly the same elevation. Referring again to the chart, it will be observed that the elevations reach from 0 to 2,800 feet above sea level and from 0 to 600 feet below sea

* Footnote:
Reproduction of map in the U. S. Geological Survey Bulletin No. 656, by Charles T. Lupton.

level. Putting it another way, the total elevation as shown on this chart would be the sum of the distances below and above sea level or 3,400 feet.

Faults.—A fault is a displacement or a slip in the strata, the result of which may be the breaking off of an oil bearing formation and abutting of its face against an impervious bed. This may either cause the oil to escape to the surface, or if the contact between the broken off oil bearing bed and the impervious rock face is sufficiently close, it may seal up the oil. Thus, on one side

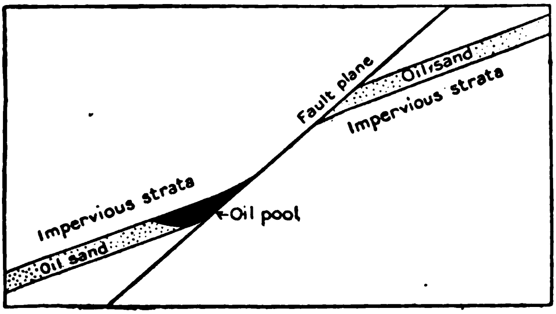
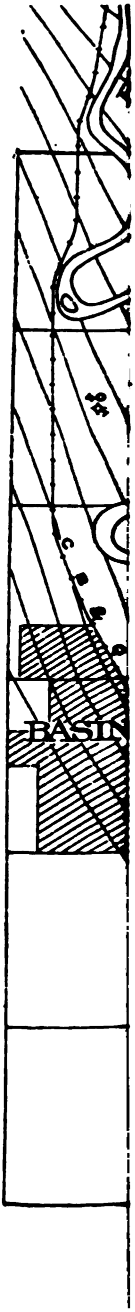


Fig. 5. Fault

of the fault line good wells would be secured, while on the other side, the sand would be barren. (See Fig. No. 5.) The oil field of the Puente Hills district of southern California is a good example of oil accumulation along faults.

Although the structures here described are favorable for the accumulation of oil, yet it does not follow that all such structures may prove to be productive. One or more necessary elements may be lacking. The sand may be too hard or close, or it may be water bearing. Also the oil or gas present in past ages may have long since escaped for want of an impervious shale or other confining "cap rock," so called.

The procedure followed by geologists in seeking for and in locating favorable structure for the accumulation of oil and gas, and in locating well sites will not here be discussed. The author is not a professional geologist, and for such geological information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respectfully refers his readers to the following works on the subject:

Economic Geology, by Frederick G. Clapp.

Oil Finding, by E. H. Cunningham-Craig.

Practical Geology, by Dorsey Hager.

Popular Oil Geology, by Victor Zeigler.

Publications of U. S. Geological Survey.

Geology is an applied science with reference to the oil and gas industry and has made good in a large way in the development of the oil fields of the United States. Recently Mr. George Otis Smith, Director of the U. S. Geological Survey, in an address before the Association of Petroleum Geologists at Dallas, Texas,* stated that at his direction a test was made of the measure of agreement between the structure mapping and the results of the drill in a number of townships of the Osage lands with the result that the geologist, when his work had been tested by the drill, had been right 87 per cent of the time.

Those undertaking the development of new fields, or selecting the location for a "wild cat" well, would do well to secure a competent geologist to assist them.

ROCK FORMATIONS

It is essential that the well driller have a working knowledge of rock formations. He should be able to identify the shales and the conglomerates, the varying grades and colors of the sandstones, the limestones and dolomites, and the slates. He should recognize also the igneous or crystalline rocks such as granites, quartz, lava, etc. Oil and gas and usually water are found only in the porous stratified formations. If, therefore, the driller should find himself working in granite or other igneous rocks (intrusions of igneous rocks in stratified formations excepted), he may as well abandon further drilling. As an exception to prove the rule: oil in commercial quantity was found in a few wells drilled in Placerita Canyon, Los Angeles County, California, where the oil occurred in the granite, as a result of the granite being faulted against

* Southwestern Oil Journal, Ft. Worth, Texas, March 26, 1920.

sedimentary rocks from which the oil had seeped into the broken granite.

POROSITY AND SATURATION OF OIL SANDS

The dolomitic limestones, due to solution, dolomitization or fracturing, are the most porous of the many formations carrying oil, their percentages of voids in some cases running as high as 33 1/3 per cent. Next in porosity are the conglomerates and loose coarse sands, similar to those found in the Coastal Plain oil fields in Texas and in California, which contain from 20 to 30 per cent. voids. The sandstones are variable, some more porous than others, but usually their voids will not exceed 15 to 20 per cent. Due perhaps to the fact that in nearly all beds of dolomite and limestone there are places where the rock is exceedingly hard and close, the sandstones are more favorably regarded as oil producing formations (for example, the Wall Creek Sandstones of Wyoming are well saturated with oil and rank with the best oil producing sands of this country). Shales are lowest in the scale and although they sometimes contain oil they are not favorable reservoirs, their porosity averaging not more than five per cent.

Oil Content of Sand.—A limestone or sandstone with 15 per cent. of voids and thoroughly saturated would contain approximately 15 per cent. of its volume in oil, or 15 cubic feet of oil per hundred feet (7.5 gallons per cubic foot). Thus an oil sand 100 feet thick, covering the space of one acre (43,560 square feet) would contain $\frac{43{,}560 \times 7.5 \times 15}{42 \text{ gals.} = 1 \text{ Bbl.}} = 116{,}678$ barrels.

The United States Government uses 10 per cent. as an average saturation of oil sands. The figures usually employed in estimating the oil content of sands are one gallon per cubic foot of sand, approximating 1,000 barrels per acre foot of sand. This estimate must be regarded as an average only, and may not be accurate when applied to specific fields or properties where the saturation factor might be as high as 25 per cent. or as low as 5 per cent.

The production curve method of approximating the oil content of sands is much more accurate as applied to individual wells, properties or localities. The U. S. Bureau of Mines, in a recent publication, deals at length in an able manner with this subject for many of the oil fields of this country. (a)

Estimates of the proportion of oil that is left in the sands, and that is not recoverable, are from 10 to 75 per cent. and vary greatly according to locality and to different authorities. J. O. Lewis estimates that the average recovery factors for the fields of the United States are from 10 to 20 per cent. (b) A recovery factor of 50 per cent. is often used, but this is only an approximation and probably is too high as an average for all fields.

(a) U. S. Bureau of Mines, Bulletin No. 177, The decline and ultimate production of oil wells, with notes on the valuation of oil properties, by Carl H. Beal, pp. 9-12.

(b) U. S. Bureau of Mines Bulletin No. 148, Oil recovery methods, J. O. Lewis, pp. 25-32.

Footnote: Ref. "Practical Oil Geology," by Dorsey Hager.

GEOLOGICAL FORMATIONS OR "SANDS" IN WHICH OIL AND GAS ARE FOUND IN THE UNITED STATES AND CANADA

Compiled from reports of the United States Geological Survey, of the Geological Surveys of several of the States and from the original chart of sands below Pittsburgh coal by the late F. H. Oliphant.

This chart was prepared with a view of showing the various oil and gas sands with reference to their age and position in the stratified rocks forming the earth's crust. Owing to the fact that some of the oil fields have not been given thorough geological study and also that geologists are not yet certain regarding the age of several of the formations, this chart is approximated. Dotted lines indicate points at which uncertainty exists.

Era	Geological System		Geological Series or Group	Producing Formation or Sand	Character	Thickness, Feet	Locality Where Productive
Cenozoic	Quaternary		Recent Series and Pleistocene				
	Tertiary		Pliocene	Sands overlying cores of salt and gypsum	Calcareous sands		In some salt domes of Gulf Coast of Texas and Louisiana
				Dewitt	Calcareous sands	1200–1500	Gulf Coast
				Fernando Group	Conglomerate sandstone, gravel and sand	1000	California
				Etchegoin Formation	Buff quartsoze sandstone	300–1000	Coalinga, McKittrick-Sunset, Santa Clara River & Los Angeles, California
		Miocene Series	Upper Miocene	Fleming Clay	Calcareous Clay	200–500	Gulf Coast
		Miocene Series	Middle Miocene and Lower Miocene	Monterey Group including Modelo and Puente Formations, Salinas Shale and Vaqueros Formation	Thinly laminated shale with layers of sandstone. Coarse brown sandstone	100-1800	Santa Maria, Summerland, Los Angeles, Puente District, Coalinga, McKittrick-Sunset and Santa Clara River, Cal.
			Oligocene	Catahoula	Blue sandstone and green clay	250–600	Gulf Coast Deep Sand

GEOLOGICAL FORMATIONS OR "SANDS" IN WHICH OIL AND GAS ARE FOUND IN THE UNITED STATES AND CANADA—Continued

Era	Geological System	Geological Series or Group	Producing Formation or Sand	Character	Thickness, Feet	Locality Where Productive
Cenozoic	Tertiary	Oligocene	White River	Clay, conglomerates and sandstone	1000	Douglas, Wyoming
			Sespe formation	Brown sandstone with beds of conglomerate	3000	Santa Clara River, and Simi Valley, Calif.
		Eocene	Yequa formation	Green clays with lenses of sand	375–750	Gonzeles, Webb and Zapata Counties, Tex. (gas)
			Cook Mountain (Claiborne)	Marls and green sands	400	Oil City, Tex. (oil)
			Tejon formation	Brown sandstone and conglomerate and gray shale	2000–3500	Coalinga, Calif.
			Meganos formation			Simi Valley, Calif.
			Wasatch sand	Yellow sandstone and gray shale	2000	Spring Valley, Fossil, Hilliard and Labarge, Wyo.
Mesozoic	Cretaceous	Upper Cretaceous	Chico formation	Massive buff sandstone with layers of gray shale	4000	Coalinga, Calif.
			Navarro formation	Clays, shales, thin beds sandstone	800	Corsicana, Tex.
			Teapot sandstone	Buff sandstone	50–1000	Wyoming
			Parkman sandstone	Buff sandstone	50–1000	Wyoming
			Pierre shales	Gray shales, buff sandstones, thin shelly lime	500–1000	Florence, Colorado, Elk Basin and Cody, Wyoming
			Hygiene	Light gray to greenish gray sandstone	100–250	Boulder, Colorado

GEOLOGICAL FORMATIONS OR "SANDS" IN WHICH OIL AND GAS ARE FOUND IN THE UNITED STATES AND CANADA—Continued

Era	Geological System	Geological Series or Group		Producing Formation or Sand	Character	Thickness, Feet	Locality Where Productive
Mesozoic	Cretaceous	Upper Cretaceous		Shannon sand	Buff sandstone	50	Salt Creek, Big Muddy and Pilot Butte, Wyo.
				Virgelle sandstone	Coarse gray sandstone interbedded with shale	200–380	Montana and Alberta, Can. (gas)
				Niobrara	Gray and buff shales, lower part sandy	200–900	Powder River, Wyo. and Boulder, Col.
			Frontier Group	Upper Wall Creek sandstone (Lentil of Benton shale)	Buff to white sandstone	100–125	Salt Creek and Big Muddy, Wyo.
				Lower Wall Creek sandstone	White quartzite sandstone	20–30	Salt Creek and Big Muddy, Wyo.
				Frontier formation	Gray, yellow, buff and brown sandstones, with thin beds of conglomerate and chert pebbles	450–650	Spring Valley, Byron, Cody, Grass Creek and Elk Basin, Wyo.
				Torchlight sand		15–67	Big Horn Basin, Wyoming
				Peay sand		50	Big Horn Basin, Wyoming
				Aspen formation	Gray and black shale with beds of gray sandstone	1200–1800	Spring Valley, Wyo.
				Mowry shale (Kimball sand)	Gray slaty shale with beds of sandstone	200–300	Basin, Greybull, Lander and Moorcroft, Wyoming

GEOLOGICAL FORMATIONS OR "SANDS" IN WHICH OIL AND GAS ARE FOUND IN THE UNITED STATES AND CANADA—Continued

Era	Geological System	Geological Series or Group	Producing Formation or Sand	Character	Thickness, Feet	Locality Where Productive
Mesozoic	Cretaceous	Upper Cretaceous	Thermopolis shale	Dark shale with beds of rusty sandstone	400–800	Oregon Basin and Cody, Wyoming
			First and second muddy sands (near base of Thermopolis shale)	Shale with beds of buff sandstone		Lance Creek and Rock River, Wyo.
			Nacatoch sand	Gray to green sandstone with layers of clay	75–200	Shreveport, Caddo, De Soto and Red River, Louisiana, Mexia and Groesbeck, Texas (gas)
			Taylor marl	Bluish gray marl or clay with layers of calcareous sandstone	500–600	Corsicana,? Thrall,? and San Antonio,? Texas
			Annona (Austin chalk)	Gray to white chalky limestone with beds of sand	200–500	Caddo, La., San Antonio, Texas
			Eagle Ford shale (Blossom sand)	Soft sandstone with layers of clay	50–100	Caddo, La.
			Woodbine sand	Shaly clay and dark greenish sand	300–400	Louisiana, Texas
			Bear River	Shale with beds of buff sandstone	800–1500	Spring Valley, Wyo.
			Dakota sandstone	Gray sandstone	200–300	North Dakota, Wyoming, Montana, Alberta, Canada (gas)

GEOLOGICAL FORMATIONS OR "SANDS" IN WHICH OIL AND GAS ARE FOUND IN THE UNITED STATES AND CANADA—Continued

Era	Geological System	Geological Series or Group	Producing Formation or Sand	Character	Thickness, Feet	Locality Where Productive
Mesozoic	Cretaceous	Lower Cretaceous	Cloverly (Greybull sand)	Conglomerates with thin layers of sandstone	10–60	Greybull, Byron, Powder River and Douglas, Wyo.
			Trinity sand	Fine sand with lentils of sandy clay	400–700	Medill, Oklahoma, N. E. Texas
		Cretaceous?	Morrison	Variegated shale and sandstone	150–250	Cody and Powder River, Wyoming
	Jurassic		Sundance formation	Shale, limestone and sandstone	150	N. E. Wyoming
	Triassic	....	Chugwater formation	Red sandy shale, thin beds of sandstone and gypsum	1000	Lander, Wyoming
Paleozoic	Carboniferous	Permian Series	Albany (Wichita)	Limestone and shale	500	Electra, Texas
			"Red Beds"	White, buff and red sandstone	10–100	Healdton, Okla., Cotton and Stephens Counties, Okla. and Southern Utah
		....	Cisco	Shales, limestones, sandstones, coal	800	Petrolia and Ranger Texas
			Strawn	Sandstone and shale	900–3000	Palo Pinto Co., Electra and Ranger, Texas
	Pennsylvania Series	Upper Coal Measures	Embar formation	Light gray limestone, shale and chert	225	Lander, Wyoming
			Goodridge sand	Sandstone		Bluff, Utah

GEOLOGICAL FORMATIONS OR "SANDS" IN WHICH OIL AND GAS ARE FOUND IN THE UNITED STATES AND CANADA—Continued

Era	Geological System		Geological Series or Group	Producing Formation or Sand	Character	Thickness, Feet	Locality Where Productive	Approximate Depth below Pittsburgh Coal, Feet
Paleozoic	Carboniferous	Pennsylvania Series	Middle coal measures	Tensleep sandstone	Cross bedded quartz sandstone	50–200	Central Wyoming	
				Connelsville sand	Yellowish gray conglomeratic sandstone	25–50	West Virginia	40
				Morgantown sand	Fine grained gray sandstone	20–75	West Virginia	80
				Macksburg sandstone	Coarse gray sandstone	5–90	S. E. Ohio	200
			Lower coal measures	First Cow Run sand	Coarse, pebbly gray sandstone	8–35	S. W. Penna., S. E. Ohio and W. Virginia	320
				500 foot Macksburg sand	Soft sandstone and conglomerate	5–30	S. W. Penna., W. Va. and S. E. Ohio	450
				Second Cow Run sand	Coarse, white sandstone	40–85	S. W. Penna., W. Va. and S. E. Ohio	600
				Bridgeport sand	Conglomerate and sandstone	20–35	Bridgeport, Illinois	
				700 and 800 ft. Macksburg sands	Coarse gray sandstone	20–60	S. W. Penna., W. Va., S. E. Ohio and Ky.	850–925
			Pottsville group	Salt sands	White sandstone	25–175	S. W. Penna., W. Va., S. E. Ohio and Ky.	950–1080
				Ralston group (Hoy sand)	Red and gray sandstone	650	Garber, Okla.	
				Buxton sandsandstone	Sandstone and shale	700–1000	Ponca, Okla.	
				Musselman sand	Sandstone and shale	300–400	Cleveland, Okla.	
				Hogshooter lime	Limestone	100–150	Oklahoma	
				Layton sand	Soft gray sandstone	25–50	Oklahoma	
				Wayside sand	Brown sandstone	5–30	Kansas	

GEOLOGICAL FORMATIONS OR "SANDS" IN WHICH OIL AND GAS ARE FOUND IN THE UNITED STATES AND CANADA—Continued

Era	Geological System		Geological Series or Group		Producing Formation or Sand	Character	Thickness, Feet	Locality Where Productive	Approximate Depth below Pittsburgh Coal, Feet
Paleozoic	Carboniferous	Pennsylvania Series	Pottsville group		Cleveland sand	Sandstone	5–35	Kansas and Oklahoma	
					Peru sand	Brown sandstone	10–50	Kansas and Oklahoma	
					Fort Scott, Oswego or Wheeler sand	Brown limestone with layers of sandstone	75	Kansas and Oklahoma	
					Squirrel sand	Sandstone	10–138	Oklahoma	
					Skinner sand	Sandstone		Oklahoma	
					Varner sand	Sandstone	10–55	Augusta, Kan. deep?	
				Cherokee shales	Winslow formation			Muskogee, Oklahoma	
					Red Fork sand	Sandstone	20–50	Oklahoma	
					Bartlesville or Glenn sand	Gray to brown sandstone	25–200	Kansas and Oklahoma	
					Booch sand			S. E. Okla.	
					Tucker sand	Bluish green sandstone	25–100	Cushing, Okla.	
					Scott or Dutcher sand	Sandstone	15–35	Oklahoma	
					Buchanan sandstone	Conglomerate and sandstone	50–130	Casey and Robinson, Ill., and Princeton, Ind.	
			Bend Series		Gordon	Limestone and shale	350–400	Electra, Ranger, Tex.	
					McClesky	Limestone and shale		Ranger, Tex.	
					Burkburnett (deep)	Limestone and shale		Burkburnett, Tex.	
		Mississippi Series	Chester group		Mounds	Sandstone	20–50	Oklahoma	
					Benoist or Kirkwood sand	White sandstone	20–55	Robinson, Bridgeport and Sandoval, Ill., Oakland City, Ind.	
					McCloskey sand	Sandy limestone	10–25	Robinson and Bridgeport, Ill.	

GEOLOGICAL FORMATIONS OR "SANDS" IN WHICH OIL AND GAS ARE FOUND IN THE UNITED STATES AND CANADA—Continued

Era	Geological System	Geological Series or Group	Producing Formation or Sand	Character	Thickness, Feet	Locality Where Productive	Approximate Depth below Pittsburgh Coal, Feet
Paleozoic	Carboniferous (Mississippi Series)	Pocono group	Boone (Mississippi lime)	White limestone	200–400	Oklahoma	
			Big lime	Massive limestone with layers of sand	140	S. E. Ohio and W. Va.	1175
			Keener sandstone	White sandstone	40–90	S. E. Ohio and W. Va.	1275
			Big Injun sand Squaw sand	Coarse gray sandstone interbedded with gray to green shale	100–300	S. W. Penna., W. Va., S. E. Ohio and Ky.	1340 1425
			Wier sand	Gray sandstone	15–105	West Va.	1535
			Berea grit	Fine grained white to gray sandstone	5–170	S. W. Penna., W. Va., S. E. Ohio and Ky.	1700
			First, 100 ft. or Gantz sand	White to gray sandstone	50–100	W. Penna., W. Va. and S. E. Ohio	1850
			50 ft. sand	White to gray sandstone	30–50	W. Penna. and W. Va.	1885
			Second or 30 ft. sand	Soft pebbly sandstone	20–35	W. Penna. and W. Va.	2000
			Beaver Creek sand	Cherty limestone	10–30	Kentucky	
	Devonian	Upper Devonian	Stray or Bowlder sands	White to gray sandstone	10–50	W. Penna. and W. Va.	2050
			Third or Gordon sand	Soft white pebbly sandstone	1–75	W. Penna., W. Va. and Ohio	2130
			Fourth, fifth and sixth sands	Soft, white sandstones	5–30 each	S. W. Penna. and W. Va.	2200, 2260 & 2590
		Chemung Group	First, second and third Warren sands	Gray sandstones and shales	5–35 each	N. W. Penna.	2700, 2815 & 2900
			Speechly sand	Hard sandstone	1–85	N. W. Penna.	2
			Tiona sand	Hard sandstone	5–100	N. W. Penna.	3020

GEOLOGICAL FORMATIONS OR "SANDS" IN WHICH OIL AND GAS ARE FOUND IN THE UNITED STATES AND CANADA—Continued

Era	Geological System	Geological Series or Group	Producing Formation or Sand	Character	Thickness, Feet	Locality Where Productive	Approximate Depth below Pittsburgh Coal, Feet
Paleozoic	Devonian	Upper Devonian	Cherry Grove sand	Gray sandstone		N. W. Penna. and W. N. Y.	3150
		Lower Devonian	Bradford sand	Chocolate colored sandstone	10–150	N. W. Penna. and W. N. Y.	3460
			Elk Co. sands	Brown sandstone		N. W. Penna. and W. N. Y.	3650
			Kane sand	Sandstone		N. W. Penna. and W. N. Y.	3775
			Hamilton formation	Gray limestone and blue shales	200–350	Petrolia and Oil Springs, Ont.	5330
			Corniferous limestone (Onondaga)	Dark gray cherty limestone	15–200	N. E. and Central Ohio, W. N. Y., Ky. and Ontario	5625
	Silurian	Niagara Group	Oriskany sandstone	Fine grained cherty white sandstone	15–55	N. Y., S. Ind. and Ont.	5660
			Guelph limestone	Light to buff dolomite	100–185	Ontario and W. New York	5700
			Niagara limestone	Dolomite	120–350	W. New York, Ont. and Ind.	5820
			Clinton limestone*	Variegated crystalline limestone	10–100	Central Ohio and Welland Co., Ont.	5985
			Clinton sandstone	Fine grained gray sandstone	5–75		6025
			Medina Red sandstone	Soft red sandstone	10–50	W. New York and Welland Co., Ont.	6085
			Medina white sands	White sandstone	5–36		6200
	Ordovician		Trenton limestone, upper	Gray-blue dolomitic limestone	50–800	N. W. Ohio, Ind. and Ky.	8700
			Trenton limestone, lower			N. W. Ohio, W. New York, Ky. and Ont.	9200
	Cambrian		Calciferous and Potsdam sandstone	Sandstone with beds of shale and dolomite	1000	New York, Ga., Ala. and Ont.	
			Quebec group			New Foundland and New Brunswick	9230

*The Clinton limestone may be the horizon of the lower sand in the Scottsville, Ky., field.

GEOLOGICAL FORMATIONS OR "SANDS" IN WHICH OIL AND GAS ARE FOUND IN THE UNITED STATES AND CANADA—Concluded

The oil bearing formations of Mexico are not included in the chart, for the reason that their exact co-relation with other formations has not yet been determined. The oil in the fields of Mexico occurs in several formations of Tertiary and Cretaceous age.

Note: The thickness of the formations co-related in this chart are the total thickness of the formation or group where an oil bearing stratum occurs. For example, in the Strawn formation of Texas, 900 to 3,000 feet thick, the actual oil bearing sand may be only a few feet in thickness. The thickness of oil sands also varies in different localities, sometimes disappearing or "pinching out," as the drillers say, only to recur in a nearby well.

The names of oil sands originate in various ways, sometimes from the town or locality where they crop out, as the Berea grit, which rises to the surface at Berea, Ohio; or from the finding of oil at a certain town, as the Macksburg and Bartlesville sands; or they may be named for the man who first drilled into a new sand; or the farm where such a sand was found. The Speechly, Glenn and McClesky were thus named.

The same sand may be known by two or more names in different localities; thus the Cow Run sand of Southern Ohio is the Bridgeport of Illinois; the Berea, the 100 foot and the Gantz are doubtless one and the same; and other sands of Pennsylvanian age bear different names in Pennsylvania, in Illinois and in Oklahoma. Making due allowance for repetition, however, and for the many "stray" and unnamed sands, there are upward of one hundred oil and gas producing sands in North America, occurring in the sedimentary rocks, from the Quaternary to the Cambrian.

GEOLOGICAL TERMS

QUATERNARY

Time division which embraces the recent and Pleistocene epochs, i.e., the later portion of the Cenozoic era, otherwise known as the post-Pliocene or Post-Tertiary. The term was proposed by J Desnoyers in 1829 to cover these formations which were formed just anterior to the present. Quaternary embraces the soft formations and more recent stratified rocks laid down during the glacial period and the early human period.

TERTIARY

Time division which includes the Eocene, Oligocene, Niocene and Pliocene periods or the earlier portions of the Cenozoic Era. The name was first used by G. Cuvier and H. Brongniart in 1810. Period of development of the mammals, snakes, birds, fishes. Rock formations of the Tertiary age, while somewhat harder than those of the Quaternary, are soft formations.

CRETACEOUS

The group of stratified rocks which normally occupy a position above the Jurassic and below the Tertiary. Named for the chalky character of many of its rock formations. Contains soft limestones and thick beds of soft sandstone, as, for example, the Wall Creek Sandstone of Wyoming. The age of the big reptiles.

JURASSIC

Period between the Triassic and Cretaceous. Named for the rocks in the Jura Mountains of Switzerland. They contain clays, shales, sandstones, limestones and coal. The age of the Dinosaurs and large marine forms.

TRIASSIC

Occupies a position above the Permian and below the Jurassic. The rocks of this age were classified by German geologists into three principal formations and grouped under the name Trias. These formations include marls, paper shales, red and mottled sandstones, dolomites, limestones, gypsum and rock salt. Life forms include earlier mammals, shell fish, etc.

CARBONIFEROUS

The great series of stratified rocks which occur above the Devonian and below the Triassic. As the name implies, these formations are the home of the principal coal beds. They contain also marine limestones, sandstones, shales, gypsum and salt. The presence of igneous (volcanic) rocks that are found in some localities inter-bedded with the sedimentary deposits may be attributed to the emanations from volcanoes. Vegetation was luxuriant and widely distributed during this age. Life forms were chiefly fishes, mollusca, various insects, and the early amphibian.

DEVONIAN

The series of stratified rocks that were formed after the Silurian period and before the Carboniferous. The name Devonian was first used by Sir R. Murchison and A. Sedgwick to describe the rocks of this period in the district of Devon, England. The stratigraphy includes the Old Red Sandstone, thick beds of limestone, slates, shales, marl grits and quartzite. Fauna was, with the exception of a few insects, confined to marine forms: crustaceous, corals, fishes. It is known as the age of fishes.

SILURIAN

The series of strata that lie above the Ordovician and below the Devonian. The name was first introduced for a series of rocks in England, a region formerly inhabited by the Silures. The rocks are principally of marine origin and consist of sandstones, limestones, shales, grits and rock salt. Life forms were limited to those of aquatic origin.

ORDOVICIAN

The period between the Cambrian and the Silurian. Next to the lowest group of stratified rocks in the Geological scale. Includs all types of sedimentation, when flat or undisturbed, and where subjected to eruptive forces, slates, quartzites, chlorite, schists, tuffs, lavas and other metamorphosed rocks are represented. Life forms were Trilobites, Mollusca (shell fish) and a few insects. Some of the shells were 12 to 15 feet in length.

CAMBRIAN

Earliest group of stratified rocks resting on the Pre-Cambrian or Igneous rocks. Stratification includes shales, slates, sandstones, hard dolomitic limestones, conglomerates and quartzites. In some parts of the world the Cambrian beds are of great thickness, 10,000 to 40,000 feet. Life forms were similar to those of the Ordovician period.

IGNEOUS ROCKS

Rocks produced by the action of intense heat, or by the soldification of the interior molten magma of the earth. These rocks lie below all of the several series of stratified rocks, except where they occur as intrusions within sedimentary rocks or as extrusion sheets and include granites, schists, basalt, lava and other metamorphosed and crystalline forms.

ORIGIN OF PETROLEUM AND NATURAL GAS

There has been much discussion by geologists, chemists and other scientists, with reference to the origin of petroleum and natural gas, but with no unanimity of conclusion. There are three general theories for the origin of the hydcrocarbons, each of which has had eminent supporters: the organic theory, the inorganic chemical theory and the volcanic theory.

The adherents of the organic theory also are divided in opinion as between vegetable, or animal and fish remains, or both, as the organisms form which the hydrocarbons were derived.

Following is a brief outline of the arguments for the divergent views:

Organic origin.*

That both oil and gas are the product of natural distillation of organic (vegetable and animal) remains imprisoned in the stratified rocks. Those who uphold these views, perhaps the most orthodox, point for evidence to the coals, admittedly formed

* References:
First report Geological Survey of Ohio, by Edward Orton.
U. S. Geological Survey Bulletin 330, Data of Geochemistry, by Frank Wigglesworth Clarke, pp. 619-641.
Hofer, Das Erdol, 1906.

from vegetable matter, to marsh gas, to the limestones which are the deposit of vast quantities of animal or fish remains.

To the argument that organic remains could hardly be confined in sufficient quantity to account for the vast amount of oil in the stratified rocks, answer is made that the quantities of seaweed known to exist, the great bodies of vegetation, such as the Sargasso Sea, and the myriads of small shellfish which must have existed in past ages would furnish the necessary elements. For further proof we are referred to the gas that is distilled from coal, to the medicinal product known as "ichthyol," an oil found in Galician fish beds, and to the various oils derived from vegetables.

Inorganic origin.

This hypothesis is that oil and gas (hydrocarbons) are the result of chemical reactions within the earth. Among the arguments advanced is that large quantities of calcium, iron and other carbides are contained within the earth, and that percolating waters, gaining access to these deposits, would generate hydrocarbon gases, which under heat and pressure are condensed into petroleum as we find it. (1 and 2) Acetylene gas produced from the action of water on calcium carbide is cited in support of this theory. Various hydrocarbons containing part at least of the constituents of petroleum have been produced by chemists in laboratory experiments. **

Volcanic origin.

This hypothesis is that the fluid magma of the earth's heated interior contains large quantites of carbon and sulphur—both chemical properties of petroleum—and that both oil and gas are the products of hydrocarbon gaseous volcanic emanations, condensed and held in their passage upward in the many porous stratified rocks where they are now found.*

References:

1. The American Petroleum Industry, pages 8-13, by Bacon and Hamor.
2. U. S. Geological Survey Bulletin No. 401, Relation between local magnetic disturbances and the genesis of petroleum, by George F. Becker.

** Mendeléefs' Principles of Chemistry, Vol. I.

* Volcanic origin of natural gas and petroleum, Journal of Canadian Mining Institute, Vol. VI, by Eugene Coste, E.M.
Petroleum and Coals, Journal of Canadian Mining Institute, part of Vol. XII, by Eugene Coste, E.M.

Many natural phenomena are cited in support of this theory: the inflammable gases and the bituminous odors in the emanations of Vesuvius, Etna and other volcanoes;† sulphuric vapors and other gases associated with hot springs; the gas, mud and hot water "blow outs" in the oil fields of Baku in the Caucasus, and in the Gulf Coast.

Other arguments advanced are:

The solid hydrocarbons, as the Ozokerite deposits of Boryslaw Galicia, which occur in veins and faults, cutting the strata; and the graphites which have been found in gneisses, in granite and in other rocks of volcanic origin.

In the oil fields of the Gulf Coast and of Mexico, much of the oil occurs around volcanic necks and in salt domes, or associated with sulphur deposits.

Analogy of the chemical composition of petroleum and that of the emanations of volcanoes: chloride salts, sulphur, carbonic acid, sulphuretted hydrogen, hydrocarbons and salt water.

The lake of asphalt on the island of Trinidad is said to be in the crater of an extinct volcano.

It is apparently the same oil and the same gas in all of the one hundred or more sands in which they are found and probably have escaped into these sands from the fluid magma below.

Eugene Coste has very fully covered the subject of volcanic origin of oil and gas in his several papers read before the Canadian Mining Institute.*

The late George F. Becker has ably reviewed the subject of the genesis of oil and he has added a new suggestion with an accompanying chart, showing irregular compass declinations in the vicinity of most of the important oil fields of this county.**

† Geologie, by A. DeLapparent.

* Natural gas in Ontario, Journal Canadian Mining Institute, Vol. III, pp. 68-89; The Volcanic Origin of Natural Gas and Petroleum, Journal Canadian Mining Institute, Vol. VI, pp. 73-128; Petroleum and Coals, Journal Canadian Mining Institute, part of Vol. XII.

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CHAPTER II

STANDARD OR CABLE TOOL SYSTEM OF DRILLING

RIGS, DERRICKS AND SPECIFICATIONS OF MATERIAL, DRILLING OUTFITS

RIG

The first requisite in the drilling of a well is the derrick or rig. The derrick may usually be built from lumber and timbers available in the locality where the operations are to be carried on. For the sills, walking beam, pitman, sampson post, headache post, bull wheel posts, jack posts, crown block and engine block, hard wood, oak preferred, should be used. For the derrick, pine, hemlock or other soft wood will answer. On the Pacific Coast Oregon pine is successfully used for the entire rig. Beech and maple can also be used for the sills, etc. Rotary rigs used in the Gulf Coast fields are built throughout of Southern pine.

The rig, so called, consists of the derrick, surmounted by the crown block, which carries the crown pulley, sand pump pulley and casing pulleys; the bull wheels for spooling the drilling cable; the calf wheel for spooling the casing line; the band wheel with shaft and crank; tug pulley, nailed on to the band wheel for transmitting power, by means of the bull rope, to the bull wheels; the sand reel for spooling the sand pump line; walking beam mounted on the sampson post; jack posts which carry the band wheel shaft; headache post; belt house; walk from derrick to engine house; all supported on posts and sills. Cement foundations are often used for heavy derricks in California.

Derricks are built in varying size and degree of strength according to the depth of well to be drilled and the weight of the pipe or casing to be handled. For the well fifteen hundred feet or less in depth and for handling light strings of casing the 72 foot derrick with single tug and four inch band wheel shaft will answer, while for the 4,000 foot California well a 106 foot derrick, doubled, with 6 inch Ideal clutch sprocket rig irons is necessary.

For shallow drilling the Star and the Cyclone Machines and the portable rig, of which the National, elsewhere illustrated, is a good type, are successfully used.

The steel derrick and the derrick made of pipe are good equipment where one derrick is to be used over and over again as in gas well drilling, or for use in hot climates where wood rapidly deteriorates, or in localities where timber is scarce. Steel derricks, including steel walking beams, bull wheels, band wheel, etc., are now manufactured in all sizes for drilling to depths up to 5,000 feet.

WOOD DERRICKS

The derrick built of wood continues to be the most generally used despite the growing popularity of the steel and pipe derrick. There are several reasons, chiefly that the average oil field worker is more familiar with the wood rig and it is easier to make repairs to it than to the rigs built of metal.

In the following pages diagrams and specifications of material are shown for practically all of the sizes and types of wood rig used in this country, for cable, combination cable and rotary, and rotary drilling. Detail diagrams, illustrating construction of the several parts, methods of framing, etc., are also included, together with the following brief description of the process of construction.

DIRECTIONS FOR ERECTING WOOD DERRICKS

(Refer to diagrams Figs. 7, 8, 9 and 10.)

The nose sill and mud sills must be framed to receive the main sill, sub sill and sand reel sill, and the latter three sills are framed to mount the sampson post, jack posts, tail post, knuckle post and braces. All mortises should be cut wide enough to admit keys or wedges. (See diagram Fig. 7.)

First place the nose sill, No. 1 on diagram, and next the mud sills, Numbers 2 and 3. Then place the main sill, No. 4, so it will

No.
1 Nose Sill.
2 Mud Sills.
3 Mud Sills.
4 Main Sill.
5 Sub Sill.
6 Sand Reel Sill.
7 Bumper, Engine Block to Main Sill.
8 Engine Block.
9 Engine Mud Sills.
10 Derrick Side Sills.
11 Derrick Floor Sills.
12 Foundation Posts.
13 Bull Wheel Posts.
14 Bull Wheel Shaft.
15 Bull Wheel, Brake Side.
16 Bull Wheel, Tug Side.
17 Calf Wheel Posts.
18 Calf Wheel Shaft.
19 Calf Wheel.
20 Calf Wheel Skeleton Rim.
21 Sand Reel Reach.
22 Band Wheel Shaft.
23 Iron Tug Wheel for Calf Wheel.
24 Back Jack Post Box.
25 Tug Pulley.
26 Band Wheel.
27 Front Jack Post Box and Cap.
28 Shaft, Crank, Wrist Pin and Flanges.
29 Iron Sand Reel.
30 Sand Reel Posts.
31 Jack Post.
32 Pitman.
33 Sand Reel Lever.
34 Sampson Post.
35 Sampson Post Braces.
36 Derrick Crane Post.
37 Headache Post.
38 Walking Beam.
39 Jack Post Brace.
40 Derrick Ladder.
41 Derrick Cornice.
42 Derrick Girts.

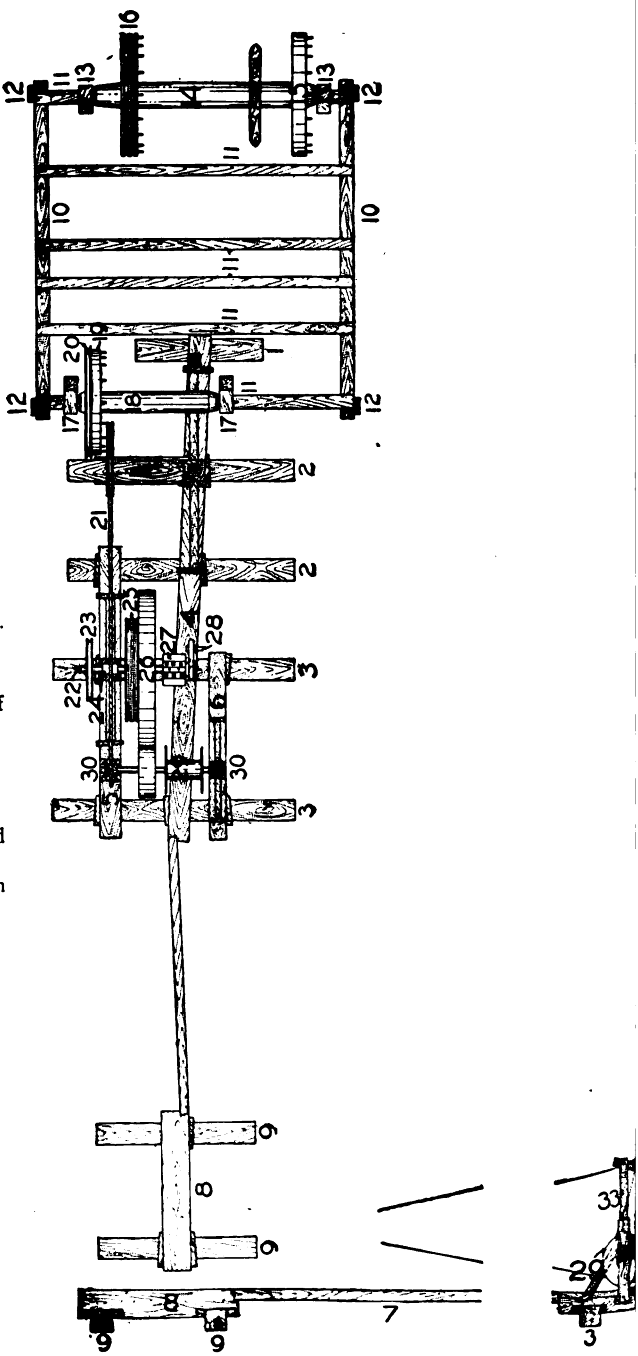
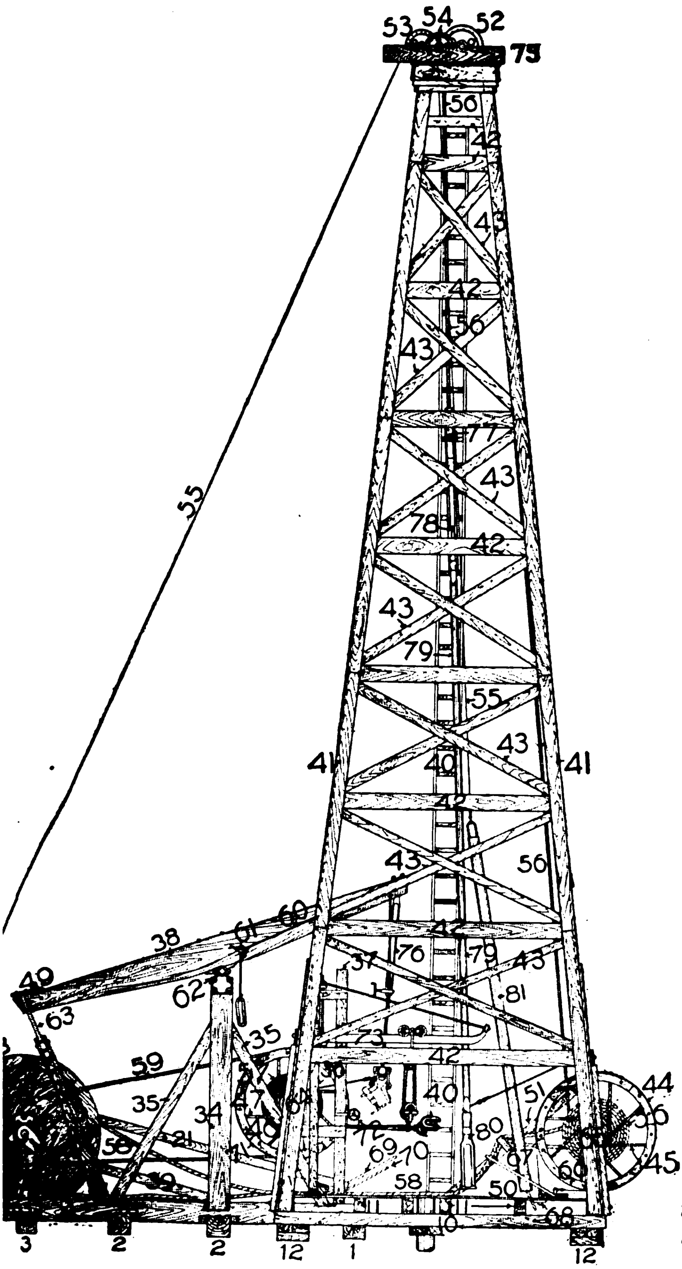


Fig. 7.—74-foot Standard derrick
(Natio
NOTE: Boiler and Engi
Refer to Pages 377-378 fo

RIG



rilling outfit with all parts numbered.
upply Co.)
e not shown on this diagram.
'e working loads for derricks.

No.	
43	Derrick Braces.
44	Bull Wheel Cants.
45	Bull Wheel Arms.
46	Calf Wheel Cants.
47	Calf Wheel Arms.
48	Belt.
49	Adjuster Board.
50	Derrick Floor.
51	Bull Wheel Post Brace.
52	Crown Pulley.
53	Sand Pump Pulley.
54	Casing Pulley.
55	Sand Line.
56	Drilling Cable.
57	Casing Line.
58	Bull Rope.
59	Calf Rope.
60	Temper Screw Elevator Rope.
61	Temper Screw Pulleys.
62	Center Irons.
63	Stirrup.
64	Calf Wheel Gudgeons (not Visible).
65	Bull Wheel Gudgeons (not Visible).
66	Brake Band for Bull Wheel.
67	Brake Lever for Bull Wheel.
68	Brake Staple for Bull Wheel.
69	Sand Reel Hand Lever.
70	Brake Lever and Staple for Calf Wheel.
71	Brake Band for Calf Wheel.
72	Telegraph Wheel.
73	Derrick Crane with Chain Hoist and Swivel Wrench.
75	Crown Block.
76	Temper Screw.
77	Rope Socket.
78	Jars.
79	Stem.
80	Bit.
81	Bailer or Sand Pump.

cross the nose and mud sills at an angle of three degrees. Set the posts for the four corners of the derrick, so that the bottom of the derrick mud or side sills, No. 10, will be flush with bottom of main sill. Next place the derrick floor sills.

Corner posts for California or other heavy derricks should be supported on either concrete or timber footings. (See diagrams Figs. 8 and 148.)

Construction of the derrick is commenced by erecting the first leg members at an angle according to the dimensions of the top and bottom and the height of the derrick. (The angle of the legs of a 74-foot derrick with 20-foot floor and 6-foot top would be about six degrees.) The two boards forming the leg, No. 41, are nailed together, one at a right angle to the other, making a corner in which are nailed the horizontal girts, No. 42, and the diagonal braces, No. 43. Heavy derricks should be doubled with extra planks, called doublers, nailed to the outside of the legs for their entire length. When erecting leg members use starting leg planks of unequal length for each leg; otherwise, if both timbers in the leg were of equal length, the joint or point where the next timbers joined, would be weakened. It is for this purpose that starting legs longer and shorter than the regular leg timbers are used. (See Fig. No. 121.) If additional strength is required or, as a protection against high winds, extra girts and braces nailed on the outside of the derrick and called "sway" or wind braces are used, see Fig. 147.

The crown block, consisting of the three or more courses of boards nailed one on the other on all four sides of the derrick top, surmounted by the water table and the two bumpers, is then built. (See Fig. 9.) Crown, sand and casing pulleys are then mounted.

If an iron crown block is used, it can be taken apart and the several parts and pulleys hoisted to the top one at a time and assembled. When the wood crown of the derrick is built a gin pole is rigged on it for convenience in hoisting parts into the derrick, walking beam, etc.

The Sampson post and braces, jack posts and braces, headache post, sand reel post and braces and knuckle post are put in their respective places, bolted and keyed (see details, Figs. 9 and 10).

Engine block and sills, and bumper from engine block to end of main sill are then placed.

Center irons are fitted to Sampson post and walking beam, and latter is hoisted into position, and the pitman connected to it.

The band wheel and tug pulley are built into the shaft, crank and flanges and mounted in the jack post boxes bolted to top of the jack posts. The bull wheel and calf wheel posts and braces are put up and these wheels are built and put in place. (See Figs. 7, 11 and 148.)

The sand reel and lever are the last working parts to be placed, for the sand reel runs by friction from the band wheel and the surface of the latter should be carefully trued up and smoothed off to insure perfect frictional contact.

The rig is completed by laying the floor in the derrick and the walk from the derrick to the engine house, building the belt house, engine house, etc.

The hole in the derrick floor, through which the well is drilled, is cut according to the length of the walking beam, usually about 8 feet from the front or side of the floor toward the band wheel. A trap door is provided about the center of the floor for convenience in handling casing, etc. Heavy derricks for underreaming or rotary drilling are sometimes equipped with a cellar, on the bottom of which the casing spider is placed. For pulling pipe the cellar is convenient as a means for supporting hydraulic jacks. (Refer to Fig. 150.)

Derricks erected in open country, or localities that are subject to high winds, should be guyed with ⅜-inch galvanized strand anchored to dead men buried in the ground. Eight guy lines are sometimes used, each line, instead of extending out from the corner of the derrick, passing diagonally across the derrick to the opposite side.

WOOD DERRICKS

SPECIFICATION OF MATERIAL REQUIRED TO BUILD A COMPLETE DOUBLE TUG STANDARD RIG WITHOUT CALF WHEELS, DERRICK 74 FEET HIGH

As Used in the Deep Fields of Penna., Ohio and West Va.

(Refer to Fig. 7.)

Number of Pieces	Pine	Size, Inches	Length, Feet
1	Main Sill	16 x 16	28
1	Sampson Post	16 x 16	16
1	Walking Beam	14 x 24	24
1	Sub Sill	14 x 16	16
2	Mud Sills	14 x 14	18
4	Mud Sills	14 x 14	14
1	Sand Reel Sill, Post and Block	12 x 12	18
2	Pony Sills	12 x 12	12
2	Engine Blocks	8 x 20	8
2	Derrick Side Sills	8 x 10	22
6	Derrick Sills	8 x 8	20
1	Bumper Post	6 x 8	22
3	Braces	6 x 8	16
4	Braces and Headache Post	6 x 8	14
3	Girts	2 x 12	18
16	Boards	2 x 12	18
25	Boards	2 x 12	16
36	Boards	2 x 10	20
90	Boards	2 x 10	16
8	Boards	2 x 8	20
20	Boards	2 x 8	16
12	Boards	2 x 6	20
30	Boards	2 x 6	16
16	Boards	2 x 6	14
30	Boards	2 x 4	16
10	Boards	2 x 4	12
3	False Arms	2 x 4	12
175	Boards	1 x 12	16
70	Boards	1 x 12	14
70	Boards	1 x 12	12
20	Boards	1 x 6	16
	Oak		
1	Bull Wheel Shaft	16 x 16	14
2	Bull Wheel Posts	12 x 12	10
1	Sand Reel Lever	8 x 10	10
1	Crown Block	6 x 13	16
1	Pitman	5 x 5 x 12	12
1	Jack Post and Knuckle Brace	4 x 16	14
1	Top of Derrick	4 x 10	12
3	Keys	3 x 5	14

Use specification of Rig Irons, Nails, Bolts, Cants, etc., shown on page 51, omitting calf wheel material as follows:

1 90-inch Skeleton Rim for Calf Wheel.
1 Iron Tug Wheel for Calf Wheel.
1 16-inch Bowl Calf Wheel Gudgeon with Band and Bolts.
1 30-inch Flange Calf Wheel Gudgeon with Band and Bolts.
4 Casing Pulleys.
1 Brake Band for Calf Wheel.
1 Brake Lever for Calf Wheel.
1 Brake Staple for Calf Wheel.
8 2½-inch Plain Cants
40 1-inch Plain Cants.
8 8-inch Oak Arms.
16 Handles.

WOOD DERRICKS

SPECIFICATION OF MATERIAL REQUIRED TO BUILD A COMPLETE DOUBLE TUG STANDARD RIG WITH CALF WHEEL, DERRICK 82 FEET HIGH, USING STANDARD RIG IRONS.

(D. D. WERTZBERGER.)

As Used in the Deep Sand Districts of Oklahoma and Kansas.

(Refer to Fig. 7.)

Number of Pieces	Pine	Size, Inches	Length, Feet
1	Walking Beam	14 x 24	24
1	Main Sill	16 x 16	28
1	Sampson Post	14 x 16	16
1	Sub Sill	14 x 16	16
2	Mud Sills	14 x 14	18
2	Mud Sills	14 x 14	16
1	Nose Sill	14 x 14	16
2	Mud Sills	14 x 14	14
2	Casing Sills in Pit	14 x 14	14
1	Tail Sill and Posts	12 x 12	18
2	Pony Sills	12 x 12	12
2	Timbers for Pit	12 x 12	12
8	Derrick Sills	8 x 8	20
1	Engine Block	8 x 20	16
3	Bunting Pole and Pit	6 x 8	22
1	Calf Wheel Brace	6 x 8	16
4	Braces	6 x 8	16
3	Braces and Headache Post	6 x 8	14
32	Boards	2 x 12	20
22	Boards	2 x 12	18
25	Boards	2 x 12	16
32	Boards	2 x 10	20
4	Boards	2 x 10	18
80	Boards	2 x 10	16
8	Boards	2 x 8	20
8	Boards	2 x 8	18
40	Boards	2 x 8	16
8	Boards	2 x 6	20
10	Boards	2 x 6	18
24	Boards	2 x 6	16
8	Boards	2 x 6	14
3	Boards	2 x 4	18
30	Boards	2 x 4	16
14	Boards	2 x 4	14
175	Boards	1 x 12	16
80	Boards	1 x 12	14
55	Boards	1 x 12	12
18	Boards	1 x 6	16
	Oak		
1	Bull Wheel Shaft	18 x 18	14
1	Jack Post	16 x 16	12
1	Calf Wheel Shaft	18 x 18	7
2	Calf Wheel Posts	12 x 12	14
2	Bull Wheel Posts	12 x 12	10

WOOD DERRICKS

SPECIFICATION OF MATERIAL REQUIRED TO BUILD A COMPLETE DOUBLE TUG STANDARD RIG WITH CALF WHEEL, DERRICK 82 FEET HIGH, USING STANDARD RIG IRONS—Continued

(D. D. WERTZBERGER)

Number of Pieces	Oak	Size, Inches	Length, Feet
1	Top of Derrick	9 x 10	12
1	Swing Lever	9 x 10	10
2	Crown Blocks	6 x 14	16
1	Pitman	6 x 14	12
4	Keys	3 x 5	16

For a rig built at a distance from supplies add:

1	Extra Pitman	......	..
1	Extra Timber	14 x 14	18

If Pit or Cellar is not needed, deduct:

2	....	12 x 12	12
2	....	6 x 8	22
22	....	2 x 12	18

If galvanized iron engine house is desired, deduct 40 1 x 12-inch x 14-foot pine boards and add 24 pieces 26-inch x 7 foot and 14 pieces 26-inch x 9-foot galvanized iron.

Specifications of 4½- or 5-inch Rig and Calf Irons.

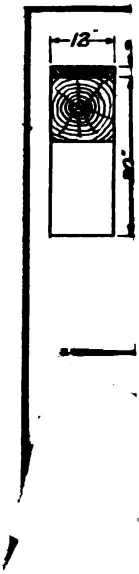
1 Shaft, Crank, Collar and Wrist Pin.
1 Pair Flanges with Keys and Bolts.
1 Set Center Irons Complete with Bolts.
1 Round Iron Stirrup with Bolts.
2 Bull Wheel Gudgeons with Bands and Bolts.
1 30-inch Crown Pulley.
1 22-inch Wire Sand Line Pulley.
1 Jack Post Box, Closed.
1 Jack Post Box, Open.
1 9-inch x 28-foot Brake Band.
1 1¾ x 9-inch Brake Lever.
1 9-inch Brake Staple.
1 90-inch Rim with 8¾ x 9-inch Bolts.
1 48-inch Tug Wheel with Split Hub.
1 16-inch Bowl Gudgeon with Band and Bolts.
1 30-inch Flange Gudgeon with Band and Bolts.
1 6-inch x 28-foot Brake Band.
1 6-inch Brake Staple.
1 1½ x 6-inch Brake Lever.
4 22-inch Casing Pulleys.

Specification of 4½- or 5-inch Rig and Calf Irons, Concluded.

40 1-inch Plain Cants for 10 foot Band Wheel.
16 2½-inch Grooved Cants }
16 2½-inch Plain Cants } For 7-foot Tug Pulley.
24 1 -inch Plain Cants }
16 2½-inch Grooved Cants }
8 2½-inch Plain Cants }
96 1 -inch Plain Cants } For 8-foot Bull Wheels.
16 10-inch Oak Arms }
32 Handles. }
8 2½-inch Plain Cants }
40 1 -inch Plain Cants } For 7½-foot Calf Wheel.
8 8 -inch Oak Arms }
16 Handles.
2 8-foot lengths ¾-inch Cable Chain.
2 1¼-inch Hook Bolts, 6½ feet long.
1 40-inch Double Drum Iron Sand Reel with Beveled Pulley and 4 or 4½-inch Shaft.

Nails, Bolts and Washers.

100 Pounds 8d Wire Nails.
200 Pounds 16d ditto.
200 Pounds 30d ditto.
8 ⅞" x 18" Machine Bolts with 2" Square Nuts
4 ⅞" x 12" Double End Bolts, 1 Square and 1 Hexagon Nut.
6 ⅞" x 28" Double End Bolts, 2" Square Nuts.
8 ⅞" x 18" Machine Bolts, with ⅞" Square Nuts.
4 ¾" x 26" Machine Bolts.
4 ¾" x 24" Machine Bolts.
8 ¾" x 20" Machine Bolts.
18 ¾" x 18" Machine Bolts.
18 ¾" x 16" Machine Bolts.
15 ¾" x 14" Machine Bolts.
4 ¾" x 12" Machine Bolts.
32 ¾" x 10" Machine Bolts.
10 ¾" x 8" Machine Bolts.
4 ¾" x 6" Machine Bolts.
4 ¾" x 4" Machine Bolts.
96 ¾" W. I. Washers.
28 ⅞" ditto.
72 ¾" Cast Washers.
4 ¾" x 40" D. E. Bolts.
20 ⅞" C. I. Washers.
1 Piece 1½" x 18" Plain End Pipe.
100 Pounds Babbitt Metal.
1 600-foot Coil Guy Wire.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WOOD DERRICKS

SPECIFICATION OF MATERIAL REQUIRED TO BUILD A CALIFORNIA RIG, DERRICK 84 FEET HIGH WITH 20-FOOT BASE.

(Refer to Figure 8.)

Pieces	Oregon Pine	Size, Inches	Length, Feet
1	Walking Beam	14 x 14 x 14 x 30	26
1	Engine Block	24 x 24	9
1	Main Sill	16 x 16	32
1	Sub Sill	16 x 16	20
1	Tail Sill and Sand Reel Post	16 x 16	16
4	Mud Sills	16 x 16	16
1	Nose Sill	16 x 16	10
1	Sampson Post	16 x 16	16
1	Jack Post	16 x 16	16
2	Engine Mud Sills	16 x 16	14
2	Engine Pony Sills	16 x 16	7
1	Knuckle Post	16 x 16	6
6†	Derrick Foundation	16 x 16	4
3	Derrick Cellar or Pit	14 x 14	14
1	Derrick Cellar or Pit	14 x 14	16
2	Casing Sills	14 x 14	12
4	Bull Wheel and Calf Wheel Posts	14 x 14	12
1	Back Brake	16 x 16	6
4	Bumpers	12 x 12	7
2	Derrick Side Sills	8 x 10	23
11	Derrick Sills, Casing Rack and Blocking	8 x 8	20
1	Sand Reel Lever	6 x 6 x 16	12
1	Headache Post	6 x 8	14
1	Bunting Pole	4 x 6	28
2	Stringers for Walk	6 x 6	20
3*	Crown Block	6 x 16	14
2	Jack Post Braces	6 x 6	18
3	Bull Wheel and Calf Wheel Post Braces	6 x 6	16
2	Sampson Post Braces	6 x 6	14
2	Dead Men	6 x 6	20
12	Derrick Cellar or Pit	6 x 6	20
8	Short Braces, Roof Stringers and Keys and J. P. Bunting Pole	4 x 6	16
1	Calf Wheel Brace	4 x 4	18
3	Engine House Studding	4 x 4	18
4	Engine House Sills	4 x 4	16
15†	Derrick Foundation (Redwood)	3 x 12	20
8†	Derrick Foundation (Redwood)	3 x 12	16
46	Walk, Floor and Girts	2 x 12	20
20	Band Wheel, Surface One Side	2 x 12	20
4	Girts	2 x 12	18
32	Girts and Top of Derrick (12), Doublers (20)	2 x 12	16
4	Girts	2 x 12	14
14	Doublers	2 x 12	24
4	Starting Legs	2 x 10	26

* Not needed if Steel Crown Block is used.
† Not needed if Concrete Piers are used.

WOOD DERRICKS

SPECIFICATION OF MATERIAL REQUIRED TO BUILD A CALIFORNIA RIG, DERRICK 84 FEET HIGH WITH 20-FOOT BASE. (Continued.)

Pieces	Oregon Pine	Size, Inches	Length, Feet
36	Derrick Legs and to cut up	2 x 10	16
4	Short Starting Legs	2 x 10	18
8	Belt House, Forge House Stringers	2 x 8	20
7	Belt House, etc	2 x 8	16
5	Belt House	2 x 6	26
17	Braces	2 x 6	20
22	Belt House, Braces and B. W. Spools	2 x 6	16
15	Belt House and Braces	2 x 6	18
6	Belt House and Engine House	2 x 6	14
3	Engine House	2 x 6	12
9	Engine House	2 x 4	20
40	Engine and Belt House, Ladder and to cut up	2 x 4	16
5	Belt House	2 x 4	12
8	Girts	1½ x 12	20
16	Braces	1½ x 6	14
16	Braces	1½ x 6	12
30	Housing and Boards	1 x 12	20
40	Housing and Boards	1 x 12	18
75	Housing and Boards	1 x 12	16
50	Housing and Boards	1 x 12	14
60	Housing and Boards	1 x 12	12
50	Ladder Strips, Roof Battens, etc	1 x 6	16
	Hardwood		
1	Bull Wheel Shaft	16 x 16	14
1	Calf Wheel Shaft	16 x 16	6
1	Pitman	5 x 5 x 5 x 14	12
1	Top of Crown Block	4 x 6	16
1	Top of Crown Block	4 x 6	12
1	Top of Beam and Dog	2 x 12	16

If outside or wind braces and girts are used, add the following:

4	Outside Girts	2 x 12	18
4	Outside Girts	2 x 12	16
4	Outside Girts	2 x 12	14
2	Outside Girts	2 x 12	20
8	Outside Braces	2 x 8	22
8	Outside Braces	2 x 8	20
8	Outside Braces	2 x 8	18
8	Outside Braces	2 x 8	16

Specification for Ideal Rig and Calf Iron Outfits.

1 Shaft, 7 6/12 feet long, with Crank, Wrist Pin, 2 Collars and 2 Keys.
1 Pair Flanges with Keys and Bolts.
1 Set Center Irons Complete with Bolts.
1 Stirrup.
2 Bull Wheel Gudgeons with Bands and Bolts.
1 30-inch Crown Pulley.
1 24-inch Sand Line Pulley.
1 7-inch x 28-foot Brake Band.
1 7-inch Brake Staple.
1 7-inch Brake Lever.
1 Jack Post Box, Closed.
1 Jack Post Plate.

WOOD DERRICKS

SPECIFICATION OF MATERIAL REQUIRED TO BUILD A CALIFORNIA RIG, DERRICK 84 FEET HIGH WITH 20-FOOT BASE—Concluded.

4 Turnbuckle Rods, 1¼ inches x 8 6/12 feet.
2 Jack Post Rods, 1¼ inches x 8 4/12 feet.
2 Eye Bolts, ⅞ x 22 inches.
2 Double End Bolts, ⅞ inch x 9 6/12 feet.
1 Double End Bolt, ⅞ inch x 8 feet.
1 7-foot Sprocket Tug Rim with Bolts.
1 42-inch Sprocket Wheel.
1 Sprocket Clutch with Straps and Keys.
1 Clutch Lever Complete with Bolts.
1 30-inch Flanged Calf Wheel Gudgeon with Bands and Bolts.
1 16-inch Calf Wheel Gudgeon with Band and Bolts.
1 Calf Wheel Box.
1 6-inch x 28-foot Brake Band.
1 6-inch Brake Staple.
1 6-inch Brake Lever.
4 22-inch Casing Line Pulleys.
2 Calf Wheel Box Eye Bolts, 1⅛ inches x 4 feet.
1 Calf Wheel Box Double End Bolt, 1⅛ x 26 inches.
55 feet No. 1030 Sprocket Chain.

Sand Reel

1 Iron Sand Reel with 5-inch Shaft and 42 x 12-inch Pulley, with Lever.

Nails, Bolts and Washers.

100 Pounds 60d Nails.
150 Pounds 30d Nails.
200 Pounds 20d Nails.
100 Pounds 16d Nails.
100 Pounds 10d Nails.
3 ¾ x 8-inch Machine Bolts.
8 ¾ x 10-inch Machine Bolts.
25 ¾ x 12-inch Machine Bolts.
10 ¾ x 14-inch Machine Bolts.
12 ¾ x 16-inch Machine Bolts.
35 ¾ x 18-inch Machine Bolts.
18 ¾ x 20-inch Machine Bolts.
2 ¾ x 22-inch Machine Bolts.
3 ¾ x 26-inch Machine Bolts.
2 ¾ x 24-inch Machine Bolts.
3 ¾ x 32-inch Machine Bolts.
2 ¾ x 42-inch Machine Bolts.
4 ⅞ x 28-inch Machine Bolts.
4 ⅞ x 28-inch D. E. Bolts.
1 Piece 1½-inch Pipe, 18 inches long, (not threaded).
125 ¾-inch Cast Iron Washers.
20 1-inch Cast Iron Washers.
100 ¾-inch Wrought Iron Washers.
30 1-inch Wrought Iron Washers.
600 feet ⅝-inch Galvanized Guy Wire.

Cants, Arms and Handles

56 1 x 8-inch x 10-foot Band Wheel Cants.
16 3 x 8-inch x 7-foot Grooved Tug Pulley Cants.
8 3 x 8-inch x 7-foot Plain Tug Pulley Cants.
24 1 x 8-inch x 7-foot Plain Tug Pulley Cants.
16 3 x 8-inch x 8-foot Grooved Bull Wheel Cants.
8 3 x 8-inch x 8-foot Plain Bull Wheel Cants.
80 1 x 8-inch x 8-foot Plain Bull Wheel Cants.
8 3 x 8-inch x 7½-foot Plain Calf Wheel Cants.
40 1 x 8-inch x 7½-foot Plain Calf Wheel Cants.
16 12-inch Oak Bull Wheel Arms.
8 12-inch Oak Calf Wheel Arms.
48 Bull and Calf Wheel Handles.

Exact Length to Cut Girts and Braces.

First Girts, 18 feet, 2½ inches.
Second Girts, 16 feet, 9¾ inches.
Third Girts, 15 feet, 4⅞ inches.
Fourth Girts, 14 feet, 1/16 inch.
Fifth Girts, 12 feet, 7¼ inches.
Sixth Girts, 11 feet, 2½ inches.
Seventh Girts, 9 feet, 9¾ inches.
Eighth Girts, 8 feet, 4⅞ inches.
Ninth Girts, 7 feet, 3/16 inch.

First Braces, 18 feet, 9 inches.
Second Braces, 17 feet, 5 inches.
Third Braces, 16 feet, 2 inches.
Fourth Braces, 14 feet, 10 inches.
Fifth Braces, 13 feet, 7 inches.
Sixth Braces, 12 feet, 3 inches.
Seventh Braces, 11 feet, 1 inch.
Eighth Braces, 10 feet.

WOOD DERRICKS

SPECIFICATION OF MATERIAL REQUIRED TO BUILD A COMPLETE DOUBLE TUG STANDARD RIG, DERRICK 84 FEET HIGH, USING IDEAL CHAIN DRIVEN CALF AND RIG IRONS, AS USED IN THE DEEP FIELDS OF NORTH TEXAS.

(PRAIRIE OIL & GAS COMPANY.)

(Refer to Figure 8.)

Note: **This rig will answer for the deep fields of Wyoming.**

Number of Pieces	Pine	Size, Inches	Length, Feet
1	Main Sill—Fir	16 x 16	32
1	Walking Beam—Fir	14 x 30	24
1	Sub Sill	16 x 16	18
1	Sampson Post	16 x 16	16
2	Mud Sills	14 x 14	18
2	Mud Sills	14 x 14	16
2	Mud Sills—Engine House	14 x 14	14
2	Mud Sills	14 x 14	14
1	Nose Sill	14 x 14	14
1	Foundation Posts	14 x 14	14
1	Back Brake	12 x 12	5
1	Derrick Corners	12 x 12	14
2	Engine Pony Sills	12 x 12	12
1	Engine Block	8 x 18	16
2	Casing Sills	10 x 12	14
2	Derrick Side Sills	8 x 10	22
6	Derrick Sills	8 x 10	20
1	Casing Sills (2–8′)	8 x 10	16
1	Bunting Pole	6 x 8	22
4	Casing Rack and Pit	6 x 8	20
1	Calf Wheel Post Brace	6 x 8	16
4	Jack Post and Sampson Post Braces	6 x 8	16
1	Braces	6 x 8	16
1	Headache Post	6 x 8	14
2	Bull Wheel Post Braces	6 x 8	14
2	Braces	6 x 8	14
1	Dead Men	6 x 6	16
3	Braces	4 x 6	16
4	Boards	3 x 12	20
10	Boards	2 x 12	20
26	Boards	2 x 12	18
40	Boards	2 x 12	16
4	Boards	2 x 12	14
4	Boards	2 x 12	12
4	Boards	2 x 10	26
4	Boards	2 x 10	24
42	Boards	2 x 10	20
22	Boards	2 x 10	18
130	Boards	2 x 10	16
4	Boards	2 x 10	12
4	Boards	2 x 10	10
6	Boards	2 x 8	20
8	Boards	2 x 6	22
24	Boards	2 x 6	20
29	Boards	2 x 6	18
74	Boards	2 x 6	16

WOOD DERRICKS

SPECIFICATION OF MATERIAL REQUIRED TO BUILD A COMPLETE DOUBLE TUG STANDARD RIG, DERRICK 84 FEET HIGH, USING IDEAL CHAIN DRIVEN CALF AND RIG IRONS, AS USED IN THE DEEP FIELDS OF NORTH TEXAS—Concluded.

(PRAIRIE OIL & GAS COMPANY.)

Number of Pieces	Pine	Size, Inches	Length, Feet
12	Boards	2 x 6	12
24	Boards	2 x 4	16
245	Boards	1 x 12	16
71	Boards	1 x 12	14
43	Boards	1 x 12	12
22	Boards	1 x 6	16
	Oak		
1	Bull Wheel Shaft	18 x 18	14
1	Calf Wheel Shaft	18 x 18	6
1	Jack Post	16 x 16	12
1	Tail Sill and Post	12 x 12	18
2	Bull Wheel Posts	12 x 12	11
2	Calf Wheel Posts	10 x 12	14
1	Bumper	8 x 10	14
1	Swing Lever	8 x 10	10
2	Crown Blocks	6 x 16	16
1	Pitman	6 x 16	14
1	Knuckle Post	6 x 16	8
3	Keys	3 x 5	14
1	Top of Beam	2 x 14	6

1 Set 5 or 6-inch Ideal Rig Irons as specified on pages 62-63.

Nails, Bolts and Washers.

200 Pounds 10D Wire Nails.
50 Pounds 16D Wire Nails.
200 Pounds 20D Wire Nails.
100 Pounds 30D Wire Nails.
100 Pounds 40D Wire Nails.
50 Pounds 60D Wire Nails.
2 ¾ x 42-inch Machine Bolts.
4 ¾ x 6-inch Machine Bolts.
2 ¾ x 8-inch Machine Bolts.
10 ¾ x 10-inch Machine Bolts.
26 ¾ x 12-inch Machine Bolts.
39 ¾ x 14-inch Machine Bolts.
7 ¾ x 16-inch Machine Bolts.
26 ¾ x 18-inch Machine Bolts.
14 ¾ x 20-inch Machine Bolts.
4 ¾ x 22-inch Machine Bolts.
2 ¾ x 24-inch Machine Bolts.
5 ¾ x 26-inch Machine Bolts.
4 ¾ x 46 D. E. Bolts.
2 ⅞ x 11′ 6″ D. E. Bolts.
2 1½ x 8′ 6″ D. E. Bolts (for back brace).
1 1¼″ x 15 D. E. Bolts.
1 Piece 2″ x 18″ Pipe.
500 foot Coil of ¼″ Galv. Strand.

WOOD DERRICKS

There has been continuous improvement in the character and construction of the wood derrick, and steel and iron are displacing wood for the working parts. The Ideal chain driven clutch sprocket rig and calf irons have become standard equipment for handling long and heavy strings of casing, and for continuous under-reaming. (See Fig. 12.)

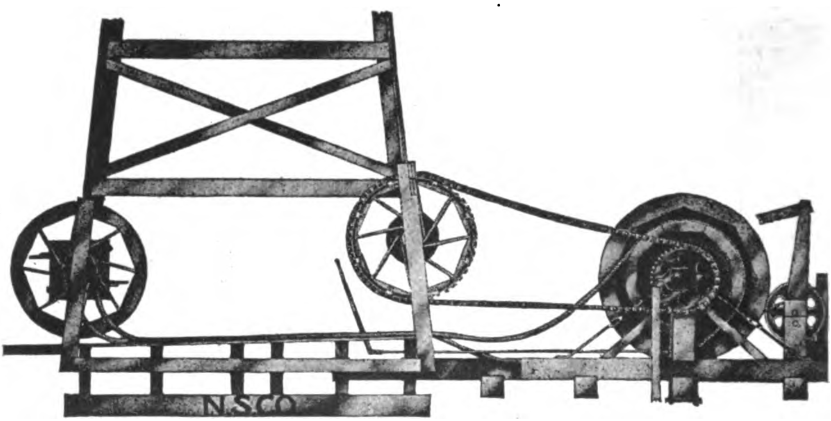


Fig. 12. Ideal Rig Irons.

The wood sand reel has almost disappeared; the reel made of iron and steel having taken its place. The drilling of deep 3,000- to 4,000-foot wells developed the need for a sand reel equipped with a double, or auxiliary, friction or brake wheel. It was found in withdrawing a heavy bailer from the hole, or in running it to the bottom and holding the reel against the back brake, that the long run generated frictional heat that injured the surface of the band wheel, the back brake block and also the sand reel pulley. To remedy this the sand reel with two pulleys was devised (see Fig. 13). The taper pulley is run by friction against the band wheel when pulling out, and the straight faced pulley is used as a brake wheel against the back brake block in lowering

Fig. 13. Iron Sand Reel.

Fig. 14. Parkersburg Steel and Wood Bull Wheel Shaft.

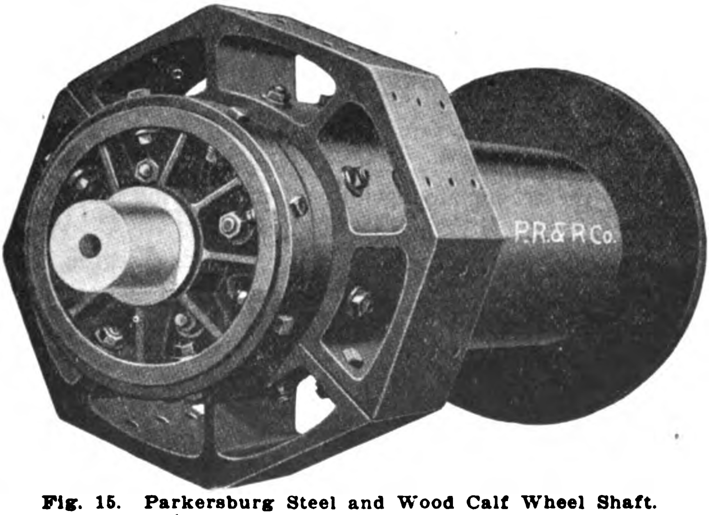


Fig. 15. Parkersburg Steel and Wood Calf Wheel Shaft.

the bailer. Thus the frictional load is divided between the band wheel and the back brake block.

Several types of steel bull wheel and calf wheel shafts are now quite generally used in California, Wyoming and Texas, of which the Parkersburg, Figs. No. 14 and 15, and Ross and Seely are good examples.

For heavy work the steel crown block with pulleys in iron bearings (Fig. 16) has quite generally superseded the wood crown block.

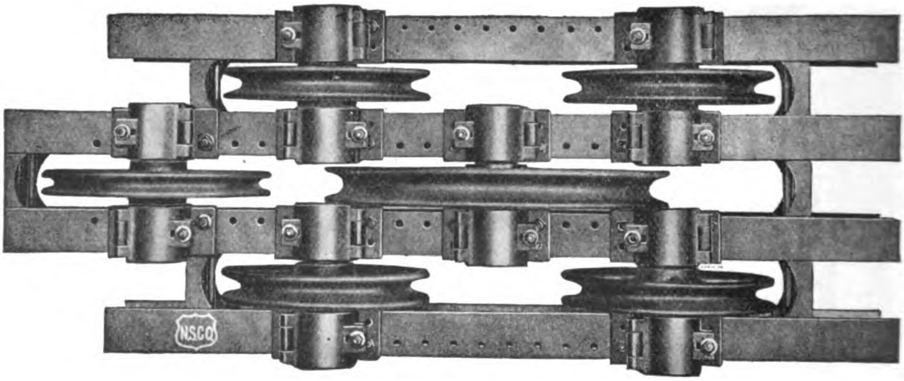


Fig. 16. Steel Crown Block.

In some of the deep fields Carnegie steel bull wheels and calf wheels are used in conjunction with the wood derrick. Minor parts of the derrick, too, are receiving more attention, as evidenced by the accompanying illustration of swing lever irons for the sand reel (Fig. 17).

Deep well drilling is becoming, in increasing degree, an engineering proposition, requiring in all its branches improved mechanical equipment.

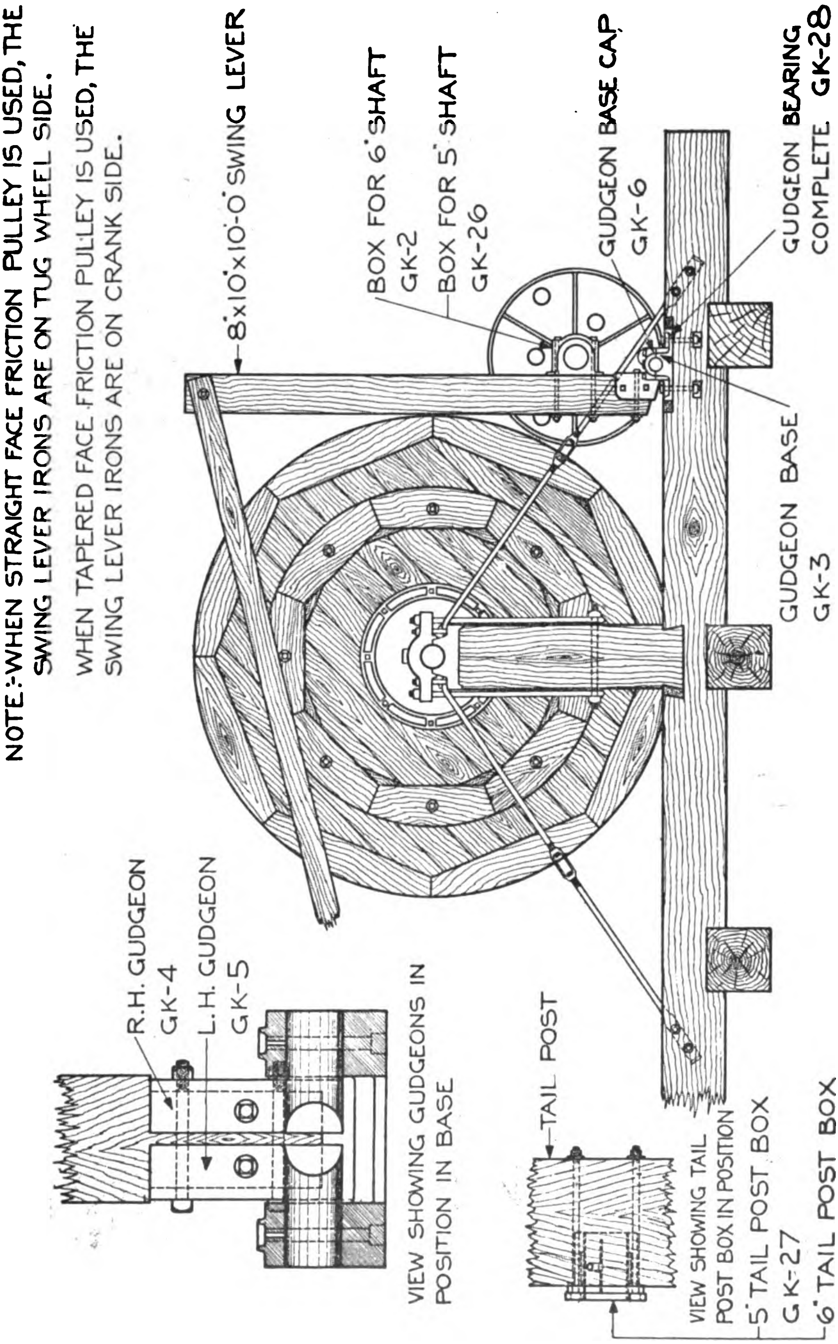


Fig. 17. Diagram Showing Swing Lever Irons for Iron Sand Reel (The National Supply Co.)

STEEL DERRICKS

DIAGRAM OF CARNEGIE 80-FOOT STRUCTURAL STEEL STANDARD DERRICK

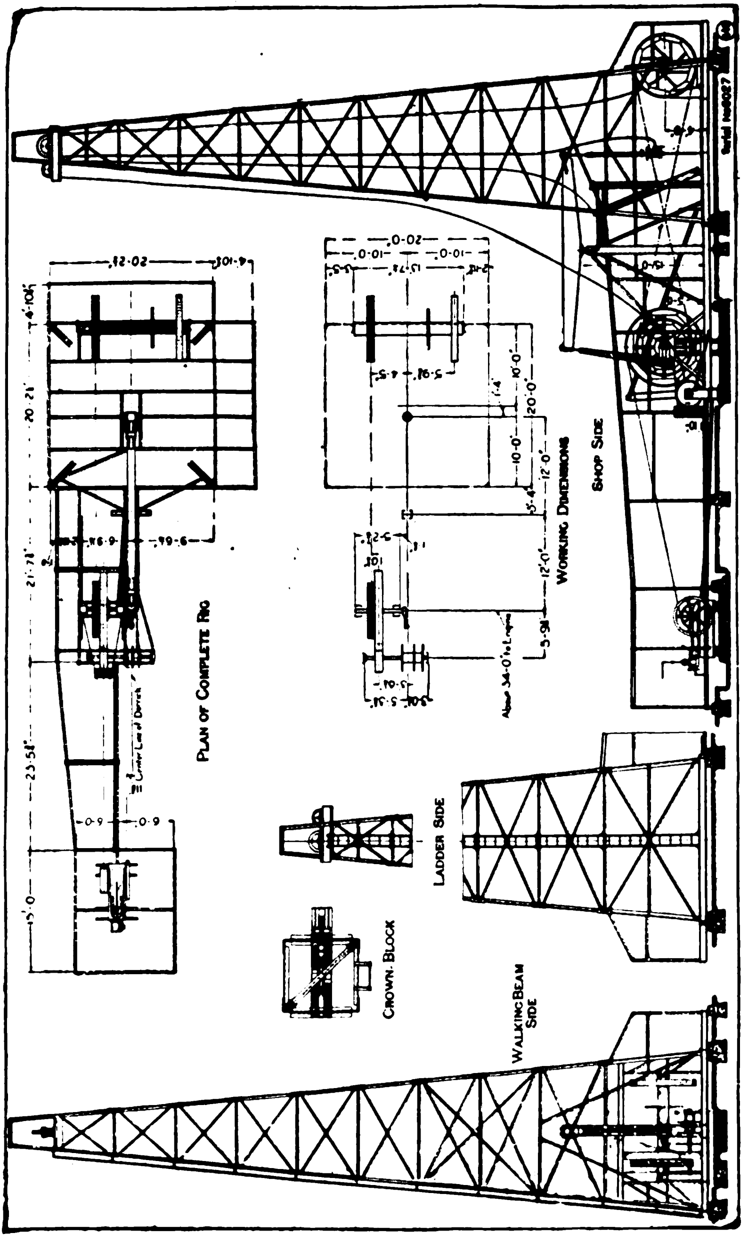


Fig. 18. The Carnegie Steel Co. makes this derrick in three sizes, 64 feet, 72 feet and 80 feet in height. Refer to Pages 375-378 for safe working loads for derricks.

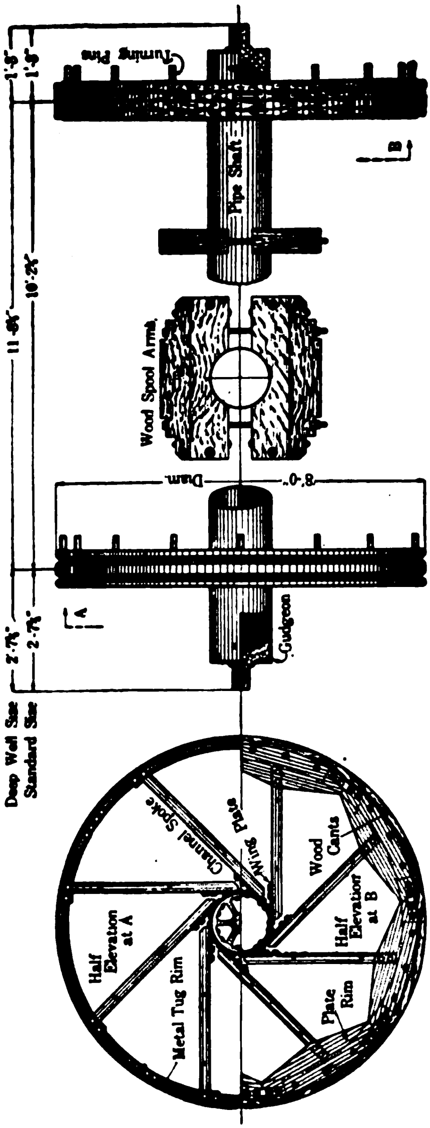


Fig. 19. Carnegie Steel Bull Wheels fitted with wood cants for tug and brake. Standard Size—14' 6" over gudgeons, shaft 16" O. D. Pipe, ⅝" thick. Weight, approximately, 3,400 lbs. Deep Well Size—15' 11¾" over gudgeons, shaft 18" O. D. Pipe, ⅝" thick. Weight, approximately, 3,600 lbs. Cast iron gudgeons, spoke type, inserted in end and riveted to shafts.

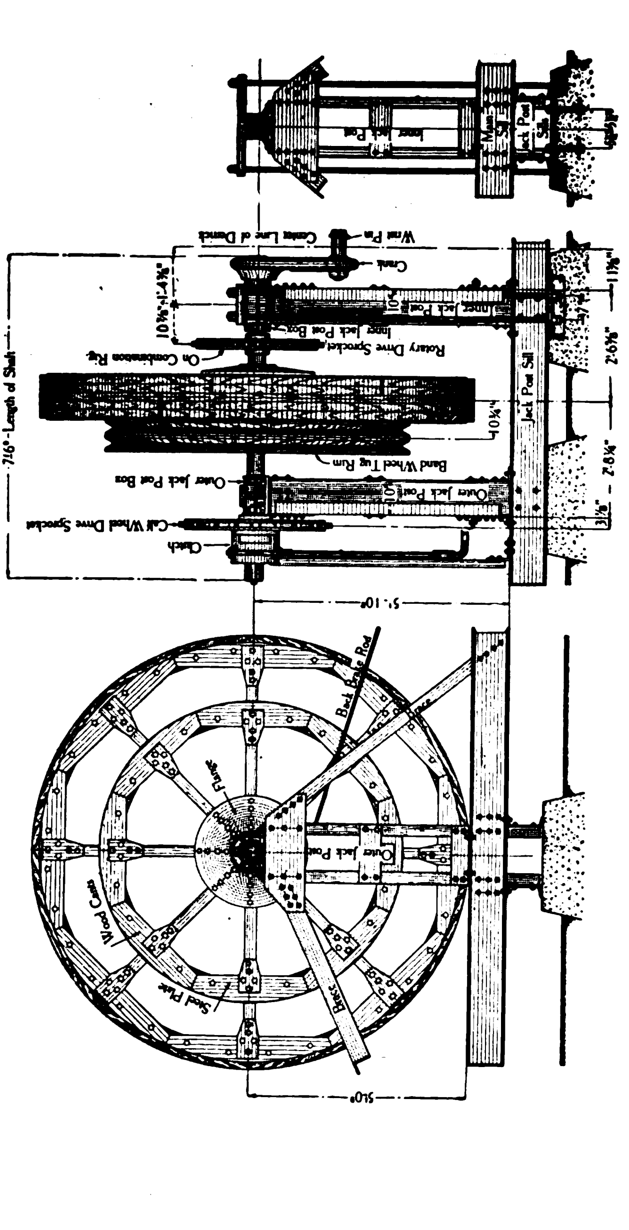


Fig. 20. Carnegie Steel Band Wheel, showing diagram of the Band Wheel with Shaft, Crank, Flanges and Sprocket Wheels mounted in Jack Post Boxes secured with Bridle Irons. These Steel Wheels are fitted with wood cants for tug and friction.

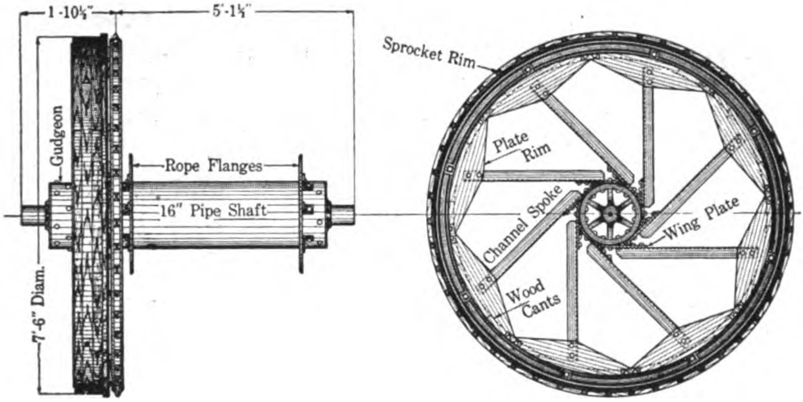


Fig. 21. Carnegie Steel Calf Wheel, Detail Diagram.

Steel Rig Size—7'-0" over gudgeons, shaft 16" O. D. Pipe, ⅜" thick. Weight, approximately, 2,400 pounds.

Wood Rig Size—6'-0" over gudgeons, shaft 16" O. D. Pipe, ⅜" thick. Weight, approximately, 2,340 pounds.

Cast iron gudgeons, spoke type, inserted in end and riveted to shafts. Standard 90" cast iron sprocket rim bolted to wood-lined steel plate rim. Made for use with either 5 or 6-inch Imperial or Ideal Rig Irons.

CORRUGATED IRON REQUIRED FOR DRILLING RIGS

80-Foot Standard Rig	80-Foot California Rig	106-Foot Cable and Rotary Rig
12 Pieces—3'-0" long	25 Pieces—3'-0" long	4 Pieces—10'-0" long
13 Pieces—3'-6" long	24 Pieces—4'-6" long	8 Pieces—9'-6" long
24 Pieces—4'-6" long	4 Pieces—5'-0" long	15 Pieces—9'-0" long
4 Pieces—5'-0" long	36 Pieces—6'-6" long	79 Pieces—8'-6" long
38 Pieces—6'-6" long	34 Pieces—7'-0" long	60 Pieces—8'-0" long
46 Pieces—7'-0" long	5 Pieces—7'-6" long	3 Pieces—7'-6" long
10 Pieces—7'-6" long	27 Pieces—8'-0" long	33 Pieces—7'-0" long
26 Pieces—8'-0" long	63 Pieces—8'-6" long	53 Pieces—6'-6" long
59 Pieces—8'-6" long	25 Pieces—9'-0" long	10 Pieces—6'-0" long
17 Pieces—9'-0" long	7 Pieces—9'-6" long	23 Pieces—5'-6" long
3 Pieces—9'-6" long	28 Pieces—10'-0" long	17 Pieces—5'-0" long
29 Pieces—10'-0" long		6 Pieces—4'-6" long
		6 Pieces—4'-0" long
		19 Pieces—3'-0" long

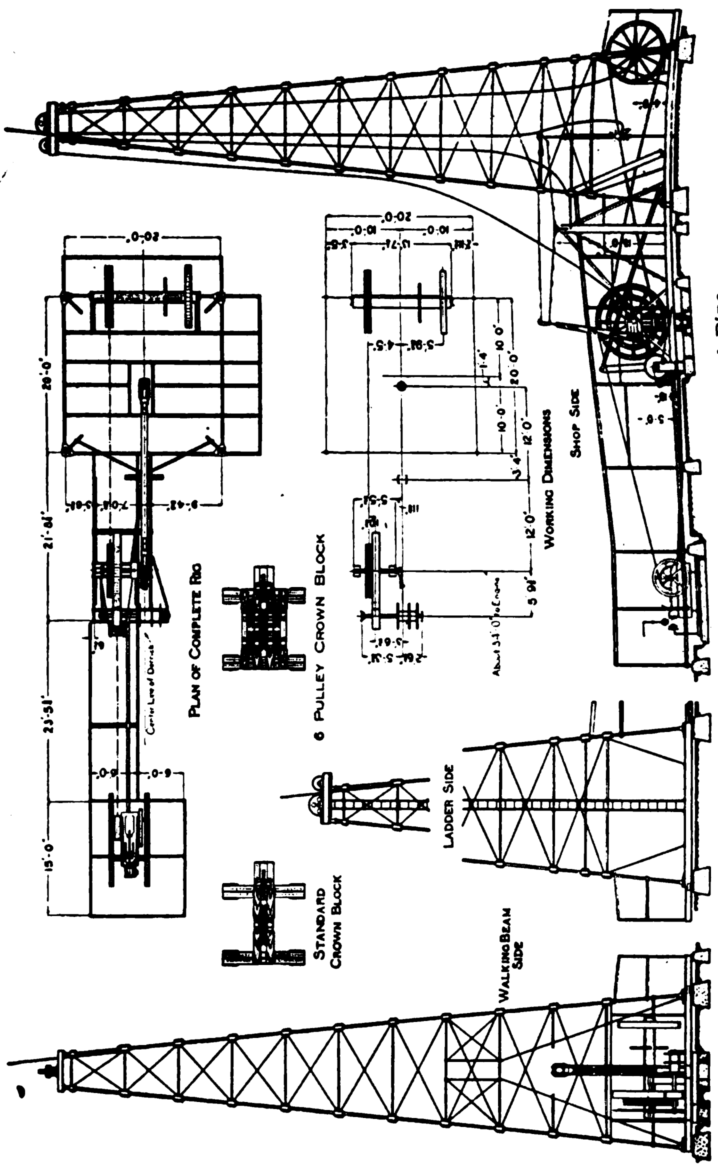


Fig. 22. Neill Tubular Derricks. Made from Steel Pipe.

NEILL TUBULAR DERRICKS

Made from Steel Pipe

The pipe derrick has grown in popularity due to its indestructibility, the ease with which it can be erected and taken down, and the fact that repair members, pieces of pipe, are readily obtainable. The Neill derrick is made by Lee C. Moore & Co., Pittsburgh, in sizes and weights for various service as follows:

Pipe Derricks, including ladder, gin pole, top and crown block.

Height, Feet	Leg Diameter, Inches	Weight, per Foot, Pounds	Total Weight, Pounds
74	3" Single	7.57	8,680
74	3" Duplex	13.37	11,050
74	3" Triplex	17.00	12,130
81	3" Single	7.57	9,530
81	3" Duplex	13.37	12,000
81	3" Triplex	17.00	13,185
84	4" Duplex	18.36	17,950
84	4" Triplex	24.15	20,350
91	4" Duplex	18.36	21,700
91	4" Triplex	24.15	22,300
98	4" Duplex	18.36	24,000
98	4" Triplex	24.15	25,000
105	4" Duplex	18.36	26,200
105	4" Triplex	24.15	29,800
112	4" Triplex	24.15	36,900
119	4" Triplex	24.15	43,000

Safe Working Load for Neill Tubular Derricks, with Safety Factor of 4

Leg Diameter, Inches	Safe Load, Pounds	Leg Diameter, Inches	Safe Load, Pounds
3 Single	64,900	4 Duplex	171,150
3 Duplex	138,470	4 Triplex	187,780

The manufacturers furnish steel sills, bull wheels, band wheel, calf wheel and walking beam if desired.

PORTABLE RIGS

The portable drilling rig is a practical outfit for drilling 1,800 to 3,000 feet where long strings of casing are not necessary. The National Portable Rig illustrated is recommended by the manufacturer, for service as follows:

No. 1 for drilling 1,800 feet, safe working load 17,000 pounds.

No. 2 (illustrated) for drilling 2,500 feet, safe working load 30,600 pounds.

No. 3. All Steel, for drilling 3,000 feet, safe working load 36,000 pounds.

Factor of safety 4.

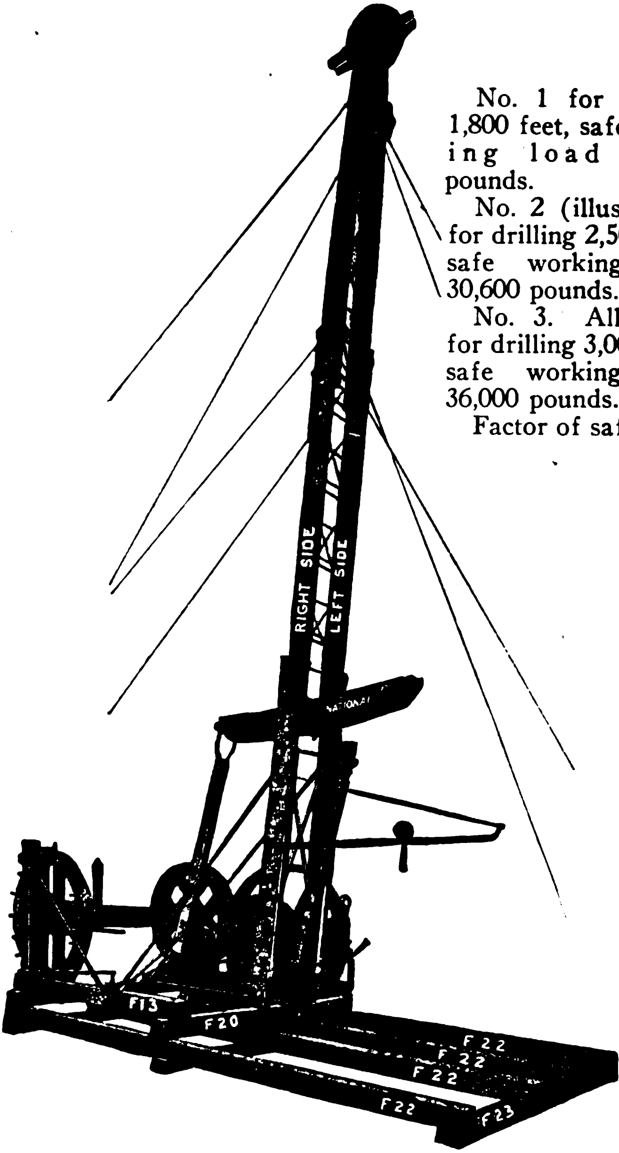
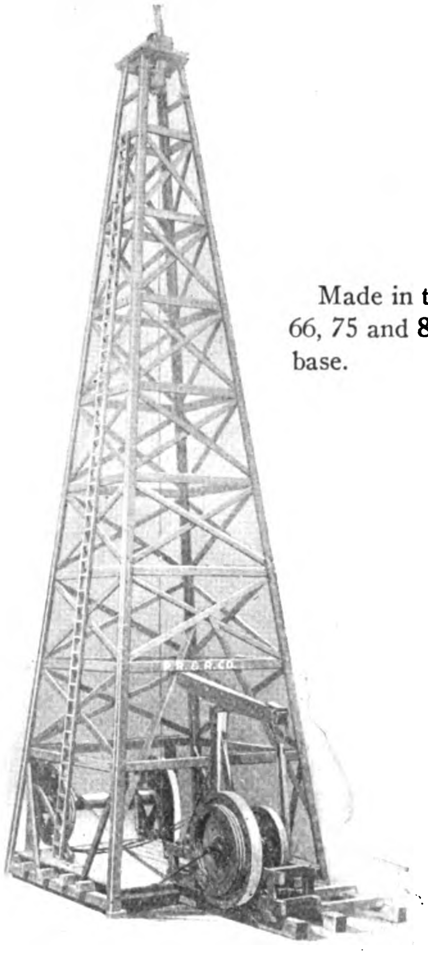


Fig. 23. National Portable Drilling Rig.



Made in three heights, 66, 75 and 84 feet, 20 ft. base.

Fig. 24. Parkersburg Portable Rig with Bolted Derrick.

For drilling not more than 3,000 feet, where under-reaming is not necessary and when it may be difficult to secure rig builders, the bolted derrick is a convenient and efficient rig. The timbers are all framed and the girts, braces and legs are all bored for bolts, ready for erection. All parts are numbered.

DRILLING OUTFITS

The drilling outfit must be selected according to the locality in which the well is to be drilled, character of formation, depth of well, etc. An outfit suitable for one district would be inadequate in another. The combinations are so many and so varied that it would be difficult to give complete specifications for drilling in all the fields. Following are specifications for several standard out-

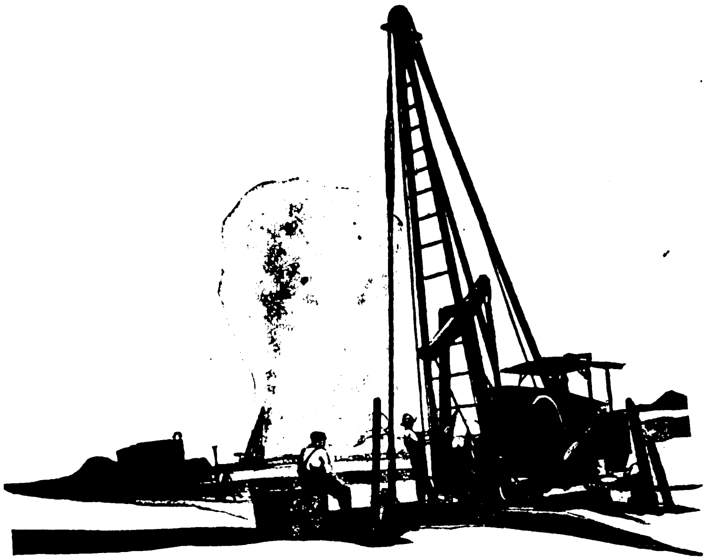


Fig. 25. Cyclone Gasoline Driven Machine.

fits, which may be added to or changed according to conditions. A practical driller may usually be depended upon to choose a suitable outfit for the well he intends to drill.

Outfit for drilling not deeper than 600 feet. A small drilling machine such as the Keystone, Star or Cyclone is a suitable outfit for this work. The Cyclone machine here shown is equipped with a gasoline engine, and driven over the roads by its own traction. These outfits are complete with all necessary ropes and tools.

Outfit for drilling 700 to 1,200 foot wells.—The Star Drilling Machine (Fig. 26) is a very good outfit for this work. It has an engine mounted on the frame, and the boiler on an extra truck.

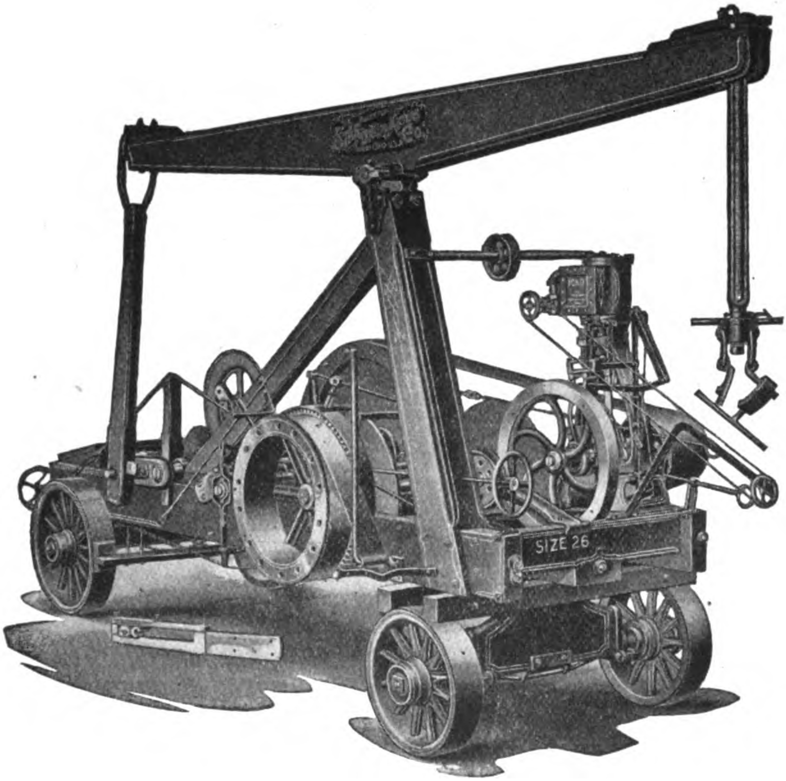


Fig. 26.

The heavy Star machines are rated by the manufacturer for drilling 2,500 and even 3,000 ft. wells and, while they will perform this service, the regular standard derrick is considered by most operators as better equipment for deep drilling.

Star machines come fully equipped with all necessary ropes and tools.

Outfit suitable for drilling to 1,800 feet and for handling not more than 1,000 feet of 17-pound casing, where rock formations stand up:

1 74-foot Standard derrick with 2 x 8-inch legs, using 4-inch or 4½-inch rig irons or No. 1 National portable drilling rig.
1 25 H. P. Boiler.
1 10½ x 12 (23 H. P.) Engine.
95 feet 10-inch 5-ply Rubber Belt with Clamps.
1 2 or 2⅛-inch x 1800-foot hawser laid Drilling Cable.
1 ⅜ or 7/16-inch x 1800-foot Steel Wire Sand Line.
1 2¼-inch x 85-foot Bull Rope.
1 1¾-inch x 6-foot Ball Bearing Temper Screw.
1 New Era Rope Socket, 2¾ x 3¾ x 7 I. & H. Joint.
1 Set 5½-inch diameter Drilling Jars, 5-inch stroke, 2¾ x 3¾-7 I. & H. Joint.
1 4½-inch x 34-foot Auger Stem, 2¾ x 3¾-7 I. & H. Joint.
1 14-inch All Steel Spudding Bit, 425 pounds, 2¾ x 3¾-7 I. & H. Joint.
1 Set (2) 10-inch All Steel Drilling Bits, 500 pounds each, 2¾ x 3¾-7 I. & H. Joint.
1 Set (2) 8¼-inch All Steel Drilling Bits, 400 pounds each, 2¾ x 3¾-7 I. & H. Joint.
1 Set (2) 6¼-inch All Steel Drilling Bits, 300 pounds each, 2¾ x 3¾-7 I. & H. Joint.
1 Each 10, 8¼ and 6¼-inch Tool Gauges.
1 Set (2) Tool Wrenches for 4-inch Squares, 200 pounds each.
1 No. 2 Barrett Type Tool Jack with Rack.
1 7-inch x 19-foot W. I. Bailer with Forged Valve.
1 5-inch x 25-foot W. I. Bailer with Forged Valve.
1 One Ton Improved Chain Hoist.
1 Swivel Wrench for 4-inch Squares.
1 2¾ x 3¾-inch-7 Box for welding.
1 2¾ x 3¾-inch-7 Pin for welding.
1 1,800-foot Aluminum Measuring Line with Reel.
1 Spudding Shoe.
1 ¾-inch x 450-foot Wire Casing Line.
1 Set (2) 10-inch Fair's Regular Wrought Iron Elevators.
1 Set (2) 8¼-inch Fair's Extra Heavy Wrought Iron Elevators.
1 Set (2) 6¼-inch Fair's Extra Heavy Wrought Iron Elevators.
1 26-inch Single All Iron Improved Snatch Block for Wire Line.
1 26-inch Double All Iron California Pattern Extra Heavy Casing Block for Wire Line.
1 4-inch Double Swivel Casing Hook.
1 Pair No. 15 Vulcan Chain Tongs.
1 Set 10-inch Drive Clamps for 4-inch Squares with Wrench.
1 10-inch Hollow Drive Head.
5 Derrick Lamps.
1 Telegraph Wheel with Line.

See pages 90-91 for list of general supplies needed with all outfits.

Estimated cost of above outfit at Pittsburgh, Pa., including general supplies but not including derrick, $4,650.00.

Note: If Standard Derrick is used add 1 Derrick Crane with 1 x 6 Beam and if National Rig is used deduct the Bull Rope.

Outfit suitable for drilling to 2,500 feet and for handling not more than 1,800 feet of 17-pound casing, where rock formations stand up:

1 74-foot Standard Derrick with 2 x 8-inch legs, using 4½-inch Double Tug Rig Irons, or No. 2 National Portable Drilling Rig or Parkersburg Bolted Derrick.
1 25 H. P. Boiler.
1 11 x 12 (25 H. P.) Engine.
95 Feet 12-inch 6-ply Rubber Belt and Clamps.
1 2¼-inch x 2,500-foot Hawser Laid Drilling Cable.
1 ½-inch x 2,500-foot Steel Wire Sand Line.
2 2¼-inch x 85-foot Bull Ropes (for Standard Rig).
1 2-inch x 6-foot Heavy Ball Bearing Temper Screw.
1 New Era Rope Socket, 2¾ x 3¾-7 I. & H. Joint.
1 Set 5½-inch diameter Drilling Jars, 5-inch stroke, 2¾ x 3¾-7 I. & H. Joint.
1 4½-inch x 36-foot Auger Stem, 2¾ x 3¾-7 I. & H. Joint.
1 4½-inch x 12-foot Sinker Bar, 2¾ x 3¾-7 I. & H. Joint.
1 14-inch All Steel Spudding Bit, 550 pounds, 2¾ x 3¾-7 I. & H. Joint.
1 Set (2) 10-inch All Steel Drilling Bits, 600 pounds each, 2¾ x 3¾-7 I. & H. Joint.
1 Set (2) 8¼-inch All Steel Drilling Bits, 500 pounds each, 2¾ x 3¾-7 I. & H. Joint.
1 Set (2) 6⅝-inch All Steel Drilling Bits, 350 pounds each, 2¾ x 3¾-7 I. & H. Joint.
1 Each 10-inch, 8¼-inch and 6⅝-inch Tool Gauges.
1 Set (2) Tool Wrenches for 4-inch squares, 225 pounds each.
1 No. 2 Barrett Type Tool Jack with Rack.
1 One Ton Improved Chain Hoist.
1 Swivel Wrench for 4-inch Squares.
1 7-inch x 19-foot W. I. Bailer with Forged Valve.
1 5-inch x 25-foot W. I. Bailer with Forged Valve.
1 5-inch Larkin Sand Pump.
1 2¾-inch x 3¾-inch-7 Box for welding.
1 2¾-inch x 3¾-inch-7 Pin for welding.
1 2,000-foot Aluminum Measuring Line with Reel.
1 Spudding Shoe.
1 ¾-inch x 600-foot Wire Casing Line.
1 26-inch Double All Iron Improved Snatch Block for Wire Line.
1 26-inch Triple All Iron California Pattern Extra Heavy Casing Block for Wire Line.
1 4-inch Double Swivel Casing Hook.
1 Set (2) 10-inch Fair's Extra Heavy Wrought Iron Elevators.
1 Set (2) 8¼-inch Fair's Extra Heavy Wrought Iron Elevators.
1 Set (2) 6¼-inch Fair's Extra Heavy Wrought Iron Elevators.
1 Pair No. 15 Vulcan Chain Tongs.
1 Set 10-inch Drive Clamps for 4-inch Squares, with Wrench.
1 10-inch Hollow Drive Head.
5 Derrick Lamps.
1 Telegraph Wheel with Line.

Estimated cost of above outfit at Pittsburgh, Pa., including general supplies but not including derrick, $5,600.00.

See pages 90-91 for list of general supplies needed with all outfits.

Note: If Standard Derrick is used, add 1 Derrick Crane with 1 x 6 Beam and if National Rig is used deduct the Bull Ropes.

Outfit suitable for drilling to 3,000 feet and for handling not more than 2,500 feet of 20-pound casing, where rock formations stand up:

1 82-foot Standard Derrick with 2 x 8-inch legs, doubled with 2 x 10-inch, using 4½-inch Double Tug Rig Irons with 8-foot Bull Wheels or Parkersburg Bolted Derrick.
1 30 H. P. Boiler.
1 11½ x 12 (28 H. P.) Engine.
95 Feet 12-inch x 6-ply Stitched Rubber Belt with Clamps.
1 2¼-inch x 3,000-foot Hawser Laid Manila Drilling Cable or
1 ⅞-inch x 3,500-foot Steel Wire Drilling Cable.
1 2¼ x 300-foot length Hawser Laid Manila Cable for splicing to Wire Cable to be used as a "cracker."
1 ½ or 9/16-inch x 3,500-foot Steel Wire Sand Line.
1 ⅞-inch x 600-foot Wire Casing Line.
1 1¼-inch x 40-foot Endless Wire Dead Line.
2 2½-inch x 95-foot Bull Ropes.
1 2-inch x 6-foot Ball Bearing Temper Screw with extra clamps for wire cable.
1 New Era Rope Socket, 3¼ x 4¼-7 I. & H. Box, 5-inch Square.
1 New Era Rope Socket, 2¾ x 3¾-7 I. & H. Box, 4-inch Square.
1 Babcock Rope Socket for Wire Cable with 3¼ x 4¼-7 I. & H. Box.
1 Babcock Rope Socket for Wire Cable with 2¾ x 3¾-7 I. & H. Box.
1 Set 6¼-inch Diameter Drilling Jars, 5-inch stroke, 3¼ x 4¼-7 I. & H. Joint.
1 Set 5½-inch Diameter Drilling Jars, 5-inch stroke, 2¾ x 3¾-7 I. & H. Joint.
1 5-inch x 32-foot Stem, 3¼ x 4¼-7 I. & H. Joints.
1 4¼-inch x 36-foot Stem, 2¾ x 3¾-7 I. & H. Joints.
1 4¼-inch x 16-foot Sinker, 2¾ x 3¾-7 I. & H. Joints.
1 Set 13-inch 1,000 pound All Steel Bits, 3¼ x 4¼-7 I. & H. Joint.
1 Set 10-inch 750 pound All Steel Bits, 3¼ x 4¼-7 I. & H. Joint.
1 Set 8¼-inch 500 pound All Steel Bits, 3¼ x 4¼-7 I. & H. Joint.
1 Set 6⅝-inch 400 pound All Steel Bits, 2¾ x 3¾-7 I. & H. Joint.
1 Substitute, 2¾ x 3¾ Pin, 3¼ x 4¼ Box.
1 Substitute, 3¼ x 4¼ Pin, 2¾ x 3¾ Box.
1 3,000-foot Aluminum Measuring Line with Reel.
1 9-inch x 19-foot Bailer.
1 7-inch x 19-foot Bailer.
1 5-inch x 25-foot Bailer.
1 Each 13, 10, 8, and 6⅝-inch Tool Gauges.
1 5½-inch Larkin Sand Pump.
1 Set 350 Pound Tool Wrenches, 5-inch Square.
1 Set 275 Pound Tool Wrenches, 4-inch Square.
1 No. 2 Barrett Jack with Rack.
1 Ball Bearing Derrick Crane with 4 x 5 Beam.
1 1 or 1½-Ton Chain Hoist.
1 Barrett Swivel Wrench with Plates for 5 and 4-inch square.
1 Spudding Shoe.
1 14-inch O. D. Drive Head.
1 Set 14-inch O. D. Drive Clamps made of 5 x 5 x 18-inch iron, with Wrench.
5 Derrick Lamps or 1 Steam Turbine Electric Generator with Wiring and Lamps.
1 Telegraph Wheel and Line.
1 Set 14-inch O D. Fair's Regular Elevators.
1 Set 10-inch Fair's Extra Heavy Elevators.
1 Set 8-inch Fair's or Scott's Extra Heavy Elevators.
1 Set 6⅝-inch Fair's or Scott's Extra Heavy Elevators.
1 28 or 32-inch Double Casing Block.
1 28 or 32-inch Triple Casing Block.
1 4½ or 5-inch Casing Hook.
1 3½-inch Casing Hook.
1 Boiler Feed Pump or 1-2½ H. P. Gasoline Engine with Pump.
1 Heavy Casing Tongs.

For 3,000 feet.

Estimated cost of above outfit at Pittsburgh, Pa., including general supplies but not including derrick, $7,500.00.

If necessary to reduce the hole below 6⅝ inch, 5 3/16-inch casing may be used and a set of 5 3/16-inch Bits, Jars, Rope Socket and Stem should be added.

See pages 90-91 for list of general supplies needed with all outfits.

Outfit suitable for drilling to 4,000 feet and for handling not more than 3,000 feet of 24-pound casing, where rock formations stand up:

1 82-foot Standard Derrick with 2 x 10-inch legs, doubled all around with 2 x 12-inch, using 5-inch Rig Irons, with 8-foot Bull Wheels, 11 or 12-foot Band Wheel and Steel Sand Reel with 5-inch Shaft, and Calf Wheel.
1 40 H P. Boiler.
1 13 x 14 (42 H. P.) Engine (12 x 12 might answer).
95 feet 12-inch 6-ply Stitched Rubber Belt with Clamps.
1 2¼ or 2⅝-inch x 4,000-foot Hawser Laid Manila Drilling Cable or
1 1-inch x 4,500-foot Extra Strong or Plough Steel Wire Drilling Cable.
1 2¼ or 2⅝-inch x 400-foot length Hawser Laid Manila Cable for "cracker."
1 ⅝-inch x 4,500-foot Steel Wire Sand Line.
2 3-inch x 95-foot Bull Ropes.
1 1-inch x 800-foot Steel Wire Casing Line.
1 1⅛-inch x 40-foot Endless Wire Dead Line.
1 2½-inch x 6-foot Ball Bearing Temper Screw with Extra Clamps for Wire Cable.
1 New Era Rope Socket with 3¼ x 4¼ I. & H. Box.
1 New Era Rope Socket with 2¾ x 3¾ I. & H. Box.
1 Babcock Rope Socket for Wire Cable with 3¼ x 4¼ I. & H. Box.
1 Babcock Rope Socket for Wire Cable with 2¾ x 3¾ I. & H. Box.
1 Set 6¼-inch diameter Drilling Jars, 5-inch Stroke, 3¼ x 4¼ I. & H. Joints.
1 Set 5½-inch diameter Drilling Jars, 5-inch Stroke, 2¾ x 3¾ I. & H. Joints.
1 5½-inch x 34 foot Stem with 3¼ x 4¼ Pin, 4 x 5 Box.
1 5-inch x 34-foot Stem with 2¾ x 3¾ Pin, 3¼ x 4¼ Box.
1 4¼-inch x 36 foot Stem with 2¾ x 3¾ Joints.
1 4¼-inch x 16 foot Sinker with 2¾ x 3¾ Joints.
1 Set 17-inch 1,600 pound All Steel Bits with 4 x 5 Pins, 5-inch Square.
1 Set 13-inch 1,200 pound All Steel Bits with 4 x 5 Pins, 5-inch Square.
1 Set 10-inch 800 pound All Steel Bits with 3¼ x 4¼ Pins.
1 Set 8¼-inch 550 pound All Steel Bits with 3¼ x 4¼ Pins.
1 Set 6⅝-inch 400 pound All Steel Bits with 2¾ x 3¾ Pins.
1 Substitute, 2¾ x 3¾ Pin, 4 x 5 Box.
1 Substitute, 3¼ x 4¼ Pin, 4 x 5 Box.
1 Substitute, 2¾ x 3¾ Pin, 3¼ x 4¼ Box.
1 Substitute, 4 x 5 Pin, 2¾ x 3¾ Box.
1 Substitute, 4 x 5 Pin, 3¼ x 4¼ Box.
1 Substitute, 3¼ x 4¼ Pin, 2¾ x 3¾ Box.
1 Each 17, 13, 10, 8¼ and 6⅝-inch Tool Gauges.
1 11-inch x 16 foot Bailer.
1 9-inch x 19 foot Bailer.

For 4,000 feet.

1 7-inch x 25 foot Bailer.
1 5-inch x 25 foot Bailer.
1 5½-inch Larkin Sand Pump.
1 Set 5-inch 450 pound Tool Wrenches, 5-inch Square.
1 Set 4-inch 300 pound Tool Wrenches, 4-inch Square.
1 No. 2 Barrett Jack with Rack.
1 Ball Bearing Derrick Crane with 4 x 5-inch Beam.
1 Bit Pulley and Chain.
1 1½ Ton Chain Hoist.
1 Barrett Swivel Wrench with Plates for 5 and 4-inch Square.
1 4,000 foot Aluminum Measuring Line with Reel.
1 Spudding Shoe.
1 18-inch O. D. Drive Head.
1 14-inch O. D. Drive Head.
1 Set Drive Clamps made of 5 x 5 x 24-inch Iron.
5 Derrick Lamps or 1 Steam Turbine Electric Generator with Wiring and Lamps.
1 Telegraph Wheel and Line.
1 Set 18-inch O. D. Regular Elevators.
1 Set 14-inch O. D. Fair's or Scott's Extra Heavy Elevators.
1 Set 10-inch Fair's or Scott's Extra Heavy Elevators.
1 Set 8¼-inch Fair's or Scott's Extra Heavy Elevators.
1 Set 6⅝-inch Fair's or Scott's Extra Heavy Elevators.

Note: If very long strings of casing are to be handled, Wilson, Dunn. O. W. S. Co. Double Gate or Lucey Rex Elevators, instead of Fair's or Scott's are recommended.

1 32-inch Triple Casing Block.
1 32-inch Double Casing Block
1 5½-inch Casing Hook.
1 3½-inch Casing Hook.
1 Type U 2½ H. P. Novo Pumping Outfit.
1 Heavy Casing Tongs.
1 Bit Ram, 300 pound.

Estimated cost of above outfit at Pittsburgh, Pa., including general supplies but not including derrick, $10,000.00.

Note: See pages 90-91 for list of general supplies needed with all outfits.

Outfit suitable for drilling 5,000 feet and for handling not more than 3,500 feet 28-pound casing, where rock formations stand up:

1 84 foot Standard Derrick with 2 x 12-inch legs, doubled all around, with 2 x 14-inch, 6-inch California Rig Irons and Steel Crown Block, Double Friction Sand Reel, 12-foot Band Wheel and Double 12-inch Brakes.
1 60-H. P. Boiler.
1 14 x 14 (50 H. P.) Engine.
1 2⅝ or 2½-inch x 5,000 foot Hawser Laid Manila Drilling Cable or
1 1-inch x 5,500-foot Extra Strong or Plough Steel Wire Drilling Cable.
1 2⅝-inch x 400 foot Manila Cable for "cracker."
1 11/16-inch x 5,500-foot Steel Wire Sand Line.
1 1⅛-inch x 800 foot Steel Wire Casing Line.
1 5,000 foot Aluminum Measuring Line with Reel.
1 36-inch Triple Casing Block.
1 6½-inch Casing Hook.

Note: Instead of using double and triple blocks, use the four casing pulleys in the steel crown block and the triple block for the traveling block.

Balance of outfit may be the same as outfit for drilling 4,000 feet.

Estimated cost of above outfit at Pittsburgh, Pa., including general supplies but not including derrick, $12,000.00.

Outfit suitable for drilling 2,500 feet and for handling not more than 2,500 feet of 20-pound casing, where under-reaming is necessary:

1 82-foot Standard Derrick, with 2 x 8-inch legs, doubled with 2 x 10-inch; using 4½ or 5-inch Double Tug Rig and Calf Irons.
1 30 H. P. Boiler.
1 12 x 12 (30 H. P.) Engine.
1 10-inch Under Reamer with Extra Set of Cutters.
1 8¼-inch Under Reamer with Extra Set of Cutters.
1 6⅝-inch Under Reamer with Extra Set of Cutters.
1 Block for dressing Under Reamer Cutters.
1 3-inch x 65-foot Calf Rope.
1 ⅞-inch x 800 foot Casing Line.
1 32-inch Triple Casing Block only.

Balance of outfit may be the same as the regular outfit for drilling 2,500 feet as shown on page 81.

Estimated cost of above outfit at Pittsburgh, Pa., including general supplies but not including derrick, $6,750.00.

Outfit suitable for drilling 3,000 feet and for handling not more than 3,000 feet 24-pound casing, where under-reaming is necessary:

1 84-foot Standard Derrick, with 2 x 10-inch legs, doubled with 2 x 12-inch, using 5-inch Ideal Clutch Sprocket Rig and Calf Irons with Steel Crown Block.
1 40 H. P. Boiler.
1 12 x 12 (30 H. P.) Engine.
95 Feet 12-inch x 6 Ply Stitched Rubber Belt with Clamps.
1 ⅞-inch x 3,500 foot Steel Wire Drilling Cable.
1 2¼-inch x 300 foot length Hawser Laid Manila Cable for Cracker.
1 ½ or 9-16-inch x 3,500 foot Steel Wire Sand Line.
1 1-inch x 800 foot Steel Wire Casing Line.
2 2½-inch x 95 foot Bull Ropes.
1 2¼-inch x 6 foot Ball Bearing Temper Screw with Extra Clamps for Wire Cable.
1 New Era Rope Socket with 3¼ x 4¼ I. & H. Box, 5-inch Square.
1 New Era Rope Socket with 2¾ x 3¾ I. & H. Box, 4-inch Square.
1 Babcock Rope Socket for Wire Cable, with 3¼ x 4¼ I. & H. Box.
1 Babcock Rope Socket for Wire Cable, with 2¾ x 3¾ I. & H. Box.
1 Set 6¼-inch diameter Drilling Jars, 5-inch Stroke, 3¼ x 4¼ I. & H. Joints.
1 Set 5½-inch diameter Drilling Jars, 5-inch Stroke, 2¾ x 3¾ I. & H. Joints.
1 5-inch x 32 foot Stem, 3¼ x 4¼-7 I. & H. Joints.
1 4¼-inch x 36 foot Stem, 2¾ x 3¾-7 I. & H. Joints.
1 4¼-inch x 16 foot Sinker, 2¾ x 3¾-7 I. & H. Joints.
1 Set 15½-inch 1,500 pound All Steel Bits, 3¼ x 4¼ I. & H. Pin.
1 Set 12½-inch 1,150 pound All Steel Bits, 3¼ x 4¼ I. & H. Pin.
1 Set 10-inch 800 pound All Steel Bits, 3¼ x 4¼ I. & H. Pin.
1 Set 8¼-inch 550 pound All Steel Bits, 3¼ x 4¼ I. & H. Pin.
1 Set 6⅝-inch 400 pound All Steel Bits, 2¾ x 3¾ I. & H. Pin.
1 12½-inch Under Reamer with extra set of Cutters.
1 10-inch Under Reamer with extra set of Cutters.
1 8¼-inch Under Reamer with extra set of Cutters.
1 6⅝-inch Under Reamer with extra set of Cutters.

For 3,000 feet.

1 Block for Dressing Under Reamer Cutters.
1 Substitute, 2¾ x 3¾ Pin, 3¼ x 4¼ Box.
1 Substitute, 3¼ x 4¼ Pin, 2¾ x 3¾ Box.
1 3,000-foot Aluminum Measuring Line.
1 11-inch x 16 foot Bailer.
1 9-inch x 19 foot Bailer.
1 7-inch x 25 foot Bailer.
1 5-inch x 25 foot Bailer.
1 Each 15½, 12½, 10, 8¼ and 6⅝-inch Tool Gauges.
1 5½-inch Larkin Sand Pump.
1 Set 350 pound Tool Wrenches, 5-inch square.
1 Set 275 pound Tool Wrenches, 4-inch square.
1 No. 2 Barrett Jack with Rack.
1 Ball Bearing Derrick Crane with 4 x 5 Beam.
1 1 or 1½ Ton Chain Hoist.
1 Barrett Swivel Wrench with Plates for 5 and 4-inch square.
1 Bit Pulley and Chain.
1 Spudding Shoe.
5 Derrick Lamps or
1 Steam Turbine Electric Generator with Wiring and Lamps.
1 Telegraph Wheel and Line.
1 Set 15½-inch Fair's or Scott's Regular Elevators.
1 Set 12½-inch Fair's or Scott's Extra Heavy Elevators.
1 Set 10-inch Fair's or Scott's Extra Heavy Elevators.
1 Set 8¼-inch Fair's or Scott's Extra Heavy Elevators.
1 Set 6⅝-inch Fair's, Scott's or Wilson's Extra Heavy Elevators.
1 5½-inch Casing Hook.
1 32-inch Triple Casing Block only.
1 2½ H. P. Novo Type U Pumping Outfit.
1 Heavy Casing Tong, Type B, Dunn.
1 Set Casing Wagons.

Note: See page 90-91 for list of general supplies needed with all outfits.

Estimated cost of above outfit at Pittsburgh, Pa., including general supplies but not including derrick, $11,250.00.

Specification for Ranger, Texas, outfit for drilling 4,000 feet and for handling not more than 3,500 feet of 28-pound casing, where under-reaming is necessary:

1 84 foot Standard Derrick with 2 x 10-inch legs, doubled with 2 x 12-inch, using 6-inch Ideal Clutch Sprocket Rig and Calf Irons, with Steel Crown Block.
1 50 H. P. Boiler.
1 12 x 12 or 13 x 14 Drilling Engine.
1 1-inch x 4,500 foot Steel Wire Cable.
1 2½-inch x 400 foot Manila Cable for Cracker.
1 ⅝-inch x 4,500 foot Steel Wire Sand Line.
1 1-inch x 1,000 foot Steel Wire Casing Line.
2 3-inch x 95 foot Bull Ropes.
95 feet 12-inch x 6 Ply Stitched Rubber Belt.
2 12-inch Belt Clamps.
1 2½-inch x 6 foot Temper Screw with Mechling Wire Line Clamps.
1 5½-inch x 34 foot Stem, 3¼ x 4¼ Pin, 4 x 5 Box.
1 5-inch x 34 foot Stem, 2¼ x 3¼ Pin, 3¼ x 4¼ Box.
1 4½-inch x 36 foot Stem, 2¼ x 3¼ Box and Pin.
1 Prosser Swivel Wire Line Rope Socket, 3¼ x 4¼ Box.
1 Prosser Swivel Wire Line Rope Socket, 2¼ x 3¼ Box.
1 New Era Rope Socket, 3¼ x 4¼ Box.
1 Set 6¼-inch Jars, 3¼ x 4¼ Joints.
1 Set 5½-inch Jars, 2¼ x 3¼ Joints.
1 Set 18-inch 2,200 Pound Bits, 4 x 5 Pins.
1 Set 15½-inch 1,800 Pound Bits, 4 x 5 Pins.
1 Set 12½-inch 1,400 Pound Bits, 3¼ x 4¼ Pins.
1 Set 10-inch 950 Pound Bits, 3¼ x 4¼ Pins.
1 Set 8¼-inch 750 Pound Bits, 3¼ x 4¼ Pins.

For 4,000 feet.

*1 Set 6¼-inch 600 Pound Bits, 2¼ x 3¼ Pins.
* 2¾ x 3¾ Pins are standard on 6¼-inch bits but if 6¼-inch 26 Pound Casing is used, the collar of the 2¾ x 3¾ joint would be too large to permit a fishing socket to go over it, so the 2¼ x 3¼ joint is a better size to use in the 26 pound casing.
1 Substitute, 2¼ x 3¼ Pin, 4 x 5 Box.
1 Substitute, 3¼ x 4¼ Pin, 4 x 5 Box.
1 Substitute, 2¼ x 3¼ Pin, 3¼ x 4¼ Box.
1 Substitute, 4 x 5 Pin, 2¼ x 3¼ Box.
1 Substitute, 4 x 5 Pin, 3¼ x 4¼ Box.
1 Substitute, 3¼ x 4¼ Pin, 2¼ x 3¼ Box.
1 15½-inch Under Reamer with Extra Set Cutters.
1 12½-inch Under Reamer with Extra Set Cutters.
1 10-inch Under Reamer with Extra Set Cutters.
1 8¼-inch Under Reamer with Extra Set Cutters.
1 6¼-inch Under Reamer with Extra Set Cutters.
1 Block for dressing Under Reamer Cutters.
1 Set 5-inch 400 pound Tool Wrenches.
1 Set 4-inch 300 pound Tool Wrenches.
1 No. 2 Barrett Jack with Rack.
1 Barrett Swivel Wrench with Plates for 5-inch and 4-inch squares.
1 2 Ton Cyclone Hoist.
1 Ball Bearing Derrick Crane with 4 x 5 Beam.
1 Bit Pulley and Chain.
1 14-inch x 15 foot Bailer.
1 11-inch x 19 foot Bailer.
1 9-inch x 19 foot Bailer.
1 7-inch x 25 foot Bailer.
1 5½-inch x 30 foot Bailer.
1 Each 18, 15½, 12½, 10, 8¼ and 6¼ Tool Gauges.
1 Set Spiders and Slips for 15½, 12½, 10, 8¼ and 6¼ Casing.
1 Set 20-inch O. D. Wilson Elevators.
1 Set 15½-inch Wilson Elevators.
1 Set 12½-inch Wilson Elevators.
1 Set 10-inch Dunn Elevators.
1 Set 8¼-inch Dunn Elevators.
1 Set 6¼-inch Dunn Elevators.
1 42-inch Triple Casing Block.
1 6½-inch Casing Hook.
1 Type A Dunn Tongs.
1 Dunn Tool Support.
1 Steam Turbine Electric Generator with Wiring and Lamps.
1 Spudding Shoe.
1 Steel Forge.
1 Slack Tub.
1 Type U 2½ H. P. Novo Pumping Outfit.
1 400 Pound Bit Ram.
1 Telegraph Wheel.
1 Wire Telegraph Line.
1 Set Casing Wagons.
1 4,000 foot Aluminum Measuring Line and Reel.

For list of small tools and fittings see pages 90-91.

Estimated cost of above outfit at Pittsburgh, Pa., including general supplies but not including derrick, $15,000.00.

Outfit suitable for drilling 5,000 feet and for handling 4,000 feet 28-pound casing, where under-reaming is necessary:

1 84 foot Standard California Derrick using 7½-inch Ideal Clutch, Sprocket Rig and Calf Irons, Steel Crown Block with 5 Casing Pulleys, and Ideal Double Friction Sand Reel, with 6-inch Shaft and Craig Swing Lever Attachment.
1 70 H. P. California Boiler.
1 14 x 14 (50 H. P.) Engine.

For 5,000 feet.

95 Feet 14-inch 8 Ply Stitched Rubber Belt.
1 1-inch x 5,500 foot Extra Strong or Plough Steel Wire Drilling Cable.
1 11/16-inch x 5,500 foot Steel Wire Sand Line.
1 1⅛-inch x 1,000 foot Steel Wire Casing Line.
1 Set 22-inch 2,500 Pound Bits, 4 x 5 Pins.
1 22-inch Tool Gauge.
1 20-inch O. D. Under Reamer with 4 x 5 Pin.
1 Set 24-inch O. D. Elevators or if these cannot be had, a special Swivel threaded to screw into Couplings of 24-inch O. D. Drive Pipe in lieu of Elevators.
1 42-inch Quadruple Extra Heavy Casing Block.
1 Spider with Liner and Slips for 20-inch O. D., 15½-inch, 12½-inch, 10-inch 8¼-inch and 6¼-inch Casing.
1 5,000 foot Aluminum Measuring Line with Reel.
1 7½-inch Casing Hook.

With the exception of the above items, the outfit for drilling 4,000 ft. for Ranger, Texas, specified on pages 86-87 may be used.

Estimated cost of above outfit at Pittsburgh, Pa., including general supplies but not including derrick, $20,000.00.

Specification of an outfit for drilling 7,500 feet and for handling 4,500 feet of 30-pound casing, where the rock formations stand up:

Note: All of the equipment for this deep drilling is not regularly manufactured by oil well supply companies and part of it would have to be made to order. This specification is based on the experience of the People's Natural Gas Co., in drilling their well 7,250 feet on the Geary farm near McDonald, Pa., and of the Hope Natural Gas Co. in drilling their wells 7,270 feet on the Goff farm near Bridgeport, W. Va., and 7,579 feet on the Lake farm near Fairmont, W. Va.

It has been the practice of the Hope Company to use standard derrick and outfit such as would be used in drilling in 3,000-foot well to drill these deep wells down to about that depth and then, as the depth of the well increases, to replace the light with heavy equipment suitable for drilling greater depths. See record of Lake log, Chapter XV.

Derrick: 100 feet in height with 26-foot base, doubled from top to bottom and reinforced with 6- x 8-inch oak timbers bolted in the corners and extending from foundation to crown block.

Crown block constructed of 8 x 20-inch oak timbers or of 15-inch steel I beams, and equipped with 4 casing pulleys. Walking beam, oak, 22 x 36 inches, 27 feet long. Bull wheels, 10 feet in diameter with 2 brake wheels for 12-inch brake bands and tug side with three grooves for triple tug, 24-inch oak shaft with 6-inch cast steel or forged gudgeons. Band wheel, 14 feet in diameter with 18-inch face, 7¼-inch diameter shaft with forged steel crank, 8 inches thick at the shaft end and 4-inch diameter wrist pin and 60-inch flanges. Tug pulley, 8 feet in diameter with 3 grooves for 3-inch bull ropes. Sampson post, 24 inches square. Crown pulley, 36 inches in diameter with 6-inch steel shaft. Center irons similar to those furnished with 7½-inch Ideal Rig irons. Stirrup made of 3-inch round iron. Sand pump pulley 24 inches in diameter with 4½-inch steel shaft. Sand reel, 6-inch by 15-foot shaft, 48-inch pulley with 16-inch face and steel flanges 1 inch thick with extra 1-inch plate for center flange, making it 2 inches thick. Jack post boxes and guy rods similar to those furnished with 7½-inch Ideal rig irons. All sills and timbers should be fifty per cent. heavier than those used on the derrick for 3,000 foot drilling.

2 30-H. P. Portable Boilers.
1 14 x 14 (50-H. P.) Engine or 2 30-H. P. Engines connected with shaft coupling.
150 feet 16-inch 8-Ply Stitched Rubber Belt.
1 2½-inch x 4,000 foot Hawser Laid Manila Drilling Cable.
1 Special 8,000-foot Plough Steel Wire Drilling Cable, 1¼ inches in diameter at top, tapering to ⅞-inch in diameter at bottom.

For 7,500 feet.

1 11-16-inch x 8,000 foot Steel Wire Sand Line.
1 2½-inch x 7-foot Ball Bearing Temper Screw with Extra Heavy Manila Clamps and Extra Heavy Wire Line Clamps.
1 New Era Rope Socket, 3½ x 4½ Box.
1 New Era Rope Socket, 3 x 4 Box.
1 Prosser Wire Line Rope Socket, 3½ x 4½ Box.
1 Prosser Wire Line Rope Socket, 3 x 4 Box.

Note: The collars on all tools for the 6⅝-inch hole with 3 x 4 joints should be turned to 5½ inches diameter. Bits for 30-pound casing should be 6¼-inch.

1 Set 8-inch diameter Drilling Jars with 5-inch stroke, 4 x 5 Joints.
1 Set 6¼-inch diameter Drilling Jars with 5-inch stroke, 3½ x 4½ Joints.
1 Set 5½-inch diameter Drilling Jars with 5-inch stroke, 3 x 4 Joints.
1 6-inch x 32-foot Stem, 3½ x 4½ Pin, 4 x 5 Box.
1 5-inch x 34-foot Stem, 3½ x 4½ Joints.
1 4½-inch x 38-foot Stem, 3 x 4 Joints.
1 Set 18-inch 2,000-pound All Steel Bits, 4 x 5 Pins.
1 Set 15½-inch 1,500-pound All Steel Bits, 4 x 5 Pins.
1 Set 12½-inch 1,150-pound All Steel Bits, 4 x 5 Pins.
1 Set 10-inch 800-pound All Steel Bits, 3½ x 4½ Pins.
1 Set 8¼-inch 600-pound All Steel Bits, 3½ x 4½ Pins.
1 Set 6¼-inch 450-pound All Steel Bits, 2¾ x 3¾ or 3 x 4 Pins.
1 Each 18, 15½, 12½, 10, 8¼ and 6¼-inch Tool Gauges.
1 11-inch x 19-foot Bailer.
1 9-inch x 19-foot Bailer.
1 7-inch x 25-foot Bailer.
1 5-inch x 40-foot Sectional Bailer.
1 7-inch Larkin or Model Sand Pump.
1 Set 550-Pound Tool Wrenches, 5½-inch square.
1 Set 450-Pound Tool Wrenches, 5-inch square.
1 Set 350-Pound Tool Wrenches, 4½-inch square.
1 No. 4 Extra Heavy Barrett Jack with Rack.
1 Ball Bearing Derrick Crane with 4 x 5-inch T Iron Arm.
1 2-Ton Moore Chain Hoist.
1 No. 3 Barrett Swivel Wrench with 4½, 5 and 5½-inch Plates.
1 Spudding Shoe.
1 Bit Ram.
1 20-inch O. D. Drive Head.
1 Set California Pattern Drive Clamps made of 7 x 7 x 24-inch Iron with Wrench.
6 Derrick Lamps.
1 Steam Turbine Electric Generator with Wiring and Lamps.
1 Telegraph Wheel and Line.
1 Set 15½-inch Wilson Extra Heavy Elevators with 2¾-inch Links.
1 Set 12½-inch Wilson Extra Heavy Elevators with 2½-inch Links.
1 Set 10-inch Wilson Extra Heavy Spring Latch Elevators with 2½-inch Links.
1 Set 8¼-inch Wilson Extra Heavy Spring Latch Elevators with 2½-inch Links.
1 Set 6⅝-inch Wilson Extra Heavy Spring Latch Elevators with 2½-inch Links.
1 40-inch Quadruple Bronze Bushed Steel Casing Block.
1 8½-inch Extra Heavy Casing Hook or Strapped C Hook.
1 4½-inch Casing Hook.
1 1¼-inch x 1,200-foot Plough Steel Wire Casing Line.
3 3-inch x 135-foot Manila Bull Ropes.
1 Novo Pumping Outfit with 4-H. P. Gas Engine.
1 M Dunn Casing Tongs with Bushings for 15½, 12½ and 10-inch Casing.
1 C. X. Dunn Casing Tongs with Bushings for 8¼ and 6⅝-inch Casing.
1 Oak Casing Pole.
12 1¼-inch Wire Rope Clips.
6 11/16-inch Wire Rope Clips.
1 7,500 foot Measuring Line with Reel.

For 7,500 feet.

1 Tool Substitute, 3½ x 4½ Pin, 4 x 5 Box.
1 Tool Substitute, 4 x 5 Pin, 3½ x 4½ Box.
1 Tool Substitute, 3 x 4 Pin, 3½ x 4½ Box.
1 Tool Substitute, 3½ x 4½ Pin, 3 x 4 Box.
1 Spider and Slips for 15½, 12½, 10, 8¼ and 6⅝-inch Casing.

Note: See Pages 90-91 for list of general supplies necessary with all outfits.

Note: In putting in the long strings of casing used in 7,500-foot well, the hole should be filled with water and a disc inserted in the casing to float it down and relieve the strain on the derrick, casing blocks, etc.

Outfit for drilling 7,500 feet where under-reaming is necessary:

No well, to the writer's knowledge, has ever been under-reamed to a depth of 7,500 feet, and the operation would be exceedingly difficult. For this purpose calf wheels, under reamers, etc., would have to be added to the above outfit and it might be necessary to use a 80- to 100-horsepower boiler and 60- to 75-horsepower engine to handle the casing, etc.

Note: No estimate of cost is furnished for this outfit, for the reason that much of the equipment would have to be specially made.

Small Tools and Supplies Needed With All Outfits

1 Steel Tool Box with Padlock.
5 Hay Fork Pulleys.
1 Never Slip Pipe Grip.
1 Anvil.
1 Star Blower for Forge.
1 Emery Wheel to run on Blower.
2 14-Pound Sledges with Handles.
2 B. P. Hammers.
2 Derrick Hatchets.
2 Blacksmith Tongs.
1 15-inch Combination Wrench.
1 18-inch Trimo Wrench.
1 Chain Tongs, ¼- to 2½-inch.
1 Chain Tongs, 1- to 6-inch.
1 2-inch Crumble Tongs.
1 2½-inch Crumble Tongs.
1 Cold Chisel.
1 Splitting Chisel.
1 Steel Punch.
1 Hardie.
1 Flatter.
1 Casing Splitter.
1 Flue Cleaner.
1 3-inch Boiler Tube Expander.
1 14-inch Flat File.
1 12-inch ½ Round File.
2 6-inch Slim Taper Files.
1 Ax with Handle.
1 Pick with Handle.
1 Mattock with Handle.
1 Brace.
3 Augers, 1- to 2-inch.
3 Auger Bits, ¼- to ¾-inch.
1 1-inch Ship Auger.
1 Auger Handle.
1 Expansive Bit.
1 Belt Punch.
1 Screw Driver.
1 Saw.
1 No. 3 Steel Square.
1 12-inch Draw Knife.
1 Shovel.
1 Coal Scoop.
1 14-inch Ditching Spade.
2 2 x 12-inch Jack Screws.
1 Crow Bar.
1 50 foot Metallic Tape.
1 No. 2 Combination Vise.
1 Ratchet Stock and Dies to Thread, 1 to 2-inch Pipe.
1 Malleable Stock and Dies to Thread ¼ to 1-inch Pipe.
1 Pipe Cutter.
1 1-inch Pipe Tap.
1 2-inch Pipe Tap.
1 Hack Saw Frame.
12 Hack Saw Blades.
1 6-inch Long Handle Melting Ladle.
1 No. 14 Steel Oiler.
1 Railroad Oiler, Long Spout.
1 Derrick Pail.
1 Wire Thread Brush.
1 Pair Combination Pliers.
10 Pounds No. 9 Smoke Stack Guy Wire.
5 Pounds Rivet Iron.
1 Pound Bailer Rivets.
1 Pound Emery.
50 Pounds Babbitt.
10 Pounds Tool Steel.
2 Pounds Hand Hole Gaskets.
1 Pound Graphite.
5 Pounds Asbestos Millboard Packing.

Small Tools and Supplies Needed With All Outfits—Concluded.

2 Pounds Square Piston Packing.
2 Pounds Hemp or Flax Packing.
5 Pounds ⅛-inch Red Sheet Packing.
5 Pounds 1/16-inch C. B. S. Sheet Packing.
5 Gallons Cylinder Oil.
5 Gallons Engine Oil.
1 Gallon Lard Oil.
1 Pail Tallow.
5 Pounds Cup Grease.
10 Pounds Jack Post Grease.
1 Pound White Lead.
5 Pounds Waste.
25 Feet 1-inch Hose with Couplings and Nozzle.
If derrick lamps are used add:
1 Barrel Torch Oil,
1 Pound Lamp Wick.
300 Feet 1-inch Pipe.
200 Feet 2-inch Pipe.
6 1-inch Tees.
6 2-inch Tees.
6 1-inch Ells.
6 2-inch Ells.
6 1-inch Plugs.
6 2-inch Plugs.
12 1-inch Assorted Nipples.
12 2-inch Assorted Nipples.
3 1-inch Lip Unions.
3 2-inch Flange Unions.
3 2 x 1-inch Bushings.
3 1 x ½-inch Bushings.
3 1-inch Brass Globe Valves.
2 2-inch Brass Globe Valves.
1 1-inch Brass Check Valve.
2 2-inch Iron Cocks.

TYPICAL COMPLETE DRILLING OUTFIT WITH EXTRA PARTS, FISHING TOOLS, ETC., FOR USE IN FOREIGN FIELDS

1 Set 6-inch Ideal Chain Driven Rig and Calf Irons, with Wood Work, Nails, Bolts, Sand Reel, etc., as specified on pages 62-63.
1 40 H. P. Oil Country Type Boiler for not less than 100 pounds pressure, complete.
1 Boiler Mounting with 8-inch Tires.
1 12 x 12 Steam Engine complete.
1 2⅝-inch x 2,000-foot Hawser Laid Manila Drilling Cable.
1 2⅝-inch x 1,000-foot Hawser Laid Manila Drilling Cable.
1 ⅞-inch x 3,500-foot extra strong, 6 x 19 Wire Drilling Cable.
1 9/16-inch x 3,800-foot Wire Sand Line.
1 1-inch x 1,100-foot Wire Casing Line.
200 Feet 1¼-inch Plain Laid Rope.
200 Feet 1-inch Plain Laid Rope.
200 Feet ⅞-inch Plain Laid Rope.
1 12-inch x 6-ply x 100-foot Rubber Belt or
1 12-inch x 6-ply x 100-foot Canvas Belt.
6 Sets 12-inch Extra Heavy Belt Clamps and 24 Extra Bolts.
1 Belt Tightener.
6 Each ½-inch, ⅞-inch and 1-inch Wire Rope Clips.
2 2⅛-inch x 95-foot Bull Ropes.
1 4½ x 2¾ x 4 Duplex Boiler Feed Pump complete with Brass Plunger.
1 Myers' Low Down Pump.
1 Moon Turbine Generator with 650 feet of Weatherproof Wire, 15 Lamp Sockets, 10-25 Watt Lamps, 4-40 Watt Lamps, 4-60 Watt Lamps and with Double Pole Switch with Fuses, 35 Knobs and Tapes.
1 5⅝-inch x 36-foot Drilling Stem, 4 x 5 Box, 3¼ x 4¼ Pin.
1 5 -inch x 40-foot Drilling Stem, 3¼ x 4¼ Box, 2¾ x 3¾ Pin.
1 4¼-inch x 40-foot Drilling Stem, 2¾ x 3¾ Box, 2¾ x 3¾ Pin.
1 4¼-inch x 27-foot Drilling Stem, 2¾ x 3¾ Box, 2¾ x 3¾ Pin.
1 3⅝-inch x 40-foot Drilling Stem, 2¼ x 3¼ Box, 2¼ x 3¼ Pin.
1 3⅝-inch x 25-foot Drilling Stem, 2¼ x 3¼ Box, 2¼ x 3¼ Pin.
3 Sets 6¼-inch, 6-inch stroke, Drilling Jars, 3¼ x 4¼ Box and Pin.
3 Sets 5½-inch, 6-inch stroke, Drilling Jars, 2¾ x 3¾ Box and Pin.
3 Sets 4½-inch, 6-inch stroke, Drilling Jars, 2¼ x 3¼ Box and Pin.
2 New Era Rope Sockets for 2⅝-inch Rope, 3¼ x 4¼ Box.
2 New Era Rope Sockets for 2⅝-inch Rope, 2¾ x 3¾ Box.
2 New Era Rope Sockets for 2⅝-inch Rope, 2¼ x 3¼ Box.
2 Babcock Rope Sockets for ⅞-inch Wire Rope, 3¼ x 4¼ Box.
2 Babcock Rope Sockets for ⅞-inch Wire Rope, 2¾ x 3¾ Box.
2 Babcock Rope Sockets for ⅞-inch Wire Rope, 2¼ x 3¼ Box.
1 Prosser Swivel Rope Socket for ⅞-inch Wire Rope, 2¾ x 3¾ Box.
1 Set of 5 3/16-inch 250 Pound All Steel Bits, 2¼ x 3¼ Pins.

1 Set of 6 ⅝ -inch 400 Pound All Steel Bits, 2¾ x 3¾ Pins.
1 Set of 8 ¼ -inch 550 Pound All Steel Bits, 3¼ x 4¼ Pins.
1 Set of 10 -inch 750 Pound All Steel Bits, 3¼ x 4¼ Pins.
1 Set 12½-inch 1,050 Pound All Steel Bits, 4 x 5 Pins.
1 Set 15½-inch 1,400 Pound All Steel Bits, 4 x 5 Pins.
1 Set 18 -inch 1,700 Pound All Steel Bits, 4 x 5 Pins.
2 4 x 5 Boxes to weld.
2 3¼ x 4¼ Boxes to weld.
2 2¾ x 3¾ Boxes to weld.
2 2¼ x 3¼ Boxes to weld.
2 3¼ x 4¼ Pins to weld.
2 2¾ x 3¾ Pins to weld.
2 2¼ x 3¼ Pins to weld.
1 Sub, 4 x 5 Box, 3¼ x 4¼ Pin.
1 Sub, 3¼ x 4¼ Box, 4 x 5 Pin.
1 Sub, 3¼ x 4¼ Box, 2¾ x 3¾ Pin.
1 Sub, 2¾ x 3¾ Box, 3¼ x 4¼ Pin.
1 Sub, 3¼ x 4¼ Box, 2¼ x 3¼ Pin.
1 Sub, 2¼ x 3¼ Box, 3¼ x 4¼ Pin.
1 Sub, 2¾ x 3¾ Box, 2¼ x 3¼ Pin.
1 Sub, 2¼ x 3¼ Box, 2¾ x 3¾ Pin.
1 Sub, from 8¼" D. B. X. Casing to 2¾ x 3¾ Tool Box.
1 Sub, from 6⅝" D. B. X. Casing to 2¾ x 3¾ Tool Box.
1 Sub, from 5 3/16" Boston Casing to 2¼ x 3¼ Tool Box.
1 4" x 25-foot Wrought Iron Bailer with Forged Steel Valve.
1 4½" x 25-foot Wrought Iron Bailer with Forged Steel Valve.
1 5½" x 25-foot Wrought Iron Bailer with Forged Steel Valve.
1 7" x 25-foot Wrought Iron Bailer with Forged Steel Valve.
1 9" x 20-foot Wrought Iron Bailer with Forged Steel Valve.
1 11" x 20-foot Wrought Iron Bailer with Forged Steel Valve.
1 14" x 20-foot Wrought Iron Bailer with Forged Steel Valve.
1 Bailer Dump for 2-inch Pipe.
1 2¼-inch x 6-foot Improved Ball Bearing Temper Screw with Inserted Boxes and with Manila Clamps for 2⅝-inch Rope
1 Set of Heavy Mechling Wire Rope Clamps with extra set of slips.
1 Set 450 Pound Tool Wrenches, 5½-inch Square.
1 Set 350 Pound Tool Wrenches, 4½-inch Square and Liner to 4-inch.
1 Set 250 Pound Tool Wrenches, 3½-inch Square.
1 5-inch Larkin Sand Pump.
1 15½-inch Double or Wilson Under Reamer, 3¼ x 4¼ Pin.
1 12½-inch Double or Wilson Under Reamer, 3¼ x 4¼ Pin.
1 10 -inch Double or Wilson Under Reamer, 3¼ x 4¼ Pin.
1 8¼-inch Double or Wilson Under Reamer, 2¾ x 3¾ Pin.
1 6⅝-inch Double or Wilson Under Reamer, 2¾ x 3¾ Pin.
1 5 3/16-inch Double or Wilson Under Reamer, 2¼ x 3¼ Pin.
1 Style D Anvil to dress 6, 8 and 10-inch Bits.
1 Style D Anvil to dress 12½ and 15½-inch Bits.
3 Extra Sets Cutters for each size Under Reamer.
2 Extra No. 17 Bolts for each size Under Reamer
1 Ball Bearing Derrick Crane complete with 2-ton Hoist and Barrett Swivel Wrench with 5½-inch Square and 5-inch Plate including Bit, Pulley and Chain.
1 No. 2 Barrett Tool Jack with Rack.
1 15½-inch Spider with Liner and Wedges for 15½, 12½, 10, 8¼, 6⅝ and 5 3/16-inch Casing.
1 6-inch Extra Heavy California Casing Hook.
1 4½-inch Extra Heavy California Casing Hook.
1 36-inch Quadruple Bronze Bushed Steel Casing Block.
1 Each 10-inch, 8-inch and 7-inch Hartz Steel Snatch Blocks.
1 Set 15½-inch Wilson or Dunn Elevators with 2½-inch Links.
1 Set 12½-inch Wilson or Dunn Elevators with 2½-inch Links.
1 Set 10 -inch Wilson or Dunn Elevators with 2 -inch Links.
1 Set 8¼-inch Wilson or Dunn Elevators with 2 -inch Links.
1 Set 6⅝-inch Wilson or Dunn Elevators with 2 -inch Links.
1 Set 5 3/16-inch Wilson or Dunn Elevators with 2 -inch Links.
1 Each 15½, 12½, 10, 8¼, 6⅝ and 5 3/16-inch Tool Gauges.
1 Spudding Shoe Complete for Manila Rope.
1 Set Box and Pin Gauges, 2¼ x 3¼, 2¾ x 3¾, 3¼ x 4¼, and 4 x 5.
1 Set 15½-inch Casing Clamps with 10-inch Ears.
1 Set 12½-inch Casing Clamps.

1 Set 10 -inch Casing Clamps.
1 Set 8¼-inch Casing Clamps.
1 Set 6⅝-inch Casing Clamps.
1 Set 5 3/16-inch Casing Clamps.
1 No. 4 Star Blower.
1 Guiberson-Mills Handle and Jaws for 15½-inch, 12½-inch, 10-inch, 8¼-inch, 6⅝-inch and 5 3/16-inch Casing.
1 3,500-foot Aluminum Measuring Line Complete with Clamps and Reel.
1 300 Pound Bit Ram.
2 No. 2, 22 x 20 x 66, Steel Tool Boxes.
1 Set 6 x 6 x 24-inch California Pattern Drive Clamps with 5-inch Square and 3 x 7 Bolts.
1 Forged Steel Drive Clamp Wrench for 3-inch Bolts.
2 3 x 17-inch Drive Clamp Bolts, California Pattern.
1 Steel Drive Shoe for 20-inch O. D. Drive Pipe.
2 Steel Drive Shoes for 15½-inch I. D. Casing.
2 Steel Drive Shoes for 12½-inch I. D. Casing.
2 Steel Drive Shoes for 10 -inch I. D. Casing.
2 Steel Drive Shoes for 8¼-inch I. D. Casing.
2 Steel Drive Shoes for 6⅝-inch I D. Casing.
2 Steel Drive Shoes for 5 3/16-inch I. D. Casing.
1 Each 20-inch O. D., 15½-inch, 12½-inch and 10-inch Hollow Steel Drive Heads.
1 Butler Portable Steam Hammer with Anvil.
1 50 Bbl. Galv. Storage Tank.
1 56 Bbl. Galv. Storage Tank.
1 60 Bbl. Galv. Storage Tank.

(The above tanks to be nested for convenient shipment.)

1 3-inch Boiler Tube Expander.
1 2-inch Pipe Tap.
1 1-inch Pipe Tap.
1 ¾-inch Pipe Tap.
1 ½-inch Pipe Tap.
1 ⅜-inch Pipe Tap.
1 ¼-inch Pipe Tap.
1 3-inch Freeman's Flue Cleaner.
1 50-foot Lufkin Metallic Tape Measure.
400 Feet ⅝-inch Wire Rope for Derrick Stays
10 Pounds No. 9 Smoke Stack Guy Wire.
1 Emery Wheel for Star Blower.
2 Never Slip Pipe Grips.
1 No. 14 Vulcan Chain Tongs.
1 No. 15 Vulcan Chain Tongs.
1 2-inch United Pattern Steel Lined Klein Tongs with 24 Extra Bits.
1 2½-inch United Pattern Steel Lined Klein Tongs with 24 Extra Bits.
1 2 -inch Crumbie Tongs.
1 2½-inch Crumbie Tongs.
1 Set Casing Wagons.
2 100-Ton Double Piston Outside Pump Hydraulic Jacks.
1 No. 3 Combination Vise.
1 No. 2 Armstrong Malleable Pipe Vise.
1 Ratchet Stock and Dies to thread 1 to 2-inch pipe.
1 No. 1 Malleable Stock and Die.
1 No. 7 Little Giant Screw Plate.
1 No. 1 Barnes 3-Wheel Pipe Cutter.
1 No. 2 Barnes 3-Wheel Pipe Cutter.
6 Extra Wheels for No. 1 and No. 2 Barnes Pipe Cutters.
8 2-inch 18½-pound B. W. Iron Cocks.
1 C Penberthy Injector.
1 1-inch Jarecki Jet.
12 2-inch Malleable Tees.
24 1-inch Malleable Tees.
12 ½-inch Malleable Tees.
12 2-inch Malleable Ells.
24 1-inch Malleable Ells.
12 ½-inch Malleable Ells.

24 2 -inch C. I. Plugs.
24 1 -inch C. I. Plugs.
12 ½-inch C. I. Plugs.
18 1-inch Jenkins Globe Valves with 24 Extra Discs.
24 1-inch Malleable Lip Unions.
12 2 x 1-inch Cast Iron Bushings.
12 1 x ½-inch Cast Iron Bushings.
12 2-inch 4-Bolt O. C. Flange Unions.
6 ½-inch Std. Brass Globe Valves.
24 2-inch Assorted Nipples.
36 1-inch Assorted Nipples.
12 ½-inch Assorted Nipples.
1 15½ x 12½-inch Swaged Nipple.
1 15½ x 10 -inch Swaged Nipple.
1 10 x 8¼-inch Swaged Nipple.
1 8¼ x 6⅝-inch Swaged Nipple.
1 6⅝ x 5 3/16-inch Swaged Nipple.
1 6⅝ x 2 -inch Swaged Nipple
1 Large size I. & H. Anvil.
1 3-Pound B. P. Hammer.
1 14-Pound C. P. Sledge with Handle.
1 14-Pound S P. Sledge with Handle.
1 12-Pound S. P Sledge with Handle.
6 3-Pound Splitting Chisels.
6 1½-Pound Cold Chisels.
1 Casing Splitter.
1 ¾-inch Calking Chisel.
1 B. S. Hardie.
1 3-inch B S. Flatter.
1 5½-Pound B. S. Set Hammer.
1 ⅝-inch Top Fuller, 3½-Pound.
1 ⅝-inch Bottom Fuller, 4-Pound.
1 ⅝-inch Top Swage, 3½-Pound.
1 ⅝-inch Bottom Swage, 4-Pound.
1 Diamond Point Chisel, 1¼-Pound.
1 Hot Chisel with large hole for handle, 5-Pound.
1 Cold Chisel, Splitting, with large hole for handle, 5-Pound.
2 1¼-Pound Steel Hand Punches.
2 26-Pound Crow Bars.
2 Pairs Blacksmiths' Tongs, 27-inch, Straight Lip.
1 Dozen Oil King Hatchets for Rig Builders.
1 6⅝-inch x 9/16-inch Sand Line Cap.
1 8¼-inch x 9/16-inch Sand Line Cap.
1 12½ x 10-inch Stuffing Box Casing Head.
1 10 x 8¼-inch Stuffing Box Casing Head.
1 8¼ x 6⅝-inch Stuffing Box Casing Head.
1 6⅝ x 5 3/16-inch Stuffing Box Casing Head.
1 6⅝-inch 4-way Common Casing Head.
1 12-inch Combination Wrench.
1 15-inch Combination Wrench.
1 24-inch Stillson Wrench.
1 14-inch Trimo Wrench.
1 6⅝ x 2¼-inch Barrel Oil Saver.
1 Drilling Oil Saver for ⅞-inch Wire Rope.
2 Peavies.
2 2-inch x 20-inch Common Jack Screws.
2 1½-inch x 12-inch Common Jack Screws.
2 Square Point D Handle Shovels.
2 Round Point Long Handle Shovels.
2 6-Pound Railroad Picks.
2 6-Pound Mattocks.
6 Pick and Mattock Handles (3 of each).
1 No. 3 Steel Square.
1 No. 106 Fray Ratchet Brace.
1 ⅞-inch x 36-inch Irwins' Solid Center Ship Auger.
1 1 -inch x 36-inch Irwin's Solid Center Ship Auger.
1 1¼-inch x 36-inch Irwin's Solid Center Ship Auger.
1 1½-inch x 36-inch Irwin's Solid Center Ship Auger.
2 26-inch No. 7 Hand Saws.

2 26-inch No. 8 Diston Rip Saws.
1 14-inch Compass Saw.
1 5-foot 6-inch Cross Cut Saw with Handle.
1 No. 9 Adjustable Hack Saw Frame.
12 12-inch Hack Saw Blades.
1 No. 1 Morrill Hand Saw Set.
1 No. 4 Morrill Cross Cut Saw Set.
1 12-inch Common Draw Knife.
1 No. 9 Carpenters' Level.
1 Screw Driver.
1 No. 5 Iron Jack Plane.
1 10-inch Combination Pliers.
1 No. 14 Copperized Oiler.
1 No. 13 Copperized Oiler.
3 No. 3 Steel Bottom Oilers.
12 Pairs of Heavy Strap Hinges, 12-inch.
1 Set 8-inch Outside and Inside Calipers.
12 12-inch Hinge Hasps and Staples.
4 1-inch Extra Heavy Turnbuckles.
5 Pounds Rivet Iron.
1 Pound Bailer Rivets.
4 Bars ⅝-inch Round Iron.
4 Bars ¾-inch Round Iron.
4 Bars ⅞-inch Round Iron.
4 Bars 1 -inch Round Iron.
10 Feet 1-inch Hexagon Tool Steel.
25 Gallons Cylinder Oil.
25 Gallons Engine Oil.
5 Gallons Lard Oil.
5 Pounds Cup Grease.
10 Pounds Jack Post Grease.
5 Pounds Waste.
1 Pail Tallow.
1 Pound White Lead.
5 Pounds Hand Hole Gaskets.
5 Pounds ¾-inch Asbestos Piston Packing.
10 Pounds ⅛-inch C. B. S. Packing.
10 Pounds 1/16-inch C. B. S. Packing.
10 Pounds ⅛-inch Red Eye Packing.
10 Pounds 1/16-inch Red Eye Packing.
10 Pounds 40 x 40 x 3/32 Asbestos Mill Board.
20 Feet 1-inch 4-ply Steam Hose.
40 Feet 1-inch 3-ply Water Hose.
100 Pounds No. 4 Babbitt.
1 6-inch Long Handle Melting Ladle.
1 1 Pound Box Dry Graphite.
6 12-inch Half-Round Bastard Files.
6 10-inch Flat Bastard Files.
2 12-inch Square Bastard Files.
2 10-inch Round Bastard Files.
6 5-inch Slim Taper Files.
6 6-inch Slim Taper Files.
1 Wire Thread Brush.
1 Clark's Large Expansive Bit with 2 Cutters.
3 No. 3 O. K. Lease Hatchets.
6 No. 3 O. K. Lease Hatchet Handles, 18-inch.
1 Double Bit Axe with Handle.
1 Single Bit Axe with Handle.
12 Sledge Handles.
1 Swan Auger Handle.
24 5-inch Hartz Steel Hay Fork Pulleys.
3 No. 1 Grooved Derrick Wheels.
3 150-foot Wire Telegraph Cords.
1 No. 14 Belt Punch.
1 No. 5 Scorcher Derrick Stove.
1 24-inch Grindstone mounted on Frame.
1 No. 5 Steel Wheelbarrow.
1 No. 1 Adze Eye Nail Hammer.
1 No. 3 Boiler Ratchet.

Fishing Tools.

1 5 3/16-inch Fluted Swage, 2¼ x 3¼-inch.
1 6⅝ -inch Fluted Swage, 2¾ x 3¾-inch.
1 8¼ -inch Fluted Swage, 2¾ x 3¾-inch.
1 10 -inch Fluted Swage, 2¾ x 3¾-inch.
1 Set 4½-inch x 36-inch stroke Fishing Jars, 2¼ x 3¼-inch.
1 Set 5½-inch x 36-inch stroke Fishing Jars, 2¾ x 3¾-inch.
1 5 3/16-inch Friction Socket, 2¼ x 3¼-inch.
1 6⅝-inch Friction Socket, 2¾ x 3¾-inch.
1 8¼-inch Friction Socket, 2¾ x 3¾-inch.
1 Side Jar Socket to run in 6⅝-inch to catch 5½-inch Dia. Jars, 2¾ x 3¾ Pin.
1 Three Prong Rope Grab for 5 3/16-inch, 2¼ x 3¼-inch.
1 Three Prong Rope Grab for 6⅝-inch, 2¾ x 3¾-inch.
1 Combination Socket for 8¼-inch Hole to catch 2⅜-inch New Era Rope Socket, 2¾ x 3¾-inch.
1 Combination Socket to run in 6⅝-inch hole, with side opening and 2 sets of Slips, 2¾ x 3¾-inch.
1 Combination Socket to run in 5 3/16-inch hole, with side opening and 2 sets of Slips, 2¼ x 3¼-inch.
1 Slip Socket for 15½-inch hole with Bowl for 18-inch hole, 2¾ x 3¾ Pin, bore of Socket to be large enough to go over 4 x 5 Box on 5½-inch Stem, with 2 sets of Slips to catch Box on Stem or Collar on 18-inch or 15½-inch Bits.
2 Slip Sockets for 10-inch hole with Bowl for 12½-inch hole, 2¾ x 3¾ Pin, one to be bored to go over 5-inch Box and the other to be bored 6½-inch, and an extra Bowl for 18-inch hole and Slips to catch 6¼ and 5½-inch Collar.
1 Slip Socket for 8-inch hole with Bowl for 10-inch hole, 2¾ x 3¾-inch, bore 5⅝-inch, with 2 sets of Slips.
1 Long Slip Socket for 8-inch hole, bore 5⅝-inch, 2¾ x 3¾, to go over Jars and take hold of Stem, with 2 sets of Slips.
1 12½-inch Fox Trip Casing Spear, 2¾ x 3¾-inch.
1 10 -inch Fox Trip Casing Spear, 2¾ x 3¾-inch.
1 8¼-inch Fox Trip Casing Spear, 2¾ x 3¾-inch.
1 6⅝-inch Fox Trip Casing Spear, 2¾ x 3¾-inch.
1 5 3/16-inch Fox Trip Casing Spear, 2¼ x 3¼-inch.
1 Spud for 8-inch hole, 7-foot, 2¾ x 3¾-inch.
1 Spud for 6⅝-inch hole, 7-foot, 2¾ x 3¾-inch.
1 Spud for 5 3/16-inch hole, 7-foot, 2¼ x 3¼-inch.
1 Jar Tongue Socket for 6⅝-inch hole, 2¾ x 3¾-inch.
1 Jar Tongue Socket for 5 3/16-inch hole, 2¼ x 3¼-inch.
1 Side Jar Socket for 5 3/16-inch hole to catch 4½-inch Jars, 2¼ x 3¼ Pin.
1 Drive Down Socket for 5 3/16-inch hole, 2¼ x 3¼ Pin.
1 Drive Down Socket for 6⅝-inch hole, 2¾ x 3¾ Pin.
1 Drive Down Socket for 8¼-inch Hole, 2¾ x 3¾ Pin.
1 Bowl for 12½-inch Casing.
1 Bowl for 10 -inch Casing.
1 Bowl for 8¼-inch Casing.
1 10-inch M. & F. Forged Steel Nipple.
1 8¼-inch M. & F. Forged Steel Nipple.
1 6⅝-inch M. & F. Forged Steel Nipple.
1 5 3/16-inch M. & F. Forged Steel Nipple.
1 Boot Jack for 6⅝-inch hole, 2¾ x 3¾ Pin.
1 Boot Jack for 5 3/16-inch hole, 2¼ x 3¼ Pin.
1 Center Rope Spear for 6⅝-inch hole, 2¾ x 3¾ Pin.
1 Center Rope Spear for 5 3/16-inch hole, 2¼ x 3¼ Pin.
1 8-inch Bit Hook, 10 ft. long, 2¾ x 3¾ Pin.
1 Horse Shoe Trip Rope Knife Complete with Jars and Sinker for Manila Rope.
1 6⅝-inch and larger Rope Knife for Wire Line.
1 Jar Bumper, 300 Pounds, 12 ft. long.
1 6⅝-inch Hollow Reamer with 2¾ x 3¾ Pin.
1 8¼-inch Hollow Reamer with 2¾ x 3¾ Pin

Estimated cost of above outfit, including rig irons and general supplies, $30,500.00.

CHAPTER III.

STANDARD, OR CABLE, TOOL SYSTEM OF DRILLING—RIGGING UP, SPUDDING, DRIVING PIPE, DRILLING, UNDER-REAMING, BIT DRESSING

RIGGING UP

When the rig is ready and the drilling outfit is on the ground the first work is the "rigging up" of the derrick and drilling outfit.

The boiler is first set up about 50 to 100 feet from the engine

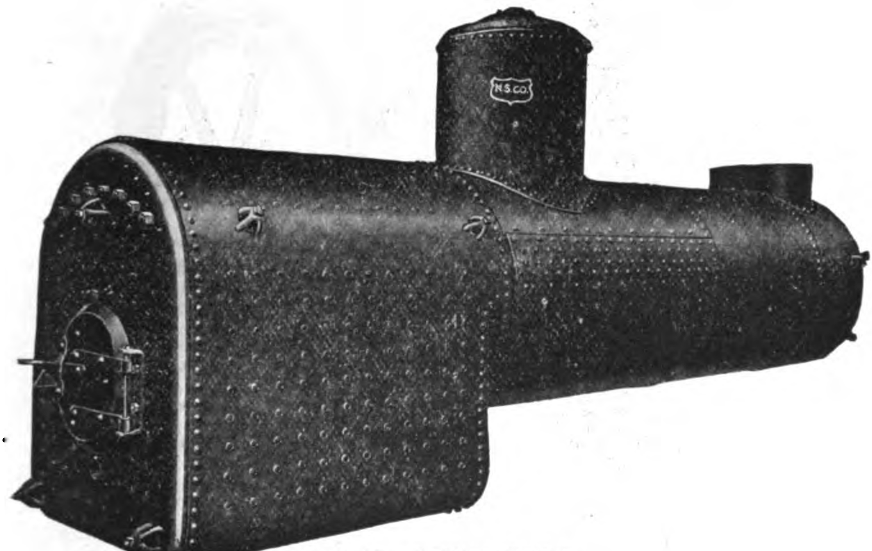


Fig. 27. Drilling Boiler

house and connected with the water supply. The stack is raised by means of a gin pole and then guyed with No. 9 wire or wire strand. Drilling boilers (See illustration) are usually tested at 150 pounds hydrostatic pressure, and they should be equipped with extra hand hole plates for convenience in cleaning. In California, a tubular boiler with dome, mounted in a frame of timbers or in brickwork, and with cast iron front and back, is extensively used instead of the fire box type boiler for drilling.

The engine is mounted on the engine block and the belt pulley is lined up with the band wheel. The boiler and engine connections are made; steam pipe from the boiler to the engine, and feed water from engine pump to boiler. Belt is next placed around belt pulley and the band wheel and properly clamped. Some drillers first clamp the belt, then place it around the

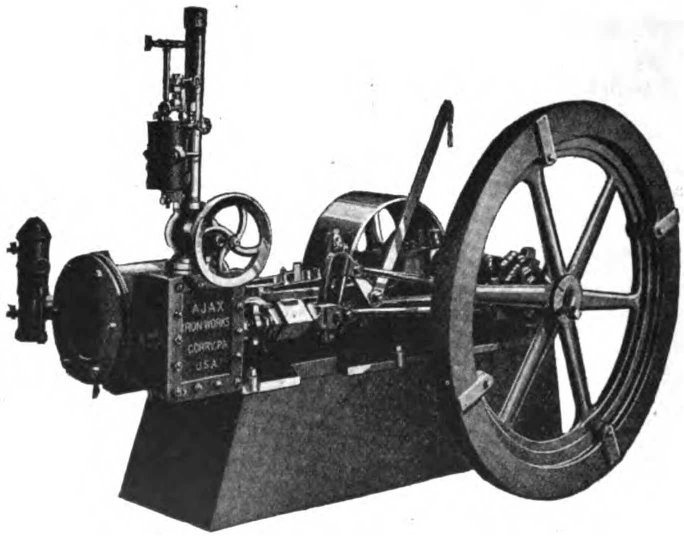


Fig. 28. Drilling Engine, Showing Fly Wheel Fitted with Extra Balances

engine pulley and start the edge of it on rim of band wheel and spike it; then start engine and run belt on band wheel, tearing the belt over head of spike in the operation. This is bad practice. A belt tightener should be used to draw the ends of belt together for clamping. Engine throttle is connected by means of a telegraph wheel on headache post and telegraph line to throttle; and engine reverse pipe is run into derrick at a place convenient to the driller's reach.

Several extra balances should be part of the equipment of a drilling engine to help balance the load when drilling at depth, or handling heavy tools. Note the type of lubricator used, capacity two quarts.

An internal combustion drilling engine manufactured by Clark Bros. Co. is now being introduced. It is a four-cylinder reversible engine of the automobile type, using gas or gasoline, and mounted on wheels. This engine might serve for use in localities where water is not available.

Two bull ropes are passed around the tug pulley on band wheel and over tug side of bull wheels. One end of sand line is carried up into derrick and over the sand sheave, thence down to the spooling drum on sand reel and spooled. The other end of the sand line is fastened by means of two clips to the bail of the bailer.

In stringing a Manila cable, it is best to select the end of the cable with the nap or projecting fibres pointing toward the coil. This end is carried up over the crown pulley and down under the bull wheel shaft and made fast. Engine is started and the cable spooled. The reason the nap or lay of the cable should be downward toward the rope socket is that the cable is subjected to greatest wear and strain when on the up stroke in drilling and in pulling out, and, if the lay of the rope is in the opposite direction, the tendency to fray and wear out will be minimized.

The Barrett jack circle (Fig. 55) is bolted to the derrick floor in a position that will allow the tool wrench handles to engage with the jack and circle post.

A forge is erected at one side of the derrick. It can be built of brick or a steel portable forge may be used. A steam blower should be used to furnish the forced draft.

The derrick crane with a chain hoist and a swivel wrench should be set up in right corner of derrick nearest walk, to handle bits from the derrick floor to the forge and on the anvil.

It is customary to swing and balance the tool wrenches by means of a pole fixed across one of the upper derrick girts, to each end of which is fastened a rope, one attached to the eye or handle in the wrench, the other connected to a counter weight sufficient to balance the wrench.

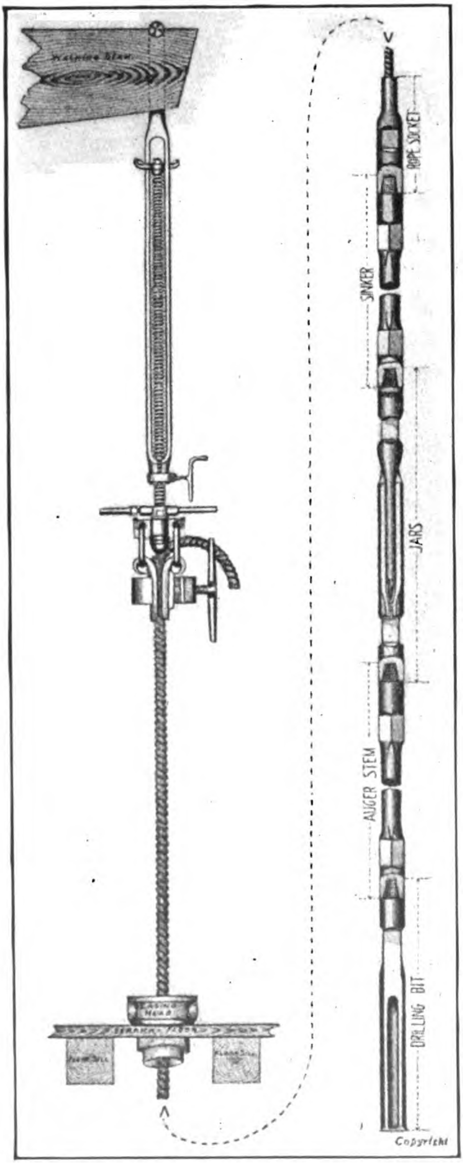


Fig. 29. (Oil Well Supply Co.)

Illustration of section of the end of a walking beam suspending a complete string of drilling tools, consisting of the temper screw with clamps, drilling cable, rope socket, s'nker bar, jars, auger stem and drilling bit, all connected and ready for drilling.

The temper screw (Fig. 44) is suspended from the walking beam and the temper screw elevator is connected with small size rope passed over hay fork pulleys, attached to walking beam, and fastened to counterweights, so that when screw is taken up while drilling the weights will balance it.

DIRECTIONS FOR CONNECTING UP THE TOOLS

Insert the end of the cable in the neck of rope socket and draw it down through the hole in the side. Unlay the three strands of the cable for a distance of about 12 to 15 inches from hole in socket, according to size of cable and socket. Take a piece of cable or bull rope about 12 inches long and separate it into yarns. Insert about 25 of these yarns between two of the strands as close to the socket as possible and wrap the two strands just below the yarns, being careful that the yarns project an equal distance on each side. Next insert the same number of yarns between the remaining strand and the two just wrapped and wrap the three strands together. Repeat this process once or twice or until the ends of the yarns last inserted come out even with the end of the cable. Then twist together the three strands of the cable and wrap them securely to the end. Smooth out the inserted yarns around the end of the cable and pull it back through the socket until the end is drawn tightly into the "woodpecker" hole. This makes a secure fastening of the cable in the socket and the greater the strain on the cable, the tighter it will hold in the socket.

Fig. 31. New Era Rope Socket

Lay the stem on the ground back of the bull wheels with a piece of timber under the pin end. Carry the cable and rope socket out over the bull wheels and above the second girt. Screw the rope socket to the stem and tighten the joint in the following manner:


Fig. 30. Stem

Place one of the tool wrenches on the wrench square of the socket, under the socket, and the other wrench on the square of the stem, over the stem. Bring the ends of the wrench handles as close together as possible. Pass the chain of a chain wrench around the two handles and tighten up with the wrench. This will make a sufficiently tight joint to hold until it can be set up in the regular way with the tool jack. Hoist the stem into the derrick, screw the pin of the bit into the box on the stem and tighten the joint with the jack. Be careful to brush and clean all grit, grease and dirt from the box and pin threads of all tools before the joints are screwed together.

COMMENCING THE WELL—SPUDDING

The first operation in the drilling of a well is spudding a hole through the surface soil to the first or bedrock and, where the rock lies close to the surface, setting a length of wood conductor; or in driving pipe to the rock where there is too great a depth of surface soil to use a conductor. This conductor or drive pipe should be of a suitable size to permit free passage of the first or largest size casing. In shallow wells drive pipe in 8 inches diameter may be used, while in deeper wells, or in wells requiring several strings of casing, drive pipe as large as 20 inches to 24 inches should be used.

As it is impossible to drill with the walking beam in commencing the well, owing to the length of the string of tools, the first drilling is done by spudding, so called. A jerk line, to which is attached a spudding shoe, is connected to the cable just above the bull wheel. (See Fig. 33.) The other end of the jerk line is made fast to an iron spool (furnished with spudding shoe) which revolves on the band wheel crank wrist pin. The crank imparts a jerking motion to the cable which causes the tools to rise and fall.

DIRECTIONS FOR APPLYING NATIONAL SPUDDING SHOE

Fig. 32. National Wire Line Spudding Shoe

The jerk line and bridle line should be carefully measured as indicated in figure No. 33.

The jerk line may be made of wire or Manila cable. If Manila is used, splice an eye in the end fastened to spudding shoe, as a knot adds weight which may cause tipping of the shoe. If wire line is used, wire rope clips may be used to make the loop or eye.

The bridle line should be made of good sand line, ½-inch or larger in diameter.

Make the jerk line according to length indicated in Fig. No. 33 and attach it to wrist pin and spudding shoe.

Slack drilling cable and hook spudding shoe over it.

Make loop about 2 feet long on one end of the bridle line.

Pass this loop between the double girts above the bull wheels and put a short block of wood through it. This block should rest about 2 feet from the center of the girts on the tug side of the derrick.

Pass bridle line back of and under bull wheel shaft and measure for length as shown at C and D in Fig. No. 33.

Fasten bridle line to spudding shoe as shown at (E) in Fig. No. 33 and be sure to bring it up under the part of the cable which passes from bull wheel shaft to spudding shoe on the forge side of the derrick. This is necessary in order that when shoe is unhooked and dropped to the floor, the bridle line will fall clear of the cable.

In spudding or drilling through the surface soil, or in soft formations, the tools should be turned; otherwise if the bit is allowed to drill without turning a "flat hole," as the drillers say, may result. The tools are turned by simply twisting the cable several turns in one direction, and then in the opposite direction. If, on twisting the cable, it has a tendency at once to twist back, it is an indication that the tools are not turning and the driller

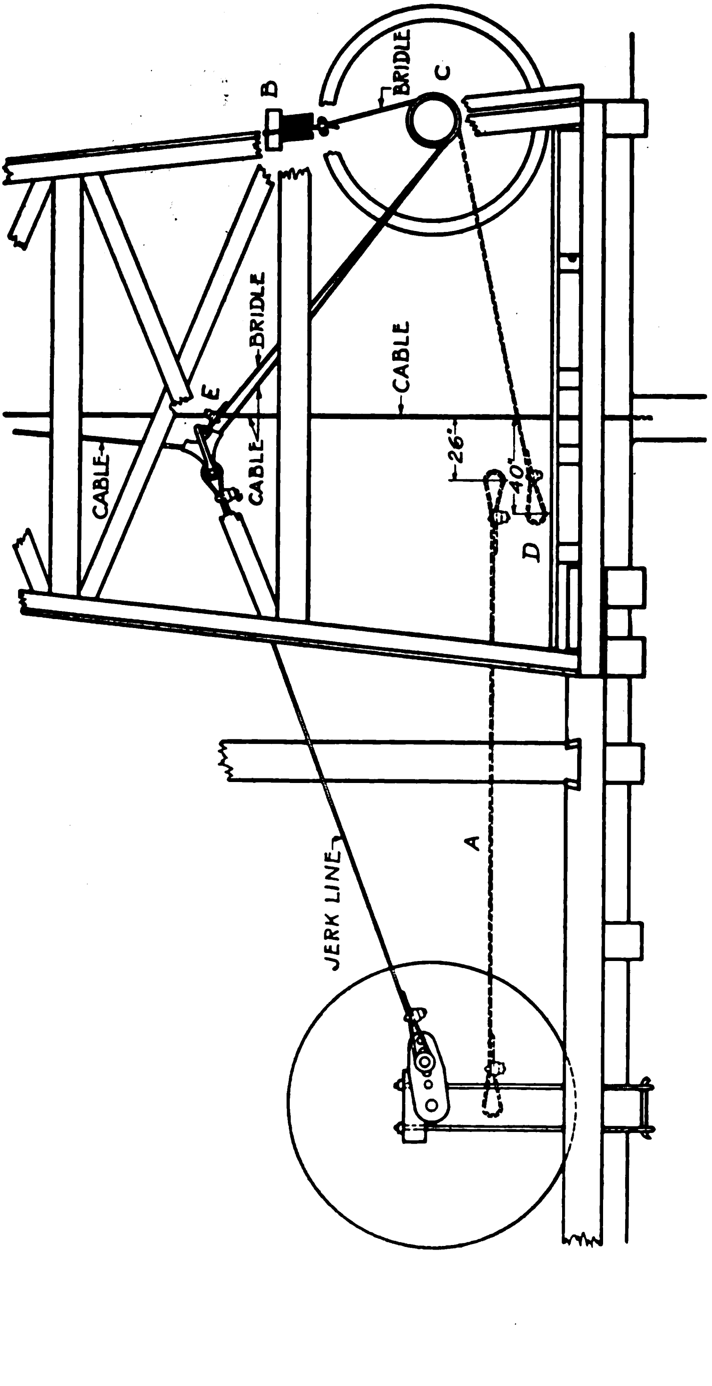


Fig. 33. Illustration of Spudding Operation, using a National Wire Line Spudding Shoe.
Note: Length of jerk line should be 26 inches shorter than distance from center of jack post to center of hole.

should pull out and resume drilling a few feet above where he stopped in order to avoid a flat hole. At intervals, as the hole deepens, the bull wheel brake is released and sufficient slack of the cable is let out to reach bottom and "make hole." Enough water is poured in the hole to mix the drillings and they are removed with the bailer or sand pump as described on page 122. When spudding has proceeded to a sufficient depth, 85 to 125 feet, the temper screw is suspended from the walking beam, then clamped to the cable, and drilling with the walking beam is begun.

DRIVING PIPE

Drive pipe, so threaded that the ends of the pipe will meet in the coupling, should be used. For shallow driving of only a few joints of pipe, casing may be used, but for driving 100 feet or more regular heavy drive pipe is necessary. A steel drive shoe should always be screwed to the lower joint, and the inside of the

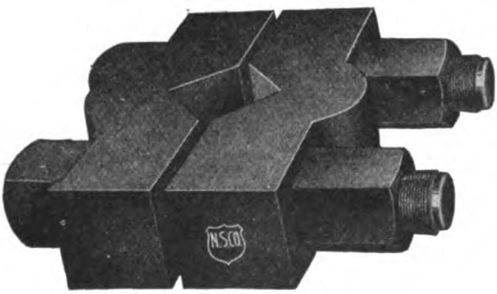


Fig. 34. Drive Clamps

shoe below the shoulder should be exactly the same diameter as the inside of the pipe. In ordering the shoe it is best to state the weight per foot of the pipe or the exact inside diameter of it. Otherwise, should the pipe be larger inside than the shoe, the resulting projection of the shoe might cause the bits to lodge in it or the shoe to break.

The driving is done with a pair of drive clamps which are clamped on the wrench square of the stem below the pin. A hollow or a drop drive head fitted to the top of the pipe receives the blow delivered by the stem and the clamps.

For very long drives a wood maul is recommended, for thus the blow is cushioned and danger of the pipe collapsing or telescoping is minimized. In driving with a maul a solid drive head

Fig. 35. Drive Head

Fig. 36. Drive Shoe

is used and a pair of guides is sometimes erected in the derrick, similar to those used in driving piles.

In both methods of driving the stroke is obtained in the same way as in spudding and the spudding shoe is used.

When driving pipe ahead of the tools, the driller should adjust the stroke of the tools so that the blow delivered is just enough to move the pipe. If, after several blows, the pipe does not drive or appears to spring back, it would be advisable to stop driving and run the tools, for it may be found that a stratum of soft shale, hard clay or a boulder has been encountered.

If it is shale or clay that has retarded the pipe, it is suggested that the driller pour about a barrel of water in the hole, run the tools and drill a few inches. This should mix and soften the formation sufficiently to drive the pipe into or through it.

If a boulder has impeded the progress of the pipe, it should be drilled through, if possible, and the pipe pulled back five to ten feet and the boulder broken up by a shot of dynamite. Water should be poured in to a depth of twenty feet over the explosive to direct its force downward. The charge may be detonated by means of water-proof fuse or an electric battery.

An effective way to shoot a boulder is to use a string of tubing reaching to the boulder, in the bottom joint of which a charge of dynamite is confined by means of a cast iron bushing screwed into the lower coupling. Water should be poured into the tubing to tamp the charge, and the explosion should break both the bushing and the boulder, without damaging the tubing.

Two strings of drive pipe should be used for extremely long drives, the larger pipe being driven as far as practicable, the core cleaned out, and the smaller pipe driven inside the larger. As the pipe is driven it becomes necessary to clean out the core of soil or sand. This is done with the drilling tools by the ordinary spudding or drilling operation and, by using water in drilling, the cuttings may be removed with the sand pump or bailer.

Fig. 37. Drive Pipe

Refer to table of sizes for drive pipe in Chapter XV, General Information.

In drilling soft formations it sometimes becomes necessary to drive the casing, which might collapse under ordinary driving methods. Long strings of casing may be driven by using an inverted or drive down trip casing spear, Fig. 106, whose slips are engaged in the lower joint of casing. The driving is done with long stroke jars on a heavy stem.

DRIVING PIPE BY THE KELLY SYSTEM

James W. Kelly, while drilling in Colombia, found it impossible to penetrate the soft formations in that country by ordinary drilling or under-reaming methods, and he devised a system of driving the casing. He rigged a drive pipe ring and wedges with links on each side to engage the beckets of double blocks for a lower clamp, and an ordinary casing clamp, made extra heavy, with similar links and single blocks for the upper clamp. He then reeved a wire casing line between these four blocks and a heavy casing block and hook operated on the casing line from the calf wheel (See Fig. 38). By this means he not only secured a powerful downward pull on the pipe or casing, but was enabled to keep a constant strain on it, thus neutralizing the tendency for it to spring back under the driving blows.

He removed the coupling from the top joint of casing and in its place used an ordinary hollow screw drive head as a protection both to the casing and the coupling. The driving was done with a heavy steel maul with a reduced shank, or mandrel, which plunged in a drop drive head, engaging in the hollow drive head. He used the maul until as much of the casing as could safely be driven by this method had been put in; then changed to a drive-down trip casing spear, which engaged in the lower joint of casing and was driven with 48-inch stroke jars operated on the drilling tools, using the walking beam.

CALIFORNIA RIVETED STOVE PIPE CASING OR DRIVE PIPE

For sinking the first or drive pipe string of casing through the soft clays, gravels and alluvium of the Tertiary period in California, there has been developed a system of driving "stove pipe" casing, so called. The use of stove pipe casing is well described in "Oil Production Methods," a treatise on California well practices,* as follows:

> "Riveted, or 'stove pipe,' casing is made of steel or iron sheets, riveted at the seams, and is used especially for the

* Oil Production Methods, by Paul M. Paine and B. K. Stroud, pp. 79-80.

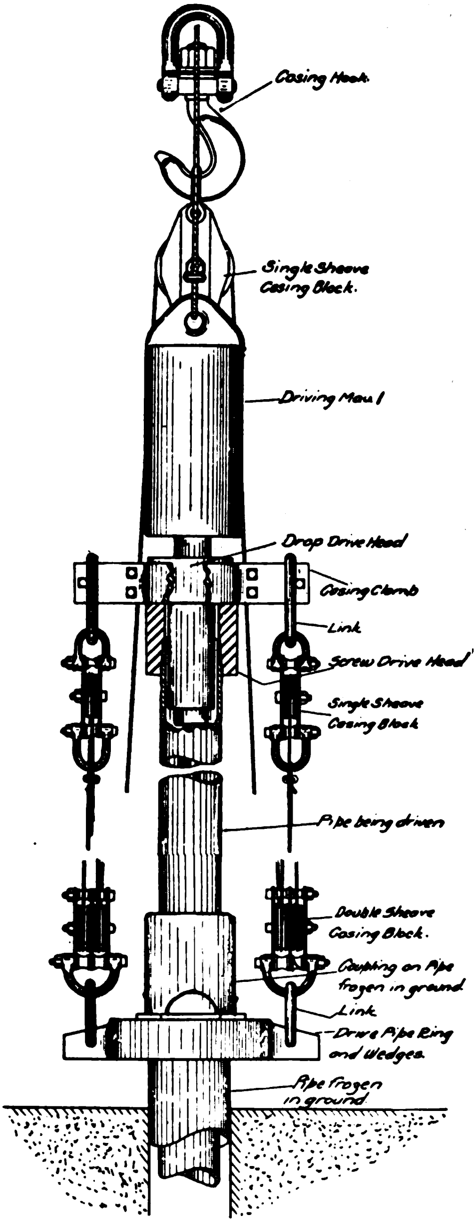


Fig. 38. Driving Pipe by the Kelly System

first string to be inserted in a well. It is made by cutting the sheets into the proper size, punching and countersinking the rivet holes, then rolling to shape and fastening with rivets. The pipe most commonly used in the United States has two thicknesses of sheets, so placed with respect to each other that the end of one sheet is set opposite the center of the other, so that at the end of a joint the inside sheet projects for half its length beyond the outside sheet, leaving a corresponding recess at the other end (See Fig. 39). This double riveted casing is made in joints two or three feet in length, and, for ease in handling, several of these joints are riveted together into sections of from ten to twenty-one feet before placing in the well. Frequently the pipe is 'picked' with a sharp-pointed pick, denting the outside to take up any slack

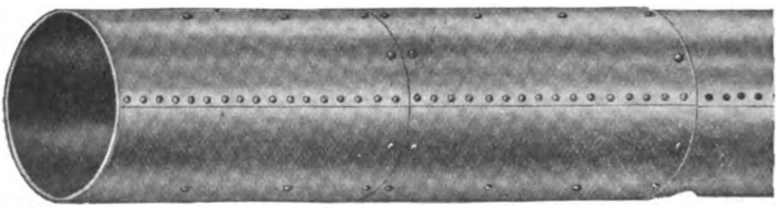


Fig. 39. Stove Pipe Casing

between the outside and inside sheets and assist the rivets to prevent it from pulling apart. It is advisable to place on the bottom of the first or 'starter' joint, a steel shoe of slightly greater diameter than the outside of the pipe. This cuts away any irregularities projecting from the side of the hole and clears a passage for the casing. Stovepipe casing shoes are made from three to fourteen inches in length and are riveted directly to the starter joint. The latter is usually made of three thicknesses for the first eighteen feet, and when a steel shoe is not used, the innermost sheet is lapped back over the outside for six or eight inches and riveted there. This is known as the 'turnback' starter and, while it is not as rigid as the solid steel shoe and does not contribute as well to the starter joint, it has the advantage of a smaller outside diameter, thus reducing the size of the hole to be drilled by the tools.

"The merits of riveted pipe are mainly that its smooth, uniform outside surface is a great aid in carrying the casing down through loose and sandy material which has a tendency to fall in and bind against the couplings on screw casing. Screw casing, however, is more easily handled and may be raised and lowered at will, while the riveted pipe, when once started in the hole, is not raised and can be lifted out only by the use of a spear."

Riveted casing is put in by the same driving and underreaming methods as screw casing.

DRILLING

The operation of drilling, or "making hole," of keeping the correct tension on the cable, of running the tools neither too tight nor too loose, of maintaining the right motion, as it is termed, is difficult of explanation and the knowledge can be acquired only by actual work in the derrick. The driller should know by the feel of the cable, which transmits the jar of the tools, whether or not his drilling stroke is right and his tools are "hitting" properly. The driller frequently grasps the cable and feels the jar, the better to determine when to let out screw, when to regulate motion, when the cuttings are impeding the bit and should be cleaned out; to know when he is passing from a hard to a soft formation and vice versa. In short the "feel" of the cable usually tells the experienced driller what he should know about the condition of his tools down in the hole. The cause of many of the driller's troubles and fishing jobs is that he may have allowed his tools to drill too far or too fast without giving them sufficient attention.

Perhaps as good a description of drilling motion as has ever been written is stated in a few words in Bureau of Mines Bulletin No. 182, "Casing Troubles and Fishing Methods in Oil Wells," page 8, by Thomas Curtin, as follows:

"'Motion' is the engine control applied by the driller in the raising and dropping of cable tools. A driller who thoroughly understands motion has mastered his trade so far as the operation of the drilling tools is concerned."

The careful driller, when lowering the tools into the hole, applies the bull wheel brake at intervals as the tools approach the bottom, and allows the tools to touch bottom on the stretch or spring of the cable. Nearly as much of the drilling stroke is imparted to the tools by the stretch of the cable as by the play of the walking beam, and if the tools should be run to bottom the result would be to "drill too loose."

The engine load varies and, of course, grows heavier as the hole deepens, thus impeding the drilling motion. This may be regulated by adding, as needed, one of the extra balances to the engine fly wheel. Drilling engines usually are equipped with three extra balance rims for this purpose.

DRILLING IN THE DIFFERENT FORMATIONS

SHALE

Shale is soft and comparatively easy to drill, however, as it breaks up into large flakelike pieces and readily mixes with water into a thick sludge, the driller should be sure his tools are turning; otherwise a flat hole, so called, may result. A long drilling stroke should be used and the tools kept well up, with a stiff tension on the cable. The driller should be careful in passing from a shale to a harder formation that his tools do not glance off into a crooked hole. In drilling soft or sticky shale that may tend to "mud up" the tools a more rapid drilling motion may be necessary.

SLATE

Slate is similar to shale, except that it is more brittle and harder. As the bit breaks through the thin bedded layers, there is a tendency for the tools to stick, and there should be the same care to avoid flat and crooked holes as when drilling shale. Tools should be kept up, with tension on the cable, and the bit should be watched to be sure it is properly dressed and true to gauge.

Hard nodules of iron pyrites, ranging in size from marbles to bowling balls, sometimes occur in the slates. They are difficult to drill or to break and have a tendency to deflect the tools into a crooked hole.

SANDSTONE

Sandstone, as its name implies, is formed from grains of sand laid down in water, and occurs in all degrees of hardness from soft stone that can be crushed in the hand to quartzite, a hard sandstone formed by the deposit of crystalline quartz between its grains. All sandstones act as an abrasive on the drilling bit and wear it down rapidly; therefore the bit should be tempered hard and frequently gauged. Sand does not mix into mud in drilling but settles to the bottom of the hole. A little clay dropped in the hole will assist in keeping the sand in suspension. Sandstone is not difficult to drill and hole can be made rapidly by using a short stroke and, with easy tension on the cable, "running loose," as the drillers say. Owing to the tendency of the sand and cuttings to settle rapidly, thus impeding the bit, the hole should be cleaned out after drilling each screw, or every few feet. A sand pump will be found better than the bailer for bailing out sandstone cuttings.

LIMESTONE

Limestone is a rock formed from pulverized shells, and other organic remains deposited in water. It is found in varying hardness from chalk to hard crystalline limestone or marble. Some limestones are exceedingly porous, and water courses and caverns occur in them, caused by the chemical action of waters carrying acids in solution. The limestones encountered in drilling in North America are usually very hard and slow progress is made in drilling them. Should the tools break into a cavern, they should be lowered until they touch bottom and then it is best to drill slowly and carefully until a few feet have been drilled. If the floor of the cavern lies at an angle, it may be difficult or impossible to prevent the tools from deflecting and the hole becoming crooked. When this occurs, a "shot" of nitro-glycerin or dynamite may break up the rock so that the hole can be continued straight. A large cavern may necessitate an additional string of casing to case it off.

Limestone should be drilled with heavy bits and long stems to give weight and force to the blow. A long stroke, with the cable at easy tension, is recommended.

Suggestion for drilling very hard limestone: temper the bits by adding two tablespoonsful of blue vitriol to the water in the slack tub. Do not allow the vapor from the tub to get into the eyes, for the vapor from blue vitriol is injurious to the eyes.

GRANITE

The granites are the base on which the vast structure of stratified rocks rests and, in so far as the hope of finding oil or gas in them is concerned, drilling may just as well be abandoned when granite is reached. In mountainous or volcanic regions, however, there sometimes occurs an intrusion of granite in the stratified rocks that it may be necessary to penetrate. Granite is an igneous (volcanic) rock, cooled and hardened into its present form from molten magma. It is, therefore, exceedingly hard and difficult to drill. Heavy, thick bits or star bits should be used, with a heavy stem, and the largest size joints possible.

Granites should be drilled slowly and carefully, for usually there are joints or cracks intersecting them in every direction. Obviously when the bit enters one of these cracks at an angle, the tools will, in all likelihood, go off crooked, and a crooked hole in granite is difficult to straighten. This may sometimes be accomplished by filling the hole past the crack with scrap iron broken into small pieces, and then drilling it out. If this is unsuccessful, shooting with dynamite or a small quantity of nitroglycerin may break up the rock sufficiently to permit the hole to be continued straight.

Caving of hole can sometimes be prevented by keeping the hole filled with water. The pressure exerted by the water will support the wall.

Sometimes in drilling a soft water sandstone the cuttings and grains of sand settle rapidly around the tools, causing them to stick, with resultant fishing jobs. This can be overcome by drop-

Note: For more detailed descriptions of drilling in various formations, refer to Drill Work, Methods and Cost, by R. R. Sanderson.

ping in the hole at frequent intervals a shovelful of blacksmith coal. The coal will prevent the tools from becoming fast.

In very soft or caving rock it may not be possible to drill with any kind of a bit. For such work an under-reamer should be used. There are several very good under-reamers on the market for this purpose.

BITS OUT OF GAUGE

When drilling in an abrasive formation, it is a good plan to gauge the bit every time it is withdrawn from the hole. If the bit has been worn off on either side enough to reduce its size, it should be removed and a fresh bit put on, and with it, a set of long-stroke fishing jars. Thus, if the new bit, out to full gauge, should become stuck in the hole that might have been drilled slightly smaller by the off-gauge bit, it can be released by a few sharp strokes on the long jars.

DRILLING WITH A MANILA CABLE

The Manila cable is better adapted to drilling in a dry hole than the wire cable. Formerly, or up to about fifteen years ago, the Manila cable was used almost exclusively for all kinds of drilling. The wire cable now has come into general use, however, particularly for drilling in wet holes and soft or caving formations.

In drilling with a Manila cable it is important that the driller use the correct motion, and that he run the tools neither too tight nor too loose. If the former, he may "strand" (one strand or third stretching more than the others) or otherwise injure the cable; if the latter he will not "make hole," as the drillers say. The driller should be able to determine by the tension on the cable and by the jar of the tools whether or not he is drilling correctly. He should regulate the speed of the engine to his drilling stroke and let out or, if need be take up screw, so that the drilling will be done, as much as possible, by the spring or stretch of the rope. Or, to put it another way, the drilling stroke should be adjusted by engine speed and by regulating the throw of the band wheel crank, so that it will conform to the rebound of the tools after the bit strikes the rock. If the driller should be in doubt about his stroke or the tension of his cable it would be advisable to slow down his motion when, if the jar is regular, he probably would be drilling too loose. If, on slowing down, the tools should "peg leg," or the jar be irregular, his tension at the usual drilling motion would be right.

When the cable begins to "lift," as the drillers say, or to take up stretch, it indicates that the tools are drilling off, or are at the limit of the cable's elasticity, and screw should at once be let out.

If the drilling motion is too slow or the tension too loose, the cuttings will settle to the bottom and obstruct the bit, or the bit will not "mix mud," meaning the required mixing of the cuttings and the water.

For ordinary drilling from one-half to two barrels of water, according to the size of the hole, is sufficient.

When drilling in a caving formation the water should not be poured in the hole; it is better to lower it to bottom in the bailer and dump it.

Should a water sand be encountered, frequent bailing may be necessary; otherwise the tools will run more slowly and drilling will be retarded.

When a new cable is used, before attempting to drill with it, the tools should be run to the bottom of the hole and out again several times, meanwhile applying warm water to the cable. This treatment will take part of the stretch out of the cable and set its lay. When commencing to drill with it, for the first few screws it will be found that hitching on will be at a point only about a foot above the previous hitch after drilling a full screw, due to the excessive stretch of the new rope.

Should a new cable be put on at depths greater than 1,500 feet, its stretch may at first keep pace with the making of hole. Therefore the driller should give a new cable careful attention and be sure not to clamp it too long or too hard in one place to avoid injuring it.

DRILLING WITH A WIRE CABLE

The wire drilling cable now is almost universally used for drilling in deep wet holes and in soft or shale formations that "mud up." Some drillers splice two or three hundred feet of manila cable to the lower end of a wire cable. This is termed a cracker and serves to add spring to the wire cable. For description of method of splicing Manila and wire rope, refer to chap.er "General Information."

When an all-wire cable is used, the cable is leaded in the rope socket, which is usually the old style Babcock socket bored with

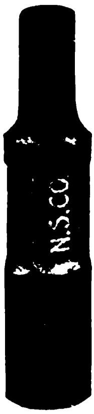


Fig. 40. Babcock Wire Rope Socket

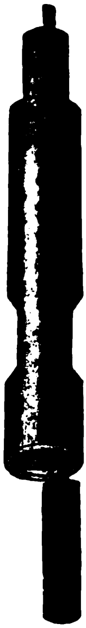


Fig. 41. Prosser Swivel Socket

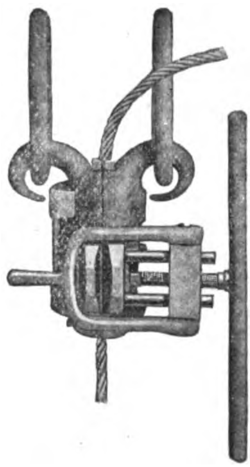


Fig. 42. Mechling Wire Line Clamps

a smaller diameter hole than the Manila rope socket. The end of rope is opened and the wires spread out. It is then fastened in the socket by melted lead or babbitt poured into the neck.

The tools will not turn so readily with an all-wire cable as with the Manila cable, or the wire cable and cracker. When an all-wire cable is used a swivel rope socket is recommended.

The Manila rope clamps on the temper screw will not answer for wire line and it is necessary to use one of several good wire line clamps for the purpose, which can be used with the ordinary temper screw.

There are several different styles of wire cable. Some drillers prefer the rope made of fine wires composed of six strands of nineteen wires each and a hemp center; while others will use only the coarse wire lines made of six strands of either seven or eight wires each and a hemp center. The rope made of small wires is more flexible and more easily handled, although not so strong as the rope composed of large wires. Also the fine wires, by the constant friction against the casing or the wall of the hole, are more easily worn and broken, thus causing the rope to fray and weaken.

Care should be given a wire cable to guard against kinking, for kinks are difficult to remove, and a line that has kinked usually wears out or breaks at that point. The use of spooling flanges on the bull wheel shaft is recommended, for they provide for proper spooling of the wire cable. It is not good practice to have too much line wound around and spread out over the length of the shaft.

The strain and vibration on the rig is much greater with a wire cable than with the Manila, and if the jack post and boxes are not anchored, there is danger of their working loose. The method of anchoring them is by means of "bridle irons" consisting of two long bolts connecting the jack-post box with a stirrup or plate fitted under the mud sill.

In drilling with a wire cable, it is good practice to drill the first few hundred feet of hole with an old Manila cable, otherwise if drilling is attempted from the surface with a wire line it should be done carefully, for with a short drilling line there is little or no spring, causing a severe strain on the cable and rig. In drilling the hard limestones of the North Texas field, it is customary to spud for the first 500 feet or to a depth where sufficient spring is secured with the wire line to warrant clamping on the temper screw.

Drilling with a wire cable is more difficult than with the Manila cable, especially when an all-wire line with no "cracker" is used, and requires the close attention of the driller. If, for example, a stratum of soft rock is encountered just below a hard formation such as limestone, the tools will make hole much more rapidly in the soft rock, necessitating the frequent "letting out of screw." If the driller should not let out screw fast enough to keep pace with the tools, the stretch of a Manila cable would largely provide for this without injury to the cable. Not so with the wire line, however, for there is little stretch to it and, if drilling proceeds beyond the limit of elasticity, the cable may part.

The driller should easily determine when to let out screw, for when that point is reached, the tools usually "peg leg," that is, they hit on every alternate stroke.

Should the driller be negligent about letting out screw, and the limit of elasticity of the cable be reached, there would be danger of breaking the jars or of whipping the cable off at the rope socket.

BACK TWIST

After the tools are run back into the hole, they should be raised clear of the bottom and, before clamping on, the cable twisted or turned, one turn for each 100 feet of depth, in the direction opposite to its lay; that is, a left lay line is twisted to the right and vice versa. This is done to neutralize the tendency of the line to twist with its lay. A special wrench with jaws to conform to the rope is made for this purpose.

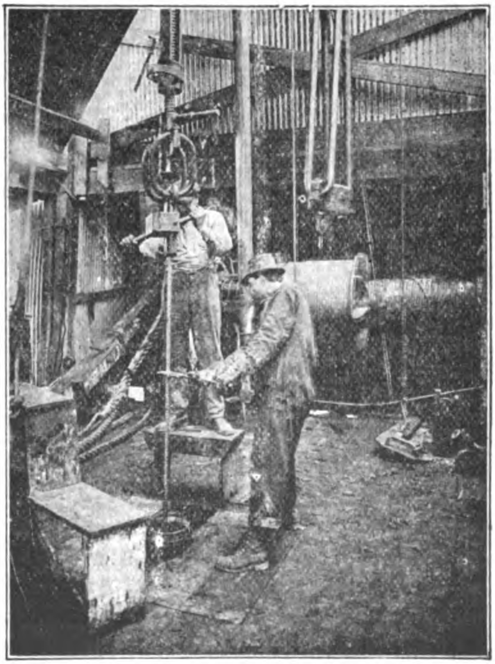


Fig. 43. Putting "back twist" in Wire Cable

In putting a wire cable on the bull wheel shaft, it should be spooled so the line will draw under the shaft instead of over it. This has a tendency to remove twist from the line.

Sometimes in drilling a formation that becomes muddy or sticky the tools "mud up" and make little or no progress. This may be overcome by a little faster motion and keeping the tools up.

When wire rope used for drilling is laid aside for any length of time it quickly rusts and deteriorates unless it is properly cared for. It should be coiled in a small fuel tank filled with oil or in a solution of soft water and soda.

When drilling with a wire cable, a wood drilling plug should be used to center the line in the hole and keep it from rubbing the casing. The plug is made with a taper, so it will wedge into the casing. A hole is bored in the center, through which the cable passes, and it is sawed in half lengthwise, for convenience in placing it around the cable.

Wire cables have a tendency to twist with their lay when they are slacked, or in jarring down, and to twist opposite to their lay when a strain is put on them. For example with a left lay cable prolonged jarring down might cause a joint to unscrew, or keeping a tension on it would tend to tighten the joints.

DRILLING

When the drive pipe has been "landed" on the rock, drilling is commenced. The tools are run in the hole and the rope clamps of the temper screw are clamped to the cable, which should be wrapped with strands of rope or marline to increase diameter of cable sufficiently to form a wedge, or knot above the clamps. The pitman is connected to the wrist pin on the band wheel crank; the engine is started, and the walking beam begins its up and down movement, thus imparting the necessary stroke to the tools. This stroke is regulated by adjusting the wrist pin to the hole in the crank which will provide the length of stroke desired.

As the bit cuts its way into the rock, the main screw of the temper screw is turned and let out until the entire length of the screw has been run out. It is customary, after drilling the length of the screw, or "running a screw," in the vernacular of the

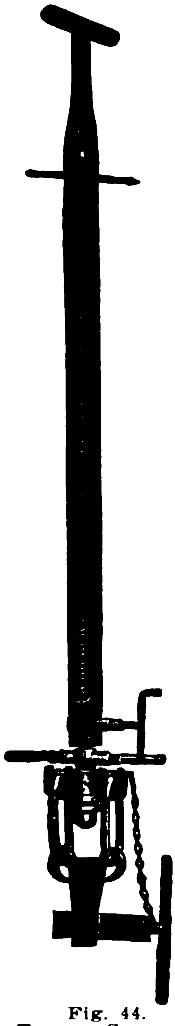


Fig. 44.
Temper Screw

driller, to withdraw the tools and clean out the hole. The bull ropes are "thrown on"; the slack of the cable is taken up until the temper screw is lifted slightly, and the temper screw rope clamps are loosened; the pitman is removed from the crank wrist pin; the walking beam is lowered out of working position, and the tools are pulled from the hole and the bull ropes thrown. The bailer or the sand pump is next run to the bottom to clean out the cuttings, and withdrawn. The tools are then run back into the hole; the pitman is replaced on the crank, and the walking beam is brought down into position; the temper screw main screw is taken up, or run back into the reins and the clamps are again clamped on to the cable, and drilling is resumed.

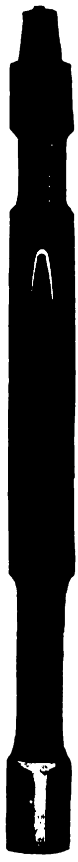


Fig. 45.
Jars

JARS

After the hole has been spudded or the pipe driven to bed-rock the jars are added to the string of tools. They are connected between the rope socket and stem. Some expert drillers drill successfully without jars, but for drilling in strata that change from sandstone or limestone to shale or slate, jars should be used. Jars are made with any length of stroke desired, but for ordinary drilling five- to eight-inch stroke is sufficient.

Should the tools stick the function of the jars is, as their name implies, to jar them loose. This can usually be done by letting out a few inches of slack in the cable, enough to lower the upper rein of the jars, and then, by the drilling operation, jar the tools free.

When drilling without jars, the driller should be careful, in passing from sandstone to a shale or slate formation, not to attempt to drill too fast nor too loose, otherwise his tools may stick in the shale.

Jars are more liable to wear and to breakage than any other tool the driller uses. They should be carefully watched and, if a crack or weak place is detected, they should at once be replaced with a new set, otherwise a difficult fishing job may result.

CLEANING OUT

Cleaning out is done with the sand pump and the bailer. The sand pump (Fig. 47) has a sucker valve with a plunger, so that when the pump is lowered to the bottom of the hole and the plunger is pulled up the mixture of drillings and water is drawn into the pump, which is then raised to the surface by means of the sand reel and sand line, and dumped.

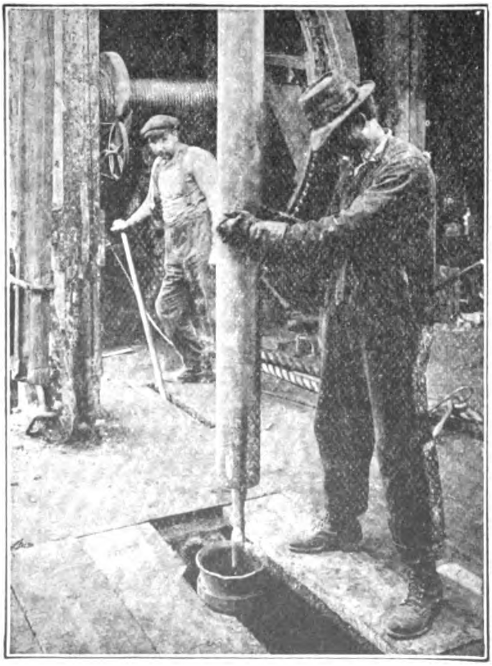


Fig. 46. Running the Bailer

The bailer is simply a long tube with a dart valve in the bottom. When it is lowered to the bottom the dart strikes and opens the valve, thus admitting the water or mixture. When the bailer is drawn up the valve closes and the fluid is retained in the tube until it reaches the surface, when it is emptied by striking the dart on the derrick floor, or in the trough for carrying off the sand pumpings.

When it is desired to clean out the hole of all cuttings, or when drilling in caving or sandy strata, it is best to use a sand pump. The bailer will handle more water or thin mud than the sand pump, but it is not as effective as the sand pump for cleaning the hole.

Fig. 47. Larkin Sand Pump

Fig. 48. Bailer

DRILLING BITS

The drilling bit is, perhaps, the most important tool in the well-driller's equipment, for while the derrick, boiler, engine and the entire outfit are necessary, yet most of it is above ground and visible, while the bit is out of sight, performing the chief operation of "making hole." The bit should be given especial attention to be sure it is of a type that is adapted to the formations to be penetrated.

There are several styles of bits for different kinds of drilling which are briefly described as follows:

Spudding Bits.—Used for commencing the well where the drilling is in soft alluvium such as sand and clay. This bit is short, wide and thin, with the edge dressed to a sharp angle for fast digging.

Regular Bits.—Used for all-round rock drilling. This bit has a long shank sloping into round shoulders, with a water course of medium width. It is a good bit for drilling hard sandstones or limestones; but for shales or slates, or formations that "mud up" the Mother Hubbard type is a better bit.

Mother Hubbard Bits.—This type of bit is quite generally used for drilling all kinds of rock formations. It has a short, straight shank, ending in sharp angular shoulders. The water course is wide and rounding. It is adapted for drilling where the hole "muds up," as the drillers say. The sharp shoulders on the Mother Hubbard bit cause it to cut its way through the mud when pulling out.

California Bits.—This bit, as its name implies, originated in California, where the drilling is in soft and caving formations.

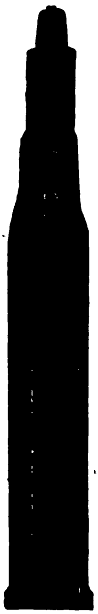


Fig. 49
Regular Bit

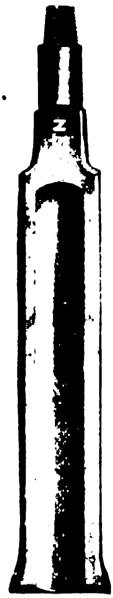


Fig. 50
Mother Hubbard Bit

Fig. 51
California Bit

Fig. 52
Star Bit

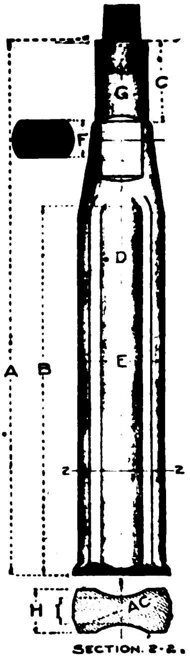


Fig. 53

The shank slopes gently to the shoulder, so that caving material will not have a tendency to lodge at the shoulder. It is from six inches to eighteen inches longer than the regular and Mother Hubbard bits, and the water course runs the entire length of the blade, through the shoulder to the wrench square. The cutting edge is concaved or slightly cut out in the center, the better to break up and cut shale.

A bit with a round blade, somewhat after the style of a round reamer, has sometimes successfully been used for drilling soft or caving formations.

Star bits are used for drilling exceedingly hard formations, such as granite, and for creviced formations, also for straightening crooked holes.

DIAGRAM AND INSTRUCTIONS FOR MEASURING BITS

(Refer to Fig. 53)

A. Length of bit.
B. Length of water course.
C. Length of collar.
D. Width of water course.
E. Width of blade.
F. Size of wrench square.
G. Diameter of collar.
H. Thickness of blade.
I. Thickness of blade through water course.
A. C. Distance across corners.

The drilling bits should be carefully watched and frequently gauged, to be sure they are true to size. Bits should be dressed as often as necessary and care should be exercised in properly tempering them after dressing. A bit that is too soft may batter and grind off at the edges, reducing the size, or a bit that is too hard will chip or crack.

CARE IN MAKING UP JOINTS

It is essential that the joints of all tools be screwed up or set up as tightly as possible. The reason taper joints are used on all drilling tools is that it is impossible to make a straight thread tight after it has been used for a short time.

The taper joint, however, after it is set up, can be made so tight by a little further use of the jack and wrenches that it is almost impossible for it to unscrew during the ordinary process of drilling, and it is difficult to take it apart or "break it" except by powerful work with the jack.

New joints should not set up tight, shoulder to shoulder, but should allow a space of at least 1/32 of an inch, after the joint has been screwed up as far as it will go, to take up future wear.

Every time a joint is screwed together the threads of both the box and the pin should be first well brushed and then washed to be sure they are perfectly clean. This is important, for a dirty thread cannot be made sufficiently tight, and might unscrew and cause an expensive fishing job.

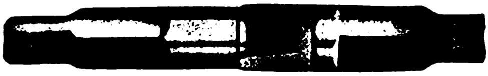


Fig. 54. Tool Joint

The Barrett Jack used to screw up tool joints should not be allowed to lie about where dirt can get into its mechanism. There

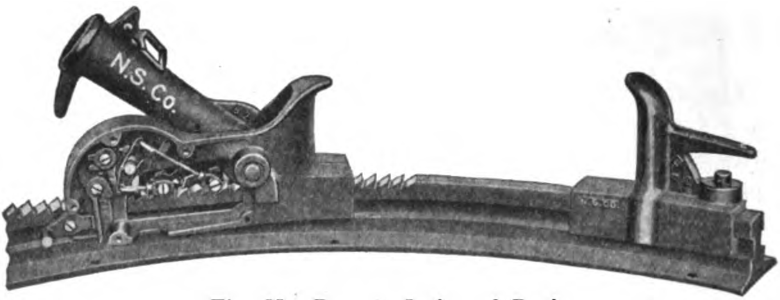


Fig. 55. Barrett Jack and Rack

have been numerous accidents to men using these jacks when the pawl would not fall in place, due to dirt, or other foreign

Fig. 56. Tool Wrench

matter, clogging the jack. Also the teeth in the circle, or rack, must be kept clean and not allowed to accumulate dirt. And if there are any broken or worn teeth, it may be best to discard the rack and get a perfect one.

TO STRAIGHTEN A CROOKED HOLE

When drilling in inclined formations, there is a tendency for the tools to follow the dip of the strata, particularly when passing from a soft to a harder formation, resulting in a "crooked" hole.

When the deflection of the tools causes the hole to start off crooked or on a slant from its true perpendicular, this condition may be determined by an examination of the bit. If the wearing edges are unduly worn, it is apparent that the bit has been rubbed against the wall of the hole, indicating that the hole has veered off at an angle. If this condition should continue, the result would be a hole in which it might be impossible to put the casing or even to proceed much further with the drilling.

There are several methods of straightening the crooked hole. Filling it up with crushed stone or cement or even with pieces of wood and drilling it out will sometimes answer. A straightening process that has proved successful is to fill up the hole to a point above that at which it started crooked with crushed limestone. On top of the stone several short pieces of rope are dropped. In the operation of drilling, the bit will pound around on the rope until it (the rope) has worked up around the bit and into the wall of the hole, which will have a tendency to keep the bit straight. When drilling is resumed, it should be done with a four-wing star bit, until the hole is straightened.

Other means of straightening a crooked hole are by using a hollow reamer (See Fig. 57), or by running a star bit or a hollow reamer on a string of casing that will just go down inside the hole. In this case the shoulder of the bit or reamer is turned off and threaded to fit the coupling on the casing.

UNDER REAMING

Under reaming in soft or caving formations is the most difficult kind of drilling and requires the constant attention of the driller. Several improved under reamers have come into use during the last few years. Of these, the Double, the Wilson and Willard and the Swan under reamers are good types.

The illustration (Fig. 58) shows a Double Under Reamer with the cutters or lugs expanded ready for reaming. The cutters are compressed to enter the casing and held in that position by a confining ring. As the under reamer enters the casing, the ring slides up on the body of the reamer and is then removed. As the under reamer passes through the bottom of the casing, the cutters are automatically expanded by powerful springs, so they extend far enough out to ream a hole of sufficient size to permit the

Fig. 57.
Hollow Reamer

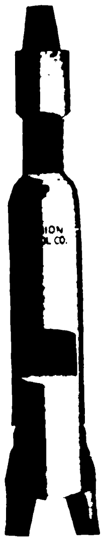


Fig. 58.
Double Under Reamer, Type K

Wilson Under Reamer

Fig. 59.
Set to Enter Casing

Fig. 60.
Ready to Ream

couplings of the casing to pass freely. When it is desired to withdraw the under reamer from the hole, the casing shoe, or the bottom of the casing compresses the cutters as the reamer is drawn into the casing.

Fig. 59 of the Wilson under reamer shows the cutters set to enter the casing. Fig. 60 shows the same reamer with the cutters expanded ready to ream. The cutters of the Wilson under reamer are set to enter the casing by means of a lever or setting pin, which is removed as the cutters pass down the casing.

For under reaming it is necessary to use a rig with a calf wheel for handling the casing, which is allowed to follow the reamer in order to prevent the hole from caving in on the tools. A drive shoe or casing shoe should be screwed on the bottom of the casing. The driller must carefully tally each joint of casing as it is added to the string, and he should make accurate allowance for the length of thread that he screws into each coupling; for he must know at all times the exact length of his string of casing. This is necessary for the reason that his reamer is rising and falling just below the bottom of the casing and, if he is not careful, he may break the reamer cutters by strking them against the casing shoe.

There has recently come into use a special adding machine for adding feet and inches which is employed by some of the drillers in North Texas.

The chief difficulty in under-reaming in soft formations where the casing follows the tools is in keeping the casing free or, as the drillers say, preventing it from "freezing," which is caused by the wall of the hole caving against it. The tendency to freeze is reduced by raising and lowering the casing at frequent intervals.

The swinging drilling spider is a valuable improvement for handling casing. It is suspended on the casing line and operated by the calf wheel.

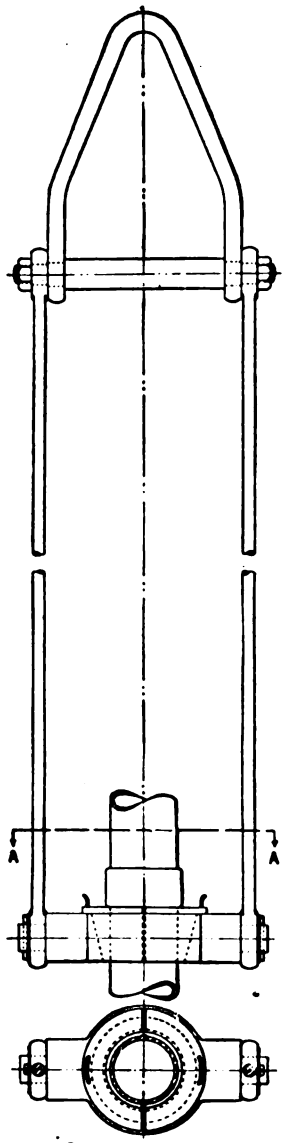


Fig. 61. Swinging Spider

By means of it, the casing can be raised or lowered at any time without interfering with or suspending drilling operations.

The hole is first drilled with an ordinary bit 15 to 40 feet, or as far ahead of the casing as the cavings or the length of the string of tools will permit, and the hole is then reamed out with the under reamer.

When hard or non-caving rock is encountered, it may be possible for the driller to ream ahead of his casing 25 to 50 feet, but he will have to use his judgment when it is safe to do this.

It is inadvisable to drill so far ahead of the casing that the top of the rope socket will be below the casing shoe, for on the upstroke of the tools the top of the rope socket might strike against the shoe and break the cable.

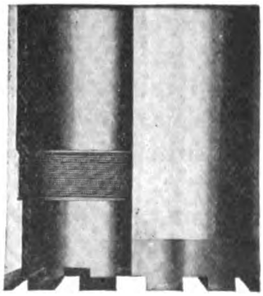


Fig. 62. Baker Shoe

The Baker spudding shoe (Fig. 62) is extensively used in California where, if the wall of the hole caves around the casing, the teeth of the shoe will cut through the cavings when the casing is worked up and down. The handling of frozen casing is further described under Fishing for Casting, pages 172-179.

The casing is supported by a spider with slips, or wedges set on the cellar floor. The wedges have milled teeth which engage in the casing and hold it suspended above the under reamer. (Refer to Fig. 162 and further description on page 275.)

In California, where nearly all cable drilled wells must be under-reamed, and an occasional stratum of hard rock or "shell" is encountered which it is difficult to ream, the drillers use an eccentric or "sidehill" bit. This is an ordinary bit with the wearing edges dressed out on one side and hammered down on the other sufficiently that the bit will ream a hole large enough for the casing to follow.*

REAMING

It sometimes becomes necessary, for the purpose of re-setting casing at a lower depth, or to enlarge a hole that has already been drilled, to ream it out to the larger diameter. For this purpose a round reamer is used. The reamer is a bit made thick enough nearly to fill the diameter of the hole, but with deep water channels.

BIT DRESSING

Correct dressing of the bits is an important part of well drilling. If the tool dresser is inexperienced, inefficient, or careless in his bit dressing, he may ruin the bits, cause serious delays, fishing jobs, or even the loss of the tools or of the hole.

The writer, years ago, in the company of one of the best drilling contractors in the country, visited one of his rigs. The tool dresser was just beginning to dress a bit. This contractor, in clean clothes and fresh linen, watched the operation for a moment, then stripped off his coat, took the sledge from the "toolie" and proceeded to dress the bit. Carefully he hammered the cherry red steel from the center of the bit out to the edge, his blows growing lighter as he reached the corner of the bit. Then he turned it over and repeated the operation. Placing the bit back in the forge, he carefully heated it, withdrawing it from the fire two or three times to observe its color. When it was heated sufficiently he again placed it on the anvil and went at it with the sledge, at intervals slipping the gauge over it, and stoving and shaping it until it looked as though it had just come from the shop. Not yet satisfied, he heated it again and then trimmed off with a splitting chisel the small fringe of steel that had worked over the shoulder or into the water course, and then he finished the job

* Oil Production Methods, by Paul M. Paine and B. M. Stroud, 1913.

with a small hand hammer, finally gauging it once more to be sure it was true to gauge. As we walked out of the rig, he remarked: "The way that tool dresser was abusing that bit might have caused me a flat hole or a fishing job, so I thought I would give him an object lesson."

The forge is usually a four-foot square box filled with clay or built up of fire brick. The bellows has given place to the Star blower operated by steam. For bits ten inches and smaller the No. 3 blower with outlet for 2-inch tuyere is large enough, but for bits 12½-inch and larger the No. 4 blower with 3-inch tuyere should be used.

Mr. R. R. Sanderson has very well covered the subject of dressing and tempering bits in his book on shallow water well drilling, "Drill Work, Methods and Cost," from which the following description is adapted:

A fire is built in bottom of forge and fuel gradually added under a light blast until the forge is filled. If blacksmith coal is used it will have a tendency to coke together, obstructing the blast. To correct this, openings should be made through the coal, at intervals, by prying it up at different points with a poker, in such a way that only the center of the mass is disturbed. The result should be a wall of heated coke surrounding the loosened center, which may be 10 to 20 inches in diameter, according to the size of the bit to be heated. An opening is made in one side of the wall of coke and enough of the fire raked from the center to leave a space somewhat larger than the bit. After the bit has been carefully cleaned of all mud and cuttings (cuttings sometimes contain iron pyrites, which when heated, liberate sulphur, harmful to steel), it is placed in the fire, so that the cutting edge extends three to four inches beyond the center of fire.

Bit should not be jammed through the wall, nor pressed down against the coals with such force as to break down the fire, thus shutting off the blast.

In winter when the bit is very cold, it should not at once be covered when put in the fire, but should remain on top of the hot coals for a few minutes and turned three or four times to warm the steel slightly, before subjecting it to the full heat of the forge. After the bit has been covered with the coked coal previously scraped from the center of the fire, a small amount of fresh fine coal should be sprinkled around the edge of the coke just put on. By repeating this at intervals the supply of coke can be maintained.

After the bit has been sufficiently heated on one side, it should be turned over so that the other side is next the fire. It is very essential to have the bit evenly heated, and it may be necessary to turn it several times to accomplish this, but it is best to turn it as few times as possible, not to disturb the fire.

If the flame and smoke have a tendency to dart back beneath the bit, through the water channel, it can be prevented by placing some ashes or earth below the bit just at the edge of the fire.

The fire should not be forced too strongly, for the bit must be allowed time to heat evenly. Also the bit should not be left to "soak" in the fire after the proper heat has been reached. Some drillers cut down the blast and allow the bit to remain in the hot coals for several minutes, after it is hot enough to dress, believing the steel in better condition to dress, owing to greater amount of heat absorbed. This is not only a waste of time, but harmful to the bit, as the hot coals draw the carbon from the outer shell of the steel.

The bit should be so placed in the fire that for 4 to 5 inches up from the cutting edge it will be heated to the same temperature. Some tool dressers think it necessary to heat the bit for only a couple of inches on the end, but if this practice is followed, a cracked bit may result, as the steel will not be heated far enough back to allow the metal to "flow" under the heavy blows used in stoving back the edge.

Owing to the fact that the corners of a bit are much thinner than any other part and will thus heat much more rapidly, they must be carefully watched, to see that they do not burn. If the fire has been made so that it has an even temperature throughout and the bit has been properly placed in it, there is not much danger of burned corners, but if the fire is "dirty" so that the heat is not uniform, the proper heating of bit becomes almost an impossibility.

A "dirty" fire may be caused by an accumulation of ashes or of burned-out coke; or it may be the result of poor quality fuel. If coke is the fuel, impurities may clinker over the tuyere, or pieces of slate obstruct the blast.

If coke is the fuel used, the forge should be cleaned out after each heat; if coal, the forge should be cleaned within the space surrounded by the coke wall.

It will be noted when cleaning out the forge in which coal is used, that there are numerous small pieces of very hard coke. This coke should not be used over again, as it is more ash than coke, and contains impurities that are very injurious to the steel.

So far as possible, the steel in the bits should be kept in the same condition as when it left the factory. Coal for heating containing sulphur or phosphorus should not be used, as both elements are injurious to steel when heated. Bits may also be ruined by overheating. Iron may be heated until the sparks fly without injury, but overheating a bit has a tendency to draw or burn out the carbon, leaving the steel porous and brittle, in other words, a "burned bit."

If by any chance a bit should be burned, it is best to cut away the injured portion, as it is impossible to work burned steel, or to temper it.

When a bit is first dressed, it should not be heated higher than a dark cherry red, or from 1,350 to 1,400 degrees Fahrenheit. During the next heat the temperature may be higher, gradually increasing during successive heats until the driller has found the heat at which the steel can best be worked and tempered to secure good drilling results. For average bit steel, temperatures of from 1,400 to 1,600 degrees Fahrenheit will be found suitable. Bit steel, however, never should be heated higher than a light cherry red.

STEEL COLORS AT HIGH TEMPERATURES

Skilled observers may vary 100° in their estimates of relatively low temperatures by color and beyond 2,200° F. it is practically impossible to make estimates with any certainty whatever. (Bulletin No. 2, Bureau of Standards, 1905.)

°C.	°F.	
400	752	Red, visible in the dark.
474	885	Red, visible in the twilight.
525	975	Red, visible in the daylight.
581	1077	Red, visible in the sunlight.
700	1292	Dark red.
800	1472	Dull cherry-red.
900	1652	Cherry-red.
1000	1832	Bright cherry-red.
1100	2012	Orange-red.
1200	2192	Orange-yellow.
1300	2372	Yellow-white
1400	2552	White welding heat.
1500	2732	Brilliant white.
1600	2912	Dazzling white (bluish white).

From booklet published by the Halcomb Steel Co., 1908.

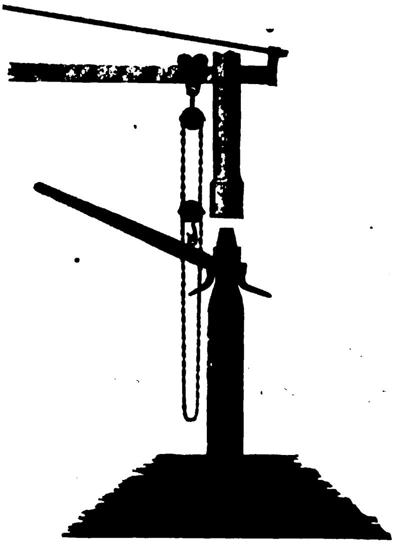


Fig. 63. Derrick Crane Outfit

For handling bits, a derrick crane, chain hoist and swivel wrench are used. Fig. 63 illustrates the method of handling a bit from the stem to the forge, thence to the anvil and for supporting it while it is being screwed into the box of the stem. A bit pulley and chain, suspended from the trolley of the crane, are sometimes used for convenience in turning bits on the anvil.

Shaping the Bit.—To shape a bit quickly and accurately, it is necessary to understand the functions of the various parts composing the cutting end and to know the relations which these parts bear to each other. These parts are the Cutting Edge, the Faces, the Corners, the Wearing Surfaces or Wearing Edges, the Shoulders and the Water Courses or Channels.

After bit has been heated to proper temperature, it is placed on the anvil block with one of the flat sides down.

For small bits an ordinary sledge and a ball pein hammer will suffice, but for large bits a bit dressing ram will be found a time saving addition to the outfit. The ram is a forged steel device, shaped something like a baseball bat, with an iron ring fitted into it at a point where it will balance when suspended from a derrick girt. A line of two inch pipe connects the suspending rope with the wrist pin on band wheel crank and the engine furnishes the power for the stroke. The tool dresser grasps the handle of the ram and directs the blows on the bit.

Hammering is begun first at center, working outward toward the corners, the heaviest blows being used at center, and gradually growing lighter as the corners are approached. After one side has been hammered for a short time, the bit is turned and the process repeated on the other side. This is continued until the bit has been sufficiently stoved. Care must be exercised to see

Fig. 64. Bit Ram

that one side does not receive more or heavier blows than the other, as unequal hammering will result in a cutting edge off center. The cutting edge should also be kept in a straight line and not allowed to become rounded, for a bit with a round edge will not cut rock rapidly.

The angle of the faces should be neither too sharp nor too flat. If the angle is too sharp, it is impossible to put sufficient wearing surface on the bit, and in hard rock drilling this may result in a hole which is not perfectly round—or as the drillers say, a "flat" hole. On the other hand, if the bottom of the bit is too flat, the cutting speed is reduced. The correct angle varies according to the size of bit, and also the condition of the rock.

For drilling hard rock a bit with flat faces and heavy corners and cutting edges should be used. The sharper bit may make hole faster when first put on, but the corners and edges will more

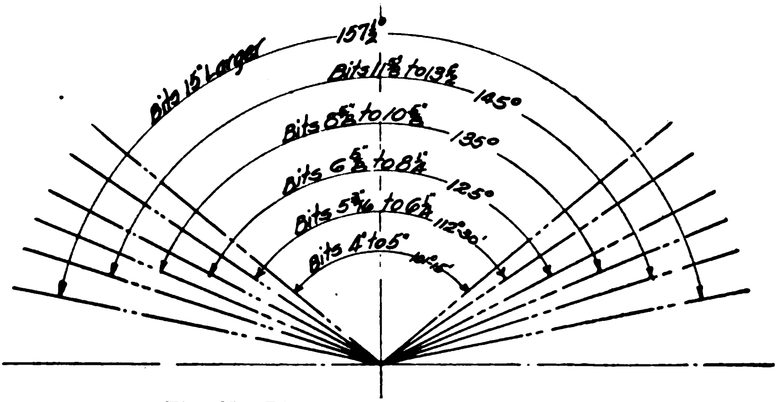


Fig. 65. Diagram of Angles for bit faces

quickly be broken down, with consequent danger of a pinched hole. When this happens, reaming is necessary to prevent the next full gauge bit from sticking in the hole.

Where broken or creviced formations are encountered a flat bit should be used, for a bit with thin cutting edge has a tendency to wedge in the cracks, thus deflecting the tools, and a crooked hole will result.

In stoving the bit, it will be noticed that not only is the width increased, but also the metal around the wearing edges is expanded. To prevent these points from becoming too far apart, they should frequently be hammered down, during the stoving operation. Some tool dressers finish stoving the bit before driving down these points, but this is not good practice, because if the bit requires much stoving, these points become so spread that it requires considerable hammering to bring them back. As this heavy hammering has a tendency not only to increase the width but to drive the metal back into the body of the bit, cutting edge is likely to be forced out of straight line. If the points are kept well worked down as the stoving proceeds, the bit will shape up more symmetrically and with less labor. Another disadvantage of waiting until after stoving before driving down the points is that, as the points project somewhat from the body of the bit, they will cool rapidly, and if driving these chilled points down into the hot steel is attempted, a cracked bit may result. All the parts being worked should be at the same temperature, so that the steel will "flow" evenly and uniformly under the hammer blows.

When evenly heated steel is hammered, the effect will be to force the grains more closely together or to refine and toughen it. If unevenly heated, however, it will cause it to crack or check where the soft grains are crushed against the harder steel. While these checks cannot be seen, they are nevertheless there, and after the bit has been tempered several times, large pieces may spall off.

As heated steel cools there is formed a thin shell of harder steel enveloping the end of the bit and increasing in thickness as cooling progresses. Should the bit be too heavily hammered while in this condition the cooler grains of steel on the surface will not fuse with the more plastic steel below, resulting in crushing the outer shell and ultimately in checking or cracking of the bit.

In stoving, the steel is forced back into the water channels, thus increasing the thickness of the bit through the center. The water channels should be hammered down at the same time that the points referred to above receive attention. To reach into the hollow channels, it will be necessary to use the peen of sledge. The bit should not become so thick through the water channels that heavy hammering is required to reduce it, thus forcing the middle of cutting edge outward, causing a "bellied" bit, as the drillers say.

As it is impossible, even by the most careful hammering, wholly to prevent an accumulation of metal around and in the water channels, it will be necessary to cut out and trim the channels with a hot chisel. For this work a chisel with a half round edge should be used. If a cutter having a straight edge is used it will form sharp corners in the bottom of channels and these may cause a crack to start in the steel.

Some drillers use a fuller, corresponding in shape and size with the channels, to keep the channels straight and clean.

If the bit being dressed is not far out of gauge and if the corners are not badly ground away or broken off, the stoving required to restore the cutting edge will be sufficient to spread the bit so that the corners and wearing edges can be sharpened and brought to gauge.

When the bit to be dressed is in bad condition, requiring much stoving, it should be heated to a light cherry red and heavy blows used until it has been sufficiently stoved, unless the operation takes so much time that the bit begins to cool, when the blows should be lightened.

Small bits and bits in bad condition usually require three heats to complete the dressing, the first for stoving, cutting out the water channel and trimming any part which shows signs of checking; the second for turning down and shaping the corners and wearing edges and finishing with a hand hammer, while the third is for tempering.

If a bit is not in bad condition and is of sufficient size to hold a heat, it can be dressed in two heats; the first for shaping and the second for tempering.

Sometimes it is necessary to dress a bit that is almost full gauge, with a good cutting edge and one good corner and one very bad corner. This is a difficult operation, for unless it is properly handled there is danger of having a low corner when the bit is finished. There are two ways to prevent this unequal distribution —to draw the steel toward the low corner by hammering, or by cutting from the good corner enough steel to make the two corners equal.

Bits in fairly good condition require little stoving, perhaps a quarter of an inch over gauge, or just enough to sharpen the cutting edge and to furnish sufficient metal to dress the corners and wearing edges. However as no two bits are alike, it is difficult to lay down a rule. To fill out the corners and edges of bits that are worn or broken they may have to be stoved an inch over gauge. Too much stoving should be avoided for the extra metal will have to be either worked back into the bit or cut off.

After the stoving operation is completed, the bit is turned on edge, so that the shoulders will clear the outer edge of anvil and the shoulders above the corners are driven down.

If one corner is farther from the center than the other, allowance must be made for this and the hammering so done that when the shoulders are both driven down, the corners will be equidistant from the center.

While shoulders are being dressed, the bit gauge should frequently be used, that the operation may not be overdone.

When the shoulders have been driven down so that the corners come to gauge, shoulders above the wearing edges are driven down by working from the corner outward. In doing this the wearing edges on both sides of the bit should be brought down together, that is, the bit should be turned over several times during the hammering. As the first part of this operation usually requires some heavy hammering, it should be done while the metal is at its highest heat.

The wearing edges are dressed down until they are 1/16 inch smaller than the gauge, while the corners come out full size. The reason for this is that in driving them down the steel will be forced out past the faces of bit and allowance must be made for the expansion which will take place when this metal is worked back into the bit.

The bit is now laid flat, as in stoving, and the wearing edges and corners are shaped.

To drive back the extra steel at these points without expanding the bit, the hammer should be so held that the blows fall at an angle toward the face. This works the steel away from the wearing edges into the body of bit.

After the bit has been thus hammered until the wearing edge is nearly even with the faces, the position of the hammer is changed and blows the same as in stoving are used, until the edges are even with the faces. The bit should just fill the gauge, but if a little large, due to the operation just described, it may easily be trued by slightly driving down the edges.

The bit should now be about a dull red or a little cooler and ready for the final hammering. Using a small hammer, 1½ to 2 pounds, the cutting edge, wearing edges and corners should be gone over with light blows, but many of them. This tends to toughen the grain of the steel, causing the bit to wear better.

In gauging a bit, it should fill the gauge, but it should be so dressed that the gauge will pass over it freely.

The angle between faces and the shape of corners, shoulders and wearing edges of a bit should vary according to the character of the formation to be drilled. For hard rock, the corners should be made rather flat, with heavy shoulders extending straight upward from the corners and wearing edges. The heavy shoulders add strength to the corners and edges by reinforcing them with metal.

Heavy shoulders and wearing edges should also be used in sandstone, owing to its abrasive qualities.

In drilling soft shale or slate, a bit with heavy shoulders has a tendency to become wedged in the hole, so the shoulders should taper backward from the corners with the wearing edges dressed out thin. This is called a "feather edge."

For rock much broken and fissured, the bit should be provided with heavy shoulders and very full wearing edges that fill a large part of the circle, somewhat similar to a round reamer.

A bit for gravel, sand or clay should have an angle of from 70 to 75 degrees between the faces, and thin wearing edges.

When boulders are encountered in this material, it is necessary to use a rock bit, as the cutting edge and corners of the gravel bit are too thin to withstand hard drilling.

Fig. No. 66 illustrates a poorly dressed bit. The cutting edge is rounding, thus making blunt corners. One corner is farther from the center than the other, which will put an extra strain on the tools, by forcing them out of center line of hole. There are no wearing edges and the water channels are filled up. This bit would only drill about one-third as many feet per day as a properly dressed bit.

Fig. No. 67 shows the result of unequal heating and deep tem-

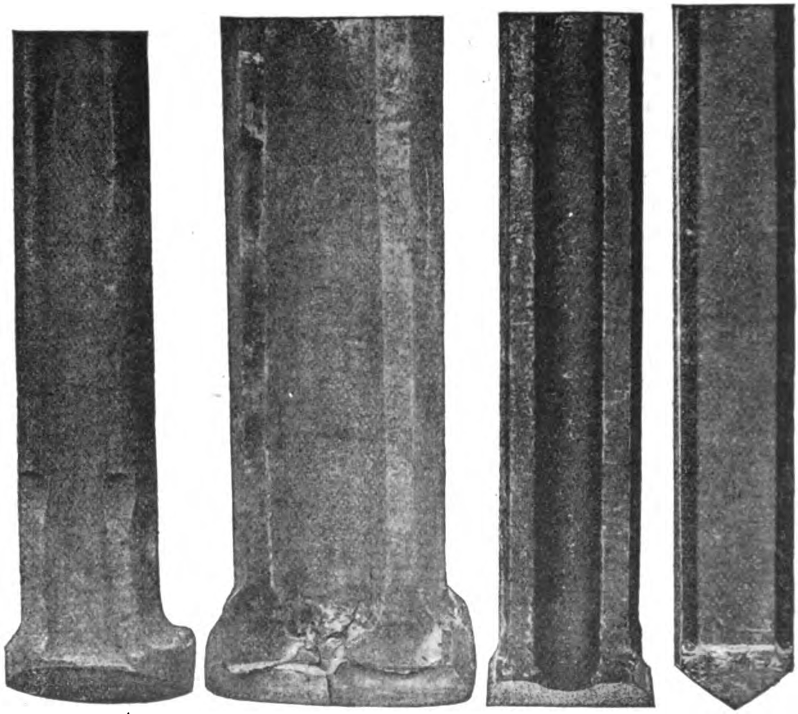


Fig. 66. Improprey Dressed Bit

Fig. 67. Cracked Bit

Fig. 68 Fig. 69 Two Views of a Bit Properly Dressed

pering. The crack through the center has been started by hammering the bit while the steel was hotter on the outside than the inside, and enlarged by setting the bit too deep in the water when tempering.

The steel in Fig. No. 66 is in fairly good condition and the bit, when corrected, can be used, but the steel in Fig. No. 67 is spoiled for a distance of about 8 inches from the end.

The cuts, Fig. Nos. 68 and 69, are different views of the same bit illustrating how it should look when properly shaped. This bit was dressed for hard rock drilling with straight cutting edge, deep corners, heavy shoulders, full wearing edges and clean water channels.

TEMPERING THE BIT

There are two methods of tempering; one is to heat the bit, set it in water to a certain depth and leave it to cool. This is known as tempering by quenching.

The other, and most satisfactory, is drawing the temper and consists of heating the bit to a certain temperature, then cooling the end by allowing it to stand in shallow water for a few minutes, after which it is withdrawn and the heat allowed to "run" (the heat of the parts to be tempered is on an ascending scale, see color chart) until the cutting edge and the steel for a distance of ½ inch above the cutting edge are at the desired temperature or color, when the bit is set back in the water and allowed to cool. We will first consider this method.

The cooling box or trough should be fitted lengthwise with two pieces of pipe, 1½ inches in diameter, and with centers 4 inches apart. The bottom of the pipes should be about 2½ to 3 inches above the bottom of the box. There are now on the market sheet steel slack tubs that are much used for this purpose.

The bit is heated for a distance of from 3 to 4 inches on the end, to a dull cherry red, never higher than this; and with some steels it may be better to heat to a lower temperature.

It is best to bring the bit to heat slowly and evenly, using a slow blast, that the metal all through the end may be, as nearly as possible, the same temperature.

Enough clear, clean water is poured into the temper box so that when the bit is put in it the water will just reach to the top of the bit faces. When the bit has been heated to the right temperature, it is placed in the box, so that the faces rest on the two pipes. While the bit is cooling, the water should be stirred to keep it in motion, or better, the box may be arranged to have a stream of water entering at the bottom and running through it. If the water is allowed to remain stationary it may cause cracking of the steel. The bit should not be set deeper in the water than the top of the faces and shallower if possible.

After the bit has been in the tempering trough for two or three minutes, it is removed and with a file, a brick or piece of sandstone, the shoulders are scoured until they are bright. The first will be a straw color and successively, a light brown, a duller brown, brown with purple spots, light purple, dark purple, light blue, darker blue, blue tinged with green and so on. The following table shows the differences in temperature to run the full color scale:

	Fahrenheit	Centigrade
Light Straw Color	430	221.1
Full Straw Color	460	237.8
Light Brown	490	254.4
Darker Brown	500	260.
Brown Fading into Purple	510	265.6
Light Purple	530	276.7
Dark Purple	550	287.8
Light Pigeon Blue	570	298.9
Darker Blue	600	315.6
Blue with Green	630	328.

For rock of medium hardness the temper should be stopped between the full straw and the darker brown. For extremely hard rock the temper may be a deeper color. Bits for drilling very soft rock and shales may be tempered hard, for the cutting edges are not easily broken in such formations and the harder temper prevents the bit from rapidly wearing out of gauge.

In limestone or other hard rock, it is best to temper as hard as possible and yet have the steel tough, in order to keep the bit to gauge as long as possible.

The colors above will vary somewhat with the kind of steel used, and the driller will have to experiment to determine the right colors for the bits he is using.

It is necessary that the water in which tempering is done be perfectly clean, as dirt or an oil film will cause the colors to show up differently; also dirty or oily water will interfere with the penetration of the temper, resulting in a thin hard shell of steel, which may cause the bit to crack or pieces to spall off.

If the steel cracks in tempering, the water should first be heated almost to the boiling point. Some drillers use salt solution or cyanide of potassium.

If it is desired to temper by the "quenching" method, it is only necessary to heat the bit to the right temperature, then set it in the water and allow it to cool. The temperature to which it should be heated depends upon the hardness of the rock being drilled, also the kind of steel used, and can be determined only by experiment.

The quenching method is all right for soft or medium hard rock, but for very hard rock, it is best to draw the temper in order to be sure the steel will stand.

INSTRUCTIONS FOR HEATING, DRESSING AND TEMPERING UNDER-REAMER CUTTERS

(Union Tool Co.)

To dress Cutters—Bring slowly to an orange heat which is about 2,000 degrees Fahrenheit and do not forge at a temperature below a red heat, plainly visible in daylight. The heel of every cutter, in dressing, must be kept parallel with the cutting edge, or, in other words, be sure the bottom of the cutter is straight across, which is the shape or form of all new cutters. If cutting edge is stove back of the heel, the cutters may wedge on the tongue, crushing them. After dressing cutters, allow them to cool to hand warm before reheating for tempering.

To temper Cutters—Heat slowly and evenly to 1,450 or 1,500 degrees Fahrenheit, which is indicated by a cherry red, then dip about ½ inch of the cutting edge into clear water, stirring the cutter around to keep the water in close contact with its surface. Allow the cutter to remain in the water until the cutting edge is cool, then quickly dip it half way into the water to prevent a check or crack forming between the hot and cold parts. Polish the cutting edge to observe the color, and when it has run down to a straw color on the edge, set the cutter to a depth of about 1 inch in clear water or a bath of mud, and allow to cool slowly.

Note: The most important feature of the treatment of cutters is to heat them slowly and uniformly, to prevent the setting up of strains in the steel, caused by uneven expansion or contraction, which might develop into cracks when the tool is put in service.

MEASURING THE DEPTH OF HOLE

At frequent intervals during the progress of drilling a well it becomes necessary to measure the depth of the hole, particularly when it is desired to keep an accurate record of the formations penetrated. A steel measuring line on a reel is used. A convenient method of handling the reel and line is by clamping the reel to the engine fly wheel and using the engine power for reeling in the line. A weight should be attached to the bottom of the line. The line should be one with raised figures for convenience in reading. When sufficient line has been run out to nearly reach the bottom of the hole, it should then be carefully let out a few inches at a time with a man holding the line in the center of the hole to keep it from binding on the casing. By keeping the line taut and feeling for the impact of the weight on the bottom, the true depth is easily determined.

Difficulty is sometimes experienced in measuring the depth of deep wells having long strings of casing, due to the measuring line adhering to the casing owing to magnetism or other agency. This can be in part overcome by using a heavier weight and soaping the line or coating it with heavy grease.

Drillers approximate both the depth at which they are drilling and the number of feet drilled during a "tour" or 12 hour shift by the simple process of tying a short piece of rope or twine around the cable at the point where it leaves the bull wheel shaft when the tools are resting on bottom. By knowing the exact height of the derrick, it is possible to determine with a fair degree of accuracy the progress being made in feet by noting the position in the derrick of the piece of string attached to the cable.

The following suggestions to operators for the correct measuring of oil wells have been issued by the California State Mining Bureau: *

"Methods of measuring the depth of oil wells and the amount of casing put into them are of extreme importance in order that water shall be shut off at the proper depth and casing perforated between the proper depths. While the water may appear of slight importance to some careful operators, it has been found that gross errors are frequent enough to justify some general regulation. * * *

"1. All measurements must be made with a steel tape. Cloth or metallic tapes cannot be depended upon, as they are subject to great change in length. A five-foot stick used on a sand or drilling line, for distances more than 200 feet, is inaccurate. The reasons for such inaccuracy are that exact markings on the line at the ends of the stick are difficult to make and their great number quickly multiplies the error.

"2. The depth of the well shall in all cases be determined by running a bailer or string of tools to the bottom. The unit of measurement, when cable tools are used, shall be the distance from the floor of the derrick along the sand line over to a point level with the top of the flanges of the reel. This is commonly known as the distance the derrick 'measures over,' and details for such measurement are stated below. If measurement is on the drilling line, it shall be from the floor over to a point near the bull wheel and five feet above the floor, as determined by setting up a five-foot stick.

"The depth of a rotary hole, before casing is put in, shall be determined by measuring each stand of drill pipe with steel tape, measurements to be from top of tool box joint to bottom of shoulder on tool joint pin.

"3. The length of a string of casing shall, when considered necessary by the supervisor or deputy, be determined by measuring to the shoe of the casing from the derrick floor. This measurement can be made on the drilling line by using an underreamer,

* Extract from Article by A. W. Ambrose, Bureau of Mines, Water Problems of the Oil Field, The Oil and Gas Journal, Nov. 5, 1920.

a latch-jack or any other tool which definitely locates the shoe of the casing.

"4. A derrick should be 'measured over' immediately before it is intended to measure the depth of well or of casing. A measurement made when the rig is new may not be correct after the rig and rig irons have been in use for some time.

"The 'distance over' can be determined in the following manner, using a bailer and sand line:

"(a) Run the bailer into the well a short distance and tie string on the sand line level with the surface of the floor, using a straight edge or steel square to determine the correct position.

"(b) Tie a strand of rope (target) tightly on the sand line at a position on a level with the top of sand reel flanges, laying a straight stick on top of the flanges to determine this position.

"(c) Lower the bailer into the well until the target is within easy reach from the derrick floor. Attach the end of a steel tape to the sand line at the target. Raise the bailer until another target can be fastened at the end of the tape and tie another target. Lower the bailer, detach tape, hoist bailer and attach tape at the second target, hoist bailer and set third target. Repeat the operation until it is possible to measure with the tape to the target first set at the floor. The tape must be shorter than the height of the derrick, so that it will not go over the pulley at the crown block.

"When a target is tied to the line, paint should be put on the line above and below the target to show any displacement of the target.

"To measure into the well, after the unit length or 'distance over' is determined, hold the bottom of the bailer dart, when raised, level with the surface of the floor, set a target at the top of the flanges of the reel, lower the bailer until the target is level with the floor and set a second target at the reel. Correct count of the targets is most easily kept by detaching and keeping each one as it reaches the floor.

"The depth can also be conveniently measured when the bailer is pulled out of the well by setting the first target even with the floor, while the bailer is on the bottom, hoisting until the target reaches the flanges of the reel, set new targets at floor level and remove old ones as they reach the reel."

WASHING OUT THE SAND

The formations penetrated by the drill should be carefully watched, particularly when a possible oil or gas bearing sand is encountered. Samples of the sand should be washed perfectly clean in warm water the better to judge of its character and quality.

LOG OF WELL

Drillers should keep an accurate log of the formations passed through during the drilling of every well. This log should show the thickness and character of each formation, including changes in color that may occur in any one stratum, and should record all showings of water, gas and oil. When a sample of the formations is required, the driller should secure a supply of small bottles with a blank label pasted on each. A sample of each formation is then placed in the bottles and the thickness, color and name of the formation recorded on the label.

Graphic charts are often employed to illustrate well logs. Geologists have established a system of symbols to designate the different formations, as, irregular dots for sandstone, blocks for limestone, etc., refer to diagram of well log, Fig. 70.

WELL LOGS

The terms used in drillers' logs to describe formations passed through do not always conform to the technical names familiar to geologists and engineers. The following extracts from a paper by Mr. Arthur Knapp, M. E., before a meeting of the American Institute of Mining Engineers entitled "Rock Classification from the Oil Driller's Standpoint"* are enlightening:

"The ordinary well log is subjected to a great deal of criticism, much of which is well founded. Sometimes, though, the difficulty in interpreting the log is due to the fact that the geologist or engineer using the logs does not know the limitations of the drill-

* Reprinted from Oil and Gas Journal.

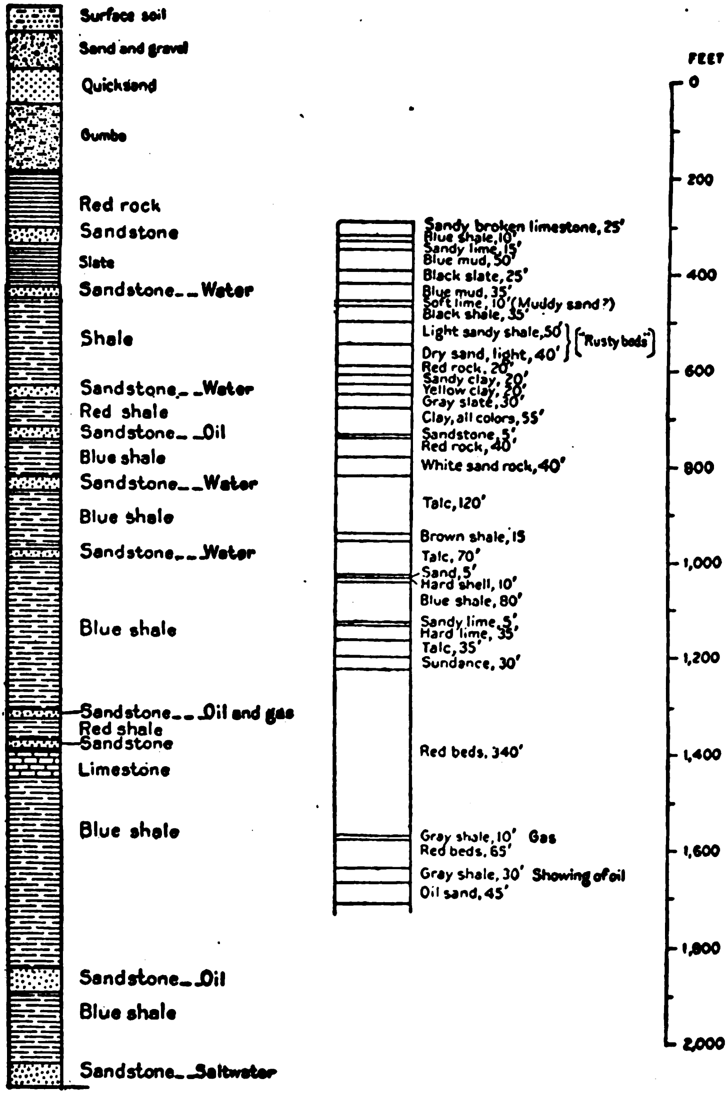


Fig. 70. Illustrating Method of Charting Well Logs
First column graphic chart.
Second column common chart showing thickness of each formation, with scale of well measurements, graduated in hundreds of feet.

ing method used. The rotary drill, especially, has inherent limitations that make it difficult to secure definite information at all times. The identification of well-defined key beds is about all that can be expected from the rotary log. The formation in a drilled hole, as reported by the driller, has a direct relation to the speed with which the drill makes the hole or to the reaction of the various strata on the bit, called the "feel of the bit." When this is not thoroughly understood by the geologist or engineer endeavoring to interpret the log, the result is an erroneous correlation with other wells or a discarding of the log as worthless.

GENERAL TERMS

"*Hard and Soft.*—Hard and soft are relative terms. In the case of well logs, they are very misleading as they are used in connection with both resistance to abrasion and resistance to percussion. In technical rock classification, hardness is relative resistance to abrasion. The term brittleness is used in connection with resistance to blows. These terms are misleading to the geologist or engineer who is not familiar with both the cable-tool, or standard tool, method of drilling and the rotary method. In the case of the standard tools, the driller's report of the hardness of the formation is in terms of its resistance to blows. * * *

"The rotary driller would reverse the terms. The limestone is hard in that it resists the abrasive action of the bit, while the gypsum might be soft in that it is readily cut by the rotary bit. It is rare that wells drilled by the standard tools are correlated with those drilled by the rotary, but the technologist who has worked with well logs from one system might be misled when working with the other.

"*Sticky.*—With the rotary drill a formation is sticky which cuts in large pieces that adhere to the bit and drill pipe. A formation that is sticky with the rotary is usually sticky with the cable tools. On the other hand, formations are encountered in which the cable tools stick, either owing to the elasticity of the formation or to the fact that the drilled-up particles do not mix readily with the water in the hole and settle so quickly as to stick the bit. These formations might not appear sticky at all to the rotary driller.

"*Sandy*.—This term may be used accurately by the cable-tool driller. He obtains samples of the formation through which he passes, of sufficient size to determine the relative amount of sand to clay or sand to shale in any formation. In the case of the rotary drill, this term is misleading.

"The rotary well is drilled with the aid of a "mud" of varying density. It is usually thought of as a mixture of clay and water with a small amount of suspended sand. As a matter of fact this mud often contains as high as 40 to 50 per cent. sand. * * *

"It is impossible to settle out the very fine sand in any rotary mud. An easy and quick way to separate the two for examination is to fill the glass of a centrifugal separator half full of mud and add a saturated solution of common salt. The sand will be thrown to the bottom when the machine is turned for a short time. The mud alone can be turned indefinitely without any appreciable separation.

"Any change in the density of the mud changes its capacity to carry sand. * * *

"These properties of the mud lead to error in the observation of the formation. If a clay formation containing a moderate amount of sand is encountered while drilling in a mud low in sand content, the mud will absorb most of the sand, which will not settle out in the overflow ditch and its presence in the formation will not be noted, if not felt by the action of the bit in drilling. If, sometime later, the mud is thinned by adding water this sand will appear in the overflow and may be attributed to a formation many feet below the one from which it actually originated.

* * * * *

"A change in the speed of pumping the mud also causes a change in the amount and size of the cuttings that appear at the surface. Thus, in the case of the rotary, "sandy" may have little or no meaning when applied to a formation. The term sandy is often used in contradistinction to stick. A formation that drills easily and is not sticky is often put down as sandy because sand tends to interfere with the stickiness; sand does not always account for the lack of stickiness but the latter is often attributed to its presence.

"*Dark and Light.*—* * * A wet specimen, fresh from the hole, has an entirely different color from the same specimen dried. Specimens, when dried, bleach and deteriorate. Many of them air slack or oxidize and change composition altogether. The terms light and dark should be used only for the extremes. * * *

"It is better to use a definite name such as slate-colored or chocolate-colored shale.

FORMATIONS

"*Clay, Gumbo, Tough Gumbo.*—Clay is readily recognizable by the "feel of the bit" while drilling with either cable tools or rotary. To some drillers all clay is gumbo while to others gumbo is only sticky clay. Some clays have the property of cutting in large pieces but do not adhere excessively to the bit and drill pipe and are designated as "tough."

"*Sand, Packed Sand, Water Sand, Quicksand, Heaving Sand, Oil Sand, Gas Sand.*—Free, uncemented sand is easily recognized by the feel of the tools in both systems of drilling. In rotary territory, we often run across the term "packed sand." This is a sand that is slightly cemented with some soft easily broken cementing materials, such as calcium carbonate. * * *

"The cementing material is dissolved by the mud, or the sand grains are all broken apart before reaching the surface, so that the driller finds only sand in the overflow. A microscopic examination of sands from the overflow often shows cementing material to be present.

"Water sand is a sand containing water. There is no specific sand associated with water; any porous formation may or may not contain water. * * *

"A sand containing no cementing material nor clay very often caves badly in the hole. If this sand settles with such rapidity as to threaten to stick the tools, it is designated quicksand. Such a free sand may, on the other hand, have such properties that it

ROCK CLASSIFICATION SUMMARY

Drillers' Term	Use in Rotary System	Use in Cable-tool System	Technical Equivalent
Sand	Any uncemented sand	Any uncemented sand; also many slightly cemented sands or very porous formations	Sand
Water sand	Sands, the samples of which appear clean and bright Sands tested and found to produce water	Sands producing water	Sand
Quicksand	Sands that cave and settle rapidly	Sands that cave and settle rapidly	Sand
Heaving sand	Sands that cave and are forced up the hole	Sands that cave and are forced up the hole	Sand
Oil sand	Sands or other porous formations containing oil	Sand or other porous formation containing oil	Oil sand
Gas sand	Sands or other porous formations containing gas	Sand or other porous formation containing gas	Gas sand
Gravel	Any formation having the feel of gravel while drilling	Correctly used	Gravel
Boulders	Large loose pieces of any formation	Correctly used	Boulders
Clay	Clay or soft shale; usually not sticky	Correctly used	Clay, or sandy clay
Gumbo	Soft sticky clay	Soft sticky clay	Clay
Shale	Formations having parallel bedding	Consolidated clays	Shale
Rock	Any consolidated formation	Term not used	Rock
Gas rock	Any rock formation containing gas	Term not used	Rock
Chalk rock	Applied to light-colored chalk only	Correctly used	Chalk
Sand rock sandstone*	Terms used interchangeably for all cemented formation	Correctly used	Sandstone
Packed sand	Loosely cemented sand	Correctly used	Sandstone
Shell	Thin layer of hard material	Thin layer of hard material	Rock
Shell rock*	Any consolidated formation containing fossil shells	Formation containing shells	Rock with shells
Flint or flinty rock	Any very brittle rock	Correctly used	Flint
Limestone	Limestone, also hard shale	Correctly used	Limestone
Lignite	All fossil wood	Correctly used	Lignite or fossil wood
Gypsum	Correctly used when recognized, also reported as limestone or shale or sticky gumbo	Correctly used	Gypsum
Shells	Fossil shells	Fossil shells	Fossil shells

seems to tend to float. It not only caves but fills the hole above its original horizon, sometimes heaving clear to the surface. This sand is called a heaving sand. The presence of gas or a high hydrostatic head often accounts for the heaving of the sand.

"An oil sand is a sand containing oil. Any porous stratum might

* These are rotary drillers' terms; the cable drillers' terms are sandstone and rock with shells, respectively.

contain oil. A porous stratum containing oil is very often called a sand, although it may actually be a limestone.

"A gas sand is any sand containing gas; even a hard limestone is sometimes designated as a gas sand.

"*Boulders and Gravel.*—True boulder formations are rarely encountered in drilling for oil. They are encountered above the Trenton in Ohio and Indiana and occasionally in California. Concretions are often encountered which fall into the hole and follow the bit for some time and are reported as boulders. * * *

"*Shale.*—Shale, to many drillers, is only that kind of true shale which appears in the overflow, or bailer, in flakes, that is, laminated shale with well-defined bedding. Other drillers include formations that are sedimentary in character and are consolidated enough to appear in the overflow, or bailer, in pieces as large as a pea or larger. They usually call a shale too hard to scratch with the finger nail rock, particularly in rotary territory.

"*Rock, Gas Rock, Chalk Rock, Sand Rock, Sandstone, Shell, Shell Rock, Flinty Rock, Limestone, Lignite.*—When the rotary driller strikes anything hard and does not know what it is, he puts down rock. If this hard substance is a concretion near the surface, it is a rock just the same as the most consolidated formations are deeper down. The cable-tool driller has a much better general knowledge and a much better chance to get samples and hunts for some name to apply to the formation.

"A gas rock is any rock formation containing gas; the term is applied to both sandstone and limestone.

"Sand rock, or sandstone, is usually recognized by the rotary driller, except when it is so soft as to be classified as packed sand. The harder formations appear in the overflow in pieces sufficiently large to be readily recognized. The cable-tool driller is able to recognize sandstone and all other hard formations as he finds large formations in the bailer.

"Shell is a very misleading term. If a driller, either rotary or cable-tool, drills from a soft formation into a hard one he gives it what he considers its proper name. If, however, after drilling for a short distance, he goes back into a soft formation again he is liable to put down shell. This shell may be from a few inches to a foot or two in thickness, it means a thin layer or shell of rock.

"Shell rock means a rock formation containing fossil shells, unless the driller is very careless or misunderstands the term shell. in which case he may put down shell rock, meaning a thin shell of rock."

GENERAL INSTRUCTIONS

DRILLING AND FISHING TOOLS

When making specifications for drilling outfits, the operator should be careful that the sizes of the joints on the drilling tools are suited to the inside diameter of the casing in which they are to be used; also that in case of a fishing operation there may be sufficient space between the casing and the collar of a lost tool for a fishing socket to go over it. For example, a 2¾ x 3¾ joint with a 5½-inch diameter box collar is the largest size joint that may be used in 6¼-inch casing, but for 6¼-inch 24-pound casing, which is 5.92-inches inside diameter, a 5½-inch collar would not leave sufficient space to enable a socket to go over it, therefore it would be hazardous to use the 2¾ x 3¾-inch joint, and the next size smaller, 2½ x 3½ would be better.

SINKER BARS

Formerly the sinker bar was considered a necessary adjunct of every string of drilling tools. For a number of years, however, the sinker has been little used, although it usually is a part of each drilling outfit specification.

The sinker is sometimes used to add weight to the tools in drilling exceedingly hard rock or for drilling in a hole full of water. Also the sinker sometimes is useful for lengthening a string of tools for purpose of straightening a crooked hole or for use as a short fishing stem.

DRILLING IN EXTREMELY COLD WEATHER

When drilling in temperatures of zero or below, the driller should be careful that his tools do not crystallize and break.

After pulling out and running the tools back into the hole they should be suspended about 20 feet off bottom for at least 10 minutes before attempting to run them. This will permit the temperature of the tools to rise approximately to the temperature of the hole. Otherwise the bit, jars or even the stem might snap like a pipe stem.

MOVING BACK BOILER WHEN DRILLING IN

If the boiler is not located at a safe distance from the well, it is good practice to move it back before drilling in; otherwise, should the well make a large volume of gas, there might be danger of its catching fire.

SHUTTING DOWN

When shutting down and leaving a drilling well, it is customary to place one of the tool wrenches over the open hole and then to rest the drilling tools on it. This closes the hole, prevents objects from falling in and people from tampering with it.

BELLING CASING

Before beginning to drill inside drive pipe or casing the top coupling should be removed and the pipe belled out to protect the drilling cable from injury through contact with threads or the top of the pipe.

CHAPTER IV

FISHING FOR TOOLS FAST OR LOST IN THE HOLE

Fishing jobs, so called, are like the accidents that sometimes happen in the best regulated families: They may often be prevented by care and attention, but they happen to the mose capable driller using the best outfit obtainable. Fishing is the bane of the drilling contractor and is the cause of vexatious delays and financial loss in many drilling operations. Therefore it is essential to take every precaution with drilling tools and to exercise care in drilling, to the end that fishing jobs may be avoided as far as possible.

Every drilling outfit should include several of the fishing tools most generally needed in fishing for lost tools, such as long stroke jars, rope knife, jar bumper, combination socket, slip socket, horn socket, rope spear, etc. Special tools for any of the unusual fishing jobs that sometimes occur may be had at supply stores or tool shops, or can be made to order according to the emergency to be met.

That the driller may be prepared intelligently to fish for lost tools it is essential that he know the exact dimensions of all of his tools that go down in the hole, including the fishing tools, for these occasionally become fast or lost in the hole. It would be well to keep a record of the following tool dimensions:

Sizes of joints, including exact length and degree of taper of all pins.
Outside diameter of neck and barrel of rope sockets; also their length, and diameter of the hole at top.
Diameter of collar of all boxes and pins.
Diameter and length of stems.
All bit dimensions, including length over all, width, thickness and size of wrench square.
Diameter and length of bailers and sand pumps.
Dimensions of under-reamer cutters.
Dimensions of all fishing tools.

Illustrating the principle of slips used in many fishing tools.*

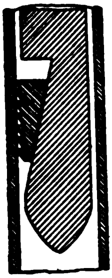


Fig. 71. Spear Slip

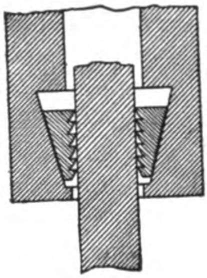


Fig. 72. Socket Slips

In the following pages are suggestions for the correct tools to use and methods to be employed for various fishing jobs.

FISHING JARS

As fishing jars are used with nearly all other fishing tools, they are the most important fishing tool the driller uses. They have a longer stroke than drilling jars, from 24 to 48 inches, and they should be well made from good quality steel, with carbon content ranging between .50% and .60%, for the work they must perform would amount to abuse for any other tool. Fishing jars are run below the stem instead of above as in drilling.

The jars are used for jarring up, for jarring down and for jarring both ways, according to the nature of the fishing operation, and it may sometimes be necessary to run them for hours in the effort to move a fast tool.

Jars should be carefully examined for cracks or other defects before running them, for broken jars in the hole would add greatly to the difficulties of the fishing operation, to say the least.

There is one important difference between drilling and fishing: in drilling the tools are loose in the hole and, if the driller has not hitched on at the proper place, the result may be that he will drill either too tight or too loose, but the cable will not be dam-

* Diagram after Oil Production Methods by Paul M. Paine and B. K. Stroud.

aged. Not so in fishing, however, for the object fished for is stationary and hitching on must carefully be done to secure the maximum stroke of the jars and to avoid straining or breaking the cable. When the fishing string has been run to the top of the lost tool and a hold secured, the tools are raised slowly, until the jars strike. As the bull ropes can be thrown off only while the bull wheels are in motion it is essential that the cable be flagged, so that in pulling out to throw the ropes the cable will not be pulled up too tight. A string, or "flag," is tied to the cable at the derrick floor or the top of the casing and the cable is run down several feet, then quickly pulled out until the string clears the floor, when the bull ropes are thrown. The cable is slacked slightly and the screw is clamped on. The engine is then turned over slowly until the jar of the jars striking is felt and screw is let out or taken up until a satisfactory jarring stroke is secured.

For jarring down the hitch would be adjusted after the jars strike down instead of up. For jarring both ways the stroke would have to be adjusted by putting the wrist pin out in the crank sufficiently to cause the jars to strike on both the up and the down stroke.

It is good practice to start jarring or fishing, using a short stroke, with the wrist pin in the second hole of the crank, and then increase the crank stroke or throw as needed.

FISHING FOR A LOST OR PARTED CABLE

If the cable breaks from its own weakness and the tools are known to be free, the cable and tools attached to it may usually be recovered by means of a rope spear run on a rope socket and set of jars, no stem being necessary. If the spear should not readily take hold, jarring down lightly should engage its prongs in the mass of rope sufficiently to enable both the cable and the tools to be withdrawn.

If the tools are found to be fast or wedged by sediment, it will be necessary to jar up until the hold of the spear is loosened, and the next operation is to cut the rope, if possible, otherwise it will have to be chopped up into fragments with a rope chopper and removed with a mouse trap, a device similar to a bailer, with an inward opening flat valve in the bottom. See Fig. 75.

To cut the rope, a V, or hook, rope knife and rope knife jars

Fig. 73. Rope Spear.

Fig. 74. Rope Grab.

Fig. 75. Mouse Trap.

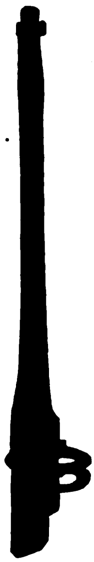


Fig. 76. Manila Rope Knife.

Fig. 77. Rope Knife Sinker.

Fig. 78. Rope Knife Jars.

are connected to a string of sucker rods and run down into the lost rope. Next a rope grab, with a small joint and collar that will go down in the hole and clear the rods carrying the rope knife, is connected, by means of a substitute from the tool joint to the sucker rod joint, to another string of sucker rods and run down, being careful not to go down as far as the rope knife. The grab is entangled in the rope and pulled up, to get a tension on it, and then the rope knife is lowered as far as it is possible to get it and the cable is cut.

After the rope has been cut, the knife and string of rods are left in the hole until after the rope grab and cable have been withdrawn. If it is found, after the cut cable is out, that it was not cut off near the rope socket, it may be necessary to repeat the operation or to cut up the remaining rope with a chopper, to clean out the rope from top of rope socket, so that a fishing tool will go over it.

FISHING FOR TOOLS FAST IN THE HOLE

When, in drilling without jars, the tools become fast, due either to the bit "muddying" or to something lodging against it, or to any other of a number of causes, the first thing usually attempted is to run the bumper, Fig. 98. A strain is taken on the cable and the bumper is operated as described on page 169. If this should not loosen them, the driller usually resorts to "switching," so called. This is done by letting out sufficient screw to provide slack in the cable, then by placing the wrist pin out in the last hole of the crank, a long stroke is secured with the walking beam. By this process the tools can often be pulled loose. A direct strain will sometimes free the tools, but this may result in parting the cable. If the tools cannot be pulled in this way, it becomes necessary to cut the cable and fish them out. Cutting is done with a rope knife, with jars and swivel, operated on the sand line.

CUTTING THE CABLE

The knife used for Manila cable is usually the horseshoe type, Fig. 76. The cutting knife is clamped around the cable and the knife, jars and sinker are lowered until the knife rests on the top of the rope socket. The line is then reeled in until the slack is taken up and, by means of alternately releasing the sand reel brake and then setting it, sufficient play is given the jars to furnish stroke for cutting off the cable.

For cutting wire cable there are several improved wire rope knives on the market, of which Fig. 79 is a type.

After the cable has been cut and removed from the hole, an-

Fig. 79.
Wire Rope Knife

Fig. 80.
Slip Socket

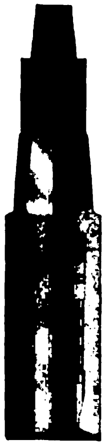


Fig. 81.
Combination Socket

other rope socket, with a stem and a set of fishing jars with twenty-four to thirty-six-inch stroke, is connected (the fishing string is connected with the stem above the jars to add weight to the stroke in jarring) with either a slip socket, Fig. 80, or a combination socket, Fig. 81. The slip socket has slips similar to an inverted U, with milled teeth on each prong. Combination socket slips are in three pieces and bear against a stiff coil spring in the barrel of the socket. The principle of operation is the same with both sockets; i. e., when the slips engage with the lost tool and the fishing tools are raised or jarred up, the taper in the bottom of the socket causes the slips to take a firm grasp, and the harder the pull, or jar, the more securely will the socket hold. This outfit is run down to within a few feet of the lost tools and then lowered very slowly until the socket is in contact with them. A gentle strain is then taken on the cable and, if the socket has taken hold, the temper screw is clamped on and jarring up is begun. If the tools are not cemented in the hole by sediment lodging around them or not otherwise hopelessly fast, a few minutes jarring should start them.

If, after jarring for a few hours, the tools cannot be released, the next operation is to jar up and jar down alternately to break the hold of the fishing socket. If the hold cannot be broken, it will be necessary again to cut the cable, pull out and string up another rope socket, short stem or sinker, and a spud, Fig. 82, or spear. Then by spudding around the tools in the hole it may be possible to loosen them so that by repeating the fishing operation with another socket both strings of tools may be recovered.

FISHING FOR A BIT OR A ROPE SOCKET

When a bit has unscrewed, or the cable has pulled out of the rope socket, a combination socket, Fig. 81, is the tool usually used. This socket is provided with two sets of slips, one set to engage in the threads of the pin on the bit, the other to take hold of the barrel or neck of the rope socket. The same outfit of fishing jars, etc., used with the slip socket may also be used with the combination socket. In a fishing job of this kind, there is usually little difficulty in picking up the lost tools and little or no jarring is necessary. Sometimes, however, in the case of a lost bit, it may be found that the bit has fallen over against the wall of the hole in such a position that the socket will not go over the pin. It is then necessary to run down with a bit hook, Fig. 83, to straighten up the bit so the socket will catch it.

HORN SOCKET

The horn socket, which has no slips, but simply takes a friction hold, is often successfully used to catch a bit or other single tool that may be loose in the hole. Horn sockets and slip sockets may be fitted with a detachable bowl, so that one socket can be used in two or more sizes of hole.

FISHING FOR ROPE SOCKET THAT CANNOT BE CAUGHT WITH COMBINATION SOCKET, SLIP SOCKET OR HORN SOCKET

In rare cases, such as the combination socket slips failing to hold, or owing to the lost tools almost filling a small diameter hole, so that the other sockets will not go over them, a rope

Fig. 82. Spud

Fig. 83. Bit Hook

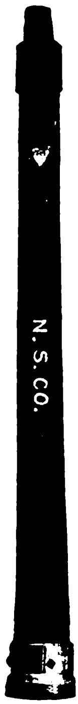


Fig. 84. Horn Socket with Bowl

Fig. 85: Corrugated Friction Socket

Fig. 86. Rope Socket Tongue Socket

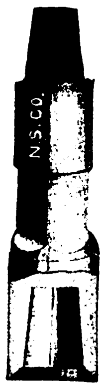


Fig. 87. Drive Down Socket

socket tongue socket, Fig. 86, may answer. This socket has a tongue, or spear, with a slip that enters the rope socket neck, taking hold both inside and outside of the rope socket.

FISHING FOR ROPE SOCKET WITH BATTERED NECK

If the top of a rope socket has been battered so that a combination socket will not take hold, a corrugated friction socket, Fig. 85, may catch it. If not, it will be necessary to reduce the neck of the rope socket with a drive down socket so that the slips in the combination socket will catch it.

After lost tools have been freed and before pulling out, it is a good plan to fill the hole for several hundred feet with water, so that, if the hold of the fishing tool should break, the water will cushion the fall of the tools.

FISHING FOR A BROKEN STEM

If the pin has broken off, the fishing operation is described under "Rasping" and "Milling a Pin."

If the stem breaks through the round, the broken part may be caught with a horn socket, long friction socket or a slip socket.

If the break occurs through the wrench square, a horn socket, long friction socket, or corrugated friction socket, may catch and hold it. If none of these will hold, a square socket that will fit over the broken square may recover it.

A stem seldom breaks through the collar, but if this happens, a collar socket should be used. If the collar is so large that it almost fills the hole, it may be possible to reduce it with a rasp so that a socket will take hold.

RASPING

For filing off the collar of a tool when the pin has broken off, or to reduce a battered pin or tool so a socket will catch it, a side rasp, or two wing rasp, is used. This tool is what its name implies and is simply used as a file to rasp off the sides of the tool until a socket will take hold.

MILLING A PIN

When a pin has been broken off of a tool and the lost tool is of a size that nearly fills the diameter of the hole, so that no socket

Fig. 88. Side Rasp

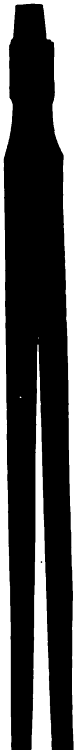


Fig. 89. Two-wing Rasp

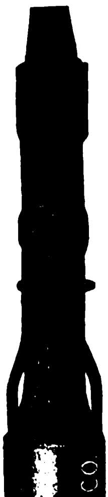


Fig. 90. Collar Socket

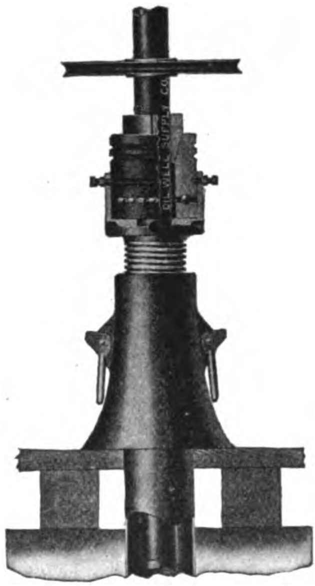


Fig. 91. Milling Jack and Wheel in operation

Fig. 92. Milling Tool.

will go over it, it can sometimes be recovered by milling a new pin on it, so a combination socket will take hold.

A milling tool is connected to the bottom of a string of tubing and let down until the tool rests on the top of the lost tool. A milling wheel is then clamped to the top of the tubing and is driven by means of rope transmission from the bull wheel shaft. The weight of the column of tubing forces the milling tool to feed down until the pin is cut. The use of a milling jack simplifies a milling job, for the jack sustains the weight and regulates the feed of the tubing.

IMPRESSION BLOCK

If a lost tool cannot be fished out it is a good plan to take an impression of the pin, or top of the tool. This is done by fitting a block of wood into the bowl of a horn socket and then pressing wax or soap in the socket and against the block. It is a good idea to drive a few nails into the face of the block, as a means of holding the wax or soap. The socket is then run down on top of the lost tool and the weight of the tools allowed to rest on it. An impression in the soft substance in the socket is thus secured.

FISHING FOR BROKEN JARS

Broken jars present several different kinds of fishing jobs. When the upper half of the jars is broken and comes out with the tools, the lower half may be caught by means of the jar tongue socket, which is provided with slips that take hold of the protruding tongue of the lower jar. A boot jack, Fig. 100, or latch jack, may also be used to catch the lower half of the jars.

If the tongue of the lower jar is broken off, leaving the two reins protruding, or if the upper part of jars breaks near the head or crotch, leaving the reins reaching up, they may be caught with the center jar socket. If one rein is broken off, a jar rein socket, or side jar socket may take hold.

A single rein of a broken jar may sometimes be fished out with a horn socket into which has been driven a piece of wood; the rein catching between the wood and the inside of the socket bowl.

If both lower reins are broken off near the crotch, a slip socket or horn socket, is the tool to use.

RELEASING LOCKED JARS

Sometimes jars stick or "lock;" or a piece of rock or other substance may lodge against the rope socket, wedging the tools above the jars so that it is impossible to get a stroke. For this fishing job a jar bumper is used. This device is operated on the sand line. It has a U shaped bottom which fits around the cable

Fig. 94.
Jar Tongue Socket

Fig. 95.
Center Jar Socket

Fig. 96.
Jar Rein Socket

Fig. 97.
Side Jar Socket

and is loosely held by a bolt passing through it. A strain is taken on the cable, the bumper is clamped on it and lowered until it reaches the rope socket, or the object lodged against it; then it is raised 10 or 12 feet and dropped. A few blows should crush the wedging material, or loosen the jars. The bumper should not be run too long, for it might batter the rope socket neck. If the bumper does not release the tools, the cable must be cut and a fishing socket used.

FISHING FOR LOST BAILER OR SAND PUMP

This is usually a simple operation, for if the bail of the sand pump or bailer is not broken, it can be caught with a latch jack, or boot jack, Fig. 100. If the bail is broken off, a sand pump grab may take hold of it, or if the bailer or pump is considerably smaller than the hole, a horn socket may catch it. For a bailer with broken bail, and that nearly fits the hole, a casing spear may be necessary.

In emergencies a latch jack or sand pump grab can be made at the well from the upper half of a set of jars.

If all other means fail to extract the lost bailer or sand pump, it will have to be drilled up and the pieces mixed with the sediment and removed with the bailer, or sand pump. The electric magnet is a convenient means of picking up such drilled up fragments of tools.

FISHING WHERE JOINT HAS UNSCREWED

Where one of the joints in the string of tools has unscrewed and the situation is discovered before the joint has been drilled on and battered, it may be possible, by turning the tools, to screw the joint together, in the well, a sufficient number of threads to hold until the tools can be pulled out and the joint tightened. If this is not possible, the dropped tools can probably be recovered with a combination socket. Should the pin be so battered that the combination socket will not catch it, other means herein described may prove efficacious.

DRILLING PAST LOST TOOLS

When it is impossible to fish out lost tools, the only alternative is to drill past them. This is done by lowering a whip stock, attached to a sand line, until the bottom of the whip stock rests on the top of the lost tools. Drilling is then resumed in the regular way, but the driller should be careful in this operation that his tools do not slant off into a crooked hole. It is sometimes possible to spud around the lost tools, thus making a recess in the wall of the hole to receive them, so that, in drilling past, the hole can be kept straight. After drilling far enough to be sure the hole is true, the tools are withdrawn and the whip stock is pulled out.

If, as sometimes happens, the whip stock breaks away from the sand line, it may be fished out with a whip stock grab.

Fig. 98.
Jar Bumper

Fig. 99.
Bailer or Sand Pump Grab

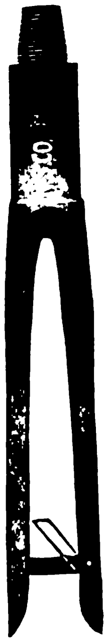


Fig. 100.
Boot Jack

Fig. 101.
Whip Stock

Fig. 102.
Whip Stock Grab

SPEARING AROUND FAST TOOLS

When tools become cemented in the hole by sediment and cuttings settling around them, or if they are covered by a caving wall, they can sometimes be loosened by spudding or spearing around them. For tools caught in only a few feet of sediment or cuttings, an 8 or 10 foot spud may answer, but where cavings have buried them a long spear is necessary. The spear should be as long, or better, a few feet longer than the total length of the tools. They are usually 50 to 65 feet in length. A spear for use in 8-inch or smaller holes is made of steel plate 1-inch thick, and formed convex on the outside and concave inside, in width about two-thirds the diameter of the hole. A spear, owing to its length, should be run slowly and carefully that it may not be bent or sprung. By drilling or spudding around the lost tools, partly filling the hole with water and occasionally bailing or pumping out the sediment, it may be possible to clean out the hole around the tools clear to the bottom. This should loosen them so they can be recovered by any of the fishing methods here described.

FISHING FOR CASING

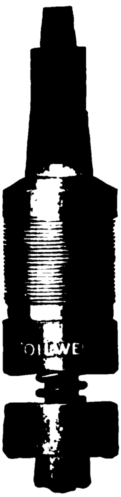


Fig. 103.
Fox Trip Spear

Fig. 104.
Die Coupling

Fig. 105.
M. & F. Die Nipple

The parting of a string of casing frequently presents troublesome fishing jobs. Parted casing can usually be removed with either a bull dog or a trip casing spear. The bull dog spear, as its name implies, takes a bull dog hold which cannot be broken, except by breaking the spear, but in this case both the casing and perhaps part of the spear are left in the hole. When parted casing is known to be free the bull dog spear is suitable, but if there is any chance that the casing may be fast in the hole, a trip spear should be used, for, if the casing cannot be pulled, the slips of the spear can be tripped, releasing its hold, and it is then drawn out. If the parted casing cannot be jarred loose and pulled out, it may be possible to connect the upper part of the string with that which has remained in the hole by means of a case hardened die nipple, or coupling. These devices are screwed on to the lower joint of casing. (When the coupling is left on the top joint of the casing in the hole, the male and female nipple is used, and when the coupling has been pulled off, the steel coupling is used to make the connection.) The casing is then lowered until the nipple or coupling, as the case may be, connects with the lost casing. It is almost impossible properly to engage the threads of the parted casing, but the steel nipple or coupling, being hardened, thread cutting dies, will sometimes cut their way on to the casing, or into the coupling, so that the string of casing is united. In calculating the depth of thread that may have been cut by the die, allowance should be made for the taking up of threads in the string of casing.

FROZEN CASING

Frozen is the term used by drillers when casing becomes immovable owing to cavings lodging against it, or if for any other reason it becomes fast. This difficulty is often experienced in soft formations where it is necessary to under-ream the casing and carry it down as drilling proceeds. If frozen casing cannot

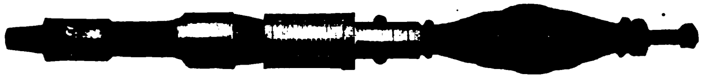


Fig. 106. Mills Drive Down Spear

be freed by means of a trip spear and long stroke jars, or by the use of hydraulic jacks, it may be possible to force or drive it down by using a drive down trip spear, Fig. 106. This spear has slips similar to the regular casing spear, except that the teeth are reversed, so that they engage in the casing on the downward thrust of the spear. It should be run with long stroke jars. Casing that

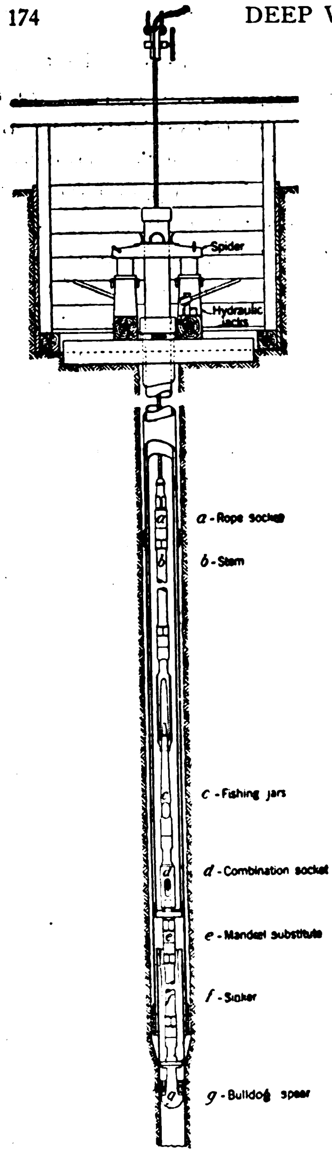


Fig. 107. Pulling Casing with Jacks. Socket and Mandrel Substitute*

cannot be pulled can thus, in many cases, be driven as far as it may be necessary or feasible to force it.

When all other means of pulling frozen casing have failed, a system of pulling and jarring, used with success in California and illustrated in the accompanying diagram may prove efficacious. A mandrel substitute is a specially made tool having a tool box, a mandrel top somewhat similar to a rope socket neck, but solid, and between the neck and box a shoulder, threaded to fit a casing coupling. The casing spear is screwed to the box of the substitute, a casing coupling is fitted to the threaded shoulder and the coupling is screwed to the bottom joint of the fishing string of casing. This outfit is lowered until the spear has engaged in the frozen casing at the point where the pulling is to be attempted. Next a slip socket or a combination socket is strung with long stroke fishing jars and stem with rope socket, and the fishing tools are lowered and a hold secured with the socket on the mandrel. Thus, with the solid connection provided by the spear and the hold with the socket, combined pulling with hydraulic jacks on the casing and jarring with the socket exert a powerful force, which can be further augmented with

* Illustration from Bureau of Mines Bulletin No. 182.

a second set of jacks pulling on the frozen casing. This is likely to result in the parting of the casing, however.

** The mandrel substitute may also be used to pull frozen casing broken off or cut off and left in the bottom of the hole. When this is done, the fishing string of casing may be of the same size as the lost casing and a short stem or sinker should be connected between the spear and the substitute, so that, if the top joint of the casing should be split, the spear may be run down far enough to secure a firm hold.

A bull dog hold of a casing spear can usually be broken by jarring both ways until the teeth of the slips either are broken or worn smooth enough for the spear to slip in the pipe.

If the casing can neither be pulled nor driven, it is possible to save that portion of it that may be above the point where the freeze occurred. This can sometimes be determined by sounding with a weight and line outside the casing. If the casing has been under-reamed and there is not sufficient space between the casing and wall of the hole for sounding, the point of the freeze may be located by running a drive down spear and testing for vibration. No vibration will be felt until the spear is above the freeze. A casing cutter is then lowered to a point just above the freeze and the casing is cut and removed.

The Jones casing cutter is lowered on tubing to the point where it is desired to cut the casing. The tubing is first turned a half turn to the left to set the springs or braces that hold the cutter in position; it is then turned to the right until the casing has been cut. This cutter has a mandrel that operates automatically by the weight of the tubing.

The California style casing cutter is used for cutting heavy California casing. It is lowered on tubing to the point at which the casing is to be cut, and the jar and mandrel are lowered on a rope inside the tubing. The mandrel enters an opening in the cutter and is jarred down to back up the cutter blocks as the cutter wheels cut into the casing.

** Bureau of Mines Bulletin No. 182, Casing Troubles and Fishing Methods in oil wells, by Thomas Curtin.

To continue the well, it is then necessary to reduce to the next size smaller casing that will go down inside the casing left in the hole.

When conditions permit, that part of the casing above the bot-

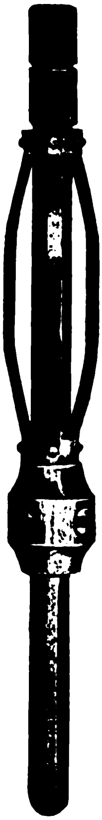


Fig. 108.
Jones Casing Cutter

Fig. 109.
California Casing Cutter

Fig. 110
Mandrel and Jars

tom of the next size larger casing may be cut off and recovered (excepting the water string.) When this is done, the casing that has been cut should either be belled out to fit the next size or a casing adapter, Fig. 111, should be lowered over the top of the cut off casing, to guide the tools on entering it. This practice is followed in California.

Occasionally in diverse ways, casing is collapsed; by the pressure of water surrounding it, a boulder lodging against it, the caving in of the wall of the hole, or by reason of its own weight. It usually can be swaged out straight by running a swage through it.

Fig. 111. Adapter

Fig. 112. Swage

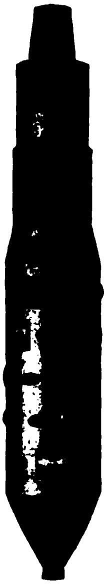


Fig. 113. Roller Swage

An improved roller swage, Fig. 113, with a series of rollers mounted in it, would probably swage out casing that was badly collapsed or dented where the old style swage might fail.

A swage should be run with long stroke fishing jars. In swaging out collapsed casing, it is a good plan, if the tools are available, first to run a swage several sizes smaller than the casing, then run the next larger size and so on until a swage fitting the casing will go through it.

If casing cannot be swaged true, the only remedy is to pull it, if possible, and remove the collapsed pieces. If this cannot be done by using double and triple snatch blocks, which will provide 5 lines to increase the leverage and reduce the strain, then it may be necessary to employ hydraulic jacks. Two 100-ton jacks should be powerful enough either to start the casing or part it.

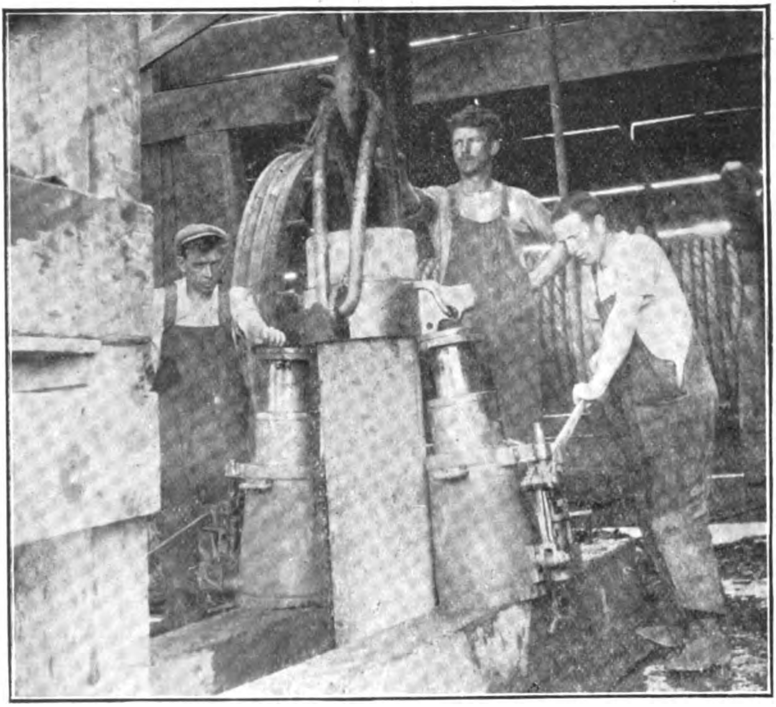


Fig. 114. Pulling Casing with Hydraulic Jacks and Elevators

A drive pipe or casing ring with wedges or slips should be set to hold the casing, and the jacks set, one on each side, under the ring. After the casing has been released, it can be pulled in the usual way.

If drive pipe ring with wedges is not available, the jacks may be set under the ears of the elevators. When this is done a firm foundation of heavy timbers should be provided for the jacks and they should be set at a slight angle toward the pipe. (See Fig. No. 114.)

SIDETRACKING CASING

Occasionally, particularly in the California fields, operators have drilled past and sidetracked casing that has been broken off and left in the hole. This could hardly be accomplished in hard formations, however. An eccentric or enlarging bit, dressed out on one side more than on the other could be used for this purpose. *

SHOOTING CASING

When it is desired to pull casing in the Mid-continent fields it is the practice to shoot it off with a charge of nitro-glycerin. This is done by lowering on a length of squib wire a casing squib, fitted with wire wickers that project upward. When the point in the casing at which it is desired to shoot is reached, the wire is pulled up, causing the wickers of the squib to engage in the coupling. The shot is exploded by dropping a weight as described under Shooting, page 317. The explosion usually breaks the coupling, but otherwise does not injure the casing and that portion of it above the shot can be recovered.

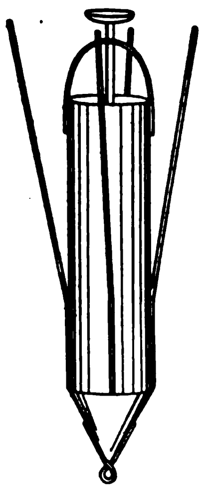


Fig. 115.
Casing Squib

When it is desired to pull casing that may be fast owing to sand pumpings, sediment or cavings lodging against it, a casing splitter, Fig. 116, is sometimes used. This tool is equipped with a mandrel with spring and a friction loop. The spring on the mandrel is set and the loop is pushed up against the body of the tool before it enters the casing, thus preventing the knife from cutting. When the tool has reached the point at which it is desired to split, it is pulled up a few inches, causing the loop to hold or drag in the casing sufficiently to trip the knife or cutter.

* U. S. Bureau of Mines Bulletin 182, Casing Troubles and Fishing Methods in Oil Wells, pp. 27-29, by Thomas Curtin.

By jarring down the casing is then split, allowing the sediment to flow in through the slots. The splitter may also be used in lieu of a perforator by cutting shorter slots and being careful not to split the couplings.

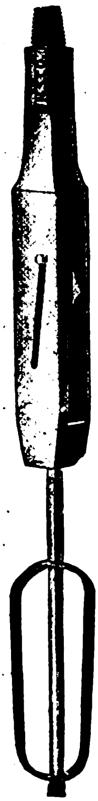


Fig. 116. Casing Splitter

FISHING FOR TOOLS IN A CAVING HOLE

When tools have become fast owing to the wall of hole caving in against them, the ordinary fishing processes may serve to aggravate the difficulty by causing further caving. In such cases, a casing bowl and slips operated on a string of casing have been used with success. It is first necessary to cut the cable. The casing bowl is then screwed to a joint of casing of a size that will go down the hole and also go over the tools. Additional joints of casing are added until the bowl reaches the lost tools. The slips are then lowered on a string of smaller pipe until they engage with the rope socket. The casing is next pulled up until the taper in the bowl causes the slips to take a firm hold. A solid connection with the fast tools is thus secured, and by using either double and triple blocks, or hydraulic jacks, or both, the casing and tools may be released.

The Kessleman Casing Bowl, Fig. 117, is sometimes used for the purpose of excluding water from the casing while fishing. It is equipped with a rubber gasket around the bottom, so that when it is lowered upon the tools, the gasket makes water-tight connection, and the water above the bowl can then be bailed out; thus, with the water pressure removed, making it easier for the fishing tools, and particularly the jars, to work.

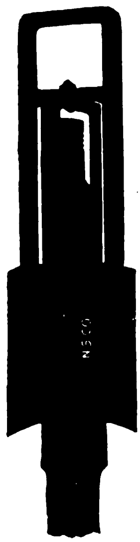


Fig. 117. Casing Bowl

FISHING FOR UNDER-REAMER CUTTERS, PIECES OF STEEL THAT ARE DRILLED UP AND OTHER SMALL OBJECTS

The "Helrazer" electric magnet fishing tool is recommended for picking out such small pieces, and the manufacturers' circular states that the magnet will lift out a bit provided it is not fast in the hole.

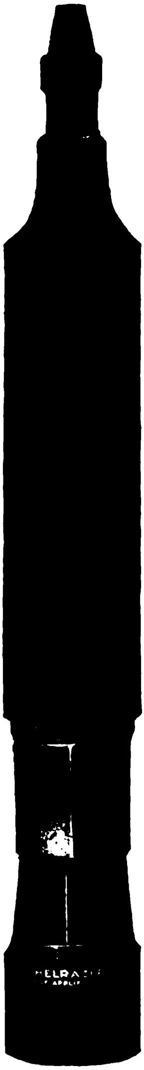


Fig. 118. "Helrazer"

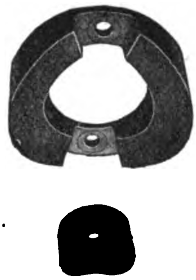


Fig. 119. Under-Reamer Cutter Attachment

Fig. 120. Magnetic Slip Catcher

This device derives its lifting power from current furnished by aeroplane non spill storage-batteries, contained within the tool. It is operated on a rope socket, or stem, and is run in the hole the same as any other fishing tool. It is equipped with a simple switch that is closed by the impact of the tool when it strikes bottom, or by a light up-stroke with the jars. The batteries may be recharged from a derrick lighting generator.

LIFTING CAPACITIES OF HELRAZER ELECTRIC MAGNET FISHING TOOLS

Size Hole for, Inches.	4¾	5 3/16	6¼	6⅝	8¼	10	12½
Lifting Capacity, Pounds.	800	1000	1500	1700	3000	5000	7500

FISHING OUT A LOST SWAB RUBBER

This may be accomplished by simply dropping in the hole a number of glass bottles and running the tools on them until the rubber has been sufficiently cut to pieces so that it can be removed with the bailer or sand pump.

FISHING FOR LOST TEMPER SCREW BALLS, SET SCREWS, ETC.

Such small objects are difficult to drill up and may injure the bit. They may be picked up by making a thick paste of cracked grain mixed with water. This dropped down the hole will envelop the small objects and the mass can be caught in the bailer. The "Helrazer" electric magnet tool is a good device for picking up such small pieces.

FISHING OUT TOOLS AND CASING TOGETHER

Occasionally the tools become lodged in the casing in such a way that they cannot be jarred nor fished out, and it may be necessary to remove the casing and tools. If, as sometimes happens, the casing cannot be started with elevators, hydraulic jacks are necessary. After the casing has been started and the first joint has been pulled out and unscrewed, it will then be necessary to "strip it," as the drillers say, over the cable. This is a tedious process and consists of removing the cable from the bull wheel shaft and passing it through each joint of casing. As the casing is pulled, joint by joint must thus be stripped, until the casing above the point where the tools have lodged in it and tools have been removed.

USE OF ACID

When tools are stuck in limestone and they cannot be spudded free, they may sometimes be successfully released by the use of muriatic acid, which acts upon the limestone and dissolves it. Acid will not be effective on any other rock formation except limestone or dolomites.

MISCELLANEOUS INSTRUCTIONS FOR FISHING

Fishing for lost tools should be done slowly, carefully and with the correct tool for the peculiar fishing job undertaken.

In running any socket or fishing tool it should be remembered that there is a chance of leaving the fishing tools in the hole on top of the lost tools, thus further complicating the situation.

Therefore lower the fishing outfit slowly, keeping accurate record of the exact depth at which the lost tools are lodged and knowing how much cable to run out to reach them. When approaching the lost tools, slow down and feel the way inch by inch until the fishing tool lands on the lost tools. Then let out a little slack in the cable, sufficient to allow the fishing tool to settle over the lost tool, take a gentle strain to see if the tool has taken hold and pull out if possible. If the tools cannot be moved, jar up a few strokes and if this does not break the hold or move the tools it may be safe to jar up, using longer and more powerful strokes, until the tools are released.

If, after several attempts, the socket does not take hold, let out slack until the jars strike, and then jar down lightly; this may force the fishing tool over the lost tools and cause it to take hold.

When the tools are free and, upon pulling out, they again lodge, instead of heavily jarring up on them in an effort to start them, jar down and force them back a few feet. Thus, by alternately jarring down and then up you may be able to get them out.

When it is impossible to make the slips of the fishing socket catch or hold on the lost or broken tool, a hold can sometimes be secured by dropping a piece of carpet down the hole or packing it into the fishing socket in such a way that it will form a friction contact between the slips and the lost tool when the socket goes over it.

CHAPTER V

ROTARY PROCESS OF DRILLING

The hydraulic rotary system of drilling has been employed for many years in the drilling of comparatively shallow water wells through soft formations. The use of the rotary system for drilling deep oil wells, however, dates from the successful drilling of the famous Spindle Top gusher near Beaumont, Texas, by Captain J. F. Lucas in the year 1901. The outfit he used was light and, as measured by present standards, very crude, and the fact that he was able to finish the well with it at all marked his work as an engineering feat. Indeed it opened a new epoch in deep drilling in alluvial deposits, and made possible the development of the Gulf Coastal fields of the United States and the fields of many foreign countries. The continuous development of and improvement in rotary drilling methods and equipment have resulted in the wide use of this system and it has superseded cable tools in practically every field where the formations can be penetrated by the rotary process.

The hydraulic rotary process consists of rotating a column of drill pipe, to the bottom of which is attached a rotary drilling bit, and, during the operation, circulating through the pipe a current of mud laden fluid, under pressure, by means of special slush pumps. The circulation of the mud fluid performs the three-fold service of washing up the cuttings outside the drill pipe; plastering up the wall of the hole, thus preventing caving. and by the mudding process (elsewhere described) sealing up water and gas bearing formations, preventing the escape of these elements, when desired.

The hole is drilled by the cable process by the rising and falling of the tools, pounding and fracturing the rock; the rotary process drills the hole by the bit rubbing or boring into the formation, aided by the circulating fluid. Fewer strings of casing are

required with the rotary process of drilling than with the cable tool method, the mudding of the walls serving the purpose, to a certain extent, of casing.

SPECIFICATION OF MATERIAL REQUIRED TO BUILD A GULF COAST ROTARY RIG—112 FT. DERRICK WITH 24-FOOT BASE. (Refer to Fig. 121.)

Pieces,		Size, Inches	Length, Feet.
2	Engine Mud Sills	16 x 16	16
2	Engine Pony Sills	14 x 14	10
1	Engine Block	18 x 24	12
4	Side Sills C	10 x 10	26
6	Derrick Sills G	8 x 10	24
2	Casing Sills H	8 x 10	26
2	Foundation Sills K	8 x 10	26
6	Corner Sills D and Blocking	8 x 10	16
1	Bumper J	8 x 10	12
2	Gin Poles L	4 x 6	14
38	Derrick Floor, Girts, Top, etc	2 x 12	24
32	Girts and Doublers	2 x 12	20
34	Derrick Corners	2 x 12	16
20	Starting Legs, Girts, Top, etc	2 x 10	18
56	Legs, Doublers and Girts	2 x 10	16
8	Girts	2 x 10	14
8	First Braces	2 x 8	24
16	Second and Third Braces	2 x 8	22
12	A Braces, Top, etc	2 x 8	20
41	Legs, etc	2 x 8	16
14	Braces	2 x 6	20
16	Braces	2 x 6	18
8	Braces	2 x 6	16
16	Braces	2 x 6	14
8	Braces	2 x 6	12
14	Ladder	2 x 4	16
8	Top Braces	1 x 6	16
10	Ladder Strips	1 x 4	16
50	Boards	1 x 12	16
4	20-inch Derrick Pulleys.		
100	Lbs. 30d Nails.		
200	Lbs. 20d Nails.		
25	Lbs. 10d Nails.		
4	¾-inch x 24-inch Mch. Bolts with Washers.		
2	⅞-inch x 11-foot D. E. Bolts with Washers.		
	Extra or Wind Girts and Braces		
6	Outside Girts	2 x 12	22
4	Outside Girts	2 x 12	20
4	Outside Girts	2 x 12	18
4	Outside Girts	2 x 12	14
8	Outside Braces	2 x 8	28
8	Outside Braces	2 x 8	24
16	Outside Braces	2 x 8	22
8	Outside Braces	2 x 8	20

For deep rotary drilling, derricks 106 to 130 feet in height are used, thus providing space for handling "stands," so-called, of drill pipe consisting of four or five joints instead of three. This enables the driller to run in and pull out the drill pipe and drill the hole in much less time.

SPECIFICATION OF MATERIAL REQUIRED TO BUILD A CALIFORNIA ROTARY RIG—106 FT. DERRICK WITH 24-FOOT BASE.

Pieces		Size, Inches	Length, Feet
2	Engine Mud Sills	16 x 16	16
2	Engine Pony Sills	14 x 14	12
1	Engine Block	24 x 24	14
2	Side Sills	12 x 12	26
8	Derrick Sills	10 x 12	24
2	Casing Sills	14 x 14	24
5	Corner Sills and Blocking	12 x 12	20
2	Bumpers and Gin Poles	12 x 12	14
2	Blocking	8 x 10	20
2	Dead Men	6 x 6	20
6	Pump Foundation	6 x 6	18
3	Outside Drill Pipe and Crown Railing	4 x 4	14
20	Derrick Foundation	3 x 12	18
52	Girts, Derrick and Pump House Floor and Doublers	2 x 12	24
4	Girts	2 x 12	22
4	Girts	2 x 12	20
16	Girts and Outside Drill Pipe Platform	2 x 12	18
40	Doublers, Girts and Top	2 x 12	16
8	Outside Drill Pipe Platform and Top	2 x 12	14
4	Starting Legs	2 x 10	26
4	Short Starting Legs	2 x 10	18
42	Derrick Legs	2 x 10	16
4	Outside Drill Pipe Platform	2 x 8	16
8	Braces	2 x 6	24
16	Braces	2 x 6	22
8	Braces	2 x 6	20
20	Braces and Outside Drill Pipe Platform	2 x 6	18
2	Crown Railing	2 x 6	16
34	Ladder, and to cut up	2 x 4	16
20	Girts	1½ x 12	16
8	Braces	1½ x 6	16
16	Braces	1½ x 6	14
16	Braces	1½ x 6	12
40	Ladder Strips, etc	1 x 6	16
50	Boards	1 x 12	16
1	Steel Crown Block with 5 Pulleys.		
100	Pounds 30d Nails.		
250	Pounds 20d Nails.		
25	Pounds 10d Nails.		
4	¾-inch x 24-inch Mch. Bolts with Washers.		
2	⅞-inch x 11-foot D. E. Bolts with Washers.		
	Add for reinforcing corners:		
4		6 x 6	12
24		6 x 6	16
	Add for outside or wind braces:		
4	Outside Girts	2 x 12	24
8	Outside Girts	2 x 12	22
4	Outside Girts	2 x 12	18
4	Outside Girts	2 x 12	14
8	Outside Braces	2 x 8	28
8	Outside Braces	2 x 8	24
16	Outside Braces	2 x 8	22
8	Outside Braces	2 x 8	20
8	Outside Braces	2 x 8	16

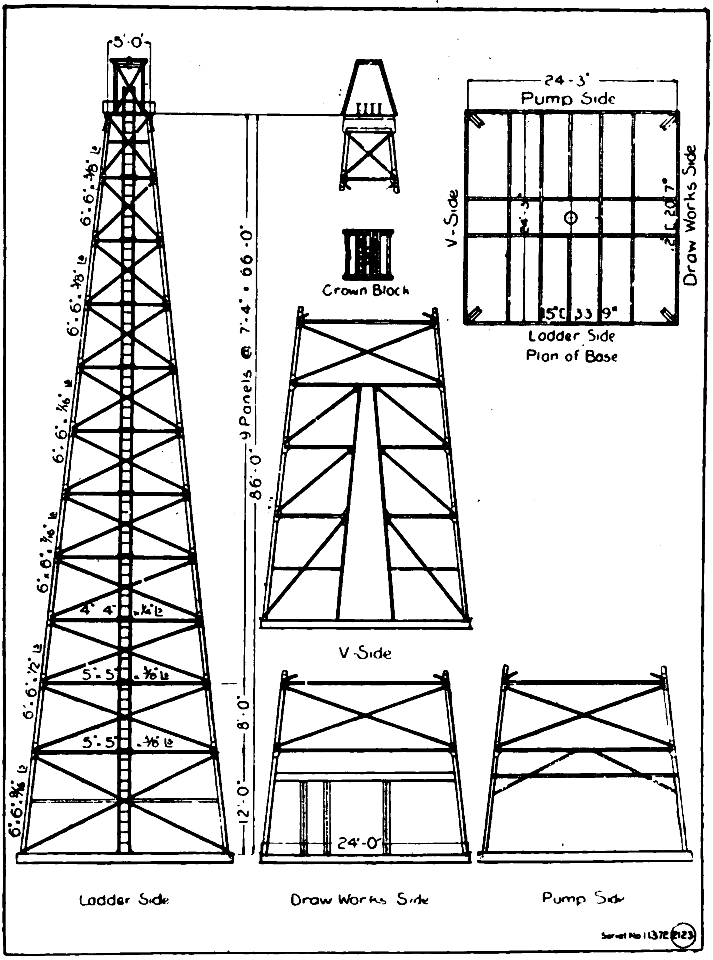


Fig. 122. Diagram of Carnegie 86-Foot Structural Steel Rotary Derrick. The Carnegie Steel Co. makes this derrick in five sizes, 59 feet, 72 feet, 80 feet, 86 feet and 106 feet in height.

Refer to pages 375-377 for safe working loads for derricks.

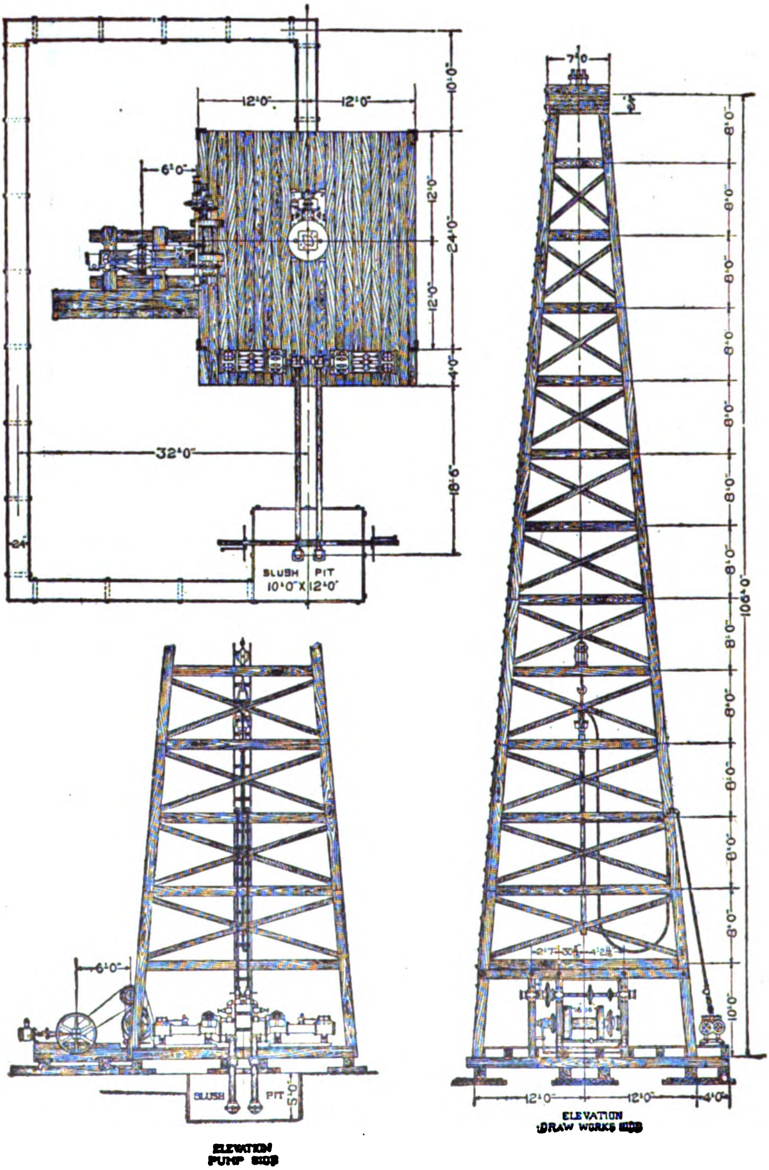


Fig 123. Side elevation and ground plan of 106-foot Texas rotary drilling rig, showing machinery installed ready for drilling.

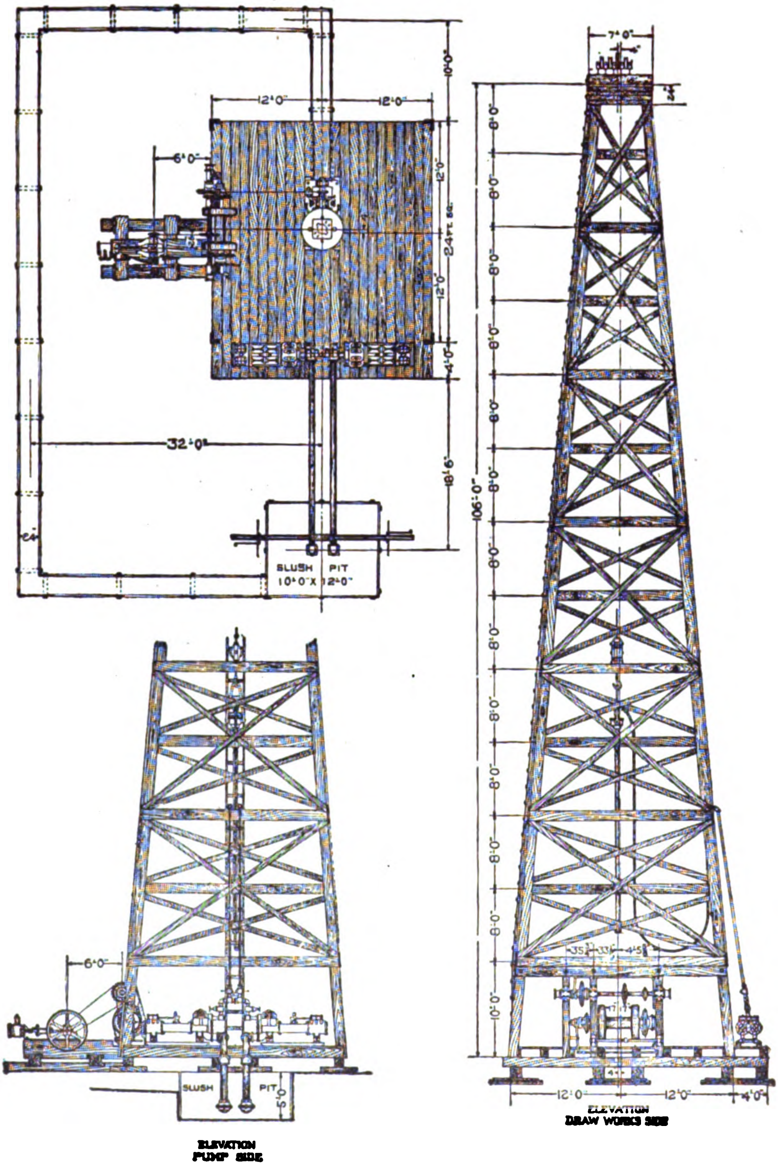


Fig. 124. Side elevation and ground plan of 106-foot California rotary drilling rig with extra wind braces, showing machinery installed ready for drilling.

RIG

The rig for rotary drilling consists of a derrick and the necessary rotary machinery, no bull wheels and walking beam being required. The sand reel is not used for there is no means of operating it. The sand line is spooled on the draw works drum, sometimes being wound over the casing or drilling line. A steel crown block is usually used.

Erecting the derrick, refer to Fig. 121.

If the ground where the derrick is to be built is not level the pump side should face toward the downward slope to secure the advantage of the drainage for the slush trench, see Fig. 156.

The derrick corners, consisting of two courses of 2 x 12-inch boards, eight feet in length, are first laid. Half way between each corner four pieces of 2 x 12-inch boards three feet in length are spaced one foot apart. The corner sills D, and the short side sills are placed on these 2 x 12-inch footings. Next the casing sills and derrick side sills are put in place. The engine mud sills are set so the ends will abut against the side sill, the engine pony sills are placed on the mud sills, and the engine block mounted on them. The engine block and sills are framed and keyed as shown in Fig. 149.

In placing the side sills a margin of two and one quarter inches should be left between the end of one sill and the sill on which it rests at each corner to provide a shoulder or base for the end of the leg timbers.

Description of the erection of a standard derrick on page 47 will answer also for the rotary derrick. The derrick floor sills are next placed and the derrick floor and engine walk are laid.

Some rotary derricks are built with the floor extended four feet, so the pumps can be installed outside the derrick. When this is done, the two derrick side sills should be four feet longer, see Fig. 123.

One or more platforms must be provided in the upper part of the derrick on which the man who handles the elevators, when pulling out or running in drill pipe, may stand. The 112-foot derrick usually has two platforms, consisting of three 2-inch planks extending across the derrick on the side opposite the

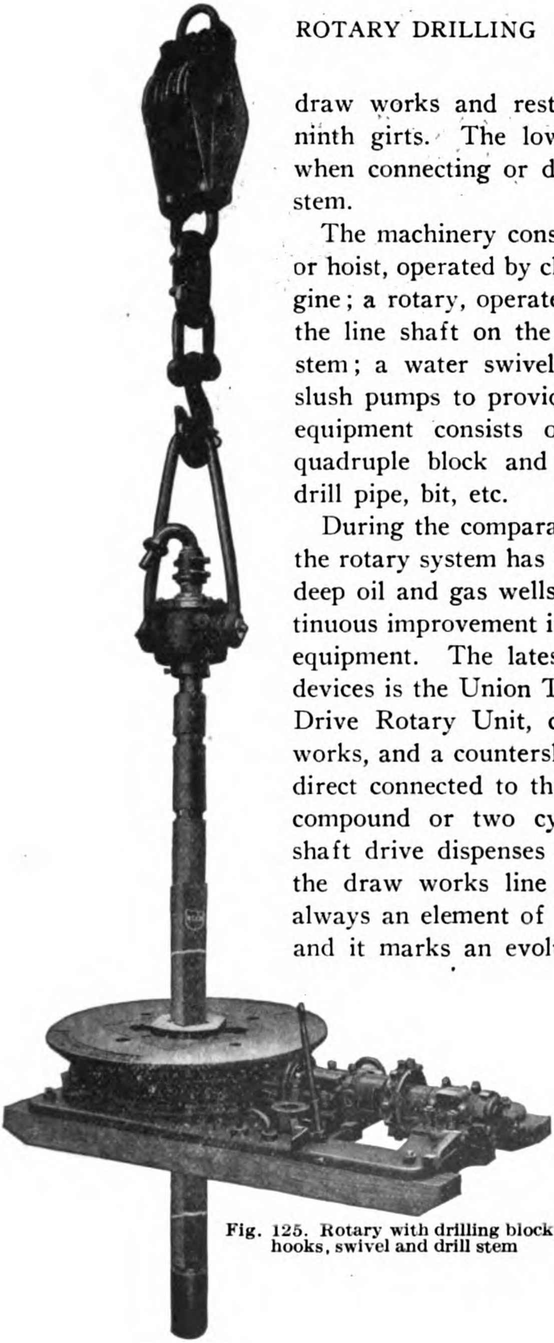


Fig. 125. Rotary with drilling block, hooks, swivel and drill stem

draw works and resting on the fifth and ninth girts. The lower platform is used when connecting or disconnecting the drill stem.

The machinery consists of a draw works or hoist, operated by chain belt from the engine; a rotary, operated by chain belt from the line shaft on the draw works; a drill stem; a water swivel with hose, and two slush pumps to provide circulation. Other equipment consists of drilling line with quadruple block and strapped "C" hook, drill pipe, bit, etc.

During the comparatively few years that the rotary system has been used for drilling deep oil and gas wells, there has been continuous improvement in the character of the equipment. The latest of these improved devices is the Union Tool Company's Shaft Drive Rotary Unit, consisting of a draw works, and a countershaft with bevel gears, direct connected to the rotary, driven by a compound or two cylinder engine. The shaft drive dispenses with the chain from the draw works line shaft to the rotary, always an element of danger to the driller, and it marks an evolution in well drilling machinery, see Fig. 127.

RIGGING UP

After the derrick has been erected and the steel crown block with four, five or six casing

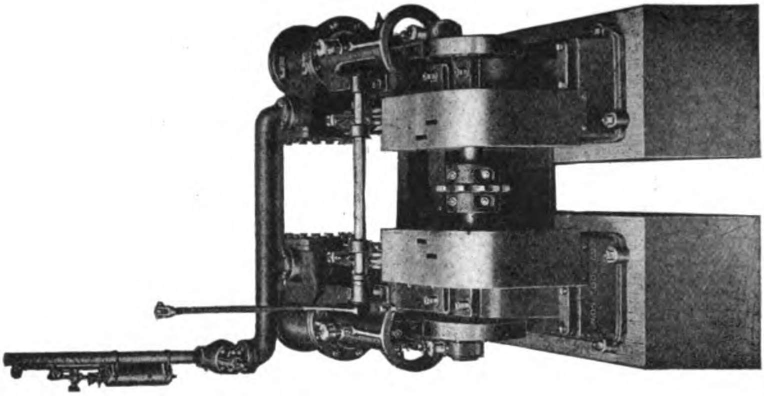


Fig. 126. Compound Engine for rotary drilling.

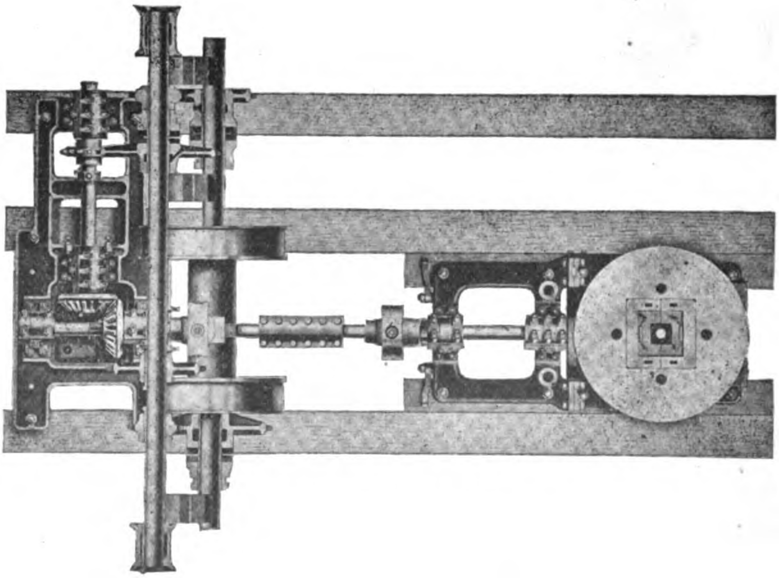


Fig. 127. Shaft driven rotary outfit.

pulleys (according to depth of well and quantity of drill pipe or casing to be handled) has been put in place,—the crown block may be taken apart and the several I beams and pulleys that compose it carried to the top of the derrick, one piece at a time, and there re-assembled—the upright timbers that carry the draw works are fitted to the derrick sills and girt, and the draw works and line shaft are mounted on them. The rotary is then placed in the exact center of the derrick floor, a portion of which is cut away so the rotary skids rest on the floor sills. The engine is set close to the derrick in such a manner that the sprocket wheel on the end of the shaft (corresponding to the belt pulley) will be in alignment with the drive sprocket on the draw works line or drive shaft. These two sprockets are then connected with forty feet of steel sprocket chain. Next the drive shaft sprockets are belted to the high and low speed sprockets on the drum shaft by means of two steel sprocket chains, and to the clutch sprocket on the rotary with another steel chain.

The two slush pumps are then set on one side of the derrick, at a right angle to the draw works (see Fig. 123) and the discharge end of each pump is connected to the manifold. The two stand pipes are next set up in the derrick and screwed into flange unions in the manifold. A thirty-foot length of wire wound rubber hose is connected by means of a special hose nozzle or coupling to each stand pipe. With the latest improved water swivels, some rotary drillers are now using but one swivel, instead of two, requiring only a single stand pipe from the manifold. A suction pipe is connected to each pump, and a foot valve with strainer is fitted to each suction pipe. The suction pipes should be long enough to extend out into the sump, or slush pit, containing the mud fluid supply.

Two five hundred-pound gauges should be connected to the manifold, one for each slush pump, to register the pump pressures, for should the circulation be obstructed, the pressure would quickly rise to a point where something might give way. One 2-Qt. Sight Feed lubricator should be connected to upright steam line leading from the boiler to horizontal line over pumps. Sometimes two boilers are used with rotary outfits, one to run the engine, the other to supply steam for the slush pumps, the

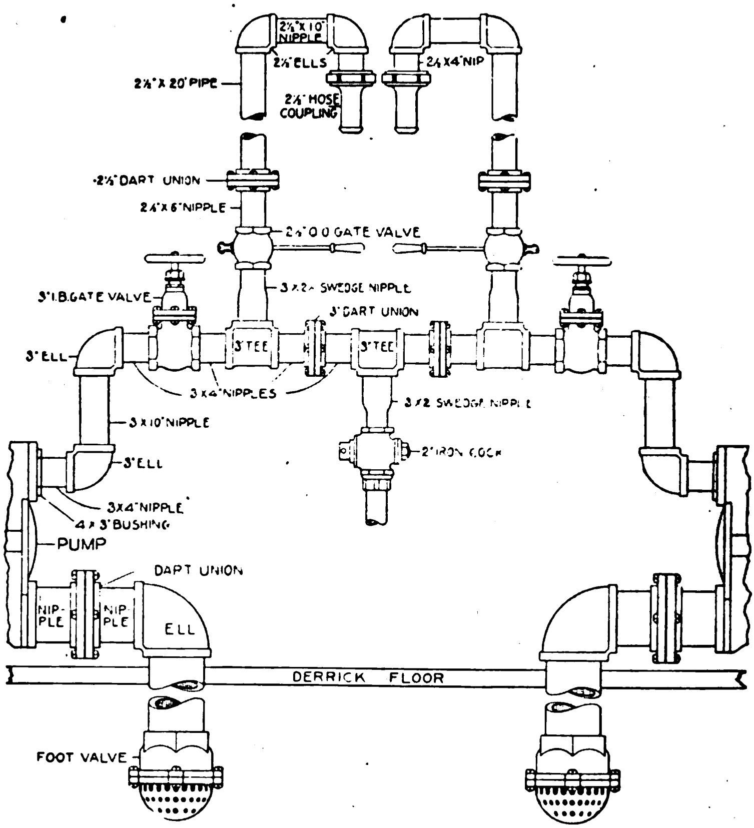


Fig. 128. Diagram of manifold and suction connections of slush pumps.

water supply pump and the lighting generator. To insure a constant water supply for the boilers and for drilling purposes, a boiler feed steam pump should be included with every rotary outfit.

The boiler is set up about 100 feet from and usually on the side of the derrick opposite the engine and if oil or gas fuel is used, the fuel supply connections are made. Water and steam conections are then made between the boiler, engine, pumps and turbine generator. The derrick is then wired for electric lights. The lighting consists of a series of lamps strung around the first girt to light the derrick floor, lamps above the platforms for the man in the derrick at the fifth and ninth girts, lamps on the crown block and, if needed, a lamp at the boiler. The engine

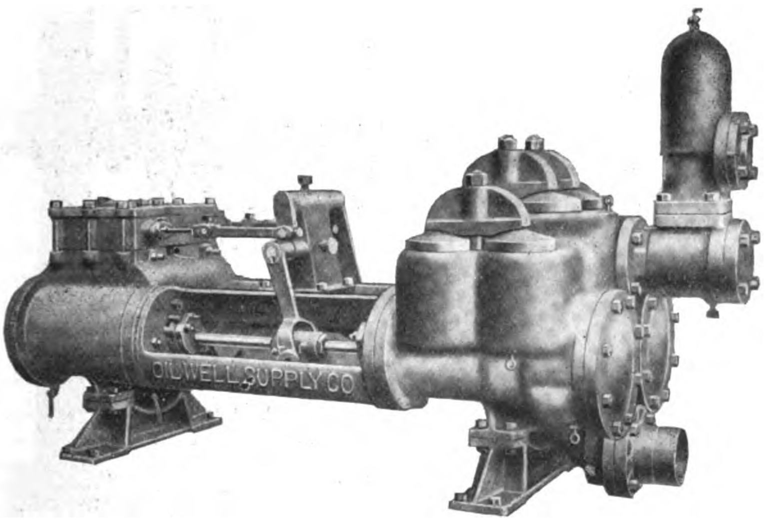


Fig. 129. Slush Pump.

reverse lever and the throttle telegraph wheel are mounted in the derrick at places convenient to the driller's reach.

A sump or slush pit with adjoining settling pit for the mud mixture with connecting trenches from the drill hole are dug and diked up, refer to Fig. 156.

The drilling crew consists of five men for each of the two tours or shifts; the driller, the tool dresser and fireman, the man who works up in the derrick and two men for general work, such as helping on the derrick floor, mixing the mud, repairing, etc.

The drilling line is spooled on the drum shaft and reeved through the four sheave traveling block and over the casing pulleys. The usual practice in stringing the drilling line is to place the block on the derrick floor and loop the line around each of the sheaves, allowing the loop from each sheave to extend from the block about 10 feet from the becket, or upper end.

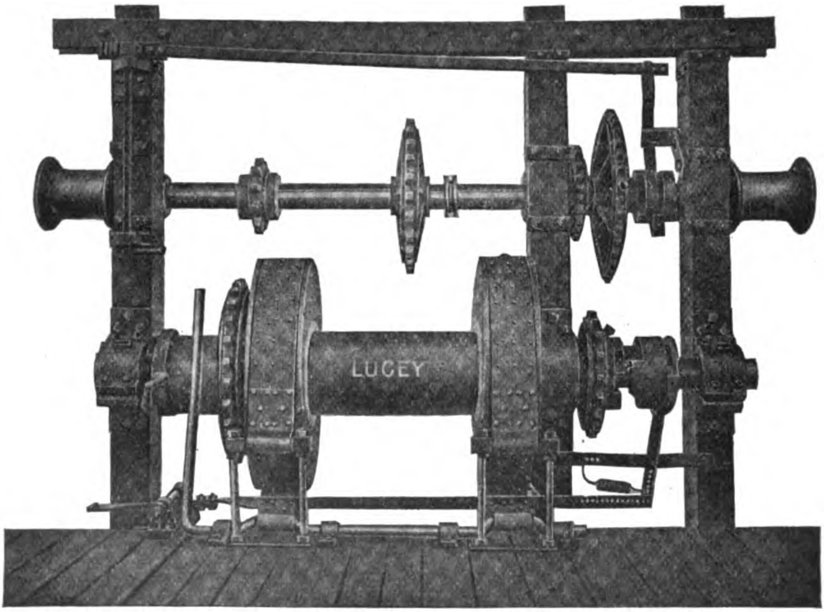


Fig. 130. Double brake, two-speed draw works.

The block is then fastened to the cat line and carried up through the derrick into working position. The pulleys are removed from the crown block, and one loop of the drilling line at a time is passed between the beams of the crown block and over the pulleys, which are then replaced in the crown block. A strapped "C" hook is engaged in the shackle of the block and the bail of the swivel. Next the swivel is screwed to the upper sub of the drill stem; a sub is screwed to the lower end of the drill stem, and a drilling bit, conforming to the size of the hole it is desired to drill, is screwed into the sub. One of the lengths of hose from the manifold is connected to the swivel and the outfit is then hoisted in the derrick and is let down through the opening in the rotary table. The rotary driver is fitted around the stem or the gripping rings are adjusted to it, depending upon the type of rotary used, and the outfit is ready to commence drilling. Next a quantity of clay and water is mixed in the slush pit to the consistency of a thin mortar to provide mud-laden fluid for drilling. (For more detailed information regarding mud fluid refer to pages 236-248.)

The engine is started; the clutch on the drive shaft is engaged, and the rotary table turns, rotating the stem and bit. The slush pump is then started; the gate valve in the manifold is opened and the stream of mud flows through the drill stem. When the drill stem has drilled its length, the rotary is stopped, the hoisting drum clutch is engaged and the stem is hoisted through the rotary table opening, and, if a flat top rotary is used, the driving device is pulled up, as the stem comes out, and removed. Next the bit is unscrewed from the stem and a drill collar is connected to the bit. The block and "C" hook are removed from the swivel and engaged in the links of the elevators, with which a length of drill pipe is hoisted and set in between the sub on the stem and the drill collar on the bit. The outfit is again lowered through the opening in the rotary table and drilling is resumed. As drilling proceeds and hole is made to the extent of the length of the drill stem, the operation of pulling out and adding a joint of drill pipe is repeated. A set of slips that grip and support the pipe left in the hole is fitted in the opening in the rotary table, the rotary and slips serving the same purpose as the spider and slips used in cable drilling. Drilling tool taper joints are often used to connect each third or fourth length of drill pipe to prevent the wearing or loosening of the pipe threads and to avoid the difficulty occasioned by freezing of the pipe threads. The Hughes Tool Joint, Fig. 131, is a recent improvement over the ordinary tool joint, for the threads are flattened, thus minimizing the danger of freezing or "hooking."

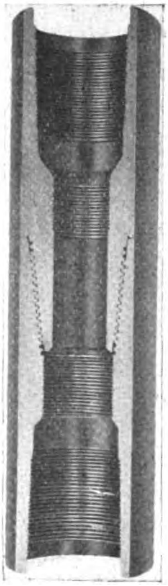


Fig. 131. Hughes Tool Joint

The accompanying illustration of the interior of a derrick shows the operation of "breaking out," or unscrewing, the joints of 6-inch drill pipe, using special breaking out tongs for the purpose.

Tool joints are used with the taper pin on the bottom of the joint of drill pipe and the box on the top, thus conforming to the thread and coupling ends of the pipe.

When unscrewing, or "breaking," the joints of drill pipe a special breaking out tongs, Fig 132½, is used for the upper tongs. It is suspended from a wire rope in the derrick and counterbalanced, and, by means of a clevis in the end of the handle, it is shackled with a piece of stout wire rope, to the corner of the derrick. An ordinary chain tongs, whose handle engages with the breaking out post protruding from the rotary table, is used for the lower tongs. Thus, with one wrench anchored by its rope to the derrick corner and the other turned by the movement of

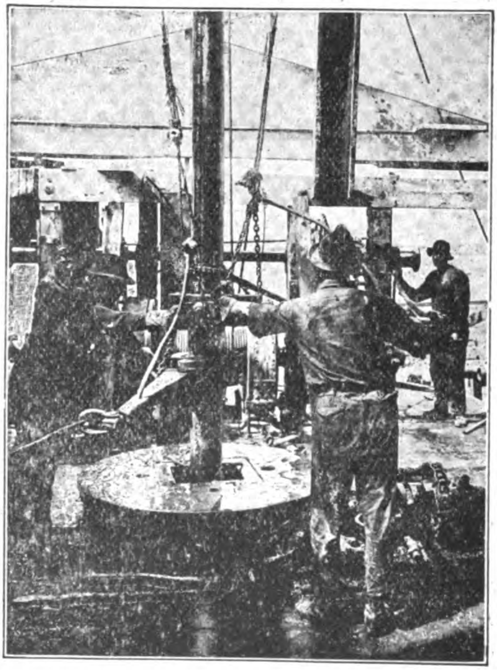


Fig. 132.

the rotary a powerful force for breaking the joints, which have been made exceedingly tight by the rotation of the pipe in drilling, is secured.

When a rotary with driver and slips is used one set of ele-

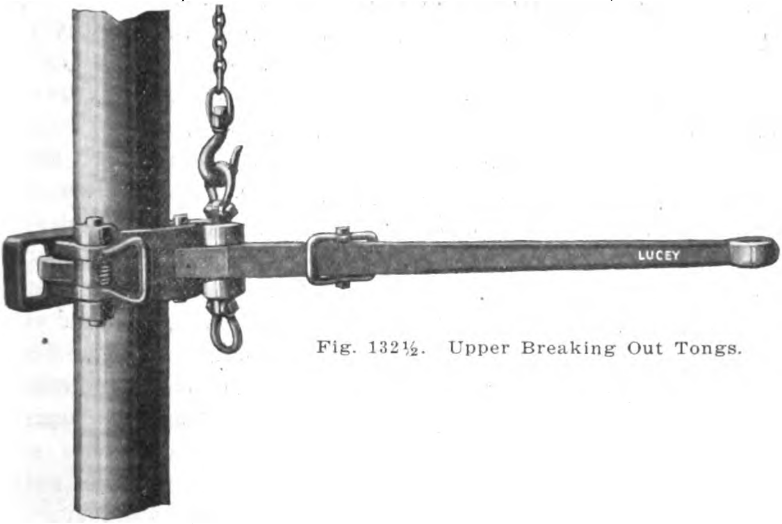


Fig. 132½. Upper Breaking Out Tongs.

vators, the set used up in the derrick only, is required. When the rotary equipped with gripping rings is used, the lower set of elevators is needed to hold the pipe and the elevators are supported on the slide tongs, Fig. 133.

Fig. 133. Slide Tongs.

The engine and rotary are not used in setting up rotary pipe or tool joints, for the reason that the twisting of the pipe during drilling tends to tighten them.

The breaking out process is not employed for unscrewing the rotary bit. It is started by striking it a few blows with a sledge; then it is unscrewed by means of chain tongs pulled by a Manila rope from the cat head.

BREAKING JOINTS OF DRILL PIPE

For quickly breaking joints of drill pipe and to prevent injury to the threads, drillers sometimes bring the dead end of the drilling line, after it has been reeved over the pulleys in the crown block and the three sheaves in the traveling block, down to a corner of the derrick and make it fast around a sill. To the dead line at a point about twenty feet above the derrick floor, a short piece of rope is attached with a counter-weight at the derrick end sufficiently heavy to balance the weight of the one or more joints of drill pipe that are unscrewed. Thus the weight lifts the pipe out of the coupling the moment the last thread is unscrewed and prevents the threads from riding around in the top of the coupling. The Wigle Spring Casing Hook has recently come into use for this purpose, the spring performing the function of the counter-weight.

When drilling gumbo or soft material, the rotary bit does not readily become dulled and it may drill for twelve hours or more, but in drilling harder shales and sandstones, the bit must be changed frequently. When the drill pipe is withdrawn, it is unscrewed at the tool joints and the "stands," each consisting of three or more lengths of pipe, are stood on the pump side of the derrick. As the pipe comes from the hole a stream of clear water should be played on it to wash off mud and cuttings.

When it is desired to verify a suspected strike of oil or gas, it is necessary to set the casing, bail out the mud filled hole and perhaps wash it out with clear water.* For bailing, the sand line is wound on the draw works drum and carried over the sand line pulley. The hole may be bailed out with a long bailer, usually 40 feet in length, in the ordinary way, or the fluid may more quickly be removed by plugging the hole in the bit and running in the string of drill pipe, thus, by displacement, expell-

* For description of method of washing the hole and the oil sand in wells drilled by the rotary system, refer to page 352.

ing most of the fluid from the hole. The fluid then remaining in the hole, however, must be bailed out.

Washing the sand is accomplished by circulating clear water with the slush pump, refer to page 352.

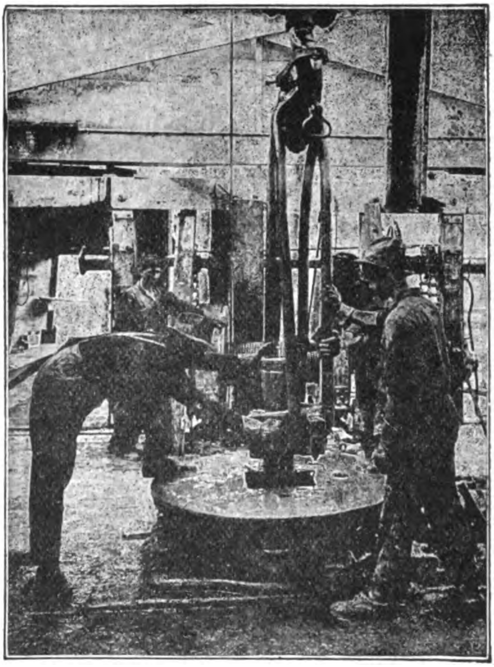


Fig. 134. Putting on elevators to pull drill pipe

It sometimes happens in the course of rotary drilling that the driller "loses his mud." This may occur in drilling through a cavern or porous formation into which the mud escapes. About all the driller can do in this case is to increase his supply of mud, work it to a thicker consistency, and pump it into the hole until the aperture is filled, or the formation is cemented and sealed.

When a boulder is encountered drillers usually continue rotating the pipe until the boulder has been dislodged. If the boulder is too large to be removed, it may be drilled through with adamantine or with a Hughes bit. Adamantine is a hard, abrasive substance, which, dropped in the hole around the bit, assists it in cutting hard rock.

Sometimes during drilling in clayey or sticky strata, the bit becomes clogged or mudded. If this should happen, raising and lowering the column of drill pipe a few times should clear it. The drillers call this operation "spudding."

When drilling in soft or caving strata and it becomes necessary for any reason to stop drilling, it is a good plan to raise and lower, or spud the column of drill pipe occasionally to prevent its freezing. Should it be necessary to make repairs to or shut down the draw works, so that pipe cannot be spudded, circulation of the fluid should be maintained.

Usually the draw works or hoist is equipped with two speeds; the high speed is used for handling a short column of drill pipe and for more quickly hoisting the block and elevators when putting in pipe, the low speed for handling long strings of pipe. putting in casing, etc. For more speedily handling short strings of pipe only two sheaves of the block are employed, and as the hole deepens and the string of pipe grows heavier, the third and, next, if a quadruple block is used, the fourth sheave is brought into play. The strapped C hook is used at all times, but the casing hook is only used for putting in and pulling out drill pipe, and is dispensed with for drilling.

Fig. 135. Fishtail Bit.

For drilling the soft alluvial formations, the ordinary rotary or "fishtail" bit is used. When, as often happens, a thin shell of harder formation is encountered, it may be penetrated by dropping in the hole a little adamantine, which, ground into the rock by the rotating bit, assists in cutting it.

For drilling alternating soft formations and hard shale or sandstone, the Hughes rotary rock drill bits are recommended. These bits will cut limestone, although it clogs the cutters; but where thick strata of limestone occur, interbedded with softer formations, the combination rotary and cable tool outfit is more suitable.

The Hughes reaming cone bit, Fig. 136, is recommended by the manufacturer for drilling hard rock. It is stated that it will drill from 12 inches to 25 feet per hour, depending on the character of the rock, and one set of cones will make from 5 to 200 feet of hole. The results obtained

Fig. 136.
Hughes Cone Bit.

from this tool will depend upon the skill of the driller for, to attain the best performance, it should be run at a speed and with a pressure suited to the formation being drilled. (See table of limits of weight bits should carry.)

Hughes bit cones have a tendency to wear so they may soon become off gauge and it is to keep the hole out to full size that the upper reaming cone is provided. These bits are equipped with a lubricating attachment for feeding oil to the cones as an aid to drilling.

Sectional cut, Fig. 137, shows the convex seat cut by the bit, thus guiding it and keeping the hole straight.

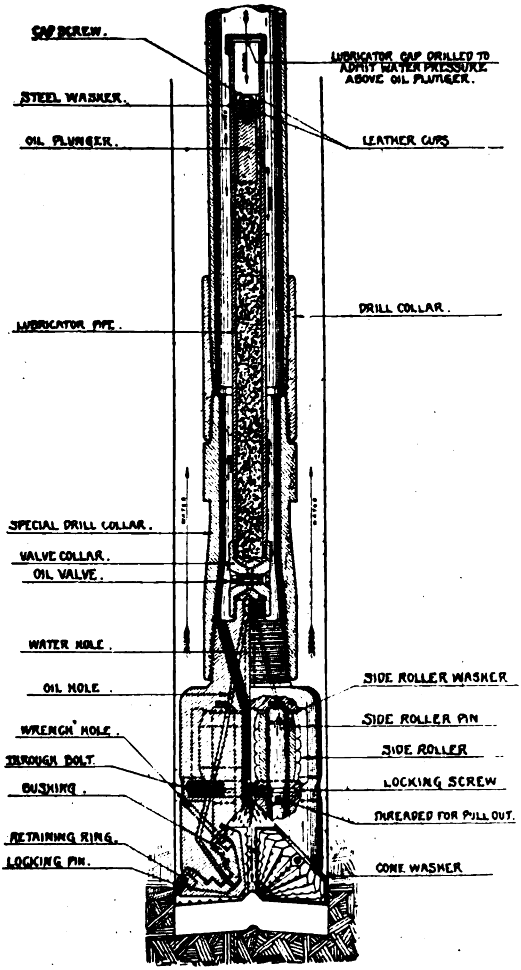


Fig. 137. Showing Operation.

DRILLING WEIGHTS RECOMMENDED FOR HUGHES BITS. EXPERIENCE HAS PROVEN THAT THE FOLLOWING WEIGHTS GIVE GOOD DRILLING RESULTS ON VARIOUS SIZED BITS:

Size Bit, Inches	Wt. on Bit, Pounds	Size Bit, Inches	Wt. on Bit, Pounds
2⅜	2.870	7⅛	8.650
2⅞	3.480	7⅝	9.270
3⅞	4.700	7⅞	9.560
4⅜	5.910	8½	10.300
5½	6.670	9	11.000
5⅞	7.140	9⅞	12.000
6½	7.900		

USE LESS WEIGHT AND MORE SPEED FOR EXTREMELY HARD FORMATIONS

This table is based upon full limit of weight. Caution is advised in exceeding weights given in above table.

The Fair's or the side gate types of elevators are quite generally used for rotary drilling, for the reason that the pulling and running in of drill pipe consumes much time, and elevators must be put on, taken off or adjusted as rapidly as possible.

Fig. 138. Rex Side Gate Elevators with long links for rotary drilling.

The man up in the derrick can quickly put on or take off Fair's or side gate elevators, but the other types have to be adjusted to the pipe, which requires more time.

There are several improved side gate elevators now on the market, such as the Lucey Company's Rex Elevator, which can be quickly opened or closed.

Wells drilled with a rotary are sometimes drilled into an oil producing formation without warning. It is best to be prepared, therefore, and an extra heavy gate valve, several nipples and a tee with plugs to fit the casing used should be kept on hand ready for use in the event of a sudden flow of oil or gas.

FISHING

Lost Bit.—

The usual practice in rotary drilling when a bit is lost is simply to drill past it and make no effort to recover it. Perhaps the simplest method to recover a lost bit would be by means of the recently invented electric magnet.

Fig. 139. Wash-down Spear.

Lost or Parted Drill Pipe.—

Pipe left in the hole can usually be fished out with a washdown spear, which is run on a string of drill pipe. This spear is equipped with a bit for cutting mud or cavings that have lodged above and in the pipe. When drill pipe has parted at the tool joint, a steel tap with a taper thread to engage in the box of the joint is run on drill pipe to recover it.

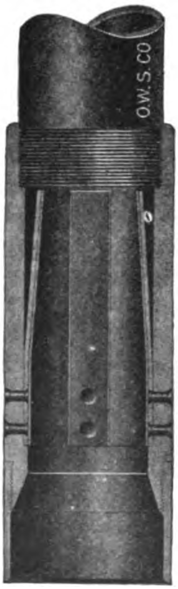


Fig. 140. Overshot.

Lost or Parted Casing.—

Either a washdown spear, as above described, or an overshot is used. The overshot is a device that goes over the lost casing or drill pipe and it is fitted with spring latches to engage under the coupling of the pipe. If the drill pipe or the casing cannot be recovered with a spear or overshot, drillers usually force it over into the wall of the hole and drill past it or, as they say, "sidetrack it."

Frozen Casing or Drill Pipe.—

Frozen pipe is released by rotating a column of pipe of large enough diameter to go down over the couplings of the frozen pipe. To the bottom of this pipe is attached a rotary cutting shoe, Fig. 141.

When the pipe has been released, both strings are pulled together. Circulation must be kept up during this process.

Fig. 141. Rotary Shoe.

Cones Dropped from a Hughes Bit.—

Either a basket cage or an electric magnet fishing tool should pick them up.

Cutting the Casing.—

A string of drill pipe or tubing, to the bottom of which is attached a rotary casing cutter, is rotated until the casing is cut off. A mandrel with jars, Fig. 143, is lowered on a sand line to expand the cutting wheels.

Most rotary fishing tools are used with a column of drill pipe and circulation is maintained to prevent the hole from caving.

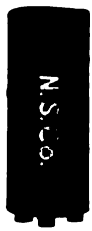


Fig. 142. Rotary Casing Cutter.

Cementing the Casing.—

Owing to the fact that casing set in soft formations may not hold, or that gas or oil might break out around it, it is customary to cement the casing in wells drilled with a rotary. See instructions for cementing processes, pages 301-315.

Fig. 143. Mandrel for Rotary Casing Cutter.

MISCELLANEOUS INFORMATION REGARDING ROTARY DRILLING.

In formations where the rotary can be used, a well may usually be drilled in much less time than by the cable process. Also as the circulation of mud fluid seals up the wall of the hole, shutting off water and caving strata, fewer strings of casing are required.

Sometimes when drilling for oil a stratum carrying a large volume of gas at high pressure may be penetrated, causing a blow out. This may usually be overcome by increasing the speed of the two pumps and putting up their pressure sufficiently to mud off the gas. A blow out preventer (Fig. 144) is sometimes used for this purpose.

The driller should keep a careful tally of the measurements of each length of drill pipe as it is added into the string, making due allowance for the length of the thread that is screwed into the coupling. This will enable him to know at all times the

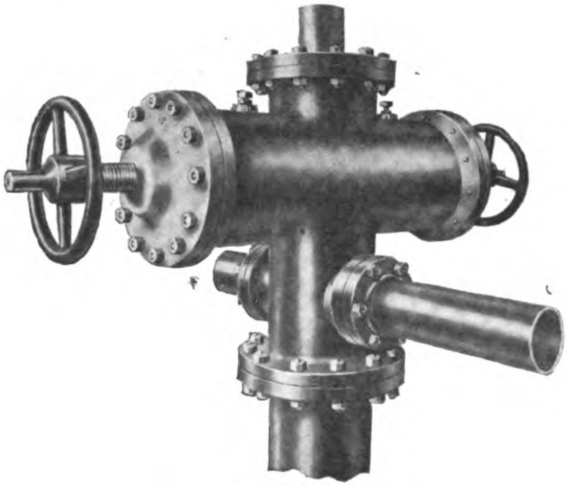


Fig. 144. Blowout Preventer.

accurate depth of his hole and also to preserve a correct log of the well.

The man up in the derrick should be protected from falling by means of a rope tied round his body or with a belt buckled about his waist and attached to a ring or snap running on the rope to give him more freedom of movement. The two ends of the rope are tied round the derrick girts.

Some rotary drillers drill a shallow well at a point midway and in front of the slush pumps, in which they rest the drill stem when not in use or when waiting to set in another joint of drill pipe. This is termed the "rat hole."

PIPE FOR ROTARY DRILLING.

(*From National Tube Co. Bulletins.*)

MATERIAL

Lap-welded Pipe is made of good quality soft weldable steel rolled from solid ingots. **Seamless** Pipe is made of mild basic open hearth steel of special analysis to meet the requirements.

PHYSICAL PROPERTIES

The physical properties of the steel used in the manufacture of this class of goods will average:

Tensile Strength: 50,000 to 60,000 lbs. per sq. in.
Elastic Limit: Not less than ½ tensile strength.
Elongation: 20 to 28% in 8 inches.
Reduction in Area: Not less than 50%.

When greater strength is desired, seamless Drill Pipe will be made to special order from basic open hearth .30-.40 carbon steel; physical properties of this material will average:

Tensile Strength: 60,000 to 70,000 lbs. per sq. in.
Elastic Limit: 40,000 to 50,000 lbs. per sq. in.
Elongation: 15 to 20% in 8 inches.
Reduction in Area: 45 to 55%.

BENDING TESTS ON "NATIONAL" WELDED PIPE.

Sections cut from the ends of each length of pipe are flattened in the direction of the diameter, to one-third (⅓) of the outside diameter—the weld being placed at 45 degrees from the point of maximum bend. If any of the sections tested show bad weldings, laminations, brittleness or any unsoundness another test piece is cut from the same end; should the second test also prove defective, the pipe is rejected.

PIPE FOR ROTARY DRILLING

INTERNAL PRESSURE TEST

Each piece of pipe, welded and seamless, is subjected to the hydraulic pressure specified for that size, as set forth in tables for Drill Pipe.

STRENGTH OF JOINT

(a) Pulling Tests on Pipe for Drilling Purposes.

In order to determine the strength of the joint for this class of goods, National Tube Company made pulling tests on a number of the different sizes, the results of which are given in Table A.

It will be noted that the loads given in this table are the actual average loads at the failure of the joint, and the averages are based on six tests in each case. From these tests an idea can be obtained of the additional strength gained by upsetting the pipe at the joint.

(b) Torsional Tests on Pipe for Drilling Purposes.

The advantage of the upset in "National" Special Upset Rotary Pipe is plainly evident from torsional tests on 4" 12½ lb. "National" Special Rotary Pipe. In each test two lengths of pipe were coupled together using various "National" Special Rotary Pipe joints, one end being held stationary while the other was rotated until failure occurred.

The value of the upset in strengthening the line against torsional strains is shown by the fact that an average of 197,000 inch-pounds was necessary to cause failure when pipe was upset at the joint, while an average of 145,000 inch-pounds caused failure with the *same joint* when the material was not upset. Moreover, with the "National" Upset Rotary Pipe the line did not fail at the joint itself, showing this to be the strongest part of the line. (See Table B.)

TABLE A

ROTARY DRILL PIPE

LENGTH OF LINE EQUIVALENT TO LOAD AT FAILURE, BASED ON ACTUAL PULLING TESTS

"NATIONAL" ROTARY DRILL PIPE

Size	Weight Per Foot Complete	Approximate Average Load at Failure, in Tons	Length of Line Equivalent to Average Load at Failure, in Feet
6	19.507	89	9125
4	12.50	56	8960
4	15.00	78	10400
4½	15.50	74	9548
4½	18.00	67	7444
5	17.50	58	6629
6	23.50	91	7745
6	29.00	118	8138

"NATIONAL" SPECIAL UPSET ROTARY PIPE

4	12.632	99	15674
6	19.551	129	13196

TABLE B

TORSIONAL TESTS ON 4"-12½ LB. "NATIONAL" SPECIAL ROTARY AND SPECIAL UPSET ROTARY PIPE

Material	Joint	Average Twisting Moment at Failure Inch-Pounds	Location of Failure
Lap-welded steel pipe	7⅝"* coupling, pipe *not upset*	145300	At joint in two tests out of three; in third test pipe twisted
Lap-welded steel pipe	7⅝" coupling, pipe *upset*	197200	No failure at joint in five tests

* This long coupling is used in practice only on Special Upset Rotary but was applied to Special Rotary Pipe, not upset, for the purpose of this test. The comparison between the Standard Drill Pipe Joint and Special Upset Rotary is even more marked.

PIPE FOR ROTARY DRILLING

ROTARY DRILL PIPE

(National Tube Co.)

Size	Diameters		Thickness	Weight Per Foot	Threads Per Inch	Couplings			Test Pressure, Pounds
	External	Internal				O. D.	Length	Weight	
2½	2.875	2.323	.276	7.830	8	3.603	5⅛	5.888	2000
2½	2.875	2.143	.366	10.000	8	3.693	5⅝	7.316	2500
3	3.500	2.764	.368	12.500	8	4.248	6⅛	8.777	2000
4	4.500	4.026	.237	11.157	8	5.303	6⅛	11.768	1500
4	4.500	3.990	.255	11.916	8	5.303	6⅛	11.768	1500
4	4.500	3.962	.269	12.500	8	5.303	6⅛	11.768	1800
4	4.500	3.826	.337	15.000	8	5.303	6⅛	11.768	2000
4½	5.000	4.506	.247	12.933	8	5.803	6⅛	12.988	1500
4½	5.000	4.396	.302	15.500	8	5.803	6⅛	12.988	1600
4½	5.000	4.290	.355	18.000	8	5.803	6⅛	12.988	1800
5	5.563	5.047	.258	15.094	8	6.334	7⅛	16.562	1500
5	5.563	4.955	.304	17.500	8	6.334	7⅛	16.562	1600
5	5.563	4.813	.375	21.000	8	6.334	7⅛	16.562	1800
6	6.625	6.065	.280	19.507	8	7.396	7⅛	19.561	1500
6	6.625	5.939	.343	23.500	8	7.396	7⅛	19.561	1500
6	6.625	5.761	.432	29.000	8	7.396	7⅛	19.561	1800

SPECIAL UPSET ROTARY PIPE

(National Tube Co.)
8 Threads per Inch.

Size	Diameters		Thickness	Weight Per Foot	Upset		Couplings			Test Pressure in Lbs.
	External	Internal			Length	Inside Diameter	Diameter	Length	Weight	
2½	2.875	2.323	.276	7.841	3¼	1$\frac{15}{16}$	3.564	6⅛	6.743	2000
2½	2.875	2.143	.366	10.000	3¼	1¾	3.678	6⅛	7.844	2500
3	3.500	2.900	.300	10.486	3¼	2½	4.248	6⅛	8.777	2000
4	4.500	3.958	.271	12.632	4	3½	5.256	7⅝	14.296	1800
4	4.500	3.826	.337	15.323	4	3⅜	5.256	7⅝	14.296	2000
5	5.563	4.975	.294	17.000	4¼	4½	6.303	8⅛	18.472	1600
5	5.563	4.859	.352	20.000	4¼	4$\frac{7}{16}$	6.303	8⅛	18.472	1900
6	6.625	6.065	.280	19.551	4½	5⅝	7.350	8⅝	22.994	1500
6	6.625	5.761	.432	28.948	4½	5$\frac{5}{16}$	7.350	8⅝	22.994	1800

The permissible variation in weight is 5 per cent above and 5 per cent below.

Taper of threads is ¾-inch diameter per foot length for all sizes.

PIPE FOR ROTARY DRILLING
SEAMLESS INTERIOR UPSET DRILL PIPE

(National Tube Co.)

Size	Diameters		Thickness	Weight Per Foot	Upset		Couplings			Test Pressure in Lbs.
	External	Internal			Length	Inside Diameter	Diameter	Length	Weight	
*2	2.375	2.000	.1875	4.477	3	1 11/16	2.892	5⅛	3.503	2500
2½	2.875	2.469	.203	6.002	3¼	2 1/16	3.564	6⅛	6.743	2200
2½	2.875	2.323	.276	7.841	3¼	1 15/16	3.564	6⅛	6.743	2500
3	3.500	3.063	.2187	7.939	3¼	2 11/16	4.248	6⅛	8.777	1800
3½	4.000	3.500	.250	10.366	3¼	3 1/16	4.771	7⅛	12.060	2000
4	4.500	4.000	.250	11.756	4	3 9/16	5.256	7⅝	14.296	1800
4	4.500	3.958	.271	12.632	4	3½	5.256	7⅝	14.296	1900
4	4.500	3.826	.337	15.323	4	3⅜	5.256	7⅝	14.296	2200
4½	5.000	4.500	.250	13.130	4	4 1/16	5.756	7⅝	15.787	1700
5	5.563	4.975	.294	17.000	4¼	4½	6.303	8⅛	18.472	1700
5	5.563	4.859	.352	20.000	4¼	4 [illegible]/16	6.303	8⅛	18.472	2000
6	6.625	6.065	.280	19.551	4½	5⅝	7.350	8⅝	22.994	1600
6	6.625	5.761	.432	28.948	4½	5 5/16	7.350	8⅝	22.994	2000

* 2-inch 10 threads per inch; larger sizes 8 threads.

The permissible variation in weight is 5 per cent above and 5 per cent below.

Taper of threads is ¾ inch diameter per foot length for all sizes.

NECESSARY PRECAUTIONS IN HANDLING AND ASSEMBLING PIPE FOR DRILLING PURPOSES

(From The National Tube Co.)

Considerable care should always be observed in the handling of Pipe for drilling purposes so as to get the best service, save time and expense, and increase the life of the pipe. For these reasons the following suggestions are made:

First—Before Drill Pipe is screwed together, the threads both on the pipe and in the coupling should be thoroughly cleaned, all sand and grit entirely removed and a good application of heavy oil or grease (mixed with graphite), applied to both. This will make the joints screw and unscrew easily.

Second—When screwing the pipe into the coupling, be sure that it is properly screwed up before lowering into the well. Do not expect the rotary machine to screw up the joint after it has been lowered.

Third—When placing a section of pipe in the coupling do not let the section drop into the coupling. Place it in lightly so that the weight of the pipe will not injure or turn over the first thread. When inserting the end of the pipe into the coupling, if it does not enter easily and rotate freely it is not properly engaged, and should be taken out and re-entered.

Inserting the pipe crookedly and straightening it up frequently breaks off a portion of the end of the threads, which going down with the pipe causes galling, and frequently spoils the joint. If the first threads are turned over they will be ground into the remaining threads as the joint is screwed up. This will cause much difficulty in unscrewing the joint, and will ruin the thread on the pipe and in the coupling.

Fourth—When Drill Pipe is being pulled out of the hole and the joints unscrewed, the weight of the section being taken off should be carried on the hoisting lines. This can be accomplished by attaching a weight (a trifle heavier than the pipe being unscrewed) to the dead end of the line. As the section is unscrewed the weight is not carried by the threads.

Fifth—Whenever a string of Drill Pipe is pulled out of a hole it should be washed off with clean water as it is drawn out, to remove all mud or sand, so that the thread will be clean when the pipe is standing in the derrick.

Pipe should always be placed on boards higher than the general level of the derrick floor.

Sixth—Do not hammer the coupling very hard. Use a small hammer and tap lightly all around the coupling before starting to unscrew. Too much or too hard hammering will injure the threads, expand the coupling, and allow the ends of the pipe to creep until they come together.

SPECIFICATION OF A TEXAS AND LOUISIANA ROTARY DRILLING OUTFIT FOR DRILLING TO A DEPTH OF 3,000 FEET AND FOR HANDLING NOT LARGER THAN 16-INCH O. D. CASING.

Standard Rotary Derrick, 112 feet high with 2 x 8-inch Legs, doubled with 2 x 10-inch, with Steel Crown Block and six Sheaves, no Bull Wheels, Band Wheel or Walking Beam.

1 40 H. P. Fire Box Boiler with Grate Bars and Stack.
1 CC Penberthy Injector.
1 12 x 12 Steam Engine with 2½-inch Throttle and Lubricator.
1 Sprocket Wheel.
1 19-inch Improved Rotary, with bushing and 1 set each 4 and 6-inch Slips, and Driver for 5½-inch Drill Stem, also Gripping Device complete.
1 Double Brake Two Speed Draw Works with 3 Oak uprights.

SPECIFICATION OF A TEXAS AND LOUISIANA ROTARY DRILLING OUTFIT FOR DRILLING TO A DEPTH OF 3,000 FEET AND FOR HANDLING NOT LARGER THAN 16-INCH O. D. CASING.

80 Feet Steel Sprocket Roller Chain.
30 Feet Steel Sprocket Roller Chain.
2 4-inch Water Swivels.
2 10 x 6 x 12 Slush Pumps.
1 6 x 4 x 6 Boiler Feed Pump.
1 No. 268 Myers L. D. Pump with Handle.
1 Set 6-inch Breaking Out Tongs for Tool Joints.
1 Set 4-inch Breaking Out Tongs.
1 40-inch Triple or Quadruple Drilling Block.
1 5-inch Drilling Hook.
1 3½-inch Strapped C Hook
1 ⅞-inch x 1,050-foot Wire Drilling Line.
1 ½-inch x 3,000-foot Wire Sand Line.
12 Each ⅞-inch and ½-inch Wire Rope Clips.
1 5½-inch x 28-foot Round Fluted Drill Stem.
1 Upper Sub for 5½-inch Round Drill Stem.
1 Lower Male and Female Sub for 5½-inch Round Drill Stem and 6-inch Pipe.
1 6-inch Connection for same.
1 6-inch Rotary Casing Shoe.
1 6-inch Overshot.
1 4-inch Overshot.
1 4-inch Bull Dog Spear or Wash Down Trip Spear.
1 3-inch Bull Dog Spear or Wash Down Trip Spear.
2 Pcs. 2-inch x 30-foot WW Drilling Hose.
4 2-inch Hose Clamps.
2 2-inch Hose Nozzles.
1 Set 3-inch Fair's Mgt. Pattern or Lucey Rex Elevators with Long Bails.
1 Set 4-inch Fair's Mgt. Pattern or Lucey Rex Elevators with Long Bails.
1 Set 6-inch Fair's Mgt. Pattern or Lucey Rex Elevators with Long Bails.
1 Set 8-inch Fair's Mgt. Pattern Elevators with Regular Bails.
1 Set 10-inch Fair's Mgt. Pattern Elevators with Regular Bails
1 Set 12½-inch Fair's Mgt. Pattern Elevators with Regular Bails.
2 No. 15 Vulcan Chain Tongs.
2 No. 14 Vulcan Chain Tongs.
2 No. 13 Vulcan Chain Tongs.
2 No. 12 Vulcan Chain Tongs.
2 Extra Sets Chains for each Tongs.
2 Extra Sets Jaws for each Tongs.
1 5-inch x 25-foot bailer.

Necessary amount of Rotary Drill Pipe to drill to required depth.
Suggested: 1,500 feet 6-inch Drill Pipe, 3,000 feet 4-inch Drill Pipe.
Necessary Tool Joints for Drill Pipe to drill to required depth. One tool joint is used between every third or fourth joint of pipe.

1 3 x 3 x 15-inch Forged Steel Drill Collar.
1 4 x 4 x 18-inch Forged Steel Drill Collar.
1 6 x 4 x 18-inch Forged Steel Drill Collar.
2 6 x 4-inch Forged Steel Bushings.
1 4 x 3-inch Hydraulic Swaged Nipple.
2 15 x 4-inch Shank Fishtail Drill Bits.
2 10 x 4-inch Shank Fishtail Drill Bits.
4 8 x 4-inch Shank Fishtail Drill Bits.
4 6 x 4-inch Shank Fishtail Drill Bits.
4 6 x 3-inch Shank Fishtail Drill Bits.
300 Feet 1¼-inch Manila Rope for Cat Line.
1 10-Pound Sucker Rod Hook.
1 10-inch Drop Link Snatch Block.
1 1 x 4-ply x 50-foot Water Hose with Connections.

SPECIFICATION OF A TEXAS AND LOUISIANA ROTARY DRILLING OUTFIT FOR DRILLING TO A DEPTH OF 3,000 FEET AND FOR HANDLING NOT LARGER THAN 16-INCH O. D. CASING.—Continued.

1 Fuel Tank.
1 Turbine Generator with Lighting Outfit.
1 2-Quart Steam Engine Lubricator for Slush Pumps.

Blacksmith Outfit, Tools and Supplies.

1 No. 3 Star Steam Blower.
1 300-Pound Anvil.
1 Forge for Blacksmith Outfit.
1 Sack Blacksmith Coal.
1 Emery Wheel, 12-inch.
50 Fire Brick.
2 14-Pound Cross Pein Sledges.
4 Sledge Hammer Handles.
1 2½-inch Sq. Flatter.
1 ⅝-inch Top Fuller.
1 1½-inch Set Hammer.
1 1½-inch Hot Cutting Chisel.
2 14-inch HR Bast. Files.
6 14-inch Flat Bast. Files.
2 ⅞-inch Hand Cold Chisels.
2 ⅝-inch Hand Punches.
1 ⅞-inch Diamond, Pt. Chisel.
1 2-inch Socket Firmer Chisel.
2 1 x 36-inch Irwins SC Ship Augers.
1 Auger Handle.
6 Auger Bits, ¼ to 1-inch.
1 100-foot Metallic Tape.
2 20-pound Crow Bars.
1 Each 10-inch and 15-inch Coes Wrench.
1 Each 18-inch, 24-inch and 36-inch Trimo Wrench.
1 Set Bolt Dies, ⅛ to 2 inches.
1 No. 1A Toledo Stock and Dies.
1 No. 25 Toledo Stock and Dies.
1 No. 1 Barnes Pipe Cutter.
1 No. 2 Barnes Pipe Cutter.
1 No. 3 Barnes Pipe Cutter.
1 No. 4 Barnes Pipe Cutter.
2 Extra Cutter Wheels for each Pipe Cutter.
1 Combination Pipe Vise, ½ to 4 inches.
150 Feet Telegraph Wire.
1 Gem Oil Burner.
1 3-inch Freeman's Flue Cleaner.
4 Long Handled R. P. Shovels.
2 6-foot CC Saws and Handles.
10 Pounds Hand Hole Gaskets.
10 Pounds Red Eye Sheet Packing.
10 Pounds Loose Hemp Packing.
10 Pounds ½-inch Sq. Hydraulic Packing.
10 Gallons Engine Oil.
10 Gallons Cylinder Oil.
1 Bbl. Torch or Burning Oil.
1 Long Spout Steel Oil Can.
1 26-inch 7-pt. Hand Saw.
2 Single Bit Axes.
1 Derrick Hatchet.
1 2-foot Steel Square.
1 Level.
1 Claw Hammer.
1 Ratchet Bit Brace.
1 Pr. 12-inch O. S. Calipers.
1 Wheelbarrow.
1 Hacksaw with 12-inch Blades.
25 Pounds White Waste.
20 Feet ¼-inch Black Pipe for Flue Cleaner.
20 Feet ½-inch Black Pipe for Engine Reverse.
2 Derrick Lamps.
5 Pounds Lamp Wick.
10 Pounds White Lead.
10 Pounds Dixons Graphite.
1 Wire Thread Brush.
20 Pounds Babbitt.
1 Babbitt Ladle.

Fittings for Connecting Pump Manifold, Pumps, Engine and Boiler

(Texas Type)

Steam Line to Engine and Pumps.

10 2-inch Mall. Ells.
6 2-inch Mall. Tees
3 2-inch Brass Globe Valves.
7 2-inch x 6-inch Nipples.
4 2-inch C. I. Plugs.
3 2-inch C I. Flange Unions.
2 2-inch Couplings.

Injector.

1 2½-inch x 2-inch Swaged Nipple.
4 1¼-inch x 4-inch Nipples.
6 1-inch x 4-inch Nipples.
1 2-inch Mall. Tee.
1 1¼-inch Mall. Ell.
6 1-inch Mall. Ells.
1 1¼-inch x 1-inch Reducer.
1 2 x 1-inch Bushing.
1 1-inch Iron Cock.
3 1-inch Brass Globe Valves.
1 1½-inch x 1¼-inch Bushing.

Water Pump.

1 2-inch Tee.
1 2-inch x 1-inch Bushing.
4 1-inch x 4-inch Nipples.
2 1-inch Mall. Ells.
1-inch Kewanee Union.
1 1-inch Iron Cock.
1 1-inch Brass Globe Valve.
1 2-inch x 6-inch Nipple.
3 2-inch Mall. Ells.
1 2-inch Mall. Tee.

SPECIFICATION OF A TEXAS AND LOUISIANA ROTARY DRILLING OUTFIT FOR DRILLING TO A DEPTH OF 3,000 FEET AND FOR HANDLING NOT LARGER THAN 16-INCH O. D. CASING.—Concluded.

1 2-inch Flange Union.
4 2-inch x 6-inch Nipples.
1 2-inch Plug.
1 1¼-inch Mall. Ell.
1 1¼-inch x 6-inch Nipple.
1 1¼-inch x 6-foot Pipe.
6 2-inch x 6-inch Nipples.
3 2-inch Mall. Ells.
1 2-inch Mall. Tee.
1 2-inch Flange Union.
1 2-inch Plug.
1 2-inch Brass Check Valve.
1 3 x 2-inch Bushing.

Slush Pumps.

4 6-inch x 10-inch Nipples.
2 6-inch C. I. Ells.
2 6-inch Flange Unions.
2 6-inch C. I. Foot Valves.
2 Pcs. 6-inch Pipe full length.

To connect Turbine Generator and Steam Blower.

5 ½-inch Kewanee Lip Unions.
6 ½-inch x 4-inch Nipples.
6 ½-inch Mall. Ells.
3 ½-inch Mall. Tees.
3 ½-inch Jenkins Brass Globe Valves.

Slush Pump Manifold

2 20-foot lengths 2-inch Pipe.
4 2½-inch Mall. Ells.
4 2-inch Mall. Ells.
3 2½-inch Mall. Tees.
2 4 x 2½-inch Cast Iron Bushing.
2 2-inch Flange Unions.
2 2½-inch Flange Unions.
2 2-inch x 10-inch Nipples.
2 2-inch x 4-inch Nipples.
2 2-inch x 6-inch Nipples.
10 2½-inch x 4-inch Nipples.
2 2½-inch x 10-inch Nipples.
3 2½-inch x 2-inch Swaged Nipples.
1 2-inch Iron Cock.
2 2-inch I. B. Quick Opening Gate Valves.
2 2½-inch I. B. B. M. Gate Valves.
1 5-inch 500-pound Pressure Gauge.
300 Feet 2-inch Black Pipe.
200 Feet 1-inch Black Pipe.
100 Feet 1¼-inch Black Pipe.

SPECIFICATION OF CALIFORNIA EXTRA HEAVY ROTARY DRILLING OUTFIT.

FOR DRILLING TO A DEPTH OF 5,000 FEET

Note: This outfit is suitable for export to foreign countries.

Standard Derrick, 106 or 112 feet high, with 2 x 10-inch Legs, doubled with 2 x 12-inch, no Bull Wheels, Band Wheel or Walking Beam.
1 Structural Steel Crown Block with 5 Pulleys.
2 50 H. P. Oil Country Boilers complete with Smoke Stack (unmounted).
2 C. C. Penberthy Injectors.
1 No. 268 Myers L. D. Pump with Handle.
1 14 x 14-inch (50 H. P.) Stripped Steam Engine with Sprocket and Heavy Rotary Fly Wheel.
1 California Type Double Brake, Two Speed Draw Works, including Oak Uprights, Drive Shaft, Drum Shaft and Brake Shaft Complete.
65 Feet Sprocket Chain for Draw Works.
40 Feet Sprocket Chain for Rotary.
1 23-inch California Type Rotary with Flat Top, Bushing, Driver and Slips, or with Bushing and Gripping Device.
1 6-inch Square Drill Stem with Subs to connect with Swivel and Drill Pipe.
2 12 x 6¾ x 14-inch California Type Slush Pumps.
2 Lengths Wire Wound Rotary Hose, 2½-inch x 30 feet.
2 2½-inch Rotary Hose Couplings.
4 2½-inch Rotary Hose Clamps.
2 6-inch Heavy Water Swivels.
1 40-inch Quadruple Rotary Drilling Block.
1 4½-inch Strapped C Hook.
1 8-inch Wigle Spring Casing Hook.

SPECIFICATION OF CALIFORNIA EXTRA HEAVY ROTARY DRILLING OUTFIT.—Continued.

1 15-pound Sucker Rod Hook for Cat Line.
1200 Feet 1-inch 6 x 19 Wire Drilling Line.
5000 Feet 9/16-inch 6 x 7 Wire Bailing or Sand Line.
6 1-inch Wire Rope Clips.
6 9/16-inch Wire Rope Clips.
1 Set 4-inch Fair's Mannington or Lucey Rex Extra Heavy Elevators with Long Links.
1 Set 6-inch Fair's Mannington or Lucey Rex Extra Heavy Elevators with Long Links.
1 Set 6¼, 8¼, 10, 12½, 15½-inch I. D. and 20-inch O. D. Extra Heavy Elevators with Regular Length Links.

Note: If size of casing is changed or other than American Collar Casing is used, specifications will necessarily have to be changed.

2 Pair Each No. 33½, 34, 35 and 16 Vulcan Chain Tongs.
2 Type CX Dunn Tongs with Bushings for 8¼ and 6¼-inch Casing, 6-inch Drill Pipe and 7¾-inch Tool Joints.
1 Type A Dunn Tongs with Bushing for 12½-inch Casing.
1 Each 4 and 6-inch Slide Tongs.
Necessary quantity of Rotary Drill Pipe to drill to required depth.
Necessary Tool Joints for Drill Pipe to drill to required depth. One Tool Joint is used between every third or fourth joint of pipe.
2 6 x 4-inch Swivel Bushings.
1 10-inch 10-Thread by 6-inch 8-Thread Steel Swaged Nipple.
2 4 x 72-inch Drill Collars, 4-inch Pipe Thread Box x 3¾ x 4½-inch Tool Joint Box.
2 6 x 72-inch Drill Collars, 6-inch Pipe Thread Box x 5 x 6-inch Tool Joint Box.
1 Each 6, 8¼, 10 and 12½-inch Rotary Shoes.
1 Each 6¼ x 14 x ⅞-inch, 8¼ x 16 x 1-inch, 10 x 16 x 1¼-inch, 12½ x 16 x 1¼-inch and 15½ x 16 x 1¼-inch Plow Steel Casing Shoes.
2 22-inch Rotary Bits, 5 x 6-inch Taper Joint.
6 18-inch Rotary Bits, 5 x 6-inch Taper Joint.
12 14-inch Rotary Bits, 5 x 6-inch Taper Joint.
10 12¾-inch Rotary Bits, 5 x 6-inch Taper Joint.
6 9⅞-inch Rotary Bits, 3¾ x 4½-inch Taper Joint.
4 7⅞-inch Rotary Bits, 3¾ x 4½-inch Taper Joint.

Note: Specification for Bits will have to be changed if other than American Collar Casing is used.

1 4-inch Wash Down Spear with Trip.
1 6-inch Wash Down Spear with Trip.
1 12½-inch Overshot to run on 10-inch Casing, to catch 6-inch Pipe.
1 10-inch Overshot to run on 8¼-inch Casing, to catch 6-inch Pipe.
1 8¼-inch Overshot to run on 6-inch Pipe, to catch 4-inch Pipe.
1 4-inch Male and Female Case Hardened Nipple.
1 6-inch Male and Female Case Hardened Nipple.
1 4-inch Tool Joint Fishing Tap.
1 6-inch Tool Joint Fishing Tap.
300 Feet 1¼-inch Manila Rope for Cat Head Line.
2 Lengths 1¼-inch x 25-foot, 4-Ply Rubber Hose with Couplings, Clamps and Nozzle for washing derrick floor and machinery.
1 Blow Out Preventer.
2 2-Quart Lubricators for Slush Pump.
1 Turbine Generator with lighting Outfit.
Blacksmith and Derrick Tools.
1 No. 11 Portable Forge.
1 No. 4 Star Blower.
1 300-Pound Anvil.
1 12-inch Emery Wheel.
1 ¾ x 20-inch C. L. Blacksmiths' Tongs.
1 1 x 20-inch C L. Blacksmiths' Tongs.
1 ¾ x 20-inch S. L. Blacksmiths' Tongs.
1 1 x 20-inch S. L. Blacksmiths' Tongs.
1 ¾ x 20-inch Single Pick Up Tongs.
1 1 x 20-inch Single Pickup Tongs.

SPECIFICATION OF CALIFORNIA EXTRA HEAVY ROTARY DRILLING OUTFIT.—Continued.

2 14-Pound Sledges with Handles.
6 36-inch Hickory Sledge Handles.
2 No. 4 B. P. Hammers.
6 Cold Chisels, 4 1-inch, 2 1¼-inch.
2 Cape Chisels.
2 Hot Splitting Chisels with Handles.
2 Hardies, ⅞-inch.
2 Hardies, ¼-inch.
2 Flatters, 1½-inch.
2 Fullers, ¾-inch.
1 2½-Pound Punch.
2 Pinch Point Crow Bars.
1 Pair 12-inch O. S. Calipers.
1 10-inch Coes Wrench.
1 10-inch Adjustable Hack Saw Frame.
12 10-inch Hack Saw Blades.
2 14-inch Half Round Bastard Files.
2 12-inch Half Round Bastard Files.
2 12-inch Flat Bastard Files
1 15-inch Briggs Screw Wrench.
2 18-inch Trimo Pipe Wrenches.
2 24-inch Trimo Pipe Wrenches.
1 36-inch Trimo Pipe Wrench.
4 Long Handle Round Point Shovels.
2 Mud Mixing Hoes.
1 100 Foot Metallic Tape.
1 No. 7 Hand Saw.
1 24-inch No. 9 Plain Steel Square.
1 24-inch No. 9 Plain Level.
1 Single Bit Axe and Handle.
1 Derrick Hatchet.
2 Derrick Brooms.
1 No. 3 Combination Pipe Vise.
1 No. 1 Barnes Pipe Cutter.
1 No. 2 Barnes Pipe Cutter.
1 No. 4 Barnes Pipe Cutter
1 No. 1 Toledo Adjustable Stock, 1 to 2 inches.
1 No. 25 Toledo Adjustable Stock, 2½ to 6-inches.
1 No. 7 Little Giant Screw Plate with Dies and Taps.
1 Common Derrick Crane, 6 x 1-inch arm.
1 1-ton Moore Anti-Friction Chain Hoist.
1 Wire Thread Brush.
1 No. 2 Sheet Iron Tool Box.
1 Each 1¼, 1½ and 2-inch Nut Augers.
1 Pratts Auger Handle.
2 1 x 36-inch Irwin's S. C. Ship Augers.
6 Auger Bits, ¼ to 1-inch.
1 Ratchet Bit Brace.
2 C. C. Saws and Handles.

Miscellaneous.

150 Feet Wire Telegraph Cord
20 Feet ¼-inch Pipe for Flue Cleaner.
20 Feet ½-inch Pipe for Reverse Lever.
10 Pounds Lamp Wick.
4 Derrick Lamps.
5 1-Pound Cans Red Lead.
5 5-Pound Cans White Lead.
5 5-Pound Cans Dixon Graphite.
12 Feet ⅜-inch Straight Link Chain.
1 10-inch Drop Link Steel Snatch Block.
1 12⅜ Rock Drill Bit Complete.
1 Drill Collar for above.
1 Extra set of Cones for above.
1 9⅞-inch Rock Drill Bit Complete.
1 Drill Collar for above.
1 Extra set of Cones for above.
10 Gallons Bit Lubricating Oil.
10 Gallons Engine Oil.
10 Gallons Cylinder Oil.
1 Barrel Torch or Burning Oil.
50 Fire Brick.
1 Wheelbarrow.
2 Galvd. Iron Pails.
1 3-inch Flue Cleaner.
1 3-inch Dudgeon Type Flue Expander.
2 Gem Oil Burners.
6 Extra Wheels each for Nos. 1, 2, and 4 Barnes Pipe Cutters.
1 Set Slips for 4-inch Wash Down Spear.
1 Set Slips for 6-inch Wash Down Spear.
2 Extra Lengths Wire Wound Rotary Hose, 2½-inch x 30 feet.
2 Extra Sets 2½-inch Hose Couplings and Clamps.
10 Pounds Hand Hole Gaskets
80 Feet Extra Sprocket Chain, for Draw Works.
25 Feet Extra Sprocket Chain, for Rotary.
3 B. P. Hammer Handles.
2 Single Bit Axe Handles.
3 Hatchet Handles.
10 Pounds Red Sheet Packing.
10 Pounds Loose Hemp Packing.
10 Pounds ½-inch Square Hydraulic Packing.
5 Pounds ½-inch Square Pure Gum Packing.
20 Pounds Babbitt.
1 Babbitt Ladle.
1 1-Quart Railroad Oiler.
1 ½-Pint Gem Oiler.
1 ½-inch Belt Punch.

SPECIFICATION OF CALIFORNIA EXTRA HEAVY ROTARY DRILLING OUTFIT.—Continued.

25 Pounds White Waste.
12 5-inch Hay Fork Pulleys.

Note: Tapes, Squares and Tools with markings shown in feet and inches should be ordered to conform to units of measurement in the country to which material is to be shipped.

Fittings for Connecting Pump Manifold, Pumps, Engine and Boilers.

Steam Line from Boilers to Engine and Pump (3-inch Main Line).

7 3-inch Mall. Iron Tees.
1 2½-inch Mall. Iron Tee.
1 2-inch Mall. Iron Tee.
1 3-inch Mall. Iron Ell.
1 2½-inch Mall. Iron Ell.
2 2-inch Mall. Iron Ells.
5 3-inch x 8-inch Nipples.
4 2½-inch x 8-inch Nipples.
6 2-inch x 6-inch Nipples.
1 3-inch x 2½-inch Swaged Nipple.
4 3-inch x 2-inch Swaged Nipples.
3 3-inch Flange Unions.
2 2½-inch Flange Unions.
1 2-inch Flange Union.
2 3-inch Couplings.
1 2½-inch Coupling.
3 3-inch Plugs.
1 2-inch Plug.
3 2-inch I. B. Globe Valves.
2 2½-inch I. B. Globe Valves.

Injector and Fittings for 3 Boilers.

3 2-inch x 6-inch Nipples.
9 1¼-inch x 4-inch Nipples.
18 1-inch x 4-inch Nipples.
3 2-inch Mall. Iron Tees.
3 1¼-inch Mall. Iron Ells.
18 1-inch Mall. Iron Ells.
3 1½-inch x 1¼-inch Mall. Iron Bushings.
3 1¼-inch x 1-inch Mall. Iron Reducers.
3 2 x 1-inch Bushings.
3 1-inch Iron Cocks.
3 1¼-inch Globe Valves.
9 1-inch Globe Valves.
3 1¼-inch Check Valves.

Water Pump.

1 2-inch Mall. Iron Tee.
2 1-inch Mall. Iron Ells.
1 2-inch x 6-inch Nipple.
4 1-inch x 4-inch Nipples.
1 2-inch x 1-inch Bushing.
1 1-inch Iron Cock.
1 1-inch Brass Globe Valve.
1 1-inch Kewanee Union.
1 1¼-inch x 6-inch Nipple.
1 1¼-inch x 6-foot Pipe.
6 2-inch x 6-inch Nipples.
3 2-inch Mall. Iron Ells.
1 1¼-inch Mall. Iron Ell.
1 2-inch Mall. Iron Tee.
1 2-inch Flange Union.
1 2-inch Plug.
1 2-inch Brass Check Valve.
1 3 x 2-inch Bushing.
3 2-inch Mall. Iron Ells.
1 2-inch Mall. Iron Tee.
1 2-inch Flange Union.
4 2-inch x 6-inch Nipples.
1 2-inch Plug.

Slush Pumps.

4 8-inch x 12-inch Nipples.
2 8-inch C. I. Ells.
2 8-inch C. I. Foot Valves.
2 Pcs. 8-inch Pipe full length.
2 8-inch Flange Unions.

To connect Turbine Generator and Steam Blower.

5 ½-inch Kewanee Lip Unions.
6 ½-inch x 4-inch Nipples.
6 ½-inch Malleable Ells.
3 ½-inch Malleable Tees.
3 ½-inch Jenkins Brass Globe Valves.

Slush Pump Manifold.

2 20-foot lengths 2½-inch Pipe.
4 2½-inch Mall. Ells.
2 2½-inch x 10-inch Nipples.
4 3-inch Mall. Iron Ells.
3 3-inch Mall. Iron Tees.
2 6 x 3-inch Cast Iron Bushings
2 2½-inch Flange Unions.
2 3-inch Flange Unions.
2 2½ x 4-inch Nipples.
2 2½-inch x 6-inch Nipples.
10 3 x 4-inch Nipples.
2 3 x 10-inch Nipples.
1 3 x 2-inch Swaged Nipple.
2 3 x 2½-inch Swaged Nipples.
1 2-inch Iron Cock.
2 2½-inch I. B. Quick Opening Gate Valve.
2 3-inch I. B.B. M. Gate Valves.
1 5-inch 500-Pound Pressure Gauge.
200 Feet 1-inch Pipe.
200 Feet 1¼-inch Pipe.
200 Feet 2-inch Pipe.
300 Feet 3-inch Pipe.

For an outfit to be shipped to foreign countries or to remote points far from base of supplies the following repair parts are recommended:

For Boilers.

2 Steam Gauges.
1 Pop Safety Valve.
6 Water Gauges.

SPECIFICATION OF CALIFORNIA EXTRA HEAVY ROTARY DRILLING OUTFIT.—Concluded.

1 Set Grate Bars.
3 Hand Hole Plates Complete.
3 Soft Plugs.
1 1¼-inch Brass Check Valve.
10 Pounds Guy Wire, No. 9.

For Engine.

1 Crank Shaft.
4 Connecting Rod Brasses, Crank End.
4 Connecting Rod Brasses, Cross head End.
4 Piston Glands.
4 Steam Chest Glands.
2 Throttle Valve Yokes with Glands and Nuts.
2 Throttle Valve Stems.
2 Throttle Valve Stem Lock Nuts.
4 Throttle Valve Valves.
4 Throttle Valve Valve Seats.
4 Throttle Valve Glands.
1 Connecting Rod Strap, Crank End.
1 Connecting Rod Strap, Crosshead End.
2 Connecting Rod Keys.
1 Crosshead.
1 Balance Valve Complete.
1 Valve Stem with Nuts.
2 Sets Steam Piston Rings.
1 Steam Piston Rod.
2 Eccentric Rods with Bushings.
1 Eccentric Complete with Hub and Rings.
1 Link Complete.
1 Engine Sprocket Wheel.

For Draw Works.

2 Set Brake Band Liners.
1 Set Drum Shaft Boxes.
1 Set Drive Shaft Boxes.
1 Drill Drive Clutch.
1 Drill Drive Clutch Dog.
1 Drive Shaft Clutch.
2 Sets Keys.
1 Low Speed Drum Shaft Clutch.
1 Drum Clutch Dog.
1 High Speed Drum Shaft Clutch.
1 Complete Set Sprockets.

For Rotary.

1 Set Journal Boxes.
2 Pinions.
1 Pinion Shaft.
2 Pinion Shaft Clutches.
2 Pinion Clutch Straps.
1 Pinion Clutch Shifting Lever.
1 Shifting Lever Finger.
2 Liners for Cone Bearing.
17 Roller Cones.
1 Locking Collar.
1 Locking Pawl.
2 Sprockets.
2 Pinion Clutch Collars.
2 Grip Ring Shafts.
2 Gripping Screws.
2 Each R. H. and L. H. Adjusting Screws.
4 Each Adjusting Sleeve Nuts and Washers.
4 Adjusting Drive Locking Pins.
1 Driving Post.
1 Set Slips or Dies for each size drill pipe.
2 Sets Keys.

For Slush Pumps.

75 Assorted Studs and Nuts.
10 Pounds Assorted Gaskets.
1 Steam Inlet Flange.
2 Stuffing Box Glands.
2 Valve Stem Forks.
2 Valve Stem Link Pins and Washers.
2 Rocker Shaft Bushings.
4 Crossheads.
6 Piston Rod Glands.
12 Assorted Piston Rod Nuts.
4 Long Rocker Arms.
4 Short Rocker Arms.
4 Shafts for Long Rocker Arms
4 Shafts for Short Rocker Arms.
8 Keys for Rocker Shaft.
2 Water Cylinder Heads.
2 Steam Cylinder Heads.
2 Steam Piston Heads.
4 Steam Piston Rings.
1 Steam Slide Valve and Stem.
2 Suction Flanges.
2 Discharge Flanges.
6 Water Cylinder Liners.
6 Water Piston Heads.
6 Water Piston Followers.
8 Water End Piston Rods.
3 Steam End Piston Rods.
16 Water Valve Seats.
8 Water Valve Springs.
8 Water Valves.
32 Water Valve Gaskets.
4 Water Valve Clamps.
4 Rocker Arm Shaft Wrist Pins
4 Rocker Arm Rollers and Pins.
Supply of 5/16 and ½-inch Square Garlock Packing, ½-inch Square Hydraulic Packing and ½-inch Pure Gum Packing.
1 Complete Set Gland Bolts and Nuts.

For Water Swivels.

1 Hose Stem.
2 Complete Roller Bearings.
1 Hose Nozzle.
2 Stuffing Box Glands
2 Drill Pipe Couplings.
25 Pounds ½-inch Square Flax Packing.
4 Friction Washers.
1 Bushing.
2 Gaskets for Hose Nozzle.

CHAPTER VI

COMBINATION CABLE AND ROTARY SYSTEM OF DRILLING

This system is successfully employed in drilling formations that are alternately hard and soft, or in penetrating soft or alluvial surface formations with the rotary equipment and finishing the well in the harder formations at depth with the cable tools.

The equipment used is the same as that for cable and for rotary drilling, the outfit being a combination of the two, but eliminating parts that might be duplicated in the two outfits.

The derrick and rig are the standard cable rig, except that the derrick should be 106 feet high, with the addition of a rotary engine block abutting the side sill and at a right angle from the standard engine block (see Fig. 145), and the derrick sills and floor extended to provide a slush pump platform on the opposite side of the derrick from the rotary engine block. (Refer to directions for erecting standard derricks, pages 46-48, and for rotary derricks, page 192.)

Directions for rigging up standard rigs and rotary rigs (refer to pages 97-100, 193-197), may also be followed for rigging up the combination rig, with the exception that the draw works is set up on the opposite side of the rig from the slush pumps, instead of at a right angle from the pumps, as in the rotary rig. The reason for this is that, with the combination rig, two opposite sides of the derrick are occupied by the calf wheels and walking beam on the one side and the bull wheels on the other.

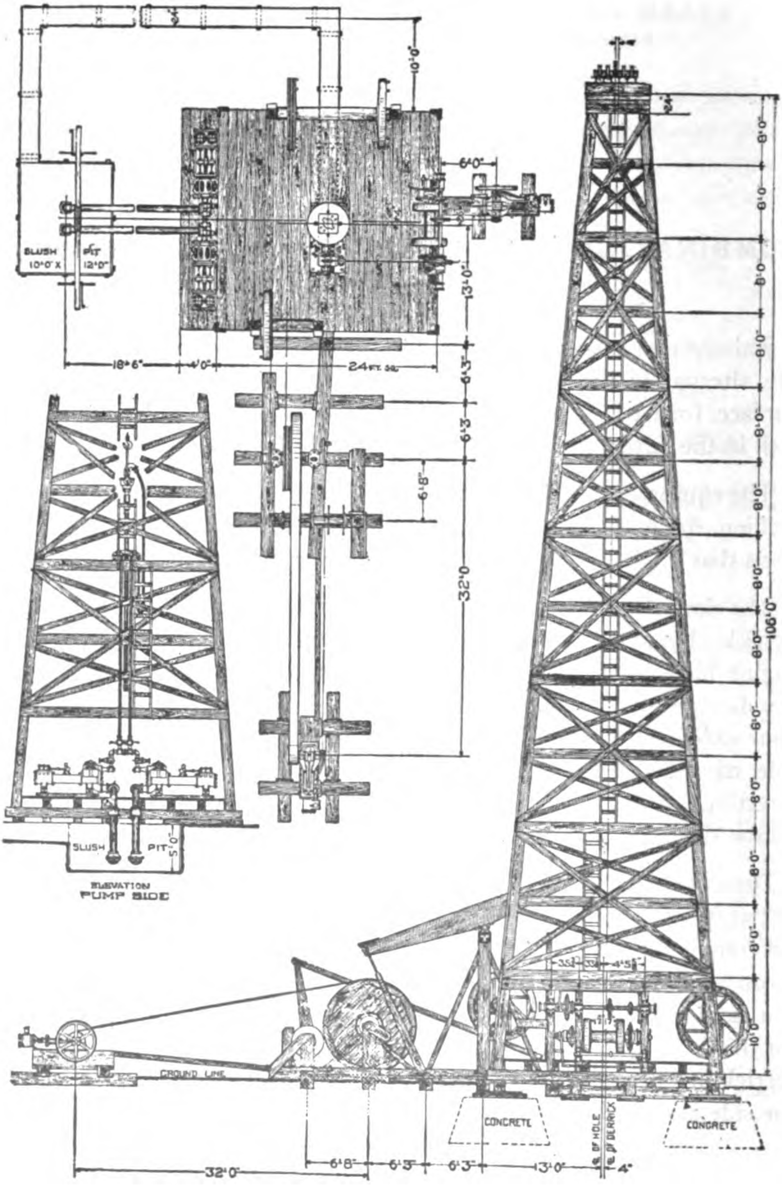


Fig. 145. Side elevation and ground plan of 106-foot California Combination Rotary and Cable Drilling Rig with extra wind braces, showing machinery installed ready for drilling.

DIAGRAM OF CARNEGIE 106-FOOT STRUCTURAL STEEL COMBINATION STANDARD AND ROTARY DERRICK

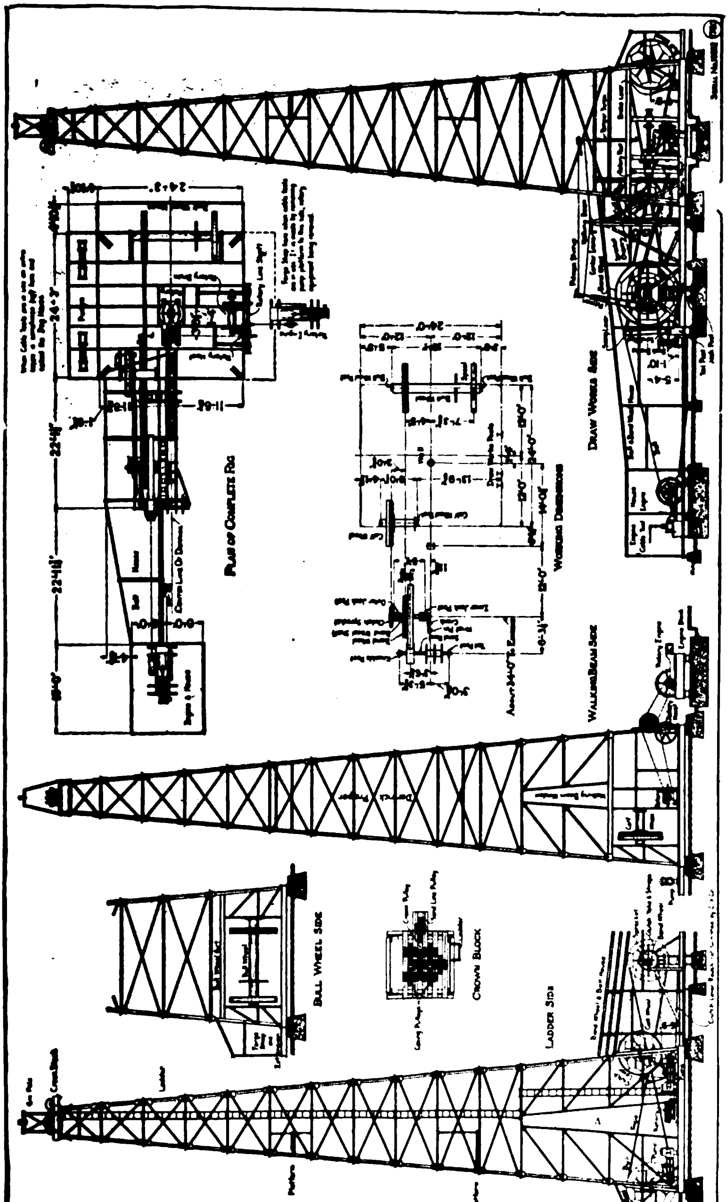


Fig. 146.
(Refer to Pages 375-377 for safe working load for Derricks.)

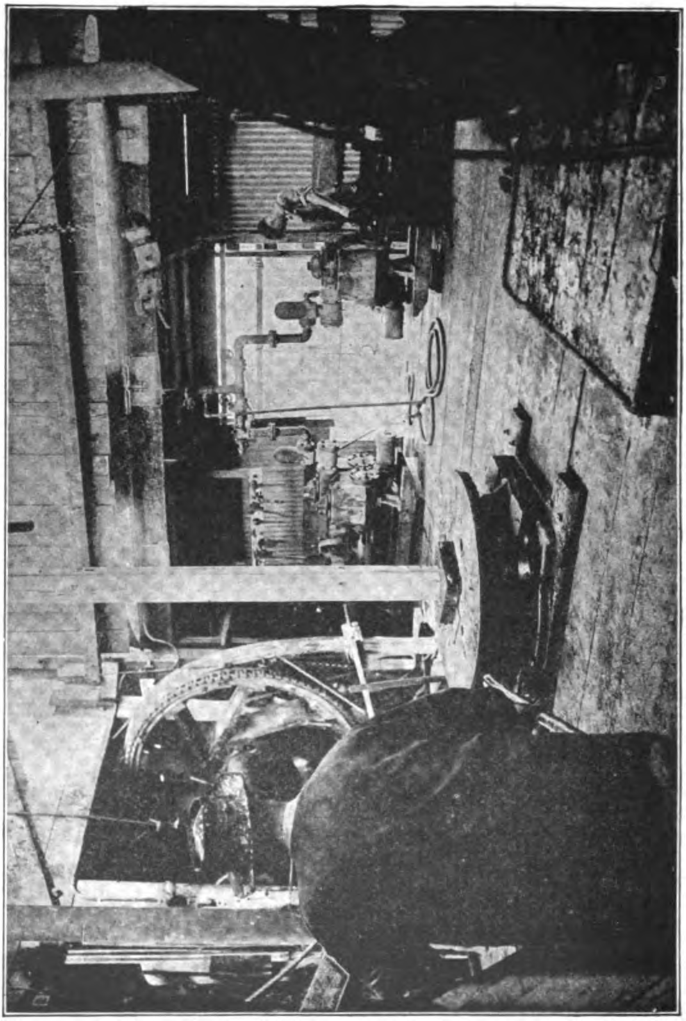


Fig. 147. Interior View of Derrick-Drilling with the Rotary.

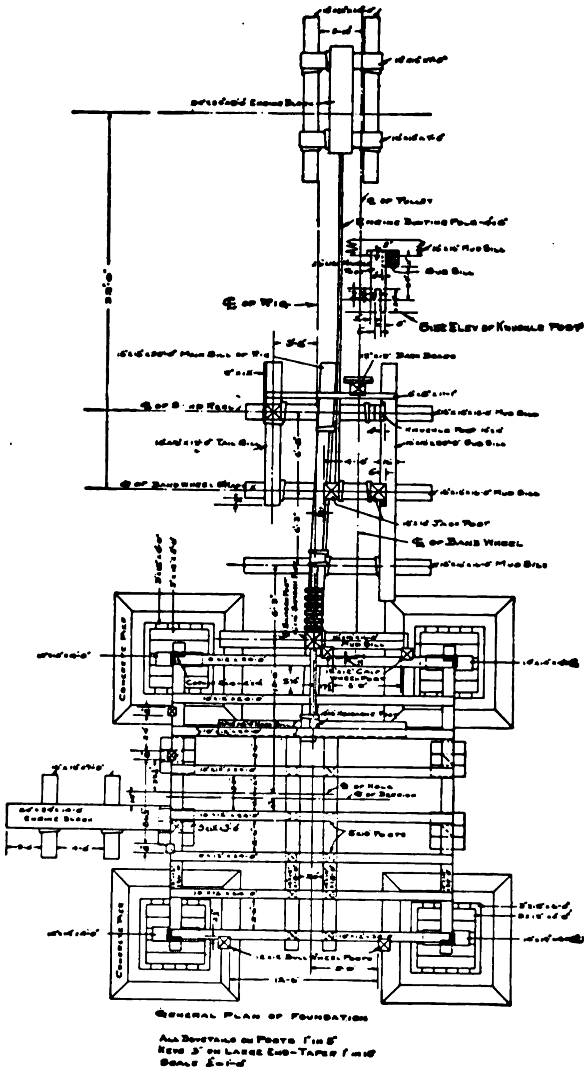


Fig. 149. Diagram of California 106-foot Combination Standard and Rotary Derrick-Foundation Plan.

DIAGRAM OF CALIFORNIA 106-FOOT COMBINATION STANDARD AND ROTARY DERRICK

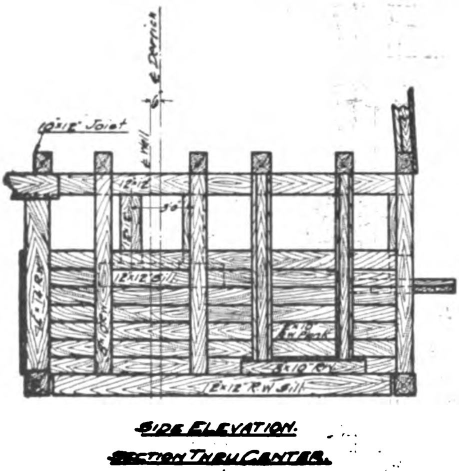


Fig. 150. Cellar-Side Elevation.

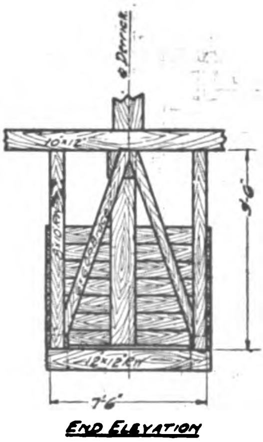


Fig. 151. Cellar-End Elevation.

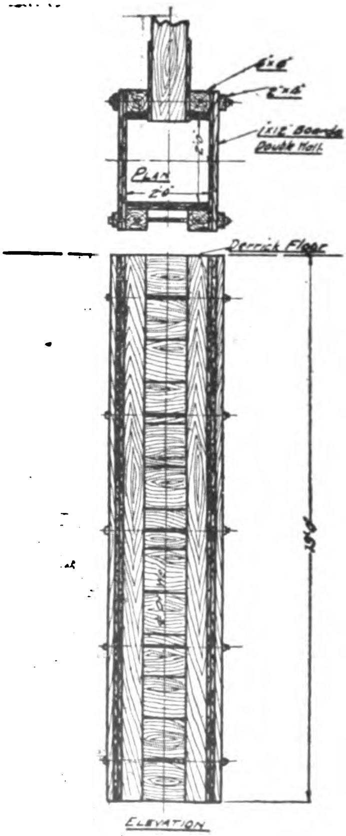


Fig. 152. Column to carry rotary mud fluid.

SPECIFICATION OF MATERIAL REQUIRED TO BUILD A CALIFORNIA COMBINATION STANDARD AND ROTARY RIG, DERRICK 106 FEET HIGH WITH 24-FOOT BASE.

Pieces	Oregon Pine	Size, Inches	Length, Feet
1	Walking Beam	14 x 14 x 14 x 30	26
1	Engine Block	24 x 24	9
1	Rotary Engine Block	24 x 24	14
1	Sampson Post	18 x 16	16
1	Main Sill	16 x 16	32
1	Sub Sill	16 x 16	20
1	Tail Sill and Sand Reel Post	16 x 16	18
4	Mud Sills	16 x 16	16
1	Nose Sill	16 x 16	16
1	Jack Post	16 x 16	16
2	Engine Mud Sills	16 x 16	14
4	Engine Pony Sills	16 x 16	7
1	Knuckle Post	16 x 16	6
6	Derrick Foundation	16 x 16	4
3	Derrick Cellar or Pit	16 x 16	14
1	Derrick Cellar or Pit	16 x 16	16
1	Back Brake	16 x 16	6
2	Mud Sills for Rotary Engine Block	16 x 16	16
2	Pony Sills for Rotary Engine Block	14 x 14	12
3	Derrick Blocking	14 x 14	10
2	Casing Sills	14 x 14	18
4	Bull Wheel and Calf Wheel Posts	14 x 14	12
4	Bumpers and Gin Pole	12 x 12	7
2	Derrick Side Sills	12 x 12	26
8	Derrick Sills	10 x 12	24
1	Head Board	10 x 12	24
3	Casing Rack and Blocking	8 x 10	20
1	Crane	8 x 8	20
3	Crown Block (not needed with steel Crown Block)	6 x 16	14
2	Sampson Post Braces	6 x 8	16
1	Headache Post	6 x 8	14
1	Sand Reel Lever	6 x 6 x 16	14
12	Derrick Cellar or Pit	6 x 6	20
6	Stringers for Walk and Roof	6 x 6	22
4	Stringers for Walk	6 x 6	8
2	Jack Post Braces	6 x 6	18
3	Bull Wheel and Calf Wheel Post Braces	6 x 6	16
2	Dead Men	6 x 6	20
	Add For Reinforcing Corners:		
4		6 x 6	12
24		6 x 6	16
1	Bunting Pole	4 x 6	30
8	Short Braces, Roof Stringers and Keys and J. P. Bunting Pole	4 x 6	16
3	Engine House Studding	4 x 4	18
1	Calf Wheel Brace	4 x 4	18
4	Engine House Sills	4 x 4	16
3	Outside Drill Pipe Platform and Crown Block Railing	4 x 4	14
6	Under Mud Sills	3 x 12	22
2	Under Mud Sills (Engine House)	3 x 12	20
5†	Derrick Foundation (Redwood)	3 x 12	20
20†	Derrick Foundation (Redwood)	3 x 12	18

† Drawing of 106-foot Derrick shows both concrete piers and wood footings. If concrete is used the wood footings are unnecessary. They are shown in drawing to illustrate method of building footings when derrick is not on concrete. Concrete piers 8 feet square at base and 2 feet square at top are usually sufficiently strong.

SPECIFICATION OF MATERIAL REQUIRED TO BUILD A CALIFORNIA COMBINATION STANDARD AND ROTARY RIG, DERRICK 106 FEET HIGH WITH 24-FOOT BASE (Continued).

Pieces	Oregon Pine	Size, Inches	Length, Feet
52	Girts (4), Derrick (24) and Pump House Floor (8) and Doublers (16)	2 x 12	24
4	Girts	2 x 12	22
72	Walk, Cellar and Girts	2 x 12	20
20	Band Wheel Surface (one side)	2 x 12	20
16	Girts and Outside Drill Pipe Platform	2 x 12	18
40	Doublers (32), Water Table (4) and Girts (4)	2 x 12	16
12	Calf Wheel Core	2 x 12	16
8	Outside Drill Pipe Platform and Top	2 x 12	14
4	Starting Legs	2 x 10	26
4	Short Starting Legs	2 x 10	18
42	Derrick Legs	2 x 10	16
8	Belt House, Forge House Stringers	2 x 8	20
11	Belt House and Outside Drill Pipe Platform	2 x 8	16
6	Belt House Stringers	2 x 6	26
8	Braces	2 x 6	24
16	Braces	2 x 6	22
8	Braces	2 x 6	20
20	Braces and Outside Drill Pipe Platform	2 x 6	18
6	Belt House and Bull Wheel Spools	2 x 6	16
8	Engine House and Crown Block Railing	2 x 6	16
5	Engine House Rafters	2 x 4	20
8	Outside Drill Pipe Platform	2 x 4	18
52	Engine and Belt House, Ladder, to cut up and Crown Block Railing	2 x 4	16
5	Belt House	2 x 4	12
160	Girts, Engine House Floor and Boards	1½ x 12	16
8	Braces	1½ x 6	16
16	Braces	1½ x 6	14
16	Braces	1½ x 6	12
30	Belt House Floor and Derrick Roof	1 x 12	20
10	Roof Boards	1 x 12	24
12	Roof Boards	1 x 12	22
75	Roof Boards	1 x 12	18
45	Roof Boards and Top	1 x 12	14
60	Housing and Boards	1 x 12	12
40	Ladder Strips, Roof Battens, etc.	1 x 6	16
32	Keys	2½ x 4—4 x 4 x 22	
	Hardwood		
1	Bull Wheel Shaft	16 x 16	16
1	Calf Wheel Shaft	16 x 16	6
1	Pitman	6 x 6 x 6 x 12	12
1	Top of Crown Block	5 x 6	16
1	Top of Crown Block	5 x 6	14
1	Top of Beam and Dog	3 x 14	16
	If Outside or Wind Braces are used, add the following:		
4	Outside Girts	2 x 12	24
8	Outside Girts	2 x 12	22
4	Outside Girts	2 x 12	18
4	Outside Girts	2 x 12	14
8	Outside Braces	2 x 8	28
8	Outside Braces	2 x 8	24
16	Outside Braces	2 x 8	22

SPECIFICATION OF MATERIAL REQUIRED TO BUILD A CALIFORNIA COMBINATION STANDARD AND ROTARY RIG, DERRICK 106 FEET HIGH WITH 24-FOOT BASE (Continued).

Pieces	Oregon Pine	Size, Inches	Length, Feet
8	Outside Braces	2 x 8	20
8	Outside Braces	2 x 8	16

Drawing shows derrick on concrete corners with 16 x 16 x 1½-foot posts between sills and concrete. If concrete is not used, add the following:

25	Footings (Redwood)	3 x 12	20

If galvanized corrugated iron is used for housing, deduct boards as follows:

120 Pieces 1½ x 12 x 16 feet, 60 1 x 12 x 18 feet, 60 1 x 12 x 12 feet.

Add 26 gauge corrugated iron:
125 sheets 26″ x 10 feet, 75 sheets 26″ x 8 feet.

Ideal Type Rig and Calf Iron Outfits.

		6-inch shaft	7½-inch shaft
1	Shaft with Crank, Writs Pin, 2 each Collars and Keys	7 6/12 feet	8 2/12 feet
1	Pair Flanges with Keys and Bolts.		
1	Set Center Irons Complete with Bolts.		
1	Stirrup	2½-inch	3-inch
2	Bull Wheel Gudgeons with Bands and Bolts.		
1	36-inch Crown Pulley.		
1	24-inch Sand Line Pulley.		
1	28-foot Brake Band	7-inch	8-inch
1	Brake Staple	7-inch	8-inch
1	Brake Lever	7-inch	8-inch
1	Jack Post Box, Closed.		
*1	Jack Post Plate	2″ x 6″ x 22″	2″ x 8″ x 30″
4	Turnbuckle Rods	1¼″ x 8 6/12′	1½″ x 10 8/12′
2	Jack Post Rods	1½″ x 8 4/12′	2″ x 9 10/12′
2	Eye Bolts, ⅞ x 22 inches.		
2	D. E. Bolts, ⅞-inch x 9 6/12 feet.		
1	D. E. Bolt, ⅞-inch x 8 feet.		
1	7-foot Sprocket Tug Rim with Bolts.		
1	42-inch Sprocket Wheel.		
1	Sprocket Clutch with Straps and Keys.		
1	Clutch Lever with Bolts.		
1	30-inch Flanged Calf Wheel Gudgeon with Band and Bolts.		
1	16-inch Calf Wheel Gudgeons with Band and Bolts.		
1	Calf Wheel Box.		
1	28-foot Brake Band	6-inch	7-inch
1	Brake Lever	6-inch	7-inch
1	Brake Staple	6-inch	7-inch
4	22-inch Casing Line Pulleys.		
2	Calf Wheel Box Eye Bolts	1½″ x 4-feet	
2	Calf Wheel Post Rods		2″ x 7 10/12′
1	Calf Wheel Box D. E. Bolt	1½ x 26-inches	
55	Feet No. 1030 Sprocket Chain.		
1	Sand Reel with Steel Plate Flanges	5-inch Shaft	
1	Dbl. Friction Sand Reel with Swing Lever Attachment		6-inch Shaft

*2 with 7½-inch outfit.

SPECIFICATION OF MATERIAL REQUIRED TO BUILD A CALIFORNIA COMBINATION STANDARD AND ROTARY RIG, DERRICK 106 FEET HIGH WITH 24-FOOT BASE (Continued).

Woodwork, Double Tug.

56 1-inch x 8-inch Plain Cants for 11-foot Band Wheel.
8 3-inch x 8-inch Plain Cants for 7-foot Tug Pulley.
16 3-inch x 8-inch Grooved Cants for 7-foot Tug Pulley.
24 1-inch x 8-inch Plain Cants for 7-foot Tug Pulley.
8 3-inch x 8-inch Plain Cants for 8-foot Bull Wheels.
16 3-inch x 8-inch Grooved Cants for 8-foot Bull Wheels.
80 1-inch x 8-inch Plain Cants for 8-foot Bull Wheels.
32 Lineal Feet 1½-inch Round O. P. for Bull Wheel Pins.
4 Pcs. 3-inch x 12-inch x 18-foot Select O. P. surfaced 4S. to 2⅝ x 11-inches for Bull Wheel Arms.
8 3-inch x 8-inch Plain Cants for 7½-foot Calf Wheels.
40 1-inch x 8-inch Plain Cants for 7½-foot Calf Wheels.
2 Pcs. 3-inch x 12-inch x 16-foot Select O. P. surfaced 4S. to 2⅝ x 11-inches for Calf Wheel Arms.

Nails, Bolts and Washers.

100 Pounds 60D Nails.
200 Pounds 30D Nails.
200 Pounds 20D Nails.
100 Pounds 16D Nails.
100 Pounds 10D Nails.

Machine Bolts	Where Used
24 ¾ x 12-inch	Band Wheel and Calf Wheel.
70 ¾ x 14-inch	Derrick.
24 ¾ x 16-inch	Derrick.
45 ¾ x 18-inch	Foundation.
8 ¾ x 20-inch	Band Wheel.
6 ¾ x 24-inch	Foundation.
4 ¾ x 26-inch	Foundation.
2 ¾ x 28-inch	Foundation.
4 ¾ x 34-inch	Foundation.
10 1 x 30-inch	Derrick.
1 1⅛-inch x 15 6/12-foot Dbl. End.	Derrick.
4 ⅞ x 28-inch Dbl. End.	

Washers.

200 Pounds ¾-inch Cast.
25 Pounds ¾-inch Wrought.
30 Pounds 1-inch Wrought.
2 Pounds 1⅛-inch Wrought.
50 Pounds Babbitt.
3 Pairs 6-inch Strap Hinges.
750 Feet ⅝-inch Galvanized Guy Wire.

Exact Length to Cut Girts and Braces.

First Girts 22 feet, 2 inches.
Second Girts 20 feet, 9¼ inches.
Third Girts 19 feet, 4½ inches.
Fourth Girts 17 feet, 11¾ inches.
Fifth Girts 16 feet, 6¾ inches.
Sixth Girts 15 feet, 2 inches.
Seventh Girts 13 feet, 9¼ inches.
Eighth Girts 12 feet, 4½ inches.
Ninth Girts 10 feet, 11¾ inches.
Tenth Girts 9 feet, 6¾ inches.
Eleventh Girts 8 feet, 2 inches.
Twelfth Girts 6 feet, 9¼ inches.
First Braces 23 feet.
Second Braces 21 feet, 9 inches.

SPECIFICATION OF MATERIAL REQUIRED TO BUILD A CALIFORNIA COMBINATION STANDARD AND ROTARY RIG, DERRICK 106 FEET HIGH WITH 24-FOOT BASE (Concluded).

Third Braces 20 feet, 5 inches.
Fourth Braces 19 feet.
Fifth Braces 17 feet, 8 inches.
Sixth Braces 16 feet, 6 inches.
Seventh Braces 15 feet, 1-inch.
Eighth Braces 13 feet, 10 inches.
Ninth Braces 12 feet, 8 inches.
Tenth Braces 11 feet, 6 inches.
Eleventh Braces 10 feet, 3 inches.

SPECIFICATIONS FOR COMBINATION CABLE AND ROTARY DRILLING OUTFITS.

Such an outfit would consist of a combination of any one of the complete cable outfits and rotary outfits, as specified on pages 80-96, 215-222, with the exception of the following equipment, which would be duplicated in combining the two outfits:

1 Rotary Derrick.

1 Boiler.

1 Sand Line.

The several sizes of casing elevators only (not the drill pipe elevators).

1 Casing or Drilling Hook.

The several sizes of bailers included with the rotary outfit.

1 Turbine Generator.

All of the blacksmith and miscellaneous tools and supplies duplicated in combining the two outfits.

Note: Two engines are required with a combination outfit, one to operate the cable tools and the other to drive the draw works and rotary.

CHAPTER VII

DRILLING BY THE HYDRAULIC CIRCULATING SYSTEM.* USE OF MUD LADEN FLUID

Combining, in a measure, the advantages of the cable and the rotary systems of drilling, the hydraulic circulating system is peculiarly adapted to the drilling of soft and caving formations, such as loose sand, boulders, etc., or alternating hard and soft formations, where a complete combination cable and rotary outfit may not be needed. Also by means of the circulating system it is possible to carry casing of large size to exceptional depths. In one instance 10-inch casing was carried to a depth of 3,336 feet in 122 days time. For this depth three or more strings of casing are usually required; the saving in expense for casing is, therefore, apparent.

By means of a circulating casing head, water impregnated with clay, otherwise known as mud laden fluid, is forced by slush pumps down inside the casing, during drilling with the cable tools, returning between the casing and the wall of the hole and carrying with it the cuttings and also any caving material that otherwise would tend to lodge against the casing and "freeze" it. Other advantages of this system are that caves and water and gas-bearing strata may be sealed off by the mud-laden fluid while drilling through them; and the casing is at all times maintained free to follow the drilling tools.

* References: U. S. Department of the Interior, Bureau of Mines technical papers:
No. 66 Mud Laden Fluid Applied to Well Drilling, by J. A. Pollard and A. G. Heggem.
No. 68 Drilling Wells in Oklahoma by the Mud Laden Fluid Method, by A. G. Heggem and J. A. Pollard.
No. 134 The Use of Mud Laden Fluid in Oil and Gas Wells, by J. O. Lewis and Wm. F. McMurray.
No. 163 Methods of Shutting Off Water in Oil and Gas Wells, by F. B. Tough.
Oil Well Supply Co. Circular, Hydraulic Circulating System.

H. B. Pearson, Superintendent of the Canadian Western Natural Gas, Light, Heat and Power Co., reports that two strings of casing, 10-inch and 8¼-inch, collapsed together in a well he was drilling in Alberta, Canada. Ordinarily this would result in the loss of the hole and of most of the casing, but by employing the circulating system he recovered both strings of casing and saved the hole.

Before building the derrick, sump holes should be dug on the side of the derrick location and the earth removed may be placed as a foundation for the engine and belt houses. These sump holes should be three in number and should be about four feet deep by twelve feet wide and twenty-four feet long. They should be connected by a sluice box provided with a gate to control the flow from the two outside sumps to the inner one. Diagram (Fig. 156) shows only two sumps of small size, but the sump capacity can be varied according to quantity of mud fluid required.

Heavy corner foundations should be laid for the derrick and the derrick mud sills should be about five feet above the ground, giving, in effect, a ten-foot cellar.

The derrick should be at least 88 feet high, with 20-foot base. The floor should be extended 6 feet on the ladder side to provide room for the pumps. The crown block should carry not less than four casing pulleys. Six-inch Ideal chain driven rig irons and calf wheel equipment are best for this purpose.

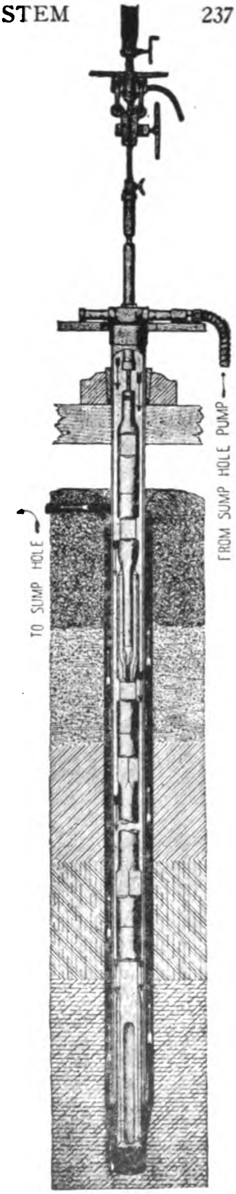


Fig. 153. Sectional View of operation (Oil Well Supply Co.)

The pump suction should be connected to the central sump, while the circulation returns should connect to one outside sump, and a trough under the derrick floor should convey the sand pumpings to the other outside sump, thus permitting the driller at all times to select the most suitable mud for circulation. A cellar about four feet deep and six feet square should be dug in the center of the derrick location and a joint of eight-inch pipe should be laid to drain from the bottom of the cellar to the sump hole. This drain pipe is recommended in preference to a ditch for it does not cut away or interfere with the stability of the derrick foundation.

Fig. 154. Interior View of Derrick.

Fig. 155. Interior View of Derrick.

In addition to the regular calf wheel rig, the circulating outfit consists of two pumps suitable for handling mud fluid, and a circulating head with hose connections to the pumps.

It is desirable to use two pumps in order that the circulation of fluid may not be interrupted by the necessity of stopping to repack or otherwise adjust them.

The most suitable pump is one made especially for this service, a heavy slush pump, having steam cylinder not less than 10 inches in diameter and 12-inch stroke.

The circulating head is a special casing head with a water inlet, closed at the top with a quick detachable oil saver. (See Fig. No. 157.)

Connection from the pumps to the circulating head is made by

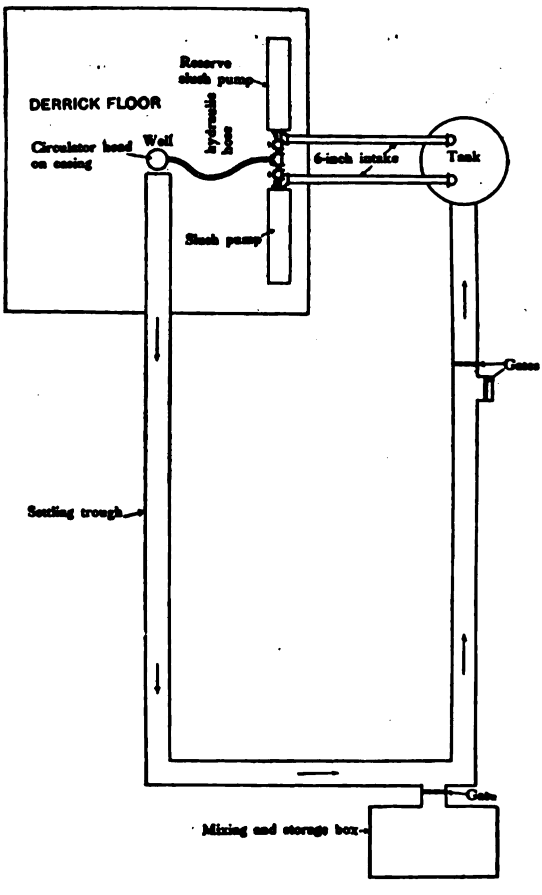


Fig. 156. Diagram of Sumps and Troughs for Mud Fluid.

means of special hydraulic hose, 2½ or 3 inches in diameter and reinforced to withstand collapsing under a vacuum, as well as to safely carry the maximum pressure delivered by the pumps.

After the surface casing is set, the hole should be drilled dry as far as possible, as this is the most rapid method of drilling and should be used wherever possible.

If gas is encountered in sufficient quantities to interfere with drilling, the hole may be filled with mud-laden fluid and by drilling and bailing, the hole may be carried down until the presence of gas or caving walls makes further progress hazardous, when casing may be inserted to five or six feet from the bottom and hung on elevators, or preferably a "spider," and the circulating head set up and connected to the pumps.

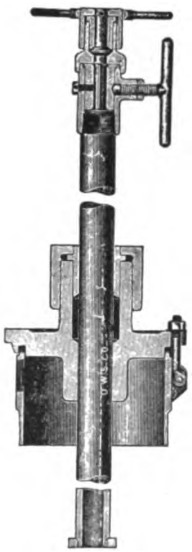


Fig. 157. "Oilwell" Circulating Head.

Mud-laden fluid is pumped down the inside of the casing and, returning on the outside, brings up all material loosened by the bit until the tools are so far below the casing that the drillings will not mix with the circulating fluid. The tools are then withdrawn and the drillings removed with the bailer.

At intervals, the hole is enlarged by underreaming and joints of casing added.

Sometimes the cuttings and fluid returning to the surface between the casing and the walls of the well may not be of sufficient volume to fill the space and the flow will take a course on one side of the casing, leaving the cuttings to settle and pack on the other side if the casing is not moved frequently. The passage of the mud fluid may be free and there may be no increase in the pump pressure, but the casing will be found to be stuck and in some cases impossible to move. If this occurs, the casing can usually be started by driving a few inches. If this does not free it, the customary methods of moving casing by jarring, the use of spears, jacks, etc., should be employed just as if there was no mud fluid in the hole.

All this can be prevented by moving the casing as occasion requires, and then the mud fluid will rise uniformly on all sides of the casing and the cuttings will have no chance to pack. In some cases it may be necessary to move the casing every thirty minutes.

Once circulation has been started, it should be maintained until the pipe is landed. Intermittent circulation frequently results in trouble.

The operator should closely watch the mud-laden fluid to be sure that:

It is a neat mixture of fine clay and fresh water. Salt water may be used, but it will not support the clay which rapidly settles out in the sump hole and requires much agitation to prevent the fluid from becoming too thin.

It is plastering the walls of the well and preventing the escape of gas or intrusion of salt water.

It is returning in the same volume that is delivered to the well.

If the mud-laden fluid is too thin, it will not only wash away the walls and cause caving, but may be lost in porous formations and allow the gas to blow out.

If the fluid is too thick, it will retard the action of the tools and may even cause the casing to stick or "freeze."

If gas or salt water is encountered in such volume as to interfere with good circulation, the outlet of the return fluid should be closed and mud pumped into the well until the troublesome stratum is completely sealed off by the clay thus forced into it.

While the circulating system has given good results in many wells, it is not equally well adapted to all fields and a careful consideration of drilling conditions should be given before it is adopted.

USE OF MUD LADEN FLUID

SHUTTING OFF GAS IN WELLS BY MUD-LADEN FLUID SYSTEM*

"Mud-laden fluid may be used to shut off water or gas and permit deeper drilling without the necessity of reducing the

* Extracts from article by Alfred G. Heggem in National Supply Co. catalogue.

diameter of the hole by casing, and the gas and water may be cased off by a single string of casing without danger of water entering the gas sand.

The inner string of casing should be anchored to prevent blowing out by gas pressure and the top should be equipped with a suitable valve that will permit the tools to readily pass through when open. The Control Casing Head is best suited for this service as it may be closed without withdrawing the tools, for it sometimes happens that the gas pressure is so great and the flow so strong, that it is unsafe to remove the tools until the gas has been "killed."

The careful operator will place an oil saver on the control casing head as soon as gas is encountered and connect one or more joints of lead line to the side outlet of the casing head to conduct the gas to a place of safety away from the rig. This permits the driller to remain at his post and continue drilling without danger or inconvenience.

When the gas sand has been drilled through or when the volume of gas is so great as to interfere with drilling, a "lubricator" may be set up in one corner of the derrick and connected to the lead line or to the side outlet of the casing head, and mud-laden fluid "lubricated" into the well without withdrawing the tools, although the operation would be the same if the tools were withdrawn.

The "Lubricator" (Fig. 158) consists of one or two joints of pipe or casing, preferably two joints of 10-inch. The top is reduced by a swaged nipple to a two or three-inch connection from which a corresponding size line of pipe is carried down to the derrick floor and closed with a valve.

The bottom of the "lubricator" should be higher than the casing head and closed with a "tee" set "bull head" across it. This "tee" should be not less than 5 3/16-inch and is better if the same size as the lead line. One outlet connects to the side outlet of the casing head and is fitted with a gate valve, while the other outlet connects to the pump discharge and has both a gate valve and a check valve. These latter valves should be about the size of the pump discharge. The gate valve is only required as a protection to the pump in case the check valve should fail to operate, and is normally left wide open.

The valve on the casing head is closed and the valve on the down pipe from the top of the lubricator is opened. The pump is started and the mud-laden fluid is forced into the lubricator until it shows at the outlet of the down pipe, when the outlet valve is closed and the pump automatically stops. The valve on the casing head is then opened and whatever gas pressure is in the well will be communicated to the "lubricator," and, owing to its great weight, the mud-laden fluid will flow into the well much the same as cylinder oil flows from a lubricator into the steam chest of a drilling engine. When the lubricator is empty, as is indicated by a clear ringing sound when struck lightly, the valve on the casing head is closed and the outlet valve is opened.

The gas which was displaced by the mud-laden fluid together with the mud that is in the down pipe will escape

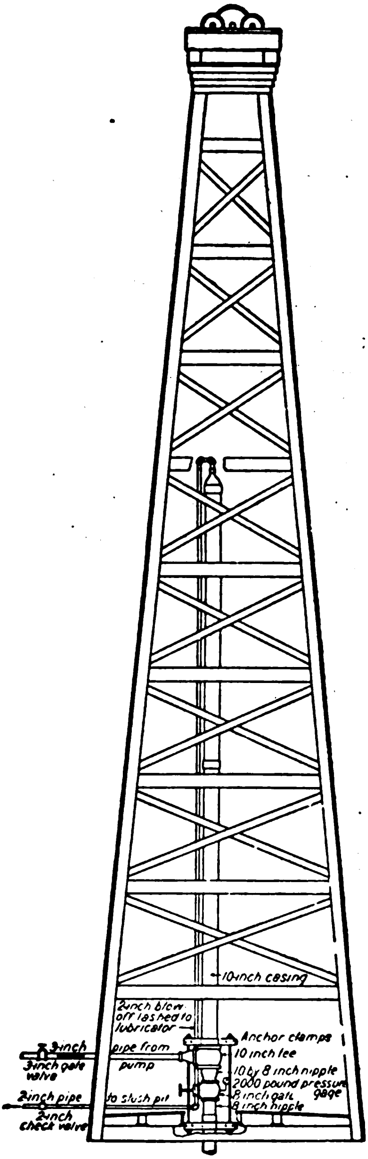


Fig. 158. Diagram of Lubricator set up in Derrick.

through the outlet valve and the pump will at once start and again fill the "lubricator" with mud-laden fluid. This process is repeated until the well is filled.

If the discharge pressure of the pump is greater than the gas pressure in the well, the mud-laden fluid will be pumped directly in as soon as the valve is opened. The outlet valve should be opened slightly to allow gas to escape while the mud-laden fluid is being pumped in direct, but not enough to allow the mud to blow out.

In some wells the pressure of the gas is greater than the pressure of the column of mud-laden fluid and it is then necessary to continue pumping until no more fluid can be forced into the well.

After the well has been "killed," drilling may be resumed without disconnecting any of the fittings and all danger of a blow out can be averted.

The following suggestions will be helpful:

Set each string of casing with a secure and water tight seat.

Keep the hole clean by frequent bailing.

Maintain the hole full of mud-laden fluid.

Do not attempt to drill out more than one screw nor more than 1½ hours without bailing.

If formation is "cavey" use smaller size bailer and run slowly in pulling out.

Case as soon as gas sand is passed and bail out mud-laden fluid from inside of casing and proceed with drilling in a dry hole.

In removing mud-laden fluid, bail slowly from the top and watch that the fluid does not break in from outside. Do not swab.

Do not close outlet valve until "lubricator" is filled, as will be indicated by the mud showing at outlet. If "lubricator" is not fully filled when the valve next to the casing head is opened, the pressure of the gas may force the fluid violently against the top of the lubricator causing a "water hammer" sufficient to break the connection."

DESCRIPTION OF MUD-LADEN FLUID.*

"Some oil workers have thought 'mud-laden fluid' implies the use of any of the drillings from the well, but this is not the case, for if the coarse materials in the drillings, such as sand, limestone fragments, etc., are left in the fluid they will settle and are likely to pack around the tools or the casing and cause serious troubles, specific instances of which are described in Bureau of Mines Technical Paper 68. The fine, sticky clays that are in many localities termed 'gumbo' are well suited for the purpose, but clay or shale from other formations may be used, provided it is separated from the sand and other coarse materials and only the part that will remain suspended in water is used. It is possible to use drillings from almost any formation containing clay or shale after proper treatment by settling.

CONSISTENCY OF FLUID TO BE USED.

"The consistency of the fluid should be varied according to the conditions for which it is to be employed. Most frequently mixtures with a specific gravity of 1.05 to 1.15 are used in drilling—that is, 5 to 15 per cent heavier than water. When the fluid is not used to drill in, thicker fluid is often employed, which has the advantages of greater weight and of clogging up the pores more readily. Experience soon enables the operator to judge the consistency of fluid required for practical uses.

"The operator who is unfamiliar with the use of mud-laden fluid is likely to use it too thin. This has been the cause of much trouble in Oklahoma. Such fluid acts like clear water. It will not clog the pores of the sand readily and hence will be forced into them for considerable distances, and in some instances near-by wells have been affected. It is also likely to cause caving and is injurious to the sand, or it may not have sufficient weight to overcome high-pressure gas. The only limit to the thickness of the fluid which it is possible to employ is whether or not it can be handled by the pumps, but it must be a fluid and not a pasty clay.

"An idea of the consistency ordinarily required can be obtained

* From U. S. Bureau of Mines Technical Paper No. 134, by James O. Lewis and Wm. F. McMurray.

by comparing the action of a stream of clear water with that of a stream of sand pumpings or muddy water running in a ditch. The sand pumpings contain clayey material which is deposited on the walls and especially the bottom of the ditch, where it forms an ever-thickening protective coating, whereas clear water cuts away the sides and bottom of the ditch and may cause it to cave. Between clear water and water containing more mud than it can hold in suspension, it is possible to find a mixture of clay and water that will deposit particles of clay as a fine protective coating, while the rest of the clay remains in suspension and passes through the ditch.

SETTLING OF MUD FLUID.

"An important consideration and one that has raised numerous inquiries is the amount of settling which a mud fluid will undergo. It is a well-known property of clays and similar colloidal materials that they will remain in suspension indefinitely. One sample of mud fluid has been standing for three years without appreciable settling and has not solidified. Numerous experiments conducted on short columns of fluid have shown that it will settle rapidly for a few hours, after which the rate of settling is very slow, and after a few days is practically nil. There is a surprising difference in what the maximum density may be. Of six samples collected from oil wells in southern California and allowed to settle two months, the variation was 10 to 30 per cent excess in weight over that of clear water. In each case the settled part was still fluid and not very viscous. It was also found that the final density in a short column of fluid is governed largely by the original density. For instance, two fluids were prepared by mixing the same kind of material in different proportions with water, one having a density 5 per cent greater than water and the other a density 15 per cent greater than water. The first settled to a much lighter consistency than the second.

"When the fluid settles in a short tube it separates into clear or turbid water at the top and mud fluid at the bottom. The specific gravity of the fluid at the bottom varies in the manner outlined above. The proportion of water to that of the fluid which settled out depends principally on the specific gravity of the original mud fluid, and the lighter the original fluid the greater is the proportion of water to the settled fluid in the bottom of the tube. Although the settling takes place quickly in a short tube, the same rate of settling applied to a long column of fluid in a well means that it takes a very long time for it to settle, and in fact there is reason to suspect that behind the casing complete settling does not take place even after long periods of time.

ACTION OF MUD FLUID ON POROUS FORMATIONS.

"The action of mud-laden fluid in a sand or other porous formation can be likened to the action of muddy water going through a filter. In any filter that has been used for some time it will be found that most of the sediment from the water has been deposited on the surface of the filter, but some of it has entered the filter, the proportion diminishing with the distance penetrated. The distance to which mud from the fluid in the well will penetrate a porous formation depends partly on the combined pressure produced by the column of fluid and the pump, and partly on the consistency of the fluid and the porosity of the formation. At first the fluid will enter the formation, but finally the mud will clog the pores and no more water will go through. Ordinarily, if a thick fluid is used on the sands encountered in the well, it will not penetrate to any great distance even under high pressure, but if the fluid is too thin it may not clog the pores readily and will act more like clear water, which may enter a sand indefinitely. Occasionally a very coarse sand, a fissured formation, or a porous limestone is found into which even thick fluid may penetrate for some distance.

"When no more fluid will enter the sand or porous formation a barrier or plug that is impervious to oil, gas, or water has been formed within the sand surrounding the hole. This plug is held in place partly by the resistance to movement of the mud deposited in the pores of the formation, but principally by the excess of pressure produced by the column of fluid in the hole. If the column of fluid is removed the pressure within the sand will usually force out the mud, and the oil, gas, or water will enter the hole again; but as long as a sufficient column of fluid remains in the hole the contents of the sealed formation can not enter the hole. It is believed that the efficiency in sealing off the porous formations in a well depends more upon the mud forced into the pores of the formation and retained by the weight of the column of fluid than upon the mud plastered on the walls of the hole, although the mud coating probably aids in protecting the walls from caving.

"When a well has been treated with mud fluid the contents of each formation is confined to its original stratum, so that there can be no movement of oil, water, or gas either from the sands into the well, from the well into the sands, or from one sand into another. Thus waste and intermingling are prevented, corrosive waters can not reach and attack the casing, and the strata are entirely sealed off from each other as they were before the well was drilled.

"Mud fluid, besides preventing caving, as stated above, is also an aid in keeping loose sands from entering the hole. The fluid clogs up all pores or crevices, and makes a solid wall which the weight of the fluid in the hole will hold up. Furthermore, the mud which has entered the formations, or is plastered on the walls, protects them from contact with air and water, which would cause slaking and caving. The fluid is especially helpful in drilling through a loose sand that otherwise would run into the hole and make drilling difficult.

"The mud-laden fluid may be prepared from clay obtained from surface deposits or from material derived from drillings. Ordinarily there will be enough clayey or shaley material in the formations encountered in the well to provide all the fluid necessary. This has been found true both in drilling with rotary tools and with cable tools. Drillings from sandstones and limestones should not be allowed to enter the slush pit. The mud fluid can be mixed and prepared in a few hours by ordinary unskilled labor whenever it is desired.

"Settling out sand, limestone cuttings, etc., in order to avoid freezing of casing and of tools, is important."

CHAPTER VIII

CASING METHODS—CASING USED IN VARIOUS FIELDS — COLLAPSING PRESSURES — SAFE LENGTHS OF STRING—CASING EQUIPMENT.

Casing (steel or iron pipe, usually with finer, or more, threads per inch than those used on ordinary pipe) is used in nearly all oil and gas wells for the following purposes:

Shutting off water.

Casing off running sand and caving formations.

Passing through caverns and workable coal measures and mines.

Shutting off intermediate oil or gas bearing strata when it is desired to drill deeper.

"Oil string" for casing through caving oil sands.

The shutting off of water is the chief and the most important purpose for which casing is used. The process consists of setting a string of casing in an impervious formation, preferably shale, at a point in the well below the lowest water bearing formation and above the oil or gas bearing sand, the object being to exclude the water from the productive sands.

The water in the stratified rocks presents many problems to the oil and gas operator, is the cause of much expense in drilling, and when careless or unintelligent methods of shutting it off are employed, may be a menace not only to his own property, but to the properties of his neighbors. Refer to Fig. 159.

In the early days of oil and gas development of the Eastern fields, scant attention was given to the casing of the well, perhaps largely for the reason that the problem in those fields was comparatively simple. The rock formations stood up and usually there were thick beds of hard impervious shale below water bearing formations to provide a tight seat for the casing. The casing was simply lowered in the reduced hole provided for it, perhaps driven a few inches to set it, and a few shovelsful of sand pumpings poured down outside to pack it.

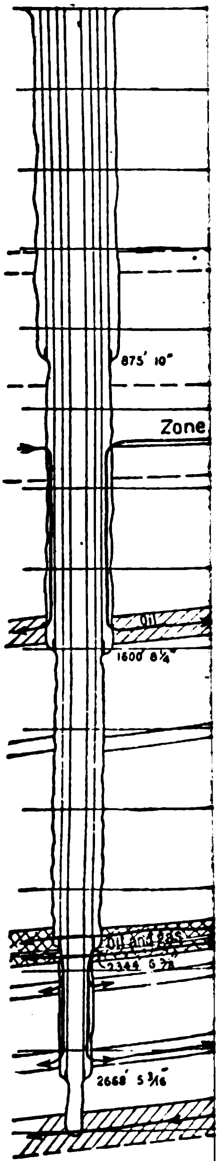
Casing shoes and packers were not used and collapsing pressures were considered only in a rule of thumb way. If the casing collapsed the operator put in another string, of heavier weight if he could secure it. Unquestionably many strings of casing have been put in wells in the fields of Eastern United States where the collapsing safety factor was much less than two and in some cases it was little more than one—that is practically nil.

The lighter weights of casing that served the purpose in the Appalachian fields were found totally inadequate for the long strings needed in the fields of California. Pipe manufacturers, to meet these requirements, began making better and heavier casing, until today we have 6¼-inch casing, for example, in varying weights of from twelve pounds to twenty-eight pounds per foot, the excess weight all being added to the inside, thus reducing the inside diameter of the heavier weights. This adds somewhat to the driller's problems when putting in smaller strings of casing within a next size larger or in running fishing tools.

The heavy California weights of casing have become standard in the fields of Wyoming, North Texas and in foreign fields.

Perhaps the first attempt to pack casing that could not be made tight was by means of the seed bag, a cotton bag of flaxseed or small grains which, when saturated with water, would expand and seal the bottom of the casing.

The several types of packer next were developed and they have come into general use in the fields where the rock formations are sufficiently hard to provide a firm support for the packer and where caving will not defeat its purpose. Now it is the custom in the fields of Kansas and Oklahoma to use a heavy casing shoe on the bottom of each of the outside strings of casing and a bottom hole packer or anchor packer


875' 10"
Zone
Oil
1600' 8¼"
Oil and gas
2344' 6⅝"
2668' 5 3/16"

on the inside, or water string. For more detailed description of the use of packers, refer to pages 291-300.

In some of the softer formations of California, Mid-continent and Gulf Coast fields, it was found difficult to case off gas sands that were passed through in drilling to lower depths for oil, and, after many hundred millions of feet of gas had been allowed to waste, the mud-laden fluid process, adapted from rotary drilling, was developed for mudding off gas sands to conserve the gas.* In these same fields the use of cement is becoming more general for thoroughly sealing the water string of casing from the encroachment of water on the oil sands.†

More attention has been given to the problems of casing of wells and to the conservation of oil and gas by correct well engineering methods by engineers and by the U. S. Bureau of Mines, and more has been written on these subjects than on any other phase of well drilling technology. To treat these subjects in an exhaustive manner, covering the different conditions in all of the oil and gas fields of this country would require a volume. The writer has, in the following pages, attempted briefly to outline the methods and equipment employed in the casing of wells and the exclusion of water from oil and gas sands in the principal fields of the United States.

The casing of wells in the Appalachian fields and in the shallower wells of the Kansas, Oklahoma and Wyoming fields is comparatively a simple matter. In these developed fields and where the formations are regular and the driller knows what to expect, it is necessary only to know the formation above the producing horizon where the lowest "break" or water bearing formation occurs and, in the next impervious stratum below that point, the casing is set. In Northern Ohio, for example, only one string of casing, usually

* Refer to use of mud-laden fluid, pages 241-248.

† U. S. Bureau of Mines Bulletin No. 163, Methods of Shutting Off Water in Oil and Gas Wells, by B. F. Tough.

400 to 500 feet of 6¼-inch, is necessary and it is set just below the Findlay break. The casing used in the early development of this field was 5⅝-inch ten-pound, somewhat light, and as the wells became older the casing in many of them rusted through, admitting water to the Trenton rock, the oil producing formation. Two methods were employed to shut off this water: where the hole was open outside the casing, many of these wells were cemented by the simple process of pouring cement down between the eight-inch hole and the casing; the other method was to set a second string of 4¼-inch casing with a packer extending below the leaky casing. The packer used for this was usually the Heinz cup packer (Fig. 160), a simple device consisting of a tube, the size of the inside casing, to which was fitted two leather cups, that packed in the outside casing or the wall of the hole below it.

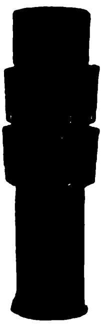


Fig. 160 Heinz Cup Packer.

Owing to the hardness of the formations in the Eastern fields, casing shoes are little used and packers are usually employed only when the casing cannot be made tight. Usually the casing is simply set in a hard shale and some sand pumping poured in outside of it as packing material. In the fields of West Virginia where long strings of casing are often necessary packers are more generally used than in the other parts of the Appalachian fields. In West Virginia, for the purpose of shutting off water or caving formations just above the deep producing sands, long liner strings of casing 3,000 feet or more, usually 5 3/16-inch, are sometimes necessary.

For much of the drilling in Oklahoma, two strings of casing only are needed, a short string of 8¼-inch and a string of 6⅝-inch, usually 17-pound, which is used as the water or caving string and is set a short distance above the producing formation. In the Cushing, Ponca, Garber and some parts of the Osage, deep sand fields of Oklahoma, much more casing is required, including larger sizes and longer and heavier strings. In the field of Eldorado, Kansas, the combination of sizes is 15½-inch, 12½, 10, 8¼, 6⅝-inch down to the liner string 5 3/16-inch.

In the fields of North Texas large quantities of casing are used. Many of the wells are commenced with 20-inch O. D. drive pipe and then, one within the other, 15½, 12½, 10, 8¼, 6¼ and in some cases a liner string of 4¾-inch are used.

The caving Cretaceous formations in the Wyoming fields also require much casing. In the Big Muddy and Lance Creek fields the wells are commenced with 15½-inch and finished with around 3,500 feet of 6⅝-inch 26 or 28-pound casing.

In the fields of California, the sizes and quantities of casing are many and varied. Several sizes of casing used in these fields, for example, 9⅝ and 7⅝-inch, are used in no other fields in the United States. In these fields also stove pipe casing is sometimes used in lieu of drive pipe or the regular casing for the first or outside string. The quantities used range from a few hundred feet of two sizes in some of the shallow wells to a combination consisting of 1,000 feet 15½-inch, 2,000 feet 12½-inch, 2,500 feet 10-inch, 3,500 feet 8¼-inch, 4,000 feet 6¼-inch, and, in emergencies, 4,200 feet or more of 4½-inch.

Each oil field has its own peculiar requirements of casing. In the more than 100 oil fields of the United States there are as many different combinations of sizes and length of string. In some fields where oil is produced from two or more sands, usually a different specification is used in drilling to each of the several sands. To record all of these specifications would require a small volume, and such a book has been published by the Oil Well Supply Co.* In the following pages is a selection of a number of typical specifications for casing as used in different fields of the United States, Canada and Mexico:

*"Useful Information—Pipe," Oil Well Supply Co., Pittsburgh, Pa.

PENNSYLVANIA

Butler *

Average depth of wells, 1,200 to 2,000 feet.

20 to 60 ft. 8¼-inch 17-lb.

500 to 700 ft. 6¼-inch 13-lb.

If water is encountered, it is necessary to use an additional string of 1,300 to 1,800 ft. of 5-inch 10-lb.

Washington *

Average depth of wells, 2,950 ft.

525 ft. 10 -inch 35-lb.

1,230 ft. 8¼-inch 24-lb.

1,600 ft. 6⅝-inch 17-lb.

2,600 ft. 5 3/16-inch 13-lb. or 17-lb.

OHIO

Northwestern Ohio

Average depth of wells, 1,250 to 1,500 ft.

20 to 80 ft. 8¼-inch 17-lb.

350 to 500 ft. 5⅝-inch 10½-lb. or 6¼-inch 13-lb.

Brink Haven, Knox County *

Average depth of wells, 2,975 ft.

30 ft. 10-inch 32½-lb.

700 ft. 8¼-inch 24-lb.

2,030 ft. 6⅝-inch 20-lb.

2,785 ft. 5 3/16-inch 17 lb.

200 ft. 4-inch flush liner.

Logan *

Average depth of wells about 3,000 ft.

20 to 80 ft. 8¼-inch 24-lb.

900 to 1,100 ft. 6⅝-inch 17-lb.

2,800 to 3,000 ft. 5 3/16-in. 17-lb.

200 ft. 4-inch flush joint liner.

Medina Co. Shallow

Average depth of wells, 475 ft.

20 to 40 ft. 8¼-inch 17-lb.

160 to 200 ft. 6¼-inch 13-lb.

Woodsfield *

Berea Grit Sand

Average depth of wells, 2,100 ft.

100 ft. 10-inch 32½-lb.

845 ft. 8¼-inch 24-lb.

1,500 ft. 6⅝-inch 17-lb.

Marietta *

Macksburg, Washington Co.

Average depth of wells, 1,400 ft.

200 ft. 8¼-inch 17½ lb. or 24-lb.

1,300 ft. 6¼-in. 13-lb. or 6⅝-in. 17-lb.

Cow Run, Washington Co.*

Average depth of wells, 400 ft.

150 ft. 8¼-inch 17½-lb.

350 ft. 6¼-inch 13-lb.

WEST VIRGINIA

Sistersville *

Average depth of wells, 1,600 to 2,200 ft.

75 to 400 ft. 10-inch 32½-lb.

400 to 1,100 ft. 8¼-inch 24-lb.

1,400 to 2,000 ft. 6⅝-inch 17-lb.

Note: In the shallow wells, 6¼-inch 13-lb is sometimes used in place of the 6⅝-inch.

Salem *

Average depth of wells, 3,000 ft.

300 ft. 10-inch 32½-lb.

1,500 ft. 8¼-inch 24-lb.

2,250 ft. 6⅝-inch 17 or 20-lb.

2,900 ft. 5 3/16-inch 13 or 17-lb.

Note.—Specifications designated by * from Oil Well Supply Co. book, "Useful Information, Pipe."

WEST VIRGINIA (Concluded)

Mannington *

Average depth of wells, 3,000 ft.

300 ft. 10-inch 32½-lb.
1,570 ft. 8¼-inch 24-lb.
2,365 ft. 6⅝-inch 17-lb.
2,800 ft. 5 3/16-inch 13-lb.

Charleston *
Roane County

Average depth of wells, 1,950 ft.

400 ft. 10-inch 32½-lb.
1,200 ft. 8¼-inch 24-lb.
1,800 to
1,900 ft. 6⅝-inch 17-lb.

Clarksburg *
2,800 ft. sand

Average depth of wells, 2,800 ft.

250 ft. 10-inch 32½-lb.
1,200 ft. 8¼-inch 24-lb.
1,800 ft. 6⅝-inch 17-lb.

In some cases an additional string of 2,600 ft. of 5 3/16-inch 13-lb. is used.

Charleston *
Cabin Creek District

Average depth of wells, 2,500 ft.

40 to 60 ft. 12½-in. 36½-lb.
300 to 700 ft. 10-in. 32½-lb.
1,200 to 1,400 ft. 8¼-in. 24-lb.
1,900 to 2,000 ft. 6⅝-in. 20-lb.

ILLINOIS

Casey *

Average depth of wells 450 to 600 feet.

20 to 30 ft. 10-in. 32½-lb.
80 to 140 ft. 8¼-inch 24-lb.
350 to 400 ft. 6¼-inch 13-lb.

Occasionally it it necessary to finish the deeper wells with an additional string of 350 to 400 ft. of 5-inch 10-lb.

Bridgeport *
Kirkwood Sand

Average depth of wells, 1,650 ft.

345 ft. 12½-inch 50-lb.
950 ft. 10-inch 32½-lb.
1,300 ft. 8¼-inch 24-lb.
1,450 ft. 6⅝-inch 17-lb.
1,580 ft. 5 3/16-inch 13-lb.

KENTUCKY

Winchester *
Lee County District

Average depth of wells, about 950 ft.

20 feet 8¼-inch 17½-lb.
125 to 450 ft. 6¼-inch 13-lb.

Some wells located on the cliffs are drilled to a depth of 1,150 ft.

Bowling Green
Scottsville

10 to 80 ft. 8¼-inch 17-lb.
60 to 400 ft. 6¼-inch 13-lb.
200 to 500 ft. 5 -inch 10-lb. for liner if needed.

Note.—Specifications designated by * from Oil Well Supply Co. book, "Useful Information, Pipe."

KANSAS

Chanute *

Average depth of wells, 1,100 ft.
20 to 30 ft. 10-inch 32½-lb.
250 to 350 ft. 8¼-inch 17½-lb.
750 to 1,100 ft. 6¼-inch 13-lb.

Augusta and Eldorado

40 ft. 20-inch O.D. 90-lb. Drive Pipe.
120 ft. 15½-inch 70-lb. Casing.
900 ft. 12½-inch 50-lb.
1,200 ft. 10-inch 35-lb.
1,800 ft. 8¼-inch 28-lb.
2,400 ft. 6⅝-inch 20-lb.
2,600 ft. 5 3/16-inch 17-lb.

Chautauqua, Elgin and Sedan Fields *

Average depth of wells, 1,600 ft.
40 ft. 10-inch 32½-lb.
500 ft. 8¼-inch 24-lb.
1,400 ft. 6⅝-inch 17-lb.

Paola *

Average depth of wells, 400 to 600 ft.
20 to 40 ft. 8¼-inch 17½-lb.
300 ft. 6¼-inch 13-lb.
400 to 500 ft. 5-inch 10-lb.

OKLAHOMA

Bartlesville District

60 ft. 8¼-inch 17½-lb.
1,150 to 1,250 ft. 6¼-inch 13-lb. or 6⅝-inch 17-lb.

Osage Country
Bartlesville District

750 ft. 8¼-inch 24-lb.
1,250 ft. to
1,900 ft. 6⅝-inch 17-lb or 20-lb.

Tulsa *
Glenn Sand

Average depth of wells, 1,650 to 1,700 ft.
20 to 50 ft. 10 in. 32½-lb.
250 to 300 ft. 8¼-inch 24-lb.
1,600 ft. 6⅝-inch 20-lb.

Cushing and Quay *

Average depth of wells, 3,100 to 3,200 ft.
400 to 600 ft. 15½-in. 70-lb.
900 to 1,200 ft. 12½-in. 50-lb.
1,600 to 1,800 ft. 10-in. 40-lb.
2,000 to 2,400 ft. 8¼-in. 28-lb.
2,500 to 3,000 ft. 6⅝-in. 24-lb.
3,000 to 3,150 ft. 5 3/16-in. 17-lb.

Drumright, Oilton and Shamrock *

Average depth of wells, 2,600 to 3,000 ft.
40 to 400 ft. 15½-in. 70-lb.
500 to 1,000 ft. 12½-in. 50-lb.
1,000 to 1,600 ft. 10-in. 35-lb.
1,100 to 1,800 ft. 8¼-in. 28-lb.
2,500 to 2,800 ft. 6⅝-in. 24-lb.
2,700 to 3,000 ft. 5 3/16-in. 17-lb.

Ponca City *
3,100 to 4,000-ft. Sand

20 to 60 ft. 20-in. O. D. 90-lb. Drive Pipe.
500 to 750 ft. 15½-in. 70-lb.
1,000 to 1,500 ft. 12½-in. 50-lb.
1,600 to 2,000 ft. 10-in. 40-lb.
2,400 to 2,800 ft. 8¼-in. 32-lb.
3,000 to 3,700 ft. 6⅝-in. 26-lb.
500 ft. 5 3/16-in. 17-lb. Liner.

Blackwell *
3,400-ft. Sand

60 ft. 15½-in. 70-lb.
750 ft. 12½-in. 50-lb.
2,200 ft. 10-in. 40-lb.
2,800 ft. 8¼-in. 32-lb.
3,350 ft. 6⅝-in. 26-lb.

OKLAHOMA (Concluded)

Cleveland *
Hominy Field—Osage

Average depth of wells, 1,900 to 2,100 ft.

150 ft. 12½-inch 50-lb.
400 ft. 10-inch 32½-lb.
800 ft. 8¼-inch 24-lb.
1,800 ft. 6⅝-inch 20-lb.

Okmulgee
2,000-ft. Sand

40 ft. 10-inch 32½-lb.
1,200 ft. 8¼-inch 24-lb.
1,900 ft. 6⅝-inch 17-lb.

3,000-ft. Sand

40 ft. 15½-inch 70-lb.
200 ft. 12½-inch 50-lb.
1,000 ft. 10-inch 35-lb.
2,400 ft. 8¼-inch 28-lb.
2,800 ft. 6⅝-inch 24-lb.

Walter *

Average depth of wells, 2,400 ft.

300 to 500 ft. 10-in. 35-lb.
1,200 to 1,600 ft. 8¼-in. 28-lb.
2,100 to 2,400 ft. 6⅝-in. 24-lb.
100 to 200 ft. 5 3/16-in. 17-lb. inserted joint liner.
(Combination System.)

Garber
2,300-ft. Sand

40 ft. 20-in. 90-lb. O. D. Drive Pipe.
600 ft. 15½-in. 70-lb. Casing.
1,100 ft. 12½-in. 50-lb.
1,400 ft. 10-in. 40 or 35-lb.
1,850 ft. 8¼-in. 28 or 32-lb.
2,150 ft. 6⅝-in. 24-lb.

Healdton *
1,100-ft. Sand

20 ft. 12½-in. 50-lb.
500 to 550 ft. 10-in. 40-lb.
900 ft. 8¼-in. 28-lb. or 32-lb.

Healdton *
2,200-ft. Sand

*350 to 400 ft. 15½-in. 70-lb.
*600 to 700 ft. 12½-in. 50-lb.
*1,200 to 1,300 ft. 10-in. 40-lb.
1,800 to 1,900 ft. 8¼-in. 32-lb.
2,100 ft. 6⅝-in. 24-lb.

* The 15½, 12½ and 10-in. casing is pulled after the well is drilled in.

LOUISIANA

Shreveport-Rotary System
2,500-ft. Sand

200 ft. 10-in. 32½-lb. Casing.
2,300 ft. 6-in. Line Pipe.
200-ft. 4½-in. 12.47-lb. Line Pipe (for liner).

TEXAS

Beaumont
1,500-ft. Sand

40 ft. 8-in. 25-lb. Line Pipe.
1,450 ft. 6-in. 19.5-lb. Line Pipe.

Wichita Falls *

Average depth of wells, 2,000 ft.
Cable Tool System.

100 ft. 12½-in. 36½-lb. or 50-lb.
750 ft. 10-in. 35 or 40-lb.
1,000 to 1,200 ft. 8¼-in. 28-lb.
1,500 to 2,000 ft. 6⅝-in. 20-lb.

Note.—Specifications designated by * from Oil Well Supply Co. book, "Useful Information, Pipe."

TEXAS (Concluded)

East Columbia

Average depth of wells, 3,000 to 3,150 ft.

600 to 800 ft. 10-in. 32½-lb. Line Pipe.

2,750 to 2,900 ft. 6-in. 19.5-lb. Line Pipe.

Houston District *

3,500-ft. Sand

100 to 150 ft. 12-in. 45-lb. or 12½-in. 45-lb.

2,100 to 2,200 ft. 8-in. 29-lb. Line Pipe.

3,100 to 3,250 ft. 6-in. 19.5-lb. Line Pipe.

Casing used in the deeper wells of the Ranger District in North Texas:

20 ft. 20-in. O. D. 90-lb. Drive Pipe.

250 ft. 15½-in. 70-lb. Casing.

700 ft. 12½-in. 50-lb.

1,500 ft. 10-in. 40-lb.

2,000 ft. 8¼-in. 28-lb.

3,200 ft. 6⅝-in. 24-lb.

4,000 ft. 4¾-in. 15-lb.

WYOMING

Rock River and Medicine Bow

40 ft. 20-in. O. D. 90-lb. Drive Pipe.

100 ft. 15½-in. 70-lb.

900 ft. 12½-in. 45-lb.

1,700 ft. 10-in. 40-lb.

2,300 ft. 8¼-in. 28-lb.

3,000 ft. 6⅝-in. 24-lb.

Big Muddy

40 ft. 20-in. O. D. 90-lb. Drive Pipe.

500 ft. 15½-in. 70-lb. Casing.

1,000 ft. 12½-in. 45-lb.

1,600 ft. 10-in. 40-lb.

2,000 ft. 8¼-in. 32-lb.

3,000 ft. 6¼-in. 26-lb.

Lance Creek

100 ft. 20-in. O. D. 90-lb. Drive Pipe.

1,000 ft. 15½-in. 70-lb. Casing.

1,500 ft. 12½-in. 45-lb.

2,000 ft. 10-in. 45-lb.

3,000 ft. 8¼-in. 32-lb.

3,700 ft. 6¼-in. 26-lb.

Salt Creek

100 ft. 15½-in. 52-lb.

500 ft. 12½-in. 45-lb.

1,000 ft. 10-in. 32-lb.

1,500 ft. 8¼-in. 24-lb.

2,000 ft. 6⅝-in. 20-lb.

Fremont Co.

40 ft. 15½-in. 52-lb.

300 ft. 12½-in. 36-lb.

800 ft. 10-in. 32-lb.

1,600 ft. 8¼-in. 24-lb.

Lost Soldier and Ferris

100 ft. 15½-in. 52½-lb.

600 ft. 12½-in. 45-lb.

1,800 ft. 10-in. 45-lb.

2,500 ft. 8¼-in. 28-lb.

3,200 ft. 6¼-in. 24-lb.

Warm Springs, Grass Creek, Elk Basin, Washakie and Big Horn Basin:

40 to 200 ft. 10-in. 32-lb.

600 to 800 ft. 8¼-in. 24-lb.

1,100 to 1,700 ft. 6⅝-in. 17-lb.

Note.—Specifications designated by * from Oil Well Supply Co. book, "Useful Information, Pipe."

MONTANA

Average depth, 3,500 to 4,000 ft.
60 ft. 20-in. O. D. 90-lb. Drive Pipe.
300 ft. 15½-in. 70-lb. Casing.
1,200 ft. 12½-in. 45-lb.
2,000 ft. 10-in. 40-lb.
3,000 ft. 8¼-in. 32-lb.
3,500 to 4,000 ft. 6¼-in. 26-lb.

CALIFORNIA

Los Angeles
Montebello Field
Cable Tool System—4,000-ft. sand

1,000 ft. 15½-in. 70-lb.
2,000 ft. 12½-in. 50-lb.
2,500 ft. 10-in. 50-lb.
3,500 ft. 8¼-in. 36-lb.
4,000 ft. 6¼-in. 26 or 28-lb.

Brea
3,700 ft.—Rotary System

200 ft. 20-in. 110-lb. Screw Casing or
200 ft. 20-in. Stove Pipe Casing.
3,000 ft. 10-in. 45-lb. Casing.
3,500 ft. 8¼-in. 32-lb. or 36-lb. Casing.

3,700 ft.—Cable System.

1,000 ft. 15½-in. 70-lb.
1,800 ft. 12½-in. 45 or 50-lb.
2,500 ft. 10-in. 40 or 45-lb.
3,500 ft. 8¼-in. 32 or 36-lb.
4,000 ft. 6¼-in. 26 or 28-lb.

Maricopa
Cable Tool System—1,400-ft. sand

350 ft. 12½-in. 40-lb.
1,000 ft. 10-in. 40-lb.
1,350 ft. 8¼-in. 28-lb.

Combination System—4,100-ft. sand

250 ft. 15½-in. 70-lb. or 16-in. Stove Pipe Casing.
3,000 ft. 10-in. 45-lb.
3,400 ft. 8¼-in. 36-lb.
3,900 ft. 6¼-in. 26-lb. or 28-lb.
4,100 ft. 4¾-in. 15-lb.

Bakersfield
Kern River Field

650 ft. 11⅝-in. 31½-lb.
900 ft. 9⅝-in. 33-lb.
1,160 ft. 7⅝-in. 20-lb.

Coalinga
Shallow Cable System

500 ft. 10-in. 40-lb.
1,000 ft. 8¼-in. 28-lb.
1,500 ft. 6¼-in. 20-lb.
or
500 ft. 11⅝-in. 31½-lb.
1,000 ft. 9⅝-in. 22¾-lb.
1,500 ft. 7⅝-in. 16-lb.

4,000 ft.—Rotary System

3,500 to 4,000 ft. 10-in. 45-lb.
4,000 ft. 8¼-in. 36-lb.

McKittrick
Cable Tool System—4,400-ft. sand

750 ft. 12½-in. 40-lb.
3,500 ft. 10-in. 45-lb.
3,900 ft. 8¼-in. 36-lb.
4,400 ft. 6¼-in. 28-lb.

Orcutt
3,500 ft.—Cable System

1,250 ft. 12½-in. 40 or 45-lb.
2,000 ft. 10-in. 40 or 45-lb.
2,500 ft. 8¼-in. 32 or 36-lb.
3,000 to 3,500 ft. 6¼-in. 26-lb.

4,200 ft. sand

1,250 ft. 12½-in. 45-lb.
2,000 ft. 10-in. 40-lb.
2,500 to 3,500 ft. 8¼-in. 32 or 36-lb.
3,000 to 4,200 ft. 6¼-in. 26-lb.
4,000 to 4.200 ft. 4¾-in. 15-lb.

CANADA

Tilbury, Ontario

85 to 170 ft. 10-in. 32-lb.
220 to 300 ft. 8¼-in. 17½-lb.
740 to 900 ft. 6¼-in. 13-lb.

Viking and Okotoks, Alberta

150 ft. 18-in. O. D. 81-lb. Drive Pipe.
700 ft. 14-in. O. D. 56-lb. Drive Pipe.
1,600 ft. 10-in. 40-lb. Casing.
2,000 ft. 8¼-in. 32-lb. Casing.
2,250 ft. 6¼-in. 24-lb. Casing.

Dover, Ontario

90 to 100 ft. 12½-in. 50-lb.
280 to 300 ft. 10-in. 32-lb.
1,190 to 1,210 ft. 8¼-in. 24-lb.
2,700 to 2,880 ft. 6⅝-in. 24-lb.

Peace River, Alberta

60 ft. 20-in. O. D. 90-lb. Drive Pipe.
650 ft. 15½-in. 70-lb. Casing.
1,100 ft. 10-in. 40-lb.
1,250 ft. 8¼-in. 28-lb.
1,900 ft. 6¼-in. 20-lb.

MEXICO

Panuco Field

Average depth of wells, 2,000 ft.

Cable Tool System

200 ft. 12½-in. 40 or 45-lb.
850 ft. 10-in. 40 or 45-lb.
1,600 ft. 8¼-in. 32 or 36 lb.

Topila Field

Average depth of wells, 2,250 ft.

Cable Tool System

100 ft. 15½-in. 70-lb.
400 ft. 12½-in. 45 or 50-lb.
900 ft. 10-in. 40 or 45-lb.
2,150 ft. 8¼-in. 32 or 36-lb.

Some of the specifications here given include very long strings of certain weights of casing which, in the writer's opinion, exceed the limits of safety in accordance with tables on pages 266-269. It is common practice in several fields to use these specifications, however, and the information is recorded without the writer's recommendation that these specifications may be applicable to other districts where conditions are different.

COLLAPSING PRESSURES

The selection of the weight of casing to be used depends upon the drilling conditions which vary in different fields. It is always good practice to assume that the water to be cased off rises to the surface and to use casing of sufficient weight to withstand collapsing pressure of a water column equal to the length of the string of casing and preserve a safety factor of not less than two (see tables of collapsing pressures, pages 266-269). Also in casing off caving strata where the hole may be dry, it is difficult to estimate the crushing or collapsing force exerted against the casing by the caving material.

In a well where several long strings of casing are necessary and an inside string extended only a few hundred feet below the net size larger in a dry hole, it might be safe to use a lighter weight of casing for that part of the string above the bottom of the next larger size. Or in a well where the water should rise only half way or less, the entire string of casing could be of a lighter weight than where the water rose to the surface. However, in using casing of a weight lighter than shown in the collapsing pressure tables, the strain on the casing due to its own weight must be taken into account. The operator will have to consider all phases of the situation and choose a weight of casing that will afford a sufficient factor of safety to safeguard both the casing and the well.

Prof. R. T. Stewart, Dean of the Mechanical Engineering Department of the University of Pittsburgh, was authorized to plan and direct a series of experiments for the purpose of supplying reliable information on the behavior of wrought tubes when subjected to fluid collapsing pressure.* The work was carried out at the National Department of National Tube Co., at McKeesport, Pa.,† occupying the time of from one

* Stewart, R. T.—Collapsing pressure of Bessemer steel lap welded tubes, 3 to 10 inches in diameter:, Trans. Am. Soc. Mech. Eng., May, 1906, pp. 730-822.

† National Tube Co. Book of Standards.

to six men continuously for a period of four years. Quoting from Prof. Stewart's report:

"**Results of Research.**—The principal conclusions to be drawn from the results of the present research may be briefly stated as follows:

1. The length of tube, between transverse joints tending to hold it to a circular form, has no practical influence upon the collapsing pressure of a commercial lap-welded steel tube so long as this length is not less than about six diameters of tube.

2. The formulas, as based upon the present research, for the collapsing pressures of modern lap-welded Bessemer steel tubes, are as follows:

$$P \text{ equals } 86{,}670 \frac{t}{D} - 1{,}386 \ldots\ldots (B)$$

$$P \text{ equals } 50{,}210{,}000 \left(\frac{t}{D}\right)^3 \ldots\ldots (G)$$

Where P = collapsing pressure, pounds per square inch.
D = outside diameter of tube in inches.
t = thickness of wall in inches.

Formula B is for values of P greater than 581 pounds per square inch, or for values of t/D greater than 0.023, while formula G is for values less than these.

These formulas, while strictly correct for tubes that are 20 feet in length between transverse joints tending to hold them to a circular form, are, at the same time, substantially correct for all lengths greater than about six diameters. They have been tested for seven sizes, ranging from 3 to 10 inches outside diameter, in all obtainable commercial thicknesses of wall, and are known to be correct for this range."

"Not one of the several hundred tubes tested failed at a pressure lower than 42 per cent. less than the probable collapsing pressure, while 0.5 per cent. of the number of tubes failed at 37 per cent. and 2 per cent. at 25 per cent. less than that pressure. In other words, with an actual factor of safety of 1.75, * * * not one of the tubes tested would have failed.

"It would appear that:

1. For the most favorable practical conditions, namely, when the tube is subjected only to stress due to fluid pressure and only the most trivial loss could result from its failure, a factor of safety of 3 would appear sufficient.

2. When only a moderate amount of loss could result from failure, use a factor of 4.

"These recommendations by Stewart are absolutely sound engineering and if a safety factor of 3 were used in oil-well work some costly redrilling jobs or collapsed casing, causing long fishing jobs, might be avoided."*

From the writer's experience he is satisfied that many operators exceed the limits of safety in putting in long strings of casing and he has known not one but many instances of strings of casing having been used where the factor of safety was much less than two.

Based on Prof. Stewart's formula and the tables of collapsing pressures shown in the National Tube Company's Book of Standards, the writer has calculated the collapsing pressures and the safe length of column for well casing of the several kinds made by National Tube Company, with factors of safety of two, of three and of four, as shown in the tables on the following pages.

Example of application of these tables: Assume that it is necessary to put in a string of 3,000 feet of 6⅝-inch casing and a factor of safety of 3 is desired. Referring to tables we find that no weight of standard casing will answer for this service, so it will be necessary to use California D. B. X. Casing, 6⅝-inch, 30-pound, whose safe limit with safety factor of 3 is 2,965 feet.

* U. S. Bureau of Mines Bulletin No. 163, Methods of Shutting Off Water in Oil and Gas Wells, by B. F. Tough.

Table of Sizes, Weights, Mill Test Pressures and Collapsing Pressures of STANDARD WELL CASING, and Safe Length of Column with Various Factors of Safety.

Size, Inches	Weight per ft. Pounds	Diameters, Inches External	Diameters, Inches Internal	Thickness, Inches	Threads per Inch	Couplings Diameter, Inches	Couplings Length, Inches	Test Pressure Pounds	Collaps'g Pressure Lbs. per Sq. In.	Length of Column with Safety Factor 2	Length of Column with Safety Factor 3	Length of Column with Safety Factor 4
2	2.340	2.250	2.050	.100	14	2.714	2⅝	750	2466	2848	1898	1424
2¼	2.820	2.500	2.284	.108	14	2.964	2⅝	750	2358	2723	1815	1361
2½	3.250	2.750	2.524	.113	14	3.214	2⅞	750	2175	2512	1674	1256
2¾	3.650	3.000	2.768	.116	14	3.464	2⅞	750	1965	2269	1513	1135
3	4.100	3.250	3.010	.120	14	3.771	3⅛	750	1814	2095	1396	1047
3¼	4.600	3.500	3.250	.125	14	4.021	3⅛	750	1709	1973	1316	987
3½	5.100	3.750	3.492	.129	14	4.271	3⅛	750	1595	1842	1228	921
3¾	5.650	4.000	3.732	.134	14	4.521	3⅛	750	1517	1752	1168	876
4	6.200	4.250	3.974	.138	14	4.771	3⅝	750	1428	1649	1099	824
4¼	6.750	4.500	4.216	.142	14	5.021	3⅝	750	1349	1558	1038	779
4¼	9.500	4.500	4.090	.205	14	5.021	3⅝	900	2562	2958	1972	1479
4½	7.250	4.750	4.460	.145	14	5.271	3⅝	750	1260	1455	970	727
4½	9.500	4.750	4.364	.193	14	5.271	3⅝	900	2136	2467	1644	1233
4¾	8.000	5.000	4.696	.152	14	5.521	3⅝	750	1249	1442	962	721
5	8.500	5.250	4.944	.153	14	5.828	4⅛	750	1140	1316	878	658
5	10.000	5.250	4.886	.182	14 or 11½	5.828	4⅛	800	1619	1870	1246	935
5	13.000	5.250	4.768	.241	14 or 11½	5.800	4⅛	1000	2593	2994	1996	1497
5	16.000	5.250	4.648	.301	11½	5.800	4⅛	1200	3583	4137	2758	2069
5 3/16	9.000	5.500	5.192	.154	14	6.078	4⅛	750	1041	1202	801	601
5 3/16	13.000	5.500	5.044	.228	11½	6.050	4⅝	1000	2207	2548	1699	1274
5 3/16	17.000	5.500	4.892	.304	11½	6.155	5⅛	1200	3404	3931	2620	1965
5⅝	10.500	6.000	5.672	.164	14	6.664	4⅛	750	983	1135	757	568
5⅝	12.000	6.000	5.620	.190	11½	6.636	4⅛	800	1359	1569	1046	785
5⅝	14.000	6.000	5.552	.224	11½	6.636	4⅛	900	1850	2136	1424	1068
5⅝	17.000	6.000	5.450	.275	11½	6.636	4⅛	1000	2586	2986	1991	1493
6¼	12.000	6.625	6.287	.169	14	7.308	4⅝	750	825	953	635	476
6¼	13.000	6.625	6.255	.185	11½	7.280	5⅛	800	1034	1194	796	597
6¼	17.000	6.625	6.135	.245	11½	7.280	5⅛	1000	1819	2100	1400	1050
6¼	20.000	6.625	6.041	.292	11½	7.280	5⅝	1200	2434	2811	1874	1405
6¼	24.000	6.625	5.913	.356	11½	7.280	5⅝	1500	3271	3777	2518	1889
6⅝	13.000	7.000	6.652	.174	14	7.692	4⅝	750	768	887	591	443
•6⅝	17.000	7.000	6.538	.231	11½	7.664	4⅝	900	1474	1702	1135	851
6⅝	20.000	7.000	6.450	.275	10	7.699	6⅛	1000	2019	2331	1554	1166
6⅝	24.000	7.000	6.334	.333	10	7.699	6⅛	1200	2737	3161	2107	1580

• 6⅝-in. 17-lb. made also 10 thread, with couplings 7.642 O. D. and 5⅛ inches long.

Table of Sizes, Weights, Mill Test Pressures and Collapsing Pressures of STANDARD WELL CASING, and Safe Length of Column with Various Factors of Safety (Concluded).

Size, Inches	Weight per ft. Pounds	Diameters, Inches External	Diameters, Inches Internal	Thickness, Inches	Threads per Inch	Couplings Diameter, Inches	Couplings Length, Inches	Test Pressure Pounds	Collaps'g Pressure Lbs. per Sq. In.	Length of Column with Safety Factor 2	Length of Column with Safety Factor 3	Length of Column with Safety Factor 4
7¼	14.750	7.625	7.263	.181	14	8.317	4⅝	750	671	775	517	387
7⅝	16.000	8.000	7.628	.186	11½	8.788	5⅛	750	629	726	484	363
7⅝	20.000	8.000	7.528	.236	11½	8.788	5⅛	800	1171	1352	901	676
8¼	17.500	8.625	8.249	.188	11½	9.413	5⅛	750	520	600	400	300
8¼	20.000	8.625	8.191	.217	11½	9.413	5⅛	800	795	918	612	459
•8¼	24.000	8.625	8.097	.264	11½	9.413	5⅛	800	1267	1463	975	732
8¼	28.000	8.625	8.003	.311	8	9.358	6⅛	1200	1739	2008	1339	1004
8⅝	19.000	9.000	8.608	.196	11½	9.788	5⅛	750	519	599	400	300
9⅝	22.750	10.000	9.582	.209	11½	10.911	6⅛	750	458	529	353	264
10	32.515	10.750	10.192	.279	8	11.958	6⅝	800	863	997	664	498
10	35.000	10.750	10.146	.302	8	11.958	6⅝	900	1049	1211	808	606
10⅝	26.750	11.000	10.552	.224	11½	11.911	6⅛	750	424	490	326	245
11⅝	31.500	12.000	11.514	.243	11½	12.911	6⅛	500	417	482	321	241
12½	36.500	13.000	12.482	.259	11½	14.025	6⅛	500	397	458	306	229
12½	45.000	13.000	12.356	.322	8	14.085	7⅛	700	760	878	585	439
12½	50.000	13.000	12.278	.361	8	14.085	7⅛	800	1020	1178	785	589
13½	42.000	14.000	13.448	.276	11½	15.139	6⅛	500	385	445	296	222
14½	47.500	15.000	14.418	.291	11½	16.263	6⅛	500	367	424	283	212
15½	52.500	16.000	15.396	.302	11½	17.263	6⅛	500	338	390	260	195

• 8¼-in. 24-lb. made also 8 threads per inch with couplings 9.358 inches diameter and 6⅛ inches long.

NOTE.—The figures in this table were checked by the Engineering Department of The National Tube Co., Pittsburgh, Pa.

The following table gives the depth of different pipe and casing threads:

8 threads per inch	.100 inch
10 threads per inch	.080 inch
11½ threads per inch	.0696 inch
12 threads per inch	.0667 inch
14 threads per inch	.0571 inch
18 threads per inch	.0444 inch
27 threads per inch	.0296 inch

Table of Sizes, Weights, Mill Test Pressures and Collapsing Pressures of CALIFORNIA D. B. X. CASING, and Safe Length of Column with Various Factors of Safety.

Size, Inches	Weight per ft. Pounds	Diameters, Inches External	Diameters, Inches Internal	Thickness, Inches	Threads per Inch	Couplings Diameter, Inches	Couplings Length, Inches	Test Pressure Pounds	Collaps'g Pressure Lbs. per Sq. In.	Length of Column with Safety Factor 2	Length of Column with Safety Factor 3	Length of Column with Safety Factor 4
4½	16.000	4.750	4.082	.334	10	5.364	6⅝	1800	4708	5436	3624	2718
4¾	12.850	5.000	4.500	.250	10	5.491	6⅝	1400	2948	3404	2269	1702
4¾	15.000	5.000	4.408	.296	10	5.491	6⅝	1700	3745	4324	2883	2162
5⅝	20.000	6.000	5.352	.324	10	6.765	7⅛	1500	3294	3804	2536	1902
6¼	20.000	6.625	6.049	.288*	10	7.390	7⅝	1400	2382	2751	1834	1375
6¼	24.000	6.625	5.921	.352	10	7.390	7⅝	1500	3219	3717	2478	1859
6¼	26.000	6.625	5.855	.385	10	7.390	7⅝	1600	3651	4216	2811	2108
6¼	28.000	6.625	5.791	.417	10	7.390	7⅝	1700	4069	4699	3132	2349
6⅝	20.000	7.000	6.456	.272	10	7.698	7⅝	1200	1982	2289	1526	1144
6⅝	24.000	7.000	6.336	.332	10	7.698	7⅝	1300	2725	3147	2098	1573
6⅝	26.000	7.000	6.276	.362	10	7.698	7⅝	1400	3096	3575	2383	1788
6⅝	28.000	7.000	6.214	.393	10	7.698	7⅝	1500	3480	4018	2679	2009
6⅝	30.000	7.000	6.154	.423	10	7.698	7⅝	1600	3851	4447	2965	2223
7⅝	26.000	8.000	7.386	.307	10	8.888	8⅛	1200	1940	2240	1493	1120
8¼	28.000	8.625	8.017	.304	10	9.627	8⅛	1000	1669	1927	1285	964
8¼	32.000	8.625	7.921	.352	10	9.627	8⅛	1100	2151	2484	1656	1242
8¼	36.000	8.625	7.825	.400	10	9.627	8⅛	1200	2633	3040	2027	1520
8¼	38.000	8.625	7.775	.425	10	9.627	8⅛	1300	2885	3331	2221	1666
8¼	43.000	8.625	7.651	.487	10	9.627	8⅛	1500	3508	4051	2701	2025
9⅝	33.000	10.000	9.384	.308	10	11.002	8⅛	1000	1283	1482	988	741
10	40.000	10.750	10.054	.348	10	11.866	8⅛	800	1420	1640	1093	820
10	45.000	10.750	9.960	.395	10	11.866	8⅛	900	1799	2077	1385	1039
10	48.000	10.750	9.902	.424	10	11.866	8⅛	1000	2032	2346	1564	1173
10	54.000	10.750	9.784	.483	10	11.866	8⅛	1200	2508	2896	1931	1448
11	47.000	11.750	11.000	.375	10	12.866	8⅛	900	1380	1594	1062	797
11	60.000	11.750	10.772	.489	10	12.866	8⅛	1200	2221	2565	1710	1282
11¾	40.000	12.000	11.384	.308	10	13.116	8⅛	800	839	969	646	484
12½	40.000	13.000	12.438	.281	10	14.116	8⅛	700	507	585	390	293
12½	45.000	13.000	12.360	.320	10	14.116	8⅛	800	747	863	575	431
12½	50.000	13.000	12.282	.359	10	14.116	8⅛	900	1007	1163	775	581
12½	54.000	13.000	12.220	.390	10	14.116	8⅛	1000	1214	1402	935	701
13½	50.000	14.000	13.344	.328	10	15.151	9⅛	800	646	746	497	373
15½	70.000	16.000	15.198	.401	10	17.477	9⅛	800	468	540	360	270

NOTE.—The figures in this table were checked by the Engineering Department of The National Tube Co., Pittsburgh, Pa.

Table of Sizes, Weights, Mill Test Pressures and Collapsing Pressures of INSERTED JOINT CASING, and Safe Length of Column with Various Factors of Safety.

Size, Inches	Weight per ft. Pounds	Diameters, Inches External	Diameters, Inches Internal	Thickness, Inches	Threads per Inch	Joint Length, Inches	Joint Diameter, Inches	Test Pressure Pounds	Collaps'g Pressure Lbs. per Sq. In.	Length of Column with Safety Factor 2	Length of Column with Safety Factor 3	Length of Column with Safety Factor 4
2	2.296	2.250	2.050	.100	14	.967	2.340	750	2466	2848	1898	1424
2¼	2.759	2.500	2.284	.108	14	.992	2.606	750	2358	2723	1815	1361
2½	3.182	2.750	2.524	.113	14	1.017	2.866	750	2175	2512	1674	1256
2¾	3.572	3.000	2.768	.116	14	1.042	3.122	750	1965	2269	1513	1135
3	4.011	3.250	3.010	.120	14	1.067	3.380	750	1814	2095	1396	1047
3¼	4.505	3.500	3.250	.125	14	1.092	3.640	750	1709	1973	1316	987
3½	4.988	3.750	3.492	.129	14	1.117	3.898	750	1595	1842	1228	921
3¾	5.532	4.000	3.732	.134	14	1.142	4.158	750	1517	1752	1168	876
4	6.060	4.250	3.974	.138	14	1.167	4.416	750	1428	1649	1099	824
4¼	6.609	4.500	4.216	.142	14	1.192	4.674	750	1349	1558	1038	779
4½	7.131	4.750	4.460	.145	14	1.217	4.930	750	1260	1455	970	727
4¾	7.870	5.000	4.696	.152	14	1.242	5.194	750	1249	1442	962	721
5	8.328	5.250	4.944	.153	14	1.267	5.446	750	1140	1316	878	658
5 3/16	8.792	5.500	5.192	.154	14	1.292	5.698	750	1041	1202	801	601
5⅝	10.222	6.000	5.672	.164	14	1.342	6.218	750	983	1135	757	568
6¼	11.652	6.625	6.287	.169	14	1.405	6.853	750	825	953	635	476
6⅝	12.685	7.000	6.652	.174	14	1.442	7.238	750	768	887	591	443
7¼	14.390	7.625	7.263	.181	14	1.505	7.877	750	671	775	517	387
7⅝	15.522	8.000	7.628	.186	11½	1.573	8.238	750	629	726	484	363
8¼	16.940	8.625	8.249	.188	11½	1.636	8.867	750	520	600	400	300
8⅝	18.429	9.000	8.608	.196	11½	1.673	9.258	750	519	599	400	300
9⅝	21.855	10.000	9.582	.209	11½	1.773	10.284	750	458	529	353	264
10¾	25.780	11.000	10.552	.224	11½	1.873	11.314	750	424	490	326	245
11¾	30.512	12.000	11.514	.243	11½	1.973	12.352	500	417	482	321	241
12½	35.243	13.000	12.482	.259	11½	2.073	13.384	500	397	458	306	229
13½	40.454	14.000	13.448	.276	11½	2.173	14.418	500	385	445	296	222
14½	45.714	15.000	14.418	.291	11½	2.273	15.448	500	367	424	283	212
15½	50.632	16.000	15.396	.302	11½	2.373	16.470	500	338	390	260	195

NOTE.—The figures in this table were checked by the Engineering Department of The National Tube Co., Pittsburgh, Pa.

It is difficult to formulate any rules for the size, kind or quantity of casing that should be used in any new field, and indeed, conditions are sometimes met in developed fields that necessitate the changing of the usual combinations of casing for that locality or adding an additional string of casing. In fields where the formations stand up, and a stratum carrying water should be encountered below the point where the casing had been set, it is customary to pull the casing and ream the hole down past the lower water and reset the casing. In drilling soft or caving formations, where it is necessary to underream the casing and carry it down, a point usually is reached where it is difficult or impracticable to carry the casing further, or the formation might cave against it, freezing it. Thus it becomes necessary in deep wells to use string after string of casing until the well is completed.

In a developed field or in one where several wells have been drilled it can usually be determined how many strings of casing are required, also the size and the approximate length of each string. In a new territory or for a wildcat well, so called, the casing becomes a serious problem. It is wise, therefore, when drilling in unknown formations or in undeveloped territory to commence the well with at least one size larger drive pipe or casing than may seem necessary. Thus, if an extra string of casing should be required, it would still be possible to complete the well with the size casing it was originally intended to use. On the other hand, if after putting in the last or smallest size casing a cave or vein of water should necessitate a smaller size, it might be difficult to secure the smaller casing; it is certain drilling would be slow in the restricted hole, and it might be impossible to complete the well at all.

The following table may be helpful in determining the sizes of casing that should be used:

Sizes of Casing Under Known Conditions	Suggested Combination for Unknown Conditions	Sizes of Casing Under Known Conditions	Suggested Combination for Unknown Conditions
	10		15½
8	8¼	12½	12½
6⅝ or 6¼	6⅝	10	10
	5 3/16	8¼	8¼
		6⅝ or 6¼	6⅝
			5 3/16
	12½		20 O. D.
10	10	15½	15½
8¼	8¼	12½	12½
6⅝ or 6¼	6⅝	10	10
	5 3/16	8¼	8¼
		6⅝	6¼
			4¾

COMBINATIONS OF DRIVE PIPE AND CASING

Of late years, to meet the demand for casing of sufficient strength to withstand the strains of under reaming and repeated pulling, manufacturers have made heavier and still heavier casing. As this extra weight is added to the inside of the casing—the outside diameter always remaining the same—the consequent reduction of inside diameter must be taken into account when calculating the different sizes of casing to be put down one within the other in one well. For example, 6⅝-inch casing is usually used as the next size inside 8¼-inch regular 24 or 28-pound casing, but as the inside diameter of 8¼-inch 38-pound California D. B. X. casing is 7.775 inches, and the outside diameter of the coupling on 6⅝-inch casing is 7.698 inches, it is obvious that it would be unwise to use it inside the 8¼-inch, consequently it has become customary in California to use 6¼-inch casing as the next size inside the 8¼-inch. The chart showing dimensions of casing on page 272 will be useful as a guide to the correct sizes of casing to use.

Inserted joint casing never has been popular with operators in the United States, although it is extensively used in foreign fields. The advantage in using inserted joint casing is that, due to the absence of couplings, the sizes will fit more closely one within the other and it is possible to use one or more additional strings of casing within the limits of sizes provided by the coupled casing. The disadvantages are the difficulty of handling it and of securing it promptly, for usually it must be made to order. Elevators cannot be used for putting in inserted joint casing, for it would be liable to pull through the elevator. A spider with slips is used to hold it and a casing swivel, a device made of a casing nipple and a swivel, is used in lieu of the upper elevator. The operation of the swivel is, of course, much slower than the elevator, for the swivel must be screwed securely into each joint and then unscrewed.

It has become the custom in the fields of the Gulf Coast, where the rotary is exclusively used for drilling, to use line pipe for casing. Six-inch line pipe, threaded 8 threads per inch, is used as the inside string. This may have developed from the use of drill pipe, which is the same size and has the same threads as the line pipe. Also the elevators, tongs and fittings used about the well will fit both kinds of pipe.

For putting in casing more men are required than the two men, the driller and tool dresser, who comprise the drilling crew. For short strings or small size casing, contractors sometimes arrange for both the day and night crews, four men, to work together during the day putting in the casing. For long and heavy strings of casing seven men are sometimes employed, the driller to operate the rig; the tool dresser to maintain steam, assist on the derrick floor, etc.; one man, the "stabber," who stands on the end of the walking beam to guide the joint of casing as it is started in the coupling to prevent cross threading; two men to handle the tongs, spider and elevators on the derrick floor, and two men to handle the casing from where it is piled into the derrick.

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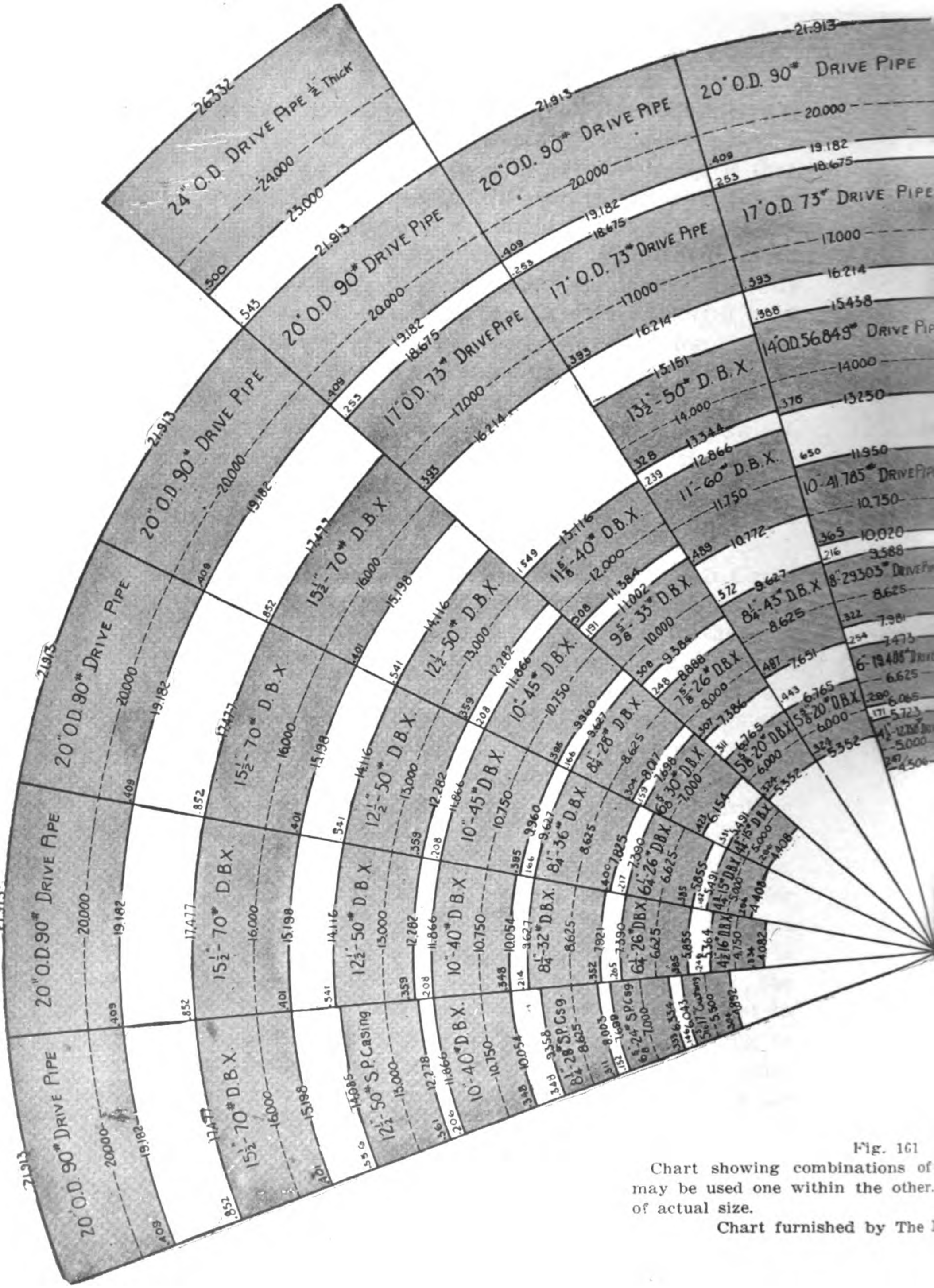
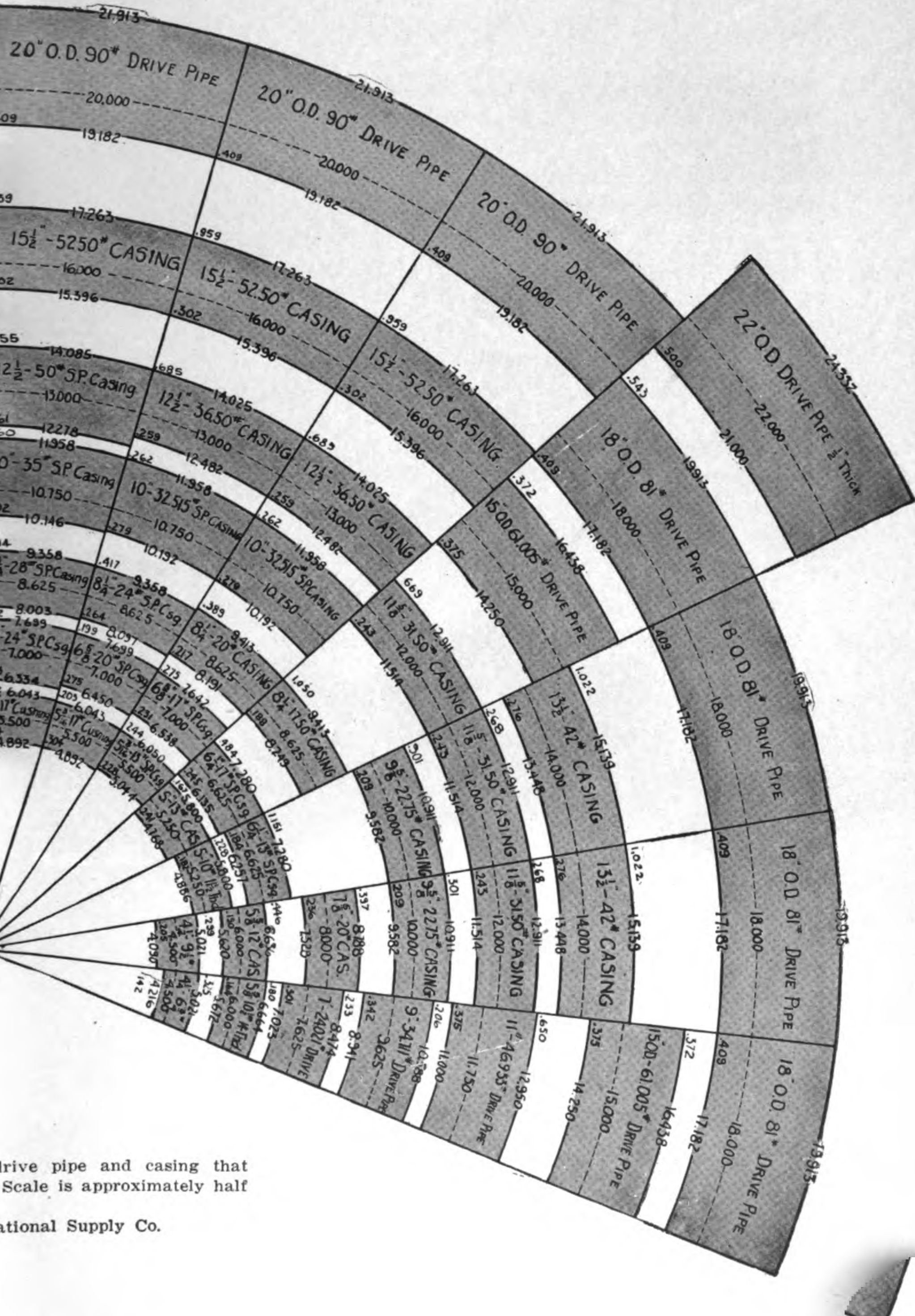


Fig. 161

Chart showing combinations of
may be used one within the other.
of actual size.

Chart furnished by The



drive pipe and casing that
Scale is approximately half

ational Supply Co.

In the deep fields of Oklahoma, Texas and Wyoming, it is customary to have casing crews, equipped for the work, put in the long strings of casing. These crews consist of about five men and they do all the work incident to handling the casing, except operating the boiler and engine, which is done by the driller and tool dresser.

USE OF SPIDERS AND SLIPS

When under reaming or handling long strings of casing, it is good practice to use, instead of the lower elevator, a spider and slips. This device will catch and hold the casing if it should slip or if a coupling should break or pull off. When putting in casing two men pull up and release the slips so the casing will pass through them. For convenience in handling the slips, each half of the set is wired together so that each man can pull up one-half of the slips when lowering the casing.

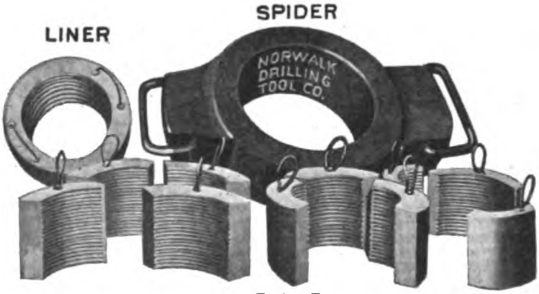


Fig. 162.

For handling long strings of casing, even though under reaming may not be necessary, it is a good idea to equip the rig with calf wheels. It is really unsafe to use the fast moving bull wheels for putting in long strings of casing. The calf wheels run much more slowly, they are designed for handling casing and are much better adapted for handling long and heavy strings of casing than the bull wheels.

The more lines used in handling casing, the slower is the operation, therefore some contractors use only two sheaves of the triple block and a light hook for putting in the first few hundred feet, and when the limit of safety is reached they string the third sheave and change to the heavier hook. It is customary in Texas, for the purpose of speeding up the casing operation, to fasten the dead end of the casing line to the calf wheel shaft, thus pulling on both ends of the line. After 2,000 feet of 6¼-inch casing have been put in, however, it is safer to attach the end of the line to the becket on the block.

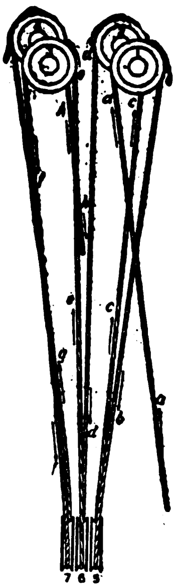


Fig. 163
Method of stringing casing blocks

STRINGING OF CASING BLOCKS*

There are several methods of stringing blocks for handling long strings of casing. The method most generally approved is shown in Figure 163. This method, it will be noted, is for the use of seven lines, but if only five lines are desired, pulleys 3 and 6 may be left unstrung, thus giving five lines.

A common error in stringing casing blocks is to bring the line direct from the calf wheel shaft to the initial pulley without the reversal noted in "a" and "b" over pulley 1. Without the reversal, the blocks are not in alignment with the hole, and the "starting" of pipe is made difficult. This causes a loss of time in handling casing and may even result in a joint of pipe being screwed in cross threaded, with the inevitable result—a parted string of casing.

Before screwing the joints of casing together, both the thread and the coupling should be carefully cleaned with a

* From U. S. Bureau of Mines Bulletin No. 182, "Casing Troubles and Fishing Methods in Oil Wells," by Thomas Curtin.

INTERIOR VIEW OF DERRICK

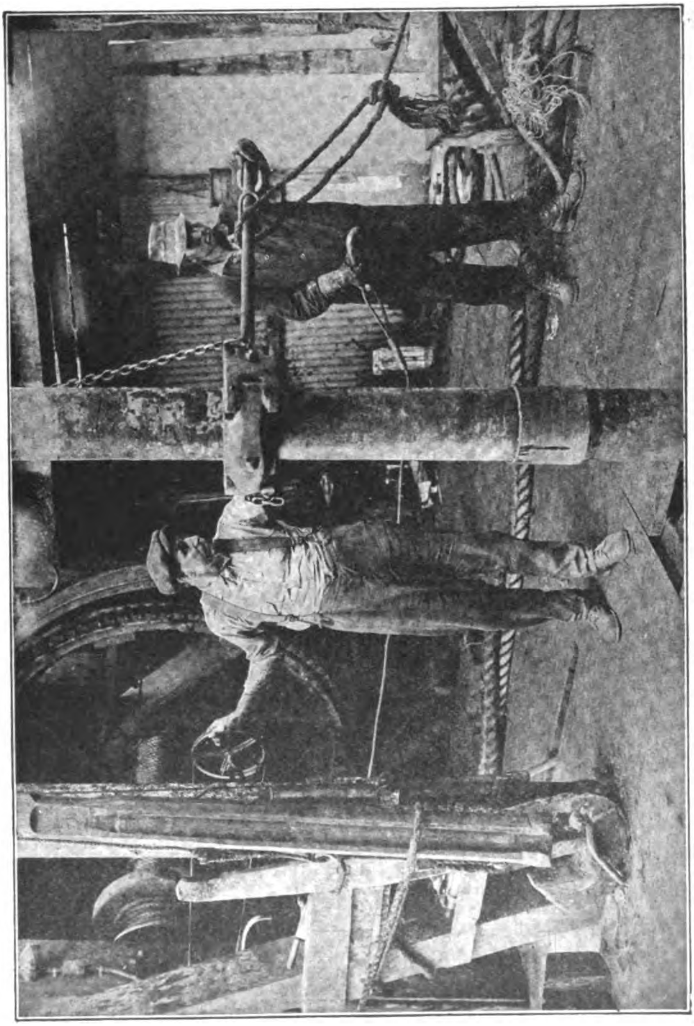


Fig. 164. Setting up Casing with Dunn Tongs and Engine

wire thread brush, and it is well to treat them with a mixture of white lead and tallow. Each thread should be screwed up as far as it will go to be sure the joint is tight. Joints are sometimes set up by power, using a jerk line from the band wheel crank to the handle of the tongs or pole. See Fig. 164.

When putting in casing, it is advisable to screw up the coupling on the mill end of each joint to be sure it is tight. Long strings of casing have been dropped due to a loose coupling stripping off.

After the casing has been set and the hole bailed dry, a casing tester should be lowered and allowed to remain for an hour to determine if the casing is tight. Should there be a leak, the tester is drawn up and allowed to remain at different points in the casing until the leak is found. The casing should then be pulled and the joint screwed tight if possible, otherwise another piece of casing should be substituted.

PUTTING IN CASING WITH A ROTARY OUTFIT

A rotary outfit is always prepared for putting in casing, for the reason that the casing can be handled with the same line, block, elevators, etc., that are used in drilling. If the rotary is equipped with slips of a size that will fit the casing, they may be used in lieu of the lower elevator. The casing is usually set up by engine power, utilizing the cat head on the draw works drive shaft. A Manila rope is attached to the end of the casing tongs and several turns taken around the cat head. The stroke is secured by alternately pulling in the slack of the line and looping it around the cat head.

If cavings or other obstruction should impede the lowering of the casing, it is spudded up and down and turned with the tongs until it is freed. When the casing has been landed on bottom, it is sometimes spudded a few times to work it into a good tight seat.

Should it be necessary to pull the casing, it is unjointed in "stands" of three or more joints, the same as drill pipe, and then stood in the derrick, thus much time is saved in replacing it.

In the Gulf Coast fields a liner is usually set from the bottom of the casing to the bottom of the well. That part of the liner which passes through the producing sand is perforated to admit the oil. In some wells a screen is used instead of the perforated part of the liner to exclude the floating sand. The liner is sometimes set with a lead seal to provide a tight connection with the bottom of the casing. Refer to chapter, Finishing the Well.

It is the practice in putting in long strings of casing in the fields of North Texas and of Wyoming to land the casing on bottom and then take a strain on it to take out the slack, as the drillers say. A string of 3,000 feet of casing can be pulled up 15 inches at the top before it clears the bottom. The casing is then hung on a heavy casing clamp which rests

Fig. 165. Casing Clamp

on the next larger size or, if it is intended to pull one or more of the strings, the clamp should have ears long enough to rest on the next larger size that is left in the hole. The casing then gradually settles to a permanent seat and the great strain of its own weight is distributed between the clamp at the top and the seat on bottom. Some operators use clamps on every string of casing, thus putting upon the larger sizes and shorter strings, part of the weight of the inside heavier strings.

It sometimes is feasible to pull out one or more of the outside strings of casing after the inside or water string has been permanently set or cemented, thereby effecting a considerable saving in the cost of casing, and, as under present conditions when there is a shortage of casing, facilitating further operations. For example, in the Ranger, Texas, field, the 15½, 12½ and 10-inch casing is sometimes pulled, leaving only the 8¼ and 6¼-inch strings in the well.

PERFORATING THE CASING

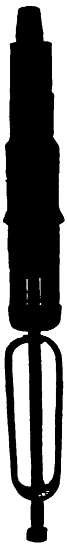


Fig. 166 Casing Perforator

Sometimes in the drilling of an oil or gas well a stratum containing a paying quantity of gas or oil may be encountered at a shallower depth than that at which the well is intended to be finished. Frequently this gas or oil is cased or packed or mudded off and recovered by drilling a shallower well close to the deep well.

However, it may be possible to save the gas or the oil by the process of perforating the casing, which will admit it to the well. For this purpose the tool shown in the illustration is used.

The tool is equipped with a brace or spring, which fits the casing. When the tool has been lowered to the point where it is desired to begin perforating, the perforator is set in the casing by pulling up on the tools, which trips the brace, so it will support the tool in the casing, while jarring. The perforating is then done by jarring down. The perforator is then pulled up a foot or more and the operation repeated and so on until sufficient perforations have been made to cover the oil producing sands.

In the fields of California it is common practice to finish the well with an oil string of casing, passing through oil sands that have a tendency to cave, and then to perforate the casing. Several casing perforators have been developed for this work, including single knife, double knife and revolving star-shaped wheel cutter types. This subject is further discussed in the chapter, "Finishing the Well," and it has been fully covered in a recent publication of the U. S. Bureau of Mines.*

CASING SHOES

It is customary in the deep fields of California, Wyoming and Mid-continent territory to use a casing shoe, similar to drive shoe (Fig. 36), on the bottom of each string of casing. The shoe serves a double purpose. It provides a sleeve or socket in which the lower joint of casing rests, thus protecting and supporting it. The bottom of the shoe is about twice the thickness of the casing and beveled, so that it works itself into a much better seat in the formation than could be secured with the unprotected casing.

Occasionally difficulty has been experienced by a casing shoe catching and hanging up in the coupling of the next larger size. To prevent this, a shoe guide, Figure 167, is sometimes used.

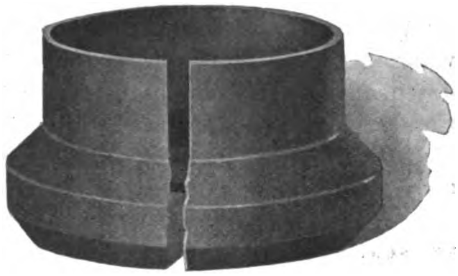


Fig. 167
Baker Shoe Guide

USE OF THE BULL HITCH FOR PULLING CASING

Pulling a string of casing that is fast in the hole is a difficult and sometimes dangerous operation, for it is impossible to know how severe a strain is put upon the rig and casing outfit.

* U. S. Bureau of Mines Technical Paper No. 247, Perforated Casing and Screen Pipe in Oil Wells, by E. W. Wagy.

A drawing was prepared by The National Supply Co. (Fig. 168), as a suggestion for a special outfit for using the bull hitch, which consists of two 40-ft. shear poles with a special stirrup at the top, two special 3-inch links to engage with the wings of the spider, special 50-inch single bull block, and a thimble to fasten the end of the bull line to engage the casing hook. This outfit contemplates the use of four casing pulleys and a quadruple traveling block, but the dead end of the casing line, instead of being fastened in the becket of the traveling block is made fast around one of the beams of the crown block.

As 18 x 18 x 40-ft. timbers would be almost impossible to secure, except through special order to the mill, the operator might be able to use two 32-ft. main sills for shear poles, which should give sufficient clearance to pull one 20-ft. joint of pipe.

A bull hitch can be rigged without the use of shear poles by placing an 18 x 18 square timber under the end of the walking beam, supported on an extra sill. The beam is let down until it rests on both the headache post and the extra timber. An endless wire deadline is then looped on the end of the beam, on which should be spiked a piece of hard wood to protect it from the cutting of the line. The deadline is then snatched into double block on the elevators and the end, or loop, is hooked into the casing hook on the traveling block, similar to the manner in which the spool and bull line are hooked in the accompanying illustration. By this means part of the pull is borne directly by the anchored walking beam and the two posts.

By the use of the walking beam it would be impossible to clear a full 20-ft. joint of casing unless the derrick is equipped with a cellar at least ten feet deep. In most cases, however, the bull hitch is used, not for pulling the casing, but for simply starting it when it is fast, after which it can be pulled in the regular way.

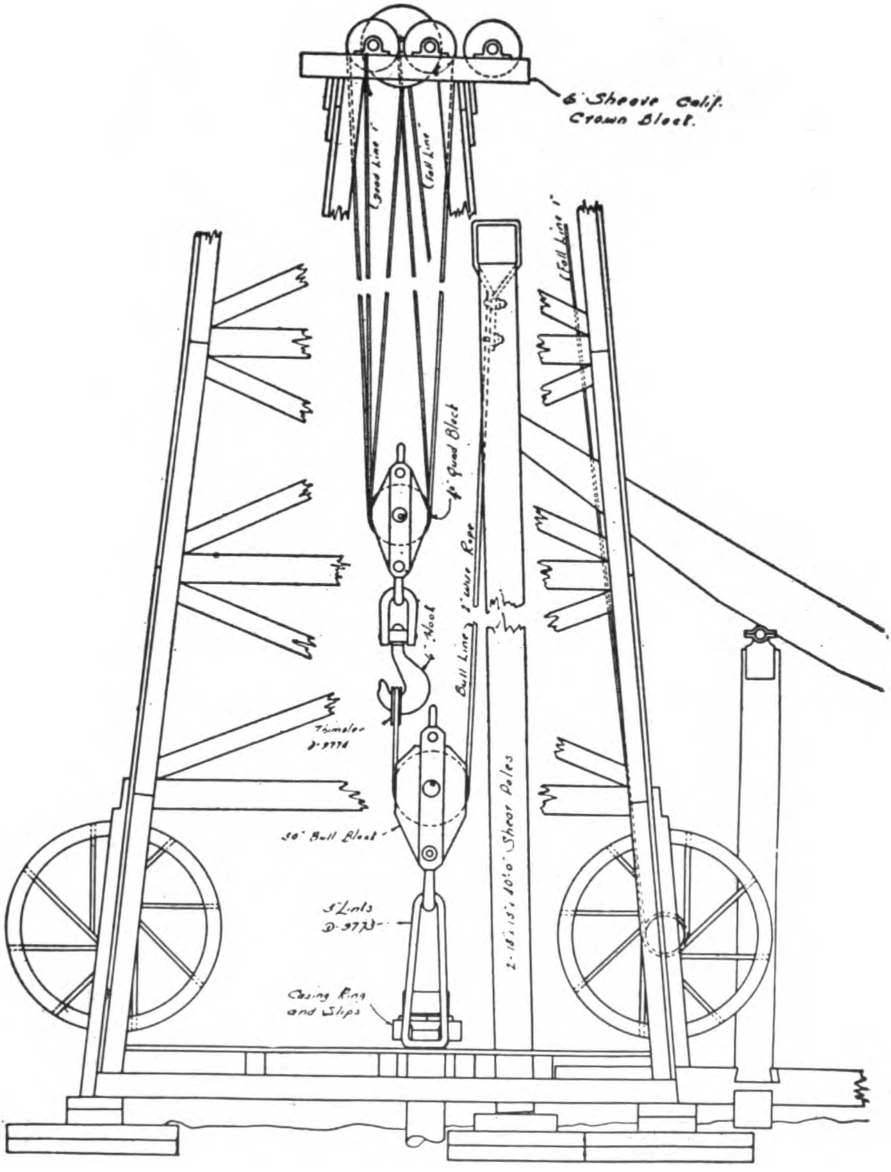


Fig. 168. Diagram of Bull Hitch Assembly (National Supply Co.)

TRUEING UP THE DERRICK

Before attempting a hard pull on casing or putting in a long and heavy string, a rig builder should be called to examine the derrick. It may be found to be out of plumb, or one of the legs might be weak. Such a derrick should be corrected before subjecting it to a severe strain.

CASING EQUIPMENT

The outfit for putting in casing should be carefully selected and of sufficient strength to handle safety the weight of the casing to be used. Particular attention should be given to the elevators. For short strings of casing the regular pattern elevators will answer, but for long strings the extra heavy Mannington pattern elevators should be used. For long

Fig. 169
Triple Block

Fig. 170
Casing Hook

Fig. 171
Wilson Elevators

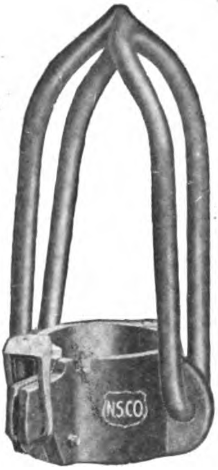


Fig. 172
Fairs Elevators

Fig. 174
O. W. S. Co. Double
Gate Elevators

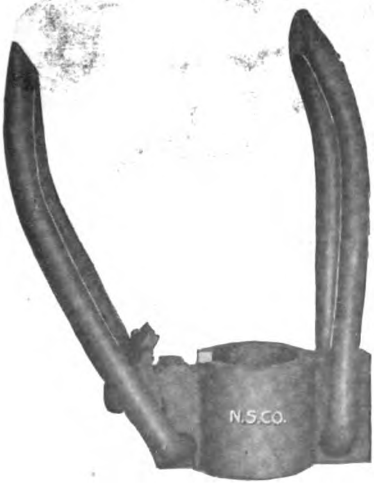


Fig. 173
Scott's Elevators

strings of casing the Scott type of elevators are the safer, for the reason that when the links are drawn up in use they keep the latch securely closed. For extremely long and heavy strings of casing Wilson Extra Heavy Spring Latch Elevators (Fig. 171), or Oil Well Supply Co. Double Gate Elevators (Fig. 174), or Lucey Company Rex Side Gate Elevators (Fig. 138) are recommended. Elevators should be carefully examined to be sure they are not too loose from wear. When a long string of casing slips through the elevators it will result either in a serious fishing job, the damaging of the casing, or loss of the well and the casing also.

On the following pages are typical specifications for casing outfits to handle strings of casing of varying length and weight.

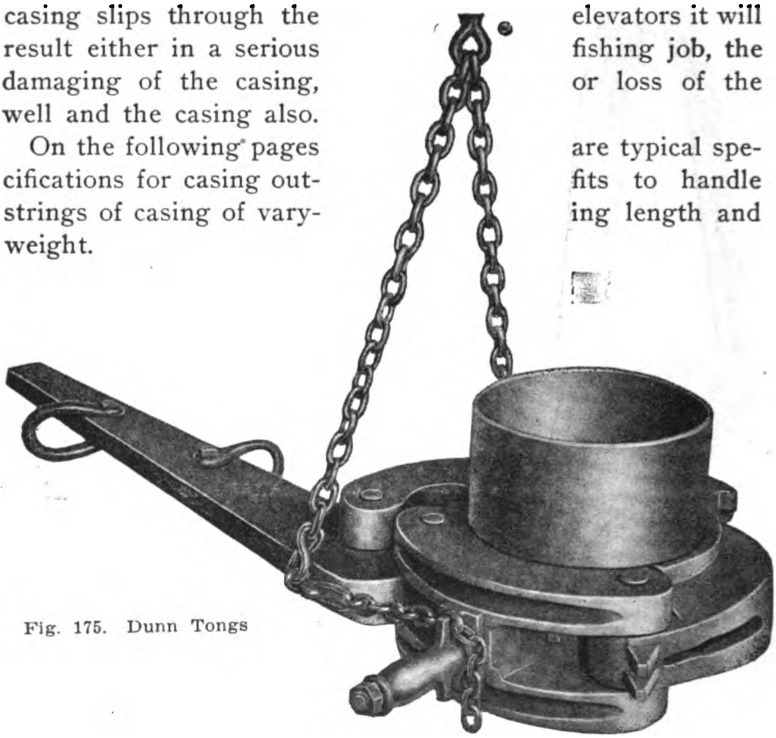


Fig. 175. Dunn Tongs

SPECIFICATIONS FOR CASING OUTFITS

For not more than 500 feet 13-pound casing or equal weight:

*300 feet ⅝-inch 6 x 19 Steel Wire Casing Line.
1 20 or 22-inch Single Steel Block—2 lines.
1 1¼-inch Casing Hook.
1 Set Fair's Malleable Iron Elevators for each size.
1 Casing Pole with rope sling and Neverslip Grip.

*** For putting in light strings of casing the drilling cable is often used in lieu of a casing line.**

SPECIFICATIONS FOR CASING OUTFITS (Continued)

For not more than 750 feet 13-pound casing or equal weight:

300 feet ⅝-inch 6 x 19 Steel Wire Casing Line.
1 24-inch Single Steel Block—2 lines.
1 2¼-inch Casing Hook.
1 Set Fair's Regular Wrought Iron Elevators for each size.
1 Casing Pole with rope sling and Neverslip Grip.

For not more than 1,200 feet 13-pound casing or equal weight:

450 feet ⅝-inch 6 x 19 Steel Wire Casing Line.
1 24-inch Single Casing Block) 4 lines.
1 24-inch Double Casing Block)
1 ⅞-inch 40-foot Endless Wire Dead Line.
1 3-inch Casing Hook.
1 Set Fair's Regular Wrought Iron Elevators for each size.
1 Casing Pole with rope sling and Neverslip Grip.

For not more than 1,500 feet 17-pound casing or equal weight:

450 feet ¾-inch 6 x 19 Steel Wire Casing Line.
1 26-inch Single Casing Block) 4 lines.
1 26-inch Double Casing Block)
1 1-inch 40-foot Endless Wire Dead Line.
1 3½-inch Casing Hook.
1 Set Fair's Regular Wrought Iron Elevators for each size.
1 Casing Pole with rope sling and Neverslip Grip.

For not more than 2,000 feet 17-pound casing or equal weight:

600 feet ¾-inch 6 x 19 Steel Wire Casing Line.
1 26-inch Double Casing Block) 6 lines.
1 26-inch Triple Casing Block)
1 1⅛-inch 40-foot Endless Wire Dead Line.
1 4-inch Casing Hook.
1 Set Scott's Extra Heavy Elevators for each size.
1 Casing Pole with rope sling and Neverslip Grip.
1 Chain Tongs.

For not more than 2,300 feet 20-pound casing or equal weight:

600 feet ⅞-inch 6 x 19 Steel Wire Casing Line.

SPECIFICATIONS FOR CASING OUTFITS (Continued)

1 28-inch Double Casing Block) 6 lines.
1 28-inch Triple Casing Block)
1 1¼-inch by 40-foot Endless Wire Dead Line.
1 4½-inch Casing Hook.
1 Set Scott's Extra Heavy Elevators for each size.
1 Casing Pole with rope sling and Neverslip Grip.
1 Chain Tongs.

For not more than 2,500 feet 24-pound casing or equal weight:

600 feet 1-inch 6 x 19 Steel Wire Casing Line.
1 32-inch Double Casing Block) 6 lines.
1 32-inch Triple Casing Block)
1 1½-inch by 40-foot Endless Wire Dead Line.
1 5-inch Casing Hook.
1 Set Wilson, Dunn, Union Single Link, or Oil Well Supply Co. or Lucey Side Gate Elevators for each size.
1 Casing Pole with rope sling and Neverslip Grip.
1 Dunn or Guiberson Tongs.

For not more than 3,000 feet 26-pound casing or equal weight: *

800 feet 1-inch 6 x 19 Steel Wire Casing Line.
1 32-inch Triple Casing Block) 7 lines
1 Calf Wheel Outfit with 4 Casing Pulleys)
1 5½-inch Casing Hook.
1 Set Wilson or Dunn Extra Heavy, Union Single Link or Oil Well Supply Co. or Lucey Side Gate Elevators.
1 Casing Pole with rope sling and Neverslip Grip.
1 Dunn or Guiberson Tongs.
1 Spider with slips for all sizes of casing used.

For not more than 3,500 feet 28-pound casing or equal weight: *

800 feet 1⅛-inch 6 x 19 Steel Wire Casing Line.
1 36-inch Triple Casing Block) 7 lines.
1 Calf Wheel Outfit with 4 Casing Pulleys)
1 6½-inch Casing Hook.
1 Set Wilson or Dunn Extra Heavy, Union Single Link, Oil Well Supply Co. or Lucey Side Gate Elevators for each size.
1 Casing Pole with rope sling and Neverslip Grip.
1 Dunn or Guiberson Tongs.
1 Spider with slips for all sizes of casing used.

SPECIFICATIONS FOR CASING OUTFITS (Concluded)

For not more than 4,000 feet 30-pound casing or equal weight: *

1000 feet 1⅛-inch 6 x 19 Steel Wire Casing Line.
- 1 36-inch Quadruple Casing Block or 1 each Single and Triple Blocks — 9 lines.
- 1 Calf Wheel Outfit with 4 Casing Pulleys and using also the Crown Pulley
- 1 7½-inch Casing Hook.
- 1 Set Wilson or Dunn Extra Heavy, Union Single Link, or Oil Well Supply Co. or Lucey Side Gate Elevators for each size.
- 1 Casing Pole with rope sling and Neverslip Grip.
- 1 Dunn or Guiberson Tongs.
- 1 Spider with slips for all sizes of casing used.

For not more than 4,000 feet 43-pound casing or equal weight: *

1000 feet 1¼-inch 6 x 19 Steel Wire Casing Line.
- 1 40-inch Quadruple Casing Block or 1 each Single and Triple Blocks — 9 lines.
- 1 Calf Wheel Outfit with 4 Casing Pulleys and using also the Crown Pulley
- 1 8½-inch Casing Hook.
- 1 Set Wilson or Dunn Extra Heavy, Union Single Link, or Oil Well Supply Co. or Lucey Side Gate Elevators for each size.
- 1 Casing Pole with rope sling and Neverslip Grip.
- 1 Dunn or Guiberson Tongs.
- 1 Spider with slips for all sizes of casing used.

NOTE.—The length of the Casing Lines in these specifications is based on the height of a standard derrick, 84 feet. If a rotary or combination derrick is used, the length of the casing line will have to be increased by the difference between 84 feet and the height of the derrick used times the number of lines in the derrick.

For example: a 114-foot derrick, 600-foot line, 7 lines: difference in height of derricks 30 feet times 7 equals 210 feet, to be added to 600-foot line—line should be 850 feet long.

*With rotary drilling outfits no casing line is required. the casing being put in with the drilling line. The spider with slips is seldom used with rotary outfits.

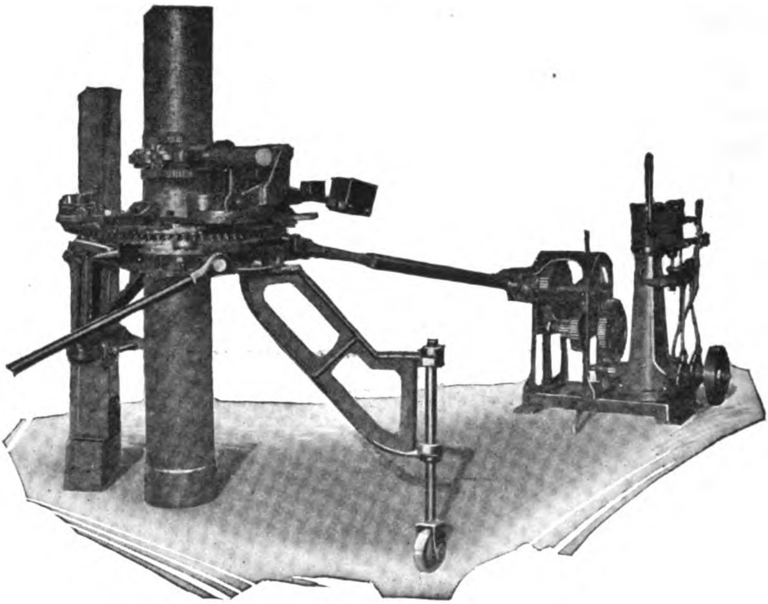


Fig. 176.
Brandon Power Casing Machine.

The Brandon Power Casing Machine, manufactured by A. H. Brandon & Co., Toledo, Ohio, is a new device for eliminating hand labor in screwing casing.

The outfit encircles the casing by means of a gate opening gear. It is equipped with a 4 H. P. steam engine and high and low speeds. It swings from a hinged mounting on the headache post and can be moved clear of the well when not in use.

The manufacturer's circular states that the outfit is designed to enable the drilling crew to put in long strings of casing without the aid of a casing crew.

CHAPTER IX

THE USE OF PACKERS*

A packer is a device used in connection with a string of casing or tubing, to close or "pack off" the space between the wall of the hole and the casing, or between the inside and the next larger size string of pipe, for the purpose of preventing the passage of either gas or fluid between the wall of the hole and the casing, or between the two strings of pipe beyond the point at which the packer is set.

The purposes for which packers are most commonly used are the following:

1. To shut off water in a drilling well:
   (a) To give a dry hole in which to drill;
   (b) To protect intermediate oil or gas bearing strata.
2. To shut off water in a completed well to exclude it from the oil or gas producing formation.
3. In a gas well, to confine the gas; prevent its escaping between the wall of the hole and the outside of the casing, or to pack the space between the casing and the tubing, to force the gas to pass through the tubing.
4. In an oil well having considerable fluid and comparatively light gas pressure, to confine the gas, so that it may accumulate sufficient pressure to cause the well to flow its production.
5. To shut off a cave.

The conditions met with and obstacles to be overcome in accomplishing these several purposes are materially different, and have necessitated the devising of various types of packers, each especially adapted to effect the particular result desired.

1-a. It frequently happens that in drilling a well for oil or gas, a stratum is penetrated which contains water in considerable quantity. If the volume of water encountered is

* From information furnished by Larkin Packer Co., Bartlesville, Okla.

too great to be readily exhausted by the use of the bailer, it is necessary that it be shut off—this for two reasons: first, that its presence in the hole renders the operation of the drilling tools slow and ineffective, and second, if water is allowed to stand in the hole for any considerable length of time, it may cause the wall of the hole to disintegrate and to fall in or "cave." To remedy this, the hole is drilled on down through the stratum containing the water into an impervious stratum below, and a string of casing is then put in and landed on the bottom of the hole, with a packer to prevent the water forcing its way around the bottom of the casing.

Fig. 177
Bottom Hole Packer

For this purpose, what is known as a "Bottom Hole Packer" (Fig. 177) is generally used. This packer has an inside pipe, usually the same size as the casing which is used in the well, turned true in a lathe, and the upper end threaded to fit a coupling, by which it is connected with the casing above, and the lower end has a shoulder which prevents it from pulling through the outside shell. The outside shell, or lower part of this packer, is a heavy steel cylinder, usually $\frac{3}{8}$ inch smaller than the hole in which it is used, and large enough inside to allow passage of the inside pipe. The lower part of this pipe is fitted with a reinforcing shoe, which rests on the bottom of the hole.

The inside pipe, or upper part of the packer, and this shell, or lower part of the packer, are connected by means of a "middle," which screws into the shell and slides over the inside pipe. A rubber cylinder, usually about 16 inches long, which fits the inside pipe snugly, and is about $\frac{3}{8}$ inch less in diameter than the hole in which it is used, is interposed between the collar on the inside pipe and the "middle."

When the packer rests on the bottom of the hole the weight of the casing above causes the outside shell and inside pipe or upper part of the packer to telescope, thus compressing the rubber cylinder and forcing it out against the wall of the hole, completely closing or packing off the space between the casing and the wall of the well. This arrests the passage of the water below this point, provided the packer has been set in a proper formation. Too much stress cannot be put on the fact that the packer must be set at a point where there is a good, hard wall, and a formation that is impervious to gas or fluid.

1-b. It frequently happens that it is desirable to drill a well to a given depth in order to reach the formation in which the principal production in the locality is found, and that before reaching this depth, a formation is penetrated which contains oil and gas. Both the interest of the well owner and the local statutes generally require that such a formation must be protected from water coming both from above and from below.

Fig. 178
Disc Anchor
Packer

This situation frequently requires that as many as three packers be set on a single string of casing: One on the bottom of the string of pipe, to give a dry hole in which to drill deeper, or to prevent the water from reaching the main producing formation below; one immediately below the intermediate producing stratum to prevent the water from reaching it from below, and one immediately above the intermediate producing stratum, to prevent the water from reaching it from above.

For the bottom of these three packers, the Bottom Hole Packer above described could be used. When such a packer has been once set, however, it cannot be lifted from the bottom without destroying the rubber, and it would be impossible to set three such packers at the same time. For the second of these packers, what is known as a Disc Anchor Packer (Fig. 178) is used. This packer is of the same general construction as the Bottom Hole Packer described above, except that instead of a shoe on the bottom of the outside shell, the lower end of this shell is swaged and threaded to screw into the casing below, and a hinged "disc" is provided between the upper and lower tubes of the packer, which prevents it from setting until this disc has been broken, even though the full weight of the string of casing is allowed to rest on it.

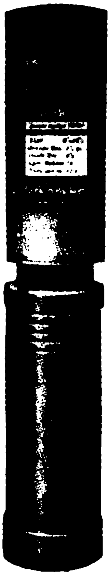


Fig. 179
Screw Anchor Packer

Owing to the fact that this packer sets as soon as the disc is broken, it can readily be seen that two disc packers could not be used on the same string of casing. For the upper, or third packer, therefore, it is necessary to use a Screw Anchor Packer (Fig. 179). The peculiar feature of this packer is that the lower end of the inside pipe is provided with a square thread, which fits into a similar thread on the upper end of the lower shell. This thread will support the full weight of the casing and prevent the packer from setting until the thread has been released. This is done by taking a strain on the casing, and screwing two full turns to the right.

The situation mentioned (1-b) above is, therefore, met by the use of the combination of the Bottom Hole, Disc Anchor and Screw Anchor Packers. Careful steel line measurements must be taken and the packers so spaced in the string of casing that each will set at the exact point desired. The casing is then run to bottom, and its full weight allowed to rest on the Bottom Hole Packer, causing it to set as above described, the disc in the Disc Anchor and the square threads in the Screw Anchor Packers preventing these packers from setting. After the Bottom Hole Packer is properly set, a weight is dropped in, or preferably, the bailer is run in, and the disc broken in the Disc Anchor Packer, causing it to set, and the threads are then released in the Screw Anchor Packer, setting it.

2. It usually is necessary that wells be cased above the producing formation, for the double purpose of preventing the wall above from caving in on it, and to prevent the water from above from reaching the producing formation. For the latter purpose it is necessary that a packer be set on the casing. For shutting off the cave, it frequently is desirable to set the casing as close as possible to the top of the producing formation. The point at which the casing is to be set is determined, and the hole is reduced at this level, from which a hole of smaller diameter is drilled into the producing formation. This leaves a shoulder on which the casing or packer will rest. If the point at which the casing is set is suitable for setting a packer, the Bottom Hole Packer above described can be used for this purpose. It very frequently happens, however, that in order to find a suitable formation in which to set the packer it is necessary to set it at a point considerably higher in the hole than where the casing is set. It then becomes necessary to use what is known as the "Special Anchor" packer. This packer is practically the same in construction as the Bottom Hole packer, except that the bottom of the outside shell is swaged and threaded to screw into the casing below.

3. When a gas well is shut in and the gas confined, the accumulated pressure becomes so great that the gas may force its way out between the outside of the casing and the wall of the well, unless this space is thoroughly packed off.

To successfully pack off high pressure gas wells it usually is necessary to secure a much greater bearing of the rubber against the wall than is required for the packing off of fluid, as above described, and for this purpose what is known as

Fig. 180
Conical Sleeve
Anchor Packer

Fig. 181
Hook Wall
Pumping Packer

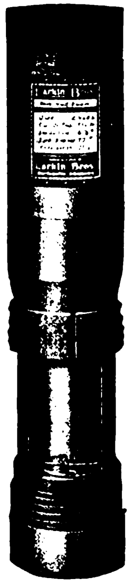


Fig. 182
Disc Wall Packer

Fig. 183
Disc Cave Packer

the Conical Sleeve Anchor Packer (Fig. 180) is generally used. This packer has a long tapering sleeve above the rubber, of such diameter as to enlarge the rubber to the full size of the hole before the weight of the casing or tubing rests on it. It gives a much greater bearing on the wall than any other packer, and is especially adapted for high pressure gas wells.

4. It frequently happens that an oil well which has considerable fluid, and only a light gas pressure, can be made to flow its production by packing off the space between the casing or wall of the well and the tubing, thus confining the gas to such extent that it accumulates pressure sufficient to cause the well to flow. For this purpose what is known as a Special Gas or Anchor Packer is used. This packer is

practically the same in principle as the Anchor packer above described, but is let in and set on the tubing instead of the casing. Sometimes such a well, in addition to having the gas pressure increased, has to be agitated by occasional pumping to make it flow. For this purpose a Hook Wall Pumping Packer (Fig. 181) is used. This packer is let in on the tubing, and can be set at any point in the casing or hole with the working barrel below. The packer is provided with slips, which, when released, engage the wall of the well or casing, and support the weight of the tubing, which in turn compresses the rubber cylinder, pressing it out against the wall of the well or casing. This effectually packs off the gas and prevents its escape between the tubing and the casing. The gas, thus confined, accumulates pressure and, when the well is pumped through the packer, will quite frequently cause the well to flow its production when otherwise it would not have sufficient pressure to do so.

It is always desirable to drill as large a hole as possible into the oil producing formation. For this reason, in the shallow sand districts particularly, where, in the process of drilling, water is not encountered in sufficient quantities to require that it be shut off for drilling purposes, a hole is sometimes drilled having the same diameter from the top on into the producing formation, the hole not being reduced above the producing formation to form a shoulder on which to set casing. It then becomes necessary, in order to shut off whatever water may be coming from above, to run in a string of casing and set a packer without having either a shoulder or an anchor below to support the weight of the casing. For this purpose, what is known as a Disc Wall Packer is generally used (Fig. 182).

This packer consists of a section of pipe the same size as the casing used, which is turned off for about one-half its length. Over this a steel cylinder slides, which is tapered on the outside for about one-half its length. Above this is the rubber cylinder which encircles the pipe, and above the rubber is a coupling, by which the packer is connected to the casing above. Below the tapered cylinder, or cone, is placed a pair of slips or wedges, which are held in place by a cast iron disc, which passes through the pipe. A tempered coil spring also surrounds the pipe and is compressed between the slips and a bottom collar. The packer is lowered on the casing to the proper place in the hole, after which a weight is dropped, or the bailer is run, to break the disc. This releases the tention on the spring, forcing the slips up on the cone, causing them to engage the wall of the well, thus stopping the travel of the cone. The weight of the casing is then supported by the slips, and in turn compresses the rubber cylinder, expanding it against the wall, thus sealing the space between the wall and the casing, and preventing the passage of water below the bottom of the casing.

The Disc Cave Packer (Fig. 183) is used in lieu of an additional string of casing to shut off a caving formation or a cavern. Sufficient casing to cover the cave, of a size that will go down through the casing in the hole, is attached to the bottom of the cave packer. The bottom ring is screwed to the lower end of the smaller casing to serve as a shoe to protect it. The letting in tool is fitted to the upper connection of the packer and, by means of a string of tubing screwed to the letting in tool, the outfit is lowered to the point in the hole where the packer will be just above the cave and the casing will extend far enough to cover and shut it off. The letting in tool, which has a left hand thread, is then unscrewed and withdrawn and the packer is set by dropping a weight or lowering the tools to break the disc.

The packer with rubber used in the hard formations will not answer for shutting off water in the unconsolidated sands and gravels of the Gulf Coast and the California fields; indeed, packers are little used in these fields and the casing is usually cemented. If, as sometimes happens, a cementing operation should fail to shut off the water or a lower water bearing formation should be encountered after the casing is set, the canvas or "bootleg" packer (Fig. 184) usually is used. This packer has a canvas covering, which, when the liner is set on bottom, is compressed, forcing the canvas out against the wall of the hole. The cavings settle on top of the packer and usually assist in shutting out the water. When the canvas packer is employed, the liner should extend to the surface, or a lead seal or another packer should be used to pack the space between the casing and the liner. See illustration.*

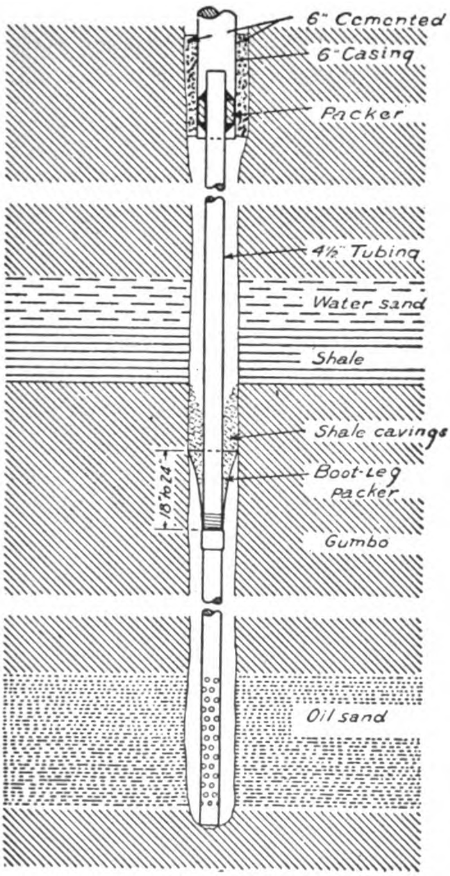


Fig. 184
Boot-leg Packer

In California a unique packer has been devised and successfully used by Mr. C. W. Stone of Maricopa.† He cut old bull ropes into 35-foot lengths and unlaid them. The bottom joint of casing with the shoe screwed on was stood in the derrick, the shoe end up. Next the strands of rope were doubled and the looped ends securely wired to the casing next the shoe until the mat of hemp was flush

* From U. S. Bureau of Mines Bulletin No. 163, Methods of Shutting Off Water in Oil and Gas Wells, by F. B. Tough.

† U. S. Bureau of Mines Bulletin No. 163, Methods of Shutting Off Water in Oil and Gas Wells, p. 62, by F. B. Tough.

with the outside of the shoe, and completely encircled the casing; it was then tied every three feet with soft rope. When the packer entered the well, as the bottom joint of casing, the rope ties were cut one by one, allowing the hemp to spread out into any enlargement of the hole. After the casing was set, the movement of the water past the packer matted down the mass of hemp fibres into an effective packer, shutting off the water.

CHAPTER X

CEMENTING CASING—SHUTTING OFF BOTTOM WATER

The difficulties encountered by operators in the fields of California and the Gulf Coast in setting Casing in soft formations to shut off water and caving strata and to prevent gas and oil from blowing out have led to the development of various methods of cementing the casing. Packers usually do not give satisfactory results in these fields, and the only way to set casing securely and to prevent damage, not only to the well in which the casing is set, but to adjoining wells and properties, is to cement the casing around the bottom and as far up around it as may be necessary to make it perfectly tight. The methods most generally employed in cementing are described in the following pages.

PERKINS PROCESS FOR CEMENTING CASING

One of the most successful methods of cementing casing is the process invented by A. A. Perkins and used by the Perkins Oil Well Cementing Company, Los Angeles, California. Following is a brief description of this process:

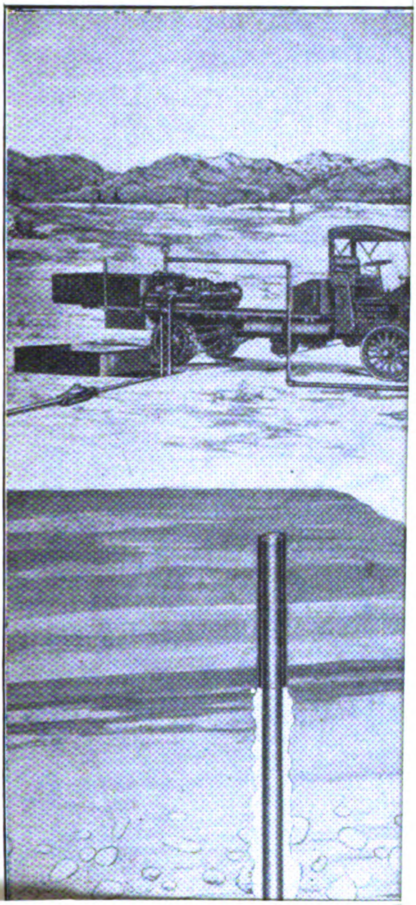
Water can be shut off equally as well above or below the oil sand. To illustrate the method employed, we will suppose a well has been drilled in which a string of 15½-inch casing was landed at a depth of 1,800 feet. At this point 10-inch casing was put in and drilling continued until a water stratum was encountered before reaching the oil-bearing sand. It was decided to land and cement the 10-inch casing at 3,000 feet and then to reduce the hole to 8¼ inches.

Two duplex steam pumps are included in the Perkins equipment, one for pressures up to 500 pounds and the other for pressures up to 1,000 pounds. The former is the service pump for pumping water and cement, while the latter is an emergency pump for starting circulation and is also used where an excess of pressure is necessary to force the cement into place.

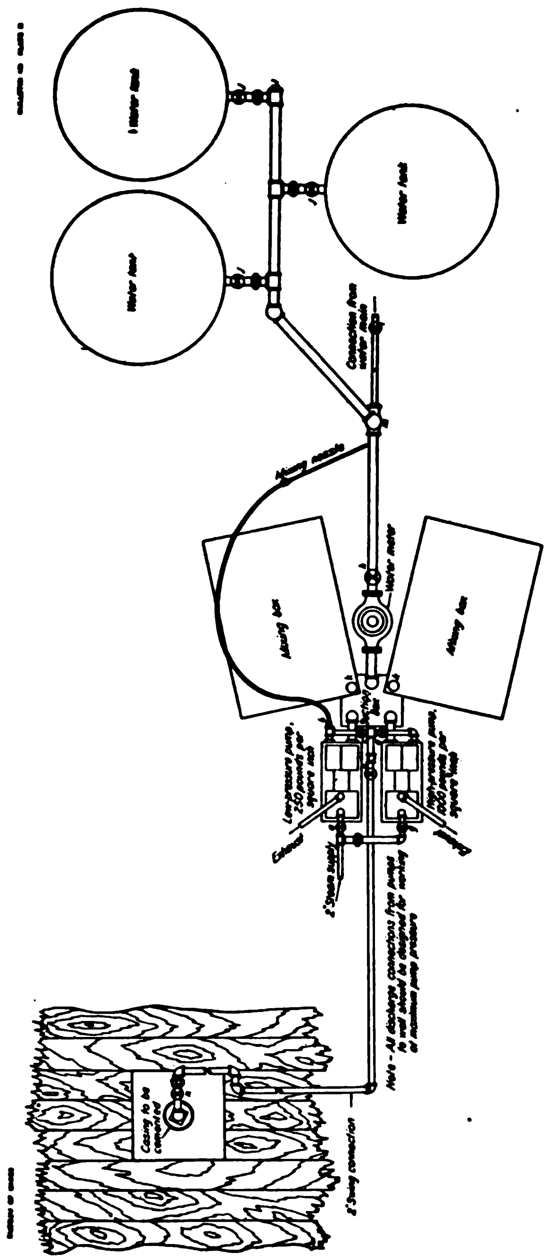
Two packers are turned out of wood and made in various sizes, according to the diameter of the casing used. The upper packer, No. 5, refer to Fig. 185, has two rubber discs and a leather cup that fit the casing very closely, and its first position is on top of the upper plunger, No. 3, in the circulating head. The lower packer, No. 4, has a rubber disc at each end and its first position is between the center and lower plungers, No. 2 and No. 1, of the circulating head. (This circulating head is not the head used in the hydraulic circulating system, but is special equipment used by the Perkins Co.)

Discharge line from manifold is connected directly to the pipe below circulating head and is fitted with a cock which is lettered "A." A riser is connected to line in front of cock "A," which also has a cock lettered "B." Connections are made from this riser into the circulating head, one between upper and center plungers with a cock lettered "C" and one into top of circulating head with cock lettered "D." With the entire cementing outfit ready for operation, cock "A" is opened and the high pressure pump started in order to get circulation by drawing the water from suction pit and forcing it through the 10-inch casing and up between this casing and the wall of the well.

While circulation is being obtained, about 7 tons of hydraulic cement should be dumped into the mixing tanks (refer to diagram Fig. 186) and worked with water to such a consistency that it can easily be handled by the pumps. The mixing process is facilitated by the use of a stream of water from a ⅜-inch nozzle under 150 pounds pressure. The amount of



PERKINS PROCESS



PLAN OF PERKINS CEMENTING SET-UP

Fig. 186

cement necessary differs according to the size of the pipe or casing to be cemented, and also the distance at which it is to be landed below the next larger size casing.

The cubical contents of the entire length of 10-inch casing should be calculated so that, by measuring the amount of water pumped through a meter into it, the location of the charge of cement can be determined at any time.

Cock "A" is now closed, cocks "B" and "C" opened, and the cement mixture turned into the suction pit, from where the pumps pick it up and deliver it on top of lower packer. The withdrawing of lower and center plungers allows this packer to start down the hole, acting as a plug between the water below it and the cement above. The water will flow up around the outside of the casing the same as when circulation has been obtained. When all the cement has been pumped through cock "C," this cock is closed and cock "D" opened to admit water which has passed through the measuring meter and delivered by the pumps to the suction pit. The upper plunger is now removed, allowing the water pressure to force the upper packer down on top of the column of cement. As this pressure is maintained, the charge of cement continues on down the casing. The cement is entirely protected from the water below by the rubber discs on the lower packer and from the water above by the rubber discs and leather cup on the upper packer.

When the lower packer reaches the bottom, it drops half way out of the casing and, as it is against a positive stop, the increasing pressure from above turns the rubber disc so that the cement can flow by the lower packer and be forced up outside of the casing. This continues until the upper and lower packers meet, when practically all the cement has been forced out of the casing.

When the upper packer stops, the increasing water pressure from above causes the leather cup to expand, arresting the passage of the water through to the cement. This pressure will increase to such an extent that it will stop the pump, indicating to the operator that the packers have come together. He may verify the relative position of the packers by the cubic feet of water pumped into the casing. This displacement can be so accurately figured and actual results checked so closely with calculated results that the time of the stopping of the pump can be determined within a few seconds.

The 10-inch casing is now lowered to its original position on the bottom, effectually shutting off the cement outside it and completing the cementing operation.

Although the well is still full of water, it should be allowed to stand in this condition until cement has hardened, which requires from 15 to 20 days. Then both packers and any small quantity of cement that has remained in the casing is drilled out in the usual manner and deeper drilling continued.

TUBING METHOD FOR CEMENTING CASING

Tubing, usually 2-inch, is inserted with a packer on the bottom to within a few feet of the bottom of the casing. The Baker Cement Retainer, Fig. 187, is sometimes used instead of a packer for this purpose.

The operator should first get circulation before attempting to put in the tubing or the cement. The cement is then mixed and pumped down inside the tubing, and as the packer or cement retainer prevents its passage up between the tubing and the casing, it is forced up outside the casing. Water is then pumped down the tubing to clear it of cement; a cock connected to the top of the string of tubing is closed and the casing is set on bottom. Next the tubing and packer are pulled up sufficiently to free them from the cement and clear water is circulated between tubing and casing to wash out cement from the inside of the casing. Tubing and packer are then withdrawn and the casing is filled with water and closed at the top until the cement has set.

The Baker cement retainer, Fig. 187, is in effect a packer with slips to engage in the casing. It is used on tubing as above described, except that the tubing is unscrewed from a left hand thread in the bottom of the retainer and the latter is left in the hole. The retainer may be set at any desired point in the hole by pulling it up a few inches, the cone causing the rubber and slips to expand. Being made of cast iron it is easily drilled up after the cement has set. The Baker cement retainer is recommended by the manufacturers for other cementing jobs, as follows:

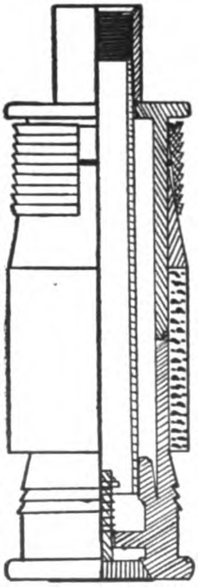


Fig. 187
Baker Cement Retainer

For cementing casing which may be fast in the hole, but where it is possible to get circulation.

For cementing through a hole or split in the casing, the casing is bridged below the opening, the cement retainer is set just above the opening and the cement pumped in.

For wells where water has broken in around the shoe and the casing is stuck, the hole is bridged just below the shoe, the cement retainer is set as close to the shoe as possible and the cement pumped in.

For wells with bottom water, the casing is landed in the formation above the water, the cement retainer is set in the bottom of the casing and the cement is pumped in.

In all of these operations, any cement that may not have been pumped through the retainer, and remaining in the hole, should be bailed out.

In deep wells where long strings of tubing are used, a tension should be taken on the tubing after starting to pump cement through it, to take up expansion caused by the cement heating it; otherwise the elongation of the tubing might trip the retainer.

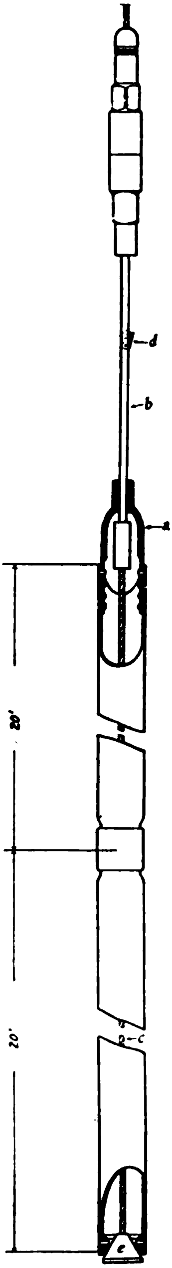
The retainer has a valve in the bottom, through which the cement passes out of the tubing, and it automatically closes when the pressure in the tubing is relieved, thus preventing the cement from backing up in the casing.

DUMP BAILER PROCESS FOR CEMENTING CASING *

"In cementing a string of casing with the dump bailer, the liquid cement is lowered to the bottom of the hole with a bailer which, as its name indicates, discharges or dumps its load instead of picking it up like the ordinary bailer. By this method 2 or 3 tons of cement is dumped into the bottom of the well. As many runs are made with the bailer as may be necessary to deposit the entire quantity of cement to be used. After this is done, the casing is pulled up 20 to 40 feet off bottom, or so that the shoe will be above the cement level. The casing is filled with water and then closed at the top with a steel plug, or other suitable fitting, and is lowered firmly to the bottom of the hole. There being no outlet at the top of the casing for water, the cement can not enter at the bottom, so it takes the only open course and rises outside the casing, filling the space between the casing and the walls of the hole.

There are several types of dump bailers in use; also, there are several ways to transform an ordinary dart bailer into a makeshift dump bailer, but such makeshifts are unsatisfactory and likely to cause trouble. A satisfactory type of dump bailer is the one shown in Fig. 188. The shell of this bailer is of two joints of pipe swaged to connect in a coupling of the same external diameter as the joints. As the bailers vary in size according to the size of casing in which they are to be used, dimensions are omitted here. The bail "a" terminates in a bottle neck through which the rod "b" is free to slide. The enlargement at the lower end of this rod is bored as a rope socket to receive the ⅞-inch wire dump line "c." The rod is provided with a latch "d," in general design similar

*After U. S. Bureau of Mines Bulletin No. 163 by F. B. Tough.



to that on the shaft of an old-fashioned umbrella. The upper end of the rod is threaded to screw into the bottom of a tool joint. This joint connects with the box of the rope socket so that the dump bailer may be run on the drilling line. Riveted to the bottom of the bailer is an annular steel valve seat. The valve "e" is of steel and in the form of a truncated cone. Of course, a ball would do the work as well as the cone. The wire line, or chain if preferred, which connects the rod "b" with the cone, must be babbitted, or otherwise securely attached to both rod and cone, as the entire weight of the bailer and contents must be carried by the dump line or chain. It is worth noting that if either of these two babbitted connections fail, only the cone, or at worst the cone and the dump line, will be left in the hole, as the shell of the bailer will hang on the butt of the rod "b."

When this bailer is run to bottom, the rod slips down through the bottle neck in the bail, thus throwing about 3 feet of slack in the connecting cable. When the bailer is lifted again the latch engages with the bail and the entire device is brought to the surface with the valve dangling about 3 feet below the valve seat. There is thus no possibility of the bailer not discharging its contents. In running such a bailer in a hole full of fluid it tends to float if lowered too rapidly. The latch will then trip the bailer and discharge the contents. Such an accident is particularly apt to occur when the fluid level is several hundred feet be-

Fig. 188
Dump Bailer
(U. S. Bureau of Mines)

low the surface. Such premature unloading may take place without the driller's knowledge and go undetected until the job is found to be unsuccessful. All this trouble will be avoided by care in lowering the bailer slowly enough, allowing no slack in the drilling cable.

The dump-bailer method is frequently used when a water string is to be set with a relatively small amount of cement, say, less than two tons. The cement is mixed in a box on the derrick floor in batches according to the capacity of the bailer. After cement has been wet, it should not be held over for the next batch. Surplus cement, after the bailer has been filled, should be discarded. A convenient rule is to figure that each sack of cement when mixed will occupy 1.15 cubic feet.

The bailer latch is set and the bailer hung in the hole with the shell seated on the cone valve "e" so that the top of the shell comes level with the floor and under a spout or swing pipe leading from the cement box. The bailer is then loaded and run to bottom in the manner described. It is advisable to have a bailer large enough so that the period from the time the first batch of cement is wet until the job is completed will not exceed two hours. It is important to have enough men with hoes at work to insure that the mixing of each batch is commenced as soon as the last of the preceding batch has left the mixing box, and that the mixed cement will not have to be kept waiting for the bailer. Frequently, while a driller and tool dresser are lowering and dumping a bailer, pulling out and resetting the latch and getting the bailer in position for the next charge of cement, the other men get the cement ready to pour.

During cementing, the hole should be kept full of water, if possible. After all the cement has been dumped, the casing is filled with water and set, as described. The well should be left undisturbed at least 24 hours before the pressure within the casing is released. After this time it is advisable to stretch the casing as much as experience has shown is allowable. The casing is then hung on clamps in this position so that it is held both at the top and the bottom; otherwise the pipe tends to bend from its own weight."

An improved and simplified dump bailer has recently been introduced by the Baker Casing Shoe Company of Coalinga, California. It consists of a bailer top and bottom with casing threads to permit elongating by the addition of one or more joints of casing. It has no chains, springs or plungers and operates by a sliding sleeve in the bottom which, when the bailer reaches the bottom of the hole, is forced upward on the body, tripping a valve which dumps the load. A vent in the bottom of the sleeve prevents premature tripping by the fluid resistance exerted against the valve disc.

For cementing by the dump bailer method, the Baker cement plug, Fig. 189, is a device sometimes used for closing the bottom of the casing. It is made of thin cast iron and fitted with a disc of canvas for packing. It is tied with a piece of soft rope to the bailer and lowered to the bottom out of the casing. A valve permits its passage through fluid. It is then drawn back into the casing shoe where the canvas wedges it, and the rope tie is broken by a sharp pull. When the casing is lowered, the cement is forced up outside by displacement, the plug preventing any cement from backing up in the casing. The plug is drilled up after the cement has set.

Fig. 189
Baker Cement Plug

For quantity of cement required to fill various sizes of hole one foot, refer to table of contents of pipe on the next page.

It is difficult to estimate the height to which cement will rise outside of casing, owing to the variations of the hole and the quantity of cement absorbed by or pumped into the formation. Following, however, is the theoretical height that cement will rise filling a true and impervious wall for a space of one inch around the outside of the casing (the hole 2 inches larger in diameter than the outside of the casing).

Theoretical height to which one gallon of cement will rise outside casing in a hole 2 inches larger in diameter:

Size Casing, Inches	Height, Inches	Size Casing, Inches	Height, Inches
4¼	13.37	8⅝	7.35
4½	12.79	9⅝	6.69
4¾	12.26	10	6.25
5	11.76	10⅝	6.13
5 3/16	11.31	11⅝	5.65
5⅝	10.5	12	5.35
6¼	9.64	12½	5.25
6⅝	9.19	13½	4.91
7⅝	8.17	14½	4.6
8¼	7.64	15½	4.34

CEMENTING CASING IN THE GULF COAST FIELDS

The two-plug process is usually used. Circulation should first be secured to wash out all cuttings, water or oil. The equipment consists of a mixing box about six by eight feet and 12 to 18 inches deep, with an outlet at one end to pour the cement, two wood plugs, and sufficient mortar hoes, shovels and pails for the men—usually six—who mix the cement. The cement should be mixed in batches of 8 to 10 sacks of cement and the necessary water. For cementing 6-inch casing 40 to 50 sacks of cement are used and it is mixed neat with water, sand seldom being used. The mixture of one sack of cement with water will fill a space of 1.15 cubic feet.

Some operators first run the two plugs through each joint of casing, to be sure there may be nothing in the casing to obstruct the passage of the plugs.

Two wood plugs, the upper 12 inches long and the lower 24 inches long, are cut of a diameter to fit loosely in the casing. Sometimes a piece of wood, 2 x 4 inches, 3 feet long, is nailed to the bottom of the upper plug. Some drillers nail a piece of rubber belt to the top of the upper plug; others place several cement sacks on top of it as packing.

The operator first makes sure that he has good circulation, then he plugs the holes in the rotary bit and runs the drill pipe in the casing to displace the mud fluid for a distance of about 500 feet to make room for the cement. The drill pipe is withdrawn and the first plug is introduced in the casing. The cement is then prepared in the mixing box on the derrick floor and it is poured in on top of the plug. The upper plug is then put in following the cement and the sacks are packed down on it. The casing is raised about 12 inches off bottom, and connections made with the swivel. The pumps are started and the plugs and cement are forced down the casing. When the upper plug has reached bottom, the pumps should stall. The casing is then lowered to bottom and rotated a few turns to insure equal distribution of the cement around it, and to overcome tendency of the cement to channel. By calculating the capacity per stroke and speed of pumps and the fluid content of the string of casing, the time required for the upper plug to reach the bottom may be determined, otherwise it is advisable to run the drill pipe to the bottom of the casing to be sure the upper plug has not lodged in the casing off bottom. After 8 or 10 days, the plugs are drilled up, the hole bailed out and the shut off is tested.

For more detailed information on cementing wells drilled by the rotary method, refer to Lucey Mfg. Co. No. 8 catalogue, pages 291 to 301, Cementing Oil and Gas Wells, by I. N. Knapp.

TESTING A WATER SHUT-OFF *

"Whenever the character of the formations and methods of drilling will permit, the driller should observe and note in the log book any peculiar characteristics of water encountered, such as freshness or salinity and sulphur content, also the

* From U. S. Bureau of Mines Bulletin No. 163, Methods of Shutting off water in oil and gas wells, by F. B. Tough.

natural level of the water in the hole, and whether there is any change in water level when various sands are encountered.

After the cementing has been done and the time allowed for setting has elapsed, the effectiveness of this work must be tested. The mere fact that the job has been done in a workmanlike manner and by approved methods does not fulfill an operator's obligation to himself, his neighbor, or society in general. The test consists of two phases. In the first phase the water is bailed out, leaving a dry hole, or, at least, the water should be lowered sufficiently below the natural water level of the locality to create a reasonable external pressure on the casing—1,000 to 2,000 feet is usually sufficient. The well is then allowed to stand 8 to 24 hours, or more. This part of the test is made before any residual cement has been drilled out of the casing, and is for the purpose of demonstrating that there is no leak of any kind in the pipe itself. In the second phase of the test the residual cement is drilled out and a few feet of new hole is drilled ahead of the casing. Unless there is danger of a gas blow out or some other weighty consideration is adverse, all the fluid should be bailed out of the well and the hole allowed to stand 12 to 24 hours. If the test shows that the cementing job is not satisfactory, corrective measures must be taken. If the second part of the test shows that the water is not shut off, effort must be made to determine whether the water is coming around the shoe or through a leak in the pipe itself. If the water is coming through a leak in the pipe and not around the shoe, drilling may be continued and the well completed in the usual way. After the inner or oil string has been set, it may be cut off somewhere between the shoe of the water string and the leak, and the upper part pulled out and set back on top of the lower section, with a packer between the two sections, thus preventing the water from entering the oil sands by way of the hole in the water string. The packing should be of more permanent material than rubber."

SHUTTING OFF BOTTOM WATER

Bottom water, so called, is sometimes encountered in nearly all of the oil fields of the United States. Sometimes the water is in a separate sand from the oil-producing sand with a thin stratum of shale between; in many fields, particularly those of Eastern and Mid-continent territory, the oil and water occur in the same sand. Thus, if the operator is not careful in drilling in the oil sand, he may penetrate into the water. Bottom water has been a source of much difficulty and loss to the oil producer and, when not properly or intelligently handled, it may be the cause of the loss of a well or of serious damage to an entire locality. The producer is naturally desirous of drilling his well as far into the oil-producing formation as possible and in so doing he frequently drills into the water.

Various methods and devices have been employed, some very successfully, in combating water, and the subject is admirably covered in the U. S. Bureau of Mines Bulletin No. 163.*

In the following pages methods of shutting off bottom water are discussed.

McDonald Process for Cementing Off Bottom Water in Oil and Gas Wells.*

"The McDonald process was developed by W. W. McDonald, of Robinson, Ill. This process is especially useful in a well that has been drilled or shot into bottom water, or where water has encroached on and claimed the lower part of an oil sand as depletion has progressed. It is particularly valuable in a shot hole, because its effectiveness is in no way impaired by any irregularity in the shape of the hole, nor by crevices or fissures.

* Methods of Shutting Off Water in Oil and Gas Wells, Bulletin No. 163, By F. B. Tough.

For successful operation of the process, it is essential that the water sand take water when the level in the well is raised above the natural level of the water to be shut off. These conditions are typical of the underlying water in the Illinois pools.

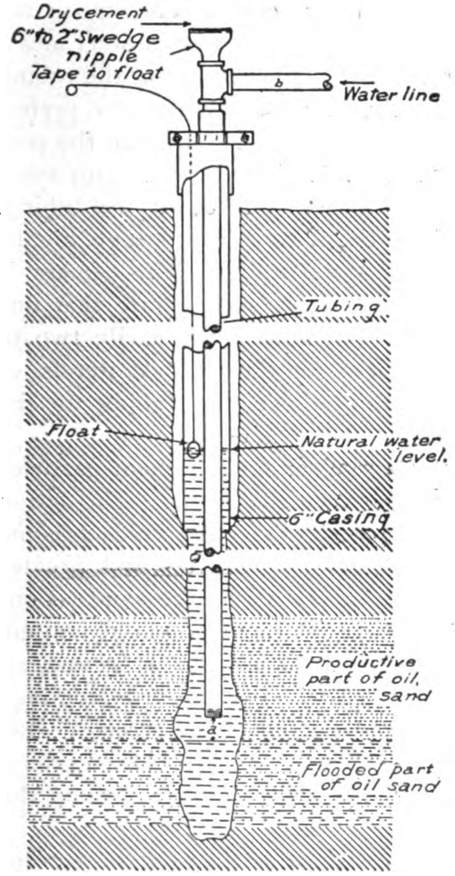


Fig. 190
Cross Section McDonald Process

Figure 190 shows a cross-section of a well being cemented by the McDonald process. Two-inch tubing is lowered into the well until the bottom end is 2 to 4 feet above the plane of contact between the oil and water-bearing part of the sand. This distance is designated "a" in Fig. 190. Determination of the exact situation of this plane may be difficult or even impossible. If the well has been shot into water, this difficulty is obviously simplified. In any event the operator estimates the position of the plane, taking care to keep on the safe side the first time, and preferring to make a low rather than a high estimate. If insufficient cement is used, more may be added at any time; but if the oil-bearing part of the sand be entirely or partly plugged off with cement, the damage to the well may be difficult to repair.

Tubing is commonly inserted with a wooden plug in the bottom to exclude oil. The plug may be knocked out either by exerting pressure on the column of water in the tubing or by running in a couple of sucker rods on a line.

If necessary, the tubing may be set over to one side of the hole to afford room for the float that is run on a steel measuring line. After the plug has been knocked out of the tubing and the natural fluid level of the hole measured, water, preferably fresh, is run or pumped into the tubing through the connection shown at "b" (Fig. 190). This water will run away into the water sand. As the water runs down the tubing, dry cement is sprinkled into the 2 to 6-inch swage nipple, serving as a funnel, on top of the tubing. The cement is put in slowly, a handful at a time, at such a rate that one sack of cement will be placed per hour. Ordinarily two to four sacks of cement is sufficient for the job. Water is, of course, kept continually running down the tubing as the cement is added.

As the water runs away into the sand, the cement particles are caught in the interstices between the grains. The action is identical with that of a sand filter. As the voids become more and more clogged with cement, greater and greater pressure is required to force the water into the sand. Consequently the fluid level in the hole is correspondingly raised. When the level has reached about 500 feet above normal, no more cement is put in, and the flow of water is maintained only long enough to flush all cement out of the tubing. This done, it may be advisable to pull out a joint or two of tubing to preclude any possibility of the cement setting around the bottom of the string.

The water level is then allowed to settle back to a point 15 or 20 feet above the normal for the hole. The object is to obtain a close balance between the fluid pressures on either side of the cement with a slight advantage in favor of the internal pressure as a precaution against any tendency there may be of the underground water forcing the cement back into the hole or causing sufficient agitation to keep it from setting. This status is maintained for about 24 hours by keeping a man at the well who runs in water in order to maintain the fluid level. Then the cement is allowed to set for a week or 10 days and the job is tested by pumping. If not enough cement has been used, the entire operation may be repeated as often as may be necessary to extend the plug up to the desired point in the hole. A time-saving variation is to run a small bob on a measuring line inside the tubing as soon as the cement has set firmly enough that its level may be detected with the bob and line. Then if insufficient cement has been used, more may be added without further delay.

In this process the cement fills the interstitial spaces and crevices in the water sand for some distance from the hole, in addition to forming a solid plug in the lower part of the hole. The process has marked advantages over merely filling the bottom of the hole with liquid cement.

Question may arise as to why the cement does not enter and collect in the pores of the oil-bearing parts of the sand, clogging them also. The explanation lies partly in the relative specific gravities of the water, cement, and oil, but chiefly in all probability in the immiscibility of water and oil, which naturally repel each other. Whatever the reason may be, the fact that the cement-bearing water selects the water-bearing part of the sand has been so thoroughly established for the Illinois conditions by Mr. McDonald's work that this phase of the problem need not deter a prospective user of the process. This statement applies only when the operator takes precautions to avoid the use of too much cement, which would, of course, plug off the oil as well as the water.

After the cement has set on such a job, to pump the water out of the oil sand and bring the oil back into the well may require several days, or a week."

Method of Using the Guiberson-Crowell Bottom Water Plug

A unique device has recently been invented for shutting off bottom water, the Guiberson Crowell bottom water plug. The makers of this plug state that the operator may drill into the water without fear of damage to his well or to surrounding properties if he uses the plug, Figure 191.

The spirals are made of boiler plate steel, fastened to the core stem on top by the top plate. They are stretched into position with powerful tension, and held by a wooden dowel driven through the nipple or anchor on the bottom. When the spirals are flat their diameter is much larger than when stretched into position, as shown. The small grooves turned in the anchor are recesses for latch.

The plug is snugly packed with oakum saturated with freshly mixed neat cement. This packing is held in place by running small wires up and down the plug through small holes bored in the periphery of the spirals for that purpose. Sufficient anchor pipe is screwed to the bottom of the plug to support it at the exact point in the hole where it is desired to shut off the water. The plug is then suspended from the bottom of a string of tools and slowly lowered into the well.

When the plug is placed in position in the well and tapped a few blows with the tools, the small wooden dowel is broken, the core descends through the nipple or anchor on the bottom, and the recesses are engaged by the "latch," which thus holds the core down; the spirals collapse and attempt to expand to their original diameter. Being sharp or bevel edged, they take a biting hold in the wall. The packing, which has been placed between the spirals before lowering the plug in the well, is squeezed and jammed tightly against the walls of the well, and against the core of the plug, and fills every crack or recess which it can reach. Bottom water cannot be shut off unless there are firm walls to which a plug can be made to adhere.

Fig. 191
Guiberson Crowell Plug

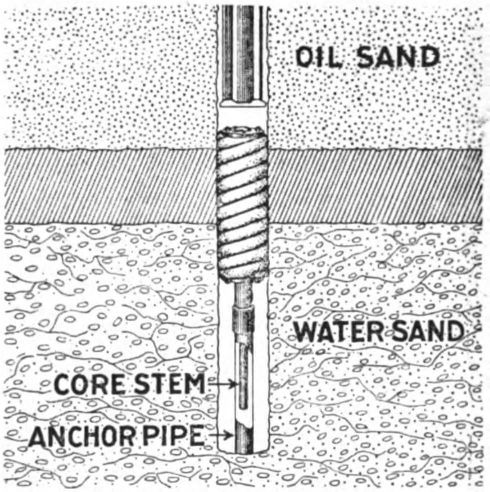


Fig. 192
Guiberson-Crowell Plug Showing Operation

Some operators saturate the oakum with melted pitch and others use tar. If the temperature of the water is such that these mixtures will remain plastic until the plug is set, there is no objection to them.

It is best to fill the bottom of the hole with freshly mixed neat cement, dumped in from a bailer just before running the plug. The plug will then be immersed in cement, and when expanded, will prevent escape of gas or water from below, thus giving the cement opportunity to set into a solid plug from the bottom of the well to the top of the bottom water plug.

Limit Plug

As shown in Fig. 193, this plug consists of an upper collapsible shell capped with lead and a wood mandrel shod with iron. When driven together they form a seal which usually is effective in shutting off water. Where the water flow is very heavy a lock, milled similar to a socket slip, is set on top of plug to engage in wall of hole and hold the

Fig. 193
Limit Plug

plug in place. For extreme pressure a lead plug is sometimes driven on top of the limit plug, the limit plug forming a secure base for the lead.

Directions for setting: Drop some broken stone in hole and run the tools on it to secure a firm foundation. Connect up the tools by placing the jars between the stem and the bit. Loop several strands of hay wire through staple in top of plug, up along water courses of bit and through the jars, so the tongue of jars will cut the wire in process of driving plug. Run the plug slowly when entering reduced holes or through caving formations and shot holes. When plug is set pound it down with the tools, using a drilling motion, until the plug is driven solidly together and the lead cap is swaged out to the wall of hole.

Lead Plugs or Lead Wool

Fig. 194
Lead Plug
with
Mandrel

In the Eastern and Mid-continent fields lead plugs of various kinds and lead wood have successfully been used for shutting off bottom water. These devices will not, however, make an effective water shut-off in soft or caving formations or in much shattered shot holes.

The solid lead plug is lowered to the bottom of the hole and pounded with the tools until the lead has been sufficiently calked into the recesses of the hole to shut off the water. When a lead plug with steel mandrel (Fig. 194) is used, the plug is expanded to the full diameter of the hole by driving down the mandrel with the drilling tools, using a flat bottom bit. Directions for setting the limit plug may be followed when setting lead plugs.

Lead wool is placed in the hole in small bundles, each being tamped down with the tools before the next is put in.

CHAPTER XI

SHOOTING WELLS

It is the general practice to torpedo, or shoot, wells drilled in hard or close formations to break up or fracture the rock, with the object of increasing the oil production. Nitro-glycerin, perhaps the most powerful explosive in general use, is usually employed for this purpose and the work is done by torpedo companies or shooters familiar with the work and equipped for it. It has been found that shooting the soft Tertiary and Cretaceous formations of the Gulf Coast and California does not sufficiently increase the production to pay for the expense, so it is not customary to shoot the softer formations. The wells in the harder Cretaceous rocks of Wyoming, however, are shot with very good results and it is the practice to shoot most of the wells in that field.

Frequently large natural or gusher wells, after their production has declined, are shot, resulting in an increase of production; also wells have been shot the second and third time with good results.

Formerly dry holes and wells showing only a trace of oil were abandoned as worthless. Now, however, due to the excessive cost of drilling, and to the high price of oil, many operators make it a practice to shoot the dry holes in the hope of converting a total loss into a paying proposition. The shooting of dry holes in the fields of North Texas has met with unusual success, many dry holes having been shot into wells whose initial production was 1,000 barrels per day or more.

It is not customary to shoot gas wells; however the practice of shooting dry holes in North Texas, which often converts them into paying oil wells would indicate that there might be a chance, in a gas field, to shoot a dry hole into a profitable gas well.

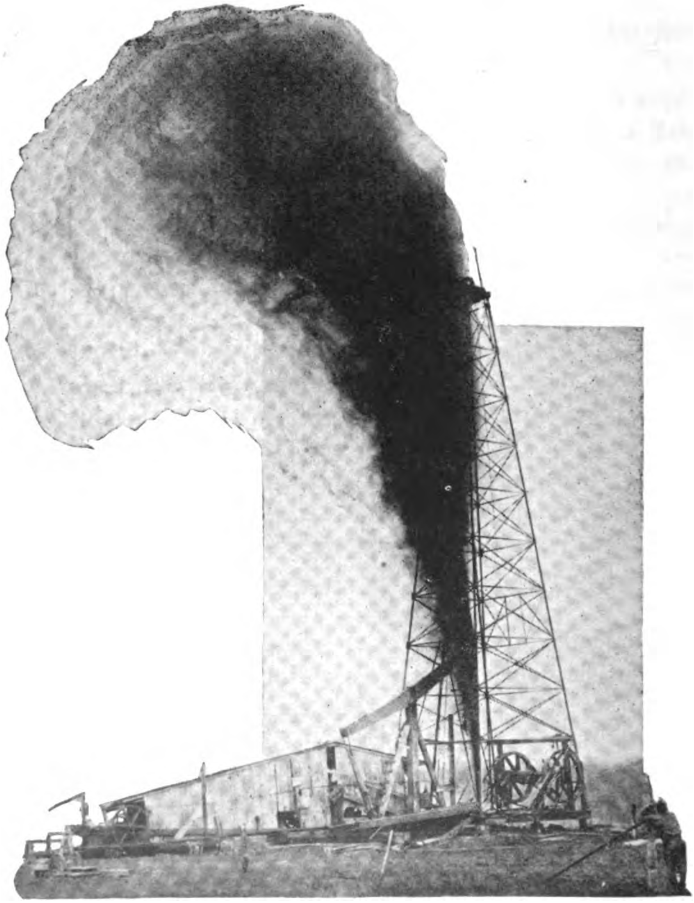


Fig. 195. Shooting An Oil Well.

Nitro-glycerin $C_3H_5(NO_3)_3$ is the product of chemical reaction obtained by treating glycerin with a mixture of 3 parts of nitric and 5 parts of sulphuric acid. The process of manufacture is to place the mixed acid in a nitrator, or other water jacketed or cooled vessel, and to introduce the glycerin slowly in a small stream, the while maintaining a constant stirring.

A thermometer is kept immersed in the mixture and, should the temperature rise to 120° F, the supply of glycerin is reduced, or cut off, until the temperature falls, when the operation is resumed. When the glycerin has been thoroughly nitrated, requiring 15 to 20 minutes, and using about 7 parts of acid to one of glycerin, the batch is dumped into a drowning tank of cold water. It is then drawn off into a wash tank equipped with paddles and is washed for about one hour with warm water to free all unabsorbed acids (about 70% of the mixture, mostly acid, is drained off into an acid pond, becoming a waste product). The nitro-glycerin is then drawn off into 10-quart cans and stored ready for use.

It is essential that nitro-glycerin be thoroughly washed, otherwise the presence of unabsorbed acid is a menace. Improperly washed nitro-glycerin, known as "bad stock," has been the cause of disastrous explosions.

Nitro-glycerin begins to decompose at 140° F and explodes at from 360° to 424° F.*

It freezes at from 43° to 46° F.

Well shooters thaw frozen nitro-glycerin by immersing the cans in warm water, after first drawing the corks. Nitro-glycerin contracts or expands about 1/12 of its volume from frozen to thawed state, or vice versa, therefore cans never should be filled, but sufficient space should be left to provide for expansion.

Before cans containing nitro-glycerin are loaded in vehicles for transportation, they should carefully be examined for leaks, and no can showing the slightest leak should be transported. Explosions have been caused by nitro-glycerin leaking into the springs or running gear of wagon or automobile.

The shooter's first operation in shooting a well is to consult the log of the well, or to ascertain from the driller the exact depth of the hole to the top of the productive formation, the thickness of the formation and the depth of the hole or "leg"

* In a series of experiments conducted by U S. Bureau of Mines, it was found that in none of the tests did nitroglycerin explode at temperature lower than 200° C and in some cases as high as 218° C=424° F. Ref. U. S. Bureau of Mines Technical Paper No. 12. The behaviour of nitroglycerin when heated, by Walter O. Snelling and C. G. Storm.

below the productive formation, and then carefully to run the measuring line to verify at least the total depth of the well, or, if an error has been made in the log, to determine the exact depth.

Sufficient water, if the hole contains little or no fluid, is poured, or better, dumped with the bailer in the well to cover the oil

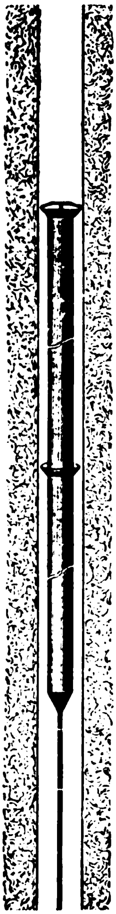


Fig. 196. Section of Well Showing Shells and Anchor.

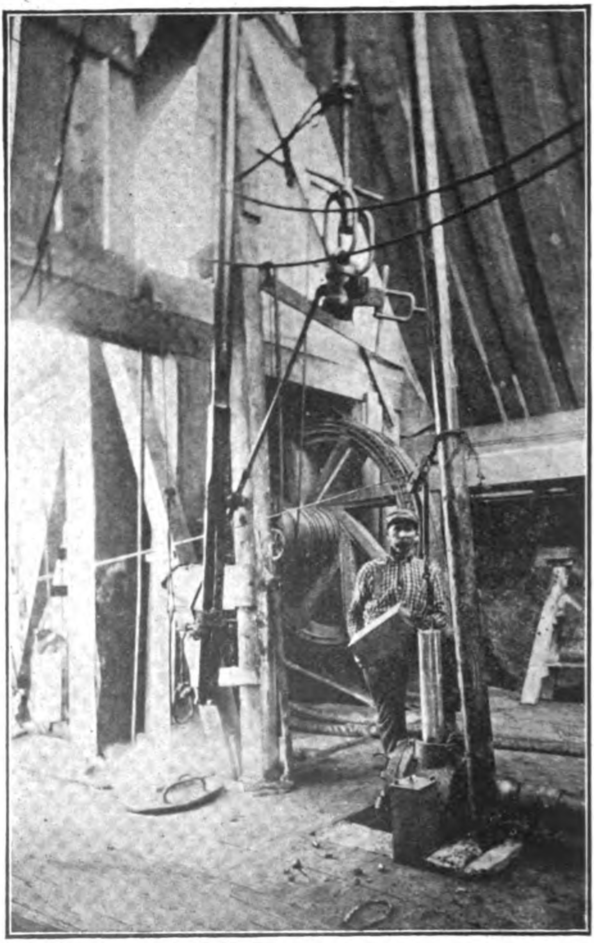


Fig. 197. Filling a Shell.

sand to a depth of 100 to 200 feet to tamp the charge and direct the force of the explosion downward.

Sometimes the operator decides that he wants a heavy shot and specifies the quantity of nitro-glycerin that is to be used, with the result that enough glycerin is put in to more than cover the productive formation to be shot. It is, of course, futile to shoot non-productive formations above or below the pay sand. It is good practice to inform the shooter the diameter of the hole and thickness of the productive formation and leave the quantity of explosive to be used to his judgment. When the shooter has established the exact measurements of hole and formation he selects tin containers, called shells, of a diameter that will easily go down the hole (shells are usually about 1 inch smaller than the diameter of the hole, with capacities of 10, 20 and 30 quarts), and, to the bottom of the first, or lower, shell he connects sufficient tin tubing, 1¼ inches in diameter, called anchor, to extend from the bottom of the hole up to the bottom of the productive formation. He then fills the first shell with nitro-glycerin, pouring it from the 10-quart cans he carries in his wagon or auto, and lowers it carefully to the bottom. On top of this shell and anchor he deposits enough more shells to fill the hole to the top of the productive formation. When, as often occurs, the productive formation is interbedded with one or more shale breaks or other barren strata, the shells are so spaced by means of loaded anchor (common anchor tubing filled with nitro-glycerin) that the shells containing the explosive cover each of the oil bearing sands, and the anchor bridges the space occupied by the non-productive formations.

A pail of water is poured over each shell after filling to wash off any nitro-glycerin that may have splashed, and to wet the casing to reduce the friction of the shell in it.

The shells and anchor are lowered on a ¼-inch diameter Manila torpedo line, tarred. The linepasses over a pulley tied to the drilling stem or bailer, see Fig. 197. It is wound on an iron reel with brake and handle, which usually is clamped to the engine fly wheel to secure power for operating. A specially made hook

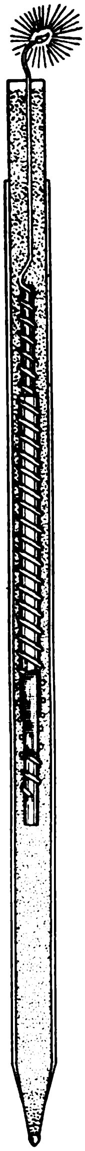


Fig. 198. Jack Squib.

that will readily unhook from the bail of the shell when the line is slacked is used.

In shooting wells where the casing is set close to the oil sand the tamping water should not reach the casing, otherwise the casing should be raised a few hundred feet, or the explosion might damage it.

There are various methods of exploding the shot. In the fields of Pennsylvania and Ohio, where the rock formations stand up, the "go devil," so called, usually serves the purpose. This is simply a cast iron weight dropped in the well which, when it strikes the firing head and detonating cap fixed to the top of the upper shell, explodes the shot.

It is the general practice in the Mid-continent and Wyoming fields to explode the shot by means of one of the several types of squib or, in caving wells where the casing is pulled, by the use of electric wire and a battery, called an electric shot. The squib is a small tin shell containing a small quantity of dynamite or nitro-glycerin and exploded by methods described in following paragraphs.

The jack squib is the one most generally used. It consists of a tin shell, 2 inches in diameter and 3 to 5 feet in length, reinforced on the outside, and with an inner tube, in which is placed one-half pint of nitro-glycerin or a stick of dynamite. Several feet of waterproof fuse are wrapped around the glycerin tube and connected with a fulminate of mercury cap fitted near the bottom. The space between the tube and fuse and the shell is then packed with sand. (See Fig. 198.) The sand serves the double purpose of weighting the jack and absorbing any nitro-glycerin that might leak out of the tube. The end of the fuse projecting at the top is then lighted and the "jack" is dropped in the hole. Should it fail to explode, a second jack is dropped or a bumper squib is used. The length of fuse used depends on the depth of the well and whether it is dry or filled with water or oil. Two feet would answer for a dry hole, while a well full of oil might require ten feet.

The line squib is a short tin shell about 15 inches long with a wire loop in the bottom for attaching a sash weight to carry it down. It is equipped with a firing head and three piece pin, to which are fitted three percussion caps, so that if one cap should fail, another might explode (see Fig. 199). It is lowered on a length of squib wire until it rests on the top shell of the charge, when a light tension is taken on the wire to take up slack. Then a nipple or short piece of pipe is dropped over the wire, which, striking the firing head explodes the charge. Some shooters pour about a barrel of water down the hole just ahead of the weight, to absorb the shock of its impact when it reaches the fluid in the hole, and to prevent cutting off the wire at that point.

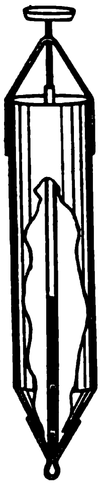


Fig. 199. Line Squib.

The bumper squib consists of an upper tube 2 inches in diameter and 4½ feet long, connected by three wires soldered to a lower shell similar to a line squib, and fitted with a firing head and pins. The bail at the top is looped, through which the end of the squib wire is passed and attached to a sash weight. Another sash weight is attached to the bottom of the squib to weight it and carry it down. Sufficient nitro-glycerin is poured into the squib to fill it up over the detonating caps fitted on the firing pins. The outfit is then lowered to the top of the charge, and a quick slacking away on the squib wire causes the upper sash weight to drop and to strike the firing head, exploding the squib. The disadvantage of the bumper squib is that, should it lodge in the casing, the weight might strike the firing head and explode it.

The squib wire is wound on a smaller iron reel and is passed over the same pulley, tied to the stem, that is used for the torpedo line.

Fig. 200. Bumper Squib.

The electric shot, so called, requires an electric wire and special squib. The electric shot is used in wells drilled through caving material, or where it may be necessary to pull the casing before exploding the shot. The shells containing the nitro-glycerin are placed in the well in the usual way. An electric squib is then lowered on a length of No. 14, 16 or 18 duplex insulated copper wire to the top of the charge. The squib is about 16 inches long with a bail, to which the electric wire is tied with a piece of rope, leaving sufficient wire below the bail to extend to the cap. The squib has an inner tube into which enough nitro-glycerin is poured to fill it up to the fulminating cap with which it is fitted. The two ends of the wire are connected to a Y shaped platinum fuse and inserted in the tube of the cap. The squib is then packed with sand to absorb any possible leakage and is weighted with a sash weight and lowered.

All wire connections made for an electric shot should be carefully taped.

When the casing is pulled, and the joints, one at a time, are stripped over the wire, if the walls of the hole should cave the wire will maintain a connection to the surface. The charge, is then exploded by means of a hand operated battery, generating an electric current which melts the platinum in the cap, detonating it. If cavings should break the wire, it will be necessary to clean out the hole with drilling tools sufficiently to explode the shot with one of the other types of squib here described. Should these means fail, it may be possible to explode the charge by lowering a string of tubing, to the bottom of which is attached a pointed wood plug. The weight of the tubing will sometimes force it down through the cavings, otherwise it may have to be turned with the tongs. When the tubing has reached the charge the plug is washed out by pouring water into it. An electric squib is then lowered on another length of insulated wire, the tubing is stripped over the wire and the charge is exploded with the battery. A simpler method that has proved efficacious is to clean out the cavings to within a few feet of the charge and then dump about ten quarts of nitro-glycerin. After waiting until the glycerin has had time to seep through the cavings, the charge is exploded by dropping a jack squib.

The dump shot sometimes is used in wells having a small body of producing sand and where no leg has been drilled below it. This is for the purpose of filling all the space in the hole with explosive. A dump shell perforated at the bottom and with a plunger valve is used to put in the nitro-glycerin and to dump it.

Usually wells are shot by experienced well shooters, equipped for the work, but it might sometimes be desired to use explosives in a well in a new field or at a place a long distance from a supply of nitro-glycerin. Solidified nitro-glycerin or dynamite is sometimes used for this purpose by drillers or other parties not familiar with well shooting. They should, however, be very careful in the measurement of the hole and be certain that the shot is placed so that its explosion will fracture the oil bearing formation. Neither of these explosives is as effective as nitro-glycerin, however.

Owing to difficulty of exploding shots in the deep wells of North Texas with the various types of squib usually used, a squib which proved efficacious has recently been improvised by a combination of an ordinary jack squib and a joint of anchor tubing in place of the glycerin tube. A stick of dynamite is placed in the bottom of the anchor, a hole is punched in the anchor about six feet from the bottom and two lengths of fuse with caps are inserted in the hole and pushed down until they reach the dynamite. The anchor tube is then fitted into the jack and packed with sand. The advantages claimed for this jack are that it is unnecessary to wrap the fuse around the tube; there are two fuses, so that if one fails, the other may explode the shot, and the weight of the sand assists in sinking the jack.

CAPACITIES OF NITRO-GLYCERIN SHELLS

Diameter, Inches	Length of One 20 Quart Shell	TOTAL LENGTH OF 2 TO 10 20-QUART NITRO-GLYCERIN SHELLS Figured to the nearest half foot — Number of Shells — Total Length of Shells								
		2	3	4	5	6	7	8	9	10
2	31 feet 6 inches....	63	94½	126	157½	189	220½	252	283½	315
2½	20 feet 1 inch......	40	60½	80½	100½	120½	140½	160½	181	201
3	13 feet 9 inches....	27½	41	55	69	82½	96½	110	124	137½
3½	10 feet 2 inches.....	20½	30½	40½	51	61	71	81½	91½	101½
4	7 feet 11 inches.....	16	24	31½	39½	47½	55½	63½	71½	79
4½	6 feet 4 inches.....	12½	19	25½	31½	38	44½	50½	57	63½
4¾	5 feet 8 inches.....	11½	17	22½	28½	34	39½	45½	51	56½
4⅞	5 feet 5 inches.....	11	16½	21½	27	32½	38	43½	49	54
5	5 feet 2 inches.....	10½	15½	20½	26	31	36	41½	46½	51½
5¼	4 feet 9 inches.....	9½	14½	19	24	28½	33½	38	43	47½
5½	4 feet 4 inches.....	8½	13	17½	21½	26	30½	34½	39	43½
6	3 feet 8 inches.....	7½	11	14½	18½	22	25½	29½	33	36½
6½	3 feet 4 inches.....	6½	10	13½	16½	20	23½	26½	30	33½
7	3 feet..............	6	9	12	15	18	21	24	27	30

Example: To find number of shells required to shoot fifty feet of sand in a 65/8-inch hole, by table, either ten 5-inch or fourteen 6-inch.

MISCELLANEOUS INSTRUCTIONS.

Flagging the Line.—The shooter should keep a permanent "flag" in his torpedo line about 150 feet from the hook on the end, also it is good practice to flag the line to indicate the fluid level in the well and the depth of the lower or first shell. He should also measure the depth of the last shell to be sure it has been correctly placed.

Careful watching of the flags on the line may prevent accidental explosions, which, at the surface, would endanger life and property and in the hole might ruin the well or at least defeat the object of the shot. When withdrawing the line from the hole and the lower flag appears, it is good practice to stop reeling with the engine and reel in the remainder of the line by hand, thus if the shell should not have unhooked and was being drawn up there would be no danger of hoisting it into the pulley. This actually is what happened at a well in North Texas. The shooter had either neglected to flag the line or the flag had pulled out and he reeled with the engine until the shell reached the surface and struck the pulley, exploding and wrecking the well. The flag to mark the depth of the first shell is to guide the shooter in lowering subsequent shells, that he may be careful not to allow the shell being lowered to strike those already placed. The best method of flagging is to open the strands of the line and insert a short piece of a strand.

When shooting a well that flows periodically a funnel with an offset should be used, so pouring may be done away from the well mouth, or better, the shells filled before being placed in the well by lowering them in the cellar or below the derrick floor. The time between flows is carefully noted and the shells are lowered during the interim. If the well is equipped with a control casing head, it may be closed after each shell has been placed. It is good practice to swab a flowing well before attempting to shoot it.

Sometimes shells lodge in the casing or in the wall of the hole. They may often be pushed down with the bailer. When this is done a block of wood should be fitted around the bailer dart. If the shell cannot be moved, it must be fished out with a grab that shooters use for the purpose. It is safer first to bleed the shell and allow the contents to drain out before attempting to pull it, but this, of course, involves the loss of the explosive. Bleeding is accomplished by lowering on the sand line a pointed steel spear weighted by a polished rod or other weight. After the shell has been removed, the tools or the bailer should be run to bottom to clear the obstruction, should there be one.

When shells of small diameter are used in a large diameter hole, each shell should be fitted with a funnel shaped anchor tip of a diameter that will prevent the upper shells from crowding down beside the lower ones.

Shells have a double bottom, the lower one cone shaped, tapering to a diameter that will fit in the anchor tubing. This cone, being empty, is sometimes collapsed by the fluid pressure, causing the upper bottom to break and the explosive to escape. To prevent this, a small hole should be punched with an awl just below the upper bottom, which will allow the fluid to displace the air in the cone.

A nitro-glycerin factory should be kept clean and all nitro-glycerin that may have leaked or splashed over the floors should be carefully washed off with warm water. No glass is used in the windows and they should be shaded to prevent the sun from shining in, for the sun's rays sometimes cause fires.

The cocks or taps through which the nitro-glycerin is drawn off should be made of a frictionless substance, such as earthenware.

It is good practice to can nitro-glycerin while it is hot, for during the cooling process its volume will shrink sufficiently to create a vacuum that will draw in the corks tightly and overcome the tendency of the can to bulge when filled. Should the explosive be placed in the cans cold a rise in the temperature might cause the contents of the can to expand, resulting in either the forcing of the corks and consequent leakage or a possible explosion.

SPONTANEOUS EXPLOSION OF NITRO-GLYCERIN IN WELLS IN NORTH TEXAS.

That nitro-glycerin, when left in the deep wells in the Ranger, Texas, oil fields, would explode spontaneously was an accidental discovery. In this field it is often necessary to pull the casing and explode the shot electrically, using insulated wire reaching from the surface to the charge of nitro-glycerin. Occasionally, due to caving of the strata, the wire connection was broken and it was impossible to explode the charge except after cleaning out the cavings covering the charge, a dangerous operation at best. It was found that nitro-glycerin, thus buried, usually would explode. The time required for such explosions ranged from one hour and fifteen minutes in one instance to over one hundred hours, but the average time is seventy-two hours. There has been much discussion regarding the probable cause of these explosions, for similar conditions have not been observed in any of the other deep fields. Internal heat, chemical action of the fluid in the well and acid that may be left in the nitro-glycerin, and the heating tendency of pyrites, which is present in some of the formations, are all given as the possible cause of these explosions. The matter has been the subject of an investigation by the U. S. Bureau of Mines, whose report* is very interesting. It is now the custom of well shooters in that field, with the consent of the well owner, to make no effort to explode the shot in wells that cave or where the casing must be pulled or raised, but to place the explosive in the well and leave it to explode spontaneously. A watchman is usually left at the well. The operator is saved the tedious work of stripping the casing over the wire and the results of such shots seem to be as effective as when the charge has been exploded in the usual way.

* Notes on spontaneous explosions of nitro-glycerin in oil and gas wells, Stephens, Palo Pinto and Young Counties, North Texas, by R. E. Collom (Petroleum Technologist) Bureau of Mines.

CHAPTER XII

FINISHING THE WELL

Finishing and Shutting in Oil Wells, Pumping Equipment, Setting Screens and Liners, Washing Wells, Shutting in Gas Wells

FINISHING AND SHUTTING IN OIL WELLS WHERE FORMATIONS STAND UP

All wells should be drilled in slowly and carefully. If the producing formation is known to contain no water, it may be safe to drill out each screw before pulling out and bailing and examining the sand. In a sand carrying bottom water or in a test well it is best to withdraw the tools and bail out every one to three feet. At the first sign of bottom water, drilling should be stopped. When conditions permit it is good practice to drill ten to fifty feet of pocket, or leg, below the producing formation. This serves the dual purpose of a receptacle in which the oil and also floating sand and cavings may collect, and prevents the latter from filling in and covering the producing formation. The top joint of casing which usually is belled, should be removed and a casing nipple and casing head substituted before drilling in, so that in the event of a sudden flow of oil or gas the operator may be prepared to connect the well to a tank or to close in the gas.

Occasionally a well is drilled into a strong flow of oil and, if the operator is unprepared, much oil may be lost. A device known as the Control Casing Head has come into general use in Mid-continent territory which prevents this waste. It really is a casing head and gate valve combined (see Fig. 201)

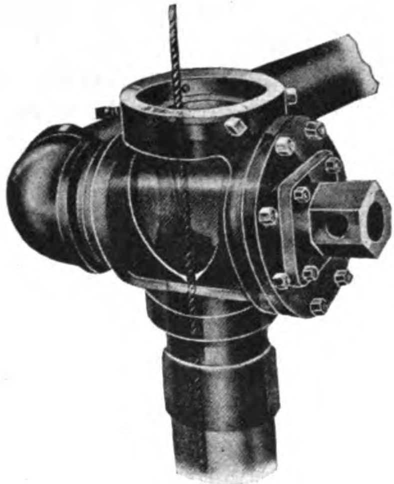


Fig. 201
Control Casing Head

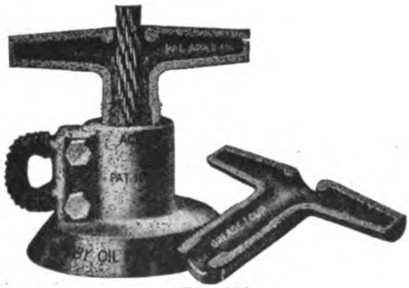


Fig. 202
Rigby Oil Saver.

and is so designed that the well may be shut in entirely, or permitted to flow in such reduced volume that the production can be cared for without loss or waste. A notch in the valve receives and closes around the drilling line, making a tight joint.

When drilling in wells in a partially developed field where gusher wells are not common, but where the well might flow, one of the several types of oil saver should be used. The oil saver (Fig. 202) is a device that fits in the top of the casing head with a plunger in which the drilling cable is confined, or a stuffing box through which it may pass, thus partially, at least, closing in the well while drilling progresses.

SHUTTING IN AN OIL WELL

Where the producing formation stands up a flowing well may be shut in the casing by means of a gate valve or by simply closing the top of the casing head with a solid top or a plug and permitting the well to flow through the side outlets, to which lead lines to the tank, equipped with stop cocks, are connected.

When the pressure and volume have diminished so the well will no longer flow through the casing, tubing, usually 2 inches in diameter, with a packer at the bottom is put in. The oil, thus confined to the smaller tubing, may continue to flow. When the well will no longer flow through the tubing, it must be put to pumping. Swabbing and agitating are sometimes effective in causing wells to resume flowing. The swab (Fig. 203) is a device fitted with a check valve and a rubber that approximates the diameter of the casing. It is operated on drilling tools and, as its name implies, is run to the bottom of the well and withdrawn, swabbing out the oil in the well and creating a suction that may cause it to flow for a short time.


Fig. 203
Swab.

Agitating is done by running the drilling tools or lowering a polished rod or other weight on the sand line and raising and lowering it, which may cause the well to flow.

In California operators sometimes raise and lower the oil string of casing as a means of agitating.

In the Mid-continent fields the "squibbing," so called, of wells that have ceased flowing is often done. This consists of shooting the well with a small quantity of nitro-glycerin when it stops flowing and repeating the process until the well fails to respond further, when it is put to pumping.

The pumping of deep wells whose production is not settled is usually done with a separate power unit for each well, usually a gas engine. Shallow wells and sometimes deep wells whose production is small are connected to a central power plant, operated with a gas engine. A pumping jack is placed over each well and these are operated by pull rods radiating from the power to the several wells, refer to Fig. 204.

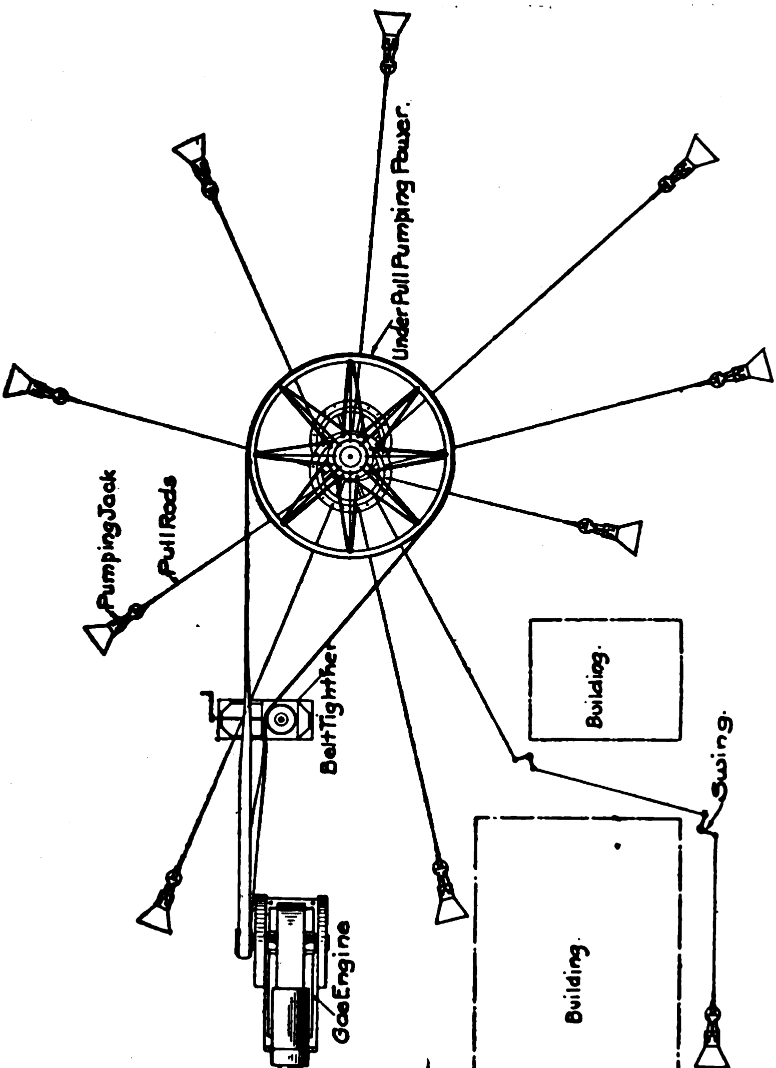


Fig. 204.—Diagram of Central Power Plant for Pumping a Group of Wells, showing Eccentric Power, Gas Engine, Pull Rods and Pumping Jack at each well.

PUMPING EQUIPMENT

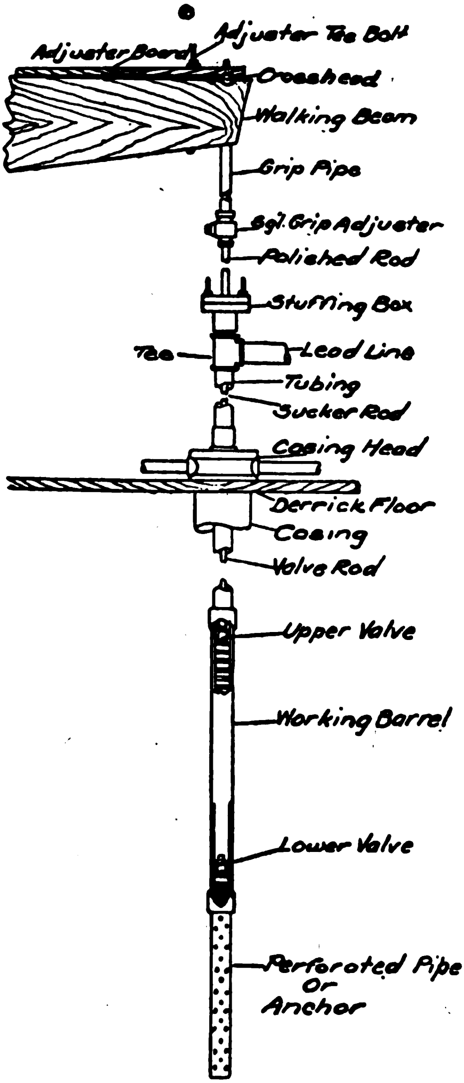


Fig. 205.
Diagram of Pumping Outfit

A pumping outfit (Fig. 205) for a well to be pumped by means of the walking beam of the derrick consists of the following:

Adjuster, fitting in the temper screw slot of the beam, used to grip and to adjust the length of stroke of the polished rod.

Adjuster board used as a top bearing for the cross-head of the adjuster.

Tee bolt to bolt the adjuster board to the beam.

Grip pipe to connect the adjuster grip with the cross-head.

Polished rod, or plunger, connecting between adjuster and sucker rods.

Stuffing box, used at top of well as a gland through which polished rod works.

Valve rod, connecting between sucker rods and upper or working valve.

Upper or working ball valve.
Lower or standing ball valve.
Working barrel or cylinder.
Perforated pipe, connected to bottom of working barrel.

In addition to the above, tubing, usually 2 inches in diameter and steel sucker or pump rods, ⅝ or 11/16 inches in diameter, sufficient to reach to the bottom of the well are required.

The tools for putting in and connecting the outfit are elevators, tubing block and hook and 2-inch and 2½-inch Crumbie tongs for the tubing; elevators, hook and wrench for the sucker rods, and ordinary chain tongs or pipe wrenches for the remainder of the outfit.

For a well to be connected with a central power plant the equipment used in pumping a single well, except the engine, adjuster, adjuster board, tee bolt and grip pipe would be required and, in addition, a pumping jack and sufficient pull, or surface, rods to connect the well with the power.

When it may be necessary to pump a large volume of salt water with the oil, 2½ or 3-inch tubing, ¾-inch or ⅞-inch steel sucker rods, or 2¼-inch wood rods and pumping outfit of sizes to conform are used. Sometimes for this purpose 2-inch tubing with a 10 or 12-foot working barrel, affording a corresponding long stroke, is used instead of the larger size tubing and the short stroke.

WIRE ROPE FOR PUMPING

Wire rope, instead of sucker rods, is used in some fields, particularly for very deep wells. Many wells in the deep fields of Ohio, West Virginia, Oklahoma and Kansas are successfully pumped with wire rope.

Advantages: Much time is saved in pulling, for it requires but a few minutes to pull out or replace a wire pumping line, spooling it on the bull wheel shaft, as compared with the several hours required to pull out and replace a long string of sucker rods. There are no joints to unscrew. The snap, or whip, sometimes given to sucker rods in the pumping motion tends to buckle and break them, while the wire rope, due to its flexibility, would not be so liable to breakage. A wire cable, after it has been used to the limit of safety in drilling, can be employed for the lighter pumping duty, thus utilizing equipment that otherwise would have to be discarded.

Disadvantages: The wire rope frays from wear and the wires break, therefore the life of a wire rope used for pumping is not so long as that of the sucker rods. Difficulty is sometimes experienced with wire rope in pumping heavy oil or in wells that paraffine, for the rope does not "drop" as readily as the rods.

Coarse laid wire rope, composed of six strands of seven wires each, is used for pumping. The rope is leaded into a socket that connects with the upper valve, and several weights or sinkers are used to give the rope the necssary drop on the down stroke. A temper screw or other hanger device that provides for quick adjustment of the rope is necessary instead of the adjuster used with sucker rods. A special stuffing box and oil saver combined is used at the top of the well in place of the stuffing box used with a polished rod. The remainder of the pumping outfit is the same as that used with sucker rods.

Electric power as a means for pumping oil wells has been slow of development, largely due to the remoteness of most oil properties from a power supply. Some of the larger producing companies have during recent years experimented with electric power with good results. Now many companies are installing power plants at favorable points to serve a group of properties.

In the oil fields of Kansas and California large power companies have installed power lines to serve the oil fields.

In addition to the power plant the equipment used in pumping consists of a motor at each well, usually of the two-speed induction type.

ELECTRICAL PUMPING EQUIPMENT

During the past few years electricity has been used in increasing degree for pumping particularly in the fields of California. Both the Westinghouse Company and the General Electric Company manufacture electrical equipment especially designed for deep well pumping. It is, of course, more convenient to use electricity for pumping when a power supply is readily available, but some of the larger operating companies have installed their own power plants when a sufficient number of wells could be pumped in one locality to justify the investment. It is claimed that electricity is a much more economical power than steam and also gas, where another market may exist for the gas. Electrical equipment is said to impart a smoother motion in pumping, with a resulting freedom from breakdowns, etc. No water being required (as for circulation in a gas engine), there is no danger of freezing in cold weather. Also, it is claimed, electrical equipment is safer to operate; for example, the liability of injury to men in starting gas engines is eliminated.

This subject has been ably discussed in a paper by Mr. W. G. Taylor, Engineer, General Electric Co.,* in which he draws comparisons of costs for electric power, steam and gas power; shows how overhead expense can be reduced and more efficient results of operation secured by the use of electrical equipment.

Several classes of equipment are used for varying service as follows:

For wells pumped from the beam a 25-10 to 50-20 H. P. two-speed, variable speed motor, according to depth of well, with countershaft, transformer and control apparatus (Fig. 206). This outfit has one speed for pumping and a higher speed for pulling or bailing. A 30-15 H. P. motor is the size commonly used for wells not deeper than 3,500 feet.

* The operation of oil wells by electric power, by W. G. Taylor, General Electric Review, May, 1919.

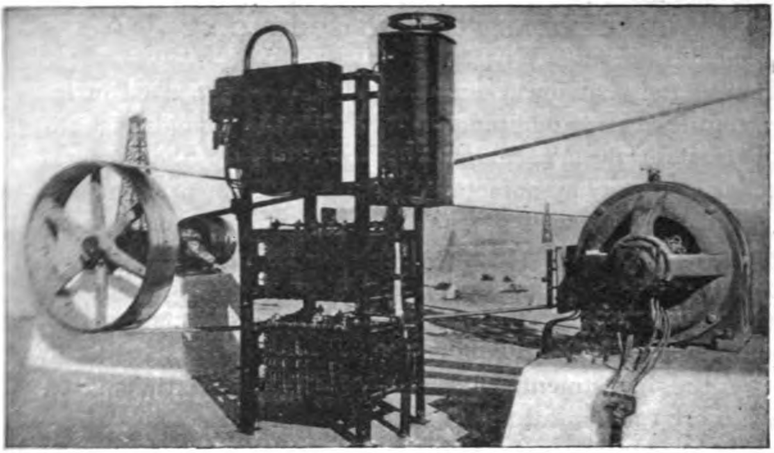


Fig. 206.
Two-speed Variable Speed Motor with Countershaft.

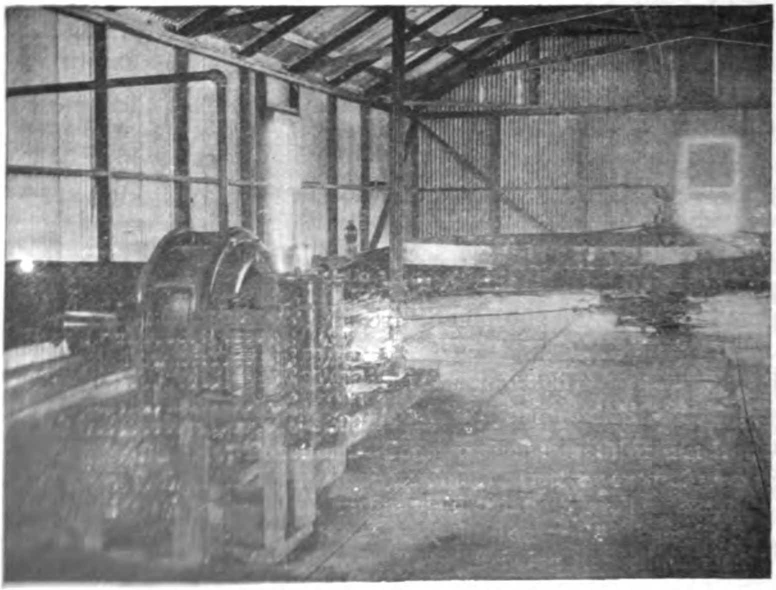


Fig. 207
Motor Driven Band Wheel Pumping Power

A variation of this equipment is sometimes used by placing a smaller single speed, variable speed motor at each well for pumping only, and then mounting on a wagon or motor truck a high speed motor or motor driven hoist which may be transported from well to well for pulling tubing and rods.

For pumping a number of wells from a central power plant, any of the several types of pumping power may be operated by motor, using the standard squirrel cage type of motor, transformer, controller, etc. With this outfit a countershaft equipped with a friction clutch is recommended to relieve the motor of heavy starting duty, engaging the clutch only after the motor has been brought up to full speed. Refer to Fig. 207. With this equipment the portable motor, described above, or a pulling machine, is required for pulling tubing and rods.

The controllers used with pumping motors are equipped with a telegraph wheel so that the outfit can be operated from the headache post of the derrick, the same as a steam engine.

The walking beam of motor driven rigs should be counterbalanced to equalize the strain of the up and down stroke of the rods and to promote smooth running of the outfit.

Well pumping operations require around 60 to 120 kilowatt hours per day for each well.

FINISHING AND SHUTTING IN OIL WELLS WHERE THE PRODUCING FORMATIONS ARE SOFT AND CAVING

In the fields of California, where the producing sands often are soft and caving, means must be employed to exclude the running sand from the well; otherwise it would soon fill up over the producing formation and greatly restrict production or obstruct the flow of oil into the well, necessitating its abandonment or frequent cleaning out. To overcome this, California operators use an "oil string" of casing, so called, which extends to the bottom of the well and the lower joints that pass through the producing formation are perforated to admit the oil, or one of several types of screen is used to cover the producing formation. In wells where it may be impracticable to pull the oil string or where the formation caves, the casing must first be carried to the bottom and afterward perforated with perforating devices specially made for the purpose. When the formation stands up sufficiently to permit the drilling in of the well, the casing may be perforated in a shop before it is put in the well. This insures a better job with the holes properly spaced and drilled. For illustration of perforator and description of perforating process refer to page 280.

SETTING SHOP PERFORATED CASING

There are several methods. The simplest way is to pull the oil string, screw on the joints of perforated pipe and lower it to bottom. When it is impracticable to pull the oil string, perforated pipe or liner of an outside diameter that will go down inside of it may be used and it may be run in with the tools, using a hook or other means of freeing the tools from the liner. When a liner of this kind is used, an adapter, swaged nipple or other packing device that will closely fit the inside of the casing should be attached to the upper end of the liner. The oil string is then pulled up until the bottom is a few feet below the top of the liner and is hung on clamps.

When the drilling conditions, depth to the producing formation, etc., are known, the perforated casing is sometimes added to the oil string before the well is drilled in. This should not be attempted in a new field or a test well, however.

USE OF SCREENS

Screens, or strainers, are quite generally used in the Gulf Coast fields and in California in wells where the sand runs in through the perforated casing faster than it can be pumped out, and in wells pumping a large volume of water carrying floating sand with the oil. Screens also are used where the producing formation is interbedded with breaks of shale or clay. With these conditions, if the sand is permitted to run into the well too rapidly the shale or clay may cave and lodge against the perforated casing, closing the holes.*

There are several kinds of screen of which the Layne and Bowler, Figures 208-B and C, and the McEvoy, Fig. 208-A, are good types. The Layne and Bowler wire screen is a perforated steel tube wrapped with brass wire whose cross section is in the shape of a keystone. It is wrapped with the wide side out, thus the opening is very narrow at the surface but widening toward the tube. The object is to prevent grains of sand that get through the opening from clogging the screen.

The Layne and Bowler screen with "skrutite" buttons is a recently improved button screen. These buttons are made with horizontal slots, in both the keystone and the shutter types, refer to Fig. 208. The buttons are threaded and screwed into holes tapped in the pipe and both the outside and inside surfaces are flush with the pipe. It is claimed that these buttons do not loosen and fall out of the pipe.

The McEvoy screen is of the button type; small slotted brass discs are inserted in the pipe under a pressure of 1,000 pounds per square inch. These discs have vertical openings instead of the horizontal slots of the wire wrapped screens. The discs are flush with the outside of the pipe and there are no wire wrappings that might be damaged while putting it in the well.

METHOD OF SETTING SCREENS

In wells drilled by the rotary process the screen is sometimes screwed to the bottom joint of casing before it is put in. The method of setting a screen in a rotary drilled well is described in following paragraphs. A method used for setting a screen in wells drilled with a cable outfit is ably described in Bureau of Mines Technical Paper No. 247,* pages 32-33, as follows:

"The screen is used as a liner and must be small enough in outside diameter to pass within the casing carried through the

* U. S. Bureau of Mines Technical Paper No. 247, Perforated Casing and Screen Pipe in Oil Wells, by E. W. Wagy.

oil sand. The screen is usually plugged at the bottom with a swaged nipple or wooden plug. On top is placed a plain joint fitted with a plain casing shoe, upside down and replac-

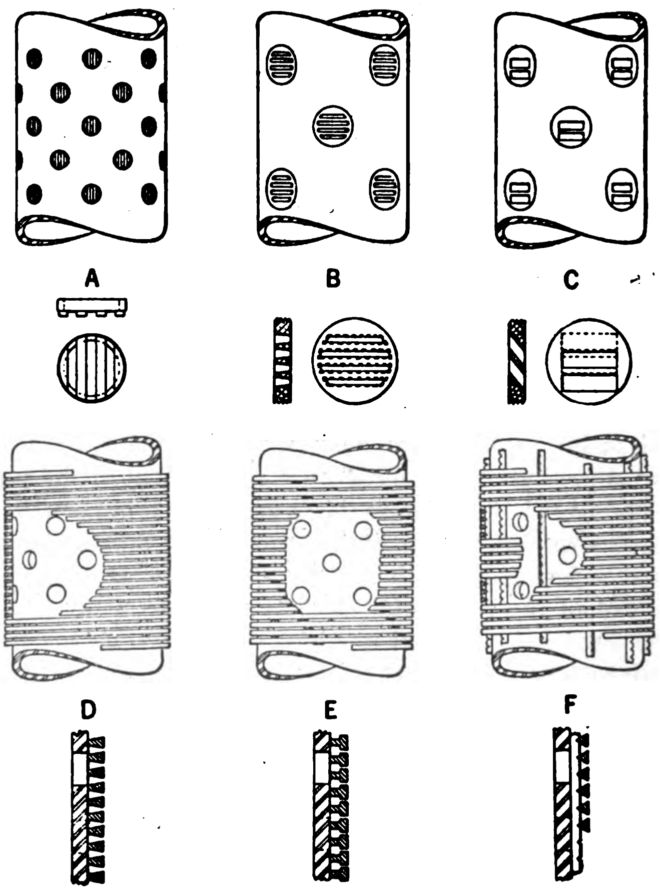


Fig. 2C8.
Type of Well Screens (Bureau of Mines)
A—McEvoy Wireless button screen.
B—Layne Skrutite button screen, Keystone type.
C—Layne Skrutite button screen, shutter type.
D—Layne wire screen, Keystone type.
E—Getty screen.
F—Stancliff screen.

ing the top collar. This serves as an adapter. The adapter is threaded with a left hand thread on top, into which the swaged nipple is screwed. This liner is then lowered inside the drilling string of casing by means of a string of tubing. When bottom has been reached, the outside casing is pulled up to the solid joint on top of the screen, allowance being made for whatever lap is desired. An allowance of 10 to 12 feet can be made for any discrepancies in taking measurements. Then the left hand swaged nipple is screwed out and the tubing removed. It is important that this work should be left until the casing has been pulled up to the proper place, to make certain that the screen liner is not moving with the outside casing as the tubing is pulled. Also, sloughing of the walls of the hole around the liner tends to prevent its rotating when an effort is made to back off the left-hand nipple."

USE OF HEAVING PLUG

Fig. 209.
Heaving Plug.

In the California fields the casing is usually carried down and landed on a shell or shale formation just above the oil sand when possible. Sometimes, however, in a new field or where an unexpected oil sand is encountered, the overlying shell or shale may have been drilled through. If the sand be soft, it may be difficult to seat the casing in it or to prevent the sand from heaving up inside the casing. In such case a heaving plug, so called (see Fig. 209), having four slips with teeth that engage in the casing on an upward thrust, is lowered to the bottom of the casing and the slips are set to hold it there, thus preventing the heaving sand from rising in the casing. The casing is then perforated to admit the oil. The heaving plug, which is made of cast iron, can easily be drilled out.

FINISHING AND SHUTTING IN OIL WELLS DRILLED BY THE HYDRAULIC ROTARY SYSTEM IN THE GULF COAST FIELDS

Finishing wells drilled by the rotary process, using mud fluid, is a more difficult operation than where cable tools are used and requires the close attention of the driller to the formations penetrated. This is particularly true of wells drilled in new territory where the depth to the producing formation may be unknown. The mud fluid under pump pressure has a tendency to "mud off" an oil or gas producing formation before its paying possibilities may be discovered by the driller. Unquestionably many wells have been drilled and abandoned as dry in the Gulf Coast fields which, by a more careful drilling and testing of the formation, might have proved profitable.

It now is customary, when drilling at a depth where a producing formation may be expected or when a change in formation occurs, to withdraw the drill pipe and substitute for the bit a core barrel. This device is made from a piece of 3-inch pipe about 4 feet long and with teeth similar to those in a rotary shoe. A hole is drilled near the top to allow passage of the mud fluid out of the drill pipe. The core barrel is connected to the drill pipe, if the pipe is of larger diameter, by means of a hydraulic (extra heavy) swaged nipple. When the pipe is rotated a core of the formation passed through is caught in the barrel, and any showing of oil or gas is readily detected. This method of testing a formation is far better than the old hit or miss practice of examining the slush trench for showings of oil or cuttings from promising formations, which, if found, could have originated at a level fifty feet above where the bit might then be working.

Unless the thickness of the producing formation and other conditions are known, the driller, upon entering a promising sand, should drill slowly and carefully, closely watching the slush trench for showings of oil and of salt water. Should the latter be encountered, drilling should, of course, be

Fig. 210.
Setting Tool for
Layne Packer.

stopped. It is best to drill into or through the sand with a core barrel, afterward finishing the hole with the bit.

Two methods are employed in the Gulf Coast fields to protect the well from filling up over the productive formation with cavings and to exclude running sand from the oil. In Texas wire wrapped screens with apertures of varying size, according to the character of the sand, refer to Fig. 208, and long enough to cover the producing formation are used in connection with sufficient pipe or liner, called blank pipe, to extend up into the casing. This blank pipe usually is made tight in the casing by means of a lead seal or other packing device. The Layne and Bowler cone lead and canvas collapsible packer, Fig. 211, is extensively used for this purpose. Where two or more productive strata are interbedded with non-producing formations, a screen is set opposite each oil sand, with a length of blank pipe connecting the screens.

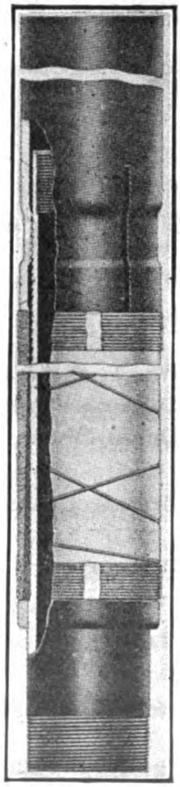


Fig. 211.
Lead and Canvas
Packer.

In the fields of North Louisiana screens are little used. Instead, perforated liners, similar to the perforated casing of California, are employed. The Louisiana laws require that the casing in all oil and gas wells be cemented, therefore, as the tendency for water or cavings to run in around the casing is minimized, the liner is sometimes set without a seal to the casing. It is, of course, safer to use the seal. It is to be hoped that the State of Texas will enact a law requiring the

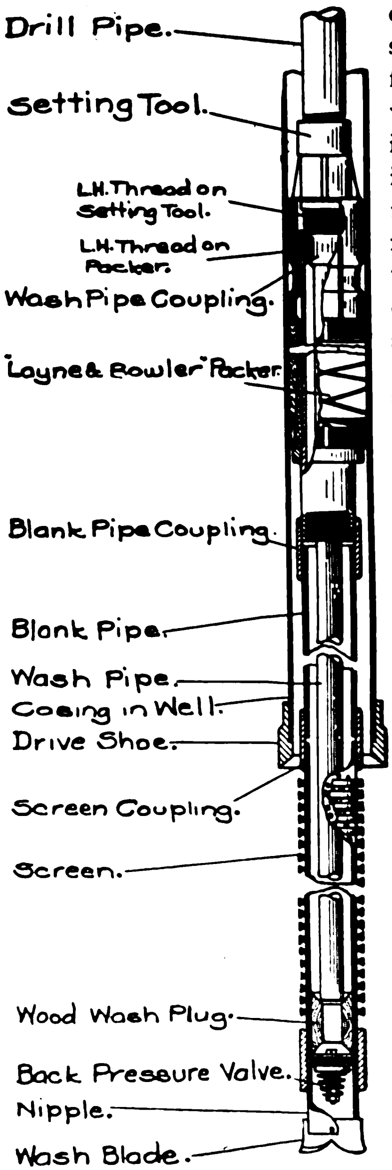


Fig. 212
Washing Well
and Setting Seal

cementing of casing in the soft formations of the Coastal fields. While the delay in waiting for the cement to set is expensive, yet the cementing of casing in the soft formations of the Gulf Coast fields is necessary to protect the producing areas from encroaching water and to conserve the natural gas.

In wells where mud fluid has been used it is necessary to clear the hole of mud fluid and sediment so the screen or liner may be set on bottom and to wash the mud from the screen and the producing formation with clear water, to insure unrestricted flow of the oil or gas from the productive stratum into the well.

For carrying the water to the bottom of the screen, so it will circulate outside of it, a wash pipe, wood wash plug and a back pressure valve are used, refer to Fig. 212.

A nipple and wash blade or rotary bit are attached to the bottom of the screen to assist in clearing the mud out of the bottom of the hole and to prevent the screen from turning when backing off the pipe used in setting. A back pressure valve is screwed in the lower coupling of the screen to hold back heaving sands and to prevent the well from flowing through the wash pipe during the setting operation. A wood wash plug is placed on top of the back pressure valve and the wash pipe, usually 2-inch, is set in a recess in the wash plug. Sufficient liner or blank pipe, usually 4½-inch drill pipe, to extend up into the casing is connected to the top coupling of the screen, and joints of wash pipe are added according to the length of the blank pipe used. If a Layne and Bowler lead seal and canvas packer is used the expanding dogs of the setting tool (Fig. 210) are compressed and the tool is screwed into the left-hand thread in the upper barrel of the packer. The lower thread of the setting tool is screwed into the upper coupling of the wash pipe and the packer is screwed on the blank pipe or liner. The drill pipe used in the setting and washing operation is attached to the top coupling of the setting tool and the outfit is ready to run. Joints of drill pipe are added until the screen reaches bottom. Meanwhile circulation of thinned mud fluid is maintained. Clear water is then circulated until the producing formation and the screen have been cleared of mud. The drill pipe is then turned to the right until it has backed off with the setting tool from the packer. The pipe is raised sufficiently for the setting tool to clear the packer, expanding the dogs, which then bear on the top of the packer (refer to Fig. 212). The weight of the drill pipe is allowed to rest on the packer until the lead has expanded and the canvas has collapsed sufficiently to telescope the packer fourteen inches, which usually makes an effective seal between the blank pipe and the casing. The drill pipe is then withdrawn, bringing with it the setting tool and the wash pipe, completing the operation. The ratchet threads on the barrel and sleeve of the Layne packer tend to lock it in its collapsed position, thus resisting heavy gas pressure.

The liners used in the fields of Louisiana are usually 4½-inch drill pipe or other pipe or casing whose couplings will go down inside the 6-inch casing. That part of the liner which passes through the productive formation is perforated with ¼-inch diameter holes, drilled about two inches apart, before it is placed in the well. The liner should extend several feet up into the casing and it is set open or with a seal according to local conditions. When it is set with a seal, the same method is employed as in setting a screen.

Fig. 212½.
Layne & Bowler Steel Wash Ring.

When the liner is left open, no seal, packer nor setting tool is required. The wash pipe is fitted in the bottom of the liner with back pressure valve and wash plug, the same as when a screen is used. The top of the liner has a right and left hand coupling and the drill pipe used for setting is connected to it with a right and left thread nipple. A steel wash and pulling ring (Fig. 212½), to prevent fluid from passing around outside of and to serve as a means of pulling the wash pipe, is fitted under top coupling of wash pipe and in the coupling connecting the right and left nipple. After the liner has been set and the well washed, the drill pipe is backed off and withdrawn, the steel ring catching under the coupling of the wash pipe, lifting it out with the drill pipe.

And after the well has been washed the mud and water in the hole will have to be bailed down until the gas pressure will flow out the remainder.

When the wells cease to flow, they are put to pumping, using pumping outfits as described for cable drilled wells. The rotary rig, however, must be equipped with walking beam for pumping and bull wheels for handling the tubing and sucker rods. Gas, oil or steam engines are used to furnish power.

In wells having a large volume of gas at high pressure, there is danger of a gas blow-out while attempting to set a screen or liner. To prevent this, circulation of mud fluid must be maintained at intervals between lowering stands of drill pipe. Most drillers use thick mud fluid for this purpose, but at least one driller found he secured better results with thinned fluid. His theory is that the thick fluid offered such resistance to the gas that it gathered a head sufficient to cause a blow-out, while the thin fluid afforded the gas a chance to escape, thus relieving its pressure. Few people who have not visited the Gulf Coast fields understand the terrific power of the gas in many of these wells. The accompanying illustration is a photograph of a 2,000-foot column of 3-inch 7.93-pound drill pipe blown out of the Humble Oil & Refining Company's Dew No. 2 well in the Blue Ridge field, near Houston, Texas. The remarkable feature of this blow-out was that the National seamless drill pipe twisted and spiraled over an acre of ground without a single break in the pipe or the couplings.

FINISHING WELLS DRILLED BY THE HYDRAULIC ROTARY SYSTEM IN THE CALIFORNIA FIELDS

In the California fields the screen or perforated pipe usually is set on the oil string of casing, no liner being used. In wells having sufficient gas pressure the screen may sometimes be simply run to the bottom, the force of the gas clearing the well and the screen of mud-laden fluid. In wells having

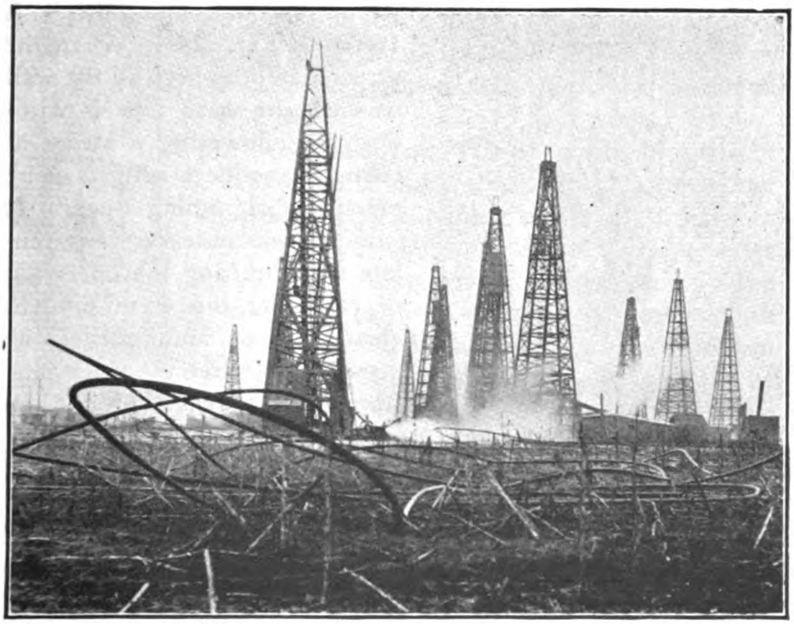


Fig. 213.
Drill Pipe Blown Out of a Well.

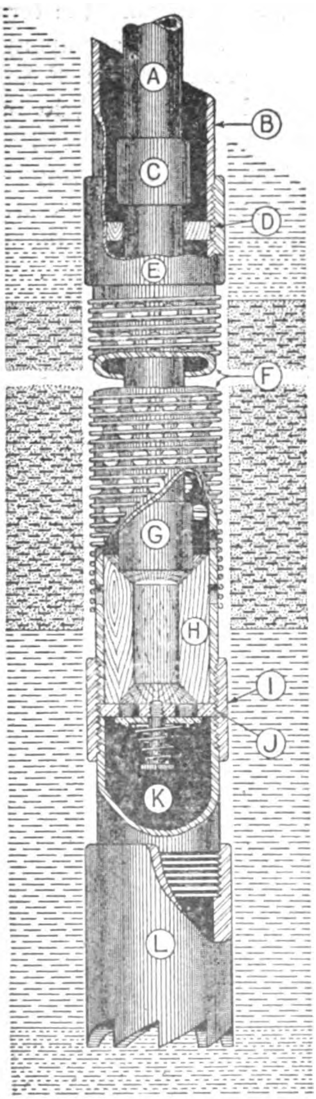


Fig. 214.
Wash Pipe Assembly.
(Bureau of Mines)

A—Wash pipe.
B—Casing.
C-G—Wash pipe couplings.
D—Wash ring.
E-I—Screen couplings.
F—Screen.
H—Wash plug.
J—Back pressure valve.
K—Nipple.
L—Rotary shoe.

a low or a very high gas pressure, however, the wash pipe method employed in the Gulf Coast fields is followed with variations. When the oil string of casing is to be left in the well a wood wash ring (D) is used to pack the wash pipe (A) in the casing to prevent fluid from passing around and outside it (refer to Fig. 214). When the screen has been set and the well washed, the wash pipe is withdrawn by lowering a string of tubing to connect with it, or by means of a tubing spear. It sometimes is necessary to circulate water during the operation of removing the wash pipe to clear sand or mud out of the strainer or to free the wash pipe from sand packed around it. For this purpose a string of pipe instead of a spear would have to be used.

When conditions make recovery of part of the oil string feasible, the operation would be as described for setting the

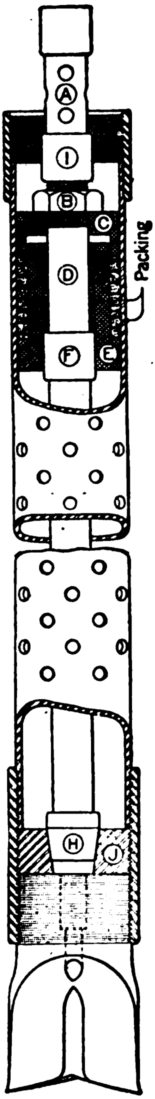


Fig. 215.
Canfield Wash Ring and Steel Wash Plug (Bureau of Mines).

screen and blank pipe with a packer or lead seal in the Gulf Coast field, when a seal is used. Sufficient of the oil string would be left in the well attached to the strainer to extend up into the next size larger casing to serve as liner or blank pipe.

When no seal is used the method of setting would be similar to that employed in Louisiana for setting a liner, with this difference: instead of a right and left thread coupling an adapter, Fig. 111, threaded with right and left threads, is used as the top coupling, for that part of the oil string which is left in the well as liner. A right and left thread nipple and steel wash and pulling ring would be used for backing off the part of the casing to be recovered and for pulling the wash pipe.*

The Canfield babbitt wash ring and steel wash plug are described in U. S. Bureau of Mines Technical paper 247, pages 37-40,' as follows:

"The wash ring (D) shown in Figure 214 is of wood. Such a ring has often served the purpose well, but there have been a number of instances where it has failed. The water used in washing out the mud leaked by the wash ring to such an extent that not enough pressure could be maintained at the bottom of the hole to wash it so the pipe could be landed. Sometimes such a high pump pressure had to be used in washing that the wooden ring could not withstand the pressure and ultimately failed.

"In order to do away with this element of risk, Mr. Wallace Canfield has devised a wash ring made of babbitt. The assembled

* U. S. Bureau of Mines Technical Paper 247, Perforated Casing and Screen Pipe in Oil Wells, by E. W. Wagy.

ring is shown in the diagram (Fig. 215). For convenience in placing this wash ring, nipples are put in the wash pipe to bring it near the top of a joint of casing. A piece of babbitt, E, is molded to fit the casing in use. The upper part of the babbitt cylinder is turned off enough to permit ⅝-inch hydraulic packing to be inserted between it and the casing. The lower part is drilled out in the center to fit the wash pipe coupling (F). A nipple (D) is then screwed into this coupling and ¼-inch hydraulic packing is wrapped around the nipple for five or six inches. The babbitt cylinder (E) is then placed over the nipple (D) resting on the packing. The space around the outside of the cylinder is filled with packing and a gland (C) of babbitt is set over this packing. A steel nut (B) is screwed onto the nipple (D) and drawn down tightly. In this manner the packing is compressed and a tight joint is made between the casing and the outside of the ring and also between the wash pipe and the inside of the wash ring.

"The ring is made of babbitt in order that it may have the required strength and also be soft enough to be worked past any rough or irregular places in the casing when it is removed. In order to do away with the swabbing effect of this ring when it is being pulled out, a short nipple (A), with ¾-inch holes drilled in it, is screwed into the coupling (I). A coupling is also screwed onto this perforated nipple to facilitate screwing on the pulling string.

"In the Canfield method, the back pressure valve (J, Fig. 214) is also omitted. This valve has sometimes given trouble by getting stuck, the pump pressure being unable to loosen it again. * * *

"In some wells the gas pressure is great enough to unseat the wash pipe and start the fluid rushing through the bottom plug. In a short time a channel is cut in the wood and when the wash pipe is again in place the fluid, instead of going out through the lower end of the casing, circulates around the bottom of the wash pipe and up the inside of the casing.

This trouble was avoided by substituting for the bottom wooden plug an iron ring two and one-half or three inches thick, shown at (J) in Figure 215. This ring is threaded and screwed into the coupling on top of the rotary bit. An annular, conical-shaped hole is drilled through the center of the ring, and the bottom coupling of the wash pipe (H) is turned to fit this opening. As metal is much more resistant than wood, channeling with its detrimental results is avoided."

MISCELLANEOUS NOTES

Occasionally, in the fields of Oklahoma, a well is finished with several hundred feet of open hole between the bottom of the casing and the top of the producing formation. If the formations below the casing should be caving it is good practice to set a liner of smaller size casing to bridge the space between the casing and the top of the oil sand.

In the North Texas field the flow line is sometimes fitted with three outlets, each equipped with a gate valve, one leading to the flow tank, another leading to the stock tank, and the third turned into the sump. The flow tanks in this field usually are equipped with a vent flue, to allow the gas to escape, consisting of a joint of eight-inch casing, or four boards nailed together into a long square box. Separating devices, such as the Smith separator, a specially fitted tank, are used to trap and save the gas produced with the oil. Thus gas that would otherwise be wasted is conserved for fuel and used in operating the property.

Mr. H. A. Melat, general manager of the Gulf Production Company, once successfully bridged temporarily a well drilled by the rotary system, which commenced flowing oil before the casing had been set and cemented. He cut a plug from a tree and left the stumps of branches protruding, placed it in the well with a number of cement sacks on top of it and pumped it down with thick mud fluid. After the casing was set the bridge was drilled up.

In the Gulf Coast field, when gusher wells are expected, the derrick is mounted on extra blocks or sills to provide space for connecting a gate valve and cross to the casing, below the derrick floor. Then, should the well "come in," it can be controlled.

This book is a treatise on well drilling methods and the author makes no attempt to treat in an exhaustive manner the different methods and appliances used to combat floating sand, gas, water and other difficulties met in pumping oil wells and in operating oil properties. These phases of the oil business have received more attention by engineers and others and much more has been written with reference to them than upon well drilling methods and problems. References are here given to books and papers on these subjects.*

SHUTTING IN GAS WELLS

If the well has a large volume of gas at high pressure, it may be closed by anchoring the casing and fitting a high

* Oil Production Methods, by Paul M. Paine and B. K. Stroud.
American Oil Industry, by Bacon & Hamor.
U. S. Bureau of Mines Bulletins, as follows:

Technical Paper 70, Methods of Oil Recovery in California, by Ralph Arnold and V. R. Garfias.

Bulletin 177, The decline and ultimate production of oil wells with notes on the valuation of oil properties, by C. H. Beal.

Technical paper 42, The prevention of waste of oil and gas from flowing wells in California, by Ralph Arnold and V. R. Garfias.

Technical paper 45, Waste of oil and gas in Mid-Continent fields, by R. S. Blatchley.

Technical paper 209, Traps for saving gas at oil wells, by W. R. Hamilton.

Bulletin 148, Methods of increasing the recovery from oil sands, by J. O. Lewis.

Technical paper 51, Possible causes of decline of oil wells and suggested methods of prolonging yield by L. G. Huntley.

Technical paper 72, Problems of the petroleum industry, by T. C. Allen.

Technical paper 130, Underground wastes in oil and gas fields and methods of prevention, by W. F. McMurray and J. O. Lewis.

Technical paper 247, Perforated casing and screen pipe in oil wells, by E. W. Wagy.

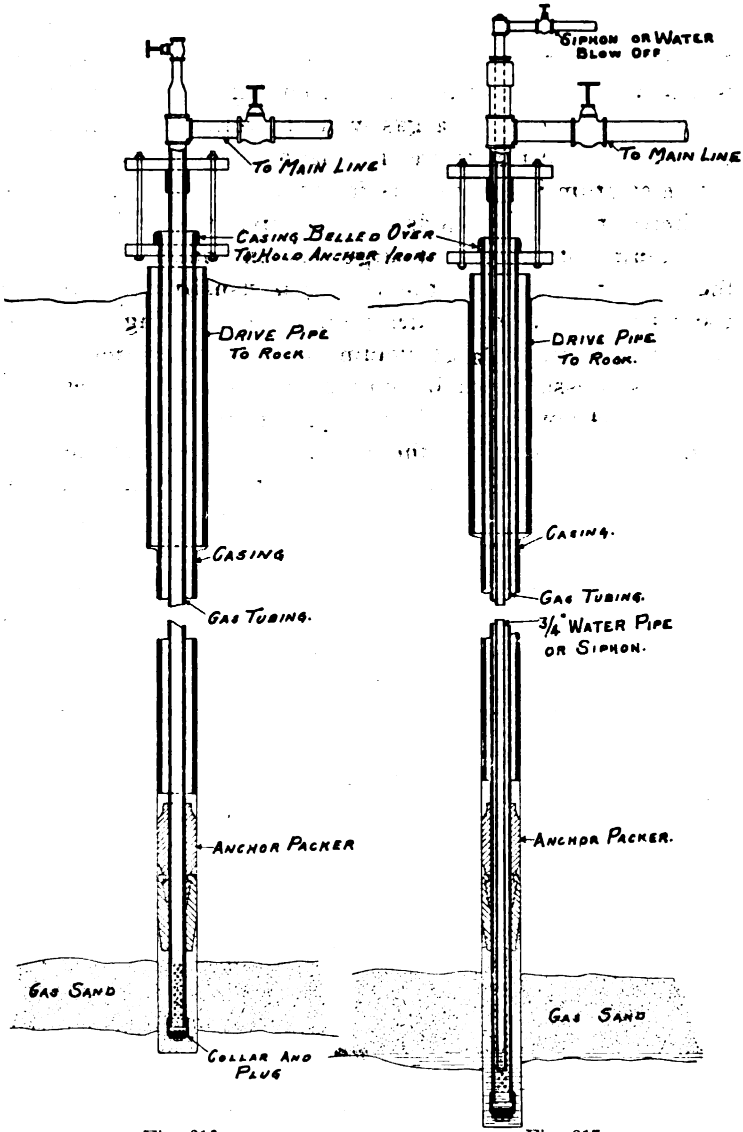


Fig. 216.
Diagram of Well Closed in and Anchored to Produce Gas.

Fig. 217.
Diagram of well Closed in and Anchored to Store the Gas in the Producing Formation.

(From Handbook of Natural Gas, by H. P. Westcott, Metric Metal Works)

pressure gate valve to the top. If, however, the casing has not been cemented or is not securely set with a packer, there is always danger of the gas escaping around the casing. It is always best to tube a gas well of average volume and use a packer at the top of the gas sand. This confines the gas to the stratum in which it is found and in the tubing.

There are two methods of anchoring the tubing. When the volume of gas is not large, and in shallow wells where the pressures are low, the tubing is usually anchored with clamps to the casing or drive pipe (refer to Fig. 216). For deep wells with a large volume of gas at greater pressure (the gas pressure usually corresponds to water pressure at depth, 0.434 pounds per foot) it is safe to anchor the tubing to the casing, provided there is a long and heavy string of casing in the well that will serve as an anchoring medium.

Where there may be no such long string of casing, it is safer to anchor the tubing in a big "gasser" to sills bolted to dead men buried in the ground, using long anchor bolts extending from the tubing clamps down through the sills. Another effective method is to dig two trenches four to six feet deep, extending about 20 feet from either side of the well, each trench to be widened near the well sufficiently to provide a space about six feet square. A joint of casing is set in each trench and anchor bolts with an eye that will slip over the casing are engaged with the tubing clamps. Concrete is then mixed and poured over the casing and around the bolts in the enlarged part of the trench and the earth replaced in the trench.

The shutting in of gas wells of large volume and high pressure drilled in hard rock formations, or in soft formations where the casing has been set and cemented, is not a difficult matter. When a heavy volume of gas is struck in a well drilled by the rotary system before casing has been set, the result is sometimes a disastrous blow-out. Such wells have created veritable craters that have swallowed the rig and machinery. The remedy is to mud off the gas, if possible,

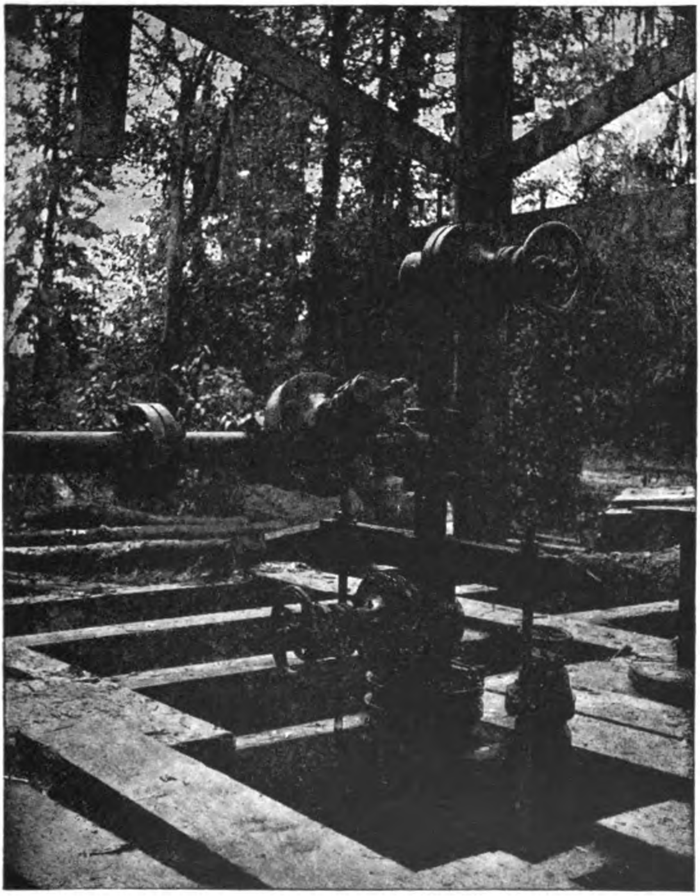


Fig. 218.
Louisiana Gas Well Shut in.
(Metric Metal Works)

until casing can be set and cemented, when the well is cleared of mud fluid by methods elsewhere described, gate valves are screwed to the top of the casing and the casing anchored so the gas may be confined. Interesting accounts of the capping of big gas wells and the extinguishing of burning wells accompanied by illustrations will be found in "Hand Book of Natural Gas" by Henry P. Westcott.* Illustration (Fig. 218) is of a gas well in the Louisiana field closed in with stuffing box casing head, otherwise known as a "Bradenhead," master gate valve, outlet gate valves and anchor clamps.

* "Hand Book of Natural Gas," published by Metric Metal Works, Erie, Pa.

CHAPTER XIII

COST OF DRILLING WELLS IN VARIOUS LOCALITIES

Many factors enter into well drilling costs, such as the local competition or the lack of it among rig and drilling contractors, the distance of the field from railway facilities with consequent high or moderate teaming expense, the character of the formations to be drilled, etc. The following cost estimates for several fields were compiled during a period of high prices and of active development work (the year 1920) and they may appear high as compared with the costs of a few years previous and the costs that may prevail in the future. They are, however, the costs that were current at the time this was written and are believed to be reliable as a basis for estimates. Some cost figures of previous years are given for the purpose of comparison.

COMPARISON OF COST OF COMPLETED DERRICKS AS OF THE YEARS 1914 AND 1920

	1914	1920
74-foot Derrick with 4½-in. Rig Irons in Pennsylvania, West Virginia and Ohio	$825.00	$1,850.00
74-foot Derrick with 4½-in. Rig Irons in Oklahoma	950.00	2,150.00
82-foot Derrick with 5-in. Rig and Calf Irons in Oklahoma	1,250.00	2,700.00
84-foot Heavy Derrick with 6-in. Ideal Chain Driven Rig and Calf Irons in North Texas	....	4,500.00
84-foot Heavy Derrick with 6-in. Ideal Chain Driven Rig and Calf Irons in California. Weight, 100,000 lbs.	1,750.00	4,000.00

COST OF DERRICKS (Concluded)

	1914	1920
106-foot Heavy Combination Standard and Rotary Derrick, with 6-in. Ideal Chain Driven Rig and Calf Irons in California. Weight, 128,000 lbs.	1,975.00	4,550.00
114-foot Heavy Combination Standard and Rotary Derrick with Concrete Corners, Iron Bull and Calf Wheel Shafts and 6-in. Ideal Chain Driven Rig and Calf Irons. Weight, 136,000 lbs. in California	2,250.00	5,500.00
82-foot Derrick with 6-in. Ideal Chain Driven Rig and Calf Irons, in Wyoming		4,500.00
84-foot Gulf Coast Rotary Derrick	300.00	650.00
112-foot Gulf Coast Rotary Derrick	400.00	850.00

CONTRACT COST OF DRILLING PER FOOT OF HOLE DRILLED—1920

Northern Ohio	$1.25 to $1.50
Central Ohio	$2.00
Pennsylvania and W. Virginia	$1.50 to $2.50
Kentucky, shallow	$4.00*
Kansas and Oklahoma, deep	$2.00 to $3.00
Kansas and Oklahoma, shallow	$2.50 to $3.50
Texas (Ranger) deep	$5.00 to $6.00
Wyoming, deep	$5.00 to 10.00
Wyoming, shallow	$3.50 to $6.00
†California	$5.25 to $6.50
Louisiana—See below.	

Drilling costs in 1914 were approximately one-half the above figures.

Contracts are taken for a completed well in the Louisiana field at from $18,000 to $25,000, according to depth. This includes rotary derrick, casing and drilling. If well is to be pumped, the derrick must be standardized and pumping equipment installed at an extra cost of approximately $4,000.

* The operator furnishes fuel and water.

† In California little drilling is done by contract. Most of the operators buy the drilling outfits and do their own drilling. These figures are for contracts to land the water string of casing only. Finishing the well is at a rate per day or the operator undertakes the work.

Note: For costs of drilling outfits refer to specifications of drilling outfits, pages 80-96.

TYPICAL EXAMPLES OF THE COST OF DRILLING AND EQUIPPING OIL WELLS, YEAR 1920

West Virginia 3,000-ft. Well

Derrick complete		$1,850.00
Drilling 3,000 ft.	@ $2.50	7,500.00
250 ft. 10-in. 35-lb. casing	@ 1.93	482.50
1,500 ft. 8¼-in. 24-lb. casing	@ 1.33	1,995.00
2,250 ft. 6⅝-in. 17-lb. casing	@ .92¾	2,086.87
2,800 ft. 5 3/16-in. casing	@ .91¾	2,569.00
Shooting 100 quarts	@ 3.00	300.00
3,000 ft. 2-in. tubing with sucker rods and pumping outfit		975.00
Gas engine and setting, belt, etc.		1,750.00
Tanks and tank house		750.00
Gas, water and oil lines, fittings and other equipment		450.00
Labor, teaming, etc. (estimated)		1,000.00
		$21,707.37

Kentucky, Bowling Green-Scottsville 450-ft. Well

Drilling 450 ft.	@ $4.00	$1,800.00
Fuel and water, estimated		600.00
40 ft. 8¼-in. 17-lb. casing	@ $1.12	44.80
400 ft. 6¼-in. 13-lb. casing	@ .77½	310.00
Shooting 40 quarts		164.00
450 ft. 2-in. tubing, sucker rods, pumping outfit, jack, fittings, etc.		275.00
Proportionate cost of gas engine, power, tanks, buildings, gas, water and oil lines, fittings, labor, etc., for power plant pumping six wells; for each well		600.00
Labor, teaming, etc. (estimated)		200.00
		$3,993.80

Oklahoma (Osage) 2,000-ft. Well

Derrick complete		$2,150.00
Drilling 2,000 ft.	@ $2.50	5,000.00
150 ft. 10-in. 35-lb. casing	@ 2.14	321.00
750 ft. 8¼-in. 24-lb. casing	@ 1.47	1,102.50
1,800 ft. 6⅝-in. 20-lb. casing	@ 1.21	2,178.00
Shooting 60 quarts		160.00
2,000 ft. 2-in. tubing with sucker rods, pull rods, pumping outfit, jack ,etc.		875.00
Proportionate cost of gas engine, power, belt, buildings, fittings for power plant pumping six wells, tanks and tank house, labor, etc.; for each well		700.00
Gas, water and oil lines, fittings and other equipment		400.00
Labor, teaming, etc. (estimated)		850.00
		$13,736.50

Oklahoma, Drumright-Quay 3,000-ft. Well

Derrick complete		$2,700.00
Drilling 3,000 ft.	@ $3.00	9,000.00
200 ft. 15½-in. 70-lb. casing	@ 5.32	1,064.00
700 ft. 12½-in. 50-lb. casing	@ 3.31	2,317.00
1,200 ft. 10-in. 40-lb. casing	@ 2.45	2,740.00
1,500 ft. 8¼-in. 28-lb. casing	@ 1.74	2,610.00
2,500 ft. 6⅝-in. 24-lb. casing	@ 1.43	3,575.00
2,900 ft. 5 3/16-in. 17-lb. casing	@ 1.02	2,958.00
Shooting 100 quarts	@ 2.50	250.00
3,000 ft. 2-in. 4½-lb. tubing with sucker rods and pumping outfit		1,350.00
Gas engine and setting, belt, etc.		2,000.00
Tanks and tank house		1,000.00
Gas, water and oil lines, fittings and other equipment		500.00
Labor, teaming, etc. (estimated)		1,750.00
		$33,814.00

Texas, Ranger-Breckenridge 3,500-ft. Well

Derrick complete		$4,500.00
Drilling 3,500 ft.	@ $5.00	17,500.00
20 ft. 20-in. O. D. 90-lb. drive pipe	@ 7.47	149.40
250 ft. 15½-in. 70-lb. casing	@ 5.32	1,330.00
700 ft. 12½-in. 50-lb. casing	@ 3.41	2,387.00
1,500 ft. 10-in. 40-lb. casing	@ 2.63	3,945.00
2,000 ft. 8¼-in. 28-lb. casing	@ 1.80	3,600.00
3,000 ft. 6⅝-in. 24-lb. casing	@ 1.49	4,470.00
3,500 ft. 4¾-in. 15-lb. casing	@ .93¼	3,263.75
Shooting 200 quarts	@ 4.00	800.00
Tanks and tank houses		1,500.00
Gas, water and oil lines, fittings and other equipment		1,000.00
Labor, teaming, etc. (estimated)		2,800.00
		$47,245.15

Note: This estimate is based on a flowing well and pumping machinery is not included.

Wyoming, Rock River-Lost Soldier, 3,000-ft. Well

Derrick complete		$4,500.00
Drilling 3,000 ft.	@ $7.00	21,000.00
40 ft. 20-in. O. D. 90-lb. drive pipe	@ 7.81	312.40
100 ft. 15½-in. 70-lb. casing	@ 5.58	558.00
750 ft. 12½-in. 45-lb. casing	@ 3.23	2,422.50
1,750 ft. 10-in. 40-lb. casing	@ 2.78	4,865.00
2,400 ft. 8¼-in. 28-lb. casing	@ 1.90	4,560.00
3,000 ft. 6¼-in. 24-lb. casing	@ 1.57	4,710.00
Shooting 80 quarts	@ 5.00	400.00
3,000 ft. 2-in. 4½-lb. tubing with sucker rods, pumping outfit, etc.		1,450.00
Gas engine and setting, belt, etc.		2,500.00
Tanks and tank house		1,500.00
Gas, water and oil lines, fittings, and other equipment		1,000.00
Labor, teaming, etc. (estimated)		3,500.00
		$53,277.90

California, Brea-Montebello, 4,000-ft. Well

Derrick complete		$4,550.00
Drilling 4,000 ft. (estimated)		26,000.00
1,000 ft. 15½-in. 70-lb. casing	@ $6.09	6,090.00
1,800 ft. 12½-in. 50-lb. casing	@ 3.96	7,128.00
2,500 ft. 10-in. 45-lb. casing	@ 3.45	8,625.00
3,500 ft. 8¼-in. 36-lb. casing	@ 2.69	9,415.00
4,000 ft. 6¼-in. 28-lb. casing	@ 2.02	8,080.00
Tanks and tank houses		2,000.00
Gas, water and oil lines, fittings and other equipment		1,000.00
Labor, teaming, etc. (estimated)		4,000.00
		$76,888.00

Note: This estimate is based on a flowing well and pumping machinery is not included.

COSTS OF WELL SHOOTING

March 1, 1921

In Ohio, Illinois and Indiana

5 quarts or less	$37.00	50 quarts	$157.50
10 quarts	64.00	60 quarts	178.00
20 quarts	93.00	70 quarts	203.50
30 quarts	114.50	80 quarts	229.00
40 quarts	136.00	90 quarts	254.50

Electric Wire 4c per ft.

100 quarts or more $2.80 per quart.

In Western Kentucky

10 quarts or less	$84.00	40 quarts	$164.00
20 quarts	92.00	50 quarts	180.00
30 quarts	128.00	60 quarts	210.00

Electric Wire 5c per ft.

60 quarts or more $3.50 per quart. Above prices are based on one day trip from nearest magazine; a charge of $35.00 will be made for each additional day.

In Kansas and Northern Oklahoma

10 quarts or less	$61.00	60 quarts	$160.00
20 quarts	87.00	70 quarts	182.50
30 quarts	105.50	80 quarts	205.00
40 quarts	124.00	90 quarts	227.50
50 quarts	142.50	100 quarts	250.00

Electric Wire 4c per ft.

100 quarts or more $2.50 per quart. Above prices are based on one day trip from nearest magazine; a charge of $40 will be made for each additional day. Casing and tubing shots $61.00 and for each additional shot on same trip $10.00.

In North Texas and Southwestern Oklahoma

10 quarts or less	$94.00	60 quarts	$260.00
20 quarts	113.00	70 quarts	300.00
30 quarts	152.00	80 quarts	340.00
40 quarts	180.00	90 quarts	380.00
50 quarts	220.00	100 quarts	400.00

Electric Wire 5c per ft.

100 quarts or more $4.00 per quart. Above prices are based on one day trip from nearest magazine; a charge of $40 will be made for each additional day. Casing and tubing shots $94.00.

At Casper and Thermopolis, Wyoming

10 quarts or less	$130.00	60 quarts	$300.00
20 quarts	175.00	70 quarts	332.00
30 quarts	210.00	80 quarts	360.00
40 quarts	240.00	90 quarts	382.00
50 quarts	275.00	100 quarts	400.00

Electric Wire 5c per ft.

100 quarts or more $4.00 per quart. Extra charge of $40.00 per day for each additional day.

These prices cover the complete service, including shells, squibs, squib wire and other material used, excepting electric wire, which is charged extra.

CHAPTER XIV

STRENGTH OF MATERIALS

STRESS AND STRAIN

Extracts from Kent's Engineers' Pocket Book

"Stresses are the forces which are applied to bodies to bring into action their elastic and cohesive properties. These forces cause alterations of the forms of the bodies upon which they act. Strain is a name given to the kind of alteration produced by the stresses. The distinction between stress and strain is not always observed, one being used for the other. (Wood.)

"Stresses are of different kinds, viz.: tensile, compressive, transverse, torsional, and shearing stresses.

"A tensile stress, or pull, is a force tending to elongate a piece. A compressive stress, or push, is a force tending to shorten it. A transverse stress tends to bend it. A torsional stress tends to twist it. A shearing stress tends to force one part of it to slide over the adjacent part.

"Tensile, compressive, and shearing stresses are called simple stresses. Transverse stress is compounded of tensile and compressive stresses, and torsional of tensile and shearing stresses.

TENSILE STRENGTH*

"The following data are usually obtained in testing by tension in a testing-machine a sample of a material of construction:

The load and the amount of extension at the elastic limit.

The maximum load applied before rupture.

"The elongation of the piece, measured between gauge-marks placed a stated distance apart before the test; and the reduction of area at the point of fracture.

"The load at the elastic limit and the maximum load are recorded in pounds per square inch of the original area. The elongation is recorded as a percentage of the stated length between the gauge-marks, and the reduction of area as a percentage of the original area. The coefficient of elasticity is calculated from the ratio the extension within the elastic limit per inch of length bears to the load per square inch producing that extension.

"**Elastic Limit.**—The elastic limit is defined as that load at which the deformations cease to be proportional to the stresses, or at which the rate of stretch (or other deformation) begins to increase. It is also defined as the load at which a permanent set first becomes visible.

"**Yield-point** is defined as that point at which the rate of stretch suddenly increases rapidly with no increase of the load."

SAFETY FACTORS AND SAFE-WORKING FIBER STRESSES

(From National Tube Co. Book of Standards)

"Each member of a mechanical structure should be capable of resisting the greatest straining action to which it can

* Author's Note.—Tests for tensile strength are expressed in pounds per square inch, i.e., from the plane, or surface, of the tested material a measurement of one inch at a right angle. Example: A piece of steel one inch square shows tensile strength of 80,000 pounds, which would be the tensile strength per square inch of the material and also the strength of that size piece. The strength of a piece of steel one inch wide and one-quarter inch thick would be one-fourth of 80,000, or 20,000 pounds.

ordinarily be subjected when in use. The designer should, therefore, consider under what conditions the straining actions are greatest. When these actions are of variable character, it is of the utmost importance to take into consideration the effects of this variation upon the endurance of the material. For example, a member may fail under a straining action that causes stresses which fluctuate, or which alternate repeatedly from tension to compression, when the same straining action would be successfully resisted under the conditions of steady loading. •

"**Margin of Security.**—It is apparent that the working load on a member of mechanical structure should be less than the calculated breaking load for the member, in order to allow for inaccuracies, deterioration, and probable contingencies, and thus provide a margin of security. It is customary, therefore, to design a member so that either (1) the statical breaking load, or (2) the load that causes the most strained fiber of the material to just reach its elastic limit, shall be a number of times the working load. This number is called the safety factor. Thus, in the first case, if the statical breaking strength were 12,000 pounds and the working load upon it 2,000 pounds, then the safety factor would be 12,000 divided by 2,000, or 6. In the second case, if the statical load that causes the most strained fiber of the member to just reach the elastic limit of the material were 6,000 pounds and the working load upon it 2,000 pounds, then the safety factor on this basis would be 3.

"The elastic and ultimate strengths of the materials, under static loading can be easily obtained. The strength, therefore, under an assumed steady loading, of any member of a mechanical structure can ordinarily be calculated with sufficient accuracy. But the proper safety factor to use under a given set of actual working conditions, involving actions of a more or less variable or uncertain character, can be arrived at in most cases only as the result of long experience, or by tedious experiment."

TABLE OF FACTORS OF SAFETY

(From Kent's Engineers' Pocket Book)

Class of Service or Materials.	Factor
Boilers	4½-6
Piston and connecting rod for single-acting engines	9-12
Shaft carrying bandwheel, fly-wheel, or armature	6¾-9
Mill shafting	24
Steel work in buildings	4
Steel work in bridges	5
Steel work for small work	6
Cast iron wheel rims	20
Steel wheel rims	8
Materials.	
Cast iron and other castings	4
Wrought iron or mild steel	3
Oil tempered or nickel steel	2¼
Hardened steel	3
Bronze and brass, rolled or forged	3

Factors of safety recommended for well drilling equipment:

Derricks	6
Wire rope	5
Manila rope	5
Casing blocks and hooks	8-10
Casing (collapsing)	2-3
Boilers	6

STRUCTURAL STEEL DERRICKS

Note: The following data on steel derricks are used through the courtesy of the Carnegie Steel Co. For more information regarding details of construction, etc., refer to Carnegie Steel Co. Catalogue, 1918.

"**Methods of Design.**—The loads which come on derricks and drilling rigs are problematical and cannot be exactly ascertained. The tables indicate what the safe loads should be, figured on the factor of safety of four which is usual in the fabrication of steel for buildings. The yield point of structural steel is rather more than twice as high as the working unit stresses.

"Consequently, the derricks will sustain safely infrequent stresses of higher amount than is set down in the tables. Care should, however, be taken not to load drilling structures beyond the tabular safe loads.

"No guy lines or other extraneous means of support are necessary. All stresses have been taken care of within the structures. Wind stresses have been figured at 30 pounds per square foot of exposed surface, which is equivalent to the pressure developed by a storm of about 70 miles per hour velocity.

"**Drilling Loads.**—The load over the crown pulley in a Standard or California derrick is made up of the load on the pulley, plus the equivalent downward pull on the drilling cable, and in consequence the load which a derrick will sustain figured on the basis of the pull on the drilling cable is to be taken as one-half of the tabular safe load.

"In pulling casing, however, the load is distributed to the crown block beams by the two or four-casing pulleys in a California derrick or by the parting of lines in a Standard derrick. While the derricks will sustain the full theoretical safe loads given, they will do so only when the loads are distributed by the crown block evenly to the four legs. It is obvious that if the entire pull in drawing casing comes on two legs, the derrick cannot be expected to stand its full theoretical load.

SAFE WORKING LOADS ON STEEL DERRICKS

"The following table shows the theoretical safe loads which various grades of derricks will sustain, computed on the factor of safety of four. It also gives the size and thickness of angles used in the top section to which other panels are proportional.

SAFE WORKING LOADS ON STEEL DERRICKS (Continued)

Size and Type	Grade	Angles in Top Section (Inches)	Working Load Pounds
64 Foot Standard	Regular	3½ x 3½ x ¼	60,000
72 Foot "	Regular	4 x 4 x 5/16	92,000
80 Foot "	Regular	4 x 4 x 5/16	92,000
80 Foot "	Extra Regular	4 x 4 x ⅜	110,000
80 Foot "	Super Regular	4 x 4 x 7/16	127,000
72 Foot California	Regular	4 x 4 x ⅜	110,000
80 Foot "	Regular	4 x 4 x ⅜	110,000
80 Foot "	Heavy	6 x 6 x ⅜	223,000
80 Foot "	Extra Heavy	6 x 6 x 7/16	259,000
86 Foot "	Heavy	6 x 6 x ⅜	223,000
106 Foot "	Heavy	6 x 6 x ⅜	223,000
106 Foot "	Extra Heavy	6 x 6 x 7/16	259,000
106 Foot "	Super Heavy	6 x 6 x ½	294,000
59 Foot Rotary	Regular	3½ x 3½ x ¼	60,000
72 Foot "	Regular	4 x 4 x ⅜	110,000
80 Foot "	Regular	4 x 4 x ⅜	110,000
86 Foot "	Regular	4 x 4 x ⅜	110,000
106 Foot "	Heavy	6 x 6 x ⅜	223,000
86 Foot Std. Combination	Regular	4 x 4 x ⅜	110,000
86 Foot Cal. Combination	Regular	4 x 4 x ⅜	110,000
86 Foot "	Heavy	6 x 6 x ⅜	223,000
106 Foot "	Heavy	6 x 6 x ⅜	223,000
106 Foot "	Extra Heavy	6 x 6 x 7/16	259,000
106 Foot "	Super Heavy	6 x 6 x ½	294,000

"The safe load figures in the above table represent the actual safe carrying capacity of each derrick, the legs of which are figured from standard steel column formulas based on a factor of safety of four on the ultimate strength of the steel. These same figures expressed in terms of the elastic limit, which is approximately one-half of the ultimate strength, would mean that the derrick should stand double the load shown in the above table before deformation would take place in any of the main members."

SAFE WORKING LOADS ON STEEL DERRICKS (Concluded)

The figures in the table may appear high and seemingly indicate that the derricks are built stronger than really necessary. It must be remembered, however, that, in addition to the actual dead weight of the string of casing, the strain of which may be reduced by the use of double or triple blocks, there must be added to the working load an amount to provide for friction in the string of casing, which, in some cases, may be as great as the dead load itself. These two factors would then represent the steady pull which must be resisted by the crown block. Even these figures do not take into account the question of impact or shock resulting from the practice on the part of some drillers to race their engine up to the load in order to release casing that may be fast or frozen in the hole. For these reasons and to provide for other unforeseen contingencies, it is apparent The Carnegie Steel Co. has made a liberal provision for factor of safety in the strength of their derricks.

SAFE WORKING LOADS FOR WOOD DERRICKS

The data worked out by the Carnegie Steel Co. (see page 376) for theoretical safe working loads for steel derricks may also be used as a basis for estimating the safe loads for wood derricks. It must be remembered, however, that a steel derrick is a structure built throughout of steel, with all parts fitted together to a scientific plan. The wood derrick, on the other hand, is built of a material less uniform in quality; it is subject to weather conditions, to faulty or careless construction and other influences which make it difficult to figure the stresses it will withstand. For example, a derrick, otherwise well built of good material, but with one leg slightly shorter than the others, or one or more legs or braces imperpectly placed or spiked, might fail with half the theoretical safe load it should carry. The following table of theoretical safe loads for wood derricks is, therefore, based on the assumption that the derrick is built of first grade material, free from defects, and well constructed, plumbed and kept under careful inspection during use.

SAFE WORKING LOADS ON WOOD DERRICKS (Concluded)

Theoretical safe working loads for wood derricks, with factor of safety of four, based on approximately perfect construction as outlined above:

Size and Type	Dimensions of Legs and Doublers	Working Load Pounds
72 Foot	2 x 8 and 2 x 10	90,000
82 Foot	2 x 8 and 2 x 10	90,000
82 Foot Heavy	2 x 8 and 2 x 10 Doubled	150,000
82 Foot California with Steel Crown Block.	2 x 10 and 2 x 12 Doubled and with Wind Braces	225,000
106 Foot California Rotary with Steel Crown Block	2 x 10 and 2 x 12 Doubled and with Wind Braces	225,000
106 Foot California Combination Heavy with Steel Crown Block.	2 x 12 and 2 x 14 Doubled and with Wind Braces	265,000

Note: A basis for comparison of these working loads for wood derricks with the working loads for steel derricks may be reached by the simple process of computing the area of the leg members and the ultimate strength of the material.

Example:

106-foot steel derrick with legs of 6-in. x 6-in. x ½-in. angles; 6 x 6 x ½ angle = end section surface 6 + 5½ = 11½ × ½ = 5.75 square inches area. Taking ultimate tensile strength of steel 64,000 pounds per square inch × 5.75 equals 368,000 pounds.

106-foot wood derrick with legs 2 x 12 in. and doubled with 2 x 14 in.; 12 in. + 14 in. = 26 in. × (2 in. doubled = 4 in.) = 104 square inches area of end section surface. Taking average ultimate tensile and compressive strength of hemlock, 6,400 pounds per square inch × 104 inches = 665,600 pounds. (See table of strength of steel and wood, pages 385, 390.)

This would be the ultimate or breaking strength of the material in one leg of the derrick and is not correct for the derrick itself, which consists of four legs, trussed by means of the girts and braces. The actual breaking strain of the derrick would be greater than the strength of one leg member, but such a calculation would have to take account of the height, bottom measurement and character of construction of the bracing members of the derrick.

From these figures it is apparent that the working loads stated for wood derricks are reasonably safe.

SAFE WORKING LOADS FOR CASING EQUIPMENT

California Pattern Iron Casing Blocks *

Note: Capacity based on bearing pressure of 3,000 pounds per square inch. Factor of safety—4.

Size Block Inches	Capacity in Tons Single	Double	Triple	Quadruple
20	10	20	30	..
22	11	21	32	
24	12	24	36	..
26	13	26	40	53
28	15	31	46	..
30	18	36	54	72
32	18	36	54	72
36	..	..	57	77
40	..	..	65	86

* Figures furnished by The National Supply Co.

SAFE WORKING LOAD FOR CASING HOOKS

Based on a unit fiber stress of 12,000 pounds per square inch. Factor of safety of 4, ultimate strength of material (wrought iron) 48,000 pounds per square inch:

Diam. of Hook Inches	Working Load Pounds	Diam. of Hook Inches	Working Load Pounds
1½	4,000	3½	26,000
1⅝	5,000	4	35,000
1¾	6,500	4½	47,000
2	9,000	5	58,000
2¼	10,000	5½	78,000
2½	13,000	6	90,000
2¾	15,000	6½	100,000
3	20,000	7½	133,000
3¼	23,000	8	150,000

TO CALCULATE THE SAFE COMBINATION OF CASING BLOCKS AND CASING LINE FOR CERTAIN LOADS

Example: To handle a string of 750 feet of 13-pound casing, equals 9,750 pounds: 20 or 22-inch single block having capacity of ten tons; ¾-inch casing line, working load 3.5 tons, equals 7,000 pounds, divided into 9,750 pounds, equals 1.4 times capacity of one line or .7 capacity of two lines, therefore a single block and two lines would be safe.

SAFE WORKING LOADS FOR CASING EQUIPMENT
(Concluded)

To handle 3,000 feet of 26-pound casing, equals 78,000 pounds: 32-inch triple block, 54 tons capacity and four casing pulleys; ⅞-inch casing line, working load 4.6 tons, equals 9,200 pounds, divided into 78,000 pounds, equals 8.5 times capacity of one line. As a triple block and four casing pulleys provide for 7 lines we must increase the number of lines or the size of the rope. 1-inch line has capacity of 6 tons, equals 12,000 pounds, divided into 78,000 pounds, equals 6.5 times capacity of one line, therefore a 1-inch line is the correct and safe size for this load.

PROPERTIES OF STEEL WIRE
From Catalogue of John A. Roebling's Sons Co.

No. Roebling Gauge.	Diam., inches.	Area, square inches.	Breaking strain 100,000 lbs. per sq. in.	Weight in pounds Per 1,000 ft.	Weight in pounds Per mile.
0	.307	.074023	7,402	248.7	1,313
1	.283	.062902	6,290	211.4	1,116
2	.263	.054325	5,433	182.5	964
3	.244	.046760	4,676	157.1	830
4	.225	.039761	3,976	133.6	705
5	.207	.033654	3,365	113.1	597
6	.192	.028953	2,895	97.3	514
7	.177	.024606	2,461	82.7	437
8	.162	.020612	2,061	69.3	366
9	.148	.017203	1,720	57.8	305
10	.135	.014314	1,431	48.1	254
11	.120	.011310	1,131	38.0	201
12	.105	.008659	866	29.1	154
13	.092	.006648	665	22.3	118
14	.080	.005027	503	16.9	89.2
15	.072	.004071	407	13.7	72.2
16	.063	.003117	312	10.5	55.3
17	.054	.002290	229	7.70	40.6
18	.047	.001735	174	5.83	30.8
19	.041	.001320	132	4.44	23.4
20	.035	.000962	96	3.23	17.1
21	.032	.000804	80	2.70	14.3
22	.028	.000616	62	2.07	10.9
23	.025	.000491	49	1.65	8.71
24	.023	.000415	42	1.40	7.37

SHEET STEEL

The above diameters of wire are the thickness of sheet steel or iron of the same gauge.

WIRE ROPE

From Catalogue of John A. Roebling's Sons Co.

DRILLING LINES

Composed of 6 Strands and a Hemp Center, 7 Wires to the Strand

	Standard Cast Steel				Extra Strong Cast Steel	
Diameter in inches.	Approximate circumference in inches.	Approximate weight per foot, pounds.	Approximate strength in tons of 2,000 pounds.	Safe working load in tons of 2000 pounds.	Approximate strength in tons of 2,000 pounds.	Safe working load in tons of 2000 pounds.
1⅛	3½	2	37	7.4	43	8.6
1	3	1.58	31	6.2	35	7.
⅞	2¾	1.20	24	4.8	28	5.6
¾	2¼	.89	18.6	3.7	21	4.2
11/16	2⅛	.75	15.4	3.1	16.7	3.3
⅝	2	.62	13	2.6	14.5	2.9

DRILLING LINES AND CASING LINES

Composed of 6 Strands and a Hemp Center, 19 Wires to the Strand

	Standard Cast Steel				Extra Strong Cast Steel	
Diameter in inches.	Approximate circumference in inches.	Approximate weight per foot, pounds.	Approximate strength in tons of 2000 pounds.	Safe working load in tons of 2000 pounds.	Approximate strength in tons of 2000 pounds.	Safe working load in tons of 2000 pounds.
1¼	4	2.45	47	9.4	53	10.6
1⅛	3½	2.00	38	7.6	43	8.6
1	3	1.58	30	6.	34	6.8
⅞	2¾	1.20	23	4.6	26	5.2
¾	2¼	.89	17.5	3.5	20.2	4.04
⅝	2	.62	12.5	2.5	14	2.8

SAND LINES

Composed of 6 Strands and a Hemp Center, 7 Wires to the Strand

Cast Steel

Diameter in inches.	Approximate circumference in inches.	Approximate weight per foot, pounds.	Approximate strength in tons of 2000 pounds.	Safe working load in tons of 2000 pounds.	Diameter in inches.	Approximate circumference in inches.	Approximate weight per foot, pounds.	Approximate strength in tons of 2000 pounds.	Safe working load in tons of 2000 pounds.
¾	2¼	.89	18.6	3.7	½	1½	.39	7.7	1.5
11/16	2⅛	.75	15.4	3.1	7/16	1¼	.30	5.5	1.1
⅝	2	.62	13	2.6	⅜	1⅛	.22	4.6	.92
9/16	1¾	.50	10	2.					

MANILA ROPE

Table of breaking strains of Manila rope as established by the United States Bureau of Standards:

		3 Strand		4 Strand	
Diameter inches	Circumference inches	Net Weight per ft. rope lbs.	Breaking Strength lbs.	Net weight per ft. rope lbs.	Breaking Strength lbs.
¼	¾	.0196	700		
⅜	1⅛	.0408	1,450		
½	1½	.0735	2,450	.0783	2,326
⅝	2	.1307	4,000	.1395	3,800
¾	2¼	.1617	4,900	.1730	4,655
⅞	2¾	.2205	7,000	.2359	6,650
1	3	.2645	8,200	.2833	7,790
1⅛	3½	.3528	11,000	.3773	10,450
1¼	3¾	.4115	12,500	.4401	11,875
1⅜	4¼	.5290	16,000	.5659	15,200
1½	4½	.5879	17,500	.6288	16,625
1⅝	5	.7348	21,500	.7865	20,425
1¾	5½	.8818	25,500	.9433	24,225
2	6	1.059	30,000	1.132	28,500
2¼	7	1.441	38,500	1.540	36,575
2½	7½	1.646	43,500	1.761	41,325
2⅝	8	1.881	49,000	2.013	46,550
2⅞	8½	2.107	55,000	2.254	52,250
3	9	2.381	61,000	2.548	57,950

MANILA HAWSER LAID DRILLING CABLES

The United States Bureau of Standards has published no report of breaking strains of hawser laid cables, but the Columbian Rope Company estimates that the breaking strain of hawser laid rope is 65% to 70% * of the breaking strain of 3-strand rope.

MANILA HAWSER LAID DRILLING CABLES * (Concluded)

Diameter inches	Net Weight per foot lbs.	Approximate Breaking Strength lbs.	Diameter inches	Net Weight per foot lbs.	Approximate Breaking Strength lbs.
1½	.75	11,700	2⅛	1.63	24,200
1 9/16	.86	13,000	2¼	1.80	25,700
1⅝	.95	14,350	2½	2.08	29,000
1¾	1.20	17,000	2⅝	2.34	32,700
1⅞	1.31	18,500	2⅞	2.60	36,700
2	1.42	20,000	3	2.95	40,700

STRENGTH AND WEIGHT OF BELTS

(From Kent's Engineers' Pocket Book)

	Tensile Strength per sq. in. Pounds	Weight per cu. in. Pounds
Single Leather	3,248 to 4,824	....
Double Leather	2,160 to 3,572	....
Cotton, Solid Woven	5,648 to 8,869	....
Cotton, Folded, Stitched	4,570 to 7,750	.026 to .05
Flax, Solid Woven	9,946	....
Flax, Folded, Stitched	6,389	....
Hair, Solid, Woven	3,852 to 5,159	....
Rubber	4,271 to 4,343	.045

LIFE OF WOOD

The natural length of life of wood and its resistance to decay vary with the kind of wood and the conditions under which it is used. In general, woods may be classed as long-lived, medium-lived and short-lived, as indicated below.

Long-lived: Cypress, redwood, red cedar, white cedar, osage orange, catalpa.

Medium-lived: White oak, slippery elm, black walnut, hickory, longleaf pine, tamarack, Douglas fir.

* The breaking strain of rope has only an indirect bearing upon the quality of it. The looser the lay, the higher is the breaking strain, because Manila fibre is quite strong along its length, but is comparatively weak across the grain. Consequently the tighter the rope is twisted together, the nearer a right angle does the stress occur in the complete rope and this accounts for a four strand rope being less strong in tensile strength than a three-strand.

Cable laid rope has a lower tensile strength than either three or four strand because the fibres in the rope are twisted back and forth several times and in some parts of the rope there are stresses directly across the grain of the fibre.

COLUMBIAN ROPE CO.

LIFE OF WOOD (Concluded)

Short-lived: Red-oak, red gum, beech, elm, spruce, short leaf pine, hemlock.

MECHANICAL PROPERTIES OF WOODS GROWN IN THE UNITED STATES

(Note: Extracts from Bulletin No. 556, by J. A. Newlin and Thomas R. C. Wilson, of the Forest Service, U. S. Department of Agriculture.)

Explanation of tables shown on following page.

"The data in these tables are based upon about 130,000 tests. Small clear specimens are used, 2 inches by 2 inches in cross section. Bending specimens are 30 inches long; others shorter, depending upon the kind of test.

"Air dry is the normal condition with respect to moisture, of wood exposed to the air, although this condition may have been obtained by artificial means.

"Elastic limit: the point where the distortion ceases to be in proportion to the load.

"Fiber stress at elastic limit: the greatest stress the timber will take under a given load and immediately return to its former position.

"Modulus of rupture is the computed fiber stress in the outermost fibers of a beam at the maximum load and is a measure of the ability of a beam to support a slowly applied load for a very short time.

"The modulus of elasticity is a measure of stiffness or rigidity of a material. In the case of a beam, modulus of elasticity is a measure of its resistance to deflection.

"In the static bending test a 2 x 2 x 30-inch beam is supported over a 28-inch span. Loading is applied to its center and at a constant rate of deflection until the beam fails.

"The maximum crushing strength is the maximum ability of a short block to sustain a slowly applied load.

"Shearing strength parallel to the grain is a measure of the ability of timber to resist slipping of one part upon another along the grain."

MECHANICAL PROPERTIES OF WOODS GROWN IN THE UNITED STATES

Tested in Air-Dry Condition

Common Name	Weight per cu. ft. lbs.	Static Bending: Fiber stress at elastic limit (lbs. per sq. in.)	Static Bending: Modulus of rupture (lbs. per sq. in.)	Static Bending: Modulus of elasticity (1,000 lbs. per sq. in.)	Maximum crushing strength (lbs. per sq. in.)	Shearing strength parallel grain (lbs. per sq. in.)
Hardwoods—						
Ash, black.....	34	8,300	13,900	1,680	6,890	1,730
Ash, Oregon...	39	8.000	14.500	1,430	7,100	2,090
Ash, white.....	40	10,200	16,800	1,810	8,190	2,110
Basswood	26	7,300	10,200	1,580	5,980	1,240
Beech	44	9,000	15,000	1,680	7,400	1,970
Birch, paper...	38	11,400	16,000	1,810	9,470	1,630
Birch, yellow...	44	12,300	18,900	2,200	9,760	1,880
Butternut	26	7,300	9,300	1,260	6,680	1,360
Chestnut	30	7,400	9,700	1,330	6,620	1,160
Cottonwood ...	28	8,600	11,400	1,640	7,830	1,120
Elm, slippery..	37	8,400	14,900	1,570	7,800	1,810
Elm, white.....	35	9,200	14,600	1,490	6,850	1,740
Gum, blue.....	54	14,900	20,600	2,600	13,900	2,050
Hickory, big shellbark	48	9,800	20,500	2,040	9,710	2,430
Hickory, bitternut	46	10,300	18,800	1,880	10,600	2,050
Hickory, pignut	53	12,700	22,500	2,410	10,640	2,450
Hickory, shagbark	50	11,900	22,600	2,290	10,700	2,340
Laurel, mountain....	47	10,900	13,200	1,410	7,120	....
Locust, black..	48	13,800	20,700	2,090	10,880	2,710
Maple, sugar...	43	10,400	15.800	1,820	8.570	2,450
Oak, burr.......	45	7,000	10,900	1,060	6,640	1,920
Oak, red........	44	8,600	14,200	1,870	7,370	1,760
Oak, white.....	48	8,300	15,200	1,780	7,610	2,090
Poplar, yellow.	27	8,400	11,800	1,610	7,480	1,170
Sycamore	34	7,600	11,300	1,510	6,280	1,460
Walnut, black..	37	14,500	17,900	1,820	10,660	1,480
Willow, black..	26	5,600	7,600	830	5,030	1,340
Conifers—						
Cedar, western red	22	6,100	8,800	1,250	6,320	920
Cedar, white...	22	5,100	6,700	810	4,140	900
Cypress, yellow	28	9,000	12.800	1.430	8,080	1,120
Douglas fir.....	34	10,600	14,000	2,210	10,680	1,270
Hemlock, east'n	28	7,200	9,700	1,300	7,060	1,160
Hemlock, westn	28	8,000	10,800	1,520	7,910	1,170
Larch, western.	36	10,100	13,500	1,830	9,640	1,530
Pine, jack......	29	6.500	9,700	1,400	7,770	1,330
Pine, lodgepole.	28	9,000	11,500	1,460	7,300	980
Pine, longleaf..	42	11,800	16,700	2,200	10,880	1,640
Pine, Norway..	34	9,200	12,300	1,790	7,080	1,260
Pine, pitch.....	35	7,800	12,400	1,500	7,600	1,670
Pine, shortleaf.	38	9,200	13,900	1,970	8,660	1,390
Pine, western white	29	7,900	11,500	1,690	7,840	590
Pine, western yellow	28	6,900	9.800	1,340	5,990	1,160
Pine, white......	27	7,000	9,600	1,420	6,360	1,070
Spruce, red......	28	7,400	10,800	1,550	6,380	1,160
Spruce, white..	28	5,900	9,200	1,390	6,020	970
Tamarack	37	8,400	12,000	1,680	7,590	1,370

RECTANGULAR WOODEN BEAMS—ONE INCH THICK

Maximum Safe Loads and Spans

Depth of Beam inches	Douglas Fir Max. Load, Lbs.	Douglas Fir Max. Span, Ft.	Spruce Max. Load, Lbs.	Spruce Max. Span, Ft.	White Oak Max. Load, Lbs.	White Oak Max. Span, Ft.	Yellow Pine Max. Load, Lbs.	Yellow Pine Max. Span, Ft.	White Pine Max. Load, Lbs.	White Pine Max. Span, Ft.
2	293	2.8	187	2.9	293	2.3	320	2.8	187	2.8
4	587	5.6	373	5.8	587	4.7	640	5.5	373	5.6
6	880	8.4	560	8.7	880	7.0	960	8.3	560	8.4
8	1173	11.2	747	11.6	1173	9.3	1280	11.	747	11.2
10	1467	14.0	933	14.6	1467	11.6	1600	13.8	933	14.0
12	1760	16.7	1120	17.5	1760	13.9	1920	16.5	1120	16.7
14	2053	19.5	1307	20.4	2053	16.3	2240	19.3	1307	19.5
16	2347	22.3	1493	23.3	2347	18.6	2560	22.	1493	22.3
18	2640	25.1	1680	26.2	2640	20.9	2880	24.8	1680	25.1
20	2933	27.9	1867	29.1	2933	23.2	3200	27.6	1867	27.9

Note: To find the safe load for beams of greater thickness than one inch multiply the figures for safe load by the thickness in inches of the beam. Example: The safe load of a spruce beam 6 x 12 inches would be 6 times 1,120 pounds, equals 6,720 pounds, safe load.

SAFE LOADS FOR SQUARE WOODEN COLUMNS IN UNITS OF 1,000 POUNDS

(From Marks Handbook)

(Based on safe end bearing compression of 1,000 lbs. per sq. in.)

Unbraced length in feet	Size of Column in inches 4 x 4	6 x 6	8 x 8	10 x 10	12 x 12	14 x 14	16 x 16
4	16.0	....	....	....	....	....	....
6	11.2	36.0	....	....	....	....	....
8	9.6	26.4	....	....	....	....	....
10	8.0	24.0	64.0	....	....	....	....
12	6.4	21.6	44.8	100.0	....	....	....
14	4.8	19.2	41.6	72.0	144.0	....	....
16	....	16.8	38.4	68.0	105.6	196.0	....
18	....	14.4	35.2	64.0	100.8	145.6	256.0
20	....	12.0	32.0	60.0	96.0	140.0	192.0
22	....	9.6	28.8	56.0	91.2	134.4	185.6
24	....	....	25.6	52.0	86.4	128.8	179.2
26	....	....	22.4	48.0	81.6	123.2	172.8
28	....	....	19.2	44.0	76.8	117.6	166.4
30	....	....	....	40.0	72.0	112.0	160.0
32	....	....	....	36.0	67.2	106.4	153.6
34	....	....	....	32.0	62.4	100.8	147.2
36	....	....	....	....	57.6	95.2	140.8
38	....	....	....	....	52.8	89.6	134.4
40	....	....	....	....	48.0	84.0	128.0

HOLDING POWER OF NAILS IN VARIOUS WOODS

(From Kent)

Tests at Watertown Arsenal on different sizes of nails from 8d to 60d, reduced to holding power per square inch of surface in wood, gave average results, in pounds, as follows:

	Cut Nails	Wire Nails
White Pine	405	167
Yellow Pine	662	318
White Oak	1,216	940
Chestnut	683	...

HOLDING POWER OF BOLTS IN WHITE PINE
(From Kent)

	Pounds
Average of all plain 1-inch bolts,	8,224
Average of all plain bolts, ⅝ to 1⅛-inch	7,805
Average of all bolts	8,383

STRENGTH OF BOLTS
(From Marks Handbook)

Bolt Diameter inches	Tensile Strength at 12,500 lbs. per sq. in. Bottom of Thread lbs.	Shearing Strength — Full Bolt at 7,500 lbs. per sq. in. lbs.	Shearing Strength — Bottom of Thread at 7,500 lbs. per sq. in. lbs.	Safe Working Load Based on Ultimate Strength 65,000 Class A Bolt Material lbs. per sq. in.
¼	340	380	200	186
5/16	570	580	340	322
⅜	850	830	510	488
7/16	1,170	1,130	700	675
½	1,570	1,470	940	915
9/16	2,030	1,860	1,220	1,186
⅝	2,520	2,300	1,510	1,480
¾	3,770	3,310	2,270	2,240
⅞	5,240	4,510	3,150	3,140
1	6,890	5,890	4,130	4,120
1⅛	8,660	7,450	5,200	5,180
1¼	11,120	9,200	6,670	6,730
1⅜	13,180	11,140	7,910	7,940
1½	16,170	13,250	9,700	9,800
1⅝	18,940	15,550	11,360	11,500
1¾	21,800	18,040	13,080	13,200
1⅞	25,610	20,710	15,370	15,600
2	28,750	23,560	17,250	17,400

FOUNDATIONS

Bearing Power of Soils.—Ira O. Baker, "Treatise on Masonry Construction."

Kind of Material	Bearing Power in Tons per Square Foot — Minimum	Maximum
Rock—the hardest—in thick layers, in native bed.	200	..
Rock equal to best ashlar masonry	25	30
Rock equal to best brick masonry	15	20
Rock equal to poor brick masonry	5	10
Clay on thick beds, always dry	4	6
Clay on thick beds, moderately dry	2	4
Clay, soft	1	2
Gravel and coarse sand, well cemented	8	10
Sand, compact, and well cemented	4	6
Sand, clean, dry	2	4
Quicksand, alluvial soils, etc	0.5	1

INTERNAL FLUID PRESSURES FOR STANDARD PIPE
(From National Tube Co. Book of Standards)

Based on Barlow's Formula $P = 2f\frac{t}{D}$

D=Outside diameter in inches. P=Pressure in pounds per square inch.
t=Thickness of wall in inches. f=Fiber stress in pounds per square inch.

Size Inches	Ultimate bursting pressure		Pressures of various factors of safety					
	Butt-weld	Lap-weld	Factor of safety = 5		Factor of safety = 6		Factor of safety = 8	
	Fiber stress 40,000 lbs. per sq. in.	Fiber stress 50,000 lbs. per sq. in.	Butt-weld fiber stress = 8000 lbs. per sq. in.	Lap-weld fiber stress = 10000 lbs. per sq. in.	Butt-weld fiber stress = 6667 lbs. per sq. in.	Lap-weld fiber stress = 8333 lbs. per sq. in.	Butt-weld fiber stress = 5000 lbs. per sq. in.	Lap-weld fiber stress = 6250 lbs. per sq. in.
1/8	13432	....	2686	....	2230	....	1679	....
1/4	13037	....	2607	....	2173	....	1630	....
3/8	10785	....	2157	....	1798	....	1348	....
1/2	10381	....	2076	....	1730	....	1298	....
3/4	8610	....	1722	....	1435	....	1076	....
1	8091	....	1618	....	1349	....	1011	....
1 1/4	6747	8434	1349	1687	1124	1406	843	1054
1 1/2	6105	7632	1221	1526	1018	1272	763	954
2	5187	6484	1037	1297	865	1081	648	811
2 1/2	5649	7061	1130	1412	941	1177	706	883
3	4937	6171	987	1234	823	1029	617	771
3 1/2	.....	5650	....	1130	....	942	....	706
4	.....	5267	....	1053	....	878	....	658
4 1/2	.....	4940	....	988	....	823	....	618
5	.....	4638	....	928	....	773	....	580
6	.....	4226	....	8 5	....	704	....	528
7	.....	3948	....	790	....	658	....	493
8	.....	3212	....	642	....	535	....	401
9	.....	3553	....	711	....	592	....	444
10	.....	2856	....	571	....	476	....	357
11	.....	3191	....	638	....	532	....	399
12	.....	2588	....	518	....	431	....	324
13	.....	2679	....	536	....	446	....	335
14	.....	2500	....	500	....	417	....	313
15	.....	2344	....	469	....	391	....	293
17 O. D.	.....	2312	....	462	....	385	....	289
18 O. D.	.....	2272	....	454	....	379	....	284
20 O. D.	.....	2045	....	409	....	341	....	256

LINK BELT USED FOR DRIVING ROTARY DRILLING EQUIPMENT

No. SS 40 Steel: Pitch 3.075 inches, 39 links per 10 feet.
Ultimate strength 25,000 pounds per square inch.
Safe working load at speed of 500 feet per minute 2,085 pounds per square inch.

No. SS 124 Steel: Pitch 4.063 inches, 30 links per 10 feet.
Ultimate strength 52,000 pounds per square inch.
Safe working load at speed of 500 feet per minute 4,333 pounds per square inch.

No. 103 Malleable-Iron: Pitch 3.075 inches, 39 links per 10 ft.
Ultimate strength 9,600 pounds per square inch.
Safe working load at speed of 500 feet per minute 800 pounds per square inch.

Rule for estimating safe working load for link belt:

For a speed of 300 feet per minute, divide ultimate strength by 8.
For a speed of 400 feet divide by 10.
For a speed of 500 feet divide by 12.
For a speed of 600 feet divide by 16.
For a speed of 700 feet divide by 20.

Note: The link belt, or sprocket chain used with rotary outfit is usually operated at high speeds, higher than the manufacturers' limit of 700 feet per minute, so the above figures for safe working loads on rotary machinery should be reduced according to the speed at which the chain is run.

To obtain the horsepower of link belt, multiply the safe working strength by the number of feet of travel per minute and divide the result by 33,000.

Example: Safe working load of No. SS 40 steel link belt is 2,085 pounds at speed of 700 ft., equals 2,085 times 700, divided by 33,000, equals 44.2 H.P.

GENERAL STRENGTH VALUES
(From Mark's Handbook)

General Strength Values.—The following tables exhibit the general range of values to be expected in various materials when subjected to various kinds of loading.

TENSILE STRENGTH OF IRON AND STEEL *
(Range of Averages)

Material.	Specific Gravity	Ultimate Strength, lb. per sq. in.	Elastic Limit, lb. per sq. in.	Yield Point, lb. per sq. in.
Cast Iron	7.207			
Gray iron	....	15,000-18,000	5,000- 6,000	
Better grade	....	20,000-30,000	10,000-24,000	
Malleable cast iron.	....	25,000-48,000	12,000-22,000	12,500-19,000
Wrought iron	7.78	42,000-52,000	21,000-26,000	28,000-34,000
Steel—				
Soft (C.-0.08-0.15).	7.833	50,000-60,000	25,000-30,000	
Medium (C.-0.15-0.30)		60,000-70,000	30,000-35,000	37,000-44,000
Hard (C.-0.30 up)		70,000-80,000	35,000-40,000	38,000-45,000
Steel castings	7.917			
Soft	....	60,000-72,000	30,000-35,000	40,000-46,000
Medium	....	72,000-78,000	36,000-39,000	
Hard	....	78,000 up	39,000 up	
Steel forgings	....	75,000-90,000	37,000-45,000	
Spring steel—				
Tempered	....	130,000-200,000	110,000-170,000	
Nickel steel—				
Forging (annealed)	....	80,000	40,000	
(oil-tempered)	....	98,000	75,000	
Vanadium steel—				
Annealed	....	54,000-96,000	27,000-48,000	
Oil-tempered	....	125,000-232,000	100,000-180,000	

TENSILE STRENGTH OF MISCELLANEOUS MATERIAL

Material	Tensile Strength, lb. per sq. in	Material	Tensile Strength, lb. per sq. in.
Brass, red	40,000	Cement	350
Brass, yellow	20,000	Limestone	670
Copper	30,000	Slate	12,000
Lead	2,000	Marble	5,200
Zinc	3,500		

* **Other Strength Functions.**—Compressive strength of cast iron = 1.6 times T. S. (Tensile Strength). Compressive strength of wrought iron and steel to be taken as the yield point. Shearing strength of cast iron = 1.10 times T. S.; of wrought iron = 0.85 times T. S.; of hard and soft steels = 0.75 times T. S. Bending strength or modulus of rupture of cast iron = 2 times T. S.; of wrought iron = T. S.; of steel, to be taken as the yield point.

CHAPTER XV

GENERAL INFORMATION

PRODUCING OIL WELLS IN THE UNITED STATES OCTOBER 31, 1920

Note.—These data were compiled by the U. S. Geological Survey from reports of pipe line companies. As some of these companies do not maintain lists of wells, part of the data is approximated.

State		Approximate number of producing oil wells	Approximate production per well per day
*California		9,490	32.3 bbls.
Colorado		70	4.1
Illinois		16,800	1.7
Indiana		2,400	1.1
Kansas		15,700	7.4
Kentucky		7,800	3.2
Louisiana—			
Northern	2,560		31.7
Coastal	140		34.6
Total Louisiana	——	2,700	31.8
New York		14,040	0.2
Ohio—			
Central and Eastern	18,500		0.8
Northwestern	21,100		0.3
Total Ohio	——	39,600	0.5
Oklahoma		50,700	6.0
Pennsylvania		67,700	0.3
Texas—			
Central and Northern	9,400		22.9
Coastal	1,700		49.7
Total Texas	——	11,100	27.0
West Virginia		19,500	1.1
Wyoming and Montana		1,000	55.9
Total		258,600	Average 4.98

* Reported by the Standard Oil Company and the Independent Producers' Agency.

WORLD'S PRODUCTION OF PETROLEUM IN 1919

(Compiled by G. B. Richardson, U. S. Geological Survey)

Country	Barrels of 42 U. S. gallons	Metric Tons	Cubic Meters	Percentage of Total by Volume
United States	a377,719,000	52,099,000	60,051,000	69
Mexico	b 87,073,000	b12,964,000	b13,843,000	16
c Russia	25,498,000	d 3,477,000	4,053,000	5
Dutch East Indies..	15,428,000	e 2,143,000	2,453,000	3
India	f 8,735,000	1,164,000	1,388,000	2
Rumania	6,614,000	g 920,000	1,051,000	1
Persia	6.412,000	h 875,000	1,019,000	1
Poland (Galicia)...	6,054,000	i 829,000	963,000	1
Peru	k 2,616,000	j 349,000	416,000)	
Japan	k 2,175,000	290,000	346,000)	
Trinidad	m 1,841,000	256,000	293,000)	
Egypt	1,501,100	n 231,100	239,000)	
Argentina	1,183,000	172,000	p 188,000)	
Venezuela	425,000	q 65,000	68,000)	
Alsace	344,000	r 47,000	55,000)	2
Canada	s 241,000	32,000	38,000)	
Germany	234,000	t 33,000	37,000)	
Italy	35,000	u 4,850	5,500)	
Algeria	5,000	v 800	800)	
England	w 1,900	250	300)	
x Other countries ..	750,000	110,000	119,000)	
Total	544,885,000	76,062,000	86,626,600	100

(a) Preliminary figures. Metric tons based on specific gravity of 0.8837.
(b) Boletin del Petroleo.
(c) Petroleum Times (London) credits Russia with 34,284,000 barrels.
(d) Oil News (London). Barrels based on specific gravity of 0.859.
(e) Bureau of Mines, Dutch East Indies. Barrels based on specific gravity of 0.8761.
(f) Reported in Imperial gallons by Geological Survey of India. Metric tons based on specific gravity of 0.8403.
(g) Moniteur du petroleu roumain. Barrels based on specific gravity of 0.8766.
(h) Reported by American consul-general at London. Barrels based on specific gravity of 0.86.
(i) Legation of Poland. Barrels based on specific gravity of 0.86.
(j) Informaciones y memorias de la Sociedad de ingenieros del Peru. Barrels based on specific gravity of 0.8403.
(k) Preliminary figures reported in koku by Oriental Economist Yearbook. Metric tons based on specific gravity of 0.8403.
(m) Reported in Imperial gallons by Trinidad Dept. Mines. Metric tons based on specific gravity of 0.8766.
(n) Reported by American consul-general at London. Barrels based on specific gravity of 0.97.
(p) Comodoro Rivadavia oil fields. Report to Minister of Agriculture. Metric tons based on specific gravity of 0.9174.
(q) Boletin del Ministerio de fomento, vol. 1, No. 1. Barrels based on specific gravity of 0.959.
(r) Bulletin Soc. de l'industrie minerale, 5th ser., vol. 17, p. 141. Barrels based on specific gravity of 0.89.
(s) Preliminary report, Canada Dept. Mines. Metric tons based on specific gravity of 0.8403.
(t) Private statistics through Consular Office, State Dept. Barrels based on specific gravity of 0.89.

WORLD'S PRODUCTION OF PETROLEUM IN 1919 (Concluded)

(u) Economista d'Italia. Quoted by Economic Review. Barrels based on specific gravity of 0.876.
(v) Algerian Bureau of Mines. Quoted in Commerce Repts. Barrels based on specific gravity of 0.98.
(w) Reported by American consul-general at London. Figures furnished by H. M. Petroleum Executive. Metric tons based on specific gravity of 0.828.
(x) Estimated.

DEEPEST WELLS IN THE WORLD

There have been four very deep wells drilled, the first in Czuchow, Germany, to a depth of 7,349 feet. The other wells have all been drilled in the United States, one by the Peoples Natural Gas Co., of Pittsburgh, on the Geary farm, near McDonald, Pa., to a depth of 7,248 feet, and two by the Hope Natural Gas Co., also of Pittsburgh. The first of the Hope wells was drilled on the Mary Goff farm, eight miles north of Clarksburg, W. Va., and reached a depth of 7,386 feet, thus breaking all records for deep drilling up to that time, March 4, 1918. The second well was drilled on the I. H. Lake farm, six miles southeast of Fairmount, W. Va., reaching a depth of 7,579 feet, June 18th, 1919, where further progress was stopped by a serious fishing job. This is the deepest well in the world and the Hope Company will doubtless hold the honor for a long time.

In the following pages is complete log of the well to the depth it has reached, 7,579 feet, together with a description of the rig and drilling outfit used.

THE DEEPEST WELL IN THE WORLD

Drilled by the Hope Natural Gas Co.

Well 4304 I. H. Lake

Located on the I. H. Lake farm, six and one-half miles southeast of Fairmount and two miles south of Samaria, W. Va.

Drilling was commenced August 5, 1916, and on June 18, 1919, the well had reached a depth of 7,579 feet, exceeding by 193 feet the depth of well No. 4190, M. O. Goff, which, until that time, had been known as "the world's deepest well."

Approximately 325 days were spent in actual drilling, the well having been shut down for about 1 year and 10 months, the longest period being 1 year and 1 month, while waiting

THE DEEPEST WELL IN THE WORLD

Hope Natural Gas Co. I. H. Lake

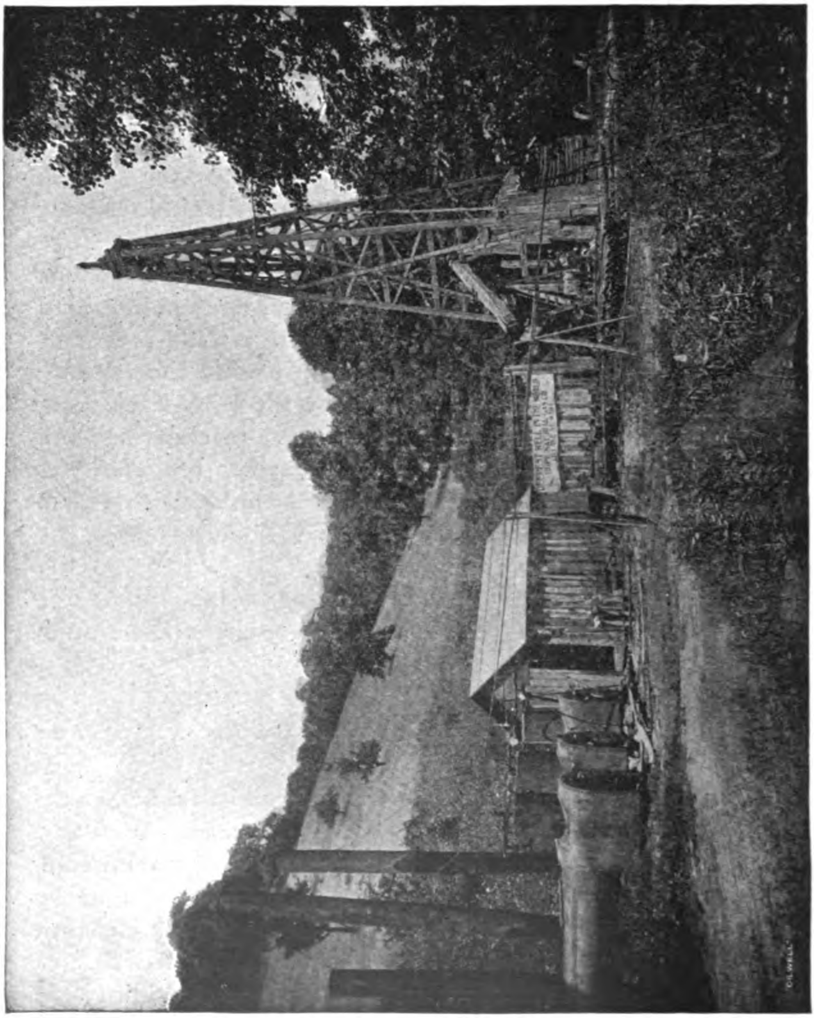


Fig. 219.—Illustration furnished by Oil Well Supply Co.

THE DEEPEST WELL IN THE WORLD (Continued)

for a cable, which was difficult to secure, due to conditions arising from the war.

The last known sand found was the Gordon at a depth of 1,474 to 1,495 feet.

No oil or gas was found.

After drilling to a depth of 6,720 feet, the heavy machinery and tools from the Goff well were moved in and drilling continued.

RECORD

Formation	Top	Bottom	Remarks
First Salt	175	190	
Second Salt	265	290	
Little Lime	585	605	
Pencil Cave	605	620	
Big Lime	620	679	
Big Injun	679	843	Gas found at 820
Squaw	848	872	
Berea	1,000	1,025	
Gantz	1,115	1,135	
Fifty Foot	1,225	1,270	
Thirty Foot	1,273	1,340	
Gordon Stray	1,448	1,470	
Gordon	1,474	1,495	
Sand	1,670	1,680	
Sand	1,695	1,705	
Sand	1,715	1,752	
Sand	1,755	1,810	
Gritty Lime	1,890	1,950	
Sand	2,045	2,050	
Lime	2,115	2,125	
Sand	2,625	2,645	
Lime	2,700	2,800	
Slate	2,800	2,840	
Sand	2,840	2,865	
Lime	2,890	2,900	
Sand	2,940	2,975	
Sand	3,420	3,428	
Slate Shells	3,428	3,750	December 23, 1916
Slate	....	4,105	
Lime Shells	4,230	4,300	
Sand	4,300	4,305	
Lime	4,305	4,360	
Slate	4,360	4,400	
Lime	4,400	4,420	
Slate	4,420	4,460	
Dark Sand	4,475	4,480	

THE DEEPEST WELL IN THE WORLD (Continued)

Formation	Top	Bottom	Remarks
Lime Slate	4,480	4,600	January 6, 1917
Slate Shells	4,600	5,520	
White Slate	5,520	5,545	July 20, 1917
Blue Lime	5,545	5,553	
Gray Slate	5,553	5,564	
White Lime	5,564	5,588	
White Slate	5,588	5,595	
White Lime	5,595	5,624	
White Slate	5,624	5,632	
Gray Slate	5,632	5,640	
White Lime	5,640	5,644	
Gray Slate	5,644	5,660	
Lime shells	5,660	5,665	
Gray Slate	5,665	5,674	
Blue Lime	5,674	5,710	
White Slate	5,710	5,722	
Lime shells	5,722	5,733	
Gray Slate	5,733	5,738	
White Slate	5,738	5,749	July 27, 1917
White Lime	5,749	5,782	
White Slate	5,782	5,786	
White Lime	5,786	5,833	
Gritty Lime	5,833	5,836	
Gray Slate	5,836	5,839	
Blue Lime	5,839	5,841	
White Slate	5,841	5,843	
Gritty Lime	5,843	5,870	
Gray Slate	5,870	5,874	
Gray Lime	5,874	5,908	
Gray Lime	5,908	5,915	
White Lime	5,915	5,937	
White Slate	5,937	5,940	
White Lime	5,940	5,950	
Gray Slate	5,950	5,957	
Blue Sand	5,957	5,960	
Light Slate	5,960	5,962	
Gray Slate	6,002	6,007	
Lime	6,007	6,009	
Gray Slate	6,009	6,015	
Blue Lime	6,015	6,024	
White Slate	6,024	6.035	
Black Slate	6,035	6,044	
Lime Shells	6,044	6,060	
Blue Lime	6,060	6,080	
White Slate	6,080	6,085	
White Slate	6,120	6,125	August 24, 1917
White Lime	6,125	6,157	
White Slate	6,157	6,168	
White Lime	6,168	6,183	
White Slate	6,183	6,224	
White Lime	6,224	6,252	

THE DEEPEST WELL IN THE WORLD (Continued)

Formation	Top	Bottom	Remarks
Gritty Lime	6,252	6,261	
Dark Slate	6,261	6,263	
Lime Shells	6,263	6,307	
Black Slate	6,307	6,317	
White Lime	6,317	6,350	
Black Slate	6,350	6,357	
Lime Shells	6,357	6,360	
Black Slate	6,360	6,363	
Black Slate	6,363	6,395	August 31, 1917
White Lime	6,395	6,408	
Black Slate	6,408	6,414	
White Lime	6,414	6,437	
Black Slate	6,437	6,460	
Lime Shells	6,460	6,462	
Black Slate	6,462	6,475	
Lime Shells	6,475	6,495	
Black Slate	6,495	6,500	
Black Lime	6,500	6,505	
Black Slate	6,505	6,512	
Lime Shells	6,512	6,521	
Black Slate	6,521	6,528	
Lime Shells	6,528	6,531	
Black Slate	6,531	6,538	
Gritty Lime	6,538	6,542	
Black Slate	6,542	6,569	
Lime Shells	6.569	6,571	
Black Slate	6,571	6,575	
Black Lime	6,575	6,637	September 7, 1917
Gray Slate	6,637	6,643	
White Lime	6,643	6,676	
Gray Slate	6,676	6,695	
White Lime	6,695	6,700	
Gray Slate	6,700	6,720	September 14, 1917
Black Slate	6,720	6,738	Shut down 1 yr. 1 mo. for cable. Drilling resumed Oct. 31, 1918.
Black Lime	6,738	6,750	
Black Slate and Gritty Lime	6,750	6,780	
Black Slate	6,780	6,800	
Black Slate	6,800	6,820	November 7, 1918
Black Slate	6,820	6,833	
Black Shells	6,833	6,836	
Black Slate	6,836	6,884	
Black Lime	6,884	6,892	
Black Slate	6,892	6,897	
Black Lime	6,897	6,902	
Black Slate	6,902	6,908	
Black Lime	6,908	6,910	
Slate	6,910	6,922	

THE DEEPEST WELL IN THE WORLD (Continued)

Formation	Top	Bottom	Remarks
Lime	6,922	6,925	
Slate	6,925	6,944	
Lime	6,944	6,949	
Black Slate	6,949	6,955	
Dark Lime	6,955	6,965	
Hard Sand	6,965	6,975	
Slate	6,975	6,976	
Gritty Lime	6,976	7,018	December, 26, 1918
Hard Sand	7,018	7,037	
Slate and Sand Shells.	7,037	7,058	
Slate	7,058	7,080	February 7, 1919
Hard Lime	7,080	7,090	
Slate	7,090	7,094	
Gritty Lime	7,094	7,110	
Lime	7,110	7,120	
Slate	7,120	7,122	
Very Hard Lime......	7,122	7,158	
Hard Gritty Lime.....	7,158	7,160	
Hard Gritty Lime.....	7,160	7,185	March 27, 1919
Gritty Lime	7,185	7,210	
White Lime	7,210	7,216	
Black Lime	7,230	7,234	
Hard Black Lime.....	7,234	7,244	
Soft Black Lime......	7,244	7,278	April 11, 1919
Hard Light Sand......	7,278	7,308	
Gritty Lime	7,308	7,312	
Hard Sand	7,312	7,328	
Black Lime	7,328	7,340	
Gray Lime	7,340	7,350	
Black Slate	7,350	7,390	
Lime and Slate........	7,390	7,404	
Slate and Lime Shells.	7,404	7,409	
Black Lime	7,409	7,420	May 5, 1919
Black Slate	7,420	7,442	
Slate and Shell........	7,442	7,460	
Hard Lime	7,460	7,466	
Slate	7,466	7,470	
Lime	7,470	7,472	
Slate and Shell........	7,472	7,486	
Unrecorded	7,486	7,579	
Total depth	7,579		June 18,1919

SIZE OF HOLE

13 inches in diameter to depth of 310 feet.
10 inches in diameter from 310 feet to 630 feet.
8¼ inches in diameter from 630 feet to 2,118 feet.
6⅝ inches in diameter from 2,118 feet to 7,579 feet.

THE DEEPEST WELL IN THE WORLD (Continued)

CASING

310 feet of 10-inch casing.
630 feet of 8¼-inch casing, set in Big Lime.
2,118 feet of 6⅝-inch casing, set in Limestone.

RIG

Standard (wood), 84 feet in height with 20-foot base. After drilling to a depth of 5,145 feet, rig was reinforced. A heavier sand reel, with 4½-inch shaft, was installed when a depth of 5,505 feet was reached.

Rig was again repaired, installing a new bull wheel with 24-inch shaft and a triple tug; with one 10-inch and one 12-inch brake wheel. Three sets of bull wheels have been used.

Band wheel, 12 feet in diameter with 18-inch face and triple tug.

Crown pulley, 7-inch steel shaft. Weight, 1,200 pounds.

4½-inch standard rig irons were used to a depth of 5,145 feet and were then replaced by a special heavy rig iron shaft 7½ inches.

Weight of band wheel irons, 8,600 pounds. These irons have been in use since the well was commenced.

At 6,720 feet, sand reel was replaced with a heavier reel with 6-inch steel shaft and 16-inch friction brake wheel.

All work of erecting and repairing rig has been under the direction of Mr. Geo. H. Stanfield, of Clarksburg, W. Va., Superintendent of Rig Building for the Hope Natural Gas Company.

BOILERS

One 25 H. P. Acme, used from top of hole to 5,105 feet.

One 25 H. P. Acme, coupled with the first at 5,105 feet, the two being used to depth of 7,100 feet.

One 25 H. P. Brennan, installed at 7,100 feet, and the three boilers used to the present depth.

ENGINES

One 12 x 12, 30 H. P. B. & S. used from top of hole to 5,145 feet.

One 14 x 14, 50 H. P. Ajax replaced the B. & S. engine at 5,145 feet and used to depth of 6,720 feet.

One 16 x 16, 70 H. P. Oil Well Supply Co. replaced the Ajax at 6,720 feet and has been used to the present depth.

CABLES

One second-hand Manila, 2¼" x 700', drilled to 150 feet.
One second-hand Manila 2¼" x 1,800', drilled to 1,500 feet.
One new Manila 2¼" x 2,800', drilled to 3,100 feet.

THE DEEPEST WELL IN THE WORLD (Concluded)

One new Wire ⅞" x 4,000', drilled to 3,900 feet.

One new Wire ⅞" x 4,000', spliced to first wire line, drilled to 5,145 feet.

One new Wire 1" x 7,000', drilled to 6,700 feet.

One new Wire 1" x 4,000' and four ⅞" x 4,000' spliced together and later spliced to 1" x 4,000', drilled to 7,158 feet.

One new Wire 1" x 7,000', to which was spliced ⅞" wire line, drilled to present depth and still in use.

TOOLS

Drilled to 2,118 feet with string of tools containing stem 35 feet in length and 5½ inches in diameter.

Drilled from 2,118 feet to 5,145 feet with string of tools containing stem 45 feet in length and 4¼ inches in diameter.

Drilled from 5,145 feet to present depth with string of tools containing stem 38 feet in length and 4¼ inches in diameter.

DRILLERS

A. L. Rawlins, driller, from 6,720 feet to present depth.

J. C. McCreight, driller, from 6,720 feet to 7,068 feet.

T. J. O'Connor, driller, from 5,145 feet to 6,720 feet.

Harley Hall, driller, from 5,145 feet to 6,720 feet.

On June 18, 1919, the well had reached a total depth of 7,579 feet, at which depth the tools stuck in the hole and cable parted, leaving tools and 4,000 feet of cable in the hole. Work has been discontinued.

FORM OF DRILLING CONTRACT

This Agreement, Made this...............day of................, A. D. 19...., between......................of.................... part......of the first part, and.. part......of the second part.

Witnesseth: That said part......of the first part hath covenanted and agreed with said part......of the second part,............... successors and assigns, that said part......of the first part will drill for said part......of the second part a certain well for the purpose of obtaining petroleum oil or natural gas, to be known as Well No.............on the farm of..................................... Section ....Town .... Range................ Township................County...................

The material, machinery and appliances necessary for drilling and completing said well shall be furnished, and the work of drilling the same shall be done, in the manner hereinafter specified, viz.:

FORM OF DRILLING CONTRACT (Continued)

A complete carpenter's rig of good quality (including wooden conductor), to be furnished by the part......of the............... part (and all repairs on same while the well is being drilled, shall be made by and at the expense of said part......of the............part.)

All casing to be furnished by part......of the...............part.

Boiler, engine, belt, bull rope, steam and water pipe and connections to be furnished at the well by part......of the............part.

The expense of fitting up and connecting same to be borne by part......of the...............part.

Fuel to be furnished at the expense of the part.........of the ....part.

Water to be furnished at the expense of the part..........of the ....part.

Oil saver and steel measuring line at expense of the part......of the...............part.

All machinery, material and appliances furnished by said part...... of the second part, shall, at the completion or abandonment of said well be returned to said part......of the second part in as good condition as when received by said part......of the first part, ordinary wear and action of the elements alone excepted.

The said part......of the first part further agrees to pay all expenses and furnish everything necessary to drill and complete said well except the articles and appliances herein specifically mentioned to be furnished by the part......of the second part.

The said well, unless sooner abandoned by direction of the party of the second part, is to be drilled.................................. .... the consideration for which shall be.....................per foot.

All fresh water shall be cased off with casing of a diameter of not less than...............inches, and all salt water cased off with casing of a diameter of not less than................inches.

When the said well approaches the oil or gas bearing sand, the part......of the first part shall notify the part......of the second part, or...........agent in charge of the farm or lease, and thereupon any further drilling and casing into or through the sand shall be as requested by the said part......of the second part, or......... agents in charge of the farm or lease, but the work in connection therewith shall be done by and under the direction and at the risk of the part......of the first part.

If oil or gas is found in sufficient quantities to endanger the rig, material or equipment, part......of the first part shall assume the

FORM OF DRILLING CONTRACT (Continued)

risk thereof and remove at...........own expense the fires and boilers to a safe distance from the well. All pipe and fittings made necessary by such removal shall be furnished by said part......of the..............part.

When completed, unless prevented by too great a volume of gas or oil, the well shall be thoroughly "bailed" and "sand pumped" by the said part......of the first part until all drillings and sediment are removed therefrom and the well thoroughly cleaned.

The part......of the first part shall carefully examine the rig, all machinery, casing and other appliances to be furnished for said well by the part......of the second part, and if any defect be found therein,sufficient to make the use of such rig, machinery, casing or other appliances unsafe, shall immediately notify the part......of the second part of such defect or defects, and the part......of the second part shall at once replace the article so found defective, with a good and safe one; but if the part......of the first part shall not make such examination, or shall not report any defects in said rig, machinery, casing or other appliances...................shall be deemed to have assumed all risks and all responsibility for any mishap which may occur in the drilling of said well, by reason of a failure in such rig, machinery, casing or other appliance.

No part of the contract price above mentioned shall in any event be paid until said well shall be completed to the depth above required, and delivered to the part......of the second part, in thoroughly good order, free and clear of all obstruction............................
....

The part......of the first part agree....to begin the drilling of the said well within................days from.....................
and prosecute the work actively and continuously (Sunday excepted) to completion.

IT IS FURTHER AGREED, That time shall be of the essence of this contract, and in case the part......of the first part shall neglect or discontinue the work of drilling said well for the space of........ days, such neglect or discontinuance shall of itself be a forfeiture of all rights and claims of the part......of the first part under this agreement without any notice or demand by the part......of the second part. The part......of the second part shall have the right at any time after such forfeiture to take possession of said well and discontinue the drilling thereof, and at its pleasure, dismantle or abandon the same without liability to the part......of the first part for any portion of the contract price above mentioned. The part....

FORM OF DRILLING CONTRACT (Concluded)

of the second part shall also have the right at any time after such forfeiture as above mentioned, if............so elect......; to take possession of said well and all the ropes, tools and appliances thereat of the part......of the first part, and drill said well to completion. In case............shall succeed in completing said well, the cost of such completion without any allowance to said part......of the first part for the use of said ropes, tools and appliances, shall be deducted from the contract price above mentioned, and the balance if any, paid to the part......of the first part; but if said part......of the second part should not succeed in completing said well, ... shall not be liable to the part......of the first part in any sum whatever and shall return said tools, ropes and appliances to the part......of the first part in as good order as when received, natural wear and tear and accidental loss or breakage excepted.

After the drilling of the well, should the part......of the second part desire to torpedo and clean out after the torpedo, the first part......agree...... to work at..................dollars per day of ....hours.

All risk and damage to tools, derrick or equipment shall be assumed by the part......of the first part at all times until all work to be done under this contract is fully and finally completed and the well is accepted as completed by the part......of the second part.

FORM OF OIL OR GAS LEASE

THIS LEASE, Made this............day of..............., A. D. 19....by and between...
of the County of......................................and State of
....of the first part, and
....of the second part,

WITNESSETH: That the said part......of the first part, in consideration of $............., in hand paid, the receipt of which is hereby acknowledged, and the stipulations, rents and covenants hereinafter contained, on the part of the said party of the second part, his executors, administrators and assigns, to be paid, kept and performed, have granted, demised and let unto the said party of the second part, his executors, administrators and assigns, for the sole and only purpose of drilling and operating for Petroleum Oil or Gas for the term of....................years, or as long thereafter as Oil or Gas is found in paying quantities, all that certain tract of land situated in......................Township.................. County, State of........................being the..............

FORM OF OIL AND GAS LEASE (Continued)

....
....
....
....

Containing....................................acres, more or less; excepting and reserving therefrom............................acres around the buildings on said premises, upon which there shall be no wells drilled; the boundaries of which shall be designated and fixed by the part......of the first part.

The said second party hereby agrees, in consideration of the said lease of the above described premises, to give said first part...... royalty share......of all the oil or mineral produced and saved from said premises, except for operating purposes on the premises, delivered in tanks or pipe lines to the credit of first part....... And further agrees to give $.............. per annum for the gas from each and every well drilled on the above described premises, in case the gas be found in quantity to transport off the above described premises, and convey to market. The said second party not to unnecessarily disturb growing crops thereon, or the fences.

Said second party has the right, which is hereby granted him, to enter upon the above described premises at any time for the purpose of mining or excavating, and the right of way to and from the place of mining or excavating, and the right to lay pipe lines for the purposes of conveying or conducting water, steam, gas, or oil over and across said premises, and also the right to remove at any time any or all machinery, oil well supplies or appurtenances of any kind belonging to the said second party.

....
....
....
....
....
....

The party of the second part agrees to commence one well........
....
from the date hereof (unavoidable accidents and delays excepted), and in case of failure to commence one well within such time, the party of the second part hereby agrees to pay thereafter to the part......of the first part for any future delay, the sum of........... dollars per annum as a rental on the same thereafter until a well is commenced or the premises abandoned, payable at.................

FORM OF OIL AND GAS LEASE (Concluded)

and the part......of the first part hereby agree....to accept such sum as full consideration and payment for such yearly delay until one well shall be commenced, and a failure to commence one well or to make any of such payments within such time and such place as above mentioned, renders this lease null and void, and neither party hereto shall be held to any accrued liability, otherwise to be and remain in full force and virtue.

It is understood by and between the parties to this agreement that all conditions between the parties hereto shall extend to their heirs, executors and assigns.

IN WITNESS WHEREOF, We, the said parties of the first and second part, have hereto set our hands the day and year first above written.

Signed and acknowledged in presence of	....
	....
....	....
....	....

LIFE OF WELL DRILLING EQUIPMENT

Tables showing number of wells different pieces of machinery, tools and other equipment may be expected to drill.

These tables may indicate the point in the life of equipment at which it may be unsafe longer to use it.

In the first column are estimates for soft formations found in California, Wyoming and Alberta, Canada (Tertiary and Cretaceous).

In the second column are estimates for the harder formations of Kansas, Oklahoma and North Texas (Carboniferous).

In the third column are estimates for the hard formations of Pennsylvania, Ohio, West Virginia, Illinois and Kentucky (Devonian, Silurian, etc.)

LIFE OF WELL DRILLING EQUIPMENT (Continued)

Stated in terms of the number of feet drilled.

	California, Wyoming, Alberta, Can.	Kansas, Oklahoma, North Texas.		Penn., Ohio W. Va., Illinois and Kentucky	
		Deep	Shallow	Deep	Shallow
*Rig Irons	20,000	15,000		20,000	
†Boiler	20,000	20,000	50,000	40,000	50,000
Engine	50,000	50,000	100,000	75,000	100,000
Belt	6,000	10,000	20,000	10,000	15,000
Manila Cable, Per foot of cable	2	1½	4	1½	2
Wire Cable, Per foot of cable	2	2	5	2½	3
Bull Rope	2,000	2,000		2,500	3,500
Sand Line, Per foot of line	3	5	10	4	5
Temper Screw	75,000	50,000	75,000	75,000	75,000
Rope Sockets	10,000	15,000	20,000	12,500	12,500
Jars-Short Stroke	4,000	4,000	5,000	3,000	4,000
Jars-Long Stroke	2,500	2,500	3,000	2,000	2,500
‡Stems	50,000	40,000	50,000	30,000	50,000
Bits, 9⅝-inch and larger	12,000	10,000	12,000	12,000	15,000
Bits, 8¼-inch and smaller	10,000	8,000	8,000	10,000	12,000
Under Reamers	12,000	10,000	.....	.....	.....
§Bailers	15,000	15,000	20,000	18,000	20,000
Tool Wrenches	75,000	75,000	100,000	75,000	100,000
Barrett Jack less Rack	15,000	12,500	25,000	12,500	25,000
Rack for Barrett Jack	25,000	20,000	40,000	20,000	40,000
Swivel Tool wrench	100,000	75,000	100,000	100,000	100,000
Derrick Crane	75,000	75,000	100,000	75,000	100,000
Chain Hoist	40,000	40,000	50,000	50,000	60,000
Elevators	60,000	60,000	75,000	75,000	100,000
Casing Line	20,000	30,000	40,000	40,000	50,000
Casing Blocks	50,000	50,000	60,000	50,000	60,000
Casing Hooks	60,000	60,000	75,000	60,000	75,000
Drive Heads	.....	.....	.....	20,000	.....
Drive Clamps	.....	.....	.....	20,000	.....
Casing Tongs	50,000	50,000	50,000	50,000	50,000
Spider and Slips	50,000	50,000	.....	.....	.....
Anvil	75,000	75,000	80,000	75,000	80,000
Steam Blower	50,000	50,000	50,000	50,000	50,000
Turbine Generator	50,000	50,000	50,000	50,000	.....
Measuring Line	75,000	75,000	75,000	75,000	75,000
Bit Ram	75,000	75,000	75,000	75,000	.....
Boiler Feed Pump	50,000	50,000	50,000	50,000	50,000
Injector	50,000	50,000	50,000	50,000	50,000

* Rig Irons: In some of the deep fields of Oklahoma a set of rig irons will drill not more than two wells, while in other localities one set may drill ten or more wells.

LIFE OF WELL DRILLING EQUIPMENT (Concluded)

† Boiler: The life of a boiler depends on the character of the water available. A boiler that would drill ten to twenty wells in West Virginia might not complete one well in Wyoming where alkaline water is used.

‡ Stems: The life of stems may be extended to the point of crystallization by renewing the boxes and pins when worn out.

§ Bailers: The valve of a bailer may batter or wear out on one well. The figures in this table contemplate the renewal of the valve when necessary.

DRILLING TOOL TAPER JOINTS

Measurement of Taper Pins and Smallest Size Hole in Which Each Size Joint Should Be Used.—The large diameter, or diameter at the base of the thread, is the basis of measurement for taper pins. This measurement is taken with a caliper at the bottom of the thread at a point three quarters of an inch from the shoulder of the collar. On this basis standard sizes of the I. & H. joints are as follows:

Smallest Size Hole Inches	Size Joint, Inches	Diameter Pin, Inches	Length * Pin, Inches	Size Square,* Inches	Diameter Collar, Inches
4	1⅝ x 2⅝-8 Thd.	2 9/32	3½	2⅝	3⅝
4	1⅝ x 2⅝-7 Thd.	2 11/32	3½	2⅝	3⅝
4½	1¾ x 2¾-8 Thd.	2⅜	3¾	2¾	3¾
4⅞	2 x 3	2 23/32	4	3¼	4⅛
5½	2¼ x 3¼	2 59/64	4	3½	4½
6	2½ x 3½	3 3/16	4	4	5
6¼	2¾ x 3¾	3 15/32	4½	4	5¼
6⅝	3 x 4	3 21/32	5	4½	6
7¼	3¼ x 4¼	3 29/32	5	5	6¼
7⅝	3½ x 4½	4 5/16	5	5	6½
8¼	4 x 5	4 25/32	5½	5½	7
9	4½ x 5½	5 15/64	6½	5½	7½

Note.—Special length pins are sometimes used; for example, 2¾ x 3¾-inch pin, 7 inches long. Box collars are ⅛ to ¼ inch larger in diameter than pin collars.

The standard taper is usually stated as 24 degrees, but this is not technically correct. It is 24 graduation marks on a Gleason lathe. Tool makers prove their joint taper by placing a square on the taper pin and a bevel protractor on the collar. When the blade of the protractor lines up with the square the taper should register 7 degrees on the bevel protractor.

* Dimensions of joints used in California differ slightly from the above. Exceptions are as follows:

Size of joint, inches	2 x 3	2¼ x 3¼	3 x 4	3¼ x 4¼	4 x 5
Size square, inches	....	3¼	4¼	5	5
Diameter collar, inches	4¼	....	5¾	6¼	....

TESTING NATURAL GAS FOR GASOLINE CONTENT *

Geo. A. Burrel and G. G. Oberfell, Chemical Engineers, Pittsburgh, Pa.

"The principle of this method for testing natural gas for gasoline content consists in absorbing the vapors in a solid absorbing medium such as charcoal, and subsequently recovering the gasoline by distillation. The method possesses several distinct advantages:

1. The method is accurate and rapid, the time consumed in absorbing the gasoline vapors from casing-head gas in a test by the charcoal absorption method being about 10 minutes.

2. The apparatus is simple to construct, easy to operate, and is readily portable, outfit containing equipment necessary for thirteen tests weighing 22 pounds.

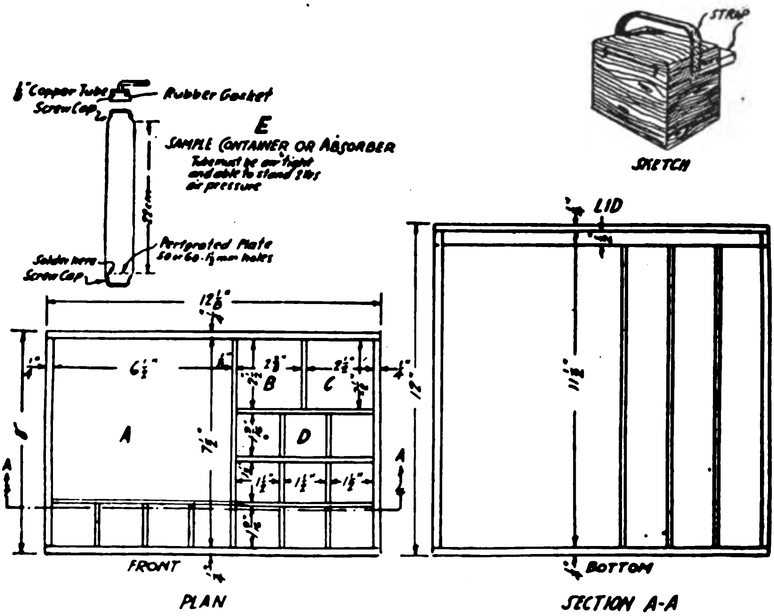


Fig. 220.

* From Natural Gas and Gasoline Journal, Dec., 1919.

TESTING NATURAL GAS FOR GASOLINE CONTENT
(Continued)

3. The method gives information both as to yield and gravity of gasoline, and is applicable to both lean and rich natural gas.

4. Pressure is not required for absorption of the gasoline vapors.

"The equipment as shown in diagram is intended for testing gas wells for flow of gas and for making the absorption tests of the gas for gasoline. The receptacle (E) may serve either as a sample container or as an absorber. After absorption of gasoline vapors from a measured volume of natural gas in the field the charcoal containing the absorbed vapors is sent to the laboratory for distillation to determine the gasoline content of the gas as described below.

EQUIPMENT CASE FOR FIELD TESTS

Compartment A holds dry test meter.

Compartment B holds "U" tube.

Compartment C holds orifice meter.

Compartment D (13) holds receptacles for samples.

Shellac all parts.

Equip lid with hinges and hooks.

See sketch for arrangement of strap handle.

"Approximately 250 c.c. of about 8 to 14 mesh charcoal of high absorption value should be used. The absorber is filled with the material to within about 2 cm. from the top.

"The apparatus is arranged so that the gas at about atmospheric pressure is passed first through calcium chloride, then through a dry meter to which a manometer is attached, and then through the charcoal.

"The dry meter was arranged with a manometer so that the pressure of the metered gas could be obtained. The temperature of the gas was taken by means of a thermometer placed at the inlet to the dry meter.

"The distillation apparatus and the method for the determination of the gravity of the distillate are essentially the

TESTING NATURAL GAS FOR GASOLINE CONTENT (Concluded)

same as those used in tests of this nature. A small Tycos hydrometer may be used for gravity determination. By using a salt water ice bath around condenser and tube or by passing vapors not condensed by an ice water mixture through a tube surrounded by a carbon-dioxide-acetone bath, the sum of condensates recovered will generally run higher than 90° Be. The yield for different gravities may then be determined from weathering losses on combined condensates of duplicate tests.

"The most satisfactory methods so far tried of removing gasoline from the charcoal are distilling in the presence of straw oil (petroleum distillate about 30° Be.) or in the presence of glycerine. The advantage of using glycerine is twofold: first, the charcoal can be regenerated easily by washing with water, and second, gasoline is not appreciably soluble in glycerine or glycerine-water solutions.

"Tests were made of natural gas for gasoline content. In Table 1 are presented the results of tests with charcoal as the absorbing medium and results of comparative tests with the portable oil absorber.* These results show that the two methods compare favorably, the yield by the portable oil absorber being about 6 per cent. low. Comparison is also made with plant production for the days during which the tests were made."

TABLE 1

Comparison of Oil Absorption Method and Charcoal Absorption Method in Tests of Natural Gas for Gasoline Content.

Oil Absorption Method

	Charcoal Absorption Method	Portable Absorber	Plant Yield
Number of tests averaged.....	4	2	2 days' product
Source of gas.	Inlet to gasoline plant.		
Gasoline recovered, Be. 60° F./60° F.	90.2	90.4	88.6
Gasoline yield, pts. M. cu. ft. gas	1.76	1.65	1.55
Gasoline yield, per cent.†......	100.00	93.8	88.1

* Extraction of Gasoline from Natural Gas by Absorption Methods by G. A. Burrell, P. M. Biddison and G. G. Oberfell, Bureau of Mines Bulletin, 120 (1917).

† Calculated from charcoal absorption method as giving 100% yield.

TABLES SHOWING DEPTHS, WEIGHT OF TOOLS AND LENGTH OF STROKE FOR WHICH WIRE DRILLING CABLES ARE RECOMMENDED*

"These tables have not taken into account unusually sticky formations or formations that require excessive under-ream-ing, but are based on the average of oil fields and are the results shown by actual drilling."

Dimensions in Feet.

For ¾-inch Cables

Weight of Tools in Pounds	18 in. Stroke	24 in. Stroke	30 in. Stroke	32 in. Stroke	36 in. Stroke
2,000	7,314	4,999	3,714	3,391	2,857
2,500	6,787	4,642	3,100	3,035	2,500
3,000	6,428	4,285	3,000	2,678	2,142
3,500	6,072	3,930	2,643	2,322	1,786
4,000	5,628	3,570	2,286	2,071	1,428
4,500	5,272	3,214	1,928	1,694	1,072
5,000	4,914	2,857	1,571	1,338	714

For ⅞-inch Cables

Weight of Tools in Pounds	18 in. Stroke	24 in. Stroke	30 in. Stroke	32 in. Stroke	36 in. Stroke
2,000	8,333	5,833	4,333	3,957	3,333
2,500	7,917	5,416	3,917	3,541	2,917
3,000	7,500	5,000	3,500	3,125	2,500
3,500	7,084	4,585	3,084	2,709	2,084
4,000	6,567	4,166	2,667	2,393	1,667
4,500	6,151	3,750	2,250	1,977	1,251
5,000	5,734	3,333	1,833	1,561	834

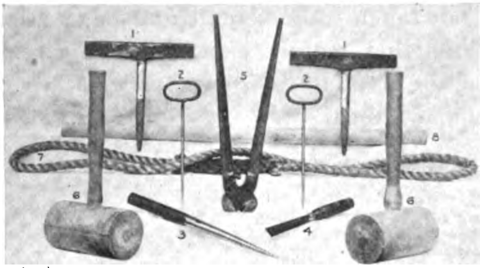
For 1-inch Cables

Weight of Tools in Pounds	24 in. Stroke	30 in. Stroke	32 in. Stroke	36 in. Stroke
2,000	6,329	4,810	4,430	3,797
2,500	6,013	4,493	4,114	3,481
3,000	5,696	4,177	3,697	3,164
3,500	5,380	3,860	3,381	2,848
4,000	5,063	3,544	3,064	2,531
4,500	4,747	3,227	2,748	2,225
5,000	4,430	2,911	2,431	1,908

Note.—The above tables are used through the courtesy of Upson Walton Co. and are for their Dreadnaut Wire Cables.

DIRECTIONS FOR SPLICING WIRE ROPE

Note.—The instructions and illustrations on this and succeeding pages were furnished by John A. Roebling's Sons Co.



1—T-shaped splicing pins.
2—Round splicing pins.
3—Taper spike.
4—Knife.
5—Wire cutters.
6—Wood mallets.
7—Hemp rope, spliced endless.
8—Hickory stick.

Fig. 221.—Tools used for splicing.

Measure back from the ends which are to be spliced a distance of ten feet for regular lay ropes and twenty feet for lang lay ropes. With smaller ropes this length may be slightly decreased, and with those larger than one inch an additional allowance is advisable. At these points place three servings of wire firmly around the rope to prevent the strands from untwisting further back. Now unlay three alternate strands at each end back to these binding wires. It is important that the strands should be alternate, that is, if we assume them numbered in regular order from No. 1 to No. 6, either strands Nos. 1, 3 and 5 or Nos. 2, 4 and 6 should be unlaid. Fig. 222 shows the rope after three strands have been unlaid.

Fig. 222.

Cut off at each end of the rope the three strands which

DIRECTIONS FOR SPLICING WIRE ROPE (Continued)

have just been unlaid, as indicated in Fig. 223.

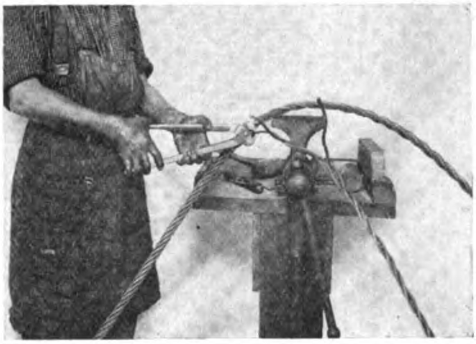


Fig. 223.

Separate the remaining three strands at each end back to the point where the other strands were cut off. This will make each of the two ends of the rope have three strands separated from each other for a distance of ten feet for regular lay ropes and twenty feet for lang lay ropes. The hemp core should be cut off at each end as shown in Fig. 224.

Bring the two ends of the rope thus prepared face to face, so that the corresponding strands for each end interlock regularly with each other in a manner similar to that in which the fingers will interlock when those of one hand are pushed between those of the other. Each of these strands must be laid into the rope as illustrated on the following pages. Temporary bindings of wire should be made around the strands where they interlock to hold them in position for the subsequent operations.

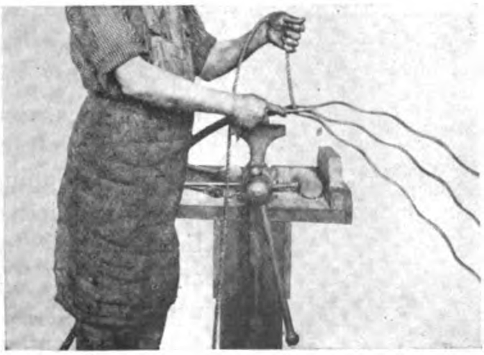


Fig. 224.

Unlay any one strand "A" and follow up with strand "No. 1" from the other end, laying it tightly in the open groove left by the unwinding of "A," making the twist of the strand agree exactly with the lay of the open groove.

DIRECTIONS FOR SPLICING WIRE ROPE (Continued)

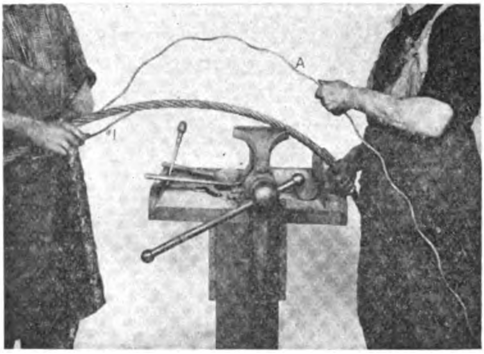


Fig. 225.

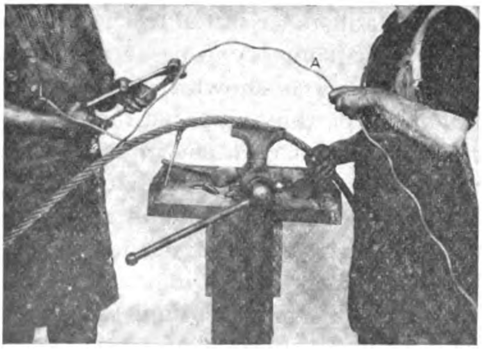


Fig. 226.

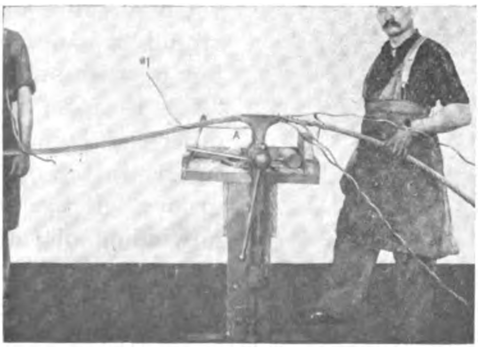


Fig. 227.

When all but a short end of "No. 1" has been laid in, the strand "A" should be cut off, leaving an end equal in length to "No. 1." This length should be, for a one-inch diameter about twelve inches for regular lay ropes, and twenty-four inches for lang lay ropes. For a smaller rope this may be slightly decreased and for a larger diameter an increased length is desirable.

Unlay another strand in the same manner that "A" was unlaid, and follow up as was done with strand "No. 1," stopping, however, back of the ends of "A" and "No. 1." The unlaid strand should be cut off as "A" was cut,

DIRECTIONS FOR SPLICING WIRE ROPE (Continued)

leaving two short ends equal in length to those of "A" and "No. 1."

The distance between the points where the ends project should be about two feet for regular lay ropes and four feet for lang lay ropes. The illustration shows the rope after the three strands on one side of the joint have been laid in the manner described. There now remain the three strands on the other side, which must be laid in the same way.

When all six strands have been laid in as directed, the splice will appear as indicated in Fig. 228. There will now be six places at which the ends of the strands extend ten inches beyond the

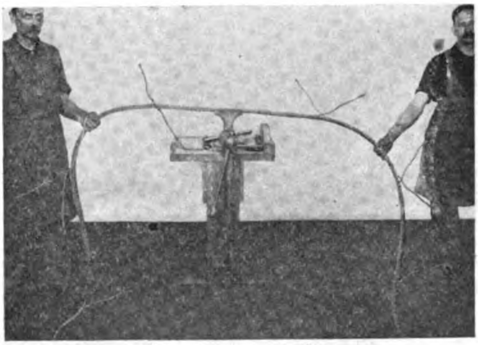


Fig. 228.

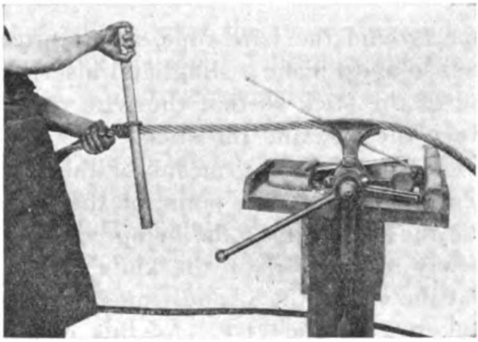


Fig. 229.

Fig. 230.

DIRECTIONS FOR SPLICING WIRE ROPE (Continued)

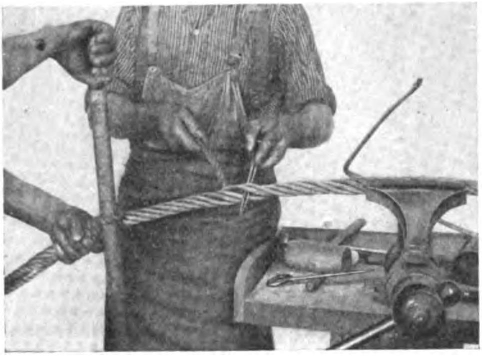


Fig. 231

rope. These ends must be secured without increasing the rope's diameter, as shown on the following pages.

Place the rope in a vise at one of the points where the ends extend.

Bind a short piece of hemp rope around the wire rope, about fifteen inches back of the vise, so as to make a sling, and insert stick in loop. Pull the end of the stick so that the wire rope will be untwisted between the vise and the stick.

The rope may, by means of the stick, be untwisted sufficiently to insert the point of the spike under two strands. Use the pin to force the hemp core into such a position that it may be reached by the knife and cut. It will be noticed that the end of the strand which is to be laid in has been bent back toward the vise. As this end must follow the twist of the rope and occupy the space left vacant by the removal of the hemp core, the end itself should have some tendency to twist in the proper direction. Bending the end back and giving it one twist in the direction of the twist of the rope will impart this tendency.

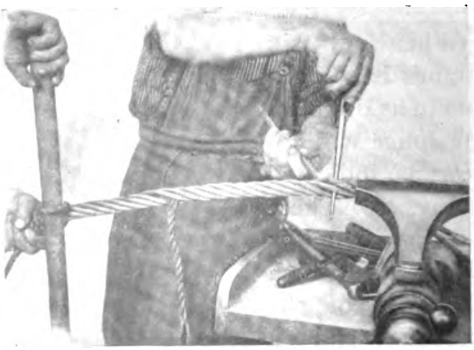


Fig. 232.

After the hemp core has been cut it

DIRECTIONS FOR SPLICING WIRE ROPE (Concluded)

should **be removed** for a distance equal to the length of the projecting end of strand. Move **spike** along the rope with one hand while the other removes the hemp core. The spike should be under two strands of the rope as shown in Fig. 231.

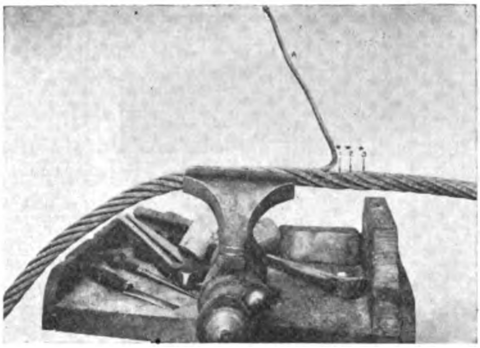


Fig. 233.

Insert spike so that it will be **over** the projecting end **and under** the next **two** strands of the rope. Pull the spike toward yourself. This will cause it to travel along the rope, leaving an opening in front. While one hand is moving the spike, the other should lay end of strand in the opening, see Fig. 232.

The plate shows the rope after the end of one strand has been laid. Strand "A" must be laid in the same manner but in the opposite direction. Tuck strand "A" in **back** of strand "No. 1" by placing spike over strand "A" and under strands "No. 2" and "No. 3." Proceed in the same manner as with strand "No. 1," Bend and twist strand "A" similar to strand "No. 1."

Fig. 234.

After an end has been laid, cut off projecting end of hemp core and hammer down any inequalities with the wooden mallets. When all the strands have been laid in rope as described the splice is complete.

INSTRUCTIONS FOR CARE OF AND PROPER METHODS OF HANDLING WIRE ROPE

Illustrations furnished by John A. Roebling's Sons Co.

WRONG WAY

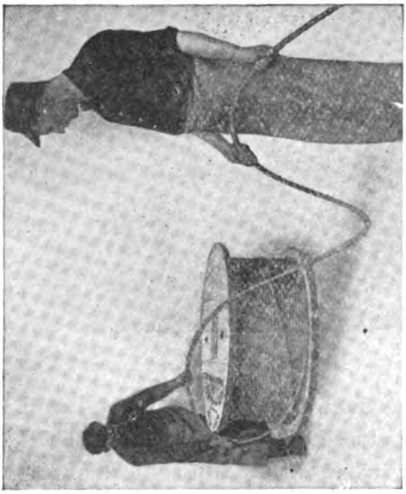


Fig. 235.—This shows a spiral effect which will remain permanently in the rope if you pull the rope off over the sides of the reel. MANY ROPES ARE RUINED IN THIS WAY.

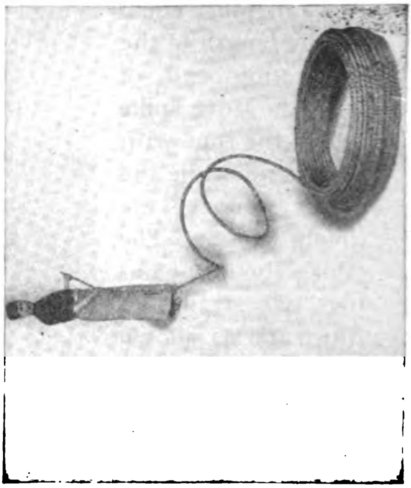


Fig. 236.—When you lay a coil flat as above illustrated, and attempt to pull the rope from the coil you will get the spiral effect as shown. THE RESULT IS A KINK.

RIGHT WAY

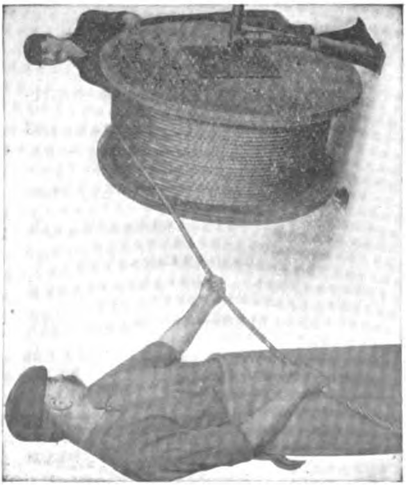


Fig. 237.—Pull the rope off in the same way it was put on the reel. Mount the reel so that it will revolve and run the rope off slowly straight ahead. In this way you will avoid any twists or corkscrew effects.

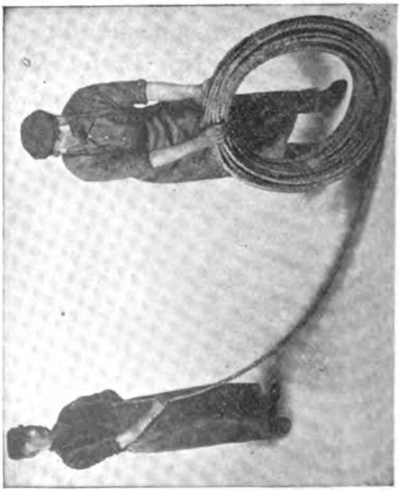


Fig. 238.—Run coil along the ground and the rope will be straight as it was before being coiled for shipment. There will be no corkscrew effect if you do this.

CLAMPING WIRE ROPE WITH CLIPS

Wire rope clips, or clamps, are frequently used as an end connection for a sling. They are not as dependable as a spliced thimble connection and will develop from 75 to 90 per cent. of the rope strength, depending on the manner of attaching. From two to five clips should be used and the flat side or body of clip should be placed on the live end of the rope with the U bolt on the dead or tail end. This method of attaching prevents the U bolt from crushing the live end of the rope and gives higher efficiency.

STRAIN CAUSED BY RUNNING WITH SLACK LINE

Experiments made by putting a dynamometer between the cable and its load have shown that a load raised suddenly with only 2½ inches of slack in the cable puts a strain on the rope 39 per cent. greater than the weight of the load, while with 12 inches of slack the rope stress was triple that caused by picking up the same weight slowly with a taut cable. The obvious conclusion that, where a line is slack, the load should not be raised with a jerk, unless the chief aim of the operator is to increase the consumption of wire rope, applies not only to drilling, but also to driving piles with a drop hammer and to many other kinds of construction work.

INSTRUCTIONS FOR SPLICING MANILA AND WIRE CABLES

First cut away for a distance of ten to fifteen feet from the end of the wire cable sufficient wires to reduce the diameter of the cable to the diameter of one strand and the hemp center. Next bind the end of the Manila cable, open it at a point about twenty-five feet from the end, and insert the reduced end of the wire cable, using for this purpose a splicing needle made of a steel rod three quarters of an inch in diameter and five feet in length, pointed at one end. By means of the needle the Manila cable is opened, inch by inch, and the wire line is "rolled in," as the drillers say. Two feet from the end of the Manila cable cut out a small portion of

INSTRUCTIONS FOR SPLICING MANILA AND WIRE CABLES (Concluded)

each strand, gradually increasing the quantity thus eliminated, in such a way that the Manila cable will taper down to slightly larger than the diameter of the wire cable. To finish the splice, wrap the end of the Manila tightly around the wire line, binding the end with a piece of hay wire, and finishing with a strand or yarn taken from the Manila cable, or a piece of marline, to prevent the wire binding from chafing off.

This splice is usually very effective, for the Manila will tighten or draw around wire in proportion to the strain or load put upon the spliced line.

Method of estimating depth of a well by calculating length of cable wound around the bull wheel shaft,* based on shaft 14½ inches in diameter.

The following tables show the length of cable in the first wrap round the shaft and in each successive layer or coil up to the tenth coil. The length of cable would be found by adding the figures for each layer or coil wound on the shaft and then multiplying the sum by the number of times the coils are wrapped round the shaft.

Coils or Layers, in Feet

	1st	2nd	3d	4th	5th	6th	7th	8th	9th	10th	Each Add. Coil†
2¼" Manila..	4.38	5.56	6.74	7.92	9.10	10.28	11.46	12.64	13.82	15.00	1.18
¾" Wire.....	3.99	4.38	4.77	5.16	5.55	5.94	6.33	6.72	7.11	7.50	.39
⅞" Wire.....	4.02	4.48	4.94	5.40	5.86	6.32	6.78	7.24	7.70	8.16	.46

Example: There are 25 wraps of a ¾-inch wire cable round a shaft and 6 coils or layers; then the first six coils $= 3.99 + 4.38 + 4.77 + 5.16 + 5.55 + 5.94 = 29.79 \times 25 = 745$ feet of cable on the shaft.

Example: There are 20 wraps of a ¾-inch wire cable round a shaft and 12 coils or layers; then the sum of the ten coils in table = 57.45. Eleventh coil $= 7.50 + .39 = 7.89$. Twelfth coil $= 7.50 + .39 + .39 = 8.28$. $57.45 + 7.89 + 8.28 = 73.62$, total length of 12 coils, one wrap $\times$ 20 = 1,472 feet of cable on the shaft.

* Adapted from tables in Practical Geology, by Dorsey Hager.
† The last column shows addition for each coil over ten.

MINUTE PRESSURE OF GAS WELLS *

The capacity of natural gas wells may be approximated by quickly shutting a gate or valve and noting the pressure on a gauge at the end of each minute. Usually the pressure at the end of the first minute is used to approximate the volume.

The following table gives the volume in different sized tubing in lengths of 100 feet, which is followed by a table of multipliers for different pressures for one minute.

Output of Gas Wells, as Measured by the Minute Pressure. Table of Diameters and Cubic Feet in 100 Feet of Tubing

Diameter in Inches	Cu. Ft. in 100 Feet	Diameter in Inches	Cubic Feet in 100 Feet	Diameter in Inches	Cubic Feet in 100 Feet
1	.55	5	13.64	6⅝	23.94
2	2.18	5 3/16	14.14	8	34.91
3	4.91	5⅝	17.26	8¼	37.12
4	8.73	6	19.63	10	54.54
4¼	9.85	6¼	21.31		

Opposite the Gauge Pressures Are Found the Multipliers for One Minute. For the Quantity per Hour Multiply Minutes by 60 and for 24 Hours Multiply Minutes by 1,440.

Gauge, Lbs.	Multipliers	Gauge, Lbs.	Multipliers	Gauge, Lbs.	Multipliers	Gauge, Lbs.	Multipliers
1	.051	24	1.621	180	12.269	410	27.969
2	.119	25	1.689	190	12.952	420	28.651
3	.187	26	1.757	200	13,634	430	29.334
4	.255	27	1.825	210	14.317	440	30.017
5	.324	28	1.894	220	15.000	450	30.699
6	.392	29	1.962	230	15.682	460	31.382
7	.460	30	2.030	240	16.365	470	32.064
8	.529	35	2.372	250	17.047	480	32.747
9	.597	40	2.713	260	17.730	490	33.430
10	.665	45	3.054	270	18.412	500	34.112
11	.733	50	3.395	280	19.095	510	34.795
12	.802	60	4.078	290	19.778	520	35.477
13	.870	70	4.761	300	20.460	530	36.160
14	.938	80	5.443	310	21.143	540	36.843
15	1.006	90	6.126	320	21.825	550	37.525
16	1.075	100	6.808	330	22.508	560	38.208
17	1.143	110	7.491	340	23.191	570	38.890
18	1.211	120	8.174	350	23.873	580	39.573
19	1.279	130	8.856	360	24.556	590	40.255
20	1.348	140	9.539	370	25.238	600	40.938
21	1.416	150	10.221	380	25.921	...	.....
22	1.484	160	10.904	390	26.604	...	.....
23	1.552	170	11.587	400	27.286	...	.....

* From Hand Book of Natural Gas, by Henry P. Westcott, Metric Metal Works.

Example: Suppose a well showed 320 pounds gauge pressure in one minute in 2-inch tubing, depth of well being 2,000 feet, then, by tables, 320 = 21.825, 2-inch = 2.18, and, as figures are based on 100 feet of tubing, then 2,000 = 20. 21.825 × 2.18 × 20 = 951.57 cubic feet per minute, 57,094.2 cubic feet per hour or 1,370,261 cubic feet per day.

If the packer is set up from the bottom, an addition will have to be made. Say that the packer was set up 120 feet in a hole 6⅝ inches in diameter, then 23.94 — 2.18 = 21.76. 21.76 × 1.20 = 26.112 and 26.112 × 21.825 = 569.894. 569.894 + 951.57 previously determined = 1,521.46 cubic feet per minute, or 91,287 cubic feet per hour.

This method only approximates the value of wells and gives results considerably under the measurement of the open flow, which is the proper method of measuring the output. Both of these methods should be accompanied by the maximum rock pressure. The best well is the one which will discharge the largest quantity of natural gas at the highest pressure.

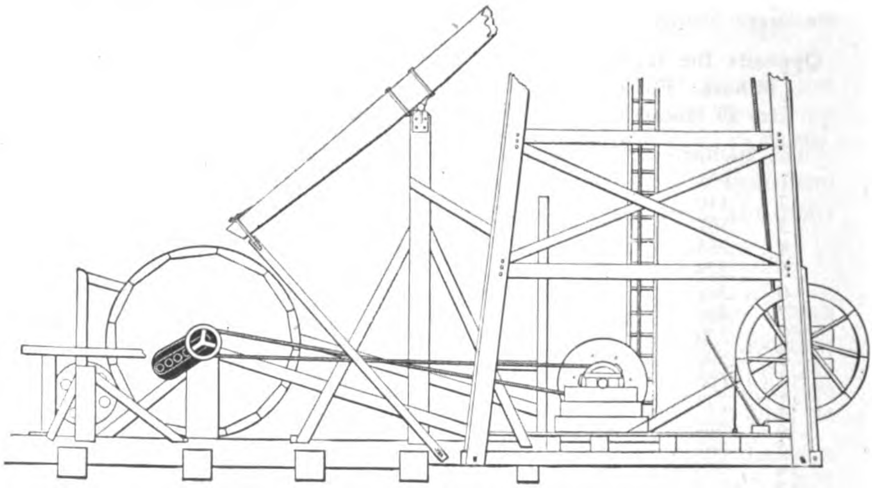


Fig. 239.

Improved method of transferring wire rope from the bull wheel, calf wheel or sand reel to the wire rope reel. The Brandon wire line spooling attachment, made by A. H. Brandon & Co., Toledo, Ohio, is a labor saving device. It consists of two special sheaves or pulleys, one to clamp on to the band wheel crank and the other to attach to the wire rope reel. The pulleys are operated by a bull rope as shown in diagram.

BELTING

Belting, when used for well drilling, is subjected to hard usage and sometimes exposure to weather. Rubber and canvas belts are chiefly used, rubber usually being preferred because it is impervious to moisture. Solid woven cotton belts have also been used with success for well drilling. Belt tighteners should be used for putting on or taking up stretch of belts. The best grades of belting obtainable only should be used.

* **Sag of Belts. Distance Between Pulleys.**—In the location of shafts that are to be connected with each other by belts, care should be taken to secure a proper distance one from the other. This distance should be such as to allow of a gentle sag to the belt when in motion. A general rule may be stated thus: Where narrow belts are to be run over small pulleys 15 feet is a good average, the belt having a sag of 1½ to 2 inches.

For larger belts, working on larger pulleys, a distance of 20 to 25 feet does well, with a sag of 2½ to 4 inches.

For main belts working on very large pulleys, the distance should be 25 to 30 feet, the belts working well with a sag of 4 to 5 inches.

If too great a distance is attempted, the belt will have an unsteady flapping motion, which will destroy both the belt and machinery.

The pulley should be a little wider than the belt required for the work.

The motion of driving should run with the laps of the belts.

Tightening or guide pulleys should be applied to the slack side of belts and near the smaller pulley.

* **To Find the Length of Belt Required for Two Given Pulleys.**—When the length cannot be measured directly by a tape-line, the following approximate rule may be used: Add the diameter of the two pulleys together, divide the sum by 2, and multiply the quotient by 3¼, and add the product to twice the distance between the centers of the shafts.

* From Kent's Mechanical Engineers' Pocket Book.

*** To Find the Length of Belt When Closely Rolled.**—The sum of the diameter of the roll, and of the eye in inches, times the number of turns made by the belt and by .1309, equals length of belt in feet.

*** To Find the Approximate Weight of Belts.**—Multiply the length of belt, in feet, by the width in inches, and divide the product by 13 for single and 8 for double belt.

Rule for Finding Width of Belt When Speed of Belt in Feet per Minute and Horsepower Wanted Are Given.—For Single Belts: Divide the speed of the belt by 800. The horsepower wanted divided by this quotient will give the width of belt required.

For Double Belts: Divide the speed of belt in feet per minute by 560. Divide the horsepower wanted by this quotient for the width of belt required.

Example: A 30 H. P. Steam Engine running 300 R. P. M., 30-inch belt pulley, belt speed = diameter pulley 30" × 3.1416 × 300 = 28,274" or 2,356 feet per minute. 2,356 ÷ 800 = 2.95 . 30 H. P. ÷ 2.95 = 10.2. Width of belt should be 10 or 12 inches.

HORSEPOWER TABLE
Main Belting Company

Belt Speed, F. P. M.		To 500	To 1000	To 2000	To 3000	To 4000	To 5000
	Smallest pulley diam.	6-in.	7 in.	9-in.	11 in.	12 in.	
4 ply belt	H.P. transmitted per in. belt width......	0.7	1.4	2.8	4.1	5.1	
	Smallest pulley diam.	8-in.	10-in.	12-in.	14-in.	16-in.	18-in.
5 ply belt	H.P. transmitted per in. belt width......	0.87	1.75	3.5	5.1	6.37	7.37
	Smallest pulley diam.	10-in.	12-in.	16-in.	18-in.	20-in.	24-in.
6 ply belt	H.P. transmitted per in. belt width......	1.05	2.1	4.2	6.1	7.6	8.8
	Smallest pulley diam.		24-in.	30-in.	33-in.	36-in.	42-in.
8 ply belt	H.P. transmitted per in. belt width......		2.45	4.9	7.17	8.92	10.32
	Smallest pulley diam.			48-in.	54-in.	60-in.	72-in.
10-ply belt	H.P. transmitted per in. belt width......			5.6	8.2	10.2	11.8

This table is based on an arc of contact of 180° and takes into account the action of centrifugal force as the speed increases.

A rough rule for figuring belt horsepower where speeds are less than 5,000 feet per minute is to divide the diameter of either pulley in inches by four, multiply the result by the r. p. m. of the same pulley, which gives the approximate speed in feet per minute, and divide that result by 800, which gives the horsepower that a four ply belt one inch wide will transmit at that speed. Multiply this result by the width of the belt in question, remembering that a six ply will transmit 1½ times as much as a four ply, eight ply 1¾ times as much, ten ply twice as much, and twelve ply 2¼ times as much.

FUELS

COMPARISON OF FUEL VALUE OF DIFFERENT COALS

From Kent's Mechanical Engineers' Pocket Book

	Fixed C. %	B. T. U. per lb.
Penna. anthracite	89	14,900
West Va. semi-bituminous	80 to 76.5	15,950 to 15,650
Arkansas semi-bituminous	84 to 77	15,250 to 15,500
Penna. bituminous	67	15,500
West Va. bituminous	67.5 to 55	15,500 to 15,000
Eastern Kentucky	60	15,000
Western Kentucky	55 to 50.5	14,400 to 13,700
Alabama	61.5 to 59	14,800 to 14,200
Kansas	62 to 53.5	14,800 to 14,100
Oklahoma	56 to 51	14,600 to 13,100
Missouri	50.5 to 47	14,300 to 12,600
Illinois	59 to 47.5	13,700 to 12,400
Iowa	57 to 53.5	13,600 to 12,700
Indiana	49	13,300
New Mexico	50.5 to 47	12,500 to 12,300
Wyoming	48 to 41.5	13,300 to 10,900
Montana	48.5	12,100
Coloradó	46	11,500
North Dakota	48.5 to 42.5	10,200 to 11,400
Texas	44.5 to 34	10,900 to 11,000

ANALYSES AND CALORIFIC VALUES OF AMERICAN FUEL OILS

From Marks Handbook

Field	Gravity Baume	Specific Gravity at 15 deg. Cent.	B. T. U. per lb.	Weight per gal., lb.
Kern River, Cal.	14.78	0.9670	18,562	8.06
Coalinga, Cal.	17.29	0.9505	18,720	7.92
McKittrick, Cal.	15.83	0.9600	18,335	8.00
Midway, Cal.	16.14	0.9580	18,565	7.98
Sunset, Cal.	14.26	0.9705	18,419	8.09
Beaumont, crude	21.6	0.924	19,060	7.69
Beaumont, crude	21.3	0.926	19.481	7.71
Tampico, crude	12 to 23	.....	18,493	7.82

FUELS

Oil is sold by the barrel of 42 gallons. The A. T. & S. F. R. R. Co. found the evaporative value of coal and oil the same when the price of coal in tons was three and a half times the price of oil in barrels. Most experience falls within the limits of three to four and one-half barrels of oil as the equivalent of one long ton of coal.

Heating Value of Wood.—The following table is given in several books of reference, authority and quality of coal referred to not stated.

The weight* of one cord of different woods (thoroughly air-dried) is about as follows:

	Lbs.		Lbs.		
Hickory or hard maple...	4500	equal to	1800	coal.	(Others give 2000.)
Beech, red and black oak.	3250	"	1300	"	(" 1450.)
White oak	3850	"	1540	"	(" 1715.)
Poplar, chestnut and elm.	2350	"	940	"	(" 1050.)
The average pine.........	2000	"	800	"	(" 925.)

COMPARATIVE FUEL VALUE OF COAL, OIL AND NATURAL GAS

1 pound of coal will evaporate 9 pounds of water at 212°, atmospheric pressure.

1 pound of oil will evaporate 15 pounds of water at 212°, atmospheric pressure.

1 pound of natural gas will evaporate 20 pounds of water at 212°, atmospheric pressure.

1	pound of coal will equal.........	10 cubic feet natural gas
2000	pounds (1 ton) will equal........	20,000 cubic feet natural gas
1	pound of oil will equal..........	16 cubic feet natural gas
1	barrel (42 gal.) will equal.......	4,800 cubic feet natural gas
4⅛	barrels (42 gal.) will equal 1 ton of good coal.	
1	cubic foot natural gas will evaporate 1 pound of water.	
1	cubic foot natural gas will equal....	966 British heat units
1000	cubic feet natural gas will equal....	966,000 British heat units
1	ton of coal will equal..............	19,307,000 British heat units
1	barrel of oil will equal.............	4,666,600 British heat units

PROPERTIES OF NATURAL GAS

Location of Wells	B.T.U. per cu. ft., 0 deg. Cent. and 760 mm. pressure
Kiefer, Okla.	1272
Jefferson County, Ky.	1205
Forest County, Pa.	1279
Allen County, Kansas	1051
Kings County, Cal.	724
Greybull Field, Wyo.	1192
Casinghead gas	1427
Caddo Parish Field, La.	1028
Casinghead gas used for production of gasoline	2424

SPECIFIC HEAT

Units of Heat.—The mean British thermal unit (B. T. U.) is defined as the 1/180 part of the heat required to raise the temperature of 1 lb. of water from 32° to 212° Fahr. This is substantially equal to the heat required to raise 1 lb. of water from 63° to 64° Fahr.

The mean calorie is 1/100 of the heat required to raise 1 g. of water from 0° to 100° Cent. It is practically the same as the 17½° calorie, that is, the heat required to raise 1 g. of water from 17° to 18° Cent. The 15° calorie is also used extensively. Because of the variation of the heat capacity of water, this is slightly larger than the mean or 17½° calorie. The present tendency is toward the mean calorie (and mean B. t. u.) as the standard heat unit.

In countries which have adopted the metric system, engineers employ the kilogram calorie (or "large calorie") as the unit in heat measurements. 1 kilogram calorie = 1,000 g. calories = 3.968 B. t. u. (1 B. t. u. = 0.252 kilogram calorie).

WATER

Water is composed of two gases, hydrogen and oxygen, in the ratio of two volumes of the former to one of the latter. It is never found pure in nature, owing to the readiness with which it absorbs impurities from the air and soil. Water boils under atmospheric pressure (14.7 pounds at sea level) at 212°, passing off as steam. Its greatest density is at 39.1° F., when it weighs 62.425 pounds per cubic foot.

WATER FACTORS

U. S. gallons	×	8.33	=	pounds
U. S. gallons	×	0.13368	=	cubic feet
U. S. gallons	×	231.00	=	cubic inches
U. S. gallons	×	0.83	=	Eng. gallons
U. S. gallons	×	3.78	=	liters
Eng. gals. (Imp.)	×	10.	=	pounds
Eng. gals. (Imp.)	×	0.16	=	cubic feet
Eng. gals. (Imp.)	×	277.274	=	cubic inches
Eng. gals. (Imp.)	×	1.2	=	U. S. gallons
Eng. gals. (Imp.)	×	4.537	=	liters
Cu. ft. water (39.1°)	×	62.425	=	pounds
Cu. ft. water (39.1°)	×	7.48	=	U. S. gallons
Cu. ft. water (39.1°)	×	6.232	=	Eng. gals.
Cu. ft. water (39.1°)	×	0.028	=	tons
Cubic foot of ice	×	57.2	=	pounds
Cu. in. water (39.1°)	×	0.036024	=	pounds
Cu. in. water (39.1°)	×	0.004329	=	U. S. gallons
Cu. in. water (39.1°)	×	0.003607	=	Eng. gals.
Cu. in. water (39.1°)	×	0.576384	=	ounces
Pounds of water	×	27.72	=	cubic inches
Pounds of water	×	0.01602	=	cubic feet
Pounds of water	×	0.083	=	U. S. gallons
Pounds of water	×	0.10	=	Eng. gallons
Tons of water	×	268.80	=	U. S. gallons
Tons of water	×	224.00	=	Eng. gallons
Tons of water	×	35.90	=	cubic feet.
Ounces of water	×	1.735	=	cubic inches

A column of water 1 inch square by 1 foot high weighs 0.434 pound.

A column of water 1 inch square by 2.31 feet high weighs 1 pound.

Sea water is 1.6 to 1.9 heavier than fresh.

One cubic inch of water makes approximately 1 cubic foot of steam at atmospheric pressure.

27,222 cubic feet of steam at atmospheric pressure weighs 1 pound.

Atmospheric pressure at sea level = 14.7 pounds average.

Height of mercury column in a vacuum at sea level = 29.9 inches.

Height of water column in a vacuum at sea level = 33.9 feet.

Friction head depends on the speed of the water and the resistance to its flow; that is, on the condition of the interior of the pipe, the number of bends, elbows, etc. The friction head can be determined roughly from the following formula:

If L is the length of a pipe, D is its diameter (both in feet) and V the velocity of flow of liquid in feet per second, the loss of head due to friction, or the friction head H is

$$H = \frac{.02LV2}{64.4\,D}$$

The total head to be pumped against is considered equal to the sum of the friction head and the actual head.

If A is the cross section in square feet of a stream flowing over a dam, V its velocity in feet per minute, and H the head, or fall in feet, then

$$H.P. = \frac{62.4AVH}{33000}$$

WATER PRESSURE

The pressure of still water per square inch against the sides of any pipe or vessel of any shape is due alone to the head or height of the surface of the water above the point pressed upon, and is equal to 0.434 pounds per square inch for every foot of head, the fluid pressure being equal in all directions. For example: The pressure in pounds per square inch at the bottom of well tubing 1,000 feet deep and filled with water would be $0.434 \times 1000 = 434$ pounds pressure.

WEIGHT OF WATER IN PIPE OF DIFFERENT DIAMETERS IN LENGTHS OF ONE FOOT

The following table will be found useful in computing the weight of water in a string of pipe or casing in a well or for calculating the H. P. to elevate.

Diam., Inches	Water Pounds	Diam., Inches	Water Pounds	Diam., Inches	Water Pounds	Diam., Inches	Water Pounds
1	.3405	4½	6.8946	8	21.790	13½	62.052
1¼	.5320	5	8.5119	8¼	23.174	14	66.733
1½	.7661	5¼	9.3844	9	27.579	15	76.607
2	1.3619	5¾	11.257	10	34.048	16	87.162
2½	2.1280	6	12.257	11	41.198	17	98.397
3	3.0643	6¼	13.300	11½	45.028	18	110.31
3½	4.1708	6½	14.385	12	49.028	19	122.91
4	5.4476	7	16.683	12½	53.199	20	136.19
4¼	6.1498	7½	19.152	13	57.540		

THEORETICAL HORSEPOWER NECESSARY TO ELEVATE WATER, SIMPLE RULE

To find the horsepower necessary to elevate water to a given height, multiply the weight of water elevated per minute in pounds (for weight of water, see above) by the height in feet (height is measured from surface of water to highest point to which water is raised), and divide by 33,000, which result represents the necessary horsepower. One horsepower is equal to about five men. It is estimated that it requires approximately one horsepower, including friction, to raise sixty gallons of water per minute thirty-three feet high. A liberal allowance (from 20 to 30 per cent.) should be made for water friction and loss in steam cylinder.

To find quantity of water elevated in one minute, running at 100 feet of piston speed per minute, square the diameter of the water cylinder in inches and multiply by 4.

Example: Capacity of a 5-inch cylinder is desired. The square of the diameter (5 inches) is 25, which, multiplied by 4, gives 100, the number of gallons per minute (approximately).

EQUATION OF PIPES

Simple Rule

It may be desired to know what number of pipes of a given size are equal in carrying capacity to one pipe of a larger size. At the same velocity of flow the volume delivered by two pipes of different sizes is proportioned to the squares of their diameters; thus, one 4-inch pipe will deliver the same volume as four 2-inch pipes. With the same head, however, the velocity is less in the smaller pipe, and the volume delivered varies about as the square root of the fifth power (i.e., as the 2.5 power). The following table has been calculated on this basis. The figures opposite the intersection of any two sizes are the number of the smaller sized pipes required to equal one of the larger. Thus, one 4-inch pipe is equal to 5.7 2-inch pipes.

Diameter, Inches	1	2	3	4	5	6	8	10	12	14	16	18
2	5.7	1.										
3	15.6	2.8	1.									
4	32.	5.7	2.1	1.								
5	55.9	9.9	3.6	1.7	1.							
6	88.2	15.6	5.7	2.8	1.6	1.						
7	130.	22.9	8.3	4.1	2.3	1.5						
8	181.	32.	11.7	5.7	3.2	2.1	1.					
9	243.	43.	15.6	7.6	4.3	2.8	1.3					
10	316.	55.9	20.3	9.9	5.7	3.6	1.7	1				
11	401.	70.9	25.7	12.5	7.2	4.6	2.2	1.3				
12	499.	88.2	32.	15.6	8.9	5.7	2.8	1.6	1.			
13	609.	108.	39.1	19.	10.9	7.1	3.4	1.9	1.2			
14	733.	130.	47.	22.9	13.1	8.3	4.1	2.3	1.5	1.		
15	787.	154.	55.9	27.2	15.6	9.9	4.8	2.8	1.7	1.2		
16	.....	181.	65.7	32.	18.3	11.7	5.7	3.2	2.1	1.4	1.	
17	.....	211.	76.4	37.2	21.3	13.5	6.6	3.8	2.4	1.6	1.2	
18	.....	243.	88.2	43.	24.6	15.6	7.6	4.3	2.8	1.9	1.3	1.
19	.....	278.	101.	49.1	28.1	17.8	8.7	5.	3.2	2.1	1.5	1.1
20	.....	316.	115.	55.9	32.	20.3	9.9	5.7	3.6	2.4	1.7	1.3

Doubling the diameter of a pipe increases its capacity four times. Friction of liquids in pipes increases as the square of the velocity.

To find the diameter of a pump cylinder to move a given quantity of water per minute (100 feet of piston being the standard of speed), divide the number of gallons by 4, then extract the square root, and the result will be the diameter in inches of the pump cylinder.

STEAM

(From National Tube Co. Book of Standards)

"**The Temperature of Steam** in contact with water depends upon the pressure under which it is generated. At the ordinary atmospheric pressure (14.7 pounds per square inch) its temperature is 212° F. As the pressure is increased, as when steam is generated in a closed vessel, its temperature, and that of the water in its presence, increases.

"**Saturated Steam** is steam in its normal state, that is, steam whose temperature is that due to its pressure; by which is meant steam at the same temperature as that of the water from which it was generated and upon which it rests.

"**Superheated Steam** is steam at a temperature above that due to its pressure.

"**Dry Steam** is steam which contains no moisture. It may be either saturated or superheated.

"**Wet Steam** is steam containing free moisture in the form of spray or mist. It has the same temperature as dry saturated steam of the same pressure.

"Water introduced into superheated steam will be vaporized until the steam becomes saturated, and its temperature becomes that due to its pressure. Cold water, or water at a lower temperature than that of the steam, introduced into saturated steam, will condense some of it, thus lowering both the temperature and pressure of the rest until the temperature again equals that due to its pressure.

The Heat-unit, or British Thermal Unit. The old definition of the heat-unit (Rankine), viz., the quantity of heat required to raise the temperature of 1 pound of water 1° F., at or near its temperature of maximum density (39.1° F.), is now no longer used. Peabody defines it as the heat required to raise a pound of water from 62° to 63° F., and Marks and Davis as 1/180 of the heat required to raise 1 pound of water from 32° to 212° F. By Peabody's definition the heat required to raise 1 pound of water from 32° to 212° is 180.3 instead of 180 units, and the heat of vaporization at 212° is 969.7 instead of 970.4 units.

The Total Heat of the Water is the number of British thermal units needed to raise one pound of water from 32° F. to the boiling point, under the given pressure.

The Latent Heat of Steam or Heat of Vaporization is the number of British thermal units required to convert one pound of water, at the boiling point, into steam of the same temperature.

The Total Heat of Saturated Steam is the number of heat-units required to raise a pound of water from 32° F. to the boiling point, at the given pressure, plus the number required to convert the water at that temperature into steam of the same temperature.

STEAM BOILERS

Safe Working Pressures in Cylindrical Shells of Boilers, Tanks, Pipes, etc., in Pounds per Square Inch

(From Kents' Engineers' Pocket Book)

Longitudinal seams double-riveted.

(Calculated from formula P = 14,000 × thickness ÷ diameter.)

Thickness in 16ths of an inch.	Diameter in Inches										
	38	40	42	44	46	48	50	52	54	60	66
1	23.0	21.9	20.8	19.9	19.0	18.2	17.5	16.8	16.2	14.6	13.3
2	46.1	43.8	41.7	39.8	38.0	36.5	35.0	33.7	32.4	29.2	26.5
3	69.1	65.6	62.5	59.7	57.1	54.7	52.5	50.5	48.6	43.7	39.8
4	92.1	87.5	83.3	79.5	76.1	72.9	70.0	67.3	64.8	58.3	53.0
5	115.1	109.4	104.2	99.4	95.1	91.1	87.5	84.1	81.0	72.9	66.3
6	138.2	131.3	125.0	119.3	114.1	109.4	105.0	101.0	97.2	87.5	79.5
7	161.2	153.1	145.9	139.2	133.2	127.6	122.5	117.8	113.4	102.1	92.8
8	184.2	175.0	166.7	159.1	152.2	145.8	140.0	134.6	129.6	116.7	106.1
9	207.2	196.9	187.5	179.0	171.2	164.1	157.5	151.4	145.8	131.2	119.3
10	230.3	218.8	208.3	198.9	190.2	182.3	175.0	168.3	162.0	145.8	132.6

STEAM BOILERS

Fusible Plugs.—The rules of the U. S. Supervising Inspectors specify Banca tin for the purpose. Its melting-point is about 445° F. The rule says: Every boiler, other than boilers of the water-tube type, shall have at least one fusible plug made of a bronze casing filled with good Banca tin from end to end. Fusible plugs, except as otherwise provided for, shall have an external diameter of not less than ¾-inch pipe tap, and the Banca tin shall be at least ½ inch in diameter at the smallest end and shall have a larger diameter at the center or at the opposite end of the plug; smaller plugs are allowed for pressures above 150 pounds, also for upright boilers.

FACTS ABOUT THE DRILLING BOILER

Dome.—The drilling boiler usually has a large dome to furnish a reserve supply of steam to be drawn upon when pulling tools or casing, and to serve that steam dry.

Hand Hole Plates.—Owing to the fact that drilling boilers often use impure water and fuel, and that they quickly become fouled, they should be fitted with extra hand holes at convenient places for cleaning.

SHORT RULES FOR ESTIMATING POWER OF STEAM BOILERS

Flue Boiler.—Twelve feet of heating surface will produce one horsepower. The heating surface is two-thirds the surface of the cylinder; also the entire surface of all the flues.

Tubular Boiler.—Fifteen feet of heating surface will produce one horsepower. The heating surface is two-thirds the surface of the cylinder; also the entire surface of all the tubes.

One nominal horsepower will require one cubic foot of water per hour. One cubic foot of water contains 7½ gallons.

BOILER AND STEAM FACTS

For all diameters the transverse pressure in a boiler tending to tear it asunder is always double the longitudinal pressure.

The boiler should be set 30 to 42 inches above the fire grate to give room for air and gases to mix.

BOILER AND STEAM FACTS (Concluded)

Steam rising from water at its boiling point (212°) has a pressure equal to the atmosphere (14.7 pounds to the square inch).

At sea level water boils at 212° Fahrenheit. For each degree (Fah.) less at which water boils, estimate the elevation at 550 feet.

Steam pipes, whether for power or for heating, should always pitch downward from the boiler, that the condensed water, etc., may have the same direction as the steam.

Globe valves should always be so placed in steam pipes that their stems are nearly horizontal.

APPROXIMATE CLASSIFICATION OF IMPURITIES FOUND IN FEED WATERS, THEIR EFFECT AND ORDINARY METHODS OF RELIEF

(From Marks' Handbook)

"The following table gives an approximate classification of the impurities found in boiler-feed water, the difficulties arising from their presence, and the means ordinarily adopted for the treatment of the water to overcome such effects

Impurity	Nature of Difficulty	Ordinary Method of Overcoming or Relieving
Sediment, mud, etc.	Incrustation	Settling tanks, filtration, blowing down
Readily soluble salts	Incrustation	Blowing down.
Bicarbonates of lime, magnesia, etc.	Incrustation	Heating feed. Treatment by addition of lime or of lime and soda. Barium carbonate.
Sulphate of lime	Incrustation	Treatment by addition of soda. Barium carbonate.
Chloride and sulphate of magnesium	Corrosion	Treatment by addition of carbonate of soda.
Acid	Corrosion	Alkali.
Dissolved carbonic acid and oxygen	Corrosion	Heating feed. Keeping air from feed. Addition of caustic soda or slacked lime.
Grease	Corrosion	Filter. Iron alum as coagulant. Neutralization by carbonate of soda. Use best hydrocarbon oils.
Organic matter	Corrosion	Filter. Use of coagulant.
Organic matter (sewage)	Priming	Settling tanks. Filter in connection with coagulant.
Carbonate of soda in large quantities	Priming	Barium carbonate. New feed supply. If from treatment, change.

"**Oil as a Scale Preventive.**—The introduction of crude oil or kerosene into a boiler has from time to time been used as a means of preventing scale formation on the heating surfaces, but this use of kerosene or of crude oil is not to be recommended. While cases may arise in which boiler waters can be effectively treated within the boiler itself, oil is not the reagent to be used. The distilling off of the lighter oils finally leaves a heavy, gum-like carbonaceous deposit on the heating surfaces, which will tend to cause a burning out of the affected parts. Further, such oils may contain materials which will saponify where the feed is sufficiently alkaline, and severe foaming will result."

STEAM ENGINES.—DRILLING ENGINES.—PUMPS

The drilling engine has a two-fold duty to perform: it must operate the walking beam in drilling, and the bull wheels and calf wheels in pulling tools and handling casing. The efficient drilling engine should have sufficient power to pull the tools or the casing and it must also be elastic enough in operation to "let go" or allow the tools to "drop" to furnish drilling stroke. It should have ample steam ports and exhaust.

General Service and Boiler Feed Pumps have a ratio of piston areas of about 2½ to 1, and are either fitted with packed pistons and driven linings, packed pistons and removable linings, or plunger and ring. The plungers are usually cast iron and the rings brass. Pumps are designed for 150-lb. water pressure. To find the size of pump to supply a given boiler, multiply the boiler horsepower by 45, which will give the pounds of water required per hour.

***Depth of Suction.**—Theoretically a perfect pump will draw water from a height of nearly 34 feet, or the height corresponding to a perfect vacuum ($14.7 \text{ lbs.} \times 2.309 = 33.95 \text{ feet}$); but since a perfect vacuum cannot be obtained on account of valve leakage, air contained in the water, and the vapor of the water itself, the actual height is generally less than 30 feet. When the water is warm the height to which it can be

* Kent's Mechanical Engineers' Pocket Book.

PUMPS

lifted by suction decreases, on account of the increased pressure of the vapor. In pumping hot water, therefore, the water must flow into the pump by gravity. The following table shows the theoretical maximum depth of suction for different temperatures, leakage not considered:

Temp. Fahr.	Absolute Pressure of Vapor, lbs. per sq. in.	Vacuum in Inches of Mercury	Max. Depth of Suction, feet	Temp. Fahr.	Absolute Pressure of Vapor, lbs. per sq. in.	Vacuum in Inches of Mercury	Max. Depth of Suction, feet
102.1	1	27.88	31.6	182.9	8	13.63	15.4
126.3	2	25.85	29.3	188.3	9	11.60	13.1
141.6	3	23.83	27.0	193.2	10	9.56	10.8
153.1	4	21.78	24.7	197.8	11	7.52	8.5
162.3	5	19.74	22.3	202.0	12	5.49	6.2
170.1	6	17.70	20.0	205.9	13	3.45	3.9
176.9	7	15.67	17.7	209.6	14	1.41	1.6

DEFINITIONS OF HORSEPOWER

Horsepower of Steam Boilers.—The A. S. M. E. has defined the unit horsepower as equivalent to 34.5 pounds of feed water per hour evaporated at temperature of 212° F. into steam at the same temperature. This is based on the original definition of the evaporation of 30 pounds of water per hour at temperature of 100° F. into dry steam under pressure of 70 pounds per square inch above atmosphere.

Horsepower of Steam Engines.—The value of this unit is defined as 33,000 foot-pounds per minute, i.e., the energy required to lift 33,000 pounds one foot in one minute.

Handy Rule for Estimating the Horsepower of a Single-cylinder Engine.—Square the diameter and divide by 2. This is correct whenever the product of the mean effective pressure and the piston-speed = ½ of 42,017, or, say, 21,000, viz., when M.E.P. = 30 and S = 700; when M.E.P. = 35 and S = 600; when M.E.P. = 38.2 and S = 550; and when M.E.P. = 42 and S = 500. These conditions correspond to those of ordinary practice with both Corliss engines and shaft-governor high-speed engines (Kent).

Note: This rule will not work out for estimating the horsepower of oil country drilling engines. To find the horsepower of the average drilling engine, square the diameter of the cylinder and divide by 5.

CONCRETE

"**Proportions for Different Structures.**—The following four mixtures will serve as a rough guide to the selection of proper proportions for various classes of work (Taylor and Thompson):

(a) Rich mixture, for columns and other structural parts subjected to high stresses or requiring exceptional water-tightness. Proportions, 1 : 1½ : 3.

(b) Standard mixture, for reinforced floors, beams and columns, for arches, for reinforced engine or machine foundations subject to vibrations, for tanks, sewers, conduits, and other water-tight work. Proportions, 1 : 2 : 4.

(c) Medium mixture, for ordinary machine foundations, retaining walls, abutments, piers, thin foundation walls, building walls, ordinary floors, sidewalks, and sewers with heavy walls. Proportions, 1 : 2½ : 5.

(d) Lean mixture, for unimportant work in masses, for heavy walls, for large foundations supporting a stationary load, and for backing for stone masonry. Proportions, 1 : 3 : 6."

For cementing casing, mixture of neat hydraulic cement and water.

BABBITT METAL

The name "Babbitt" is derived from that of the inventor (Isaac Babbitt) of soft metal-lined bearings. The term "babbitting" has been applied to the process of applying soft anti-friction metals inside of a harder shell for the purpose of producing bearings. Authorities differ regarding the proportions of Babbitt's original alloy, as follows:

Tin	83.3% to 89.3%
Copper	3.6% to 8.3%
Antimony	7.1% to 8.3%

OTHER BEARING METAL FORMULAS

	Copper	Tin	Lead	Antimony	Iron
Anti-friction metal %	1.60	98.13	....	....	trace
Hard Babbitt %	3.70	88.90	....	7.40	.....
Number 1 %	10.	....	65.	25.	.....
Number 2 %	5.55	83.33	....	11.12	.....
Number 3 %	....	10.	70.	20.	.....
Number 4 %	....	12.	80.	8.	.....

TO MAKE BABBITT RUN FREELY

Put a piece of resin, the size of a walnut, into the babbitt; stir thoroughly, then skim. It makes poor babbitt run better, and improves it. Babbitt heated just hot enough to light a pine stick, will run in places with the resin in, where without it, it would not. It is also claimed that resin will prevent blowing when pouring in damp boxes.

PULLEYS

Relations of the Size and Speeds of Driving and Driven Pulleys

The driving pulley is called the driver, D, and the driven pulley the driven, d. If the number of teeth in gears is used instead of diameter, in these calculations, number of teeth must be substituted wherever diameter occurs. R = revolutions per minute of driver, r = revolutions per minute of driven.

$$D = dr \div R;$$

Diam. of driver = diam. of driven × revs. of driven ÷ revs. of driver.

$$d = DR \div r;$$

Diam. of driven = diam. of driver × revs. of driver ÷ revs. of driven.

$$R = dr \div D;$$

Revs. of driver = revs. of driven × diam. of driven ÷ diam. of driver.

$$r = DR \div d;$$

Revs. of driven = revs. of driver × diam. of driver ÷ diam. of driven.

SIMPLE RULES FOR CALCULATING SPEED OF PULLEYS

Problem I.—The diameter of the driver and driven being given, to find the number of revolutions of the driven:

Rule.—Multiply the diameter of the driver by its number of revolutions, and divide the product by the diameter of the driven; the quotient will be the number of revolutions.

Problem II.—The diameter and the revolutions of the driver being given to find the diameter of the driven, that shall make any given number of revolutions in the same time:

RULES FOR CALCULATING SPEED OF PULLEYS, Concluded.

Rule.—Multiply the diameter of the driver by its number of revolutions, and divide the product by the number of revolutions of the driven; the quotient will be its diameter.

Problem III.—To ascertain the size of the driver:.

Rule.—Multiply the diameter of the driven by the number of revolutions you wish to make, and divide the product by the revolutions of the driver: the quotient will be the size of the driver.

The above rules are practically correct. Though owing to slip, elasticity and thickness of the belt, the circumference of the driven seldom runs as fast as the driver.

Belts, like gears, have a pitch line, or a circumference of uniform motion. This circumference is within the thickness of the belt, and must be considered if pulleys differ greatly in diameter, and a required speed is absolutely necessary.

PULLEYS OR BLOCKS
(From Kent's Mechanical Engineers' Pocket Book)

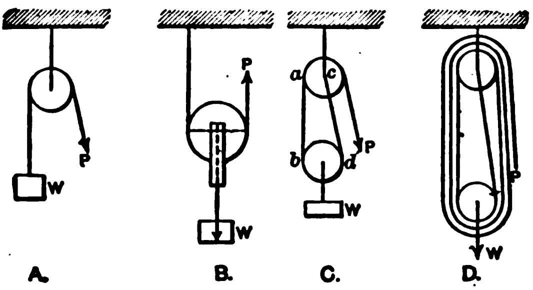


Fig. 240.

"P = Force applied, or pull; W = Load lifted, or resistance. In the simple pulley A (Fig. 240) the point P on the pulling rope descends the same amount that the load is lifted, therefore P = W. In B and C the point P moves twice as far as the load is lifted, therefore, W = 2P. In B and C there is one movable block, and two plies of the rope engage with it. In D there are three sheaves in the movable block, each with two plies engaged, or six in all. Six plies of the rope are

PULLEYS OR BLOCKS (Continued)

therefore shortened by the same amount that the load is lifted and the point P moves six times as far as the load, consequently W = 6P. In general, the ratio of W to P is equal to the number of plies of the rope that are shortened, and also is equal to the number of plies that engage the lower block. If the lower block has 2 sheaves and the upper 3, the end of the rope is fastened to a becket in the top of the lower block, and then there are 5 plies shortened instead of 6, and W = 5P."

SPECIFIC GRAVITIES AND WEIGHTS OF MATERIALS

Water at 4° C. and Normal Atmospheric Pressure

Metals, Alloys, Ores—	Specific Gravity	Wt., Pounds per cu. ft.
Aluminum, cast-hammered	2.55-2.75	165
Aluminum, bronze	7.7	481
Brass, cast-rolled	8.4-8.7	534
Bronze, 7.9 to 14% Sn	7.4-8.9	509
Copper, cast rolled	8.8-9.0	556
Copper, ore, pyrites	4.1-4.3	262
Gold, cast-hammered	19.25-19.35	1205
Iron, cast, pig	7.2	450
Iron, wrought	7.6-7.9	485
Iron, spiegel-eisen	7.5	468
Iron, ferro-silicon	6.7-7.3	437
Iron ore, hematite	5.2	325
Iron ore, magnetite	4.9-5.2	315
Iron slag	2.5-3.0	172
Lead	11.37	710
Lead ore, galena	7.3-7.6	465
Manganese	7.2-8.0	475
Manganese ore, pyrolusite	3.7-4.6	259
Mercury	13.6	849
Nickel	8.9-9.2	565
Nickel, monel metal	8.8-9.0	556
Platinum, cast-hammered	21.1-21.5	1330
Silver, cast-hammered	10.4-10.6	656
Steel	7.8-7.9	490
Tin, cast-hammered	7.2-7.5	459
Tin ore, cassiterite	6.4-7.0	418
Zinc, cast-rolled	6.9-7.2	440
Zinc ore	3.9-4.2	253
Minerals—		
Asbestos	2.1-2.8	153
Barytes	4.50	281
Basalt	2.7-3.2	184
Bauxite	2.55	159
Borax	1.7-1.8	109

SPECIFIC GRAVITIES AND WEIGHTS OF MATERIALS (Continued)

Water at 4° C. and Normal Atmospheric Pressure

	Specific Gravity	Wt., Pounds per cu. ft.
Chalk	1.8-2.6	137
Clay, marl	1.8-2.6	137
Dolomite	2.9	181
Feldspar, orthoclase	2.5-2.6	159
Gneiss, serpentine	2.4-2.7	159
Granite, syenite	2.5-3.1	175
Greenstone, trap	2.8-3.2	187
Gypsum, alabaster	2.3-2.8	159
Hornblende	3.0	187
Limestone, marble	2.5-2.8	165
Magnesite	3.0	187
Phosphate rock, apatite	3.2	200
Porphyry	2.6-2.9	172
Pumice, natural	0.37-0.90	40
Quartz, flint	2.5-2.8	165
Sandstone, bluestone	2.2-2.5	147
Shale, slate	2.7-2.9	175
Soapstone, talc	2.6-2.8	169
Stone, Quarried, Piled—		
Basalt, granite, gneiss		96
Limestone, marble, quartz		95
Sandstone		82
Shale		92
Greenstone, hornblende		107
Bituminous Substances—		
Asphaltum	1.1-1.5	81
Coal, anthracite	1.4-1.7	97
Coal, bituminous	1.2-1.5	84
Coal, lignite	1.1-1.4	78
Coal, peat, turf, dry	0.65-0.85	47
Coal, charcoal, pine	0.28-0.44	23
Coal, charcoal, oak	0.47-0.57	33
Coal, coke	1.0-1.4	75
Graphite	1.9-2.3	131
Petroleum	0.87	54
Petroleum, refined	0.79-0.82	50
Petroleum, gasoline	0.66-0.69	42
Pitch	1.07-1.15	69
Tar, bituminous	1.20	75
Coal and Coke, Piled—		
Coal, anthracite		47-58
Coal, bituminous, lignite		40-54
Coal, peat, turf		20-26
Coal, charcoal		10-14
Coal, coke		23-32
Mortar Rubble Masonry—		
Granite, syenite, gneiss	2.2-2.8	155
Limestone, marble	2.2-2.6	150
Sandstone, bluestone	2.0-2.2	130

SPECIFIC GRAVITIES AND WEIGHTS OF MATERIALS
(Concluded)

	Specific Gravity	Wt., Pounds per cu. ft.
Dry Rubble Masonry—		
Granite, syenite, gneiss	1.9-2.3	130
Limestone, marble	1.9-2.1	125
Sandstone, bluestone	1.8-1.9	110
Brick Masonry—		
Pressed brick	2.2-2.3	140
Common brick	1.8-2.0	120
Soft brick	1.5-1.7	100
Concrete Masonry—		
Cement, stone, sand	2.2-2.4	144
Cement, slag, etc	1.9-2.3	130
Cement, cinder, etc	1.5-1.7	100
Various Building Materials—		
Ashes, cinders		40-45
Cement, portland, loose		90
Cement, portland, set	2.7-3.2	183
Lime, gypsum, loose		53-64
Mortar, set	1.4-1.9	103
Slags, bank slag		67-72
Slags, machine slag		96
Slags, slag sand		49-55
Earth, etc., Excavated—		
Clay, dry		63
Clay, damp, plastic		110
Clay and gravel, dry		100
Earth, dry, loose		76
Earth, dry, packed		95
Earth, moist, loose		78
Earth, moist, packed		96
Earth, mud, flowing		108
Earth, mud, packed		115
Riprap, limestone		80-85
Riprap, sandstone		90
Riprap, shale		105
Sand, gravel, dry, loose		90-105
Sand, gravel, dry, packed		100-120
Sand, gravel, dry, wet		118-120

MELTING POINTS OF VARIOUS SOLIDS

These melting points were collected by Dr. G. K. Burgess, of the Bureau of Standards, Washington, D. C. Those shown in CAPITALS are accepted by the Bureau as standard at this time (1911).

These melting points were obtained on the purest metals obtainable. Lower melting points may be expected with metals of less purity.

MELTING POINTS OF VARIOUS SOLIDS (Concluded)

	Fahrenheit Degrees	Centigrade Degrees		Fahrenheit Degrees	Centigrade Degrees
ALUMINUM	1216	658	NICKEL	2642	1450
ANTIMONY	1166	630	PALLADIUM	2822	1550
Arsenic	1472	800	Phosphorous	111	44
Bismuth	518	270	PLATINUM	3191	1755
CADMIUM	610	321	POTASSIUM	144	62
Calcium	1481	805	Rhodium (?)	3452	1900
Chromium	2741	1505	Silicon	2588	1420
COBALT	2714	1490	SILVER	1762	961
COPPER	1981	1083	SODIUM	207	97
GOLD	1945	1063	Tantalum (?)	5252	2900
Iridium (?)	4172	2300	TIN	450	232
LEAD	621	327	Titanium (?)	3362	1850
Magnesium	1204	651	TUNGSTEN	5432	3000
Manganese	2237	1225	Uranium	4352	2400
MERCURY	—38	—39	Vanadium (?)	3182	1750
Molybdenum (?)	4532	2500	ZINC	786	419

(?) Doubtful.

SOME OTHER MELTING POINTS

	Fahrenheit Degrees	Centigrade Degrees		Fahrenheit Degrees	Centigrade Degrees
GLASS	1832	1000	STEEL	2550	
GLASS, Lead free	2192	1200	Sulphur	(237	(114
DELTA METAL	1742	950		(248	(120
BARIUM CHLORIDE	1635	891	Fusible Metals: 1 Tin, 2 Lead	361	183
			1 Tin, 1 Lead	304	151
POTASSIUM FERROCYANIDE	1145	618	3 Tin, 2 Lead	275	135
POTASSIUM CHLORIDE	1325	718	4 Tin, 4 Lead, 1 Bismuth	263	128
SODIUM CHLORIDE	1472	800	3 Tin, 5 Lead, 8 Bismuth	212	100
CAST IRON	2070		RUBBER	257	
WROUGHT IRON	2640		PORCELAIN	2820	

FREEZING POINTS OF LIQUIDS AT ATMOSPHERIC PRESSURE

Fahrenheit Degrees

Alcohol (absolute)	—148.0	Ether	—180
Ammonia	—108.4	Glycerine	—40
Aniline	21.2	Linseed oil	—4
Benzol	41.0	Rape-seed oil	25.7
Carbon bisulphide	—171.0	Turpentine	14.0
Carbon dioxide	—110.2	Sulphuric acid	51.0
Chloroform	—83.0	Salt (NaCl) sol., sat.	—0.4
Calcium chloride (sat. sol.)	—40	Seawater	27.5
		Toluene	—148

THERMOMETER COMPARISONS

Centigrade to Fahrenheit

Temperature Fahrenheit = 9/5 Temperature Centigrade + 32

Examples: Centigrade 20° × 9/5 = 36 + 32 = 68° Fahrenheit
Centigrade —20° × 9/5 = —36 + 32 = —4° Fahrenheit

Fahrenheit to Centigrade

Temperature Centigrade = 5/9 Temperature Fahrenheit — 32

Examples: Fahrenheit 50° — 32 = 18° × 5/9 = 10° Centigrade
Fahrenheit —5° — 32 = —37° × 5/9 = —20.55° Cent.

Note: —20 and —5 above mean 20 and 5 below zero respectively.

Absolute Zero.—The value of the absolute zero has been variously given as from 459.2 to 460.66 degrees below the Fahrenheit zero. 460 degrees is usually used in engineering calculations.

MISCELLANEOUS FACTS

Utilizing Gas from a Drilling Well.—Gas can be utilized from a well in the process of drilling by the simple means of laying a 2-inch pipe to the mouth of the well and just to the edge of the casing, so that it will not protrude over the edge to impede the passage of the tools. Connect a steam jet in such a way that it will create a suction on the 2-inch pipe and this suction will draw the gas from the well through the pipe to the boiler.

To Save Jars from Breaking.—Watch for small checks or cracks. If a crack is noted, chip it out with a cold chisel which may prevent it from spreading or growing larger.

Cracks in Castings.—To stop the progress of a crack in a casting, drill a small hole at each end of the crack.

The hole in a New Era Rope Socket should always have a rounding edge. If the edge wears sharp, file it round; otherwise it may crack.

ANALYSES OF STEEL SUITABLE FOR USE IN MAKING DRILLING TOOLS

Bit Steel..........	Carbon—	.65% to .75%
	Phosphorous—	Not over .04%
	Sulphur—	Not over .04%
	Manganese— content.	10 to 20 points above the carbon
Jar Steel..........	Carbon—	.50% to .60%
	Other elements same as bit steel.	
Stem Steel.........	Carbon—	.20% to .30%
	Other elements same as bit steel.	

Note: .25% carbon content is about correct for stem steel. Stems made of steel lower in carbon than .20% would have a tendency to bend, while those made of steel carrying carbon. .30% or higher might crack or break.

WORKSHOP FORMULAS

(From Waverly Oil Works Co. Book "Waverly Products")

Tempering Mixtures.

Resin, 2 lbs.; tallow, 2 lbs.; pitch, 1 lb. Melt together and dip the hot steel in it.

Salt, ½ cupful; saltpeter, ½ oz.; alum, pulverized, 1 teaspoonful; soft water, 9 gal. Never heat above a cherry red nor draw any temper.

By melting together 1 gal. spermacetti oil, 2 lbs. tallow and ¼ lb. wax, a mixture is obtained very convenient for tempering any kind of steel article of small size. Adding 1 lb. resin makes it suitable for larger articles.

To Temper Steel Very Hard.—Water, 4 parts; flour, 1 part; salt, 2 parts; mixed to a paste. Heat the steel until a coating adheres when dipped into the mixture; then heat to a cherry red and cool in cold soft water. The steel will come out white and very hard.

To Temper Steel on One Edge Only.—Dip the edge to be tempered into hot lead until the proper color; then temper in ordinary fashion.

To Drill Hardened Steel.—Cover the steel with melted beeswax; when coated and cold, make a hole in the wax with a needle or other article the size of hole you require, put a drop of strong nitric acid upon it; after an hour rinse off and apply again; it will gradually eat through.

WORKSHOP FORMULAS (Continued)

A mixture of 1 ounce of sulphate of copper, ¼ ounce of alum, ½ teaspoonful of powdered salt, 1 gill vinegar and 20 drops of nitric acid will make a hole in steel that is too hard to cut or file easily.

To Anneal Steel.—For small pieces of steel, take a piece of gas pipe two or three inches in diameter, and put the steel in it, first heating one end of the pipe, and drawing it together, leaving the other end open to look into. Place in a charcoal fire and when the pieces are of a cherry red, cover the fire with sawdust and leave the steel in over night.

In Turning Steel or Other Hard Metal.—Use a drip composed of petroleum two parts, and turpentine one part. This will insure easy cutting and perfect tools when otherwise the work would stop, owing to the breakage of tools from the severe strain.

Case Hardening Mixture.—3 prussiate of potash, 1 sal-ammoniac; or, 1 prussiate of potash, 2 sal-ammoniac, 2 bone dust.

Fluxes for Soldering or Welding.—Steel.—Pulverize together 1 part of sal-ammoniac and 10 parts of borax and fuse until clear. When solidified, pulverize to powder.

Iron	Borax
Tinned Iron	Resin
Copper and Brass	Sal Ammoniac
Zinc	Chloride of Zinc
Lead	Tallow of Resin
Lead and Tin Pipes	Resin and Sweet Oil

Case Hardening.—Place horn, hoof, bone dust, or shreds of leather, together with the article to be case hardened, in an iron box subject to a blood red heat; then immerse the article in cold water.

To Remove Rust from Steel.—Steel which has been rusted can be cleaned by brushing with a paste compound of ½ oz. cyanide potassium, ½ oz. castile soap, 1 oz. whiting, and water sufficient to form a paste. The steel should be washed with a solution of ½ oz. cyanide potassium in 2 oz. water.

WORKSHOP FORMULAS (Continued)

To Preserve Steel from Rust.—1 caoutchouc, 16 turpentine. Dissolve with a gentle heat, then add 8 parts boiled oil. Mix by bringing them to the heat of boiling water; apply to the steel with a brush, in the way of varnish. It may be removed with turpentine.

Thread Cutting Compound.—1 qt. thread cutting oil, 1 qt. lard oil, ¼ lb. good castile soap chips, 5 gal. water (hot). Dissolve soap in the water and stir in the oil.

Universal Cement.—21 parts boiled linseed oil, 20 parts gelatine size, 15 parts slaked lime, 5 parts tur-min-tine, 5 parts alum, and 5 parts acetic acid. Melt the size in the acetic acid, add the alum and the slaked lime, then the turps and the boiled oil. Mix the whole thoroughly and keep in well-stopped bottles. This, as the name implies, is a cement for wood, glass, cardboard, porcelain, etc.

Iron Cement.—28 lbs. litharge, 56 lbs. whiting, 4 lbs. venetian red, 10 lbs. yellow ochre, and 1 lb. finely powdered sugar of lead. Mix well together and pass through fine sieve. For use make into putty with 2 gal. boiled linseed oil for the above quantity.

Fire and Water-proof Cement.—Mix 10 parts of finely sifted unoxidized iron filings and 5 parts of perfectly dry, pulverized clay, with vinegar spirit, by thoroughly kneading until the whole is a uniform plastic mass. If the cement thus made is used at once, it will harden rapidly and withstands fire and water.

Cement for Steam Pipes.—Litharge, 2 parts; powdered slaked lime, 1 part; sand, 1 part. Mix with a sufficient quantity of hot linseed oil to make a stiff paste and use while warm.

Rust Joint Cement (Quickly Setting).—1 sal-ammoniac in powder (by weight) 2 flour of sulphur, 80 iron borings, made to a paste with water.

Rust Joint Cement (Slowly Setting).—2 sal-ammoniac, 1 flour of sulphur, 200 iron borings. The latter cement is the best if the joint is not required for immediate use.

WORSHOP FORMULAS (Concluded)

Red Lead Cement for Face Joints.—1 of white lead, 1 of red lead, mixed with linseed oil to the proper consistency.

Glue to Resist Moisture.—1 lb. of glue melted in 2 quarts of skim milk.

Fire Extinguisher Liquid.—4 av. oz. calcium chloride crude, 1 av. oz. sodium chloride, 15 fl. oz. water. The resulting solution is thrown into the fire by a hand pump. The burning portions become incrusted and cease to be combustible.

MEASURES OF VOLUME

Cubic measure applies to measurement in the three dimensions of length, breadth and depth or thickness. Any convenient linear unit may be employed, because quantities are always expressed in cubes of fixed linear measurement, as cubic inch, cubic foot, cubic yard.

SOLID OR CUBIC MEASURE

1,728 cubic inches	=	1 cubic foot
27 cubic feet	=	1 cubic yard
128 cubic feet	=	1 cord
24¾ cubic feet	=	1 perch.

A perch of masonry is 16½ feet long, 1½ feet thick, and 1 foot high = 24¾ cubic feet.

Timber measured in bulk and not to be computed in cubic feet is reduced to board measure, that is, in terms of square feet of surface by 1 inch in thickness.

MENSURATION

Circumference of circle = diameter × 3.1416.
Circumference of circle = radius × 6.2832.
Area of circle = radius^2 × 3.1416.
Area of circle = diameter^2 × .7854.
Area of circle = circumference^2 × .07958.
Area of circle = ½ circumference × ½ diameter.
Radius of circle = circumference × .159155.
Diameter of circle = circumference × .31831.
Side of inscribed equilateral triangle = diameter of circle × .86.
Side of inscribed square = diameter of circle × .7071.
Side of inscribed square = circumference of circle × .225.
Side of equal square = circumference of circle × .282.
Side of equal square = diameter of circle × .8861.
Surface of sphere = circumference × diameter.
Surface of sphere = diameter^2 × 3.1416.
Surface of sphere = circumference^2 × .3183.

MENSURATION (Continued)

Volume of sphere = diameter^3 × .5236.
Volume of sphere = radius^3 × 4.1888.
Volume of sphere = circumference^3 = .016887.
Side of inscribed cube = radius of sphere × 1.1547.
Surface of cube = area of one side × 6.
Area of ellipse = both diameters × .7854.
Area of triangle = base × ½ altitude.
Volume of cone or pyramid = area of base × 1/3 altitude.
Area of parallelogram = base × altitude.
Area of trapezoid = altitude × ½ sum of parallel sides.
Area of trapezium = area of 2 constituent triangles.
Area of regular polygon = sum of its sides × perpendicular from its center to one of its sides ÷ 2.
Surface of cylinder or prism = areas of both ends plus (length × circumferences).
Contents of cylinder or prism = area of end × length.
Surface of frustrum of cone or pyramid = sum of circumference of both ends × ½ slant height + area of both ends.
Contents of frustrum of cone or pyramid = multiply area of two ends and get square root. Add the 2 areas and × 1/3 altitude.
Contents of a wedge = area of base × ½ altitude.

MEASURE OF SURFACE

A linear unit squared is a corresponding square unit in determining the areas of surfaces. The side of the square may be an inch, foot, yard or any other conventient unit.

SUPERFICIAL MEASURE

144	square inches	=	1 square foot
9	square feet	=	1 square yard
30¼	square yards	=	1 square rod
160	square rods	=	1 acre
640	acres	=	1 square mile
1	rood	=	¼ acre.

With the exception of the acre, the above units of superficial square measure are derived from the corresponding units of linear measure.

A square inch is the area of a rectangle the side of which is one inch.

A circular inch is the area of a circle one inch in diameter—0.7854 square inch.

One square inch = 1.2732 circular inches.

One square foot = 144 square inches = 183.35 circular inches.

Slate and other roofing is often reckoned by the square, meaning 100 square feet of surface.

MENSURATION (Concluded)

Plastering and painting are commonly reckoned by the square yard.

SURVEYOR'S SQUARE MEASURE

625 square links	= 1 square rod
16 square rods	= 1 square chain
10,000 square links	= 1 square chain
10 square chains	= 1 acre
640 acres	= 1 square mile
36 square miles	= 1 township.

An acre is 208.71 feet square = 43,560 square feet. This is the common unit of land measure.

The public lands of the United States are divided by north and south meridianal lines crossed by others at right angles forming Townships of six miles square.

Townships are sub-divided into Sections one mile square.

A section one mile square contains 640 acres. It is divided into half-sections of 320 acres; quarter sections of 160 acres; half-quarter sections of 80 acres, and quarter-quarter sections of 40 acres.

Board Measure is used in measuring lumber. The unit is 1 square foot of surface by 1 inch in thickness, or 1/12 of a cubic foot.

Unless otherwise stated, boards less than an inch thick are reckoned as if they were of that thickness. Boards over an inch thick are reduced to the inch standard; that is, for 1¼-inch boards add ¼ to the surface measure, for 1½-inch boards add ½ to the surface measure, and so on for any thickness. All sawed timber is measured by board measure.

1000 feet, board measure = 83.33 cubic feet.

THE METRIC SYSTEM

(Extract from tables of equivalents published by the Department of Commerce and Labor, Bureau of Standards.)

(From National Tube Co. Book of Standards)

The fundamental unit of the metric system is the meter (the unit of length).

From this the units of mass (gram) and capacity (liter) are derived.

All other units are the decimal subdivisions or multiples of

THE METRIC SYSTEM (Continued)

these. These three units are simply related, so that for all practical purposes the volume of one kilogram of water (one liter) is equal to one cubic decimeter.

Prefixes		Meaning			Units
Milli-	=	one thousandth	1/1000	.001	
Centi-	=	one hundredth	1/100	.01	Meter for length
Deci-	=	one tenth	1/10	.1	
unit	=	one		1.	Gram for mass
Deka-	=	ten	10/1	10.	
Hecto-	=	one hundred	100/1	100.	Liter for capacity
Kilo-	=	one thousand	1000/1	1000.	

The metric terms are formed by combining the words "Meter," "Gram" and "Liter" with the six numerical prefixes.

Length

10 milli-meters (mm)	=	1 centi-meter (cm)
10 centi-meters	=	1 deci-meter (dm)
10 deci-meters	=	1 Meter (about 40 in.) (m)
10 meters	=	1 deka-meter (dkm)
10 deka-meters	=	1 hecto-meter (hm)
10 hecto-meters	=	1 kilo-meter (about 5/8 mile) (km).

Mass

10 milli-grams (mg)	=	1 centi-gram (cg)
10 centi-grams	=	1 deci-gram (dg)
10 deci-grams	=	1 gram (about 15 grains) (g)
10 grams	=	1 deka-gram (dkg)
10 deka-grams	=	1 hecto-gram (hg)
10 hecto-grams	=	1 kilo-gram (about 2 lbs.) (kg).

Capacity

10 milli-liters (ml)	=	1 centi-liter (cl)
10 centi-liters	=	1 deci-liter (dl)
10 deci-liters	=	1 liter (about 1 quart) (l)
10 liters	=	1 deka-liter (dkl)
10 deka-liters	=	1 hecto-liter (about a bbl.) (hl)
10 hecto-liters	=	1 kilo-liter (kl).

Equivalents

The square and cubic units are the squares and cubes of the linear units.

The ordinary unit of land area is the Hectare (about 2½ acres).

For ordinary mental comparison it is convenient to know the approximate relations: e.g., 1 meter = 40 inches; 3 decimeters = 1 foot; 1 decimeter = 4 inches; 1 liter = 1 liquid quart; 1 kilogram = 2 1/5 pounds; 30 grams = 1 avoirdupois ounce; 1 metric ton = 1 gross ton.

THE METRIC SYSTEM (Continued)

All lengths, areas and cubic measures in the following tables are derived from the international meter, the legal equivalent being 1 meter = 39.37 inches (law of July 28, 1866). In 1893 the United States Office of Standard Weights and Measures was authorized to derive the yard from the meter, using for the purpose the relation legalized in 1866, 1 yard equals 3600/3937 meter. The customary weights are likewise referred to the kilogram. (Executive order approved April 5, 1893.) This action fixed the values, inasmuch as the reference standards are as perfect and unalterable as it is possible for human skill to make them.

All capacities are based on the practical equivalent of 1 cubic decimeter equals 1 liter. The decimeter is equal to 3.937 inches in accordance with the legal equivalent of the meter given above. The gallon referred to in the tables is the United States gallon of 231 cubic inches. The bushel is the United States bushel of 2150.42 cubic inches. These units must not be confused with the British units of the same name, which differ from those used in the United States. The British gallon is approximately 20 per cent. larger, and the British bushel 3 per cent. larger, than the corresponding units used in this country.

The customary weights derived from the international kilogram are based on the value 1 avoirdupois pound = 453.5924277 grams. This value is carried out farther than that given in the law, but is in accord with the latter as far as it is there given. The value of the troy pound is based upon the relation just mentioned, and also the equivalent 5760/7000 avoirdupois pound equals 1 troy pound.

Length

Centimeter	= 0.3937 inch.
Meter	= 3.28 feet
Meter	= 1.094 yards
Kilometer	= 0.621 statute mile
Kilometer	= 0.5396 nautical mile
Inch	= 2.540 centimeters
Foot	= 0.305 meter
Yard	= 0.914 meter
Statute mile	= 1.61 kilometers
Nautical mile	= 1.853 kilometers

THE METRIC SYSTEM (Continued)

Area

Square centimeter	=	0.155 square inch
Square meter	=	10.76 square feet
Square meter	=	1.196 square yards
Hectare	=	2.47 acres
Square kilometer	=	0.386 square mile
Square inch	=	6.45 square centimeters
Square foot	=	0.0929 square meter
Square yard	=	0.836 square meter
Acre	=	0.405 hectare
Square mile	=	2.59 square kilometers

Volume

Cubic centimeter	=	0.0610 cubic inch
Cubic meter	=	35.3 cubic feet
Cubic meter	=	1.308 cubic yards
Cubic inch	=	16.39 cubic centimeters
Cubic foot	=	0.0283 cubic meter
Cubic yard	=	0.765 cubic meter

Capacity

Milliliter	=	0.0338 U. S. liquid ounce
Milliliter	=	0.2705 U. S. apothecaries' dram
Liter	=	1.057 U. S. liquid quarts
Liter	=	0.2642 U. S. liquid gallon
Liter	=	0.908 U. S. dry quart
Dekaliter	=	1.135 U. S. pecks
Hectoliter	=	2.838 U. S. bushels
U. S. liquid ounce	=	29.57 milliliters
U. S. apothecaries' dram	=	3.70 milliliters
U. S. liquid quart	=	0.946 liter
U. S. dry quart	=	1.101 liter
U. S. liquid gallon	=	3.785 liter
U. S. peck	=	0.881 dekaliter
U. S. bushel	=	0.3524 hectoliter

Weight

Gram	=	15.43 grains
Gram	=	0.772 U.S. apothecaries' scruple
Gram	=	0.2572 U. S. apothecaries' dram
Gram	=	0.0353 avoirdupois ounce
Gram	=	0.03215 troy ounce
Kilogram	=	2.205 avoirdupois pounds
Kilogram	=	2.679 troy pounds
Metric ton	=	0.984 gross or long ton
Metric ton	=	1.102 short or net tons
Grain	=	0.0648 gram
U.S. apothecaries' scruple	=	1.296 grams
U. S. apothecaries' dram	=	3.89 grams
Avoirdupois ounce	=	28.35 grams
Troy ounce	=	31.10 grams
Troy-pound	=	0.373 kilogram
Avoirdupois pound	=	0.4536 kilogram
Gross or long ton	=	1.016 metric tons
Short or net ton	=	0.907 metric ton

THE METRIC SYSTEM (Concluded)

CONVENIENT FACTORS FOR CONVERSION

To convert:

Grain to Grammes, multiply by	.065
Ounces to Grammes, multiply by	28.35
Pounds to Grammes, multiply by	453.6
Pounds to Kilogrammes, multiply by	.45
Cwts. to Kilogrammes, multiply by	45.35
Tons to Kilogramems, multiply by	906.3
Grammes to Grains, multiply by	15.4
Grammes to Ounces, multiply by	.035
Kilogrammes to Ounces, multiply by	35.3
Kilogrammes to Pounds, multiply by	2.2
Kilogrammes to Cwts., multiply by	.02
Kilogrammes to Tons, multiply by	.001
Inches to Millimeters, multiply by	25.4
Inches to Centimeters, multiply by	2.54
Feet to Meters, multiply by	.3048
Yards to Meters, multiply by	.9144
Yards to Kilometers, multiply by	.0009
Miles to Kilometers, multiply by	1.6
Millimeters to Inches, multiply by	.04
Centimeters to Inches, multiply by	.4
Meters to Feet, multiply by	3.3
Meters to Yards, multiply by	1.1
Kilometers to Yards, multiply by	1093.6
Kilometers to Miles, multiply by	.62

1 Yard = 0.9144 Meter. 1 Square Meter = 1.196 Square Yards.
1 Liter = 1.760 Imperial Pints or 0.22 Imperial Gallons.
1 Liter = 2.113 U. S. Pints.

MISCELLANEOUS FACTORS

Inches	×	0.08333	=	feet.
Inches	×	0.02778	=	yards.
Inches	×	0.00001578	=	miles.
Square inches	×	0.00695	=	square feet.
Square inches	×	0.0007716	=	square yards.
Cubic inches	×	0.00058	=	cubic feet.
Cubic inches	×	0.0000214	=	cubic yards.
Cubic inches	×	0.004329	=	U. S. gallons.
Feet	×	0.3334	=	yards.
Feet	×	0.00019	=	miles.
Square feet	×	144.00	=	square inches.
Square feet	×	0.1112	=	square yards.
Cubic feet	×	1728.00	=	cubic inches.
Cubic feet	×	0.03704	=	cubic yards.
Cubic feet	×	7.48	=	U. S. gallons.
Yards	×	36.000	=	inches.
Yards	×	3.000	=	feet.
Yards	×	0.0005681	=	miles.
Square yards	×	1296.000	=	square inches.
Square yards	×	9.000	=	square feet.
Cubic yards	×	46656.000	=	cubic inches.
Cubic yards	×	27.000	=	cubic feet.

MISCELLANEOUS FACTORS (Concluded)

Miles	×	63360.000	=	inches.
Miles	×	5280.000	=	feet.
Miles	×	1760.00	=	yards.
Avoir. oz.	×	0.0625	=	pounds.
Avoir. oz.	×	0.00003125	=	tons.
Avoir. lbs.	×	16.000	=	ounces.
Avoir. lbs.	×	0.001	=	hundredwt.
Avoir. lbs.	×	0.0005	=	tons.
Avoir. lbs.	=	27.681 cubic in. water at 39.2° F.		
Avoir. tons	×	32000.00	=	ounces.
Avoir. tons	×	2000.00	=	pounds.
Watts	×	0.00134	=	horsepower.
Horsepower	×	746.00	=	watts.

TO FIND THE CAPACITY OF A TANK IN GALLONS

First step **(all measurements to be in inches):**

For rectangular tanks, multiply the length by the width, by the depth.

For cylindrical tanks, multiply the depth by the square of the diameter, by .7854.

For elliptical section tanks, multiply the length by the short diameter, by the long diameter by .0339.

Second step.

Divide the result by 231, which is the number of cubic inches in one gallon; the answer is the capacity of the tank in gallons.

Example: To find capacity of round tank ten feet in depth and eight feet in diameter: 10 feet = 120 inches, 8 feet = 96 inches, $120 \times 96^2 \times .7854 \div 231 = 3{,}760$ gallons.

A shorter rule—square the diameter in inches and multiply by the length or heighth in inches. Multiply by .0034 and the result will be capacity in gallons.

GASOLINE OR OIL FIRE

Gasoline or oil fire is best extinguished with flour, sand or earth in the order named; water should not be used. If the fire be confined in small space, ammonia will smother it. Some users of gasoline find it well to hang a bottle containing about a gallon of ammonia from the top of the tank or room containing the gasoline or oil, by a string or fusible link, so that if the gasoline takes fire the bottle will fall and be broken, releasing the ammonia and promptly putting out the burning gasoline or oil.—From Power and Transmission.

EXTINGUISHING BURNING OIL OR GAS WELLS

Steam from a battery of boilers is usually effective. As many as 25 boilers have been set up around one well before a sufficient volume of steam could be directed against the fire to extinguish it. Sometimes the steam is augmented with a supply of mud fluid pumped with slush pumps. Large sheet metal hoods have been successfully used to snuff out the blaze when the pressure or volume of the gas or oil was not too great. Dynamite was used with success after other usual means failed to extinguish a large burning well in California. The force of the explosion temporarily diverted the flow of the well and snuffed out the fire.

WEIGHTS OF STEEL BARS

Thickness or Diameter, Inches	Round Bars Weight per foot Pounds	Square Bars Weight per foot Pounds	Thickness or Diameter, Inches	Round Bars Weight per foot Pounds	Square Bars Weight per foot Pounds
⅛	0.042	0.053	1⅞	9.39	11.95
3/16	0.094	0.119	2	10.68	13.60
¼	0.167	0.212	2⅛	12.06	15.35
5/16	0.261	0.333	2¼	13.52	17.22
⅜	0.375	0.478	2⅜	15.07	19.18
7/16	0.511	0.651	2½	16.69	21.25
½	0.667	0.850	2⅝	18.40	23.43
9/16	0.845	1.08	2¾	20.20	25.71
⅝	1.04	1.33	2⅞	22.07	28.10
11/16	1.26	1.61	3	24.03	30.60
¾	1.50	1.91	3¼	28.20	35.92
13/16	1.76	2.25	3½	32.71	41.65
⅞	2.04	2.60	3¾	37.56	47.82
15/16	2.35	2.99	4	42.73	54.40
1	2.67	3.40	4¼	48.24	61.41
1 1/16	3.01	3.84	4½	54.07	68.85
1⅛	3.38	4.30	4¾	60.25	76.71
1 3/16	3.77	4.80	5	66.76	85
1¼	4.17	5.31	5¼	73.60	93.72
1 5/16	4.60	5.86	5½	80.77	102.8
1⅜	5.05	6.43	5¾	88.29	112.4
1 7/16	5.52	7.03	6	96.14	122.4
1½	6.01	7.65	6½	112.8	143.6
1 9/16	6.52	8.30	7	130.9	166.6
1⅝	7.05	8.98	7½	150.2	191.3
1¾	8.18	10.41	8	171	217.6

RULES FOR OBTAINING APPROXIMATE WEIGHT OF IRON

For Round Bar.—Rule: Multiply the square of the diameter in inches by the length in feet, and that product by 2.6. The product will be the weight in pounds, nearly.

For Square. and Flat Bars.—Rule: Multiply the area of the end of the bar in inches by the length in feet, and that by 3.32. The product will be the weight in pounds, nearly.

Wrought Iron, Usually Assumed.—A cubic foot = 480 lbs.

ELECTRICITY

(Extracts from "Essentials of Electricity," by W. H. Timbie. John Wiley & Sons, New York)

Electricity may be considered to flow as a current along a conductor, as water flows through a pipe.

Electric current is measured in Amperes. The ampere is the quantity of electricity passing through a conductor in one second. Corresponds to volume of gas or quantity of water.

The pressure which causes current to flow is measured in Volts. Corresponds to pounds per square inch with water or gas.

Resistance of the conductor to the current is measured in Ohms, corresponds to friction of water flowing in pipe.

Ohms law: The current which an electric pressure forces through a resistance equals the pressure divided by the resistance, = Volts ÷ Ohms.

Ohms law is used in three forms as follows:

Current or Amperes = Volts ÷ Ohms.

Pressure or Volts = Amperes × Ohms.

Resistance or Ohms = Volts ÷ Amperes.

When a pressure of 1 volt can force 1 ampere of current through a wire, the resistance of the wire is 1 ohm. If 1 volt can force only ½ an ampere through a wire, the resistance is 2 ohms.

Unit of Power is the Watt, and denotes the power used when one volt causes one ampere of current to flow. Power

ELECTRICITY

or watts equal amperes × volts. Example: If an electric lamp takes 0.5 amperes when used on a 110-volt line, the power consumed equals 0.5 × 110 = 55 watts.

Kilowatt equals 1,000 watts. Electric power is measured by the kilowatt hour; equals kilowatts × hours.

Current is measured by inserting a low resistance ammeter into the line on the same principle as a water meter is used to measure the volume of water flowing through a pipe.

Voltage is measured by tapping a high resistance voltmeter across two points in the line, corresponding to the use of a pressure gauge to register water pressure.

Power is measured by multiplying the ammeter reading by the voltmeter reading, the result being power in watts.

Example: A generator delivers current of 5 amperes at 120 volts. In the circuit is a resistance of 10 volts, and a motor which requires 110 volts.

The resistance consumes 10 volts × 5 amperes = 50 watts.

The motor consumes 110 volts × 5 amperes = 550 watts.

50 watts + 550 watts = 600 watts, the equivalent of 5 amperes at 120 volts.

Resistance of Wire.—A round wire 1/1000 inch in diameter (called a mil) and 1 foot long is the unit round wire. Wires of larger diameters contain as many unit wires as the square of the number of mils or thousandths of their diameter, thus a wire 1/100 or 10/1000 inch in diameter equals 10 × 10 = 100 mils.

Resistance in wire is reduced as the diameter of the wire is increased. Total resistance of a length of wire equals the resistance of one foot multiplied by the length. The unit of resistance for copper wire, 1 mil (1/1000 inch) in diameter and 1 foot long is usually taken at 10.4 ohms. To find the resistance of 1 foot of copper wire 5/1000 inch in diameter 5 × 5 = 25 circular mils diameter. The resistance of 1 foot of 5-mil wire would be 10.4 ÷ 25 = 0.416 ohms. The resistance of 1,000 feet of 5-mil wire would be 1000 × 0.416 = 416 ohms.

ELECTRICITY

Table of Resistance and of Allowable Carrying Capacities of Soft Copper Wire

B. & S. Gauge No.	Diameter in Mils	Ohms per 1,000 Feet at 68° F.	Capacity with Rubber Insulation Amperes*	B. & S. Gauge No.	Diameter in Mils	Ohms per 1,000 Feet at 68° F.	Capacity with Rubber Insulation, Amperes*
9	114.43	0.7908	30	15	57.068	3.179	11
10	101.89	0.9972	25	16	50.820	4.009	6
11	90.742	1.257	23	17	45.257	5.055	4½
12	80.808	1.586	20	18	40.303	6.374	3
13	71.961	1.999	18	19	35.890	8.038	
14	64.084	2.521	15	20	31.961	10.14	

Generator.—A machine driven by mechanical power for generating electric power.

Motor.—A machine driven by electric power for delivering mechanical power.

1 kilowatt = 1 1/3 horsepower.

1 horsepower = ¾ kilowatt.

Batteries are of two kinds, wet and dry.

A wet cell consists of a negative plate of zinc, a positive plate of carbon and wood spacers, immersed in a solution of sal-ammoniac, contained in a vulcanite jar. Volts about 1.5; internal resistance 1 to 4 ohms.

A dry cell consists of a positive plate of carbon surrounded by paste containing sal-ammoniac solution, contained in a zinc jar which forms the negative plate. Volts about 1.5; internal resistance less than 0.1 ohm.

The foregoing touches only the rudiments of electricity. A very good book of reference and instruction for practical use is "Essentials of Electricity," by W. H. Timbie.

Few electrical devices are used in well drilling practice. Chief of these is the steam turbine generator for lighting the derrick. The Moon Manufacturing Company furnishes the following directions for the care and operation of the Moon turbine generator:

* Carrying capacities of wire with other than rubber insulation are about one-third greater than shown in table.

The resistance of iron wire is about seven times greater than copper.

ELECTRICITY

CARE AND OPERATION OF MOON TURBINE GENERATORS

All electrical machinery should be kept clean, as oil and dirt have a tendency to break down insulation and cause trouble.

Commutator should be kept clean by wiping it off with a clean dry cloth. If very dirty, the cloth may be dampened slightly with oil and applied when the machine is running, afterwards commutator must be wiped off with a clean dry cloth, not waste, as particles of the waste may catch and wind around the shaft, or may be drawn in between armature and pole pieces and cause trouble.

If the commutator has become very rough and it is necessary to smooth it, this can be done by using a strip of fine sandpaper (not emery paper), cut the width of the commutator. Remove brushes and while machine is running, hold sandpaper down at each end but do not press it down against the commutator with fingers, as this will have a tendency to increase any low spots there may be in the commutator. After the commutator has been thoroughly cleaned, wipe out brush holders and reapply brushes.

The commutator is in its best condition when it is smooth and has acquired a dark chocolate color.

The two dynamo brushes, located opposite one another, should be sandpapered to fit the curvature of the commutator, and should be wiped off, and kept free from oil.

The tension of brush springs should be kept tight enough to insure the brushes making firm contact with the commutator.

Outfit required for wiring a derrick for electric lights:

1 Steam Turbine Generator.
500 feet No. 14 Triple Braid Wire.
30 No. 5½ Porcelain Split Knobs with Screws.
12 Weatherproof Sockets.
12 Lamp Guards.
10 40 Watt Lamps.
2 60 Watt Lamps.
1 No. 4014 Double Pole Knife Switch with two Fuses.
½ Pound Friction Tape.

ELECTRICITY

DIRECTIONS FOR WIRING

Mount the generator in the engine house and connect with steam supply. Connect wires to positive and negative terminals and run wires up wall and connect switch at convenient place. Carry wires out over walk and into derrick and round the four sides of derrick at the first girt. Extend wires up in one corner of derrick to crown block. Connect lamps to line as follows: one in engine house, one over walk, four to eight strung around first girt to light the derrick, one on crown block and one about halfway up in derrick. Solder all wire connections and then carefully tape them. If impossible to solder use extra care in taping. For supporting wires use the porcelain split knobs.

SIMPLE RULES TO FIND POSITIVE AND NEGATIVE WIRES IN A GENERATOR

(1) Cut a potato in half and apply half to the two wires about one-half inch apart. Start generator and in a few minutes the potato will turn green round the positive wire and it will bubble round the negative wire.

(2) Immerse the two wires in a salt solution: the negative wire will cause bubbles.

LUBRICATION OF A DRILLING OUTFIT

The following lubricants are usually used:

Engine, cylinder:	Cylinder Oil, Tallow.
Engine, bearings and working parts:	Engine Oil, Cup Grease.

Note: The drilling engine is usually equipped with a two-quart sight feed lubricator in which cylinder oil should be used. For the old style lubricator or tallow cup, tallow will answer.

Boiler Feed Pump:	Cylinder Oil.
Gasoline Engine for pumping water:	Gas Engine Oil.
Star Blower:	Engine Oil.
Turbine Generator:	Cylinder or Valve Oil.
Jack Post Boxes:	Heavy Grease known as Jack Post Grease.

LUBRICATION OF A DRILLING OUTFIT (Concluded)

Crown Block and Pulleys:	Engine Oil.
Walking Beam Center Irons:	Engine Oil.
Calf Wheel and Bull Wheel Gudgeons:	Jack Post Grease.
Sand Reel:	Engine Oil.
Wire Drilling Cables, Sand Lines and Casing Lines:	Light Graphite Grease.

Note: Some wire rope manufacturers supply a special lubricant for this purpose.

ROTARY OUTFIT

Rotary Draw Works—Sprockets and Chain:	Graphite Grease.
Shafts, etc.:	Cup Grease, Engine Oil.
Swivel:	Engine Oil.
Tool Joints:	Compound of White Lead and Tallow.

LUBRICANTS FOR ROTARY TOOL JOINTS AND FOR CASING THREADS *

The following formulas for lubricants were supplied by E. S. Durward, of the Shell Oil Co., Coalinga, California.

Formula for lubricant for rotary tool joints:

	Per Cent.
Tallow	33.4
White lead ground in oil	23.2
Graphite	2.9
Cylinder oil	40.5

Melt tallow, add white lead, mixing well. Then add oil, stirring continually. Then add graphite and mix all together.

Formula for lubricant for casing threads:

Tallow	Pounds	200
White lead ground in oil	Pounds	300
Graphite	Pounds	24
Lard oil	Gallons	30

Mix lead with some oil, then melt the tallow. Finally mix everything together and continue stirring until thoroughly mixed.

* Bureau of Mines Bulletin 182, by Thomas Curtin.

CHAPTER XVI

STATE LAWS RELATING TO DRILLING, ABANDONING AND PLUGGING OIL AND GAS WELLS AND TO OIL AND GAS

ARKANSAS LAWS

An Act to Conserve Natural Gas Resources of the State of Arkansas

Be it enacted by the General Assembly of the State of Arkansas:

Be it enacted by the people of the State of Arkansas:

Section 1. In order to determine the open flow volume of gas produced by any well, it shall be the duty of the State Gas Inspector or his duly authorized deputy to test all wells producing gas in the State of Arkansas, from which gas is being used or marketed, between the 1st day of December and the 1st day of January in each year, and as often thereafter as in his judgment it may be necessary—for the purpose of determining the open flow volume and rock pressure of said wells. The State Oil and Gas Inspector shall be paid a fee of $25.00 a day and his actual expenses by the person, firm or corporation whose wells are tested by him or his deputy under the provisions of this Section.

Section 2. In determining the open flow volume and rock pressure of said well, said Gas Inspector shall first close the well for a period of five minutes, and then take a test, to determine its closed-in pressure. He shall then immediately open said well and flow it for five minutes, and then take a test of its open flow volume, with approved instruments and devices in use for that purpose.

Section 3. Immediately after the said tests are made, the Gas Inspector shall furnish the person, firm or corporation owning or operating said well or wells with a copy of the tests made by him, showing the amount of gas which said owner or operator may take from each of said wells daily, and shall file his report of said tests with the county clerk of the County in which said well or wells are situated, showing the closed-in rock pressure and open flow volume, size of the tubing with which said well or wells are closed in, and the condition of the well or wells at the time the test was made; said report to be verified by said Gas Inspector and preserved by the County Clerk in the County records.

Section 4. Before making said tests, the Gas Inspector shall give five days notice in writing to the person, firm or corporation owning, operating or controlling said gas well or wells, of the time when said tests will be made, and the person, firm or corporation owning, operating or controlling said well or wells, or any other person interested therein, shall have the right to be present when said test is being made, and shall afford to said Gas Inspector every means and facility possible for the purpose of making an accurate test of said well or wells, as provided in this Act.

Section 5. If, in the judgment of the Gas Inspector, it shall be deemed advisable or necessary to test said wells oftener than set out in Section 1, he shall have the right to do so, and for the purpose of making said tests and determining the amount of gas taken therefrom, he shall have access to all wells and to all well records, and all companies, contractors, drillers, lessees or owners of the land upon which said well or wells are located shall permit said Gas Inspector or his deputy to come upon any lease or property owned or controlled by them, and to inspect any and all wells and the records of said wells, and to have access at all times to all wells and to any and all records of said wells used, owned or operated by any person, firm or corporation or the lessees or owners of the land upon which said wells are located.

Section 6. Uniform rules of procedure must be followed by said Gas Inspector in making the tests hereinabove set out, so that all wells tested by him under this Act shall be upon the same basis and under like conditions, to the end that all wells shall show accurately their rock pressure and volume as closed in at the time said tests are made, and shall be tested under similar conditions.

Section 7. In addition to the annual test provided for in Section 1, it shall be the duty of the Gas Inspector, within ten days after the gas from any well is being used or marketed, to make a test of said well as provided for in Section 2, and to make out and file his report of said test with the County Clerk of the county in which said well is located, as provided in said Section 2.

Section 8. When the gas from any well is being used, the flow of production thereof shall be restrained to twenty per cent. of the potential capacity of said well; that is to say, in any day of twenty-four hours, the well shall not be permitted to flow or produce more than twenty per cent. of the open flow capacity of said well, as shown by the last test of said well made by the Gas Inspector.

Provided that whenever the rock pressure of any well, when tested as provided in Section 2, is reduced to one hundred pounds, by putting gas into the pipe line under its own volition or pressure, the provisions of this section shall not apply.

Section 9. All gas produced from gas wells drilled in this State, when sold or used from said well, shall be accurately metered through proper devices, in order to determine the amount of gas taken from said well, which said meters shall be read at least once in every forty-eight hours, for the purpose of determining the amount of gas taken from each well, and such meter readings shall be subject to the examination of the Gas Inspector or any other person interested, for the purpose of determining whether or not the amount of gas being taken from said well is in excess of twenty per cent of the daily open flow of the well as shown by the last test made of said well by the Gas Inspector, provided that when the rock pressure of any well falls below one hundred, this Section shall not apply.

Section 10. All oil or gas sands, even though unproductive of oil or gas in the well being drilled, if known to produce oil or gas in any field, shall be protected by mudding off such known oil or gas sand by the use of mud-laden fluid, or any other effective method, in the discretion of the Gas Inspector.

Section 11. Whenever a packer or tubing used to shut in the gas in any well does not effectively shut off the oil, gas or water in the strata in which they occurred, said well shall be filled outside of the tubing from the packer to the next producing sand with mud-laden fluid of a maximum density of at least twenty-five per cent and the well shall be equipped with what is commonly known as a Braden Head or any other device that will prevent the escape of gas provided that if the next producing sand is not profitable, then it may be filled as above provided to the top, at the discretion of the Gas Inspector.

Section 12. Before any person, corporation or contractor shall commence to drill a well for gas or oil, a separate slush-pit or slump-hole shall be constructed by the owner, operator or contractor, for the reception of all pumpings or sand-balings taken from the well, in order to have the same on hand for the purpose of making mud-laden fluid to be used as provided in Sections 10 and 11.

Section 13. Any person, firm or corporation violating any of the provisions of Sections 8, 9, 10 or 11 of this Act shall be subject to a penalty of not less than One Hundred Dollars nor more than One Thousand Dollars for the first conviction, for violating the provisions of said sections, and for the second conviction, to a penalty of not less than Two Hundred Dollars, nor more than One Thousand Dollars, and for the third conviction, to a penalty of not less than Five Hundred Dollars or imprisonment in the County Jail for not less than thirty days, or both such penalty and imprisonment.

The penalties provided for herein, to be recovered in an action therefor, brought by the Prosecuting Attorney in the name of the State, together with a reasonable attorney's fee for the Prosecuting Attorney to be fixed by the Court, and recovered in the same manner and in the same action.

The proceeds of penalties collected shall be turned in to the General Road fund of the county wherein occurred, to be used on the roads, bridges and highways of said County, in the discretion of the County Court, and the attorney's fee shall be paid over to such prosecuting attorney.

Section 14. This Act being necessary for the immediate preservation of the public peace, health and safety, shall take effect and be in force and effect from and after its passage.

Approved: February 18, 1921.

CALIFORNIA LAWS

California laws relating to the protection of natural resources of petroleum and natural gas flow:

AN ACT Establishing and creating a department of the State mining bureau for the protection of the natural resources of petroleum and gas from waste and destruction through improper operations in production; providing for the appointment of a State oil and gas supervisor, prescribing his duties and power, fixing his compensation; providing for the appointment of deputies and employees, providing for their duties and compensation; providing for the inspection of petroleum and gas wells; requiring all persons operating petroleum and gas wells to make certain reports; providing procedure for arbitration of department rulings; creating a fund for the purposes of the act; providing for assessment of charges to be paid by operators and providing for the collection thereof; and making an appropriation for the purposes of this act.

[Approved June 10, 1915. Amended 1917. Chapter 759.]

The people of the State of California do enact as follows:

Establishment of Department—Appointment of Supervisor.

Section 1. A separate department of the State mining bureau is hereby established and created to be known as the department of petroleum and gas. Such department shall be under the general jurisdiction of the State mineralogist. He shall appoint a supervisor who shall be a competent engineer or geologist, experienced in the development and production of petroleum, and who shall be designated the "State oil and gas supervisor," and whose term of office shall be four years from and after the date of his appointment.

Duties of Supervisor.

Sec. 3. It shall be the duty of the State oil and gas supervisor so to supervise the drilling, operation, and maintenance and abandonment of petroleum or gas wells in the State of California as to prevent, as far as possible, damage to underground petroleum and gas deposits from infiltrating water and other causes and loss of petroleum and natural gas.

Orders by Supervisor—Agents of Operators.

Sec. 8. It shall be the duty of the supervisor to order such test or remedial work as in his judgment are necessary to protect the petroleum and gas deposits from damage by underground water, to the best interests of the neighboring property owners and the public at large.

The order shall be in written form, signed by the supervisor, and shall be served upon the owner of the well, or the local agent appointed by such owner, either personally or by mailing a copy of said order to the post-office address given at the time the local agent is designated, or if no such local agent has been designated, by mailing a copy of said order to the last known post-office address of said owner, or if the owner be unknown by posting a copy of said order in a conspicuous place upon the property, and publishing the same in some newspaper of general circulation throughout the county in which said well is located, once a week for two successive weeks.

Said order shall specify the condition sought to be remedied and the work necessary to protect such deposits from damage from underground waters. For this purpose each operator or owner shall designate an agent, giving his post-office address, who resides within the county where the well or wells are located, upon whom all orders and notices provided for in this act may be served.

Rejection of Supervisor's Orders, and Appeal.

Sec. 9. The well owner or his local agent may within ten days from the date of service of any order from the supervisor, file with the supervisor or his deputy in the district where the property is located, a statement that the supervisor's order is not acceptable and that appeal from said order is taken to the board of commissioners. Such appeal shall operate as a stay of any order issued under or pursuant to the provisions of this act.

Complaint, Investigation, and Order.

Sec. 11. Upon receipt by the supervisor or deputy supervisor of a written complaint specifically setting forth the condition complained against, signed by a person, firm, corporation, or association owning land or operating wells within a radius of 1 mile of any well or group of wells complained against, or upon the written complaint specifically setting forth the condition complained against, signed by any one of the board of commissioners for the district in which said well or group of wells complained against is situated, the supervisor must make an investigation of said well or wells and render a written report, stating the work required to repair the damage complained of or stating that no work is required. A copy of said order must be delivered to the complainant, or if more than one each of said complainants, and if the supervisor order the damage repaired a copy of such order shall be delivered to each of the owners, operators, or agents having in charge the well or wells upon which the work is to be done. Said order shall contain a statement of the conditions sought to be remedied or repaired and a statement of the work required by the supervisor to repair such condition. Service of such copies shall be made by mailing to such persons at the post-office address given.

Testimony.

Sec. 12. In any proceeding before the board of commissioners as herein provided, or in any other proceeding or proceedings instituted by the supervisor for the purpose of enforcing or carrying out the provisions of this act, or for the purpose of holding an investigation to ascertain the condition of any well or wells complained of, or which in the opinion of the supervisor may reasonably be presumed to be improperly drilled, operated, maintained, or conducted, the supervisor and the chairman of the board of commissioners shall have the power to administer oaths and may apply to a judge of the superior court of the State of California in and for the county in which said proceedings or investigation is pending for a subpœna for witnesses to attend at said proceeding or investigation. Upon said application of said supervisor or said chairman of said board of commissioners said judge of said superior court must issue a subpœna directing said witness to attend said proceeding or investigation: Provided, however, That no person shall be required to attend such proceeding, either with or without such books, papers, documents, or accounts unless residing within the same county or within thirty miles of the place of attendance. But the supervisor or the chairman of the board of commissioners may in such case cause the deposition of witnesses residing within or without the State to be taken in the manner prescribed by law for like deposition in civil actions in superior courts of this State, and to that end may, upon application to a judge of the superior court of the county within which said proceeding or investigation is pending, obtain a subpœna compelling the attendance of witnesses and the production of books, papers, and documents at such places as he may designate within the limits hereinbefore prescribed. Witnesses shall be entitled to receive the fees and mileage fixed by law in civil causes payable from the fund hereinafter created. In case of failure or neglect on the part of any person to comply with any order of the supervisor as hereinbefore provided, or any subpœna, or upon the refusal of any witness to testify to any matter regarding which he may lawfully be interrogated, or upon refusal or neglect to appear and attend at any proceeding or hearing on the day specified, after having received a written notice of not less than ten days prior to such proceeding or hearing, or upon his failure, refusal, or neglect to produce books, papers, or documents as demanded in said order or subpœna upon such day, such failure, refusal, or neglect shall constitute a misdemeanor, and each day's further failure, refusal, or neglect shall be and be deemed to be a separate and distinct offense, and it is hereby made the duty of the district attorney of the county in which said proceeding, hearing, or investigation is to be held, to prosecute all persons guilty of violating this section by continuous prosecution until such person appears or attends or produces such books, papers, or documents or complies with said subpœna or order of the supervisor or chairman of the board of commissioners.

Final Decision, and Order by Commissioners.

Sec. 13. Within ten days after hearing the evidence the board of commissioners must make a written decision with respect to the order appealed from, and in case the same is affirmed or modified, shall retain jurisdiction thereof until such time as the work ordered to be done by such order shall be finally completed. This written decision shall be served upon the owner or his agent and shall supersede the previous order of the supervisor. In case no written decision be made by said board of commissioners within thirty days after the date of notice by the supervisor as provided in section ten hereof the order of the supervisor shall be effective and subject only to review by writ of certiorari from the superior court as provided in section fourteen hereof.

Repair of Wells by Supervisor—Review by Superior Court.

Sec. 14. On or before thirty days after the date of serving an order of the supervisor, provided for in section eight hereof, or in case of appeal to the board of commissioners on or before thirty days after date of serving the decision of the board, as provided in sections twelve and thirteen hereof, or in the event review be taken of the order of the board of commissioners within ten days after affirmance of such order, the owner shall commence in good faith the work ordered and continue until completion. If the work has not been so commenced and continued to completion, the supervisor shall appoint agents as he deems necessary who shall enter the premises and perform the work. Accurate account of such expenditures shall be kept and the amount paid from the fund hereinafter created upon the warrant of the State controller. Any amount so expended shall constitute a lien against the property upon which the work is done. The decision of the board of commissioners in such case may be reviewed by writ of certiorari from the superior court of the county in which the district is situated if taken within ten days after the service of the order upon said owner, operator, or agent of said owner or operator as herein provided, or within ten days after decision by the board of commissioners upon petitions by the supervisor. Such writ shall be made returnable not later than ten days after the issuance thereof and shall direct the district board of oil and gas commissioners to certify their record in the cause to such court. On the return day the cause shall be heard by the court unless for good cause the same be continued, but no continuance shall be permitted for a longer period than thirty days. No new or additional evidence shall be introduced in the court before the cause shall be heard upon the record of the district board of oil and gas commissioners. The review shall not be extended further than to determine whether or not

1. The commission acted without or in excess of its jurisdiction.
2. The order, decision, or award was procured by fraud.
3. The order, decision, rule, or regulation is unreasonable.
4. The order, decision, regulation, or award is clearly unsupported by the evidence.

If no review be taken within ten days, or if taken in case the decision of the board is affirmed, the lien upon the property shall be enforced in the same manner as the other liens on real property are enforced, and shall first be enforced against the owner of the well, against the operator and against the personal property and fixtures used in the construction or operation thereof, and then if there be any deficiency against the land upon which the work is done, upon the request of the supervisor, the State controller must in the manner provided in section forty-four of this act, bring an action for the enforcement of said lien.

Casing—Water Shut-off.

Sec. 15. It shall be the duty of the owner of any well now drilled, or that may be drilled in the State of California, on lands producing or reasonably presumed to contain petroleum or gas, to properly case such well or wells with metal casing, in accordance with methods approved by the supervisor, and to use every effort and endeavor in accordance with the most approved methods to effectually shut off all water overlying or underlying the oil or gas-bearing strata, and to effectually prevent any water from penetrating such oil or gas-bearing strata.

Whenever it appears to the supervisor that any water is penetrating oil or gas-bearing strata, he may order a test of water shut-off and designate a day upon which the same shall be held. Said order shall be in written form and served upon the owner of said well at least ten days prior to the day designated in said order as the day upon which said shut-off test shall be held. Upon the receipt of such order it shall be the duty of the owner to hold said test in the manner and at the time prescribed in said order.

Abandonment of Well.

Sec. 16. It shall be the duty of the owner of any well referred to in this act, before abandoning the same, or before removing the rig, derrick, or other operating structure therefrom, or removing any portion of the casing therefrom, to use every effort and endeavor in accordance with methods approved by the supervisor, to shut off and exclude all water from entering oil-bearing strata encountered in the well. Before any well is abandoned the owner shall give written notice to the supervisor, or his local deputy, of his intention to abandon such well and of his intention to remove the derrick or any portion of the casing from such well and the date upon which such work of abandonment or removal shall begin. The notice shall be given to the supervisor, or his local deputy, at least five days before such proposed abandonment or removal. The owner shall furnish the supervisor, or his deputy, with such information as he may request showing the condition of the well and proposed method of abandonment or removal. The supervisor, or his deputy, shall, before the proposed date of abandonment or removal, furnish the owner with a written order of approval of his proposal or a written order stating what work will be necessary before approval, to abandon or remove will be given. If the supervisor shall fail within the specified time to give the owner a written order such failure shall be considered as an approval of the owner's proposal to abandon the well, or to remove the rig or casing therefrom.

Commencement of Drilling.

Sec. 17. The owner or operator of any well referred to in this act shall, before commencing the work of drilling an oil or gas well, file with the supervisor, or his local deputy, a written notice of intention to commence drilling. Such notice shall also contain the following information: (1) Statement of location and elevation above sea level of the floor of the proposed derrick and drill rig; (2) the number or other designation by which such well shall be known, which number or designation shall not be changed after filing the notice provided for in this section, without the written consent of the supervisor being obtained therefor; (3) the owner's or operator's estimate of the depth of the point at which water will be shut off, together with the method by which such shut-off is intended to be made and the size and weight of casing to be used; (4) the owner's or operator's estimate of the depth at which oil or gas-producing sand or formation will be encountered.

After the completion of any well the provisions of this section shall also apply, as far as may be, to the deepening or redrilling of any well, or any operation involving the plugging of any well or any operations permanently altering in any manner the casing of any well: And provided further, That the number or designation by which any well heretofore drilled has been known, shall not be changed without first obtaining a written consent of the supervisor.

Log of Well—Prospect Well.

Sec. 18. It shall be the duty of the owner or operator of any well referred to in this act to keep a careful and accurate log of the drilling of such well, such log to show the character and depth of the formation passed through or encountered in the drilling of such well, and particularly to show the location and depth of the water-bearing strata, together with the character of the water encountered from time to time (so far as ascertained) and to show at what point such water was shut off, if at all, and if not, to so state in such log, and show completely the amounts, kinds, and size of casing used, and show the depth at which oil-bearing strata are encountered, the depth and character of same, and whether all water overlying and underlying such oil-bearing strata was successfully and permanently shut off so as to prevent the percolation or penetration into such oil-bearing strata; such log shall be kept in the local office of the owner or operator, and together with the tour reports of said owner or operator, shall be subject, during business hours, to the inspection of the supervisor, or any of his deputies, or any of the commissioners of the district, except in the case of a prospect well as hereinafter defined. Upon the completion of any well, or upon the suspension of operations upon any well, for a period of six months if it be a prospect well, or for thirty days, if it be in proven territory, a copy of said log in duplicate, and in such form as the supervisor may direct, shall be filed within ten days after such completion, or after the expiration of said thirty-day period, with the field supervisor, and a like copy shall be filed upon the completion of any additional work in the deepening of any such well.

The State oil and gas supervisor shall determine and designate what wells are prospect wells within the meaning of this act and no reports shall be required from such prospect wells until six months after the completion thereof.

The owner or operator of any well drilled previous to the enactment of this act shall furnish to the supervisor or his deputy a complete and correct log in duplicate and in such a form as the supervisor may direct, or his deputy, of such well, so far as may be possible, together with a statement of the present condition of said well.

Test of Shut-off.

Sec. 19. It shall be the duty of the owner or operator of any well referred to in this act to notify the deputy supervisor of the time at which the owner or operator shall test the shut-off of water in any such well. Such notice shall be given at least five days before such test. The deputy supervisor or an inspector designated by the supervisor shall be present at such test and shall render a report in writing of the result thereof to the supervisor, a duplicate of which shall be delivered to the owner. If any test shall be unsatisfactory to the supervisor he shall so notify the owner or operator in said report and shall, within five days after the completion of such test, order additional tests of such work as he deems necessary to properly shut off the water in such well and in such order shall designate a day upon which the owner or operator shall again test the shut-off of water in any such well, which day may, upon the application of the owner, be changed from time to time in the discretion of the deputy supervisor.

Sections 20 to 53 inclusive of the California laws relating to oil and gas wells cover the production reports required by the State, charges and assessments on production, annual reports of producing well owners, penalties, etc., with reference to the production of oil and gas and which are omitted here.

TO PREVENT WASTING OF NATURAL GAS

AN ACT Prohibiting the unnecessary wasting of natural gas into the atmosphere; providing for the capping or otherwise closing of wells from which natural gas flows; and providing penalties for violating the provisions of this act.

[Approved March 25, 1911]

The people of the State of California, represented in senate and assembly, do enact as follows:

Section 1. All persons, firms, corporations, and associations are hereby prohibited from willfully permitting any natural gas wastefully to escape into the atmosphere.

Sec. 2. All persons, firms, corporations, or associations digging, drilling, excavating, constructing, or owning or controlling any well from which natural gas flows shall upon the abandonment of such well, cap or otherwise close the mouth of or entrance to the same in such a manner as to prevent the unnecessary or wasteful escape into the atmosphere of such natural gas. And no person, firm, corporation, or association owning or controlling land in which such well or wells are situated shall willfully permit natural gas flowing from such well or wells wastefully or unnecessarily to escape into the atmosphere.

Sec. 3. Any person, firm, corporation, or association who shall willfully violate any of the provisions of this act shall be deemed guilty of a misdemeanor, and upon conviction thereof shall be punished by a fine of not more than $1,000 or by imprisonment in the county jail for not more than one year, or by both such fine and imprisonment.

Sec. 4. For the purposes of this act each day during which natural gas shall be willfully allowed wastefully or unecessarily to escape into the atmosphere shall be deemed a separate and distinct violation of this act.

Sec. 5. All acts or parts of acts in conflict herewith are hereby repealed.

Sec. 6. This act shall take effect immediately.

LOUISIANA LAWS

RULES AND REGULATIONS

Rules, Regulations and Requirements Governing the Conservation of Natural Gas and Crude Oil or Petroleum

Rule 1.—Waste Prohibited.—Natural gas and crude oil or petroleum shall not be produced in the State of Louisiana in such manner and under such conditions as to constitute waste.

Rule 2.—Waste Defined—Protection.—The term "waste" as used herein, in addition to its ordinary meaning, shall include economic waste, underground waste, surface waste, and waste incident to the production of crude oil or petroleum in excess of transportation, storage, or marketing facilities.

Rule 3.—Gas to Be Confined—Strata to Be Protected.—Whenever natural gas in commercial quantities, or a gas bearing stratum known to contain natural gas in such quantities is encountered in any well drilled for oil or gas in this State, such gas shall be confined to its original stratum until such time as the same can be produced and utilized without waste, and all such strata shall be adequately protected from infiltrating waters.

Rule 4.—Approved Methods of Preventing Waste to Be Used.—All operators, contractors, or drillers, pipe line companies, gas distributing companies, or individuals, drilling for or producing crude oil or natural gas, or piping oil or gas for any purpose, shall use every possible precaution in accordance with the most approved methods, to stop and prevent waste of oil or gas, or both, in drilling and producing operations, storage, or piping or distributing, and shall not wastefully utilize oil or gas, or allow same to leak or escape from natural reservoirs, wells, tanks, containers or pipes.

Rule 5.—Notice of Intention to Drill, Deepen, Pull, Plug, or Abandon.—Written notice to drill, deepen, pull or plug a well or wells shall be given to the Department of Conservation, made out on such blank or forms as provided or designated by the Department of Conservation for that purpose.

Rule 6.—A Complete and Accurate Log of Each Well Drilled or Deepened Required.—Oil and gas operators in Louisiana shall keep an accurate and complete log of each and every well they drill or deepen, and furnish the Department of Conservation with two typewritten copies of same, not later than ten days after the completion of any and all such work.

Rule 7.—Plugging Dry and Abandoned Wells.—All dry or abandoned wells must be plugged by confining all oil, gas or water in the strata in which they occur by the use of mud-laden fluid, and in addition to mud-laden fluid, cement and plugs may be used. These wells must first be thoroughly cleaned out to the bottom of the hole and before the casing is removed from the hole, the hole must be filled from the bottom to the top with mud-laden fluid of maximum density and which shall weigh at least 25 per cent. more than an equal volume of water, unless the Department of Conservation directs that some other method shall be used.

Rule 8.—Proper Anchorage to Be Laid.—Before any well is begun in any field where it is not known that high pressure does not exist, proper anchorage shall be laid, so that the control casing-head may be used on the two outer strings of casing at all times, and this type of casing-head shall be kept in constant use unless it is known from previous experience and operations on wells adjacent to the one being drilled that high pressure does not exist or will not be encountered therein.

Rule 9.—Equipment for Conserving Natural Gas to Be Provided Before "Drilling in."—In all proven or well defined gas fields, or where it can be reasonably expected that gas in commercial quantities will be encountered, adequate preparation shall be made for the conservation of gas before "drilling in" any well; and the gas sands shall not be penetrated until equipment (including mud pumps, lubricators, etc.) for "mudding in" all gas strata or sands, shall have been provided.

Rule 10.—Separate Slush Pit to Be Provided.—Before commencing to drill a well, a separate slush pit or sump hole shall be constructed by the owner, operator, or contractor, for the reception of all pumpings from clay or soft shale formations in order to have the same on hand for the making of mud-laden fluid.

Rule 11.—Wells Not to Be Permitted to Produce Oil and Gas from Different Strata.—No well shall be permitted to produce both oil and gas from different strata unless it be in such manner as to prevent waste of any character to either product. Therefore, if a stratum should be encountered bearing gas and the owner, operator, or contractor should go deeper in search for either gas or oil bearing sands, the stratum first penetrated and likewise each and every sand in turn, shall be closed separately, and if it is not wanted for immediate use, it shall be securely shut in so as to prevent waste, either open or underground.

Rule 12.——Strata to Be Sealed Off.—No well shall be drilled through or below any oil, gas or water stratum without sealing off such stratum or the contents thereof, after passing through the sand, either by the mud-laden fluid process or by casing and packers, regardless of volume or thickness of sand.

Rule 13.——Mud-Laden Fluid to Be Applied.—No gas sand or stratum upon being penetrated shall be drilled or left open, except at the discretion of the Department of Conservation without the application of mud-laden fluid to prevent the escape of gas while further drilling in or through such sand or stratum.

Rule 14.—Fresh Water to Be Protected.—Fresh water, whether above or below the surface, shall be protected from pollution, whether in drilling or plugging.

Rule 15.—Gas to Be Separated from Oil.—No gas found in the upper part of a level of sand which can be separated from the oil in the lower part of same sand or in a lower or different sand shall be allowed or used to flow oil to the surface and all gas, so far as it is possible to do so, shall be separated from the oil and securely protected.

Rule 16.—Separating Device to Be Installed upon Order of the Department of Conservation.—Where oil and gas are found in the same stratum and it is impossible to separate the one from the other, the operator shall, upon being so ordered by the Department of Conservation, install a separating device of approved type, which shall be kept in place and used as long as necessity therefor exists, and after being installed such device shall not be removed, nor the use thereof discontinued without the consent of the Department of Conservation.

Rule 17.—Notification of Fires and Breaks or Leaks in Lines.—All drillers, operators, pipe line companies and individuals operating oil and gas wells or pipe lines shall immediately notify the Department of Conservation by telegraph or telephone and by letter of all fires which occur at oil and gas wells or oil tanks owned, operated or controlled by them or on their property, and shall immediately report all tanks struck by lightning and any other fires which destroy crude oil or natural gas, and shall immediately report in the manner heretofore described any breaks or leaks in the tanks or pipe lines from which oil and gas are escaping. In all reports of fires, breaks, or leaks in pipes, or other accidents of this nature, the location of the well, tank or line break shall be given, showing location by quarter, section, township and range.

Rule 18.—Drilling Records to Be Kept at Well During the Process of Drilling.—All operators, contractors, or drillers shall keep at each well accurate records of the drilling, redrilling, deepening of all wells, showing all formations drilling through, casing used and other information in connection with drilling and operation of the property and any and all of its information shall be furnished to the Department of Conservation upon request, or to any Conservation Agent of the Department.

Rule 19.—Conservation Agents to Have Access to All Wells.—Conservation agents of the Department shall have access to all wells at any and all times, and all companies, contractors, or drillers shall permit any Conservation Agent of the Department of Conservation to come upon any lease or property operated or controlled by them, and to inspect any and all wells, etc., provided, that information so obtained by conservation agents shall be considered official information and shall be reported only to the Department of Conservation.

Rule 20.—Notice to Contractors, Drillers and Others to Observe Rules.—All contractors and drillers carrying on business or doing work in the oil or gas fields of the State, as well as lease holders, land owners, and operators generally, shall take notice of any, and are hereby directed to observe and apply the foregoing rules and regulations; and all contractors, drillers, land owners, and operators will be held responsible for infraction of said rules and regulations.

Rule 21.—Three Strings of Casing to Be Used in Ouachita, Morehouse, Richland and Union Parishes.—In drilling any and all wells in the above mentioned parishes it shall be unlawful for any operator or operators to use less than three strings of casing made up of 10-inch, 8-inch and 6-inch. The first two strings to exclude the upper waters and the 6-inch cemented as near the gas or oil sands as possible. The casing so used shall be cemented and the cement brought up on the hole outside the casing so as to effectually shut off all water. The casing must be properly set in suitable formation and cemented with a liberal quantity of cement. Should it become necessary at any time to use different size casing, other than the sizes mentioned here, a special permit must be secured from the Department of Conservation to do so. Any and all such requests must be accompanied by a full explanation setting forth the reasons, etc., for it. Any person, firm, association or corporation who drills a well in the above mentioned parishes for either gas or oil or for testing or relief purposes of any description shall adhere strictly to the above rule in the prosecution of any and all such work.

Rule 22.—Protection of the Shallow Oil Strata in Claiborne Parish.—In setting 6-inch casing, two sacks of cement to sack of sand must be used as follows:

Size of hole.	Outside diameter of pipe.	Sacks of cement to be used.	Sacks of sand to be used.
7⅞-inch	6.625	8.52	4.26
8½-inch	6.625	12.15	6.25
9⅞-inch	6.625	23.54	11.77

The above table is figured for a depth of 100 feet, and on the assumption that hole is drilled true to dimensions. Deviations from the above, caused by unevenness of hole or falling dirt, to be left to the discretion of the driller. Any person, firm, association or corporation desirous of deepening any shallow well, or wells that are now in or hereafter brought in, shall adhere strictly to the above rule in the prosecution of any and all such work.

Rule 23.—Only 25 Per Cent. of Capacity of Gas Wells to Be Taken.—All operators, companies, associations, corporations, pipe line and transportation companies are hereby prohibited from taking more than 25 per cent. of the daily natural flow of any and all gas wells within the limits of the State of Louisiana.

Rule 24.—Flambeau Lights Unlawful.—It shall be unlawful for any operator, contractor, driller, company, association, or corporation to use natural gas for illuminating purposes in what is known as Flambeau Lights, but nothing herein shall prohibit the use of "Jumbo" burners or other burners in glass globes consuming no more gas than such "Jumbo" burners.

Rule 25.—Gas to Be Metered.—All gas produced from nature's deposits in the State of Louisiana shall be measured through properly constructed and accurately adjusted meter or meters. Each producing well must be on a separate meter at all times and accessible to any Conservation Agent at any time.

Rule 26.—Burning Gas During the Day.—No gas shall be used or burned for illuminating purposes between the hours of eight o'clock A. M. and five o'clock P. M. unless the same is regulated by meter.

Rule 27.—Disposition of Waste from Wells.—No inflammable product from any oil or gas well shall be permitted to run into any tank, pool, or stream used for watering live stock, and all waste of oil and refuse from tanks or wells must be drained into proper receptacles at a safe distance from the tanks, wells, or buildings, and be immediately burned or transported from the premises, and in no case shall it be permitted to flow over the land. Salt water shall not be allowed to flow over the surface of the land.

Rule 28.—Reports from Oil and Gas Well Operators and Pipe Line Companies Required.—The Department of Conservation requires monthly reports on forms or blanks furnished by or designated by the Department of Conservation to be filled out completely, showing their completed oil and gas wells and their oil and gas production by Parishes and the pipe line runs by Parishes.

Rule 29.—It shall hereafter be unlawful for any person, firm, corporation, or association to commence the erection in the State of Louisiana of any carbon plant or plants for the manufacture of carbon black from natural gas or to make any extensions or enlargements of such carbon plant or plants hereafter begun, or enlargements of existing plants wherein the erection of such enlargements has not been commenced prior to the promulgation hereof, without having first obtained from the Department of Conservation of the State of Louisiana a special permit, officially signed.

All permit applications as referred to here must be accompanied by a complete and accurate copy of the plans and specifications of the proposed work, having the size of the plants, number of houses to each unit of each plant, etc., together with the plant location, name and postoffice address of the company or owner of such plant or plants.

All special permits so issued by the Department of Conservation automatically expire 12 months from date of such permit or permits, and the renewals thereof shall be left to the discretion of the Department of Conservation as to whether or not the available supply of natural gas, at the time such application for permits are received by the Department of Conservation, is sufficient to justify further drain on the natural gas resources in the territory or district from which the gas is taken.

Rule 30.—Extraction of Gasoline from Natural Gas Used by Carbon Plant.—Before any carbon plant or manufacturer can utilize any natural gas in Louisiana, known to contain gasoline (to make the extraction therefrom beneficial and profitable), for making or manufacturing carbon, the gasoline therein must be extracted and saved.

Rule 31.—Taking Control of Abandoned and Other Wells.—Any oil or gas well, or wells, or any abandoned well, or wells, in the State of Louisiana that is not properly drilled, capped, or plugged according to law, or any oil or gas well, or wells, wasting oil or gas, or both, in violation of the state laws or the rules and regulations of the Department of Conservation, the said Department of Conservation will exercise its rights, privileges, and power under Act No. 250 of 1920 in such cases, and take charge and control of any and all such well, or wells, with the view and purpose of correcting any defect or waste therefrom, etc., that might be in violation of the state's laws or the rules and regulations of the Department of Conservation. This act gives a lien and privilege in favor of the Department of Conservation, State of Louisiana, for all reasonable expenses and costs incurred by it or under its authority, in the closing, capping, plugging, or correcting the conditions of each and every such well, or wells, and extending this lien and privilege to all leases, property, equipment and mineral products therefrom that are owned by any such company, firm, individual, corporation, or association.

Rule 32.—Conservation Agents to Assist in Enforcement of Rules.—All conservation agents of the Department shall assist in the enforcement of these rules and shall immediately notify the Department of Conservation upon observance of any infraction thereof.

Rule 33.—Additional Rules Will Be Prescribed from Time to Time.—The Department of Conservation will from time to time prescribe additional rules, regulations, and requirements for the conservation of crude oil, or petroleum, and natural gas.

Rule 34.—Notice of Intention to Plug.—Before plugging dry or abandoned well or wells, advance written notice (including a complete description as to the location of any such well or wells, and the date and time of day (near as possible), as to when the work will be done), shall be given to the Department of Conservation in order that a representative of the Department of Conservation might be present to witness the plugging or abandonment of any such well or wells in the State of Louisiana.

Rule 35.—Any rule or regulation or any part of any rule, or regulation in conflict herewith is hereby repealed.

This order adopted October 1, 1920, and to be in full force and effect thirty (30) days thereafter.

Extract from Act 250 of 1920:

Section 6. Be it further enacted, etc., That the Department of Conservation shall have the right to appear in court, through its chief officer or other designated agent, or subordinate officer, duly designated by the chief officer to enforce rules and regulations and any provision of this act by civil or criminal process before any court in the State of Louisiana of competent jurisdiction.

Any corporation, partnership, association or individual who shall wilfully violate any provisions or any rule or regulation adopted by the Department of Conservation, pursuant hereto, upon conviction thereof by any court of competent jurisdiction shall be deemed guilty of a misdemeanor and may be fined not less than Fifty ($50.00) Dollars nor more than Fifteen Hundred ($1,500.00) Dollars or suffer imprisonment for not more than fifteen (15) days in the Parish jail, or both, at the discretion of the court.

OHIO LAWS

Section 973. Any person, firm or corporation causing to be drilled any well for oil or gas, or elevator well, or any test well within the limits of any coal producing county of this state, must give notice in writing of such fact to the chief inspector of mines, stating the location of the land upon which such well is to be drilled.

It shall be the duty of any such person, firm or corporation to make or cause to be made an accurate map on a scale of one inch to 400 feet, showing on said map the location and number of wells, the property lines of the property upon which located in the township, section and quarter section in which the same is being drilled, together with a measurement from the section line, and also from the quarter section line, together with the sworn statement of the person, firm or corporation making said map, the same to be kept on file in the office of the state mining department and shall be open for inspection by the public at all reasonable hours. The original map shall be retained by the owner or surveyor and one blue print filed with the chief inspector of mines and one with the recorder of the county in which such well is located within sixty days after the passage and approval of this act, or after commencing to drill any oil or gas well and if drilling is still continued on the property already surveyed, a complete blue print shall be made and filed at the end of each year.

No oil or gas well shall be drilled nearer than three hundred feet to any opening to a mine used as a means of ingress or egress for the persons employed therein, or nearer than one hundred feet to any building or inflammable structure connected therewith and actually used as a part of the operating equipment of said mine.

In the event that a well being drilled for oil or gas penetrates the excavations of any mine, it must be cased with casing of approximately the same diameter as the diameter of the hole, the hole to be drilled thirty feet or to solid slate or rock and not less than ten feet below the floor of such mine, and the casing shall be placed in the following manner: one string of casing shall be placed at a point above the roof of said mine so as to shut off all of the surface water and then the hole drilled through said mine and another string of casing put in and the bottom of the second string of casing, or the one passing through said mine shall not be nearer than ten feet or more than thirty feet from the floor of the mine where it passes through the same.

When any well which has been drilled for oil or gas is to be abandoned and has passed through the excavations of any coal mine from which the mineral coal has not all been removed the person, firm or corporation owning said well shall leave in said well the casing passing through said mine from a point not less than ten feet, nor more than thirty feet below the floor of said mine and extending above the roof of said mine five feet and a seasoned wooden plug, or iron ball shall be driven to a point forty feet below the floor of the mine and shall then fill the hole and the casing left in with the cement or a seasoned wooden plug or iron ball shall be driven on top of the same, and the hole shall then be filled for a distance of not less than twenty feet with cement. If any oil or gas well has passed through a workable vein or seam of coal, it shall when it is abandoned be plugged in the following manner: a seasoned wooden plug or iron ball shall be driven to a point 30 feet below the lowest workable seam of coal and the hole filled with cement to a point 20 feet above the first seam of coal and another wooden plug or iron ball driven and the hole filled for a distance of twenty feet with cement.

The property owner or owners shall report to the chief inspector of mines of the commencing to drill of any well or wells for oil or gas on his or their property and shall report at the end of each year thereafter, if drilling is continued, the number of wells drilled on his or their property, the date drilled and by whom drilled.

When any oil or gas well is to be abandoned, the person, firm or corporation having drilled or operated such well shall notify the chief inspector of mines at least ten days in advance so that he may direct one of his district inspectors to be present at the time of abandonment.

Section 6311. The owner or operator of a well for the production of petroleum oil, natural gas or mineral water, before drilling into the oil and gas bearing rock shall incase such well with good and sufficient wrought iron casing, so that the surface or fresh water from the lower part of such well will not penetrate the oil or gas bearing rock. If a well is drilled through the first oil or gas bearing rock into a lower one, it must be cased so as to exclude all fresh water above the last oil or gas bearing rock penetrated.

Section 6312. The owner or operator of a well, constructed for any of the purposes named in the next preceding section, intending to abandon or cease operating it, and before drawing the casing therefrom, shall securely fill such well with rock sediment, or mortar composed of two parts sand and one part cement, to the depth of two hundred feet above the top of the first oil or gas bearing rock, so as to prevent the surface or fresh water from penetrating to the oil or gas bearing rock, and the gas and oil from escaping therefrom.

Section 6313. If such owner or operator fails to comply, or inefficiently complies with the next preceding section, the owner of the land upon which such well is situated shall forthwith comply therewith. If all the persons heretofore named fail to so fill, or inefficiently so fill such well, any person, after written demand therefor to any of such persons, may enter, take possession of such well and fully comply with such section.

Section 6314. The reasonable cost and expense of so filling such well shall forthwith be paid by such owner or operator, and on his default, by the owner of the land. The amount of such cost and expense shall be a lien upon the fixtures, machinery and leasehold interest of the owner and operator and upon the interest of the land owner in the land upon which the well is situated, and may be recovered and enforced against the owner or operator and the land owner in the order named.

Section 6315. A person, co-partnership or corporation, in possession as owner, lessee, agent or manager of a well producing natural gas, in order to prevent the gas wasting by escape, shall shut in and confine the gas therein, within ten days after penetrating the gas bearing rock, until such time as it is utilized for light, fuel or power purposes.

Section 6316. The provisions of the next preceding section shall not apply to an oil well.

Section 6317. A person, co-partnership or corporation shall not use natural gas for illuminating purposes on flambeau lights; but "jumbo" burners or other burners consuming no more gas than such "jumbo" burners may be so used. A person, co-partnership or corporation consuming natural gas with such burners in the open air or in or around derricks, shall turn it off not later than eight o'clock in the morning of each day such lights or burners are used, and shall not turn on or relight it between the hours of eight o'clock a.m. and five o'clock P. M.

Section 6318. The next preceding section shall not prohibit the burning of flambeau lights within the derrick of a drilling well or for lighting the streets of cities and villages.

Section 6319. A person, co-partnership or corporation violating any provision of this chapter shall be liable to a penalty of one hundred dollars, to be recovered, with costs of suit, in a civil action in the name of the state in the county in which the act was committed or omitted. Such suit may be brought at the instance of a resident of this state without security or liability for costs. Such penalty shall be paid one-half into the school fund of the county in which such suit is brought and one-half to such person at whose instance such suit was brought.

OKLAHOMA LAWS

Corporation Commission of Oklahoma

Cause No. 2935. Order No. 1299.

IN RE

PROPOSED ORDER No. 159 FOR THE PROMULGATION OF ADDITIONAL AND SUPPLEMENTAL RULES FOR THE CONSERVATION OF OIL AND NATURAL GAS.

ORDER.

The Corporation Commission having held hearing and investigation pursuant to Proposed Order No. 159 and the Oil and Natural Gas Conservation Laws of the State and in accordance with the provisions thereof, having made its findings of fact, and being fully advised in the premises, it is therefore considered, ordered and adjudged that the following rules, regulations and requirements be and are hereby prescribed:

Rule 1.—Waste Prohibited.—Natural gas and crude oil or petroleum shall not be produced in the State of Oklahoma in such manner and under such conditions as to constitute waste. (Sec. 1, Ch. 197, S. L. 1915; Rule 1, Order No. 937.)

Rule 2.—Waste Defined.—The term "waste" as above used in addition to its ordinary meaning, shall include (a) escape of natural gas in commercial quantities into the open air; (b) the intentional drowning with water of a gas stratum capable of producing gas in commercial quantities; (c) underground waste; (d) the permitting of any natural gas well to wastefully burn; and (e) the wasteful utilization of such gas. (Sec. 2, Ch. 197, S. L. 1915; Rule 2, Order No. 937.)

Rule 3.—Gas to Be Confined—Strata to Be Protected.— Whenever natural gas in commercial quantities or a gas bearing stratum known to contain natural gas in such quantities is encountered in any well drilled for oil or gas in this State, such gas shall be confined to its original stratum until such time as the same can be produced and utilized without waste, and all such strata shall be adequately protected from infiltrating waters. (Sec. 3, Ch. 197, S. L. 1915; Rule 3, Order No. 937.)

Rule 4.—Commercial Quantities Defined.—Any gas stratum showing a well defined gas sand and producing gas shall be considered capable of producing gas in commercial quantities and any gas coming from such a stratum or sand shall be considered a commercial quantity, and such stratum or sand shall be protected the same as if it produced gas in excess of two million cubic feet per day of twenty-four hours. (Sec. 3, Ch. 197, S. L. 1915; Rule 4, Order No. 937.)

Rule 5.—Gas to Be Taken Ratably.—Whenever the full production from any common source of supply of natural gas in this State is in excess of the market demands, then any person, firm or corporation having the right to drill into and produce gas from any such common source of supply, may take therefrom only such proportion of the natural gas that may be marketed without waste, as the natural flow of the well or wells owned or controlled by any such person, firm or corporation bears to the total natural flow of such common source of supply having due regard to the acreage drained by each well, so as to prevent any such person, firm or corporation securing any unfair proportion of the gas therefrom; provided, that the Corporation Commission may by proper order, permit the taking of a greater amount whenever it shall deem such taking reasonable or equitable. (Sec. 4, Ch. 197, S. L. 1915; Rule No. 5, Order No. 937.)

Rule 12.—Approved Methods of Preventing Waste to Be Used.—All operators, contractors, or drillers, pipe line companies, gas distributing companies or individuals, drilling for or producing crude oil or natural gas, or piping oil or gas for any purpose, shall use every possible precaution in accordance with the most approved methods, to stop and prevent waste of oil and gas, or both, in drilling and producing operations, storage, or in piping or distributing, and shall not wastefully utilize oil or gas, or allow same to leak or escape from natural reservoirs, wells, tanks, containers, or pipes. (See also Rule 28 infra.)

Rule 13.—Notice of Intention to Drill, Deepen or Plug.—Notice shall be given to the Corporation Commission of the intention to drill, deepen or plug any well or wells and of the exact location of each and every such well. In case of drilling, notice should be given at least five days prior to the commencement of drilling operations.

Notice of intention to plug must be accompanied by a complete log of the well, on forms prescribed by the Corporation Commission.

Blanks for notification and reports can be obtained on application to the Corporation Commission or its conservation agents.

Rule 14.—Plugging Dry and Abandoned Wells.—(a) Must Be Plugged Under Supervision of Conservation Agent.

All abandoned or dry wells shall immediately be plugged under the supervision of an oil and gas conservation agent of the Corporation Commission.

(b) Manner of Plugging.

All dry or abandoned wells must be plugged by confining all oil, gas or water in the strata in which they occur by the use of mud-laden fluid, and in addition to mud-laden fluid, cement and plugs may be used.

These wells must first be thoroughly cleaned out to the bottom of the hole and before the casing is removed from the hole, the hole must be filled from the bottom to the top with mud-laden fluid of maximum density and which shall weigh at least 25 per cent. more than an equal volume of water; unless the Commission directs that some other method shall be used.

(c) Notice of Intention to Plug.

Before plugging dry and abandoned wells, notice shall be given to the Corporation Commission or its conservation agent in the field and to all available adjoining lease and property owners, and representatives of such lease and property owners, may, in addition to the oil and gas conservation agent of the Commission, be present to witness the plugging of these wells if they so desire, but plugging shall not be delayed because of failure or inability to deliver notices to adjoining lease and property owners.

Rule 15.—Log and Plugging Record to Be Filed with Commission.—The owner or operator shall, upon the completion of any well, file with the Corporation Commission a complete record or log of the same, duly signed and sworn to, upon blanks to be furnished by the Commission upon application; and upon plugging any well for any cause whatsoever, a complete record of the plugging thereof shall be made out and duly verified on blanks to be furnished by the Commission. (Rule 25, Order No. 937.)

Rule 16.—Proper Anchorage to Be Laid.—Before any well is begun in any field where it is not known that high pressure does not exist, proper anchorage shall be laid, so that the control casing-head may be used on the inner string of casing at all times, and this type of casing-head shall be kept in constant use unless it is known from previous experience and operations on wells adjacent to the one being drilled that high pressure does not exist or will not be encountered therein. (Rule 15, Order No. 937.)

Rule 17.—Equipment for Conserving Natural Gas Shall Be Provided Before "Drilling In."—In all proven or well defined gas fields, or where it can reasonably be expected that gas in commercial quantities will be encountered, adequate preparation shall be made for the conservation of gas before "drilling in" any well; and the gas sands shall not be pénetrated until equipment (including mud pumps, lubricators, etc.), for "mudding in" all gas strata, or sands, shall have been provided.

Rule 18.—Separate Slush Pit to Be Provided.—Before commencing to drill a well, a separate slush pit or sump hole shall be constructed by thé owner, operator or contractor for the reception of all pumpings from clay or soft shale formations in order to have the same on hand for the making of mud-laden fluid. (Rule 14, Order No. 937.)

Note.—In order to avoid freezing casing, operators are cautioned not to allow sand or lime to be mixed with clay or soft shale pumpings.

Rule 19.—Wells Not to Be Permitted to Produce Oil and Gas from Different Strata.—No well shall be permitted to produce both oil and gas from different strata unless it be in such manner as to prevent waste of any character to either product. Therefore, if a stratum should be encountered bearing gas and the owner, operator, or contractor should go deeper in search for other gas or oil bearing sands, the stratum first penetrated and likewise each and every sand in turn, shall be closed separately, and if it is not wanted for immediate use, it shall be securely shut in so as to prevent waste, either open or underground. (Rule 16, Order No. 937.)

Rule 20.—Strata to Be Sealed Off.—No well shall be drilled through or below any oil, gas or water stratum without sealing off such stratum or the contents thereof, after passing through the sand, either by the mud-laden fluid process or by casing and packers, regardless of volume or thickness of sand. (Rule 17, Order No. 937.)

Rule 21.—Mud-Laden Fluid to Be Applied.—No gas sand or stratum upon being penetrated shall be drilled or left open more than three days without the application of mud-laden fluid to prevent the escape of gas while further drilling in or through such sand or stratum. (Sec. 3, Ch. 197, S. L. 1915; Rule 18, Order No. 937.)

Rule 22.—Density of Mud Fluid Where Well Containing Water Is Drilled Into Oil or Gas Producing Strata.—No operator shall drill a well into an oil or gas producing sand with water from a higher formation in the hole, or with a sufficient head of water introduced into the hole to prevent gas blowing to the surface. The well shall either be allowed to blow until the sand has been drilled in or it shall be drilled in under a head of fluid consisting of not less than 25 per cent. mud; but in no case shall gas be allowed to blow for a longer period than three days. Mud fluid used for protecting oil and gas bearing sands in upper formations while oil or gas is being produced from deeper formations shall have a density of not less than 25 per cent. mud and should contain not less than 28 per cent. mud.

Rule 23.—Mud-Laden Fluid to Be Applied in Pulling or Redeeming Casing.—No outside casing from any oil or gas well in an unexhausted oil or gas field shall be pulled without first flooding the well with mud-laden fluid behind the inside string of casing, after unseating the casing, and as casing is withdrawn, well shall be kept full to top with said mud-laden fluid and same shall be left in the hole; and said mud-laden fluid shall be so applied as to effectively seal off all fresh or salt water strata, and all oil or gas strata not being utilized. (Rule 23, Order No. 937.)

Rule 24.—Mud-Laden Fluid—When to Be Applied to Completed Wells.—When necessary (or in any event when ordered by the Corporation Commission) to seal off any oil, gas or water sand, casing shall be seated in mud-laden fluid; and concerning wells already drilled, the operator shall, upon the order of the Corporation Commission, raise any string or strings of casing and re-set them in mud-laden fluid when it is thought advisable to do so in order to avoid existing underground waste, pollution or infiltration. (Rule 22, Order No. 937.)

Rule 25.—Fresh Water to Be Protected.—Fresh water, whether above or below the surface, shall be protected from pollution, whether in drilling or plugging. (Rule 14, Order No. 937.)

Rule 26.—Gas to Be Separated from Oil.—No gas found in the upper part of a level or sand which can be separated from the oil in the lower part of the same sand or in a lower or different sand shall be allowed or used to flow oil to the surface and all gas, so far as it is possible to do so, shall be separated from the oil and securely protected. (Rule 19, Order No. 937.)

Rule 27.—Separating Device to Be Installed Upon Order of Commission.—Where oil and gas are found in the same stratum and it is impossible to separate the one from the other, the operator shall, upon being so ordered by the Corporation Commission, install a separating device of approved type, which shall be kept in place and used as long as necessity therefor exists, and after being installed, such device shall not be removed nor the use thereof discontinued without the consent of the Corporation Commission. (Rule 20, Order No. 937.)

Rule 28.—Gas Wells Not to Produce from Different Sands at the Same Time Through the Same String of Casing.—No gas well shall be permitted to produce gas from different levels, sands or strata at the same time through the same string of casing (Sec. 3, Ch. 197, S. L. 1915), and when gas upon being found is not needed for immediate use, the same shall be confined in its original stratum until such time as the same can be produced and utilized without waste (Sec. 3, Ch. 197, S. L. 1915), and in confining gas to its original place, the mud-laden fluid process shall be used unless the character of the formation involved is sufficiently ascertained and understood to know that the casing and packer method with Braden-head attachment can be safely applied and competently used, and in the use of the casing, packing and Braden-head method, separate strings of casing shall be run to each sand and the application of the latter method in preference to the former shall not be made without notice to and consent of the Corporation Commission. (Rule 21, Order No. 937.)

Rule 29.—Vacuum Pumps Not to Be Installed Except upon Application to This Commission.—The future installation of vacuum pumps or other devices for the purpose of putting a vacuum on any gas or oil bearing stratum is prohibited, provided that any operator desiring to install such apparatus may, upon notice to adjacent lease owners or operators, apply to the Commission for permission; and in the matter of vacuum pumps heretofore installed, the use of same is authorized unless specifically discontinued by order of the Commission upon notice and hearing. (Rule 22, Order No. 937.)

Rule 30.—Shooting of Wells.—(a) Wells Not to Be Shot into Salt Water.

No wells shall be so shot as to let in salt water or other foreign substance injurious to the oil or gas sand.

(b) Reports to Be Made to the Corporation Commission.

Reports shall be made to the Corporation Commission on all wells shot, showing the condition of the well before and after shooting, including the size of the shot, sand or sands shot, production before and after shooting, per cent. of water in well before and after shooting.

(c) Damaged Wells to Be Abandoned.

In case irreparable injury is done to the well, or to the oil or gas sand or sands by shooting, the well shall immediately be abandoned and plugged as provided by Rule No. 14 herein.

Rule 31.—Gauge to Be Taken—Reports to Commission.—All oil and gas operators shall between the first and tenth of each calendar month take a gauge of the volume and rock pressure of all wells producing natural gas, and shall forthwith report to the Corporation Commission on gauge blanks furnished by the Commission. (Rule 26, Order No. 937.)

Rule 32.—Production to Be Restrained to 25 Per Cent. of Potential Capacity.—When the gas from any well is being used, the flow or production thereof shall be restrained to 25 per cent. of the potential capacity of the same; that is to say in any day (24 hours) the well shall not be permitted to flow or produce more than one-fourth of the potential capacity thereof ,as shown by the last monthly gauge. (Rule 29, Order No. 937.)

Rule 33.—Notification of Fires and Breaks or Leaks in Lines.—All drillers, operators, pipe line companies, and individuals operating oil and gas wells or pipe lines shall immediately notify the Commission by telegraph or telephone and by letter of all fires which occur at oil and gas wells or oil tanks owned, operated or controlled by them, or on their property, and shall immediately report all tanks struck by lightning and any other fires which destroy crude oil or natural gas, and shall immediately report in the manner heretofore described any breaks or leaks in tanks or pipe lines from which oil or gas is escaping. In all reports of fires, breaks, or leaks in pipes, or other accidents of this nature, the location of the well, tank, or line break shall be given, showing location by quarter, section, township, and range.

Rule 36.—Conservation Laws and Rules of the Corporation Commission to Be Complied with Before Connecting Wells with Pipe Lines.—Owners or operators of oil or gas wells shall, before connecting with any oil or gas pipe line, secure from the Corporation Commission a certificate showing compliance with the oil and gas conservation laws of the State and conservation orders of the Corporation Commission; provided that this rule shall not prevent temporary connection with pipe lines in order to take care of production until opportunity shall have been given for securing such certificate; provided, further, that the owners or operators of such wells shall in a known or proven field make application for such certificate in anticipation of production.

Rule 37.—Drilling Records to Be Kept at Wells.—All operators, contractors, or drillers shall keep at each well accurate records of the drilling, re-drilling, or deepening of all wells, showing all formations drilled through, casing used, and other information in connection with drilling operation of the property and any and all of this information shall be furnished to the Commission upon request, or to any conservation agent of the Commission.

Rule 38.—Conservation Agents to Have Access to All Wells and All Well Records.—Conservation agents of the Commission shall have access to all wells and to all well records, and all companies, contractors, or drillers shall permit any conservation agent of the Corporation Commission to come upon any lease or property operated or controlled by them, and to inspect any and all wells and the records of said well or wells, and to have access at all times to any and all wells, and any and all records of said wells.

Provided, that information so obtained by conservation agents shall be considered official information and shall be reported only to the Corporation Commission.

Rule 39.—Notice to Contractors, Drillers, and Others to Observe Rules.—All contractors and drillers carrying on business or doing work in the oil or gas fields of the State, as well as lease-holders, land owners, and operators generally, shall take notice of and are hereby directed to observe and apply the foregoing rules and regulations; and all contractors, drillers, land owners, and operators will be held responsible for infraction of said rules and regulations.

Rule 40.—Conservation Agents to Co-operate with Oil and Gas Inspectors of the Department of the Interior.—All conservation agents appointed by the Corporation Commission shall co-operate with and invite the co-operation of the oil and gas inspectors of the United States Bureau of Mines of the Department of the Interior.

Rule 41.—Conservation Agents to Assist in Enforcement of Rules.—All conservation agents of the Commission shall assist in the enforcement of these rules and shall immediately notify the Commission upon observance of any infraction thereof.

PENNSYLVANIA LAWS

Section 1. Be it enacted, etc., That if any person shall wilfully and maliciously injure any well sunk for the production of oil, or gas, or water, or any tank intended or used for the storage of oil, or gas, or water, or any line of pipe intended or used for the transportation of oil, or gas, or water, or any machinery connected with such wells, tanks or lines of pipe, he shall be guilty of a misdemeanor, and upon being thereof convicted, shall be sentenced to pay a fine not exceeding one thousand dollars, and undergo imprisonment, not exceeding three years, or both, or either at the discretion of the court.

Section 2. That whenever any well shall have been put down on lands of any person, or corporation, for the purpose of exploring for or producing gas, upon abandoning, or ceasing to operate the same, the person, or corporation, drilling or owning the well, shall, before drawing the casing, fill up the well with sand, or rock sediment to the depth of at least twenty (20) feet above the gas bearing rock, and drive a round seasoned wooden plug, at least two feet in length, equal in diameter to the diameter of the well below the casing to a point at least five feet below the bottom of the casing, and immediately after the drawing of the casing, shall drive a round wooden plug into the well, at the point just below where the lower end of the casing shall have rested, which plug shall be at least three feet in length, tapering in form, and to be of the same diameter at the distance of eighteen inches from the smaller end of the diameter of the well below the point which it is to be driven. After the plug has been properly driven, there shall be filled in on the top of the same, sand or rock sediment, to the depth of at least five feet.

Section. 3. Any person, who shall violate the provisions of the preceding section, shall be liable to a penalty of two hundred ($200) dollars, to be recovered as debts of like amount are by law recoverable.

Section 4. Whenever any person shall neglect, or refuse to comply with the provisions of this act, with regard to plugging wells, any owner of lands adjacent, or in the neighborhood of such unplugged well, may enter and take possession of said abandoned well, and plug the same, as provided by this act, at the expense of the person, or company, whose duty it may have been to plug the same.

(Laws of Pennsylvania, June 23, 1885, P. 145.)

Section 1. Be it enacted, etc. That upon the abandonment or ceasing to operate or use any well which shall have been drilled for oil or gas, it shall be the duty of the person or persons interested in such well, to plug the same so as to completely shut off and prevent the escape of all water therefrom which may be impregnated with salt or other substances which will render such water unfit for use for domestic, steam making or manufacturing purposes, and in such manner as to prevent water from any such well injuring or polluting any spring, water well or stream which is or may be used for the purposes aforesaid.

Section 2. Any person violating the provisions of this act shall be deemed guilty of a misdemeanor, and shall be sentenced, upon conviction thereof, to pay a fine of not more than one thousand dollars, or to undergo an imprisonment for a period not exceeding six months, or both, or either, at the discretion of the court.

Section 3. Whenever any person may be injured by neglect or refusal to comply with the first section of this act, it shall be lawful for such person, after notice to the owner or lessee of the premises upon which such well is located, to enter upon and fill up and plug such well in the manner directed by the first section hereof, and thereupon to recover the expense thereof from the person or persons whose duty it was to plug and fill up said well, in like manner as debts of such amount are recoverable.

(Laws of Pennsylvania, May 26, 1891, page 122.)

TEXAS LAWS

OIL AND GAS CONSERVATION LAW

S. B. No. 350.] CHAPTER 155.

Acts of Thirty-sixth Legislature, Regular Session.

An Act to conserve the oil and gas resources of the State of Texas.

Be it enacted by the Legislature of the State of Texas:

Article 1. Natural gas and crude oil or petroleum shall not be produced in the State of Texas in such manner and under such condition as to constitute waste. The term "waste" in addition to its ordinary meaning shall include (a) escape of natural gas in commercial quantities into the open air from a stratum recognized as a natural gas stratum; but this is not intended to have application to gas pockets in high points in strata recognized as oil strata; (b) drowning with water of a gas stratum capable of producing gas in commercial quantities; (c) underground waste; (d) the permitting of any natural gas well to wastefully burn; (e) the wasteful utilization of such gas; (f) burning flambeau lights, except when casing head gas is used in same; provided, not more than four may be used in or near the derrick of a drilling well, and (g) the burning of gas for illuminating purposes between 8 o'clock A. M. and 5 o'clock P. M., unless the use is regulated by meter.

Article 2. Whenever natural gas in such quantity or quantities, in a gas bearing stratum known to contain natural gas in such quantities, is encountered in any well drilled for oil or gas in this State, such gas shall be confined to its original stratum until such time as the same can be produced and utilized without waste and all such strata shall be adequately protected from infiltrating waters. All operators, contractors, or drillers, pipe line companies, gas distributing companies drilling for or producing crude oil or natural gas or piping oil or gas for any purpose shall use every possible precaution in accordance with the most approved methods to stop and prevent waste of oil and gas, or both, in drilling and producing operations, storage or in piping or distributing and shall not wastefully utilize oil or gas, or allow same to leak or escape from natural reservoirs, wells, tanks, containers or pipes.

Article 3. It shall be the duty of the Railroad Commission to make and enforce rules and regulations for the conservation of oil and gas; it shall have authority to prevent the waste of oil and gas in drilling and producing operations and in the storage, piping and distribution thereof, and to make rules and regulations for that purpose; it shall be its duty to require dry or abandoned wells to be plugged in such way as to confine oil, gas and water in the strata in which they are found and to prevent them from escaping into other strata, and to establish rules and regulations for that purpose. It is empowered to establish rules and regulations for the drilling of wells and preserving a record thereof, and it shall be its duty to require such wells to be drilled in such manner as to prevent injury to the adjoining property, and to prevent oil and gas and water from escaping from the strata in which they are found into other strata, and to establish rules and regulations therefor; it shall be its duty to establish rules and regulations for shooting wells and for separating oil from gas; it shall have authority to require records to be kept and reports made by oil and gas drillers, operators and pipe line companies and by its inspectors; it is authorized to do all things necessary for the conservation of oil and gas whether here especially enumerated or not, and to establish such other rules and regulations as will be necessary to carry into effect this Act and to conserve the oil and gas resources of the State.

Article 4. It shall be the duty of the pipe line expert provided for in Section 11, Chapter 30, of the Acts of 1917, to be the supervisor for the Railroad Commission in enforcing its rules and regulations. The Railroad Commission may appoint such deputy supervisors as may be necessary. It shall have the authority to increase the salary of the supervisor to a sum not exceeding $5,000.00 per annum and to fix the salaries of the deputies at not exceeding $3,600.00 per annum, all salaries and other expenses of the administration and enforcement of this Act shall be paid out of the funds created in Chapter 30 of the Acts of 1917, and in the manner therein provided. It shall be the duty of the supervisor and his deputies to supervise the plugging of all abandoned wells and the shooting of wells and to conform to the rules and regulations of the Railroad Commission, dealing with the production and conservation of oil and gas.

Article 5. Owners or operators of gas wells shall, before connecting with any oil or gas pipe lines, secure from the Railroad Commission a certificate showing compliance with the oil and gas conservation laws of the State and conservation orders of the Railroad Commission. Pipe line companies shall not connect with oil or gas wells until the owners or operators thereof shall furnish certificate from the Railroad Commission that the conservation laws of the state have been complied with, provided this Act shall not prevent a temporary connection with any well or wells in order to take care of production and prevent waste until opportunity shall have been given the owner or operator of said well to secure certificate showing compliance with the conservation laws of the State.

Article 6. It is hereby made the duty of all owners or operators of oil and gas wells to keep books showing the amount of oil and gas produced and disposed of, with the price for which same was sold, together with the receipts from the sale or transfer of leases or other property and the disbursements made in connection with or for the benefit of such business which books shall be kept open for the inspection of the Railroad Commission or any accredited representative thereof; and of any stockholder or shareholder in said business and any owner or operator refusing to comply with the provisions of this article shall be subject to the penalties imposed by this Act.

Article 7. In addition to any penalty that may be imposed by the Railroad Commission for contempt, any firm, person, corporation or any officer, agent or employe thereof, directly or indirectly violating the provisions of this Act or the orders or regulations of the Railroad Commission made in pursuance thereof, shall be subject to a penalty of not more than five thousand ($5,000.00) dollars, to be recovered in any court of competent jurisdiction, such suit to be brought in the name of the State of Texas, and to be instituted and conducted by any county or district attorney, on the direction of the Railroad Commission. Each day that such violation continues shall be considered a separate offense.

Article 8. This Act shall be cumulative of all the laws of this State which are not in direct conflict herewith, regulating the conservation of oil and gas, but it shall repeal all laws or parts of law in conflict with its provisions.

Article 9. If any of the provisions of this Act shall be held unconstitutional, or for any other reason shall be held void, such holdings shall not have the effect to nullify the remaining parts of this Act, but the parts not so held to be void shall nevertheless remain in full force and effect.

Article 10. Whereas, there is now no law in this State regulating corporations, persons or associations of persons engaged in the production of oil and gas, and adequately conserving these resources, and whereas great waste of gas is now daily occurring in the oil fields of Texas; now, therefore, it is hereby declared that an emergency exists creating an imperative public necessity for the suspension of the constitutional rule requiring bills to be read on three several days, and the same is hereby suspended and this law shall take effect and be in force from and after its passage, and it is so enacted.

Approved March 31, 1919.

Took effect June 18, 1919.

OIL AND GAS CIRCULAR NO. 11

CONSERVATION RULES AND REGULATIONS

Rule 1. **Waste Prohibited.**—Natural gas and crude oil or petroleum shall not be produced in the State of Texas in such manner and under such conditions as to constitute waste.

Rule 2. **"Waste" Defined.**—The term "waste" as above used, in addition to its ordinary meaning, shall include:

(a) Escape of natural gas in commercial quantities into the open air from a stratum recognized as a natural gas stratum; but this is not intended to have application to gas pockets in high points in strata recognized as oil strata;

(b) Drowning with water of a gas stratum capable of producing gas in commercial quantities;

(c) Underground waste;

(d) The permitting of any natural gas to wastefully burn;

(e) The wasteful utilization of such gas;

(f) Burning flambeau lights except when casing head gas is used in same; provided, not more than four may be used in or near the derrick or a drilling well, and

(g) The burning of gas for illuminating purposes between eight o'clock A. M. and five o'clock P. M., unless the use is regulated by meter.

Rule 3. **Gas to Be Confined—Strata to Be Protected.**—Whenever natural gas in commercial quantities, in a well defined gas-bearing stratum known to contain natural gas in such quantities, is encountered in any well drilled for oil or gas in this State, such gas shall be confined to its original stratum until such time as the same can be produced and utilized without waste, and all such strata shall be adequately protected from infiltrating waters. This rule shall not apply to the Gulf Coast oil fields of Texas; nor shall this rule, as to the fields in which it applies, prevent the drilling deeper in search for oil in any well, if such drilling shall be prosecuted with diligence and if said gas be confined in its stratum and protected as aforesaid upon completion of such well; but at any time after the expiration of seven (7) days from the penetration of such gas-bearing stratum, even though such drilling deeper is being prosecuted with diligence, the Railroad Commission, or its Conservation Agent or any deputy of the latter, may require such gas-bearing stratum to be cased off and so protected, if in their judgment it shall be reasonably necessary and proper to do so.

Rule 4. **Approved Methods of Preventing Waste to Be Used.**—All operators, contractors or drillers, pipe line companies, or gas distributing companies, drilling for or producing crude oil or natural gas, or piping oil or gas for any purpose, shall use every possible precaution in accordance with the most approved methods to stop and prevent waste of oil and gas, or both, in drilling and producing operations, storage, or in piping or distributing, and shall not wastefully utilize oil or gas, or allow same to leak or escape from natural reservoirs, wells, tanks, containers or pipes.

Rule 5. **"Commercial Quantities" Defined.** — Any gas stratum showing a well defined gas sand and producing gas shall be considered capable of producing gas in commercial quantities, and any gas coming from such a stratum or sand shall be considered a commercial quantity, and such stratum or sand shall be protected the same as under Rule 3.

Rule 6. **Gas to Be Taken Ratably.**—Whenever the full production from any common source of supply of natural gas in this State is in excess of the market demands, then any person, firm or corporation having the right to drill into and produce gas from any such common source of supply may take therefrom only such proportion of the natural gas that may be marketed without waste, as the natural flow of the well or wells owned or controlled by any such person, firm or corporation bears to the total natural flow of such common source of supply, having due regard to the acreage drained by each well, so as to prevent any such person, firm or corporation securing any unfair proportion of the gas therefrom;

provided, that the Railroad Commission of Texas may, by proper order, permit the taking of a greater amount whenever it shall deem such taking reasonable or equitable.

Rule 7. **Commission Will Regulate the Taking of Natural Gas.**—The Railroad Commission of Texas will, as occasion arises, prescribe rules and regulations for the determination of the natural flow of any well or wells in this State, and will regulate the taking of natural gas from any and all common sources of supply within the State so as to prevent waste, protect the interests of the public and of all those having a right to produce therefrom; and to prevent unreasonable discrimination in favor of one common source of supply as against another.

Rule 8. **Gas to Be Metered.**—All gas produced from the deposits of this State when sold shall be measured by meter, and each gas well, or the entire property on which it is located, shall be equipped with such meter.

Rule 9. **Notice of Intention to Drill, Deepen or Plug.**—Notice shall be given to the Railroad Commission of Texas or its agents of the intention to drill, deepen or plug any well or wells and of the exact location of each and every such well. In case of drilling, notice shall be given at least five (5) days prior to the commencement of drilling operations.

Notice of intention to plug must be given at least twenty-four (24) hours prior to beginning of plugging, and must be accompanied by a complete log of the well, on forms prescribed by the Railroad Commission of Texas.

Blanks for notification and reports can be obtained by application to the Railroad Commission of Texas or its conservation agent in the field.

Rule 10. **Plugging Dry and Abandoned Wells.**—(a) All abandoned or dry wells shall immediately be plugged according to the following rules:

(b) **Manner of Plugging.**—All dry and abandoned wells must be plugged by confining all oil, gas or water in the strata in which they occur, by the use of mud-laden fluid, or by some other method approved by the Commission. In case of cable-drilling, cement and plugs may be used.

(c) **Notice of Intention to Plug.**—Before plugging dry and abandoned wells, notice shall be given to the Railroad Commission of Texas or its conservation agent in the field, and to all available adjoining lease and property owners, and representatives of such lease and property owners may, in addition to the oil and gas conservation agent of the Commission, be present to witness the plugging of these wells if they so desire, but plugging shall not be delayed because of failure or inability to deliver notices to adjoining lease or property owners.

Rule 11. **Log and Plugging Record to Be Filed with Commission.**—The owner or operator shall, upon the completion of any well, file with the Railroad Commission of Texas a complete record or log of the same, duly signed and sworn to, upon blanks to be furnished by the Commission upon application; and upon plugging any well for any cause whatsoever, a complete record of the plugging thereof shall be made out and duly verified on blanks to be furnished by the Commission.

Rule 12. **Proper Anchorage to Be Laid.**—Before any well is begun in any field where it is not known that high pressure does not exist, proper anchorage shall be laid so that the control casing-head may be used on the inner string of casing at all times, and this type of casing-head shall be kept in constant use unless it is known from previous experience and operations on wells adjacent to the one being drilled that high pressure does not exist or will not be encountered therein.

Rule 13. **Equipment for Conserving Natural Gas Shall Be Provided Before "Drilling-in."**—In all proven or well-defined gas fields, or where it can reasonably be expected that gas in commercial quantities will be encountered, adequate preparations shall be made for the conservation of gas before "drilling-in" any well.

Rule 14. **Separate Slush Pit to Be Provided.**—Before commencing to drill a well, a separate slush pit or sump hole shall be constructed by the owner, operator or contractor for the reception of all pumpings from clay or soft shale formations in order to have the same on hand for the making of mud-laden fluid.

Note.—In order to avoid freezing casings, operators are cautioned not to allow sand or lime to be mixed with clay or soft shale pumpings.

Rule 15. **Wells Not to Be Permitted to Produce Oil and Gas from Different Strata.**—No wells shall be permitted to produce both oil and gas from different strata unless it be in such manner as to prevent waste of any character to either product and in accordance with Rule 3.

Rule 16. **Strata to Be Sealed Off.**—No well shall be drilled through or below any oil, gas or water stratum without sealing off such stratum or the contents thereof, after passing through the sand, either by the mud-laden fluid process or by casing and packers, regardless of volume or thickness of sand; provided this rule shall be subject to Rule 3 as that rule relates to natural gas.

Rule 17. **Density of Mud-Fluid Where Well Containing Water Is Drilled into Oil or Gas-Producing Strata.**—No operator shall drill a well into a known oil or gas-producing sand with water from a higher formation in the hole, or with a sufficient head of water introduced into the hole to prevent gas blowing to the surface. The well shall either be allowed to blow until the same has been drilled-in or it shall be drilled in under a head of fluid consisting, when necessary, of not less than 25 per cent. mud; but in no case shall gas be allowed to blow for a longer period than three (3) days after completion of well. Mud-laden fluid used for protecting oil and gas-bearing sands in upper formations while oil or gas is being produced from deeper formations should have a density of not less than 25 per cent. mud and should contain not less than 28 per cent. mud.

Rule 18. **Mud-Laden Fluid to Be Applied in Pulling or Redeeming Casing.**—No outside casing from any oil or gas well in an unexhausted oil or gas field, shall be pulled without first flooding the well with mud-laden fluid behind the inside string of casing, after unseating the casing, and as casing is withdrawn, well shall be kept full to top with said mud-laden fluid and same shall be left in the hole; and said mud-laden fluid shall be so applied as to effectively seal off all fresh or salt water strata, and all oil or gas strata not being utilized.

Rule 19. **Mud-Laden Fluid—When to Be Applied to Completed Wells.**—When necessary (or in any event when ordered by the Railroad Commission of Texas) to seal off any oil, gas or water sand, casing shall be seated in mud-laden fluid; and concerning wells already drilled, the operator shall, upon the order of the Railroad Commission of Texas, raise any string or strings of casings and re-seat them in mud-laden fluid when it is thought advisable to do so in order to avoid existing underground waste, pollution or infiltration.

Rule 20. **Fresh Water to Be Protected.**—Fresh water, whether above or below the surface, shall be protected from pollution, whether in drilling or plugging.

Rule 21. **Separating Devices.**—Where oil and gas are found in the same stratum and it is impossible to separate the one from the other, the operator shall, upon being so ordered by the Railroad Commission of Texas, install a separating device of approved type, which shall be kept in place and used as long as necessity therefor exists, and after being installed, such device shall not be removed, nor the use thereof discontinued, without the consent of the Railroad Commission of Texas.

Rule 22. **Gas Wells Not to Produce from Different Sands at the Same Time Through the Same String of Casing.**—No gas well shall be permitted to produce gas from different levels, sand or strata at the same time through the same string of casing, and when gas upon being found is not needed for immediate use, the same shall be confined in its original stratum until such time as the same can be produced and utilized without waste, and in confining gas to its original place the mud-laden fluid process shall be used unless the character of the formation involved is sufficiently ascertained and understood to know that the casing and packer method with Braden-head attachment can be safely applied and competently used, and in the use of the casing, packing and Braden-head method, separate strings of casing shall be run to each sand.

Rule 23. **Shooting of Wells.**—(a) All shooting of wells shall be under rules and regulations of the Railroad Commission of Texas.

(b) **Wells Not to Be Shot into Salt Water.**—No well shall be so shot as to let in salt water or other foreign substance injurious to the oil or gas sand.

(c) **Reports to Be Made to the Railroad Commission of Texas.**—Reports shall be made to the Railroad Commission of Texas on all wells shot, showing the condition of the well before and after shooting, including the size of the shot, sand or sands shot, production before and after shooting, per cent. of water in well before and after shooting.

(d) **Damaged Wells to Be Abandoned.**—In case irreparable injury is done to the wells, or to the oil or gas sand or sands by shooting, the well shall immediately be abandoned and plugged as provided by Rule No. 10.

(e) **Notice of Intention to Shoot.**—Notice of intention to shoot must be given the Railroad Commission of Texas, on blank form prescribed by it, at least two (2) days prior to shooting.

Rule 24. **Gauge to Be Taken—Reports to Commission.**—All oil and gas operators shall, between the first and tenth of each month, take the rock pressure of all wells producing natural gas which is being marketed, and shall forthwith report to the Railroad Commission of Texas, on gauge blanks furnished by the Commission.

Rule 25. **Production of Gas to Be Restrained to Fifty Per Cent. of Potential Capacity.**—When the gas from any well is being used, the flow or production thereof shall be restrained to fifty (50) per cent. of the potential capacity of the same; that is to say, in any day (24 hours) the well shall not be permitted to flow or produce more than one-half of the potential capacity thereof as shown by the last monthly gauge; provided, that this rule shall not apply to casing-head gas, and provided further that, in cases of emergency, greater production may be used after special authority therefor has been secured from the Railroad Commission of Texas.

Rule 26. **Notification of Fires and Breaks or Leaks.**—All drillers, operators, pipe line companies, and individuals operating oil and gas wells or pipe lines shall immediately notify the Railroad Commission of Texas by letter of all fires which occur at oil or gas wells or oil tanks owned, operated, or controlled by them or on their property, and shall immediately report all tanks struck by lightning and any other fires which destroy crude oil or natural gas, and shall immediately report, in the manner heretofore described, any breaks or leaks in tanks or pipe lines from which oil or gas is escaping. In all reports of fires, breaks, or leaks in pipes, or other accidents of this nature, the location of the well, tank or line break shall be given, showing location by county and survey. The reports provided for under this rule shall only be required when the loss by fire, breaks or leaks or other accident is material and only as regards losses connected with production or transportation in this State over which the Railroad Commission of Texas has jurisdiction.

Note.—Rules 27 and 28 relating to pipe line companies omitted.

Rule 29. **Certificates—Showing Compliance with Conservation Laws and Rules Prior to Connection.**—Owners or operators of oil or gas wells shall, before connecting with any oil or gas pipe line, secure from the Railroad Commission of Texas a certificate showing compliance with the oil and gas conservation laws of the State and conservation orders of the Commission; provided that this rule shall not prevent temporary connection with pipe lines in order to take care of production until opportunity shall have been given for securing such certificate; provided, further, that the owners or operators of such wells shall, in a known or proven field, make application for such certificate in anticipation of production.

Rule 30. **Drilling Records to Be Kept.**—All operators, contractors, or drillers shall keep at each well, while drilling same, accurate records of the drilling, redrilling, or deepening of all such wells, showing all formations drilled through, casing used, and other information in connection with drilling and operation of the property, and any and all of this information shall be furnished to the Railroad Commission of Texas upon request, or to any conservation agent of the Commission.

Rule 31. **Conservation Agents to Have Access to All Wells and All Well Records.**—Conservation agents of the Railroad Commission of Texas shall have access to all wells and to all well records, and all companies, contractors, or drillers, shall permit any conservation agent of the Commission to come upon any lease or property operated or controlled by them and to inspect any and all wells and the records of said well or wells, and to have access at all times to any and all wells and any and all records of said wells. Provided, that information so obtained by conservation agents shall be considered official and confidential information and shall be reported only to Commission.

Rule 32. **Books to Be Kept—Reports to Be Made.**—All owners and operators of oil and gas wells in this State shall keep books showing accurately the amount of stock sold and unsold and amount of promotion money paid, amount of oil and gas produced and disposed of, with the price for which the same was sold, together with the receipts from the sale or transfer of leases or other property, and the disbursements made in connection with or for the benefit of such business;

which books shall be kept open for the inspection of the Railroad Commission of Texas or any accredited representative thereof, and of any stockholder or shareholder or royalty owner in said business, and shall report such information to the Railroad Commission of Texas for its information, when required by the Commission to do so. Any person, firm, partnership, joint stock association, corporation or other organization, domestic or foreign, operating wholly or partially within this State, acting as principal or agent for another, for the purpose of drilling, owning or operating any oil or gas well, or owning or controlling leases of oil and mineral rights, or the transportation of oil or gas by pipe line, shall immediately file with the Railroad Commission of Texas, at Austin, the name of the company or organization, giving the name and postoffice address of the organization, the plan under which it was organized, and the names and postoffice addresses of the trustee or trustees thereof, and the names and postoffice addresses of the officers and directors.

Rule 33. **Notice to Contractors, Drillers and Others to Observe Rules.**—All contractors and drillers carrying on business or doing work in the oil or gas fields of the State, as well as leaseholders, land owners and operators generally, shall take notice of and are hereby directed to observe and apply the foregoing rules and regulations; and all contractors, drillers, land owners and operators will be held responsible for infractions of said rules and regulations.

Rule 34. **Conservation Agents—Co-operation with Federal Inspectors.**—All conservation agents appointed by the Railroad Commission of Texas shall co-operate with and invite the co-operation of the oil and gas inspectors of the United States Bureau of Mines of the Department of the Interior.

Rule 35. **Conservation Agents—To Enforce These Rules.**—All conservation agents appointed by the Railroad Commission of Texas shall be governed by, and are charged with the enforcement of, the law and these rules and regulations.

This order to take effect and be in force on and after July 26, 1919, until amended or canceled by this Commission.

ALLISON MAYFIELD, Chairman;
EARLE B. MAYFIELD,
CLARENCE E. GILMORE,
Commissioners.

Attest:
E. R. McLean, Secretary.

Rule 37. No well for oil or gas shall hereafter be commenced nearer than three hundred (300) feet to any other completed or drilling well on the same or adjoining tract or farm; and no well shall be drilled nearer than one hundred and fifty (150) feet to any property line; provided, that the Commission, in order to prevent waste or to protect vested rights, will grant exceptions permitting drilling within shorter distances than as above prescribed, upon application filed fully stating the facts, notice thereof having first been given to all adjacent lessees affected thereby. Rule 37 shall not for the present be enforced within the proven oil fields of the Gulf Coast.

Rule 38. All maps or sketches of any kind of any separate lease or tract of land, filed with the Oil and Gas Department of the Railroad Commission, must be drawn on a scale of four hundred (400) feet to one inch, unless the area involved is less than two acres, when the scale must be forty (40) feet to one inch, or unless the Commission specially grants permission that maps furnished may be drawn on another scale.

Rule 39. (1) All permanent oil tanks or battery of tanks must be surrounded by a dike or ditch of at least the capacity of the tank or battery of tanks.

(2) No flow tank, unless it is entirely buried, or other oil tank of any size, shall hereafter be placed nearer than 150 feet to any derrick, rig, building, power plant or boiler of any description, except where topography does not permit.

(3) No field working tank having a capacity of 5,000 barrels

or more shall hereafter be built nearer than 200 feet (measured from shell to shell) to any other like tank or tanks.

(4) No battery of field storage tanks shall hereafter be placed nearer than 200 feet to any other battery.

(5) Printed signs reading "Dangerous, No Smoking Allowed," or similar words, shall be posted in conspicuous places on each producing lease or farm.

(6) All lessees' premises shall be kept clear of high grass, weeds and combustible trash, within a radius of 100 feet around an oil tank, tanks or producing wells.

(7) Open earthen storage for merchantable oil is hereafter prohibited, except when the Commission grants special permission in order to meet an unforeseen emergency. Where such storage is now in use, it must be discontinued within a reasonable time.

(8) Swabbing into open pits is prohibited except when testing a well or cleaning out and such swabbing shall not continue for a longer period than ten days, without permission from the Railroad Commission.

(9) All oil tanks, where there is a gas hazard, shall be well covered and provided with adequate gas vents.

(10) No forge or open light shall be placed inside the derrick of a well showing oil or gas.

(11) Boilers must be equipped with steam lines for fighting fire and must not be set nearer than 100 feet to any producing well.

(12) All oil and gas pipe lines laid upon or across a public road or highway must be buried to a reasonably safe depth.

(13) Wherever available and practicable, electric light and power shall be installed in congested drilling areas, upon order of the Commission.

Rule 40. **Vacuum Pumps Prohibited.**—The use of vacuum pumps or other devices for the purpose of extracting oil or gas, except casing head gas where the same is utilized, from any well by the vacuum process, is prohibited, except in depleted or practically depleted fields.