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Cyclopedia

of

Heating, Plumbing and Sanitation

A Complete Reference Work

ON PLUMBING, GAS FITTING, SEWERS AND DRAINS, HEATING AND VENTILATING, STEAM FITTING, CHEMISTRY, BACTERIOLOGY AND SANITATION, HYDRAULICS, WATER SUPPLY, ELECTRIC WIRING, MECHANICAL DRAWING, SHEET METAL WORK, ETC.

Prepared by a Corps of

SANITARY EXPERTS, CONSULTING ENGINEERS, AND SPECIALISTS OF THE HIGHEST PROFESSIONAL STANDING

Illustrated with over One Thousand Engravings

FOUR VOLUMES

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THE editors have freely consulted the standard technical literature of America and Europe in the preparation of these volumes. They desire to express their indebtedness, particularly, to the following eminent authorities, whose well-known treatises should be in the library of everyone interested in Sanitary Engineering.

Grateful acknowledgment is here made also for the invaluable co-operation of the foremost Engineering Firms and Manufacturers in making these volumes thoroughly representative of the latest and best practice in every branch of the broad field of Heating, Plumbing, and Sanitation; also for the valuable drawings, data, suggestions, criticisms, and other courtesies.

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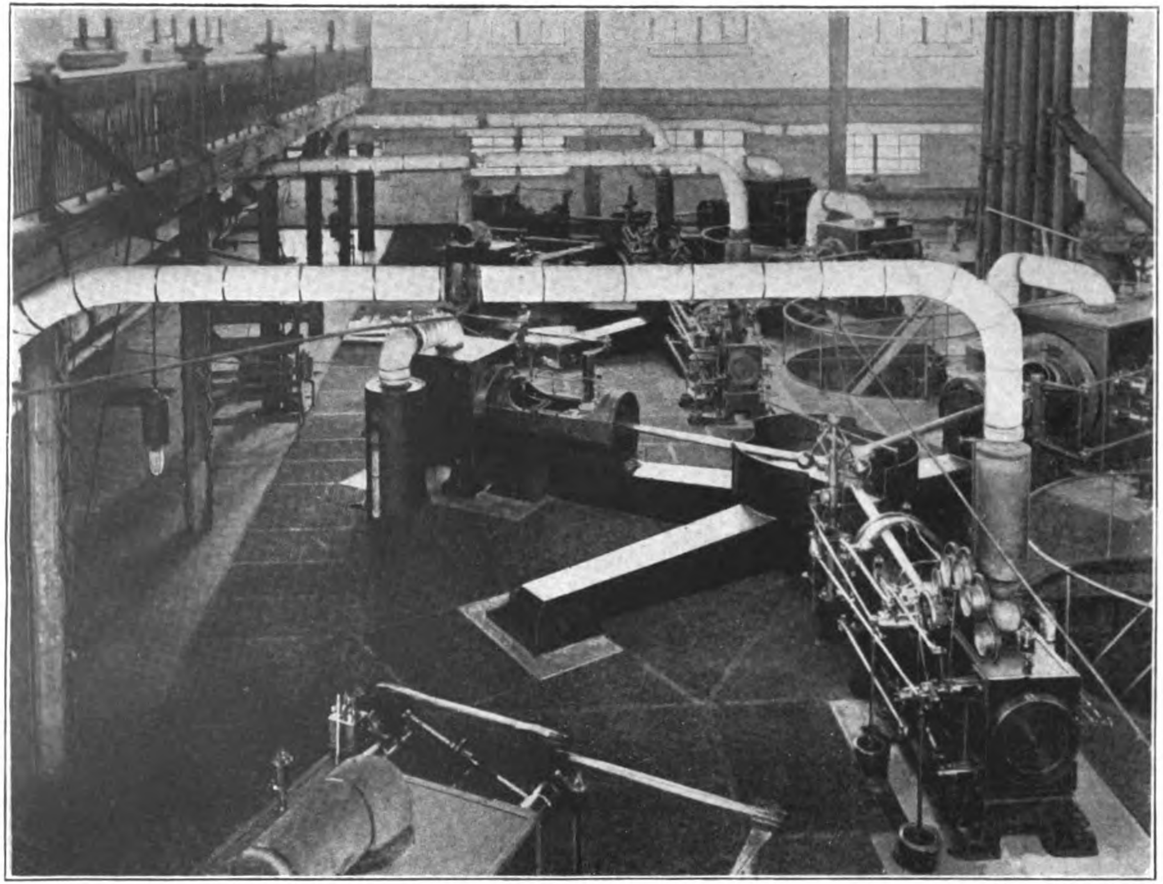

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Foreword

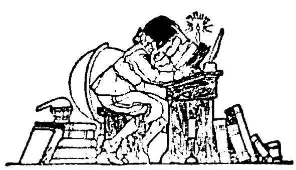
THE widespread need for a more scientific knowledge of the principles of Sanitation on the part of thousands of practical men of limited education, calls for an authoritative work of general reference embodying the results of modern experience and the latest approved practice. The Cyclopedia of Heating, Plumbing, and Sanitation is designed to fill this acknowledged need.

¶ The Cyclopedia of Heating, Plumbing, and Sanitation is based upon the method which the American School of Correspondence has developed and successfully used for many years in teaching the principles and practice of engineering in its different branches. It is a compilation of representative Instruction Books of the School, and forms a simple, practical, concise, and convenient reference work for the shop, the library, the school, and the home.

¶ The success which the American School of Correspondence has attained as a factor in the machinery of modern technical and scientific education, is in itself the best possible guarantee for the present work. Therefore, while these volumes are a marked innovation in technical literature—representing, as they do, the best ideas and methods of a large number of *different* authors, each an acknowledged authority in his work—they are by no means an experiment, but are in fact based on what has proved itself to be the most successful method yet devised for the education of the busy workingman. They have been prepared only after the most careful study of modern needs as developed under the conditions of actual practice.

¶ Neither pains nor expense have been spared to make the present work the most comprehensive and authoritative in its field. The aim has been, not merely to create a work which will appeal to the trained expert, but one that will commend itself also to the beginner and the self-taught, practical man by giving him a working knowledge of the principles and methods, not only of his own particular trade, but of all allied branches of it as well. The various sections have been prepared especially for home study, each written by an acknowledged authority on the subject. The arrangement of matter is such as to carry the student forward by easy stages. Series of review questions are inserted in each volume, enabling the reader to test his knowledge and make it a permanent possession. The illustrations have been selected with unusual care to elucidate the text.

¶ Grateful acknowledgment is due the corps of authors and collaborators—men of wide practical experience, and teachers of well-recognized ability—without whose hearty co-operation this work would have been impossible.



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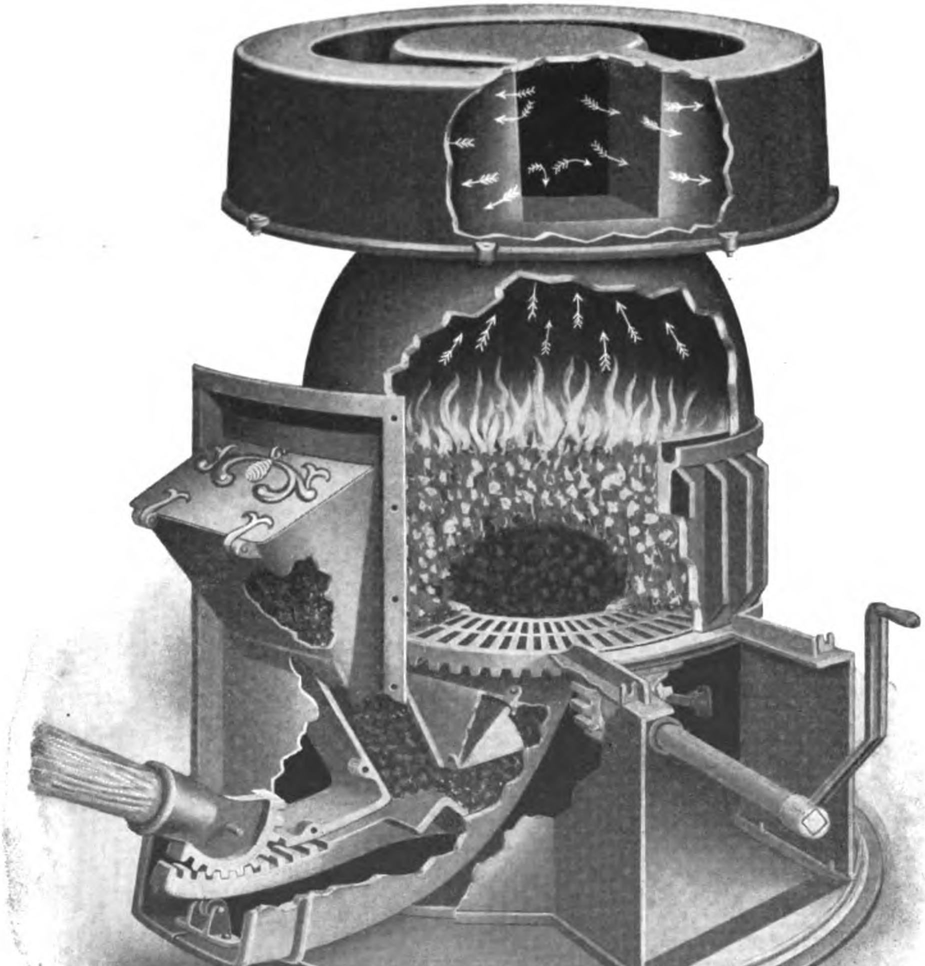


INTERIOR VIEW OF PECK-WILLIAMSON UNDERFEED FURNACE

HEAT.

Until the time of Count Rumford and Sir Humphry Davy the most widely accepted notion of the nature of heat was that it was an elastic fluid, penetrating the pores of all matter and filling the spaces between molecules. To this fluid the name caloric was given. In order to explain the various manifestations of heat, it was necessary to ascribe various properties to the caloric fluid, such as indestructibility, absence of weight, differences in the intensity of its affinity for different kinds of matter, and so on. But these explanations were not borne out by experiment; and in 1798 Count Rumford showed, by a series of experiments with a blunt boring bar and a brass cannon, that the heat developed in boring the cannon had no relation to anything but the friction of the apparatus. He thus proved that heat could not be a material substance, for it was produced without limit from a limited quantity of matter, provided only that the motion were maintained; and he announced his conviction that heat was in reality a form of motion.

Sir Humphry Davy showed that two pieces of ice might be melted by rubbing them together. He thus proved that heat can be produced by the expenditure of work only. This leads to the important conclusion that heat must be a form of energy, since it can be produced from energy, and (as we know in the case of the steam engine) can itself be converted into well-recognized forms of energy.

Heat-energy is now understood to lie in the rapid irregular vibrations of the molecules of which all matter is composed. We shall see that the idea of rapidly-moving molecules affords a ready explanation of many of the phenomena of heat.

This motion may be communicated from one body to another; or, in other words, heat may flow from one body to another. The condition that determines which way the flow will take place is called **temperature.**

Temperature, then, has nothing to do with quanuty of heat. If a spoonful of water be dipped from a full pail, it is clear that the quantities of heat in the two masses of water are very unequal, yet there is no tendency for heat to travel from either to the other.

Our study of the phenomena and laws of heat thus naturally divides itself as follows:

1. The measurement of temperature, or thermometry.
2. The measurement of quantities of heat, or calorimetry.
3. The relation between heat and mechanical work, or thermodynamics.

Equality of temperature may be estimated quite accurately simply by touching two bodies with the hand, provided they are of a similar nature and neither very hot nor very cold. The power which enables us to do this is called the temperature sense. It does not help us much, however, if the bodies are of very different nature, nor does it tell us whether they are actually hot or cold. The sensation really depends on the rate at which heat is communicated to (or taken from) the hand, and this depends on the temperature of the hand as well as on the nature of the material tested.

A simple experiment will illustrate this. Place the right hand in ice-water and the left hand in hot water; after a minute withdraw them and place them simultaneously in water just drawn from the faucet. It will seem warm to the right hand and cold to the left hand, because in the first case heat passes from the water to the hand, and in the second case from the hand to the water. Again, a stone in winter feels colder to the hand than a piece of fur or woolen cloth. The stone conducts the heat away from the hand faster than the fur does, and thus gives the sensation of a lower temperature.

THERMOMETERS.

Instruments for the measurement of temperature are called **thermometers.** In designing a thermometer we may use any substance one of whose properties varies continuously with the temperature. Among the properties most convenient for use are:

1. Expansion; used for ordinary temperatures.
2. Change of electrical resistance; used for very low temperatures.
3. Thermo-electric effects; used for very high temperatures.

The first of these is discussed in this paper; the principles on which the others depend will be explained in the Instruction Papers on Electricity.

Besides these, many other properties of substances that depend on temperature are useful in special cases. For example, when a piece of polished steel is heated its surface changes color, each color corresponding to a certain definite temperature. The process of **tempering** consists in heating the previously hardened articles until they assume the proper temperature, as shown by their color, and then plunging them again into cold water or oil. In this way each piece is made to indicate its own temperature without possibility of mistake.

Liquid Thermometers. In the most common form of thermometer, temperature is measured by the expansion of mercury in glass. On the end of a glass tube of very fine bore, a bulb is blown (see Fig. 1), and the bulb and part of the tube are filled with mercury. The whole is then heated until the mercury completely fills the tube, after which it is sealed and allowed to cool. The space in the tube above the mercury is thus entirely freed from air. Changes in temperature cause the mercury to expand or contract, and the liquid in the tube will rise or fall accordingly.

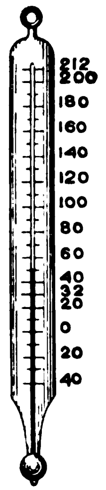


Fig. 1.

But the thermometer thus made is not yet ready for use. It must have its divisions properly spaced and in the right places on the tube. All thermometers for accurate work should have their scales engraved on the tube itself, and not on a plate attached to it. Before we can engrave the scale we must know at least two points on the stem that correspond to known temperatures. The two points commonly taken are known as the **freezing point** and the **boiling point**.

The freezing point can easily be found by putting the thermometer into a mixture of clean pounded ice (or snow) and water. The boiling point is found by immersing the whole thermometer in steam from boiling water. The freezing point is always the same under ordinary conditions, but the temperature of the boiling point rises or falls slightly as atmospheric pressure increases or decreases.

Thermometer Scales. Two scales of temperature are in use. On the *Fahrenheit* scale, devised about 1714, the boiling point is marked 212°, and the freezing point 32°, there being thus 180 degrees between them. The *Centigrade* scale, which is more convenient for scientific work, has its boiling point marked 100° and its freezing point marked 0°.

We may convert Centigrade to Fahrenheit temperatures in the following way :

Since 100 Centigrade degrees cover the same temperature interval as 180 Fahrenheit degrees, one Centigrade degree is $\frac{180}{100}$ or $\frac{9}{5}$ as long as one Fahrenheit degree. Hence a temperature of m degrees Centigrade is equal to $\frac{9}{5}m$ Fahrenheit degrees above the Centigrade zero. But this point is marked 32° on the Fahrenheit scale, consequently the total reading on the Fahrenheit thermometer will be

$$\frac{9}{5}m + 32.$$

The formula for changing a temperature C° Centigrade to its Fahrenheit equivalent F°, therefore, is

$$F^\circ = \frac{9}{5}C^\circ + 32;$$

and by transposing we obtain the corresponding formula,

$$C^\circ = \frac{5}{9}(F - 32).$$

EXAMPLES FOR PRACTICE.

1. To what temperature F does 58° C correspond?

Ans. 136.4° F.

2. To what temperature C does 149° F correspond?

Ans. 65° C.

3. The difference between the temperatures of two bodies is 45° F. What is it in Centigrade degrees?

Ans. 25° C.

4. Lead melts at 327° C. What is its melting point on the Fahrenheit scale?

Ans. 620′ ° F.

Temperatures below the zero point can be dealt with by calling them negative and using them with a minus sign.

Example. To what temperature F does — 20° C correspond?

Solution. $F^\circ = \left(\frac{9}{5} \text{ of } -20\right) + 32$

$= -36 + 32 = -4^\circ$. Ans.

EXAMPLES FOR PRACTICE.

1. To what temperature F does — 18° C correspond?

Ans. — 0.4° F.

2. To what temperature C does — 40° F correspond?

Ans. — 40° C.

The temperature T_s of steam in Centigrade degrees is given by the following formula:

$$T_s = 100^\circ + \frac{3}{80}(H - 760),$$

where H is the barometric pressure in millimeters.

In Fahrenheit degrees the temperature T'_s is

$$T'_s = 212^\circ + 1.71(H'' - 29.92),$$

where H″ is the barometric pressure in inches.

When the barometer stands at exactly 760 millimeters or 29.92 inches, the temperature of steam is therefore 100° C or 212° F. The Centigrade scale is used in almost all scientific work, while the Fahrenheit scale is more common in daily life.

EXAMPLES FOR PRACTICE.

1. What is the temperature of steam when the barometer reads 772.8 millimeters?

Ans. 100.48° C.

2. What is the temperature of steam when the barometer on a mountain stands at 27.44 inches?

Ans. 207.76° F.

EXPANSION OF SOLIDS.

When the temperature of a body rises, as a rule we find an increase in its dimensions. This is called **expansion.** It depends on the rise of temperature and on the nature of the body itself. A rod whose length is unity at 0° C will have at any other temperature t the length

$$1 + a\,t,$$

where a is a small constant called the **coefficient of linear expansion.** If $t = 1°$, then the length at 1° would be simply

$$1 + a \times 1 = 1 + a,$$

and the increase in length would be

$$(1 + a) - 1 = a.$$

We may therefore define the coefficient of linear expansion as the increase in length per Centigrade degree of a rod whose length is unity at 0° C. It varies a little at different temperatures and is usually larger at higher temperatures.

The following table gives the average value of the coefficient of linear expansion for various solids, between 0° and 100° C (32° to 212° F). Different specimens of the same substance sometimes give different results, and the figures do not hold for temperatures much beyond the given limits. They may, however, be used for all ordinary purposes.

COEFFICIENTS OF LINEAR EXPANSION.

	PER DEGREE CENTIGRADE.	PER DEGREE FAHRENHEIT.
Porcelain	0.00000806	0.00000448
Gas carbon	0.0000055	0.0000031
Glass	0.0000057 to 0.00000883	0.0000032 to 0.00000491
Pine wood, along grain	0.00000608	0.00000338
Cast iron	0.00001075	0.000005972
Platinum	0.00000907	0.000005039
Steel	0.00001088 to 0.00001098	0.000006044 to 0.00000610
Wrought iron	0.00001228	0.000006822
Copper	0.00001666 to 0.00001718	0.00000925 to 0.00000954
Brass	0.00001840 to 0.00001906	0.00001022 to 0.00001059
Silver	0.00001943	0.00001079
Zinc	0.00002976	0.00001653
Ice	(—12° to 0°), 0.0001050	(10° to 32°), 0.0000583

The coefficient of surface expansion may be found by multiplying the above figures by two; and the coefficient of cubical or volume expansion, by multiplying by three.

It is clear from the table that different substances expand very unequally; zinc, for example, expanding over three times as much as platinum and more than twice as much as iron. If then

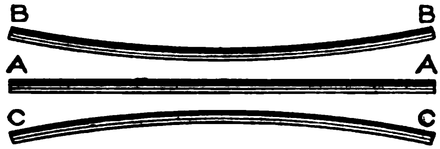


Fig. 2.

we make a bar like A of Fig. 2, by riveting together a strip of zinc and one of iron, and heat it, the bar will not only lengthen but become curved, the zinc being on the convex side. If cooled below its original temperature, the bar curves the opposite way; and by fixing one end of the bar the other end may be made to show a considerable motion for small changes of temperature.

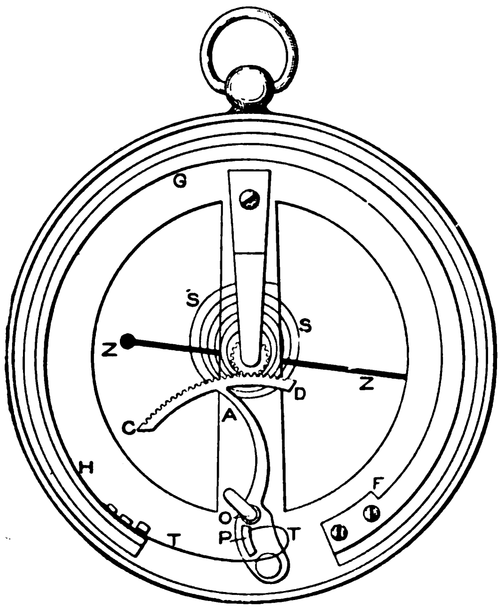


Fig. 3.

This principle is employed in some forms of metallic thermometer (see Fig. 3). The metal spring F G H is fastened at F, the remaining part being free to expand or contract. To this spring, at H, is fastened a finer spring T T, clamped at P to the arm A, which is pivoted at O. The segment C D of a gear on the arm A operates the pinion to which the hand Z Z is attached. An additional spring S S tends to move the hand in the opposite direction. Heat causes expansion of the spring F G H, and the hand Z Z moves in a direction opposite to that of the hands of a clock. The same principle is also used in thermostats. In these instruments the free end of the bar is sometimes made to move between stops connected with electric circuits; and in this way the temperature of a furnace or a room can be easily controlled.

With the help of the table we can calculate the expansion of a rod of any length. Let l_0 represent the length of a rod at 0° C, and l_t its length at the temperature $t°$; and let us find the relation between l_0 and l_t.

Since a rod of unit length at 0° will have at $t°$ the length $1 + a\,t$, the length of a rod l_0 times as long will be l_0 times as much, or $l_0(1 + a\,t)$. That is,

$$l_t = l_0(1 + a\,t). \qquad (1)$$

By transposing, we may put this into the form

$$l_0 = \frac{l_t}{1 + a\,t}. \qquad (2)$$

Example. A copper wire is 65 inches long at 30° C. How long is it at 0° C?

Solution. From equation 2 we have:

$$\text{Length at } 0° = \frac{65}{1 + 0.00001666 \times 30}$$

$$= \frac{65}{1.0005} = 64.967 \text{ inches. Ans.}$$

Example. A sheet of zinc twenty inches by thirty is heated from 32° F to 100° F. What is its increase in area?

Solution. The surface expansion of zinc is 2×0.00001653 or 0.00003306 per degree F.

The surface of the sheet is $20 \times 30 = 600$ sq. in.

The sheet is heated through $100° - 32° = 68$ degrees F.

Therefore the area of the heated sheet will be

$$600\,(1 + 0.00003306 \times 68) = 600\,(1 + 0.002248) = 601.35.$$

The increase in area is therefore 1.35 sq. in. Ans.

EXAMPLES FOR PRACTICE.

1. A brass disk has a diameter of four inches at 32° F. What is its diameter at 72° F?

Ans. 4.00164 inches.

2. A copper tank holds ten gallons of ice water. How many gallons of boiling water will it hold?

Ans. 10.05 gallons.

Suppose the length of a rod to be given at a certain temperature $t°$, and we wish to find the length at some other temperature $t'°$. Inspection of equation 2 shows that we may write

$$l_{t'} = l_o (1 + at').$$

We also have directly

$$l_t = l_o (1 + at).$$

Dividing one equation by the other, we have

$$\frac{l_{t'}}{l_t} = \frac{l_o (1 + at')}{l_o (1 + at)};$$

or,

$$l_{t'} = l_t \frac{1 + at'}{1 + at} \qquad (3)$$

A more convenient form of this equation, which will give approximately correct results, is as follows:

$$l_{t'} = l_t [1 + a (t' - t)]. \qquad (4)$$

Equation 4 may be used to determine the length of a bar which has been heated through a known temperature, when the original length and the coefficient of expansion are known.

EXAMPLES FOR PRACTICE.

1. A rod of copper is 10 feet long at 25°C. What will be its length at 85°?

Ans. 10.01 feet, nearly.

2. A bar of wrought iron is 200 inches long at 40° F. What will be its length at 148° F?

Ans. 200.147 inches.

3. If the extreme difference between summer and winter temperatures is 100 degrees F, what will be the change in length of an iron bridge which is 250 feet long in summer?

Ans. 0.1705 foot shorter.

EXPANSION OF LIQUIDS.

In the case of liquids and gases we have to deal only with cubical expansion, since fluids have no definite form. The expansion of liquids is much greater than that of solids. For mercury the average coefficient between 0°C and 100°C is 0.0001825 per degree. For other liquids the expansion increases rapidly with the temperature and is very great at high temperatures. The following table gives some values for three common liquids .

TEMP.	WATER.	ALCOHOL.	ETHER.
0°	1.	1.	1.
10°	1.0001	1.0105	1.0152
20°	1.0016	1.0213	1.0312
30°	1.0041	1.0324	1.0483
40°	1.0076	1.0440	1.0665

Water presents a partial exception to the increase of volume by rise of temperature. As its temperature rises from 0° (ice just melted) to 4°C, it contracts instead of expanding, the amount of contraction being 129 parts in a million. Above 4° it expands like any other liquid.

This curious fact is of immense importance in nature. As the water of rivers and lakes cools, it becomes denser and sinks, the coldest water thus going to the bottom until 4° is reached. Below this temperature, however, the water becomes lighter as it cools, and stays at the surface. Ice thus forms first at the surface and the life beneath is protected, as ice is a poor conductor of heat. If the water contracted down to the freezing point, ice would form from the bottom up, and a pond would become a solid mass which would probably never thaw completely.

An interesting application of the expansion of liquids is in the mercurial pendulum used in large clocks (Fig. 4). The pendulum rod carries at its end a jar of glass or iron holding a quantity of mercury. A rise in temperature lengthens the rod and lowers the center of gravity of the pendulum; but the mercury also expands and rises in the jar, producing the opposite effect. In this way, by using the proper amount of mercury, it is possible to make a pendulum whose vibrations are unaffected by changes in temperature.

Fig.4.

EXPANSION OF GASES.

If we partially fill a bladder with air and place it near a fire, it will become distended, showing that the air has expanded. This expansion is practically the same for all gases, and, for each degree, is $\frac{1}{273}$ or 0.00366 of their volume at 0°C; for each degree F a gas will expand $\frac{5}{9}$ as much, or $\frac{1}{491}$ of its volume at 32° F. These figures assume that the pressure on the gas remains constant.

If then we have a quantity of gas V at 0°C, at 1° it will have the volume $\frac{274}{273}$V, at 2° it will have the volume $\frac{275}{273}$ V, and so on. We may express the general law as follows:

If V_0 be the volume at 0°C, then the volume V_t at any other temperature t will be

$$V_t = V_0(1 + \frac{t}{273}). \qquad (5)$$

Or, in decimal form,

$$V_t = V_0 (1 + 0.00366t). \qquad (6)$$

If t is below zero, we subtract the second term instead of adding it.

With this formula we may work exactly as with the formulas for the expansion of solids on page 11.

Example. Find the volume at 150°C of a gas measuring 10 cubic centimeters at 15°.

Solution. Applying formula 6 twice, we obtain

$$V_{150} = V_0 (1 + 0.00366 \times 150) = 1.549 V_0;$$

$$V_{15} = V_0 (1 + 0.00366 \times 15) = 1.0549 V_0.$$

Therefore

$$V_{150} = V_{15} \frac{1.549}{1.0549} = 10 \times \frac{1.549}{1.0549} = 14.68 \text{ cub. cm., nearly.}$$

EXAMPLES FOR PRACTICE.

1. What will be the volume of 400 cubic inches of oxygen at 0°C, when heated to 30°?

Ans. 444 cubic inches, nearly.

2. If 160 cubic centimeters of hydrogen be measured at 60° C, what will be the volume of the gas at —50°?

Ans. 110.49 cub. cm., nearly.

3. If 1,750 cubic feet of coal gas at 20°C are cooled to 0°, what will be the volume?

Ans. 1,630.6 cubic feet.

If the temperatures are expressed on the Fahrenheit scale, formula 6 becomes

$$V_{t'} = V_{32} \left[1 + 0.002035\,(t' - 32)\right], \qquad (7)$$

where t' is the temperature F.

EXAMPLES FOR PRACTICE.

1. 1,000 cubic feet of air are heated from 32° F to 90° F. What is the increase in volume?

Ans. 118 cub. ft.

2. 360 cubic feet of nitrogen at 70° F are cooled to 10° F. What is the volume after cooling?

Ans. 319.2 cub. ft.

When a quantity of gas confined in a given space is heated its pressure rises, and if the volume of the gas is kept constant the increase of pressure is very nearly the same as the above-described increase of volume at constant pressure. We may therefore deal with pressure changes due to temperature just as with changes of volume, employing formulas 6 and 7 as before.

EXAMPLE FOR PRACTICE.

A closed iron tank contains air at 50 lbs. pressure at 32° F. What will the pressure be if the temperature rises to 68° F, neglecting the effect of the expansion of the tank?

Ans. 53.66 lbs.

Since a reduction of temperature from 0° C to — 1° C is accompanied by a loss of $\frac{1}{273}$ of the pressure of a gas, it would appear that by lowering the temperature to — 273° C (= — 459°* F) all the gas pressure would disappear, and the molecules would come completely to rest. But this means, from our definition of heat, the total absence of heat energy. This point, therefore, is called the **absolute zero** of temperature. Of course it can never be reached experimentally, but recent researches have carried the range of available temperatures far down toward it. By the evaporation of liquid and solid air and hydrogen, a temperature of —260°C has been attained.

Thus we see that to reduce ordinary temperatures to absolute temperature we add 273 if we are using Centigrade units, or 461 for Fahrenheit units.

LIQUEFACTION.

When heat is applied to an amorphous substance like glass or pitch, it changes gradually from a solid to a liquid, and there is no definite point at which melting occurs; but for most crystalline substances the change from solid to liquid is well marked. For such substances, melting (also called fusion) takes place according to the following laws:

1. Every substance melts at a certain temperature, which is always the same if the pressure on the substance is the same.
2. After fusion begins, the temperature of the mass remains at the melting point until the solid is completely melted.
3. In cooling, the substance solidifies at the temperature of melting.

TABLE OF MELTING POINTS.

	Centigrade.		Centigrade.
Ether,	—117°	Zinc,	418°
Mercury,	—39.4	Silver,	908
Ice,	0	Gold,	1072
Paraffin,	46	Copper,	1082
Wood's metal,	65 to 70	Cast iron,	1100 to 1200
Sulphur,	114	Wrought iron,	1600
Tin,	232	Platinum,	1775
Lead,	327	Iridium,	1950

* NOTE. Some authorities quote —461° F.

Most substances increase in volume on melting, but some contract. The reverse change takes place on solidifying. Good castings can be made only from those metals or alloys which expand on solidifying, like cast iron and type-metal. Gold, aluminum, lead and silver must be stamped to get sharp impressions.

VAPORIZATION.

Since heat is the rapid, irregular vibratory motion of the molecules, it follows that if we add heat to a body we increase this motion. At a certain stage the vibration is so vigorous that the molecules (if the body is a solid) can no longer hold fast to one another, and the solid literally falls to pieces, that is, it melts. By applying more heat to the liquid and still further raising its temperature, we may finally reach a point at which some of the molecules are moving so violently as to escape into the air, altogether free from one another's influence. We then have a **vapor,** and the change into this aëriform condition is called **vaporization.**

If vaporization takes place slowly, and only at the surface of a liquid, it is called **evaporation.** Evaporation will be hastened by anything that facilitates the escape of molecules from the liquid surface, as by increasing the temperature of the liquid, lowering the pressure on it, or causing a breeze to play over the surface.

The fact that heat is due to molecular motion explains why evaporation is a cooling process. Naturally those molecules will escape first whose motion is most violent, that is, whose temperature is highest. The more sluggish (and therefore colder) molecules stay behind. Thus, as the liquid evaporates, the departing molecules take with them more than their proportionate share of heat, and the remaining liquid grows colder.

Cooling by evaporation may be illustrated by a simple experiment. Drop about a teaspoonful of water on a table or smooth board, and set a small tin dish on the water. Pour three or four tablespoonfuls of ether into the dish, and blow upon it with a pair of bellows. After two or three minutes of vigorous blowing, the dish will be found frozen fast to the board. (Caution.— *Keep ether away from lights.* Ether vapor is highly inflammable.)

When water is heated over a flame, the air (or any other gas) present is first driven off in tiny bubbles which rise to the surface and escape without noise. When the water nearest the flame is raised to the boiling point, bubbles of vapor are formed, which also rise through the water, but are condensed by the cooler layers before getting to the surface. This formation and condensation of steam bubbles produces the sound known as singing or simmering. The "water hammer" in steam pipes is of a somewhat similar nature but on a larger scale. When the entire mass is heated to the boiling point, the steam bubbles rise to the surface and break, discharging their contents into the air with a characteristic noise. This stage is called **ebullition** or boiling.

Like air, steam is colorless, transparent and invisible. What is commonly called "a cloud of steam" is really a cloud of fine water particles condensed from steam. Observe any steam jet, and notice that at the end of the pipe nothing whatever can be seen, the jet becoming visible only after it has gone far enough from the pipe to be cooled and condensed.

The increase of volume by vaporization is usually very great. For example, a cubic inch of water will make 1,661 cubic inches of steam at atmospheric pressure.

By increasing the pressure on the surface of a boiling liquid, we make it more difficult for the molecules to escape; they cannot escape unless given more motion, that is, unless they have a higher temperature than before. In other words, an increase of pressure raises the boiling point. The following table gives the boiling point of water under different pressures, as measured by a steam gage:

BOILING POINT OF WATER.

GAGE PRESSURE.	TEMPERATURE, FAHR.
0 (atmosphere)	212°
50 lbs.	297.4
100 "	337.6
150 "	365.7
200 "	387.8

The laws of vaporization are similar to the laws of fusion given on page 15. The following table gives the boiling points in degrees Centigrade of some liquids, under a pressure of one atmosphere:

BOILING POINTS.

Liquid air,	—188°	Chloroform,	61.2°
Ammonia,	— 38.5	Alcohol,	78.4
Sulphurous anhydride,	— 10 1	Mercury,	357.
Ether,	34.9	Sulphur,	444.5

DISTILLATION.

The difference in the boiling points of substances has an important application in the arts, in the separation of liquids from

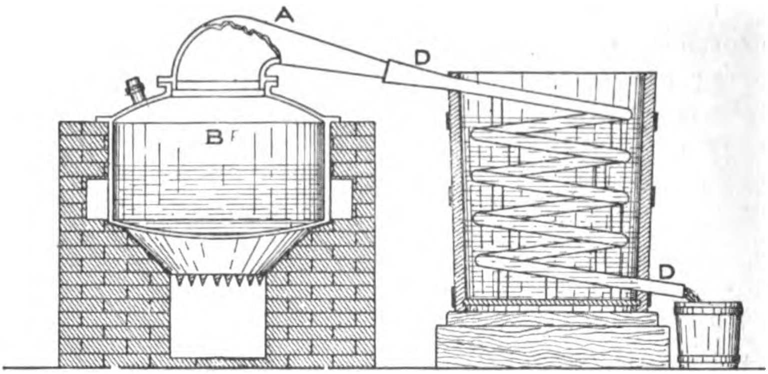
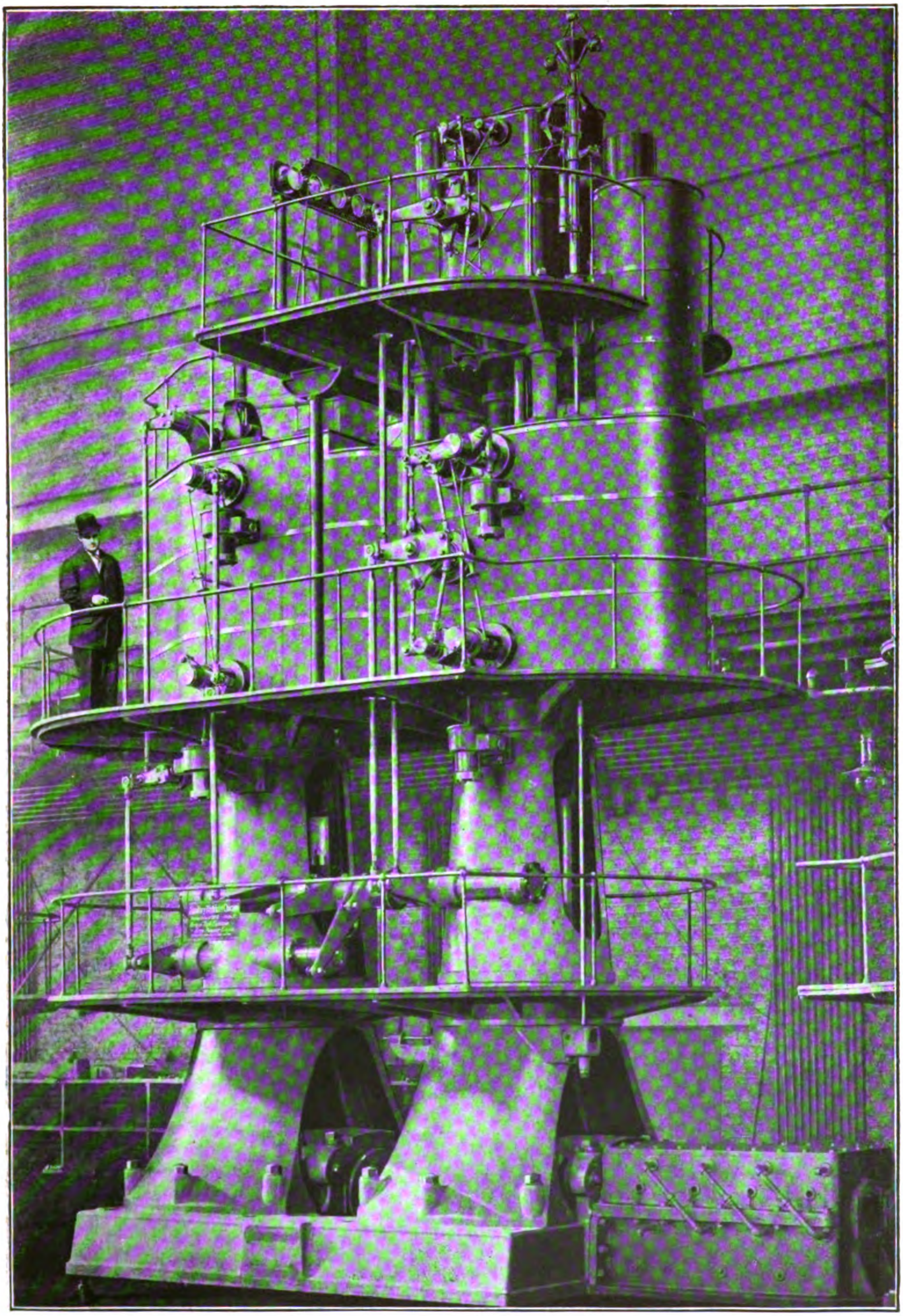


Fig. 5.

solids, or of liquids from each other. The simple removal of a liquid from a solid, as in evaporating brine to recover the salt, needs no special appliances; but when the evaporated liquid is to be saved, an apparatus called a **still** is used, and the process is called **distillation.**

A still consists essentially of two parts: a *retort* in which the liquid is vaporized, and a *condenser* in which it is reduced to liquid again. Fig. 5 shows a form of the apparatus for separating a liquid from a solid, or one liquid from another of different boiling point, such as alcohol and water. The mixture is poured into the retort B, and then heated to about 90° C, which is above the boiling point of alcohol but below that of water. The vaporized alcohol escapes through A to the *worm* D. This is a simple



VERTICAL TRIPLE EXPANSION ENGINE BUILT TO OPERATE ONE OF THE SCREW PUMPS IN THE 39TH STREET SEWAGE PUMPING STATION, CHICAGO, ILL.

Allis-Chalmers Co., Milwaukee, Wis.

helical coil of pipe surrounded by cold water, and serving to condense the vapor, which runs out as a liquid at the bottom. The cooling water is constantly changed by supplying fresh cold water at the bottom and drawing off the heated water from the top.

This process is called **fractional distillation,** and is carried out on an enormous scale in the refining of petroleum. When the distillate is to be very pure, it is necessary to repeat the operation one or more times. When practicable, especially with inflammable liquids, the heating is done by steam pipes supplied from a distant boiler.

THE MEASUREMENT OF HEAT. Heat Units.

There are two units of measurement for determining quantities of heat. The **British thermal unit** (often abbreviated B. T. U.) is the amount of heat required to raise one pound of water from 59° to 60° Fahrenheit. The French unit, or **calorie,** is the amount of heat required to raise the temperature of one gram of water from 15° to 16° Centigrade. The former is much used in engineering calculations involving steam and fuels, and the latter in all other scientific work.

LATENT HEAT.

If we put a block of very cold ice into a vessel over a flame and insert a thermometer into the ice, we shall observe the thermometer rise to 0° C, at which point the ice begins to melt. The temperature of the ice and water then shows no further change until all the ice has melted, though the heat is applied continuously. Only after the melting is complete will the temperature of the water begin to rise. It will then increase until 100° C is reached, when ebullition begins, the temperature not rising above 100° until all the water has boiled away.

We thus see that in changing from ice to water and from water to steam there is absorbed a considerable quantity of heat which does not show on the thermometer. The quantities of heat absorbed in the processes of fusion and vaporization are called the *latent heat of fusion* and the *latent heat of vaporization* respectively.

The following example shows how the latent heat of fusion of ice may be measured. If we mix a gram of water at 80° C with a gram at 0°, we get, as we should expect, two grams at 40°. But if we mix a gram of water at 80° with a gram of ice at 0°, we get two grams of water as before, but the temperature is 0° instead of 40°. The heat which in the first case raised the temperature of the water has in the second case been needed merely to melt the ice. The calculation of the latent heat is made in the following way:

One gram of water falling through 80 degrees of temperature will give out 1 × 80, or 80 calories. This quantity of heat is required to change one gram of ice at 0° into water at 0°. Therefore the latent heat of fusion of ice is 80; in other words, the heat which will just melt a quantity of ice will raise 80 times as much water one degree C.

By a somewhat similar method it is found that the latent heat of vaporization of water at atmospheric pressure is 536.5. That is, to evaporate one gram of water (already at the boiling point) will require as much heat as would raise the temperature of 536.5 grams one degree, or 5.365 grams from freezing to boiling (0° to 100° C).

Expressed in terms of the Fahrenheit degree and the British thermal unit, the latent heats of fusion and vaporization are 144 and 966 respectively.

The large values of these quantities are of the greatest importance both in nature and in the arts. The great amount of heat necessary to melt the ice of winter makes the melting a slow process, and lessens the danger of destructive floods in the spring. In the autumn the water in freezing gives out again the heat absorbed in melting, and the transition to winter is thus rendered less abrupt.

Since a pound of steam in condensing will give out as much heat as 53.65 pounds of water cooling from 100° C to 90° C, or from 90° to 80°, it follows that steam pipes for heating may be made smaller than water pipes for the same service. It also shows the value of steam as a carrier of heat; and in the arts advantage of this is taken in innumerable ways. (See also page 19).

SPECIFIC HEAT.

When equal quantities of different substances are raised equally in temperature, different amounts of heat are required; and in cooling through equal temperature intervals different substances give out different amounts of heat.

For example, if we mix a pound of water at 80° C with a pound at 0° C, we get two pounds at 40°; but if we pour a pound of lead shot at 80° into a pound of water at 0°, the resulting temperature will be only 2.3°. A pound of lead, therefore, falling through 77.7 degrees of temperature, is able to raise a pound of water only 2.3 degrees. The fall of temperature of the hot body is nearly twice as great as in the first case, and the heat given out in the fall only about one-seventeenth as much. The heat capacity of the lead is therefore much less than that of the water.

If we know how much heat will raise the temperature of a given substance a certain amount, and how much is required to raise the temperature of an equal quantity of water by the same amount, then the ratio of these two quantities is called the specific heat of the substance. In other words, if we take the specific heat of water as our standard (as we practically do in defining the units of heat), the specific heat of a substance is expressed by the number of heat units required to raise the unit quantity of the substance one degree in temperature.

One of the simplest methods of determining specific heat is by mixing the substance with water. Suppose that 6 pounds of mercury at 100°C are poured into 2 pounds of water at 0°C, and that the resulting temperature of the "mixture" is 9°. The specific heat S of the mercury can then be found as follows:

In falling from 100° to 9° the 6 pounds of mercury give out $6 \times (100 - 9) \times S$, or 546 S heat units. These have gone to heat 2 pounds of water from 0° to 9°, which requires 2×9, or 18 heat units. Hence we may write

$$546\ S = 18$$

Therefore $$S = 0.033.$$

EXAMPLE FOR PRACTICE.

Half a pound of a metal at 212° F is dropped into one pound of water at 68° F. The temperature of the mixture is then observed to be 76° F. What is the specific heat of the metal?

Ans. 0.117.

TABLE OF SPECIFIC HEATS.

Hydrogen,	3.4090	Wrought iron,	0.1124
Alcohol,	0.602		
Ammonia (gas),	0.5084	Copper,	.0949
Ice,	.5040		
Air,	.2375	Zinc,	.0935
Aluminum,	.2122	Tin,	.0562
Glass,	.193 to .198	Mercury,	.0330
Cast iron,	.1298	Lead,	.0314
Steel,	.1181		

With the foregoing principles and the help of suitable tables, many problems can be solved. For example, let us find how many calories will be required to convert 10 grams of ice at — 12° C into steam at 100° C.

Solution. Required to raise the ice from — 12° to 0°,

$$10 \times 12 \times 0.504 = 60.48 \text{ calories.}$$

Required to melt the ice,

$$10 \times 80 = 800 \text{ calories.}$$

Required to raise the water from 0° to 100°,

$$10 \times 100 = 1{,}000 \text{ calories.}$$

Required to vaporize the water,

$$10 \times 536.5 = 5{,}365 \text{ calories.}$$

Total number of calories required,

$$60.48 + 800 + 1{,}000 + 5{,}365 = 7{,}225.5 \text{ (nearly).}$$

EXAMPLES FOR PRACTICE.

1. What weight of water at 75° C will just melt 15 pounds of ice at 0°?

Ans. 16 pounds.

2. One kilogram of water at 40°, 2 kilograms at 30°, 3 kilograms at 20°, and 4 kilograms at 10° are mixed. Find the temperature of the mixture.

Ans. 20°.

3. How many heat units will be required to melt 5 grams of ice at — 20° C? How many grams of water at 50° C would do it?

Ans. 450.4 heat units; 9.01 grams.

If we wish to use Fahrenheit degrees and British thermal units in our calculations, it is necessary to remember that the numbers representing the heats of fusion and of vaporization are different, but that the specific heat, which is a mere ratio, is the same in both systems.

For example, let us find how many B. T. U. are required to convert 12 lbs. of ice at 10° F into steam at 212° F.

Solution. Required to raise the ice from 10° F to 32° F,

$$12 \times 22 \times 0.504 = 133.056 \text{ B. T. U.}$$

Required to melt the ice,

$$12 \times 144 = 1{,}728 \text{ B. T. U.}$$

Required to raise the water from 32° to 212°,

$$12 \times 180 = 2{,}160 \text{ B. T. U.}$$

Required to vaporize the water,

$$12 \times 966 = 11{,}592 \text{ B. T. U.}$$

Total number of B. T. U. required,

$$133.056 + 1{,}728 + 2{,}160 + 11{,}592 = 15613 \text{ (approx.)}.$$

EXAMPLE FOR PRACTICE.

How many B. T. U. are required to convert 10 lbs. of ice at 15° F into steam at 212° F?

Ans. 12,985 B. T. U.

For ordinary purposes we may proceed as above; but as the specific heat and latent heat of water vary for different temperatures, we must, where great accuracy is necessary, employ a table of the properties of steam and water.

THE PROPERTIES OF STEAM.

The relation between the external pressure and the boiling point of water is a perfectly definite one, but cannot be exactly expressed by any mathematical equation. In dealing with this and other properties of steam and water, it is therefore customary to refer to suitable tables where the values are given, as determined by experiment. Such tables are called **steam tables**, and are much used in engineering calculations.

In the following table are given (1) the pressure above absolute vacuum, (2) the corresponding temperature, (3) the amount of heat in B. T. U. required to raise a pound of water from 32° F to the given temperature, (4) the amount of heat in B. T. U. required to vaporize a pound of water at the given temperature; (5) equals the sum of (3) and (4).

A steam gage measures pressures above the atmospheric pressure; hence, when readings are taken from a steam gage, the barometric pressure (averaging 14.7 lbs. per sq. in., or in round numbers 15 lbs.) must be added to obtain the "absolute" pressure.

With a steam table we can extend considerably the range of problems like those on page 23. For example, let us find how many pounds of steam at 65 lbs. gage pressure will be needed to raise the temperature of 60 pounds of water from 50° F to 100° F.

Solution. To raise one pound of water from 50° to 100° requires 50 B. T. U.; and for 60 pounds we need 50 × 60, or 3,000 B. T. U. At 65 lbs. gage pressure (80 lbs. absolute) the total heat of one pound of steam is 1,177 B. T. U., and this amount would all be available if we cooled it down to 32° F. But since the cooling is not carried below 100° F, we cannot use 100—32,

TABLE OF PROPERTIES OF SATURATED STEAM.

Pressure in pounds per sq. in. above vacuum.	Temperature in degrees Fahrenheit.	Heat in liquid from 32° in units.	Heat of vaporization, or latent heat in heat units	Total heat in heat units from water at 32°.	Density or weight of cubic ft. in pounds.	Volume of 1 pound in cubic feet.	Total pressure above vacuum.
1	101.99	70.0	1043.0	1113.1	0.00299	334.5	1
2	126.27	94.4	1026.1	1120.5	0.00576	173.6	2
3	141.62	109.8	1015.3	1125.1	0.00844	118.5	3
4	153.09	121.4	1007.2	1128.6	0.01107	90.31	4
5	162.34	130.7	1000.8	1131.5	0.01366	73.21	5
6	170.14	138.6	995.2	1133.8	0.01622	61.67	6
7	176.90	145.4	990.5	1135.9	0.01874	53.37	7
8	182.92	151.5	986.2	1137.7	0.02125	47.06	8
9	188.33	156.9	982.5	1139.4	0.02374	42.12	9
10	193.25	161.9	979.0	1140.9	0.02621	38.15	10
14.7	212.00	180.9	965.7	1146.6	0.03794	26.36	14.7
15	213.03	181.8	965.1	1146.9	0.03826	26.14	15
20	227.95	196.9	954.6	1151.5	0.05023	19.91	20
25	240.04	209.1	946.0	1155.1	0.06199	16.13	25
30	250.27	219.4	938.9	1158.3	0.07360	13.59	30
35	259.19	228.4	932.6	1161.0	0.08508	11.75	35
40	267.13	236.4	927.0	1163.4	0.09644	10.37	40
45	274.29	243.6	922.0	1165.6	0.1077	9.287	45
50	280.85	250.2	917.4	1167.6	0.1188	8.414	50
55	286.89	256.3	913.1	1169.4	0.1299	7.696	55
60	292.51	261.9	909.3	1171.2	0.1409	7.097	60
65	297.77	267.2	905.5	1172.7	0.1519	6.583	65
70	302.71	272.2	902.1	1174.3	0.1628	6.143	70
75	307.38	276.9	898.8	1175.7	0.1736	5.762	75
80	311.80	281.4	895.6	1177.0	0.1843	5.426	80
85	316.02	285.8	892.5	1178.3	0.1951	5.126	85
90	320.04	290.0	889.6	1179.6	0.2058	4.859	90
95	323.89	294.0	886.7	1180.7	0.2165	4.619	95
100	327.58	297.9	884.0	1181.9	0.2271	4.403	100
105	331.13	301.6	881.3	1182.9	0.2378	4.205	105
110	334.56	305.2	878.8	1184.0	0.2484	4.026	110
115	337.86	308.7	876.3	1185.0	0.2589	3.862	115
120	341.05	312.0	874.0	1186.0	0.2695	3.711	120
125	344.13	315.2	871.7	1186.9	0.2800	3.571	125
130	347.12	318.4	869.4	1187.8	0.2904	3.444	130
140	352.85	324.4	865.1	1189.5	0.3113	3.212	140
150	358.26	330.0	861.2	1191.2	0.3321	3.011	150
160	363.40	335.4	857.4	1192.8	0.3530	2.833	160
170	368.29	340.5	853.8	1194.3	0.3737	2.676	170
180	372.97	345.4	850.3	1195.7	0.3945	2.535	180
190	377.44	350.1	847.0	1197.1	0.4153	2.408	190
200	381.73	354.6	843.8	1198.4	0.4359	2.294	200
225	391.79	365.1	836.3	1201.4	0.4876	2.051	225
250	400.99	374.7	829.5	1204.2	0.5393	1.854	250
275	409.50	383.6	823.2	1206.8	0.5913	1.691	275
300	417.42	391.9	817.4	1209.3	0.644	1.553	300
325	424.82	399.6	811.9	1211.5	0.696	1.437	325
350	431.90	406.9	806.8	1213.7	0.748	1.337	350
375	438.40	414.2	801.5	1215.7	0.800	1.250	375
400	445.15	421.4	796.3	1217.7	0.853	1.172	400
500	466.57	444.3	779.9	1221.2	1.065	.939	500

or 68 B. T. U., and the amount available is therefore 1,177 — 68 = 1,109 B. T. U.

The quantity of steam therefore needed is

$$\frac{3,000}{1,109} = 2.705 + \text{pounds.}$$

Ans. 2.705 + pounds.

The small quantity of steam in this example well illustrates the great heating power of steam.

EXAMPLES FOR PRACTICE.

1. How many pounds of steam at 100 lbs. absolute pressure will raise 250 pounds of water from 50° F to 150° F?

Ans. 23.5 pounds.

2. How many pounds of steam at 35 pounds gage pressure will just melt 1,000 pounds of snow at 32° F?

Ans. 123.3 pounds.

It will be seen that the values of the total heat column in the table increase but slowly, while the pressure and temperature increase rapidly. A pound of high-pressure steam thus contains but little more heat than a pound of low-pressure steam, and consequently requires but little more fuel to produce it. Since high-pressure steam is more effective in steam engines, there is therefore a decided thermodynamic advantage in using steam of the highest practicable pressure.

Superheated Steam. From the table we see that there is a perfectly definite temperature for steam at any given pressure. Steam or other vapors in this condition are said to be **saturated**, for if the temperature is lowered some of the vapor will condense immediately into liquid. If, however, we pass steam through a separately heated pipe or chamber it is easily possible to raise its temperature by any desired amount above the given values. Steam in this condition is called **superheated**. For steam engines it has certain advantages over saturated steam, which are discussed in the Instruction Papers on the Steam Engine.

TRANSFER OF HEAT.

Heat may be transferred from one body to another by conduction, convection or radiation.

Conduction. When one end of a metal bar is heated in the fire the other end gradually becomes warmer. The heated molecules communicate their motion to their immediate neighbors; and the heat thus travels along the bar, and may be removed by a cold body at the distant end. This process is called conduction. In this way the heat of a boiler furnace is communicated to the water in the boiler.

A brass pin held in a gas flame will burn the fingers almost in-

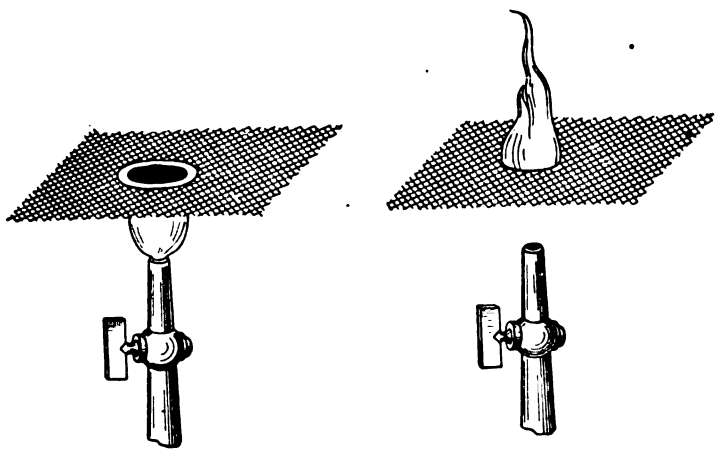


Fig. 6.

stantly, while a bit of glass may be melted at one end before the other becomes hot, and a match may be burned to the finger-tips without discomfort. It is thus clear that substances differ greatly in conductivity. There are great differences even among metals; a copper rod will conduct heat much more rapidly than an iron rod.

If a piece of wire gauze is held over an unlighted gas jet, the gas may be lighted on either side (Fig. 6), but the flame will not pass through the meshes. The wires conduct the heat away so rapidly that the gas on the other side does not get hot enough to ignite. This is the principle of the safety lamp, used in coal mines where inflammable gases collect. The lamp flame is surrounded by a wire gauze, and thus kept from igniting the dangerous gases outside.

The following table gives the relative conductivity of several substances. The table well shows the great value of a layer of snow as a protective blanket on the earth:

RELATIVE THERMAL CONDUCTIVITIES.

Silver,	100	Lead,	7
Copper,	66 to 74	Marble,	0.0074
Brass,	18 to 23	Ice,	0.0052
Iron,	15	Snow,	0.00046

Convection. Excepting mercury, liquids and gases are poor conductors of heat; but when such bodies are heated from below, the heated portion expands and rises through the mass, and is replaced below by a colder portion, which is heated and rises in its turn. In this way what are called **convection currents** arise, and the heat is distributed throughout the fluid by actual motion within the mass itself. The heating of houses by hot water is an application of this principle.

Convection also takes place in gases; the winds of the atmosphere illustrate it on a large scale.

Radiation. We have seen that the molecules of a hot body are in very rapid vibration. Some of the energy of this vibration is communicated in the form of waves to the space surrounding the body. If the motion happens to lie within certain limits, the waves affect our eyes and we call them light-waves. But all such waves, visible or otherwise, represent energy which is sent out by the hot body. When they fall upon any other body, they are either reflected or absorbed and transformed into heat. Polished silver reflects over 90 per cent of the waves falling on it; charcoal absorbs nearly all, and hence rises in temperature when exposed to the radiations of a hot body.

Energy in this form is called radiant energy. By it the heat of the sun is transmitted to the earth. Since it is in the form of ether-waves, many of the experiments ordinarily performed with light-waves may be repeated with the radiations from a hot body, whether visible or not. The common burning-glass shows the result of bringing such rays to a focus by refraction. If a pair of concave mirrors be set facing each other, as shown in Fig. 7, and a source of heat be placed in the focus of one, a thermometer in the focus of the other will quickly show a rise in temperature though the mirrors are many feet apart.

It does not follow, however, that bodies transparent to light are equally transparent to other radiations. Glass, for example, is quite opaque to the invisible radiations that are most effective in

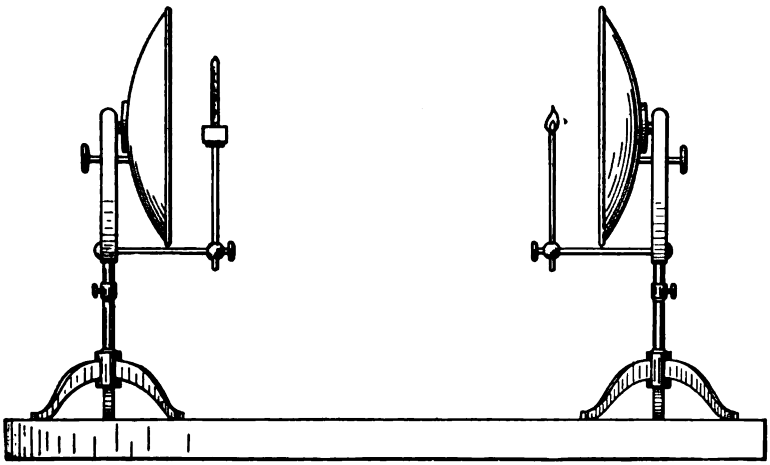


Fig. 7.

producing heat. Also, a solution of alum in water will cut off most of these radiations, while allowing the light-waves to pass freely; and a glass tank of alum water is often used in stereopticons to keep the heat of the lamp from the rest of the apparatus.

It is important to note that though the radiation from a hot body is often called radiant heat, yet in the process of transmission it is not heat at all, but a wave motion in the ether, which is energy of a very different kind. A somewhat analogous case is present in the incandescent lamp; the heat which appears at the lamp does not come along the wires as heat, but as electrical energy, which is altogether different. It is indeed transformed into heat in the lamp, but is not itself heat. In like manner, radiant energy is transformed into heat only by falling on some body which absorbs it. It is thus possible to make a good burning-glass by shaping a piece of clear ice into the form of a lens, a thing which would clearly be impossible if the energy passing through the ice lens were in the form of heat.

THERMODYNAMICS.

This is the science which deals with the relations between heat and mechanical energy. It rests on two fundamental propositions called the first and second laws of thermodynamics.

The **first law** states that when heat is transformed into

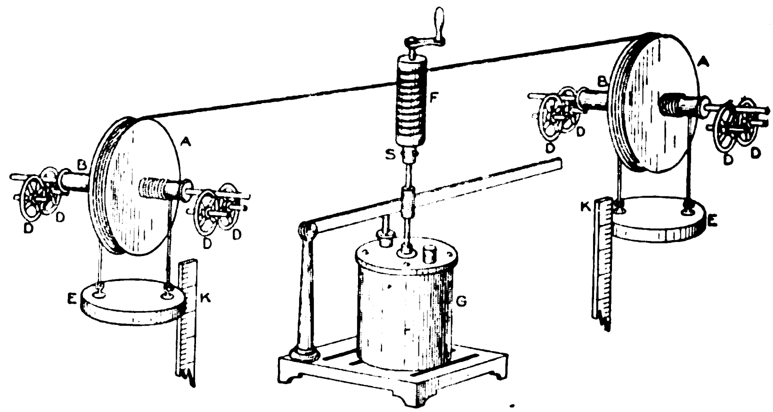


Fig. 8.

mechanical energy, or the reverse, the quantity of heat is always exactly equivalent to the quantity of mechanical energy.

The production of heat by friction is familiar to every one; but it is not so clear that there is an exact equivalence between the energy lost by friction and the heat produced. Joule was the first to establish the relation accurately. The principle of his apparatus is shown in Fig. 8. The falling weights EE turned a paddle-wheel stirrer inside the cylindrical vessel G, which was filled with water and was much like the common ice-cream freezer. The friction of the stirrer heated the water; and when the distance was measured through which the weights fell, it was possible to calculate the relation between the work done by the falling weights and the heat developed in the water.

Later experiments on a larger scale have given results which are more accurate than was possible with this apparatus. The values now accepted are the following:

427.3 kilogrammeters of work or energy are required to raise the temperature of one kilogram of water from 15° to 16° C at sea-level, in latitude 45°.

In English units, 778.8 foot-pounds of work are required to raise the temperature of one pound of water from 59° to 60° Fahrenheit at sea-level, in latitude 45°.

These values vary slightly for different places, because the weight of a pound depends on the pull of gravity, and this varies in different places; but for most engineering purposes 779 foot-pounds would be near enough.

This law states in effect that we cannot get energy for nothing. Whenever we get work from heat, a definite quantity of heat disappears; and whenever we convert mechanical energy into heat, we must expend 779 foot-pounds for every British thermal unit produced.

The **second law** of thermodynamics asserts that heat cannot of itself pass from a cold to a hot body. Since a hot body in cooling gives out heat which, in part at least, may be converted into work, it might seem that by cooling it indefinitely we could get an infinite amount of work from it But the second law declares that the process stops as soon as the hot body has cooled to the temperature of its surroundings; and if we wish to cool it further we must expend energy in so doing. It follows from this that no heat engine can convert into work all the heat which it receives. As soon as the steam (or other working fluid) has fallen to the temperature of the exhaust, the remaining heat in it is no longer available for doing useful work. If the heat is supplied at the absolute temperature T_1 and the exhaust is at the temperature T_2, the efficiency of the engine cannot be greater than $\frac{T_1 - T_2}{T_1}$, no matter what is used as the working fluid of the engine.

THERMODYNAMICS OF PERFECT GASES.

The subject of thermodynamics cannot be fully treated by elementary methods of analysis; in the following brief discussion, however, no advanced methods are used.

The thermodynamics of steam will be more readily understood by first taking up the simpler case of a perfect gas. Air, oxygen, nitrogen, hydrogen and some others, behave very nearly as perfect gases; others, as ammonia, carbon dioxide and sulphur dioxide, do not.

Boyle's Law. The product of the pressure P and the volume V of a perfect gas is constant if the temperature is constant; that is, if at a pressure P_1 a body of gas has the volume V_1, and at some other pressure P_2 has the volume V_2, then

$$P_1V_1 = P_2V_2 = \text{constant.}$$

Example. If 12 cubic feet of air at 135 pounds absolute pressure expand to 27 cubic feet at the same temperature, what will be the pressure? What pressure would a gage indicate?

Solution. $P_{135}V_{135} = P_{27}V_{27}$

$$135 \times 12 = P_{27} \times 27$$

Therefore $P_{27} = 60$ pounds, absolute.

Gage pressure = absolute pressure — atmospheric pressure.

$$P_{gage} = 60 - 14.7 = 45.3 \text{ pounds.} \quad \text{Ans.}$$

EXAMPLE FOR PRACTICE.

Ten cubic feet of air at 2.3 lbs. gage are compressed until the gage pressure is 7.3 lbs. Find the volume.

Ans. 7.727 cub. ft.

Since one pound of air at 32° F occupies 12.387 cubic feet, we may calculate the product PV of a pound of air as follows:

$$V = 12.387$$

$$P = 14.7 \times 144 = 2{,}117 \text{ (nearly).}$$

Hence $PV = 2{,}117 \times 12.387 = 26{,}223.$

Law of Boyle and Charles. For a perfect gas the product PV is proportional to the absolute temperature T. In the form of an equation, this becomes $\frac{PV}{T}$ = constant, or $PV = \text{constant} \times T$.

This is usually written $PV = RT$. For air we may easily calculate R as follows: We have just seen that at 32° F, $PV = 26,223$, and $T = 32 + 461$, or 493° absolute temperature. Therefore,

$$\frac{26,223}{493} = R = 53.2.$$

Example. What volume will be occupied by a pound of air at 50° F and 40 pounds pressure (absolute) per sq. in.?

Solution. $P = 40 \times 144 = 5,760$ lbs. per sq. ft.

$T = 50 + 461 = 511°$ absolute temperature.

Therefore $5,760 \times V = 53.2 \times 511.$

$$V = \frac{53.2 \times 511}{5,760}.$$

$V = 4.72$ cub. ft. (nearly).

Example. A quantity of air at 75 lbs. gage pressure and 60° F is heated to 90° F. What is the pressure?

Solution. Since the volume is unaltered, the pressure is proportional to the absolute temperature. We have

$60° F = 60 + 461 = 521°$ absolute.

$90° F = 90 + 461 = 551°$ absolute

Therefore $P_1 : P_2 :: T_1 : T_2.$

$$P_2 = \frac{T_2}{T_1} \times P_1.$$

$$P_2 = \frac{551}{521} \times (75 + 14.7) = 94.86 \text{ lbs.} \quad \text{Ans.}$$

EXAMPLES FOR PRACTICE.

1. What is the weight of 6 cubic feet of air at 60° F and 25 pounds absolute pressure per square inch?

Ans. .78 lbs.

SUGGESTION. First find the volume of one pound under the given conditions.

2. A reservoir containing 4 cubic feet of air at a temperature of 40° F and a pressure of 100 pounds per square inch abs., is heated to 80° F. What will the pressure be, and how much does the air weigh?

Ans. { 107.98 + lbs.
2.16 + lbs.

Isothermal and Adiabatic Expansion. When a gas expands and does work, as by pushing a piston in a cylinder, we see from the first law of thermodynamics that the equivalent in the form of heat must be supplied from somewhere. If the temperature of the gas is to be kept constant, heat must be supplied to it from the outside, in exact equivalent to the work done. In such cases the expansion is said to be **isothermal**, and the relation between pressure and volume is as shown by the dotted curve I of Fig. 9. This curve is an equilateral hyperbola. But if no heat be allowed to enter the gas, as would be the case if the cylinder and piston were perfect non-conductors of heat, the work done in expansion will be at the expense of the heat energy in the gas itself, and its temperature will therefore fall during the expansion. We have seen that the pressure is less as the temperature falls, other things being equal; hence under the conditions the pressure will fall faster than if the temperature were kept up by the addition of heat from outside. This is shown by the curve A of Fig. 9. Curves of this kind, representing expansion or compression without communication of heat to or from the gas, are called **adiabatics.** It is evident that adiabatic expansion along A from v_2 to v_1 is accompanied by a greater fall of pressure than isothermal expansion along I.

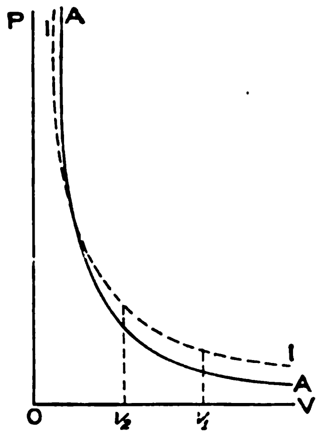


Fig. 9.

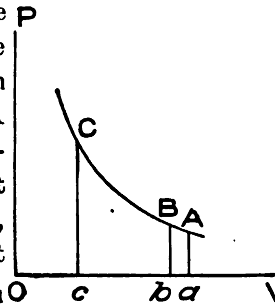
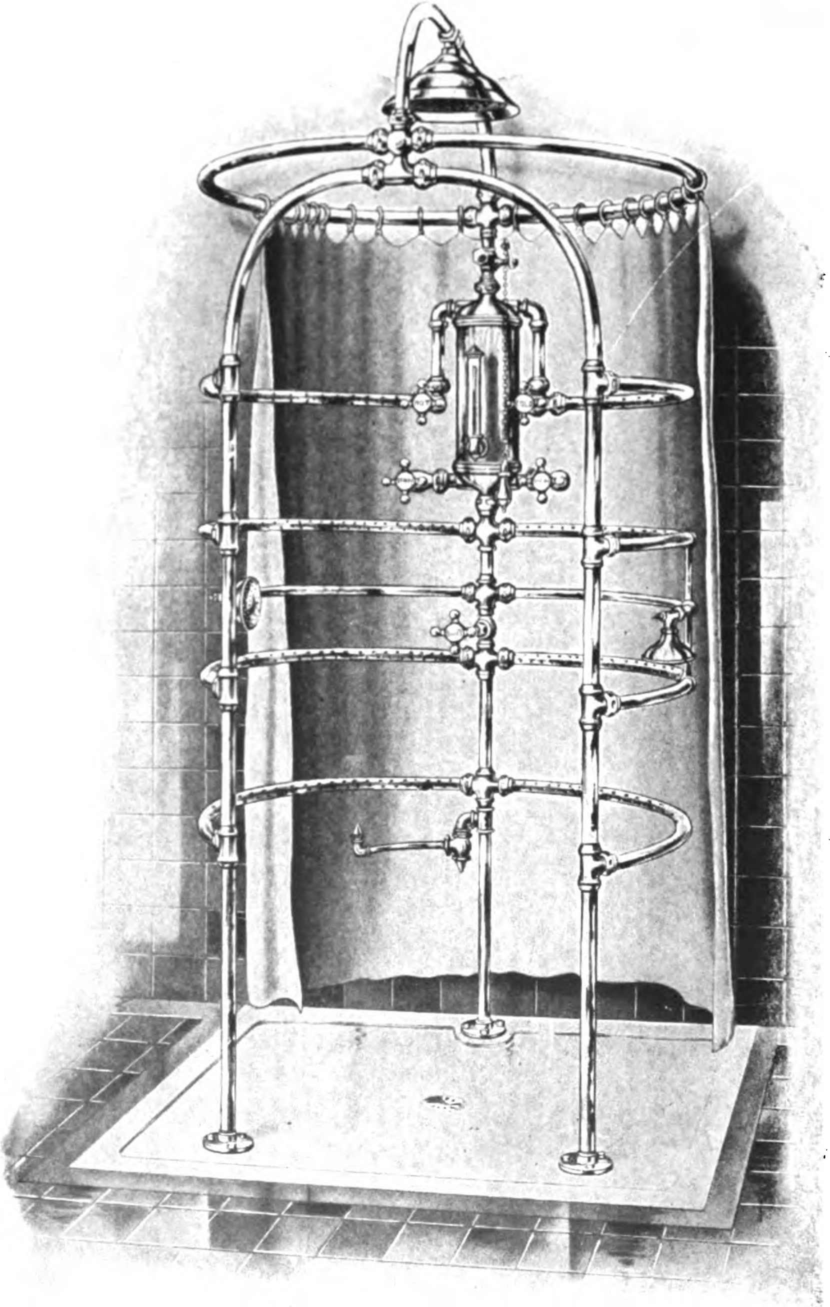


Fig. 10.

Both isothermal and adiabatic curves are of great importance



COMBINED NEEDLE AND SHOWER BATH ARRANGED FOR HOT AND COLD WATER.
The Federal Company.

in thermodynamic studies, but they represent conditions that are only imperfectly realized in practice. The general expression for an adiabatic curve is PV^n = constant. For air, n = 1.405. Most problems involving adiabatic and isothermal curves cannot be solved without the aid of higher mathematical processes than are used in this Paper.

Work Done in Expansion. Suppose we have a piston whose

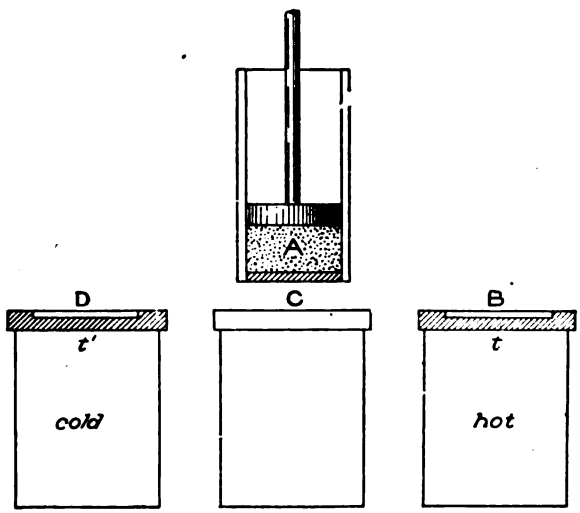


Fig. 11.

area is A square inches, which is acted upon by a pressure of p pounds per square inch, and which moves through a distance of m feet in consequence. Then the total pressure is pA pounds, and the work done is $p\text{A} \times m$ foot-pounds. But $\text{A} \times m$ is the volume of the cylinder swept out by the piston in its stroke; and calling this V, we have:

$$\text{Work done} = \text{pressure} \times \text{volume} = \text{PV}.$$

This can be conveniently shown on the pressure-volume diagram. Suppose B (Fig. 10) represents the pressure and volume of a gas, which then expands a little to the condition A. Then the average pressure during the expansion will be $\frac{1}{2}$ (Bb + Aa), and the work done will be $\frac{1}{2}(\text{B}b + \text{A}a) \times ab$ = the area BAab.

Since we may regard the whole change from C to A as made up of portions like that from B to A, it follows that in changing from C to A along the path CBA the expanding gas will do the work represented by the area CA*ac*.

The Carnot Cycle. This principle can be applied to the operation of heat engines. Let the working substance of a heat engine be a gas A, enclosed in a cylinder (Fig. 11) with non-conducting walls and piston and a perfectly conducting bottom. Let B be a hot body kept at the temperature t, and D a cold one kept at the temperature t'; and let C be a nonconducting stand. Then we may imagine the gas to undergo the following cycle of operations:

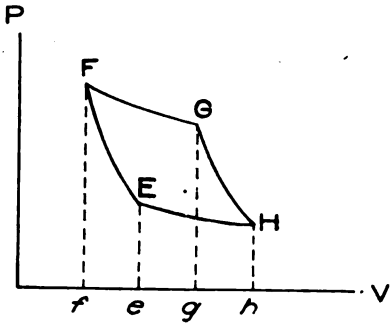


Fig. 12.

1. Set the cylinder on the stand C, with the gas at the temperature t', and compress the gas adiabatically until its temperature rises to t. On the pressure-volume diagram (Fig. 12), this stage will be represented by the line EF, starting at E. The work done in compressing will be represented by the area EF*fe*.

2. Transfer the cylinder to the hot body B (Fig. 11), and allow the piston to rise by the expansion of the compressed gas. To maintain the temperature t during expansion, a certain quantity Q of heat must be supplied from B. This stage will be represented by the isothermal line FG (Fig. 12), and the work done by the expanding gas by the area FG*gf*.

3. Set the cylinder on the stand C (Fig. 11), and allow the gas to expand still further, until it cools to the temperature t'. This change is shown by the adiabatic line GH (Fig. 12), and the work done in the expansion by the area GH*hg*.

4. Place the cylinder on D and push the piston down to its first position. The heat Q' developed by the compression will be removed by the cold body D, and the temperature of the gas will remain unchanged. The change is shown by the isothermal line HE (Fig. 12), and the work done on the gas by the area HE*eh*.

The gas has now reached its initial condition. It has done an amount of work represented by the area FGHhf, and has had done on it the work represented by HEFfh. The difference EFGH is the net work done in the cycle; and to do it, it has been necessary to take a quantity of heat Q from the hot body, and to discharge a quantity Q′ into the cold body. The efficiency of the operation is

$$\frac{\text{Heat utilized}}{\text{Heat received}} = \frac{Q - Q'}{Q}.$$

The above cycle of operations is called the Carnot cycle, because Carnot first applied it as a method of reasoning. The efficiency of a steam engine working on the above cycle can be shown as follows:

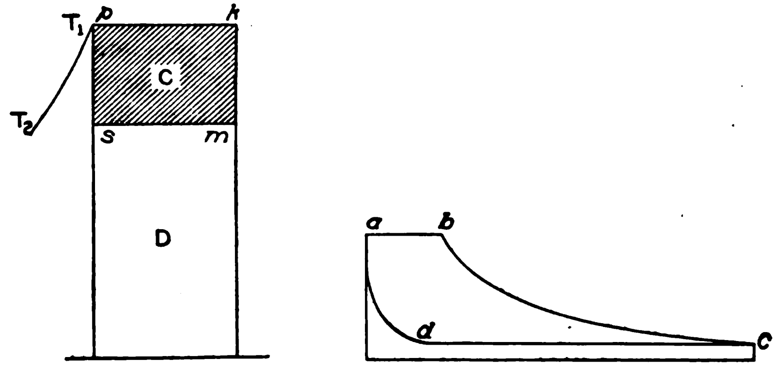


Fig. 13.

Instead of drawing a pressure-volume diagram whose vertical distances are pressures and whose areas represent work, let us draw one whose vertical distances are temperatures and whose areas represent the quantities of heat added during any change in the working fluid. A diagram of this kind is called a temperature-entropy diagram. Starting with a pound of water at T_1 (Fig. 13), let us convert it completely into steam at that temperature. This will be represented in our diagram by the line pk, and the heat added to produce the change will be shown by the areas C + D. Then let the steam expand adiabatically until it reaches the temperature T_2. This is represented by the line km, which is vertical and represents no additional area, because no heat is added to or withdrawn from the steam from outside. Suppose, during the return stroke of the piston, the steam is cooled within the cylinder itself, until it arrives at the point *s*. In this operation we shall reject from the cylinder a quantity of heat represented by the area D. Finally, let us compress adiabatically the mixture of steam and water in the cylinder until we have once more a pound of water at the higher temperature T_1. This gives the line *sp*, ending where the cycle began.

We have thus supplied during the cycle the heat represented by the areas C + D, and the heat rejected is represented by D. Therefore the efficiency is $\frac{C}{C + D}$, and from the diagram it will be seen that this is equal to $\frac{T_1 - T_2}{T_1}$.

In the actual engine the last step is very imperfectly performed, because only a small amount of steam remaining in the cylinder is compressed; the remainder, exhausted from the cylinder at the lower temperature T_2, must be heated to the temperature T_1 by heat from the boiler, or replaced by an equal amount thus heated.

We thus have the important conclusion that the efficiency of a steam engine depends entirely on the ratio of the temperatures between which it operates; it follows that the efficiency is always small. For example, suppose an engine takes steam at 300° F and exhausts at 212° F. Its efficiency cannot be greater than

$$\frac{(300 + 461) - (212 + 461)}{(300 + 461)} = 11.6 \text{ per cent.}$$

EXAMPLE FOR PRACTICE.

Using the steam table on page 25, find the maximum possible efficiency of an engine taking steam at 150 lbs. absolute pressure and exhausting at 5 lbs. absolute pressure.

Ans. 23.9 per cent.

THE STEAM ENGINE.

Without entering into a detailed description of the mechanism, it will be sufficient here to say that in the steam engine, steam is admitted under pressure from a boiler into a metal cylinder behind a piston, as represented in Fig. 14. Its pressure drives the piston forward, doing useful work. When the piston has moved through a part of its stroke the steam supply is cut off, and the stroke is completed by the expansion of the steam confined in the cylinder. By the first law of thermodynamics this expansion cools the steam, since work is done in the process; but the expansion is not adiabatic, since the cylinder and piston give up some heat to the steam within. At the end of the stroke the exhaust valve opens and the cooled steam escapes into the atmosphere or condenser through the exhaust pipe A. The operation is then repeated on the other side of the piston.

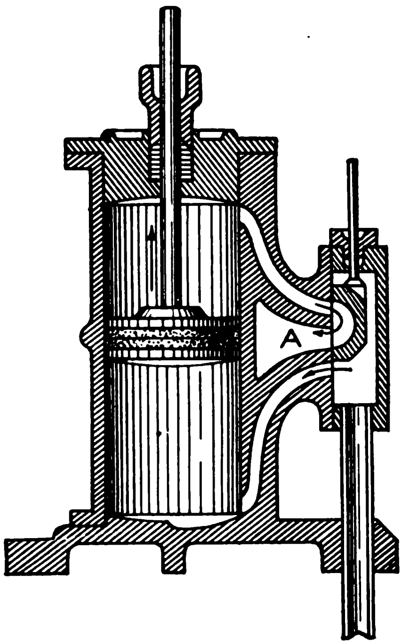


Fig. 14.

The pressure-volume diagram in Fig. 13 shows the process graphically, and can be instructively compared with the temperature-entropy diagram of the same figure. For purposes of analysis it is immaterial whether we consider the steam to be supplied from outside, or whether we consider the whole operation of heating to take place inside the cylinder. The line pk, representing the conversion of water into steam at constant pressure, will appear on the pressure-volume diagram as the "admission-line" ab. The adiabatic line km is shown by the falling "expansion-line" bc, which shows the relation between pressure and volume after the steam is cut off. The line ms becomes the "exhaust-line" cd on our new diagram, representing the steam pressure while the steam is being pushed out of the cylinder. Near the end of the return stroke of the piston, the exhaust valve closes and the steam remaining in the cylinder is compressed by the piston. This process, nearly adiabatic, is shown by the line *da*, corresponding to the line *sp* on the other diagram.

A pressure-volume diagram like the above is called an **indicator card.** It is very valuable in determining the power and performance of engines.

Compound Engines. Since the efficiency of a heat engine is evidently much improved by extending the range of temperature through which it works, and since we have also seen that it takes but little more fuel to produce a pound of high-pressure steam than a pound of low-pressure steam, it should now be clear that it is economical of fuel to use the highest pressures practicable, and to expand the steam as much as possible. But for certain reasons, discussed fully in the Instruction Papers on the Steam Engine, it is advisable to divide the expansion among two, three or even four cylinders, according to the initial steam pressure. Such engines are called compound, triple or quadruple-expansion, and are usually worked with a condenser. In such cases, while the first or high-pressure cylinder is intensely hot, the last or low-pressure cylinder is scarcely more than uncomfortably warm to the hand. The difference represents the heat spent in expansion, a part of which has gone to produce the useful work done by the engine, and a part of which is wasted.

The Hot-Air Engine. There are many forms of these machines, but their general principle varies little. A quantity of air is heated in an iron chamber over a fire, and then is allowed to expand behind a piston, doing work. At the end of the stroke the air is transferred, either by a pump or an auxiliary piston, to a cold chamber, kept cool by air or running water. On the next stroke the air, reduced in volume by its cooling, is forced by the pump into the hot chamber, where it is again heated and the cycle repeated.

Hot-air engines are economical in operation, but necessarily bulky for the amount of power produced. An examination of Fig. 13 will show why this must be so. The heat which must be supplied to the cylinder for every stroke of the piston is represented by the areas C + D, no matter what substance is used as a carrier. But since the heat capacity of air is very small compared with that of steam, the cylinder of the hot-air engine must necessarily be much larger than that of the steam engine for equal power. For this reason hot-air engines are used only in comparatively small powers. The hot-air engine may indeed work between wider temperature limits, but this is not enough to offset the difference between steam and air as carriers of heat.

The Gas Engine. In the gas engine, so called, the energy is derived from the rapid combustion or explosion of a mixture of gas or gasoline vapor and air. In one form of engine the cycle of operations is as follows: A forward stroke of the piston draws into the cylinder a mixture of gas and air in such proportions as to make an explosive mixture. On the return stroke the "charge" is compressed. At or near the end of the stroke, the mixture is exploded, usually by a properly-timed electric spark, and the pressure within the cylinder rises to a high value. The piston is driven forward by the expansion of the hot gases, doing useful work at the expense of the heat-energy in them. At the end of the stroke the exhaust valve opens, and on the second return stroke the burnt gases are pushed out of the cylinder.

The above cycle is often called the **Otto cycle.** For engines working in this way there is thus only one working stroke in every four, and they must be provided with a very heavy fly wheel. Some engines are arranged to have every alternate stroke a working stroke. These are commonly called two-cycle engines, and are much used in propelling boats.

The gas engine has the thermodynamic advantage of working between very wide temperature limits, but is nevertheless subject to serious losses. It is not practicable to expand the exploded charge down to the atmospheric pressure; the gases are discharged while still possessing much available energy. This may be noticed in the sharp, barking exhaust from a gas engine unprovided with a muffler. But the most serious loss is in the transmission of heat to the cylinder walls. This loss is also present in the steam engine, but to a small extent may be recovered. In the gas engine, however, it is practically all wasted.

REFRIGERATING MACHINES.

The cooling produced by the evaporation of a volatile liquid has a very important application in refrigerating machinery.

Ammonia is generally used as the working substance, because it is cheap and satisfactory.

Fig. 15 shows the essential parts of a compression machine. The *compressor* A, kept cool by a jacket of running water, draws ammonia vapor through the valve *a*, compresses it highly and sends it through the valve *b* to the *condenser* B. This is a coil of pipe, also kept cool by running water; and it serves to condense the ammonia, which collects in the bottom coils. The valve D admits the liquid ammonia to the *vaporizer* C, which is also made

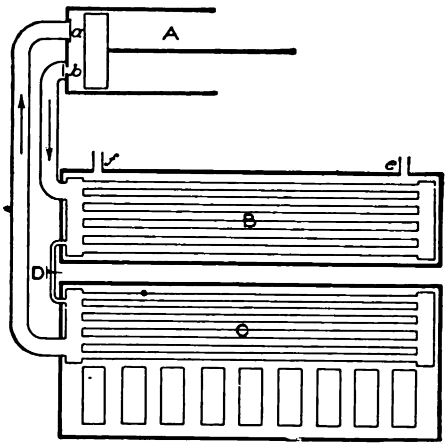


Fig. 15.

of pipe coils. In these it vaporizes and falls much below the freezing point of water. (It is well here to refer back to the experiment described on page 16.)

Many gases can be liquefied and used in this way; ammonia, carbonic acid and sulphurous anhydride (sometimes called sulphurous acid) in the liquid state, are regular articles of commerce.

In ice making, the vaporizer coils are immersed in a tank of strong brine. The water to be frozen is put into thin metal cans, which are then set into the cold brine, as represented in the figure.

In this way the heat liberated from the water in freezing is carried away by the ammonia vapor, and finally discharged into the cooling water circulating around the compressor and condenser. But since this is at a higher temperature than the source of the heat, the machine is not self-acting. It requires power to operate it, which is expended in compressing the vapor in A.

Instead of drawing the vaporized ammonia back into the pump cylinder, it may be absorbed by cold water, for which it has a strong affinity. Such a machine is called an *absorption machine*, and Fig. 16 shows the principle of a continuously operating absorption machine. The *generator* B contains a concentrated solution of ammonia in water, from which the ammonia is expelled by heat. The *condenser* C is a pipe coil, kept cool by running water, in which the ammonia condenses to the liquid state as soon as its pressure rises to the necessary value. The regulating valve V

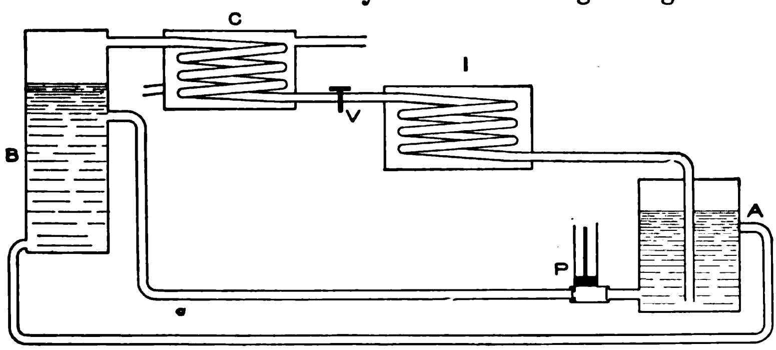


Fig. 16.

allows the condensed ammonia to escape to the *refrigerator* I, which corresponds to the vaporizer C of the compression apparatus. The *absorber* A is a tank of cold water in which the gaseous ammonia from I is absorbed. The pipes connecting A and B are arranged to take the most concentrated solution from A to B, and to return to A the water from which the ammonia has been driven. This is effected by the pump P.

In practice the generator B is placed over a furnace, and arrangements are also made for transferring heat from the hot liquid flowing from B to A into the cold liquid flowing from A to B.

LIQUEFACTION OF AIR.

That work done in compressing a gas heats the gas, is a fact familiar to every one who uses a bicycle pump. Similarly, the expansion of a gas against atmospheric or other pressure is accompanied by as decided a cooling. This may readily be observed by holding the finger in the jet of air escaping from a bicycle tire valve. By suitable applications of this principle, it is possible to produce the most intense cold.

One of the simplest methods of liquefying air is shown in principle in Fig. 17. After thorough drying, the air to be liquefied enters through the pipe *a*, and in the compressor C is compressed to about 200 atmospheres (1 atmosphere = 14.7 pounds per square inch). R is a water cooler, to remove the heat of compression. The air thus cooled and strongly compressed passes

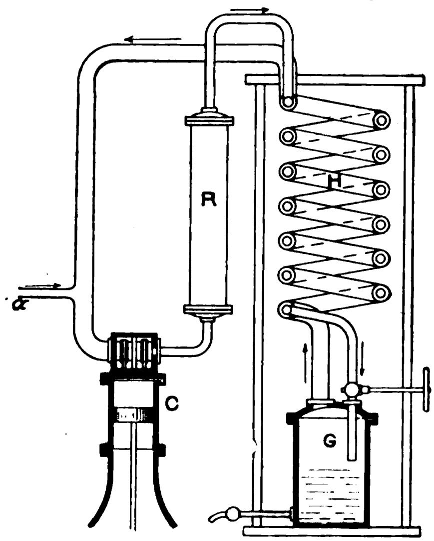
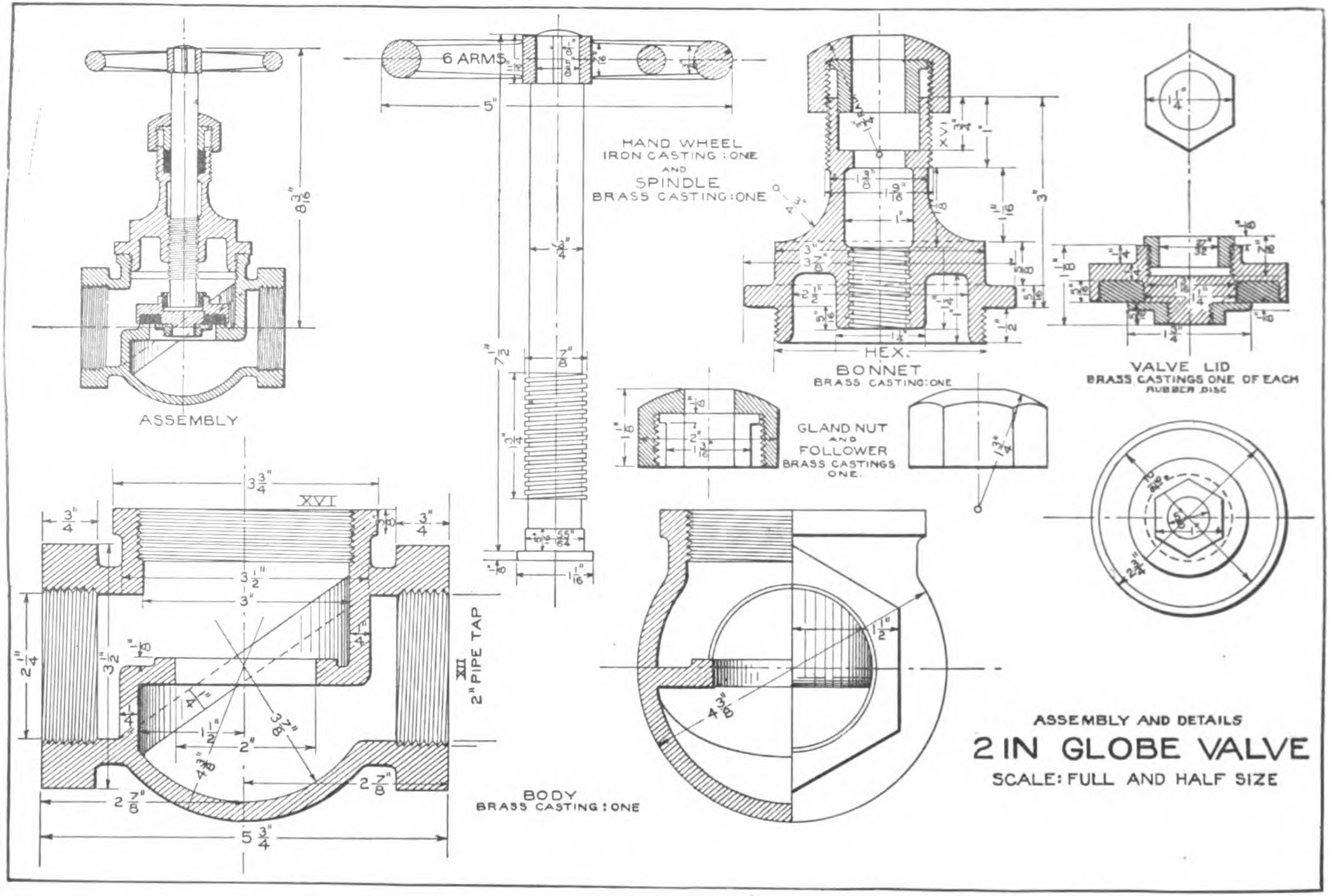


Fig. 17.

down through the inner tube of the helical coil H to a valve below.

Through this valve it escapes into the reservoir G, the expansion producing a considerable fall in temperature. The cold air then passes from the reservoir up through the outside tube of the helical coil, which surrounds the tube down which the air comes, thus cooling the compressed air in the inner tube. This cooled air is allowed to escape in its turn, becoming still colder by its expansion. As the process continues the temperature falls until liquid air begins to collect in the bottom of G, from which it may be drawn off.

With a 3-horse-power engine the yield is about a quart of liquid air per hour.



A TYPICAL WORKING DRAWING.

MECHANICAL DRAWING

PART I

The subject of mechanical drawing is of great interest and importance to all mechanics and engineers. Drawing is the method used to show graphically the small details of machinery; it is the language by which the designer speaks to the workman; it is the most graphical way to place ideas and calculations on record. Working drawings take the place of lengthy explanations, either written or verbal. A brief inspection of an accurate, well-executed drawing gives a better idea of a machine than a large amount of verbal description. The better and more clearly a drawing is made, the more intelligently the workman can comprehend the ideas of the designer. A thorough training in this important subject is necessary to the success of everyone engaged in mechanical work. The success of a draftsman depends to some extent upon the quality of his instruments and materials. Beginners frequently purchase a cheap grade of instruments. After they have become expert and have learned to take care of their instruments they discard them for those of better construction and finish. This plan has its advantages, but to do the best work, strong, well-made and finely finished instruments are necessary.

INSTRUMENTS AND MATERIALS.

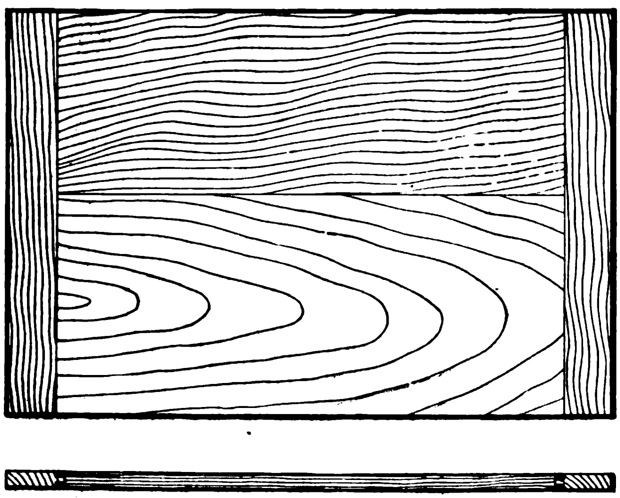
Drawing Paper. In selecting drawing paper, the first thing to be considered is the kind of paper most suitable for the proposed work. For shop drawings, a manilla paper is frequently used, on account of its toughness and strength, because the drawing is likely to be subjected to considerable hard usage. If a finished drawing is to be made, the best white drawing paper should be obtained, so that the drawing will not fade or become discolored with age. A good drawing paper should be strong, have uniform thickness and surface, should stretch evenly, and should neither repel nor absorb liquids. It should also allow considerable erasing without spoiling the surface, and it should lie smooth when stretched or when ink or colors are used. It is, of course, impossible to find all of these qualities in any one paper, as for instance great strength cannot be combined with fine surface.

In selecting a drawing paper the kind should be chosen which combines the greatest number of these qualities for the given work. Of the better class Whatman's are considered by far the best. This paper is made in three grades; the *hot pressed* has a smooth surface and is especially adapted for pencil and very fine line drawing, the *cold pressed* is rougher than the hot pressed, has a finely grained surface and is more suitable for water color drawing; the *rough* is used for tinting. The cold pressed does not take ink as well as the hot pressed, but erasures do not show as much on it, and it is better for general work. There is but little difference in the two sides of Whatman's paper, and either can be used. This paper comes in sheets of standard sizes as follows:—

Cap,	13 × 17 inches.	Elephant,	23 × 28 inches
Demy,	15 × 20 "	Columbia,	23 × 34 "
Medium,	17 × 22 "	Atlas,	26 × 34 "
Royal,	19 × 24 "	Double Elephant,	27 × 40 "
Super-Royal,	19 × 27 "	Antiquarian,	31 × 53 "
Imperial,	22 × 30 "	Emperor,	48 × 68 "

The usual method of fastening paper to a drawing board is by means of thumb tacks or small one-ounce copper or iron tacks. In fastening the paper by this method first fasten the upper left hand corner and then the lower right pulling the paper taut. The other two corners are then fastened, and sufficient number of tacks are placed along the edges to make the paper lie smoothly. For very fine work the paper is usually stretched and glued to the board. To do this the edges of the paper are first turned up all the way round, the margin being at least one inch. The whole surface of the paper included between these turned up edges is then moistened by means of a sponge or soft cloth and paste or glue is spread on the turned up edges. After removing all the surplus water on the paper, the edges are pressed down on the board, commencing at one corner. During this process of laying down the edges, the paper should be stretched slightly by pulling the edges towards the edges of the drawing board. The drawing board is then placed horizontally and left to dry. After the paper has become dry it will be found to be as smooth and tight as a drum head. If, in stretching, the paper is stretched too much it is likely to split in drying. A slight stretch is sufficient.

Drawing Board. The size of the drawing board depends upon the size of paper. Many draftsmen, however, have several boards of various sizes, as they are very convenient. The drawing board is usually made of soft pine, which should be well seasoned and straight grained. The grain should run lengthwise of the board, and at the two ends there should be pieces about $1\frac{3}{4}$ or 2 inches wide fastened to the board by nails or screws. These end pieces should be perfectly straight for accuracy in using the T-square. Frequently the end pieces are fastened by a glued



DRAWING BOARD

matched joint, nails and screws being also used. Two cleats on the bottom extending the whole width of the board, will reduce the tendency to warp, and make the board easier to move as they raise it from the table.

Thumb Tacks. Thumb tacks are used for fastening the paper to the drawing board. They are usually made of steel either pressed into shape, as in the cheaper grades, or made with a head of German silver with the point screwed and riveted to it. They are made in various sizes and are very convenient as they can be easily removed from the board. For most work however, draftsmen use small one-ounce copper or iron tacks, as they can be forced flush with the drawing paper, thus offering no obstruction to the T-square. They also possess the advantage of cheapness.

Pencils. In pencilling a drawing the lines should be very fine and light. To obtain these light lines a hard lead pencil must be used. Lead pencils are graded according to their hardness, and are numbered by using the letter H. In general a lead pencil of 5H (or HHHHH) or 6H should be used. A softer pencil, 4H, is better for making letters, figures and points. A hard lead pencil should be sharpened as shown in Fig. 1. The wood is cut away so that about $\frac{1}{4}$ or $\frac{1}{2}$ inch of lead projects. The lead can then be sharpened to a chisel edge by rubbing it against a bit of sand paper or a fine file. It should be ground to a chisel edge and the corners slightly rounded. In making the straight lines the chisel edge should be used by placing it against the T-square or triangle, and because of the chisel edge the lead will remain sharp much longer than if sharpened to a point. This chisel edge enables the draftsman to draw a fine line exactly through a given point. If the drawing is not to be inked, but is made for tracing or for rough usage in the shop, a softer pencil, 3H or 4H, may be used, as the lines will then be somewhat thicker and heavier. The lead for compasses may also be sharpened to a point although some draftsmen prefer to use a chisel edge in the compasses as well as for the pencil.

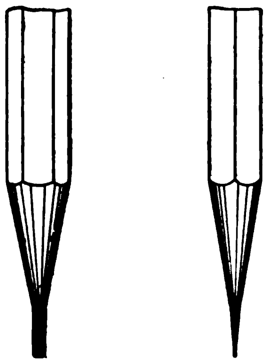


Fig. 1.

In using a very hard lead pencil, the chisel edge will make a deep depression in the paper if much pressure is put on the pencil. As this depression cannot be erased it is much better to press lightly on the pencil.

Erasers. In making drawings, but little erasing should be necessary. However, in case this is necessary, a soft rubber should be used. In erasing a line or letter, great care must be exercised or the surrounding work will also become erased. To prevent this, some draftsmen cut a slit about 3 inches long and $\frac{1}{8}$ to $\frac{1}{4}$ inch wide in a card as shown in Fig. 2. The card is then placed over the work and the line erased without erasing the rest of the drawing. An erasing shield of a form similar to that shown in Fig. 3 is very convenient, especially in erasing letters. It is made of thin sheet metal and is clean and durable.

For cleaning drawings, a sponge rubber may be used. Bread crumbs are also used for this purpose. To clean the drawing

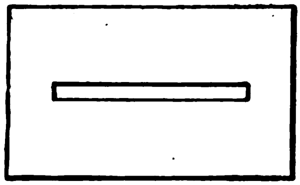


Fig. 2.

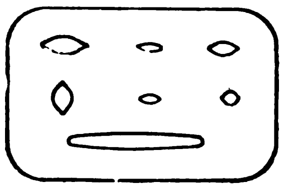


Fig. 3.

scatter *dry* bread crumbs over it and rub them on the surface with the hand.

T-Square. The T-square consists of a thin straight edge called the blade, fastened to a head at right angles to it. It gets

Fig. 4.

its name from the general shape. T-squares are made of various materials, wood being the most commonly used. Fig. 4 shows an ordinary form of T-square which is adapted to most work. In Fig. 5 is shown a T-square with edges made of ebony or mahogany, as these woods are much harder than pear wood or maple, which is generally used. The head is formed so as to fit against the left-hand edge of the drawing board, while the blade extends over the surface. It is desirable to have the blade of the T-square form a right angle with the head, so that the lines drawn with the T-square will be at right angles to the left-hand edge of the board. This, however, is not absolutely necessary, because the lines drawn with the T-square are always with reference to one edge of the board only, and if this edge of the board is straight, the lines drawn with the T-square will be parallel to each other. The T-square should never be used except with the left-hand edge of the board, as it is almost impossible to find a drawing broad with the edges parallel or at right angles to each other.

The T-square with an adjustable head is frequently very convenient, as it is sometimes necessary to draw lines parallel to each

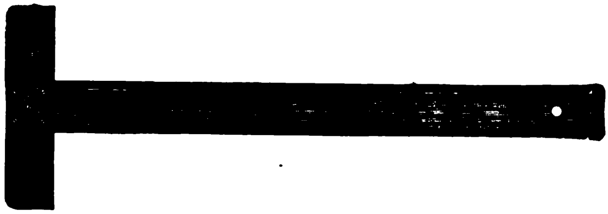


Fig. 5.

other which are not at right angles to the left-hand edge of the board. This form of T-square is similar to the ordinary T-square already described, but the head is swiveled so that it may be clamped at any desired angle. The ordinary T-square as shown in Figs. 4 and 5 is, however, adapted to almost any class of drawing.

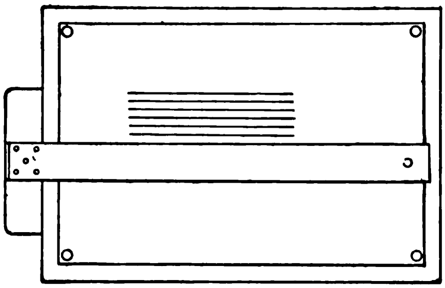


Fig. 6.

Fig. 6 shows the method of drawing parallel horizontal lines with the T-square. With the head of the T-square in contact with the left-hand edge of the board, the lines may be drawn by moving the T-square to the desired position. In using the T-square the upper edge should always be used for drawing as the two edges may not be exactly parallel and straight, and also it is more convenient to use this edge with the triangles. If it is necessary to use a straight edge for trimming drawings or cutting the paper from the board, the lower edge of the T-square should be used so that the upper edge may not be marred.

For accurate work it is absolutely necessary that the working edge of the T-square should be exactly straight. To test the straightness of the edge of the T-square, two T-squares may be placed together as shown in Fig. 7. This figure shows plainly that the edge of one of the T-squares is crooked. This fact, however, does not prove that either one is straight, and for this determination a third blade must be used and tried with the two given T-squares successively.

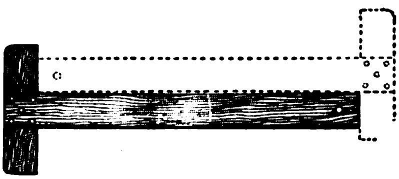
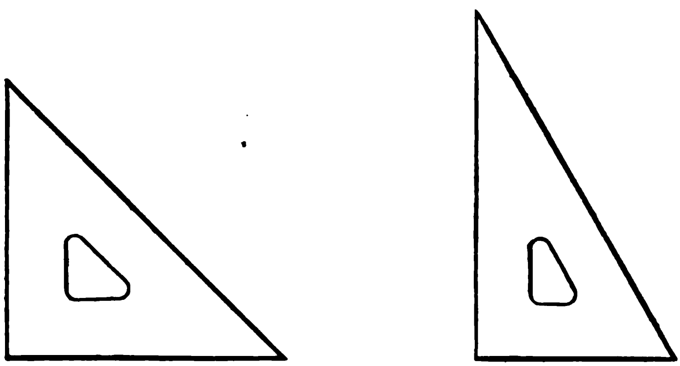


Fig. 7.

Triangles. Triangles are made of various substances such as wood, rubber, celluloid and steel. Wooden triangles are cheap but are likely to warp and get out of shape. The rubber triangles are frequently used, and are in general satisfactory. The transparent celluloid triangle is, however, extensively used on account of its transparency, which enables the draftsmen to see the work already done even when covered with the triangle. In using a rubber or celluloid triangle take care that it lies perfectly flat or



TRIANGLES.

is hung up when not in use; when allowed to lie on the drawing board with a pencil or an eraser under one corner it will become warped in a short time, especially if the room is hot or the sun happens to strike the triangle.

Triangles are made in various sizes, and many draftsmen have several constantly on hand. A triangle from 6 to 8 inches on a side will be found convenient for most work, although there are many cases where a small triangle measuring about 4 inches on a side will be found useful. Two triangles are necessary for every draftsman, one having two angles of 45 degrees each and one a right angle; and the other having one angle of 60 degrees, one of 30 degrees and one of 90 degrees.

The value of the triangle depends upon the accuracy of the angles and the straightness of the edges. To test the accuracy of the right angle of a triangle, place the triangle with the lower edge resting on the edge of the T-square, as shown in Fig. 8. Now draw the line C D, which should be perpendicular to the edge of the T-square. The same triangle should then be placed in the position shown at B. If the right angle of the triangle is exactly 90 degrees the left-hand edge of the triangle should exactly coincide with the line C D.

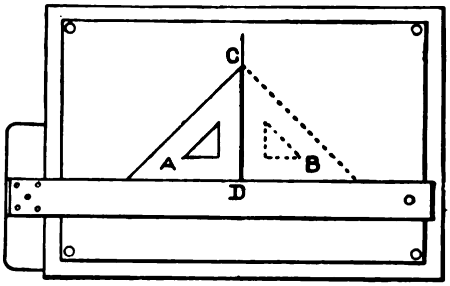


Fig. 8.

To test the accuracy of the 45-degree triangles, first test the right angle then place the triangle with the lower edge resting on the working edge of the T-square, and draw the line E F as shown in Fig. 9. Now without moving the T-square place the triangle so that the other 45-degree angle is in the position occupied by the first. If the two 45-degree angles coincide they are accurate.

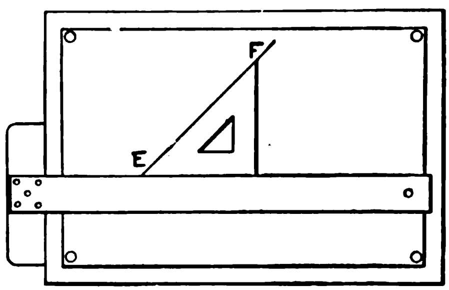


Fig. 9.

Triangles are very convenient in drawing lines at right angles to the T-square. The method of doing this is shown in Fig. 10. Triangles are also used in drawing lines at an angle with the horizontal, by placing them on the board as shown in Fig. 11. Suppose the line E F (Fig. 12) is drawn at any angle, and we wish to draw a line through the point P parallel to it

First place one of the triangles as shown at A, having one edge coinciding with the given line. Now take the other triangle and place one of its edges in contact with the bottom edge of triangle A. Holding the triangle B firmly with the left hand the triangle A may be slipped along to the right or to the left until the edge of the triangle reaches the point P. The line M N may then be drawn along the edge of the triangle passing through the point P. In place of the triangle B any straight edge such as a T-square may be used.

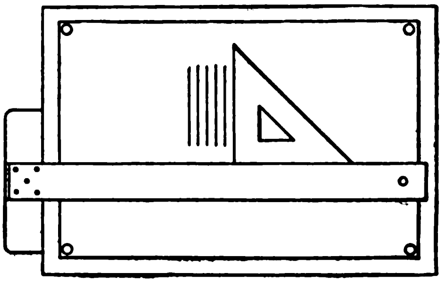


Fig. 10.

A line can be drawn perpendicular to another by means of the triangles as follows. Let E F (Fig. 13) be the given line, and suppose we wish to draw a line perpendicular to E F through the point D. Place the longest side of one of the triangles so that it coincides with the line E F, as the triangle is shown in position at A. Place the other triangle (or any straight edge) in the position of the triangle as shown at B, one edge resting against the edge of the triangle A. Then holding B with the left hand, place the triangle A in the position shown at C, so that the longest side passes through the point D. A line can then be drawn through the point D perpendicular to E F.

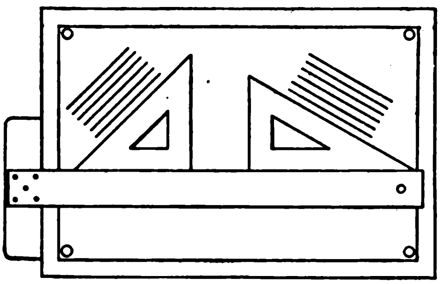


Fig. 11.

In previous figures we have seen how lines may be drawn making angles of 30, 45, 60 and 90 degrees with the horizontal. If it is desired to draw lines forming angles of 15 and 75 degrees the triangles may be placed as shown in Fig. 14.

In using the triangles and T-square almost any line may be drawn. Suppose we wish to draw a rectangle having one side horizontal. First place the T-square as shown in Fig. 15. By moving the T-square up or down, the sides A B and D C may be drawn, because they are horizontal and parallel. Now place one of the triangles resting on the T-square as shown at E, and having the left-hand edge passing through the point D. The vertical

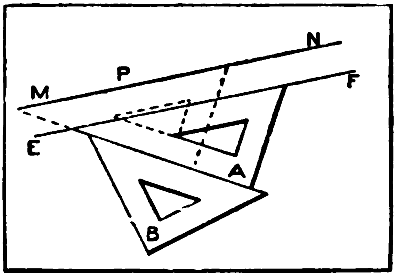


Fig. 12.

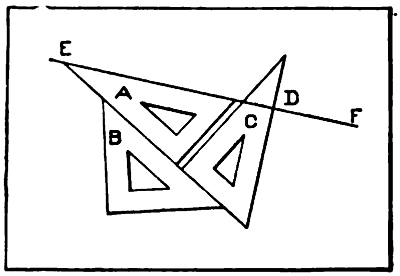


Fig. 13.

line D A may be drawn, and by sliding the triangle along the edge of the T-square to the position F the line B C may be drawn by using the same edge. These positions are shown dotted in Fig. 15.

If the rectangle is to be placed in some other position on the drawing board, as shown in Fig. 16, place the 45-degree triangle F so that one edge is parallel to or coincides with the side D C. Now holding the triangle F in position place the triangle H so that its upper edge coincides with the lower edge of the triangle F. By holding H in position and sliding the triangle F along its upper edge, the sides A B and D C may be drawn. To draw the sides A D and B C the triangle should be used as shown at E.

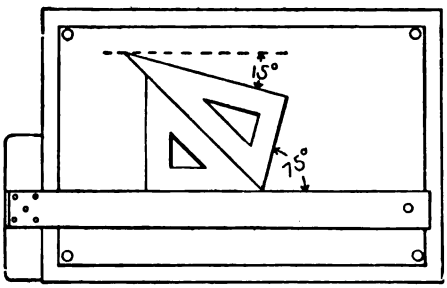


Fig. 14.

Compasses. Compasses are used for drawing circles and arcs of circles. They are made of various materials and in various sizes. The cheaper class of instruments are made of brass, but they are unsatisfactory on account of the odor and the tendenc to tarnish The best material is German silver. It does not soi readily, it has no odor, and is easy to keep clean. Aluminum instruments possess the advantage of lightness, but on account of the soft metal they do not wear well.

The compasses are made in the form shown in Figs. 17 and 18. Pencil and pen points are provided, as shown in Fig. 17. Either pen or pencil may be inserted in one leg by means of a shank and socket. The other leg is fitted with a needle point which is placed at the center of the circle. In most instruments the needle point is separate, and is made of a piece of round steel wire having a square shoulder at one or both ends. Below this shoulder the needle point projects. The needle is made in this form so that the hole in the paper may be very minute.

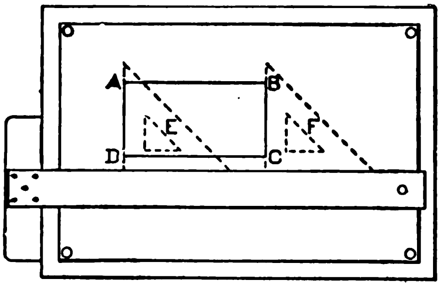


Fig. 15.

In some instruments lock nuts are used to hold the joint firmly in position. These lock nuts are thin discs of steel, with notches for using a wrench or forked key. Fig. 19 shows the detail of the joint of high grade instruments. Both legs are alike at the joint, and two pivoted screws are inserted in the yoke. This permits ample movement of the legs, and at the same time gives the proper stiffness. The flat surface of one of the legs is faced with steel, the other being of German silver, in order that the rubbing parts may be of different metals. Small set screws are used to prevent the pivoted screws from turning in the yoke. The contact surfaces of this joint are made circular to exclude dust and dirt and to prevent rusting of the steel face.

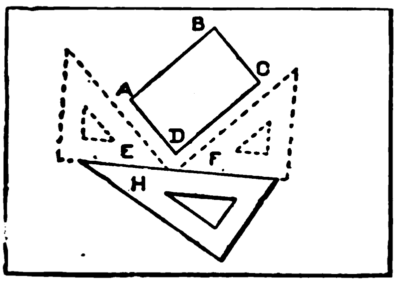


Fig. 16.

Figs. 20, 21 and 22 show the detail of the socket; in some instruments the shank and socket are pentagonal, as shown in Fig. 20. The shank enters the socket loosely, and is held in place by means of the screw. Unless used very carefully this arrangement is not durable because the sharp corners soon wear, and the pressure on the set screw is not sufficient to hold the shank firmly in place.

In Fig. 21 is shown another form of shank. This is round, having a flat top. A set screw is also used to hold this in position. A still better form of socket is shown in Fig. 22; the hole

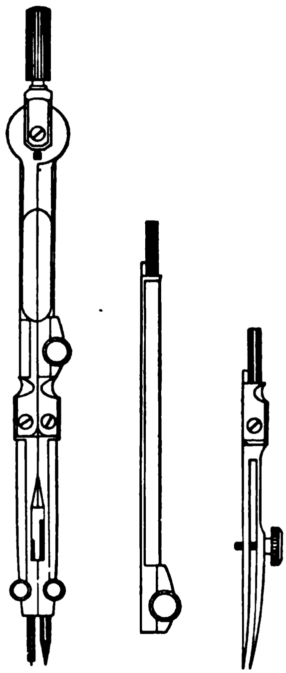


Fig. 17.

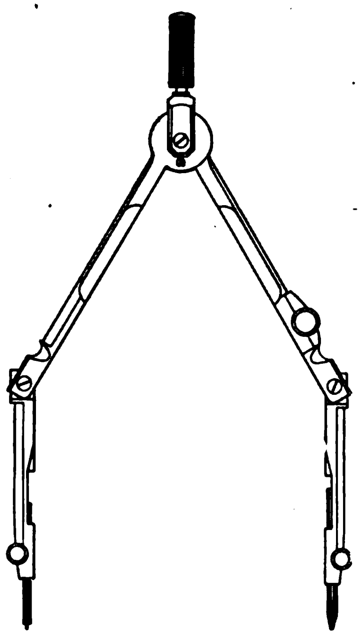


Fig. 18.

is made tapered and is circular. The shank fits accurately, and is held in perfect alignment by a small steel key. The clamping screw is placed upon the side, and keeps the two portions of the split socket together.

Figs. 17 and 18 show that both legs of the compasses are jointed in order that the lower part of the legs may be perpendicular to the paper while drawing circles. In this way the needle point makes but a small hole in the paper, and both nibs of the pen will press equally on the paper. In pencilling circles it is not as necessary that the pencil should be kept vertical; it is a good plan, however, to learn to use them in this way both in pencilling and inking. The compasses should be held loosely between the thumb and forefinger. If the needle point is sharp, as it should be, only a slight pressure will be required to keep it in place. While drawing the circle, incline the compasses slightly in the direction of revolution and press lightly on the pencil or pen.

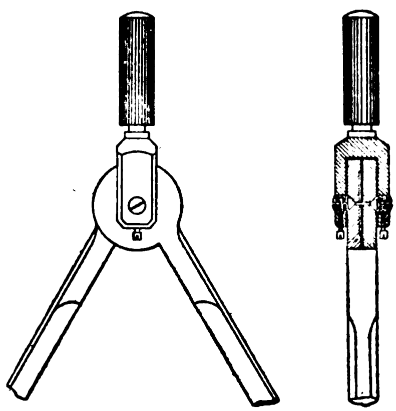


Fig. 19.

In removing the pencil or pen, it should be pulled out straight. If bent from side to side the socket will become enlarged and the shank worn; this will render the instrument inaccurate. For drawing large circles the lengthening bar shown in Fig. 17 should be used. When using the lengthening bar the

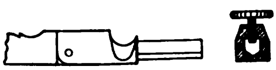


Fig. 20.

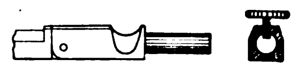


Fig. 21.

needle point should be steadied with one hand and the circle described with the other.

Dividers. Dividers, shown in Fig. 23, are made similar to the compasses. They are used for laying off distances on the drawing, either from scales or from other parts of the drawing. They may also be used for dividing a line into equal parts. When dividing a line into equal parts the dividers should be turned in the opposite direction each time, so that the moving point passes alternately to the right and to the left. The instrument can then be operated readily with one hand. The points of the dividers should be very sharp so that the holes made in the paper will be small. If large holes are made in the paper, and the distances between

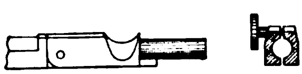


Fig. 22.

the points are not exact, accurate spacing cannot be done Sometimes the compasses are furnished with steel divider points in addition to the pen and pencil points. The compasses may then be used either as dividers or as compasses. Many draftsmen use a *needle point* in place of dividers for making measurements from a scale. The eye end of a needle is first broken off and the needle then forced into a small handle made of a round piece of soft pine. This instrument is very convenient for indicating the intersection of lines and marking off distances.

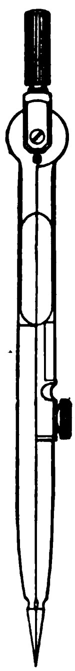


Fig. 23.

Bow Pen and Bow Pencil. Ordinary large compasses are too heavy to use in making small circles, fillets, etc. The leverage of the long leg is so great that it is very difficult to draw small circles accurately. For this reason the bow compasses shown in Figs. 24 and 25 should be used on all arcs and circles having a radius of less than three-quarters inch. The bow compasses are also convenient for duplicating small circles such as those which represent boiler tubes, bolt holes, etc., since there is no tendency to slip.

The needle point must be adjusted to the same length as the pen or pencil point if very small circles are to be drawn. The adjustment for altering the radius of the circle can be made by turning the nut. If the change in radius is considerable the points should be pressed together to remove the pressure from the nut which can then be turned in either direction with but little wear on the threads.

Fig. 26 shows another bow instrument which is frequently used in small work in place of the dividers. It has the advantage of retaining the adjustment.

Drawing Pen. For drawing straight lines and curves that are not arcs of circles, the line pen (sometimes called the ruling pen) is used. It consists of two blades of steel fastened to a handle as shown in Fig. 27. The distance between the pen points can be adjusted by the thumb screw, thus regulating the width of line to be drawn. The blades are given a slight curvature so that there will be a cavity for ink when the points are close together.

The pen may be filled by means of a common steel pen or with the quill which is provided with some liquid inks. The pen should not be dipped in the ink because it will then be necessary to wipe the outside of the blades before use. The ink should fill the pen to a height of about $\frac{1}{4}$ or $\frac{3}{8}$ inch; if too much ink is placed in the pen it is likely to drop out and spoil the drawing. Upon finishing the work the pen should be carefully wiped with

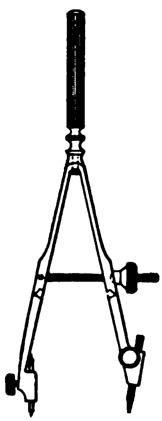


Fig. 24.

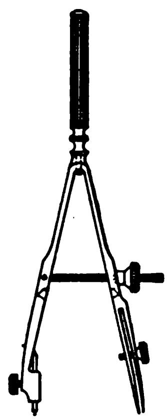


Fig. 25.

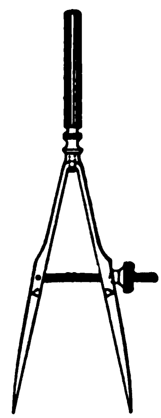


Fig. 26.

chamois or a soft cloth, because most liquid inks corrode the steel.

In using the pen, care should be taken that both blades bear equally on the paper. If the points do not bear equally the line will be ragged. If both points touch, and the pen is in good condition the line will be smooth. The pen is usually inclined slightly in the direction in which the line is drawn. The pen

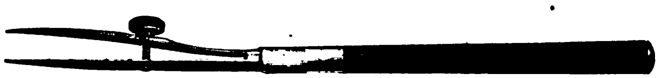


Fig. 27.

should *touch* the triangle or T-square which serve as guides, but it should not be pressed against them because the lines will then be uneven. The points of the pen should be close to the edge of the triangle or T-square, but should not touch it.

To Sharpen the Drawing Pen. After the pen has been used for some time the points become worn, and it is impossible to make smooth lines. This is especially true if rough paper is used. The pen can be put in proper condition by sharpening it. To do this take a small, flat, close-grained oil-stone. The blades should first be screwed together, and the points of the pen can be given the proper shape by drawing the pen back and forth over the stone changing the inclination so that the shape of the ends will be parabolic. This process dulls the points but gives them the proper shape, and makes them of the same length.

To sharpen the pen, separate the points slightly and rub one of them on the oil-stone. While doing this keep the pen at an angle of from 10 to 15 degrees with the face of the stone, and give it a slight twisting movement. This part of the operation requires great care as the shape of the ends must not be altered. After the pen point has become fairly sharp the other point should be ground in the same manner. All the grinding should be done on the *outside* of the blades. The burr should be removed from the inside of the blades by using a piece of leather or a piece of pine wood.

Ink should now be placed between the blades and the pen tried. The pen should make a smooth line whether fine or heavy, but if it does not the grinding must be continued and the pen tried frequently.

Ink. India ink is always used for drawing as it makes a permanent black line. It may be purchased in solid stick form or as a liquid. The liquid form is very convenient as much time is saved, and all the lines will be of the same color; the acid in the ink, however, corrodes steel and makes it necessary to keep the pen perfectly clean.

Some draftsmen prefer to use the India ink which comes in stick form. To prepare it for use, a little water should be placed in a saucer and one end of the stick placed in it. The ink is ground by giving it a twisting movement. When the water has become black and slightly thickened, it should be tried. A heavy line should be made on a sheet of paper and allowed to dry. If the line has a grayish appearance, more grinding is necessary. After the ink is thick enough to make a good black line, the grinding should cease, because very thick ink will not flow freely from the pen. If, however, the ink has become too thick, it may be diluted with water. After using, the stick should be wiped dry to prevent crumbling. It is well to grind the ink in small quantities as it does not dissolve readily if it has once become dry. If the ink is kept covered it will keep for two or three days.

Scales. Scales are used for obtaining the various measurements on drawings. They are made in several forms, the most convenient being the flat with beveled edges and the triangular. The scale is usually a little over 12 inches long and is graduated for a distance of 12 inches. The triangular scale shown in Fig. 28 has six surfaces for graduations, thus allowing many graduations on the same scale.

The graduations on the scales are arranged so that the drawings may be made in any proportion to the actual size. For mechanical work, the common divisions are multiples of two.

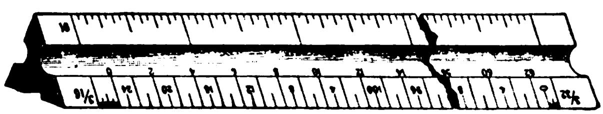


Fig. 28.

Thus we make drawings full size, half size, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$, etc. If a drawing is $\frac{1}{4}$ size, 3 inches equals 1 foot, hence 3 inches is divided into 12 equal parts and each division represents one inch. If the smallest division on a scale represents $\frac{1}{16}$ inch, the scale is said to read to $\frac{1}{16}$ inch.

Scales are often divided into $\frac{1}{10}$, $\frac{1}{20}$, $\frac{1}{30}$, $\frac{1}{40}$, etc., for architects, civil engineers, and for measuring on indicator cards.

The scale should never be used for drawing lines in place of triangles or T-square.

Protractor. The protractor is an instrument used for laying off and measuring angles. It is made of steel, brass, horn and paper. If made of metal the central portion is cut out as shown in Fig. 29, so that the draftsman can see the drawing. The outer edge is divided into degrees and tenths of degrees. Sometimes the graduations are very fine. In using a protractor a very sharp hard pencil should be used so that the lines will be fine and accurate.

The protractor should be placed so that the given line (produced if necessary) coincides with the two O marks. The center of the circle being placed at the point through which the desired line is to be drawn. The division can then be marked with the pencil point or needle point.

Irregular Curve. One of the conveniences of a draftsman's

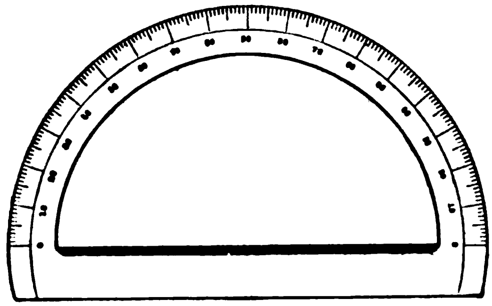


Fig. 29.

outfit is the French or irregular curve. It is made of wood, hard rubber or celluloid, the last named material being the best. It is made in various shapes, two of the most common being

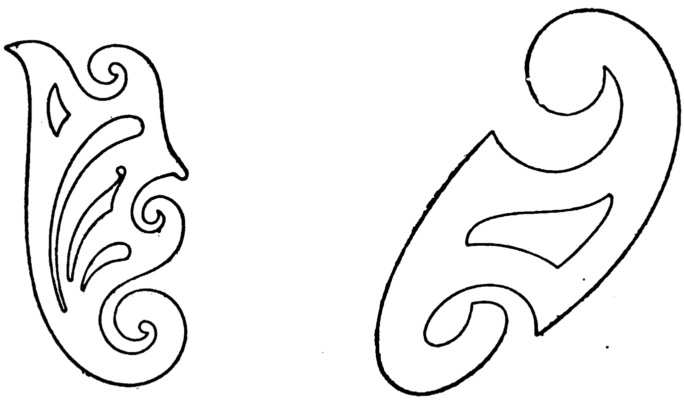


Fig. 30.

shown in Fig. 30. This instrument is used for drawing curves other than arcs of circles, and both pencil and line pen can be used.

To draw the curve, a series of points is first located and then the curve drawn passing through them by using the part of the irregular curve that passes through several of them. The curve is shifted for this work from one position to another. It frequently facilitates the work and improves its appearance to draw a free hand pencil curve through the points and then use the irregular curve, taking care that it always fits at least *three* points.

In inking the curve, the blades of the pen must be kept

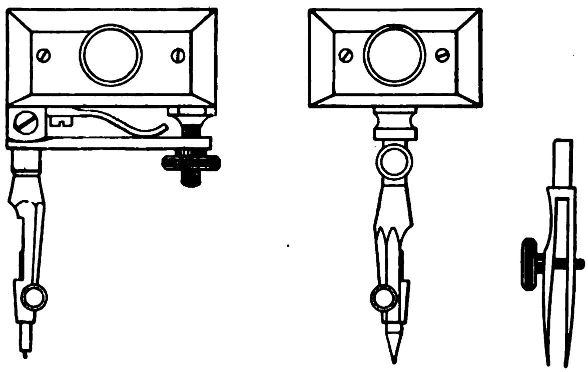


Fig. 31.

tangent to the curve, thus necessitating a continual change of direction.

Beam Compasses. The ordinary compasses are not large enough to draw circles having a diameter greater than about 8 or 10 inches. A convenient instrument for larger circles is found in the beam compasses shown in Fig. 31. The two parts called channels carrying the pen or pencil and the needle point are clamped to a wooden beam; the distance between them being equal to the radius of the circle. Accurate adjustment is obtained by means of a thumb nut underneath one of the channel pieces.

PLATES.

Plates I, II and III are provided to give practice in the use of the drawing instruments. Drawing paper at least 11 inches by 15 inches should be used to allow border lines 10 inches by 14 inches. First, draw carefully in pencil and then ink in. Especial care should be taken as to quality and width of line, intersections, and the joining of curved and straight lines.

These are followed by examples for lettering. Plate IV should be drawn first in pencil and then in ink.

PLATE I

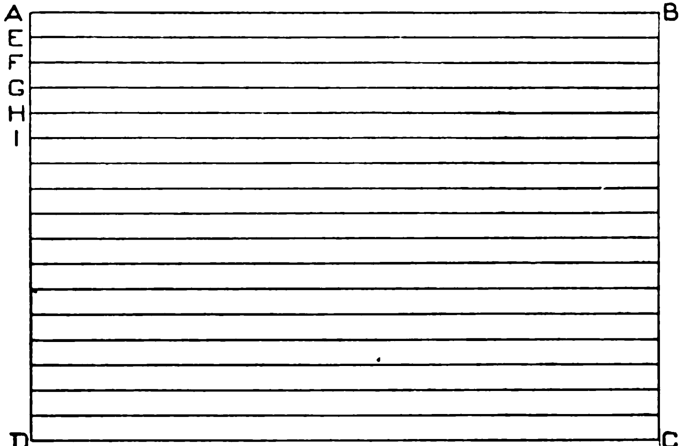


FIG. 1

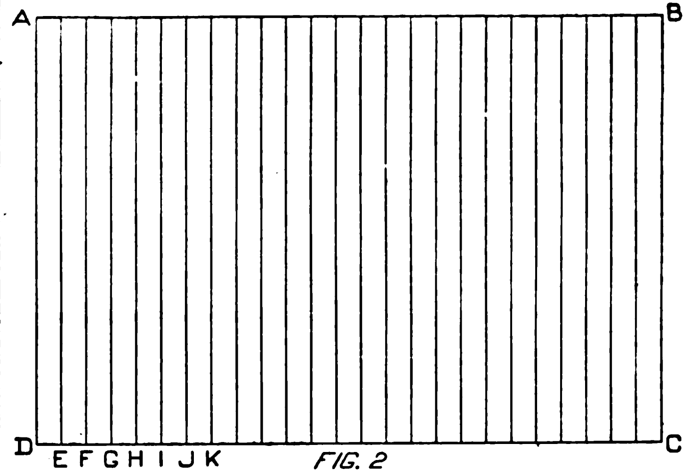


FIG. 2

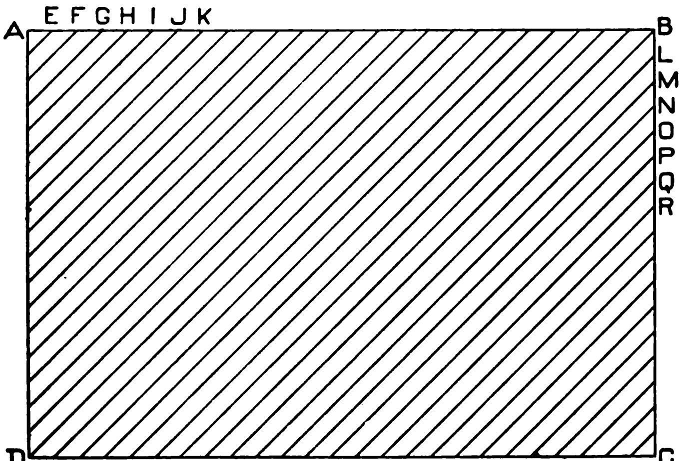


FIG. 3

A B

LETTERING

THE SUBJECT OF LETTERING IS OF GREAT IMPORTANCE TO THE MECHANICAL DRAUGHTSMAN. MANY WELL EXECUTED DRAWINGS HAVE BEEN DISFIGURED BY POOR LETTERING.

Proficiency can be acquired only by practice. Practice lettering. Practice.

ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefghijklmnopqrstuvwxyz

1234567890

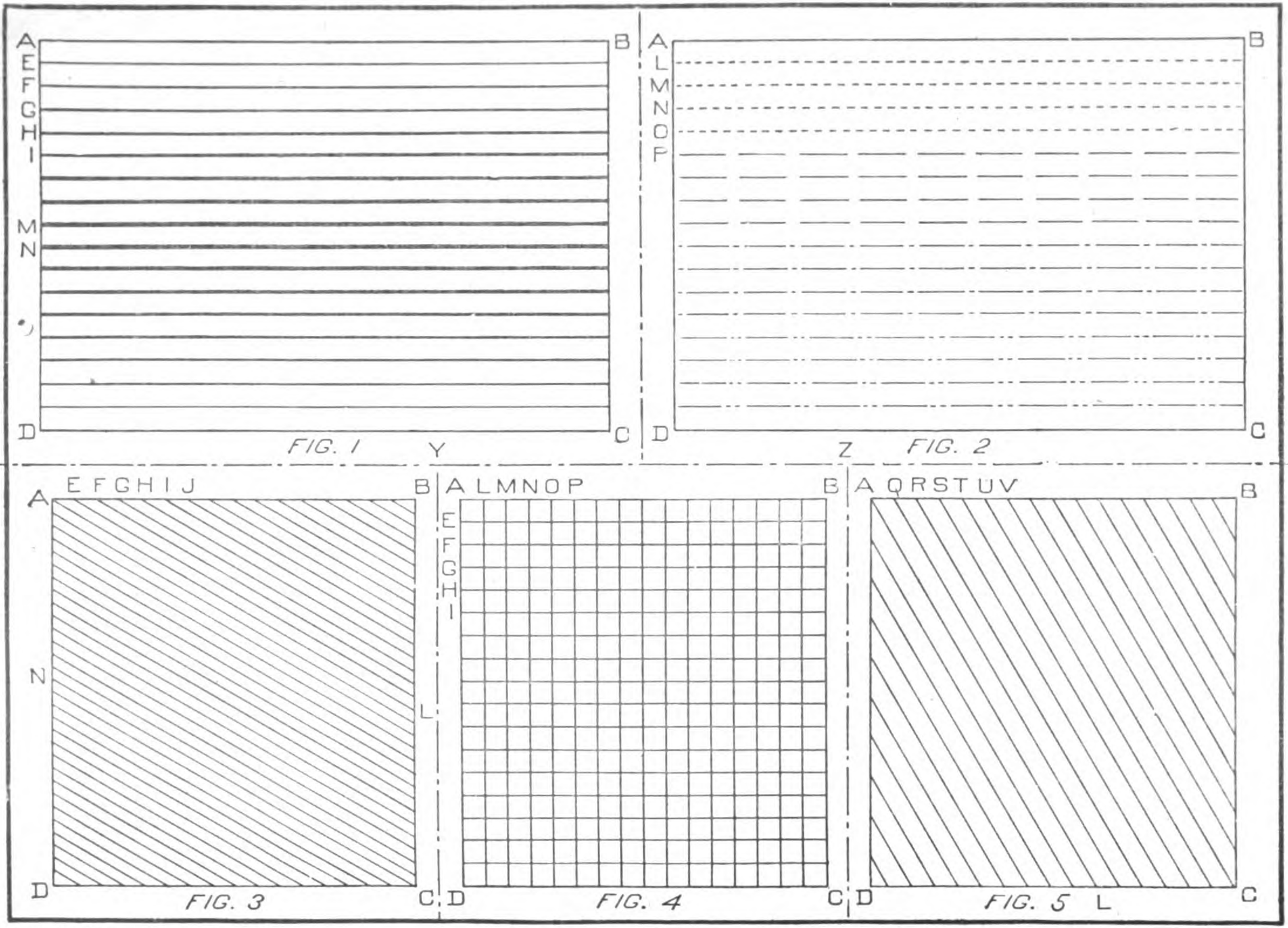
I II III IV V VI VII VIII IX X

D C

FIG. 4

JANUARY 1. 1907 HERBERT CHANDLER CHICAGO. ILL.

PLATE II



JANUARY 9, 1907 HERBERT CHANDLER CHICAGO, ILL.

PLATE III

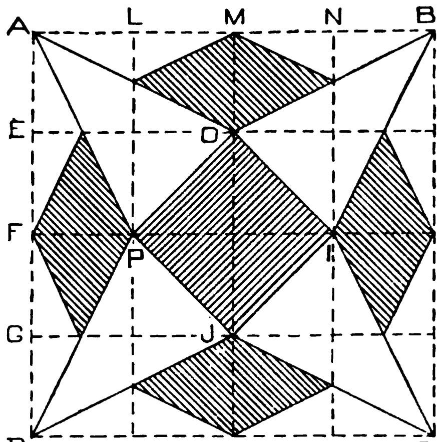


FIG 1

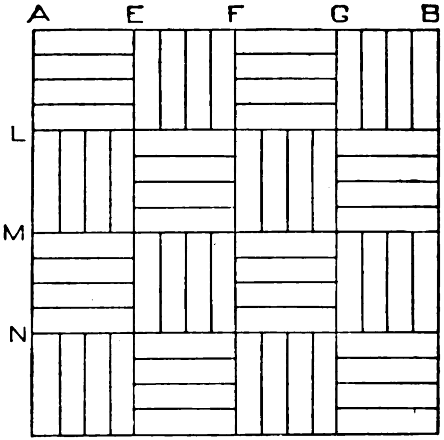


FIG. 2

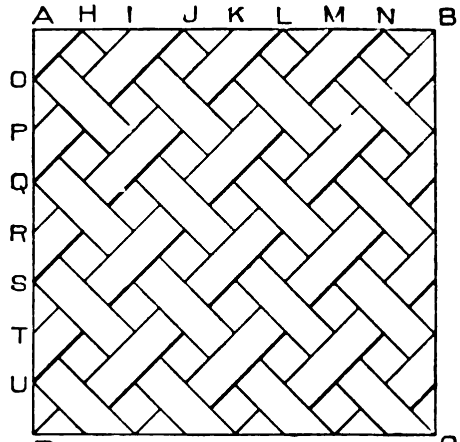


FIG. 3

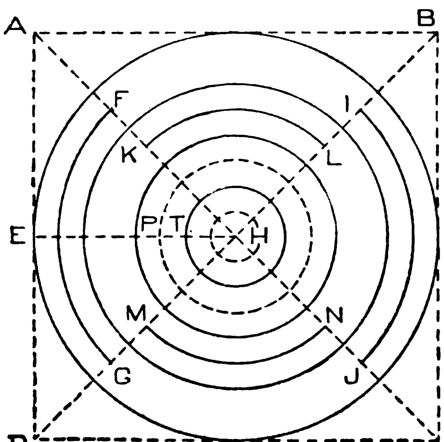


FIG. 4

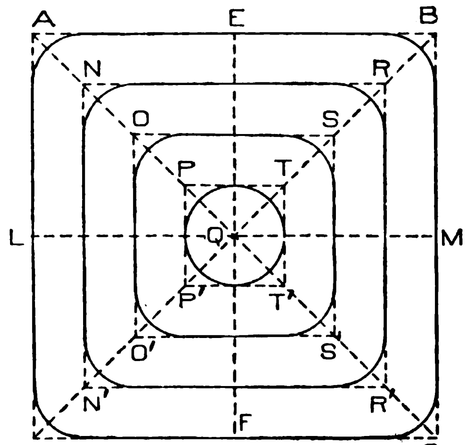


FIG. 5

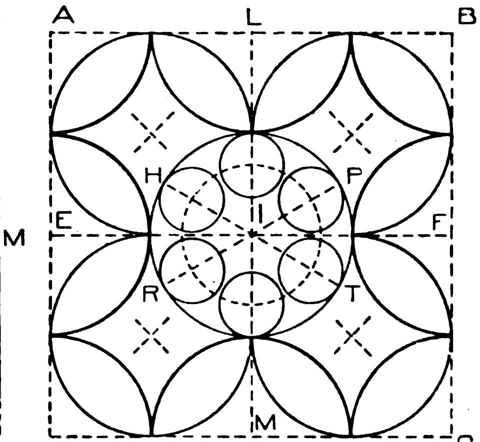


FIG. 6

JANUARY 14, 1907

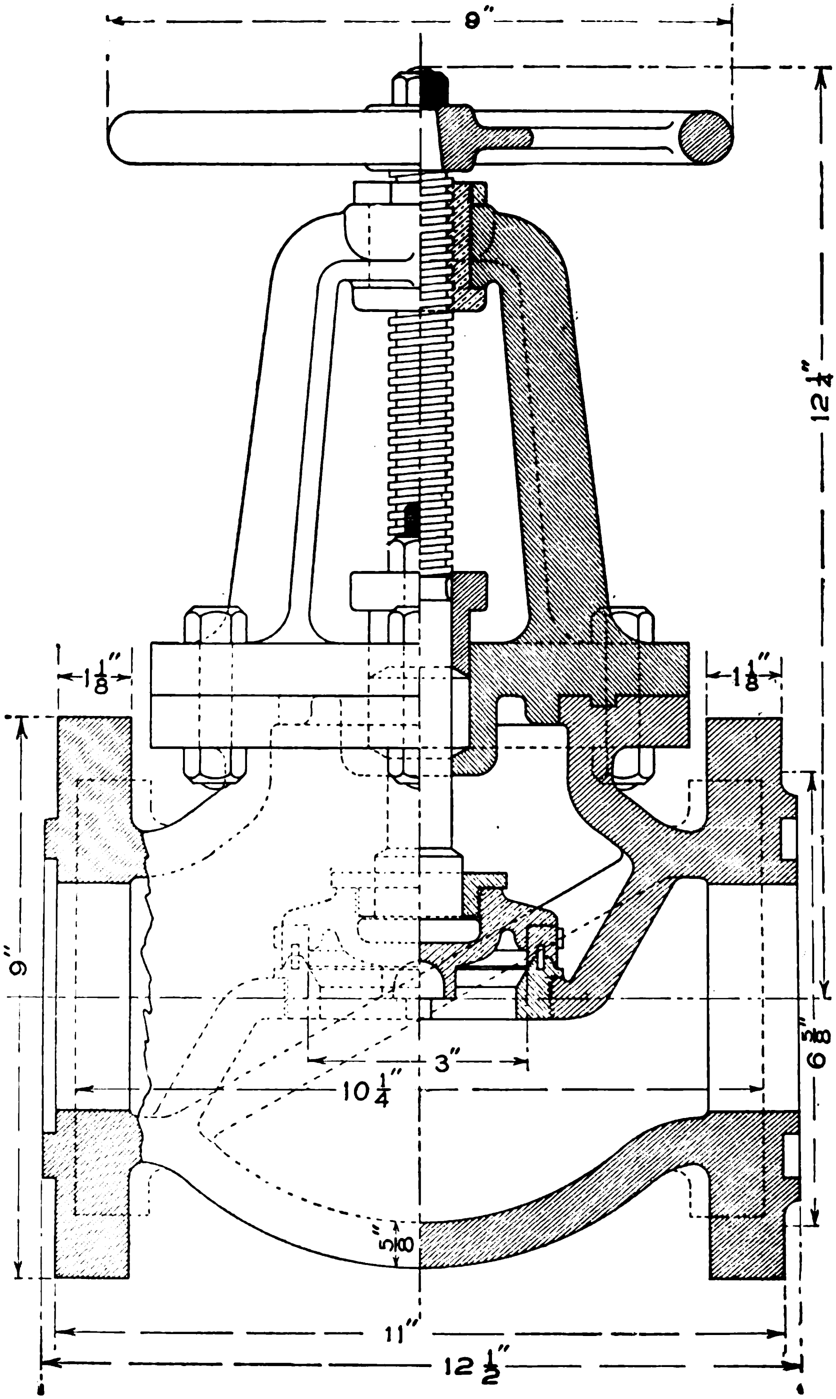
HERBERT CHANDLER

CHICAGO, ILL.

PLATE IV

COURSE
IN
MECHANICAL DRAWING
MACHINE DRAWINGS
AND
PROJECTIONS
BOSTON, MASS., U.S.A.

APRIL 24, 1907 HERBERT CHANDLER CHICAGO, ILL



WORKING DRAWING SHOWING PRINCIPAL DIMENSIONS OF SPRING SEAT VALVE.

Crosby Steam Gage & Valve Co.

MECHANICAL DRAWING.

PART II.

PROJECTIONS.

Orthographic Projection is the art of representing an object upon two planes, at right angles to each other, by lines drawn from all points on the edges or contour perpendicular to these planes. The intersections of the perpendiculars with the planes give figures which are called projections of the object.

The two planes are called *planes of projection*, or *coördinate planes*, one being vertical and the other horizontal, as shown in Fig. 1. These planes are sometimes designated V and H respectively. The intersection of V and H is known as the ground line, or G L. If a in Fig. 1 is a point in space, and a perpendicular is drawn to the vertical plane, the point a^v will be the projection of the point on the vertical plane, and in a similar way a^h will be the projection of a on the horizontal plane. The line B has its vertical projection at B^v, and its horizontal projection at B^h. Instead of *horizontal* projection and *vertical* projection, the terms **plan** and **elevation** are commonly used. It will be seen from the figure that the plan of a point or line is directly underneath on the H plane, and the elevation directly behind on the V plane.

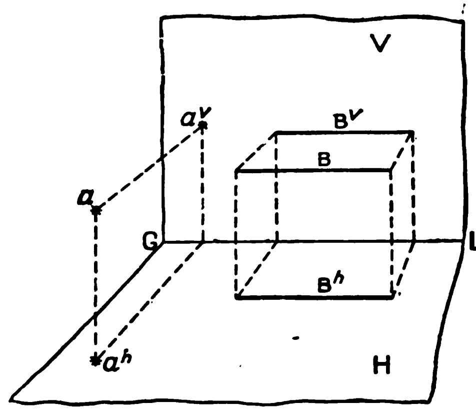


Fig. 1.

Suppose in Fig. 2 a cube one inch on a side be placed with the top horizontal and the front face parallel to the vertical plane. Then the plan will be a one-inch square, and the elevation also a one-inch square. In general the plan is a representation of the top of the object, and the elevation a view of the *front*. The plan then is a top view, and the elevation a front view. Since the plan is directly below the object, and the elevation directly behind, it follows that in actual drawing the plan must be vertically below the elevation, point for point. This is one of the fundamental principles of projection, and should be thoroughly understood.

The projection of a point can never be anything but a point. By referring to Fig. 1 it is clear that the height of *a* above the horizontal plane is equal to the distance of a^v above the ground

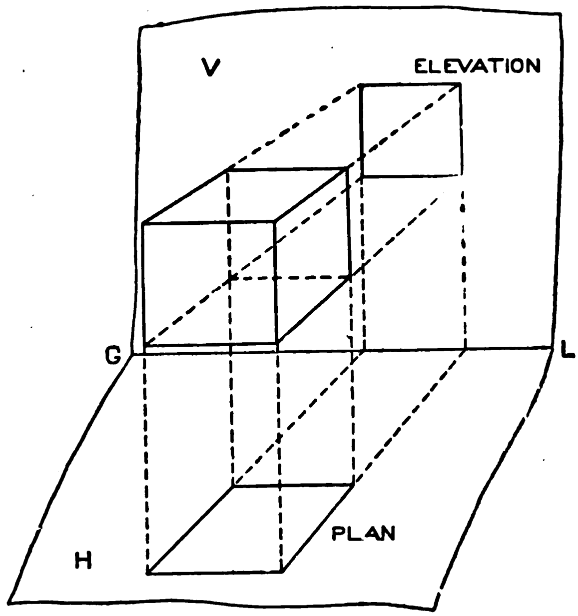


Fig. 2.

line, and the distance of *a* in front of the vertical plane is equal to the distance of a^h in front of the ground line. Applying this principle to Fig. 3, the point represented by a^v and a^h must be a point $\frac{3}{4}$ inch above H and 1 inch in front of V.

All points on an object at the same height must appear in elevation at the same distance above the ground line. If numbers 1, 2, 3 and 4 on the plan indicate the top corners of the cube, then these four points, being at the same height, must be shown in elevation at the same height and at the top, $\frac{4}{1}$ and $\frac{3}{2}$. The top of the cube, 1, 2, 3, 4, is shown in elevation as the straight line

$\frac{4}{1} - \frac{3}{2}$. This illustrates the fact that *if a surface is perpendicular to either plane of projection, its projection on that plane is simply a line; a straight line if the surface is plane, a curved line if the surface is curved.* From the same figure it is seen that the top edge of the cube, 1 4, has for its projection on the vertical plane

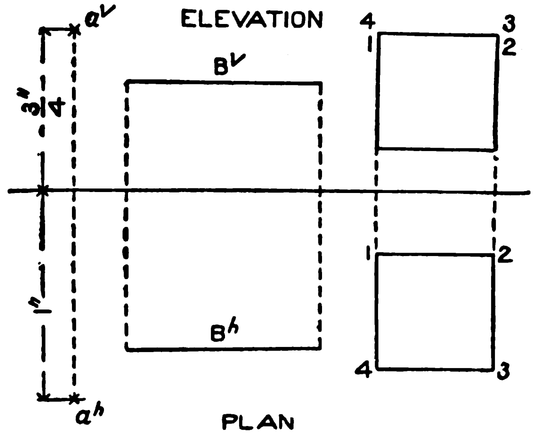


Fig. 3.

the point $\frac{4}{1}$, the principle of which is stated in this way: If a straight line is perpendicular to either V or H, its projection on that plane is a point, and on the other plane is a line equal in length to the line itself, and perpendicular to the ground line.

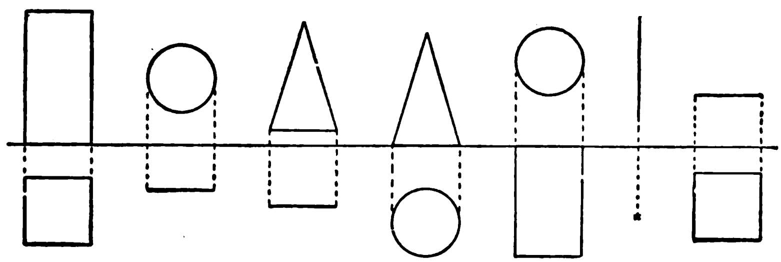


Fig. 4.

Fig. 4 is given as an exercise to help to show clearly the idea of plan and elevation. The student should answer the following question for himself: What does each of these projections represent?

Suppose in Fig. 5, that it is desired to construct the projections of a prism $1\frac{1}{2}$ in. square, and 2 in. long, standing on one end on the horizontal plane, two of its faces being parallel to the vertical plane. In the first place, as the top end of the prism is a square, the top view or plan will be a square of the same size, that is, $1\frac{1}{2}$ in. Then since the prism is placed parallel to and in front of the vertical plane the plan, $1\frac{1}{2}$ in. square, will have two edges parallel to the ground line. As the front face of the prism

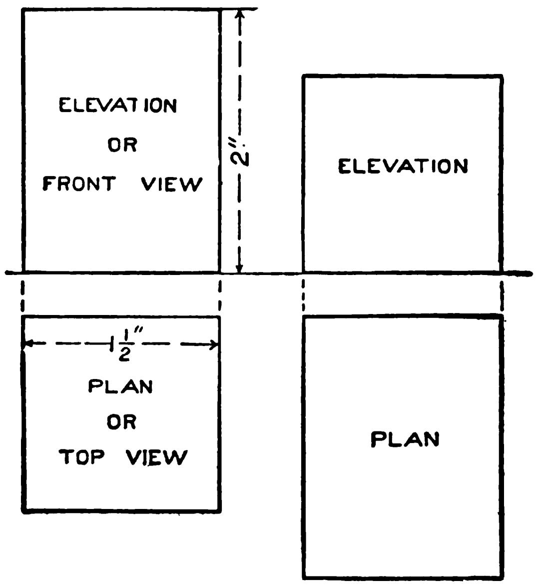


Fig. 5.

is parallel to the vertical plane its projection on V will be a rectangle, equal in length and width to the length and width respectively of the prism, and as the prism stands with its base on H, the elevation, showing height above H, must have its base on the ground line. Observe carefully that points in elevation are vertically over corresponding points in plan.

The second drawing in Fig. 5 represents a prism of the same size lying on one side on the horizontal plane, and with the ends parallel to V.

The principles which have been used thus far may be stated as follows, —

1. If a line or point is on either plane, its other projection must be in the ground line.

2. Height above H is shown in elevation as height above the ground line, and distance in front of the vertical plane is shown in plan as distance from the ground line.

3. If a line is parallel to either plane, its actual length is shown on that plane, and its other projection is parallel to the ground line. A line oblique to either plane has its projection on that plane shorter than the line itself, and its other projection oblique to the ground line. No projection can be longer than the line itself.

4. A plane surface if parallel to either plane, is shown on

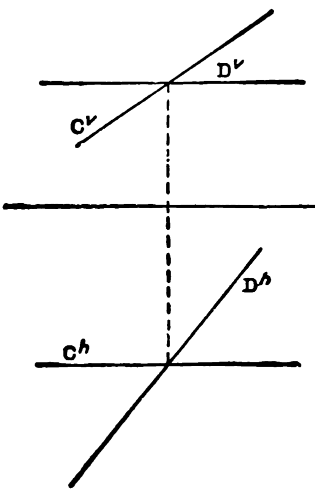


Fig. 6.

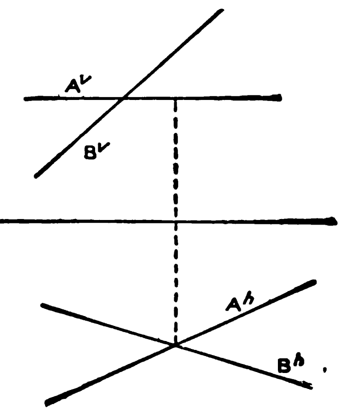


Fig. 7.

that plane in its true size and shape; if oblique it is shown smaller than the true size, and if perpendicular it is shown as a straight line. Lines parallel in space must have their V projections parallel to each other and also their H projections.

If two lines intersect, their projections must cross, since the point of intersection of the lines is a point on both lines, and therefore the projections of this point must be on the projections of both lines, or at their intersection. In order that intersecting lines may be represented, the vertical projections must intersect in a point vertically above the intersection of the horizontal projections. Thus Fig. 6 represents two lines which do intersect as C^v crosses D^v at a point vertically above the intersection of C^h and D^h. In Fig. 7, however, the lines do not intersect since the intersections of their projections do not lie in the same vertical line.

In Fig. 8 is given the plan and elevation of a square pyramid standing on the horizontal plane. The height of the pyramid is the distance A B. The slanting edges of the pyramid, A C, A D, etc., must be all of the same length, since A is directly above the center of the base. What this length is, however, does not appear in either projection, as these edges are not parallel to either V or H.

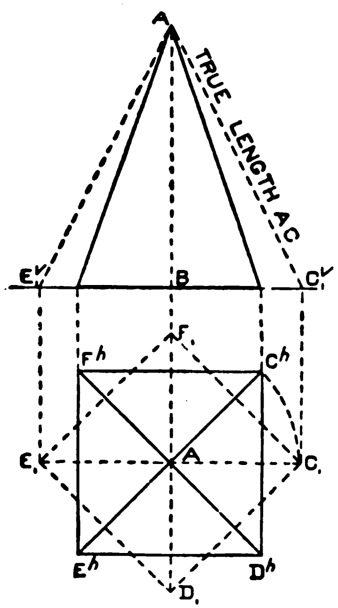
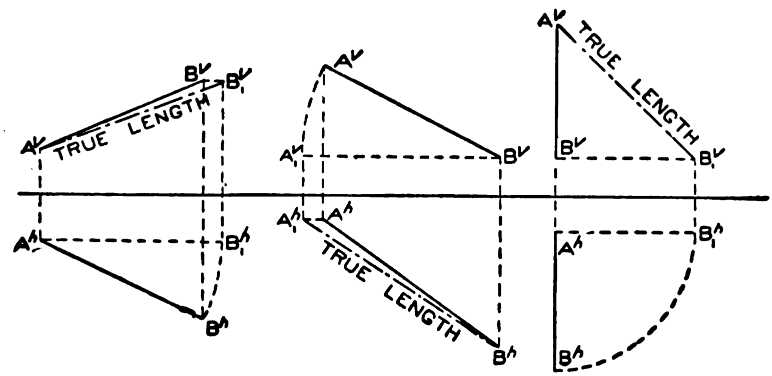


Fig. 8.

Suppose that the pyramid be turned around into the dotted position C_1 D_1 E_1 F_1 where the horizontal projections of two of the slanting edges, A C_1 and A E_1 are parallel to the ground line. These two edges, having their horizontal projections parallel to the ground line, are now parallel to V, and therefore their new vertical projections will show their true lengths. The base of the pyramid is still on H, and therefore is projected on V in the ground line. The apex is in the same place as before, hence the vertical projection of the pyramid in its new position is shown by the dotted lines. The vertical projection A C_1^v is the true length of edge A C. Now if we wish to find simply the true length of A C, it is unnecessary to turn the whole pyramid around, as the one line A C will be sufficient.

The principle of finding the true length of lines is this, and can be applied to any case: Swing one projection of the line parallel to the ground line, using one end as center. On the other projection the moving end remains at the same distance from the ground line, and of course vertically above or below the same end in its parallel position. This new projection of the line shows its true length. See the three Figures at the top of next page.

Third plane of projection or profile plane. A plane perpendicular to both co-ordinate planes, and hence to the ground line, is



called a *profile plane.* This plane is vertical in position, and may be used as a plane of projection. A projection on the profile plane is called a profile view, or *end view*, or sometimes edge view, and is often required in machine or other drawing when the plan and elevation do not sufficiently give the shape and dimensions.

A projection on this plane is found in the same way as on the

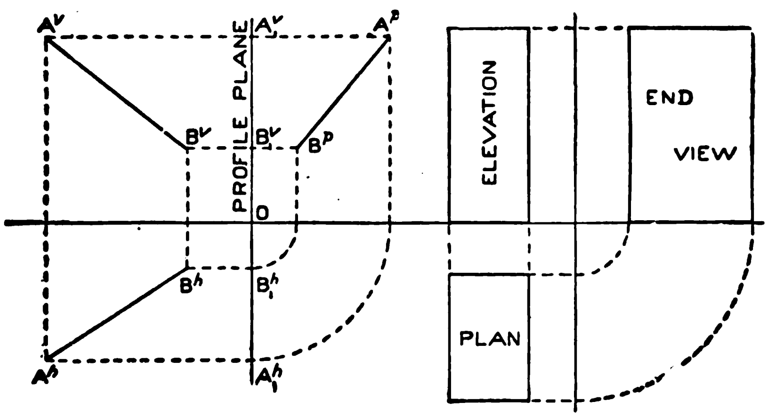


Fig. 9.

V plane, that is, by perpendiculars drawn from points on the object.

Since, however, the profile plane is perpendicular to the ground line, it will be seen from the front and top simply as a straight line; in order that the size and shape of the profile view may be shown, the profile plane is revolved into V using its intersection with the vertical plane as the axis.

Given in Fig. 9, the line A B by its two projections A^v B^v and A^h B^h, and given also the profile plane. Now by projecting the line on the profile by perpendiculars, the points A_1^v B_1^v and B_1^h A_1^h are found. Revolving the profile plane like a door on its hinges, all points in the plane will move in horizontal circles, so the horizontal projections A_1^h and B_1^h will move in arcs of circles with O as center to the ground line, and the vertical projections B_1^v and A_1^v will move in lines parallel to the ground line to positions directly above the revolved points in the ground line, giving the profile view of the line A^p B^p. Heights, it will be seen, are the same in profile view as in elevation. By referring to the rectangular prism in the same figure, we see that the elevation gives vertical dimensions and those parallel to V, while the end view shows vertical dimensions and those perpendicular to V. The profile view of any object may be found as shown for the line A B by taking one point at a time.

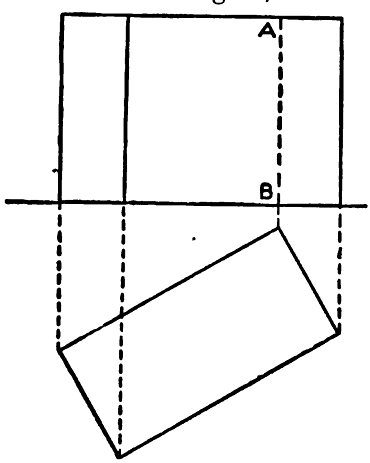


Fig. 10.

In Fig. 10 there is represented a rectangular prism or block, whose length is twice the width. The elevation shows its height. As the prism is placed at an angle, three of the vertical edges will be visible, the fourth one being invisible.

In mechanical drawing lines or edges which are invisible are drawn *dotted.* The edges which in projection form a part of the outline or contour of the figure must always be visible, hence always *full lines.* The plan shows what lines are visible in elevation, and the elevation determines what are visible in plan. In Fig. 10, the plan shows that the dotted edge A B is the back edge, and in Fig. 11, the dotted edge C D is found, by looking at the elevation, to be the lower edge of the triangular prism. In general, if in elevation an edge projected *within* the figure is a back edge, it must be dotted, and in plan if an edge projected within the outline is a lower edge it is dotted.

Fig. 12 is a circular cylinder with the length vertical and

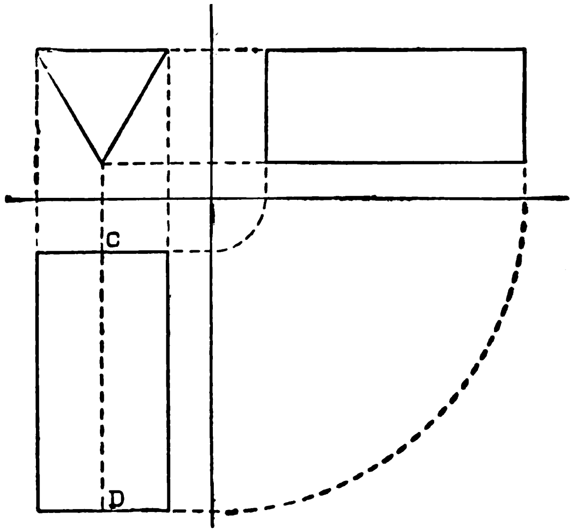


Fig. 11.

with a hole part way through as shown in elevation. Fig. 13 is plan, elevation and end view of a triangular prism with a square hole from end to end. The plan and elevation alone would be insufficient to determine positively the shape of the hole, but the end view shows at a glance that it is square.

In Fig. 14 is shown plan and elevation of the frustum of a square pyramid, placed with its base on the horizontal plane. If the frustum is turned through 30°, as shown in the plan of Fig. 15, the top view or plan must still be the same shape and size, and as the frustum has not been raised or lowered, the heights of all points must appear the same in elevation as before in Fig. 14. The elevation is easily found by projecting points up from the plan, and projecting the height of the top horizontally across from the first elevation, because the height does not change.

The same principle is further illustrated in Figs. 16 and 17. The elevation of Fig. 16 shows a square prism resting on one edge, and raised up at an angle of 30° on the right-hand side. The plan gives the width or thickness, $\frac{5}{8}$ in. Notice that the length of the plan is greater than 2 in. and that varying the angle at

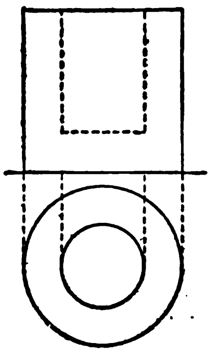


Fig. 12.

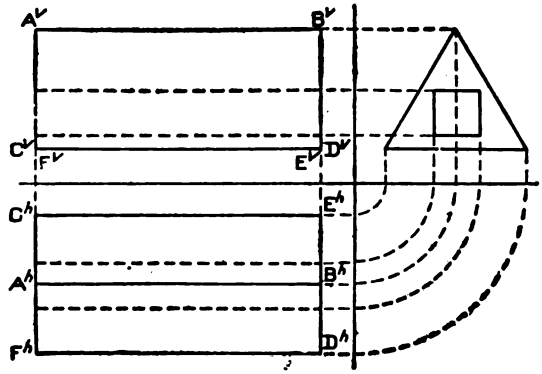


Fig. 13.

which the prism is slanted would change the length of the plan. Now if the prism be turned around through any angle with the vertical plane, the lower edge still being on H, and the inclination

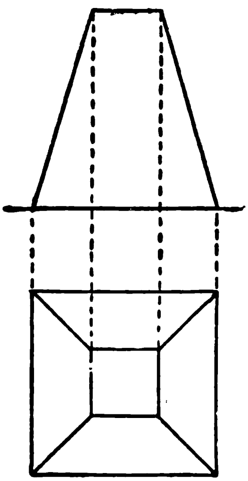


Fig. 14.

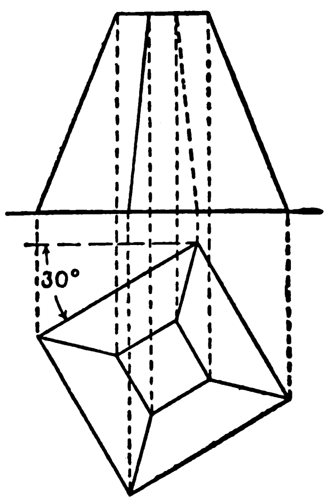


Fig. 15.

of 30° with H remaining the same, the plan must remain the same size and shape.

If the angle through which the prism be turned is 45°, we have the second plan, exactly the same shape and size as the first. The elevation is found by projecting the corners of the prism ver-

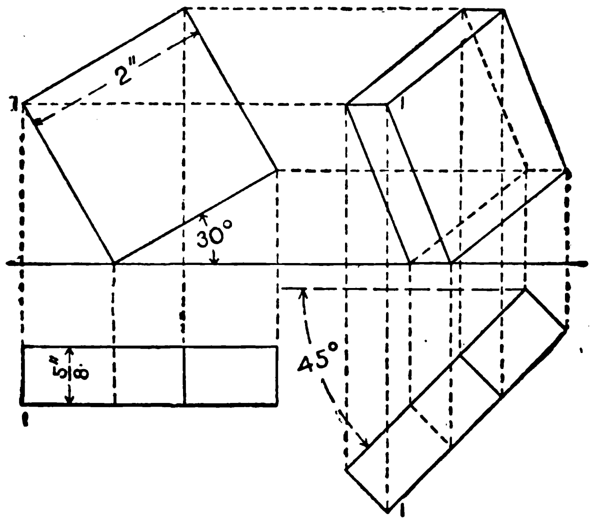


Fig. 16.

tically up to the heights of the same points in the first elevation. All the other points are found in the same way as point No. 1.

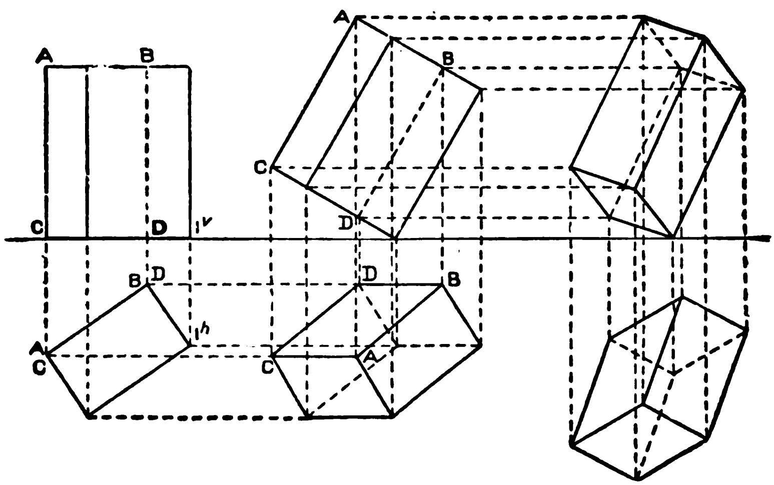


Fig. 17.

Three positions of a rectangular prism are shown in Fig. 17. In the first view, the prism stands on its base, its axis therefore is parallel to the vertical plane. In the second position, the axis is still parallel to V and one corner of the base is on the horizontal plane. The prism has been turned as if on the line $1^h\ 1^v$ as an axis, so that the inclination of all the faces of the prism to the vertical plane remains the same as before. That is, if in the first figure the side A B C D makes an angle of 30° with the vertical, the same side in the second position still makes 30° with the ver-

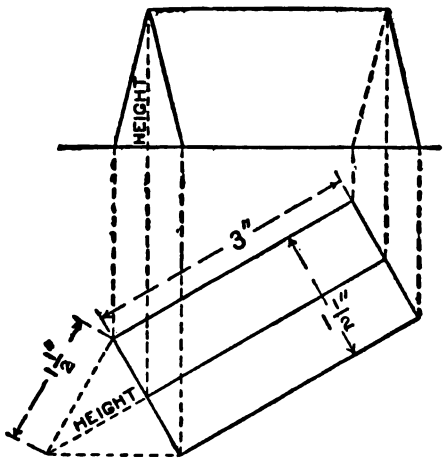
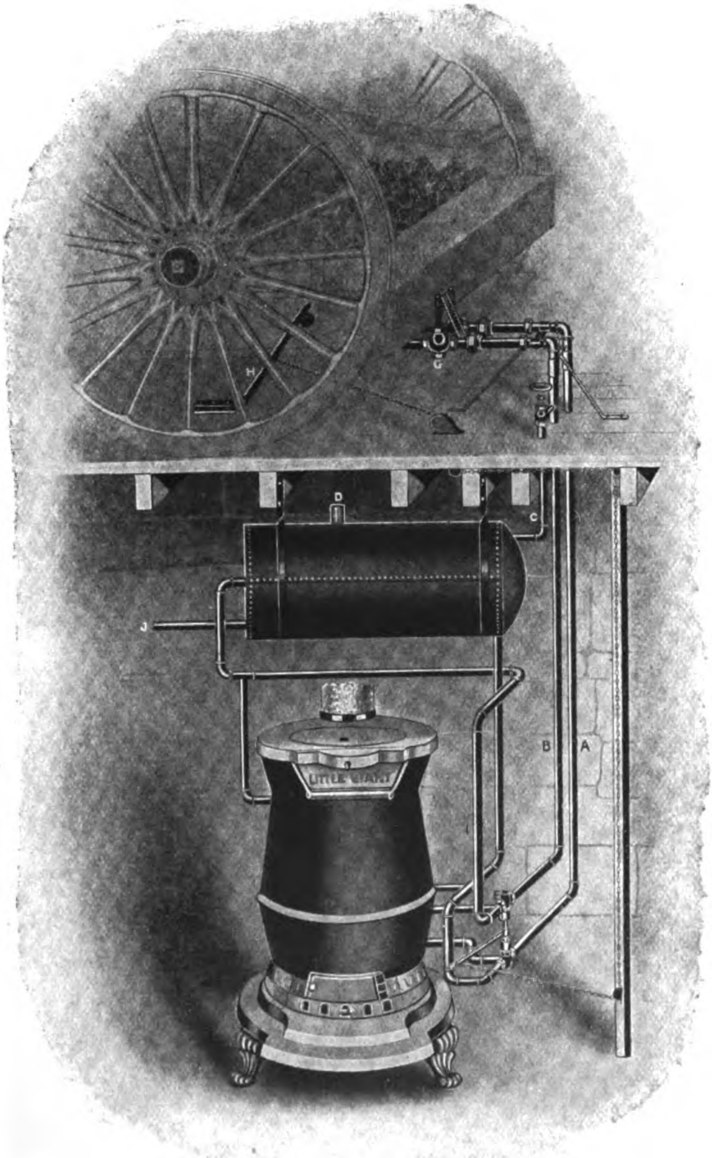


Fig. 18.

tical plane. Hence the elevation of No. 2 is the same shape and size as in the first case. The plan is found by projecting the corners down from the elevation to meet horizontal lines projected across from the corresponding points in the first plan. The third position shows the prism with all its faces and edges making the same angles with the horizontal as in the second position, but with the plan at a different angle with the ground line. The plan then is the same shape and size as in No. 2, and the elevation is found by projecting up to the same heights as shown in the preceeding elevation. This principle may be applied to any solid, whether bounded by plane surfaces or curved.

This principle as far as it relates to heights, is the same that was used for profile views. An end view is sometimes necessary before the plan or elevation of an object can be drawn. Suppose that in Fig. 18 we wish to draw the plan and elevation of a triangular prism 3" long, the end of which is an equilateral triangle



LITTLE GIANT BOILER AS INSTALLED FOR FIRE DEPARTMENT SERVICE
Pierce, Butler & Pierce Mfg. Co.

$1\frac{1}{2}''$ on each side. The prism is lying on one of its three faces on H, and inclined toward the vertical plane at an angle of 30°. We are able to draw the plan at once, because the width will be $1\frac{1}{2}$ inches, and the top edge will be projected half way between the other two. The length of the prism will also be shown. Before we can draw the elevation, we must find the height of the top edge. This height, however, must be equal to the altitude of the triangle forming the end of the prism. All that is necessary, then, is to construct an equilateral triangle $1\frac{1}{2}''$ on each side, and measure its altitude.

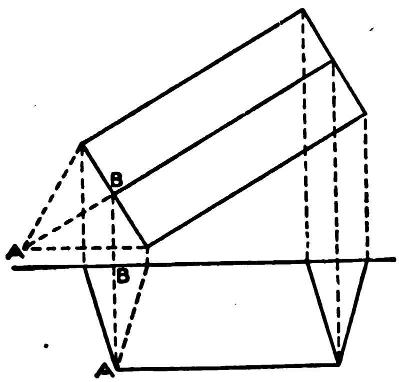


Fig. 19.

A very convenient way to do this is shown in the figure by laying one end of the prism down on H. A similar construction is shown in Fig. 19, but with one face of the prism on V instead of on H.

In all the work thus far the plan has been drawn below and the elevation above. This order is sometimes inverted and the plan put above the elevation.

PLATES.

PLATE V.

The plates of this paper should be laid out the same size as the plates in Part I. The center lines and border lines should also be drawn as shown.

First draw two ground lines across the sheet, 3 inches below the upper border line and 3 inches above the lower border line. The first problem on each ground line is to be placed 1 inch from the left border line and spaces of about 1 inch should be left between the figures.

Isolated points are indicated by a small cross ×, and projections of lines are to be drawn full unless invisible. All construction lines should be fine dotted lines. Given and required lines should be drawn full.

Problems on upper ground line;

PROBLEM 1. Locate both projections of a point on the horizontal plane 1 inch from the vertical plane.

PROBLEM 2. Draw the projections of a line 2 inches long which is parallel to the vertical plane and makes an angle of 45 degrees with the horizontal and slants upward to the right.

The line should be 1 inch from the vertical plane and the lower end $\frac{1}{2}$ inch above the horizontal.

PROBLEM 3. Draw the projections of a line $1\frac{1}{2}$ inches long, which is parallel to both planes 1 inch above the horizontal and $\frac{3}{4}$ inch from the vertical.

PROBLEM 4. Draw the plan and elevation of a line 2 inches long which is parallel to H and makes an angle of 30 degrees with V. Let the right-hand end of the line be the end nearer V, $\frac{1}{2}$ inch from V. The line to be 1 inch above H.

PROBLEM 5. Draw the plan and elevation of a line $1\frac{1}{2}$ inches long which is perpendicular to the horizontal plane and 1 inch from the vertical. The lower end of line is $\frac{1}{2}$ inch above H.

PROBLEM 6. Draw the projections of a line 1 inch long which is perpendicular to the vertical plane and $1\frac{1}{2}$ inch above the horizontal. The end of the line nearer V, or the back end, is $\frac{1}{2}$ inch from V.

PROBLEM 7. Draw two projections which shall represent a line oblique to both planes.

NOTE: Leave 1 inch between this figure and the right-hand border line.

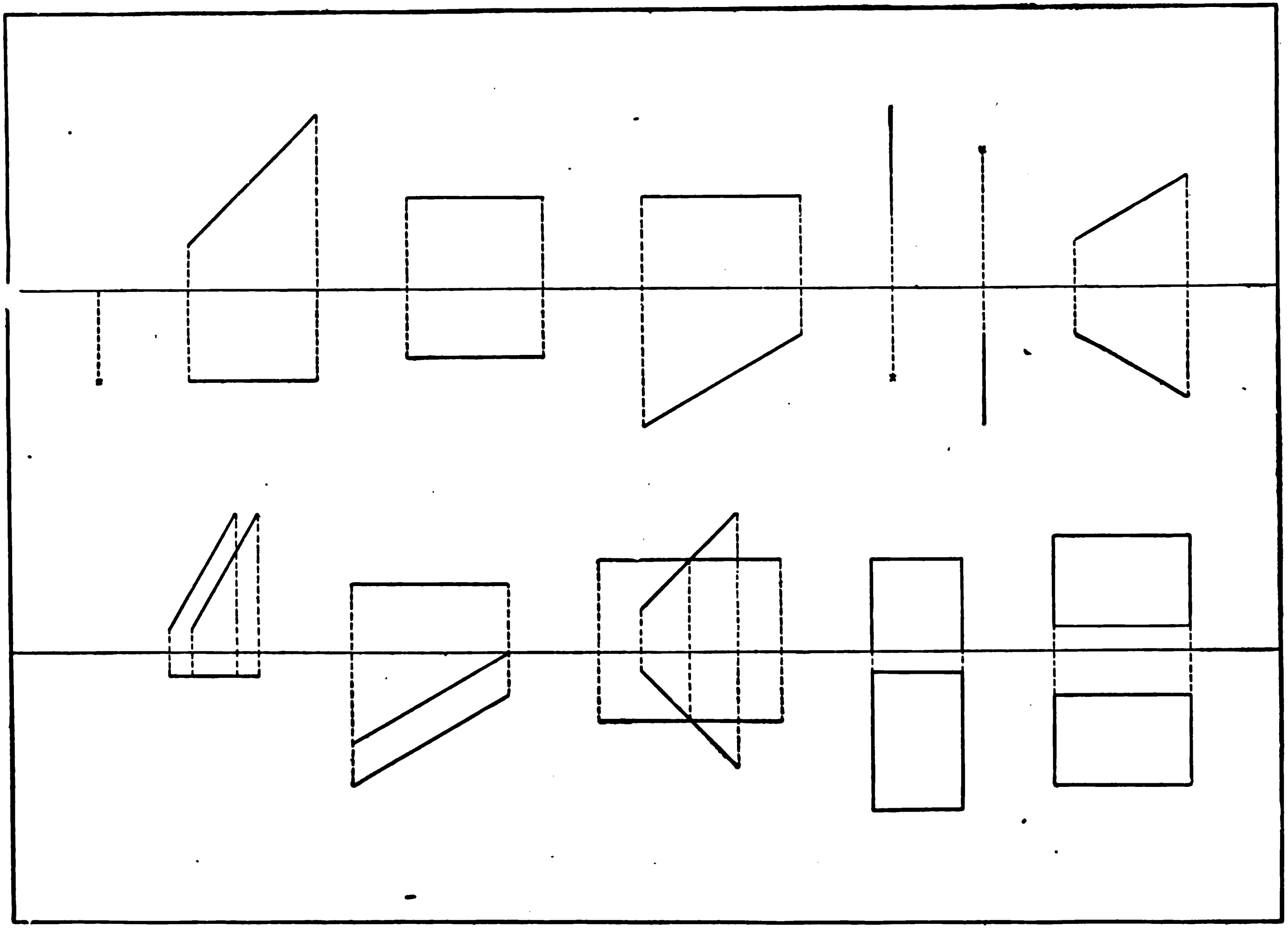
Problems on lower ground line.

PROBLEM 8. Draw the projections of two parallel lines each $1\frac{1}{2}$ inches long. The lines are to be parallel to the vertical plane and make angles of 60 degrees with the horizontal. The lower end of each line is $\frac{1}{4}$ inch above H. The right-hand end of the right-hand line is to be $2\frac{3}{4}$ inches from the left-hand margin.

PROBLEM 9. Draw the projections of two parallel lines each 2 inches long. Both lines to be parallel to the horizontal and make an angle of 30 degrees with the vertical. The lower line to be $\frac{3}{4}$ inch above H and one end of one line to be against V.

PROBLEM 10. Draw the projections of two intersecting lines. One 2 inches long to be parallel to both planes 1 inch

PLATE V



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above H and $\frac{3}{4}$ inch from the vertical, and the other to be oblique to both planes and of any desired length.

PROBLEM 11. Draw plan and elevation of a prism 1 inch square and $1\frac{1}{2}$ inches long. The prism to have one side on the horizontal plane and the long edges perpendicular to V. The back end of the prism is $\frac{1}{4}$ inch from the vertical plane.

PROBLEM 12. Draw plan and elevation of a prism the same size as given above, but with the long edges parallel to both planes, the lower face of prism parallel to H and $\frac{1}{4}$ inch above it. The back face to be $\frac{1}{2}$ inch from V.

PLATE VI.

The ground line is to be in the middle of the sheet, and the location and dimensions of the figures are to be as given. The first figure shows a rectangular block with a rectangular hole cut through from front to back. The other two figures represent the same block in different positions. The second figure is the end or profile projection of the block. The same face is on H in all three positions. Be careful not to omit the shade lines, and try to see why each one is put on

PLATE VII.

Three ground lines are to be used on this plate, two at the left, $4\frac{1}{2}''$ long and $3''$ from top and bottom margin lines, and one at the right, half way between the top and bottom margins, $9\frac{1}{2}''$ long.

The figures 1, 2, 3 and 4 are examples for finding the true lengths of the lines. Begin No. 1 $\frac{3}{4}''$ from the border, the vertical projection $1\frac{3}{4}''$ long, one end on the ground line, and inclined at 30°. The horizontal projection has one end $\frac{1}{2}''$ from V and the other $1\frac{1}{2}''$ from V. Find the true length of the line by completing the construction commenced by swinging the arc, as shown in the figure.

Locate the left-hand end of No. 2 $3''$ from the border, $1''$ above H and $\frac{5}{8}''$ from V. Extend the vertical projection to the ground line at an angle of 45°, and make the horizontal projection at 30°. Complete the construction for true length as commenced in the figure.

In figures 3 and 4 the true lengths are to be found by completing the revolutions indicated. The left-hand end of Fig. 3 is $\frac{3}{4}''$ from the margin, $1\frac{1}{2}''$ from V and $1\frac{3}{8}''$ above H. The horizontal projection makes an angle of 60° and extends to the ground line, and the vertical projection is inclined at 45°.

The fourth figure is 3″ from the border and represents a line in a profile plane connecting points *a* and *b*. *a* is $1\frac{1}{4}''$ above H and $\frac{3}{4}''$ from V, and *b* is $\frac{1}{4}''$ above H and $1\frac{1}{2}''$ from V.

The figures for the middle ground line represent a pentagonal pyramid in three positions. The first position is the pyramid with the axis vertical and base $\frac{5}{8}''$ above the horizontal. The height of pyramid is $2\frac{1}{2}''$ and the diameter of the circle circumscribed about the base is $2\frac{1}{2}''$. The center of the circle is 6″ from the left margin and $1\frac{3}{4}''$ from V. Spaces between figures to be $\frac{3}{4}''$.

In the second figure the pyramid has been revolved about the right-hand corner of the base as an axis through an angle of 15°. The axis of the pyramid, shown dotted, is therefore at 75°. The method of obtaining 75° and 15° with the triangles was shown in Part I. From the way in which the pyramid has been revolved, all angles with V must remain the same as in the first position, hence the vertical projection will be the same shape and size as before. The points on the plan are found on T-square lines through the corners of the first plan and directly beneath the points in elevation. In the third position the pyramid has been swung around about a vertical line through the apex as axis, through 30°. The angle with the horizontal plane remains the same, consequently the plan is the same size and shape as in the second position, but at a different angle with the ground line. Heights of all points of the pyramid have not changed this time, and hence are projected across from the second elevation. Shade lines are to be put on between the light and dark surfaces as determined by the 45° triangle.

PLATE VI

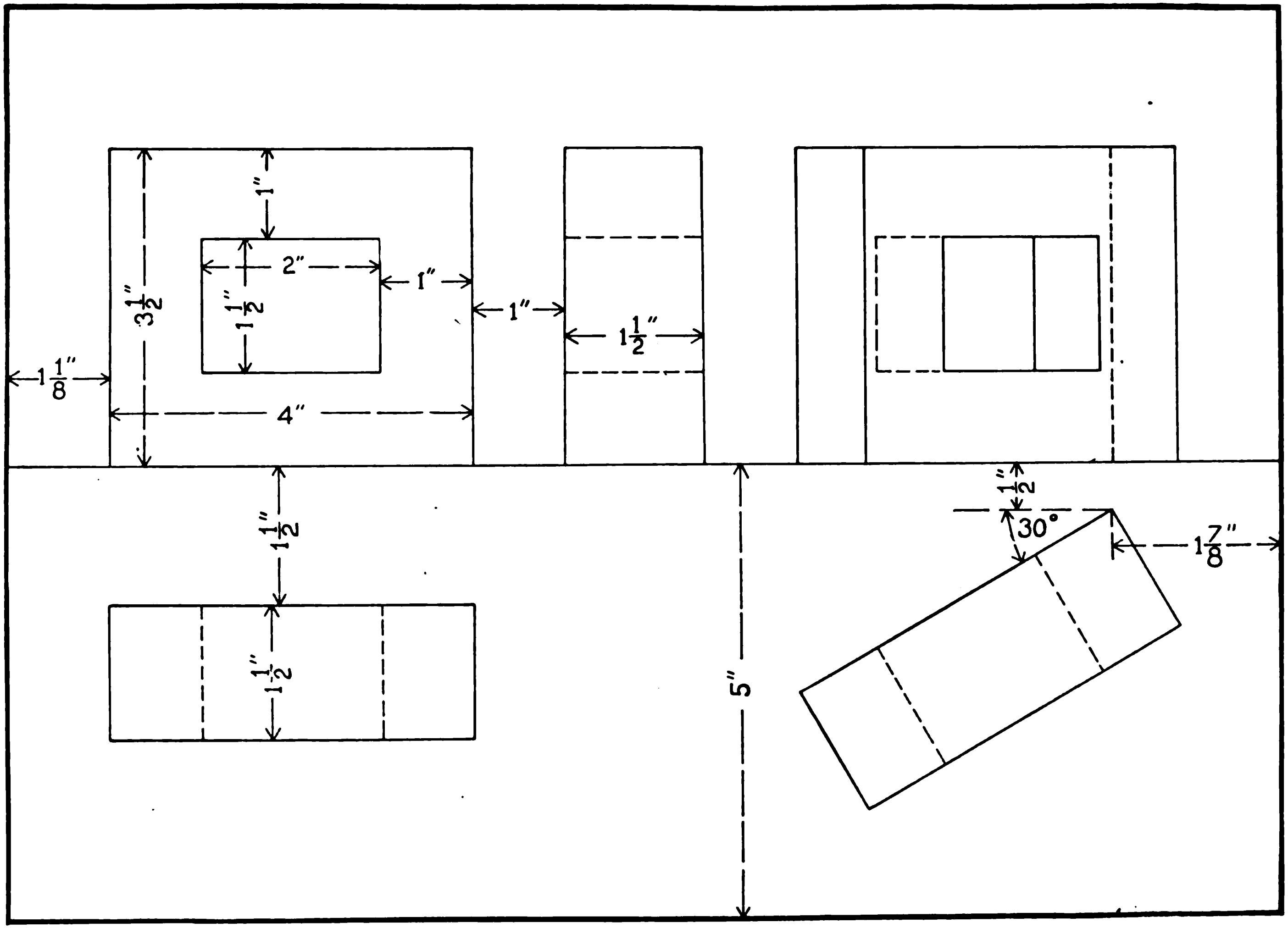

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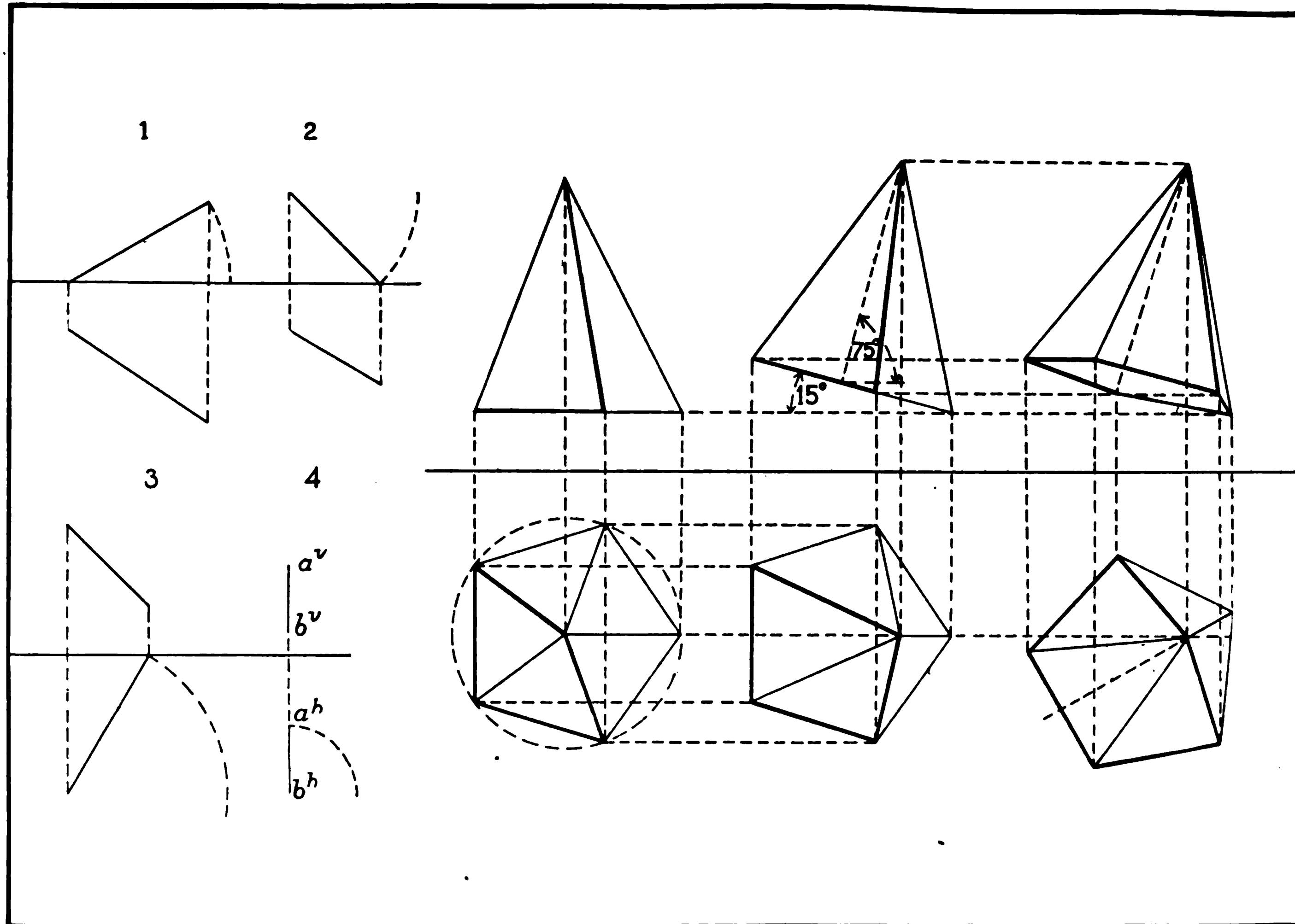
PLATE VII



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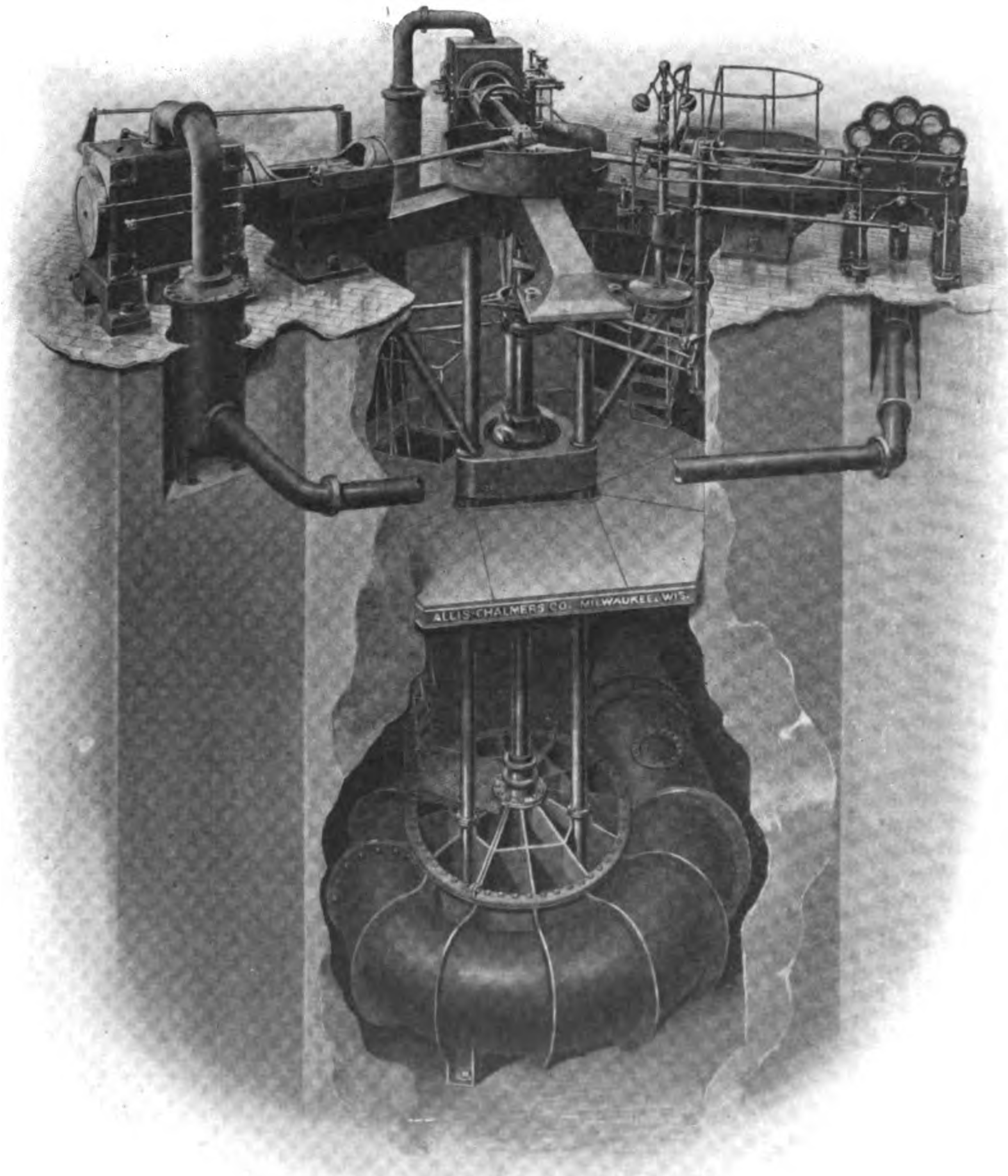


ONE OF THE FOUR CENTRIFUGAL PUMPING UNITS IN THE 39TH ST. SEWAGE PUMPING STATION, CHICAGO, ILL.

Allis-Chalmers Co., Milwaukee, Wis.

MECHANICAL DRAWING.

PART III.

WORKING DRAWINGS.

In Mechanical Drawing Parts I and II, instruments and materials are described and some hints given regarding the use of compasses, line pen, triangles, T-square, etc. In addition, the general principles upon which all Mechanical Drawing depends, are explained. After completing this work the student should be able to draw neatly and accurately and apply the fundamental principles.

Let us now take up the subject of working drawings and see how the principles of orthographic projection are made of practical use. We shall see, as we go on, that to a great extent the theoretical principles already learned in the study of projections are used in practical working shop drawings. Nevertheless, there are certain instances in which actual practice differs slightly from the theory.

We shall also find that all draftsmen do not follow the same customs in the matter of minor details, but that in many cases there are several ways of representing objects, all of which may be equally correct, one draftsman using one method either because he prefers it or because it best serves the purpose for which his particular work is being done, while another draftsman uses a different method. The more important principles and customs, however, are pretty well established.

A study of the subject of working drawings should, first, teach us the methods of the best drafting rooms; second, should train our judgment to decide how best to represent the particular object which we have to draw; third, should train our hand and eye to make a clear, neat and well-executed drawing, without unnecessary expenditure of time.

Definition of Working Drawing. A working drawing of any object is a drawing which completely describes the object in every particular, showing its form, size, material, finish, and all other details, so that a workman may take the drawing and without any further instructions make the object exactly as the draftsman intended it to be made. The drawing is, therefore, a sort of language, by which the man who designs the object describes it to the man who is to make it. Fig. 1 shows the working drawing of a bell crank lever. The drawing itself shows the shape and the dimensions show the size.

Aside from drawings of buildings, etc., that is Architectural drawings, the greater part of the working drawings which are made are for machines, and we will consider chiefly the latter, or, as they are called, machine drawings. These drawings are almost always orthographic projections, as this is by far the easiest and best way to represent a machine or a part of a machine. Sometimes, when it is desired to give a sort of bird's-eye view of a machine, an isometric or an oblique projection is made, but this method involves so much labor that it is seldom used.

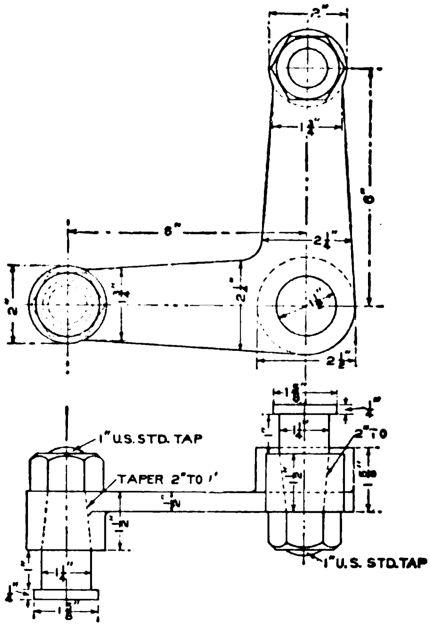


Fig. 1.

Lines. In order to make a drawing perfectly clear, and to avoid confusing one line with another, different kinds of lines are used for different purposes. Fig. 2 shows the six most common kinds used. The ordinary *full lines* are used to represent visible lines of the object which is being drawn.

The *invisible lines* are used to represent lines of the object which would be hidden from sight if a person looked in the direction in which he imagines himself to be looking while he is drawing it.

The use of the *shade lines* will be explained later.

Center lines are used to connect different views of an object, the line being drawn through the center of the piece and extending through both views. Locations of holes are usually shown by having two center lines drawn at right angles to each other through their centers, and the position of these center lines located. Wherever a dimension is to be given to the center of a piece a center line is drawn through the piece and the dimension given to this line.

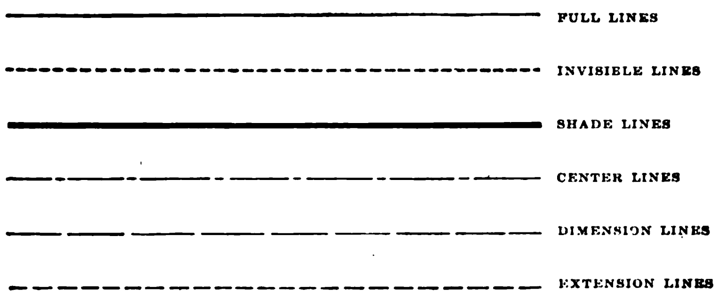


Fig. 2.

Extension lines are sometimes used to connect two views of a piece, but, wherever it is possible to use a center line, instead, the latter is preferable. The principal use of extension lines is, as the name implies, to extend the lines of the object so as to give dimensions between them.

Dimension lines are used in giving dimensions from one line or point to another.

The ordinary lines and the invisible lines should be made of the same width; the shade lines should be made considerably heavier, and the center lines, extension lines and dimension lines should be lighter.

Location of Views. In our preceding study of projections we imagined our object to be held in the angle formed by two planes which intersect at right angles, the planes and the object being supposed to be in the position represented in Fig. 3, the horizontal plane H being below the object, and the vertical plane V being beside the object. We then projected down to the horizontal plane and represented there the object as it would appear if seen squarely in the direction indicated by arrow A. We next projected into the vertical plane, and represented the object as it would appear if the line of vision took the direction of the arrow B. Our planes, with the horizontal and vertical projections of the object on them, when laid out flat, as a sheet of paper is when we actually draw on it, would appear as in Fig. 4, the horizontal projection, or top view, being *underneath* the vertical projection, or side view. This is the practice followed by some draftsmen in making working drawings. Many of the best draftsmen, however, think that it is not as clear and convenient to have the top view of the object underneath the side view, but that it is better to have the view of the top above the other view. Consequently, it is becoming more and more a general custom to suppose the planes to be transparent and to be located with respect to the piece which is being drawn as shown in Fig. 5, the H plane being above the object and the V plane in front of the object. They then draw on the H plane the object as it appears when looking at it

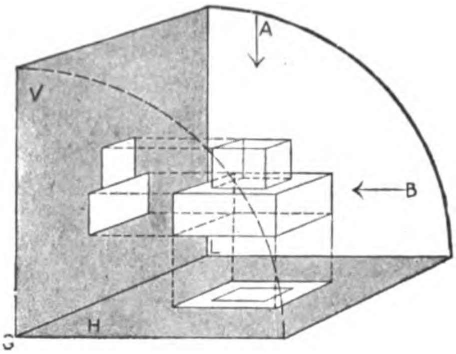


Fig. 3.

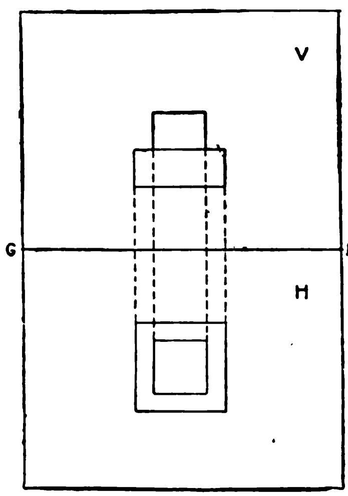


Fig. 4.

through the transparent plane in the direction indicated by arrow C, and on the V plane the object as it appears when looking in direction of arrow D. Now, when the two planes are laid out flat, the top view is above the side view, as in Fig. 6.

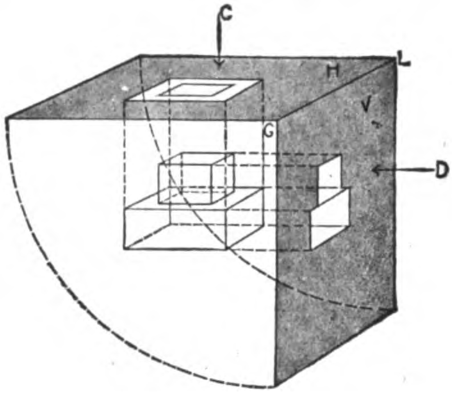


Fig. 5.

Another way of showing this is to suppose the object to be located in a transparent box, and that we look at it from the top and the various sides of the box, and draw on these sides the object as it appears from that side. Then, if the sides of the box are laid out flat, the side view will come in the middle, with the top view above, the view of the bottom underneath, the view of the right-hand side on the right, and the view of the left-hand side on the left.

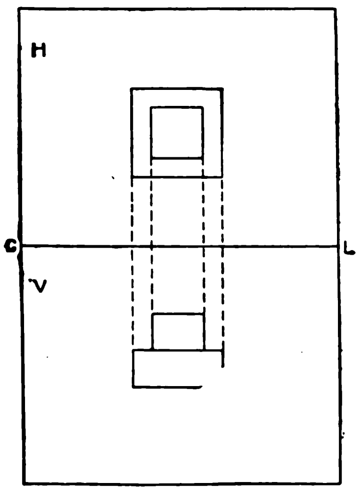


Fig. 6.

From now on, in our work on drawing, we shall follow this rule.

Cross-sections. Very often it occurs that a piece is hollow and the inside construction is more or less complicated, so that if in the drawing the outside view is shown, with the invisible interior drawn in dotted lines, the latter are so confused that the drawing is not easily understood. For this reason it is often convenient to imagine the piece to be cut open, and to draw it as if we were looking directly at the inside. Such a drawing of a piece is called a cross-section of the piece. The material which must be cut if the object were actually split open is then crosshatched, different kinds of crosshatching being used for different materials. Fig. 7 shows the kinds of cross-hatching in ordinary use.

Fig. 8 shows a plan and elevation of a simple piece with a hole through it, the hole being shown in the elevation by dotted lines. Fig. 9 shows a plan and a cross-section of the same piece, the cross-section being drawn as if we were looking in the same direction as in the elevation of Fig. 8, but in Fig. 9 the front half is supposed to be cut away and we are looking at the inside of the back half. It will be observed that even on a piece as

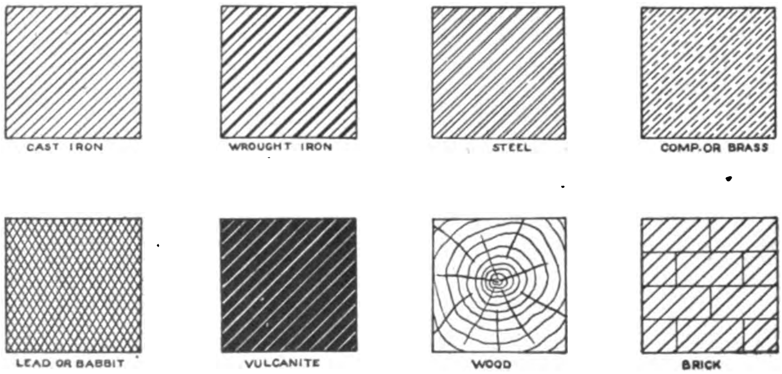


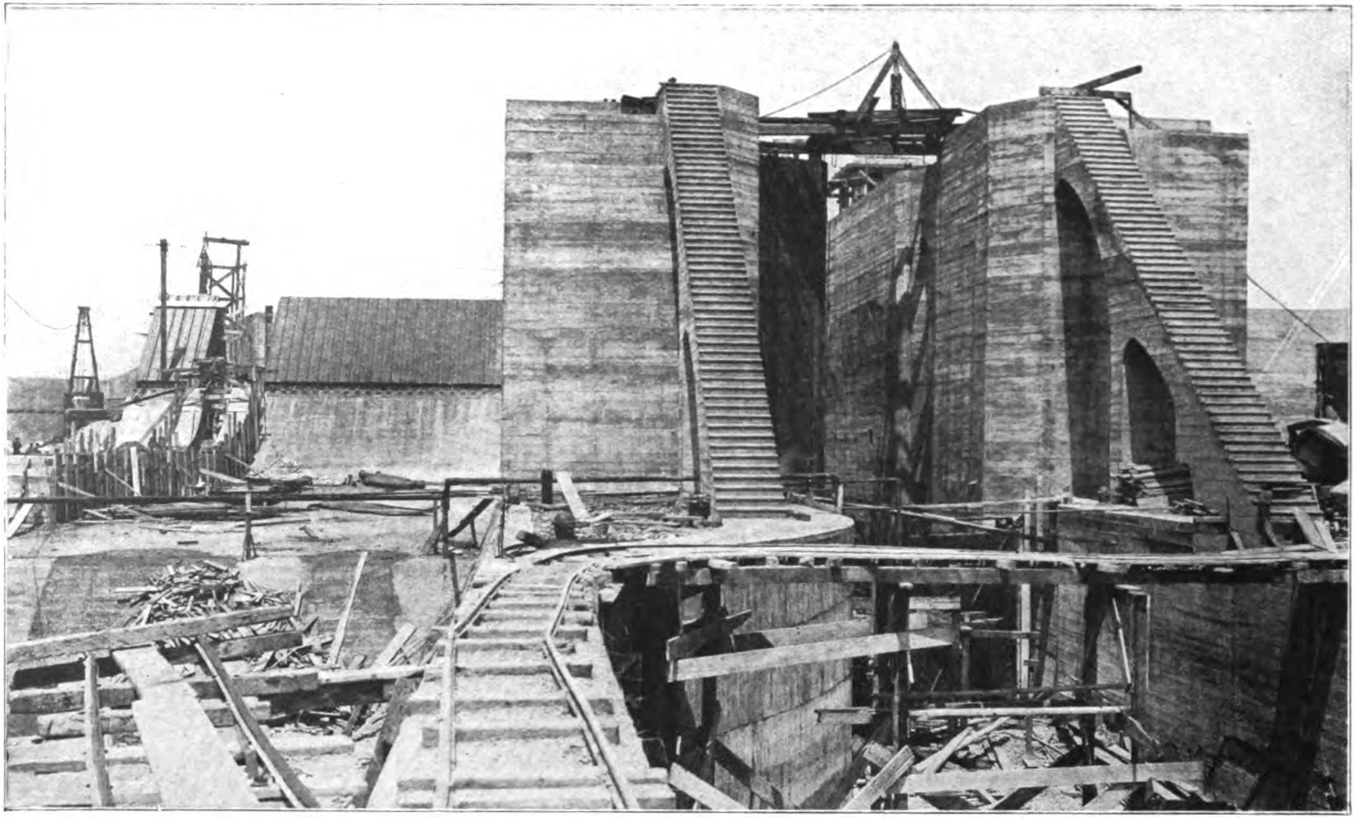
Fig. 7.

simple as the one here shown, the shape of the interior is much clearer from the cross-section than from the elevation, and on a more complicated piece the same will be true to a greater extent.

It should be borne in mind that ordinarily in making a cross-section we show not only those parts of the object which lie in the plane in which it is supposed to be cut, but also all which lie back of that plane.

Sometimes it is desirable to show the inside and the outside of a piece on the same view. Fig. 10 shows the same piece as in Fig. 8, but in Fig 10 the left-hand half of the lower view is an elevation and the right-hand half is a cross-section, the section and the elevation each extending to the center and being separated by a center line. This is as if one-quarter of it were cut away, the cuts being made along the lines C A and C B of the plan view.

Of course this combination of an elevation and cross-section



ENTRANCE TO LOCK ON CHICAGO DRAINAGE CANAL, LOCKPORT, ILL.
Lift, 40 feet.

Courtesy of R. I. Randolph.

can be used only when the right-hand and left-hand halves of the piece are alike.

Shade Lines. In order to make drawings easier to read, and to make the parts of the object stand out more clearly, shade lines are often put on the drawing. The general principle which determines what lines shall be shade lines is the same as that which governs shade lines already studied under the subject of projections. If, however, this theoretical principle were to be followed out exactly on drawings of machines, and other complicated drawings, it would involve a great deal of time and labor.

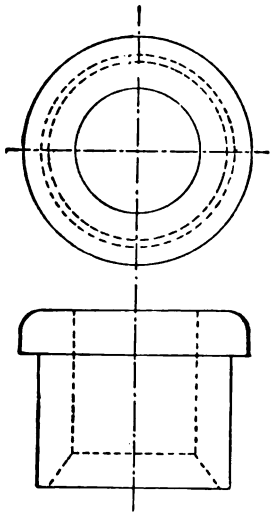


Fig. 8.

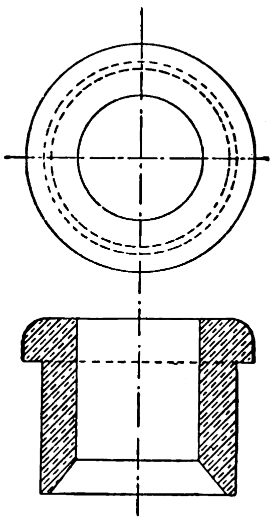


Fig. 9.

Consequently, most draftsmen place shade lines on all lines which represent lower and right-hand edges if these edges are sharp.

The contour lines of cylinders, cones and other rounded surfaces should not be shade lines, although some draftsmen shade them. If the cylinder is drawn in cross-section, however, the edge should be shaded, as the intersection of the plane and cylindrical surface is a sharp edge.

All views are shaded alike, and both are shaded as though they were elevations. The ray of light is supposed to come over the left shoulder of the draftsman, as he faces the paper, at such an angle that the projection of the ray of light on the drawing paper is in the direction of the arrow in Fig. 11.

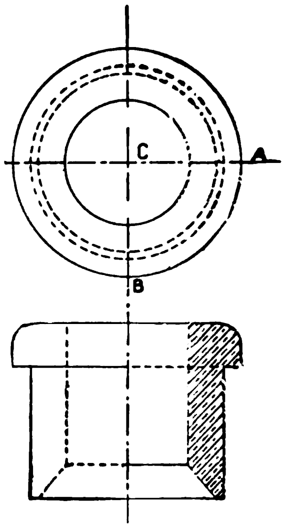


Fig. 10.

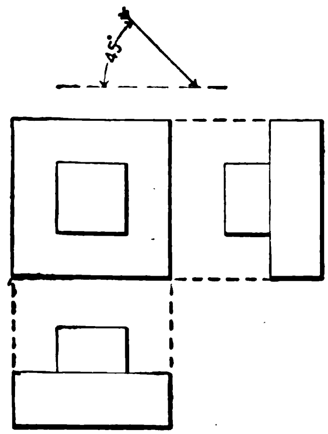


Fig. 11.

Figs. 11 to 18 show some of the most common shapes met with in drawings, and illustrate how the shade lines are placed on each. Fig. 11 is an elevation, plan, and side view of a rectangular

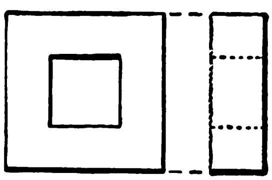


Fig 12.

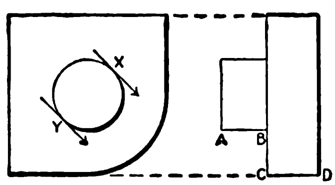


Fig. 13.

prism with a smaller one resting on top of it. Fig. 12 is a plan and side view of a rectangular prism with a rectangular hole through it. It is to be noticed that the shade lines come on the upper and left-hand sides of the hole, since these lines are the lower and right-hand edges of the material which surrounds the hole. Fig. 13 is a plan and side view of a rectangular prism with one corner rounded, and with a cylinder resting on it. Here the lines A B and C D are not shaded, since they are the contour lines of curved surfaces. In the plan view, the lower right-hand part of the circle, between X and Y, is shaded. To find these points X and Y, draw two lines tangent to the circle and making an angle of 45° with the T-square line as shown by the arrows; X and Y are the points where the arrows are tangent to the circle. Fig. 14 is a plan, elevation and cross-section of a cylinder.

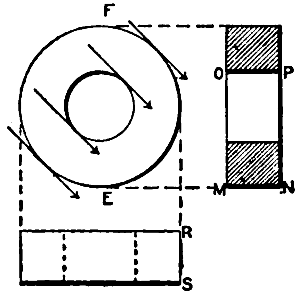


Fig. 14.

Here, in the plan, the larger circle is shaded on the lower side, and the circle which represents the hole is shaded on the upper side. The points where the shade begins are determined as explained for Fig. 13. The lines M N and O P are shaded since,

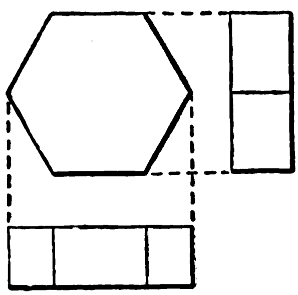


Fig. 15.

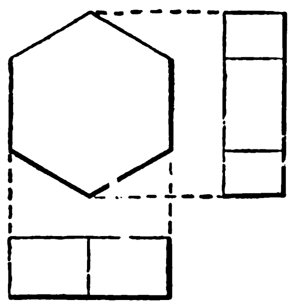


Fig. 16.

as the cylinder is supposed to be cut open, these lines now represent sharp edges. Fig. 15 is a plan, elevation and side view of a hexagonal prism with its long diameter parallel to the bottom of the paper. Fig. 16 is the same except that here the short diameter of the prism is parallel to the bottom of the paper. Fig. 17 is a plan and end view of a rectangular block with a wide slot of the shape H I J K M L O N, cut through it lengthwise. The main point to which attention should be called here is that the line

C D is shaded, although the slot might be so deep that the light might not strike in there because of the shadow of the projecting lip marked in the side view G H I. Fig. 18 is a cross-section and end view of a circular cylinder with a large hole extending part way through and a smaller hole extending the rest of the way. The small circle in the end view is shaded, although it is so far in that no light could strike it.

The student should study these figures carefully, and before

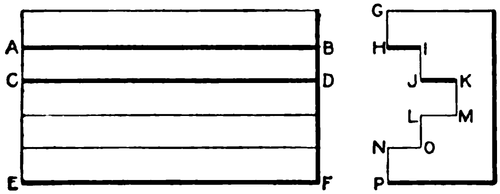


Fig. 17.

leaving them should understand what each figure means and how the shade lines are determined, so that when he meets similar forms in machine drawings he may know where the shade lines should be placed.

Dimensions. In giving the distance from one line to another, a dimension line is drawn between the two lines and arrowheads

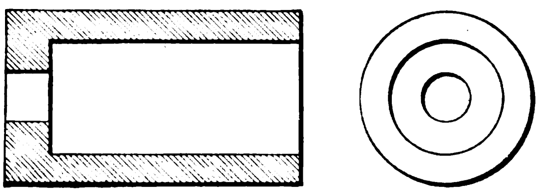


Fig. 18.

are placed at each end of the dimension line; the points of the arrowheads being *exactly on* the lines to which the measurement is being given. At a convenient place between the arrowheads a space is left in the dimension line for the figure.

Fig 19 is a plan and elevation of a rectangular piece with a cylinder on the center of its upper surface, and with four holes through it; the holes being symmetrically located with respect to the center line of the piece; that is, the holes A and B are just as far above the center line E F as C and D are below it, and the holes B and D are just as far to the right of the center line G H as A and C are to the left of it. The fact that the cylinder is on the center of the rectangular piece is shown by the lines E F and G H being drawn through the center of the circle in the plan view, these lines being the center lines both of the cylinder and of the rectangular piece. If the cylinder were not on the center, two other center lines would be drawn through the circle and the dimensions given from each of these lines to the center lines of the rectangular piece, or to the edges of the piece. The fact that the holes are symmetrically located is shown by the dimensions being given between the center lines of the holes and no dimensions being given from these center lines to the center lines of the piece.

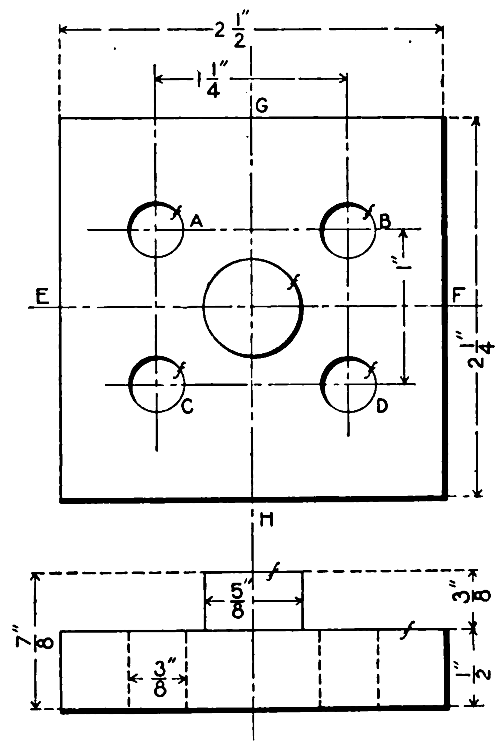


Fig. 19.

Fig. 20 shows how the piece might be dimensioned if the cylinder were not on the center of the rectangular piece and the holes were not symmetrically located with respect to the center of the rectangular piece.

If the centers of a set of holes are so located that a circle can be drawn through them, we always locate the holes by drawing a center line circle through their centers and giving the diameter of this circle, and if no other dimension than this is given for the location of the holes, it is understood that they are equally spaced around this circle. Fig. 21 illustrates this. If the holes are not equally spaced around the circle, they may be located as shown in Fig. 22.

Diameters of circles, and of arcs of circles which are greater than semicircles, should be given rather than radii, but if the arc of the circle is less than a semicircle, its radius should be given. Fig. 23 shows how this should be done when the radius is large enough to permit; but if the radius is small, or the dimensions would interfere with other parts of the drawing, it may be done as in Fig. 24.

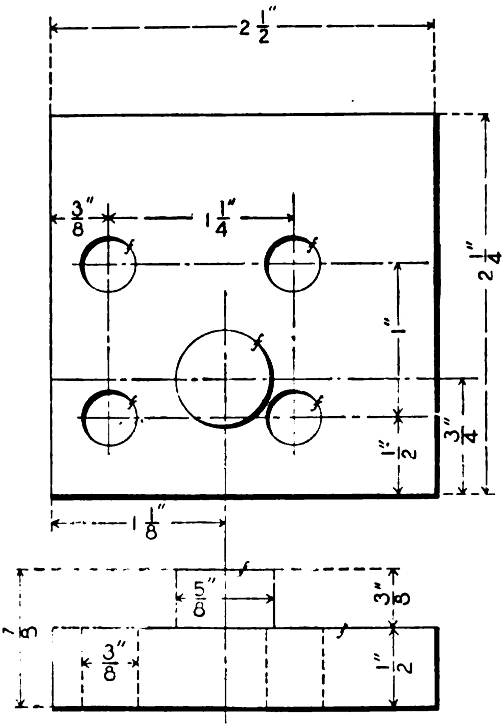


Fig. 20.

In Fig. 23 a small circle is drawn (free hand) around the center about which the arc is drawn, and a dimension line carried from the edge of this circle to the arc; an arrowhead being placed on the arc, and the figures placed in the dimension line in the usual way. In this case it is not necessary to put the letter R (abbreviation for radius) after the dimension. In the two methods shown in Fig. 24 the R should be placed after the figures.

In putting dimensions on a drawing, the figures should be placed to read from only two sides of the paper, usually from the bottom for dimension lines which are horizontal, as the $2\frac{1}{2}''$ dimen sion in Fig. 20, and from the right hand for dimension lines which are vertical, as the $2\frac{1}{4}''$ dimension in the same figure. Dimensions should never be placed on center lines if it can be avoided.

If a dimension is given in one view of an object, the same dimension need not be repeated in the other views.

In putting on fractions it is better to have the line which

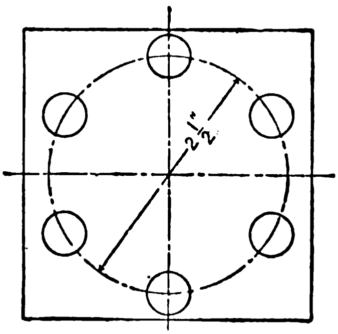


Fig. 21.

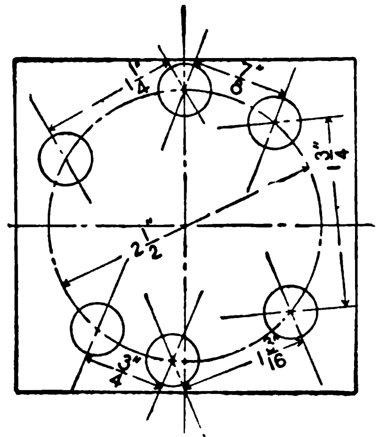


Fig. 22.

divides the numerator and denominator of the fraction extend in the same direction as the dimension line rather than at an angle; that is, the fraction would appear thus, $\frac{1}{2}$, rather than $^1/_2$.

Finished Surfaces. Since a working drawing is not only to

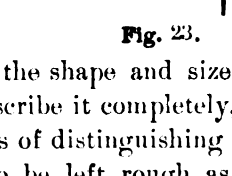


Fig. 23.

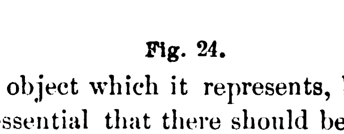


Fig. 24.

show the shape and size of the object which it represents, but is to describe it completely, it is essential that there should be some means of distinguishing between the surfaces of the object which are to be left rough as they come from the forge or from the foundry, and the surfaces which are to be finished. Any surface which has been smoothed off in a lathe, planer, or any machine tool, or has been filed or scraped, is called a finished surface, and is indicated on a drawing by a letter placed on the *edge view* of this surface. In Fig. 19 the whole of the cylindrical part is finished, also the top of the rectangular part. The holes are also finished. The student should notice carefully how the finish marks are used to indicate this fact.

If a piece is to be finished all over, it should be marked "*f* all over." If it is desired to specify what kind of finish is to be put on a surface, that is, whether rough turned, smooth turned, filed, scraped, etc., a note may be made to that effect.

On some conspicuous place on the drawing the words "*f* means finish" should be printed, so that there may be no misunderstanding on the part of a person examining the drawing.

Material. The material of which the piece is to be made should be indicated plainly. If any part of the drawing is a cross-section, the crosshatching might show the material, provided that in some conspicuous part of the drawing a sample of the crosshatching is shown and the material which it represents is stated. It is better, however, to mark on or near each piece, in plain letters, the material of which it is to be made.

Conventional Methods. In drafting, as in many other kinds of work, all unnecessary labor should be avoided. The drawing should give the instructions clearly, but need not be so elaborate as to require unnecessary time in the execution. It frequently happens that if an exact drawing were made representing every line of the object, a great deal of time would be required. Accordingly, if there is any way of representing an object by a few lines only, without sacrificing clearness, it should be used. There are many details such as screw threads, springs, bolts, etc., which occur so frequently on nearly all drawings that easy methods of representation have been universally adopted. In some cases, these ways of representing objects are approximations of the exact drawings and in other cases they are not. Such methods are called conventional methods, or conventions. For some details there is more than one convention, but the same convention should not be used for two different things, nor should several objects of the same kind on the same drawing be represented conventionally by two different methods.

Screw Threads. The exact drawing of screw threads is a difficult part of mechanical drawing, but enough attention will be given it here to enable the student to make a simple working drawing which includes threads. The common conventional way of drawing a thread is shown in Figs. 25, 26 and 27, Fig. 25 being a single right-hand thread, and Fig. 26 a double right-hand thread.

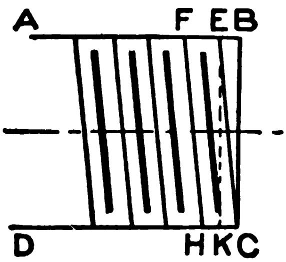


Fig. 25.

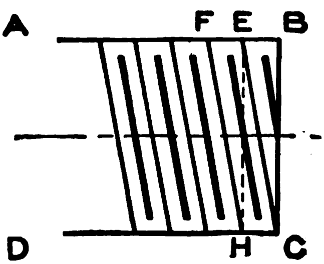


Fig. 26.

First, the plain cylindrical piece ABCD is drawn as if there were no threads upon it. The thread is then indicated by the lines EC, FH, etc., with the shorter and heavier lines between. The lighter lines are all parallel and the same distance apart. This distance is not necessarily the same as the actual pitch of the thread on the screw itself, but is usually $\frac{3}{32}$ inch or $\frac{1}{8}$ inch on drawings of common sizes of bolts. The heavy lines are parallel to the lighter ones and midway between them. The angle which the lines make with the center line of the screw depends on the distance apart of the lines, the slant being such that for a single thread, Fig. 25, a line perpendicular to the center line through one end of one of the lighter lines, as E, will strike the opposite contour of the screw DC, at a point K, which is half way between C and H. To draw the lines so that they will have this slant, choose the distance FE, which is to represent the pitch, and space it off on either of the contour lines, as AB, starting anywhere (in the figure the starting point E is one-half of the distance FE away from B). Next, draw EK per-

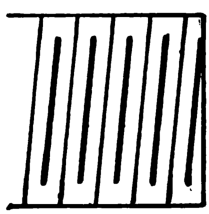


Fig. 27.

pendicular to the center line, thus finding point K, and start the spacing on the contour CD at a distance either side of K equal to ½ FE.

The lighter lines can thus be drawn and the heavy lines put in parallel and half way between. The heavy lines should be a little shorter than the others, and, for the sake of neatness, all should be of the same length. The double thread, Fig. 26, is drawn similarly to the single thread, except that the slant is such that the perpendicular through E will pass through H.

After a little practice the student can draw the threads in this way with his triangles, getting the proper slant and the angle spacing by eye, without the necessity of measuring; he should practice with this end in view, for threads occur so frequently on drawings that the draftsman must be able to draw them rapidly.

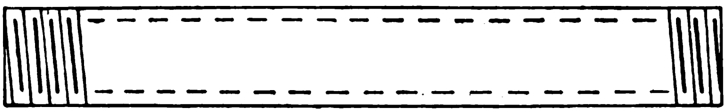


Fig. 28.

Notice should be taken of the fact that if the page be held so that the center lines of the screws in Figs. 25 and 26 are vertical, the lines which represent the threads slant downward from right to left. If the thread is left-handed the lines slant from left to right, as in Fig. 27.

In case of a long screw a few threads may be represented at each end and dotted lines carried the rest of the way, as in Fig. 28.

On any drawing of a screw which is intended for a working drawing, the pitch of the thread, or more commonly the number of threads for an inch of length should be specified; when the thread be standard, it is not always necessary to specify. Even in that case it is well to state the fact that the thread is standard. In giving the number of threads per inch it may be abbreviated, thus 12 THDS, or 12 TH. Examples of this will occur in what follows.

Threaded Holes and Invisible Threads. Fig. 29 shows a piece with a threaded hole in it. The hole is represented in the side view by the four parallel dotted lines. The distance apart of the two outer lines is equal to the diameter of the piece which is to be screwed into the hole. The inner lines are at a distance from the outer approximately equal to the depth of the thread. In the plan view of the piece (that is, the view looking at the end of the hole) the hole is shown by a full circle of a diameter equal to the distance apart of the inner dotted lines of the other view, and around this full circle a dotted circle whose diameter is equal to the diameter of the bolt; or, in other words, equal to the distance apart of the outer dotted straight lines. The dimension might be given on either view. In the figure it is given on the side view. In giving the diameter of a threaded hole, the diameter of the piece which is to be screwed into the hole is always given. In Fig. 29, the number of threads per inch is not stated, and in this case it would be understood to be standard. Fig. 30 shows another way of dimensioning a tapped hole, which is satisfactory and convenient.

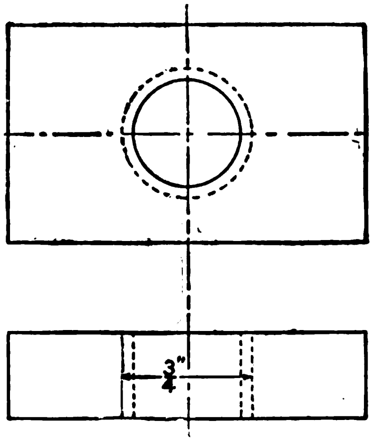


Fig. 29.

Fig. 31 shows the side view of the same piece as Fig. 29, with a part of the screw inserted in the hole. Attention is called to the fact that where the screw is hidden as it goes through the hole the thread is not shown, the parallel dotted lines representing the thread in the same manner as when the hole had no screw in it. Another point to be noted is that the cross-hatching of the broken ends for wrought iron is similar to the representation of the screw thread and one must learn to judge when the light and heavy lines mean a thread and when they are cross-hatching.

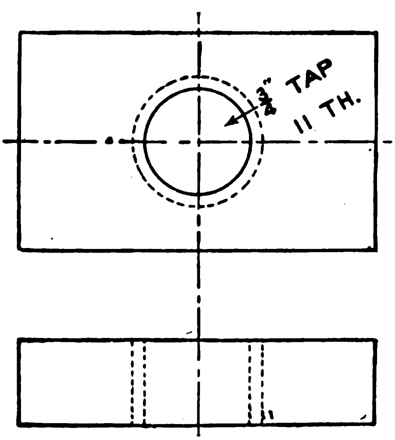


Fig. 30.

Threads in Sectional Pieces. Figs. 32, 33 and 34 illustrate the common method of representing threads when they occur on pieces which are drawn in cross-section. Fig. 32 is the same piece as Fig. 29, shown cross-sectioned. The front half of the piece is supposed to be removed and we are looking at the back half. Now the thread on the back side of a screw slants the opposite way from what it does on the front side, and of course the same is true of the thread in a tapped hole. Consequently, since it is the back side of the hole which is seen, the slant of the lines which represent the thread is opposite to the direction they would have were we looking at the front side of the screw which goes into the hole. We have just learned that for a right-handed thread on a screw the lines slant downward from right to left, and therefore for a right-handed thread seen on the back side of a tapped hole, the lines will slant downward from left to right. In other words, for a right-handed thread in a hole which comes in a cross-section, the lines slant the same as they would on the front of a left-hand thread on a bolt; and for a left-hand thread in a sectioned hole, he slant is the same as for a right-hand thread on a bolt.

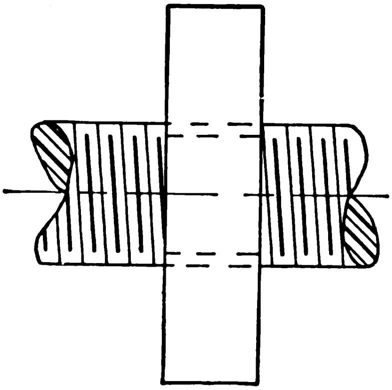


Fig. 31.

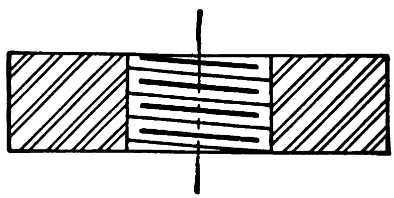


Fig. 32.

Fig. 33 is a piece which has a smooth hole through it and a thread on the outside. Here the entire thread is invisible, except at the contour of the cylinder, and must be indicated by the notches. These are drawn by spacing off the distance which is used for the pitch and from the points thus founa drawing lines with the triangle which make an angle of 60 degrees with the axis of the cylinder. For a single thread the notches on one side have their outer points opposite the inner points of the notches on the other side. For a double thread the notches are directly opposite each other.

Fig. 34 shows two ways of quarter-sectioning a threaded piece, the only difference being that on one the contour of the sectional part is drawn a straight line, while on the other the contour is notched. Either one may be used. The straight contour can, of course, be drawn much more quickly and in places where there is no danger of sacrificing clearness it should be used for that reason. If the drawing is somewhat complicated, so that without the notches it might not be quite clear that the piece was threaded, the notches should be used.

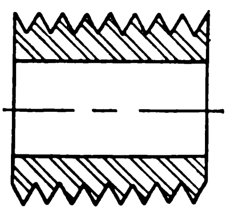


Fig. 33.

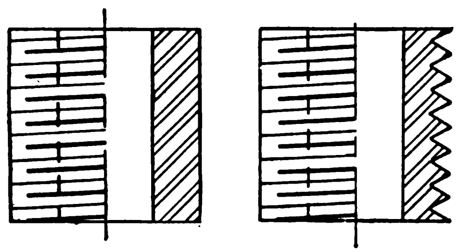


Fig. 34.

As has already been suggested, the student will doubtless find many other customs in the matter of drawing threads which are quite as good as the above. These have been given as ones which are common, and easily drawn. As a matter of convenience the following tables are given, which show the number of threads per inch on some of the most common sizes of bolts, according to the standard adopted by the United States Government, and the Whitworth or English standard.

UNITED STATES STANDARD SCREW THREADS.

Diameter of Bolt.	Threads per Inch.	Diameter of Bolt.	Threads per Inch.	Diameter of Bolt.	Threads per Inch.
$\frac{1}{4}$	20	$\frac{5}{8}$	11	$1\frac{3}{8}$	6
$\frac{5}{16}$	18	$\frac{3}{4}$	10	$1\frac{1}{2}$	6
$\frac{3}{8}$	16	$\frac{7}{8}$	9	$1\frac{5}{8}$	$5\frac{1}{2}$
$\frac{7}{16}$	14	1	8	$1\frac{3}{4}$	5
$\frac{1}{2}$	13	$1\frac{1}{8}$	7	$1\frac{7}{8}$	5
$\frac{9}{16}$	12	$1\frac{1}{4}$	7	2	$4\frac{1}{2}$

WHITWORTH STANDARD SCREW THREADS.

Diameter of Bolt.	Threads per Inch.	Diameter of Bolt.	Threads per Inch.	Diameter of Bolt.	Threads per Inch.
$\frac{1}{4}$	20	$\frac{5}{8}$	11	$1\frac{3}{8}$	6
$\frac{5}{16}$	18	$\frac{3}{4}$	10	$1\frac{1}{2}$	6
$\frac{3}{8}$	16	$\frac{7}{8}$	9	$1\frac{5}{8}$	5
$\frac{7}{16}$	14	1	8	$1\frac{3}{4}$	5
$\frac{1}{2}$	12	$1\frac{1}{8}$	7	$1\frac{7}{8}$	$4\frac{1}{2}$
$\frac{9}{16}$	12	$1\frac{1}{4}$	7	2	$4\frac{1}{2}$

Bolts and Nuts. Among the most common pieces of machinery are bolts and nuts, and the draftsman has frequent occasion to draw them. Fig. 35 is a conventional drawing of a $\frac{1}{2}$-inch bolt with a hexagonal head and nut. This figure shows the dimensions necessary to be given in order that a workman shall be able to make the bolt from the drawing.

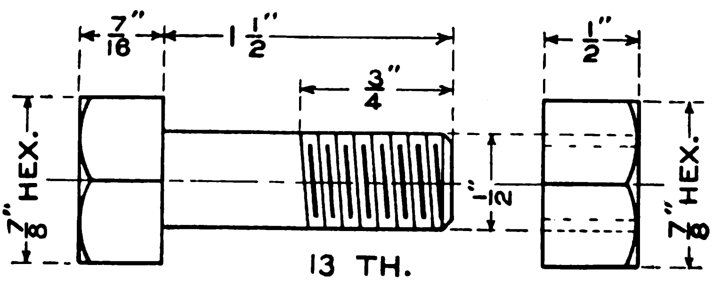


Fig. 35.

Beginning with the head of the bolt, let us study the various parts of this drawing in detail. The head is a hexagonal prism the end of which has been chamfered. We might expect that two views of the head would be necessary to completely define its shape, but the letters HEX printed after the dimension for the diameter of the head indicates that it is hexagonal. In like manner, if the head were square the letters SQ would be placed after the dimension. If two views were drawn, they would appear as in Fig. 36 The head is drawn as if the tool which cut the chamfer, cut off just the corners of the top, so as to make the top a circle tangent to the sides of the hexagon at B, E, G, etc.; the parts BCE, EFG, etc.. being portions of a cone or sphere according to the manner of chamfering. The curves ABC and CEF are tangent to the line

GK in the side view, and the lines AJ, CD, and FH are all equal in length. The curves ABC and CEF are properly the lines of intersection of a cone or sphere, as the case may be, with the hexagonal prism, but a convenient and sufficiently accurate way of drawing them is by arcs of circles with the center on the line HJ, half way between HD and DJ, as indicated. The chamfer is represented in the end view by a circle inscribed in the hexagon.

It will be noticed that in Fig. 35 that view of the head is given which shows two faces of the prism, so that the shortest dimension of the hexagon is given. That is, the view is taken in the direction of the arrow L, Fig. 36, instead of in the direction of the arrow M.

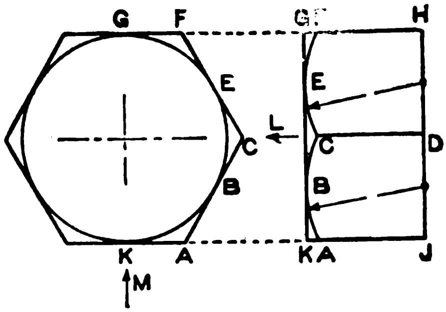


Fig. 36.

This rule should be followed on all detail drawings. The case when it is desirable to give a view in the direction of the arrow M will be discussed later.

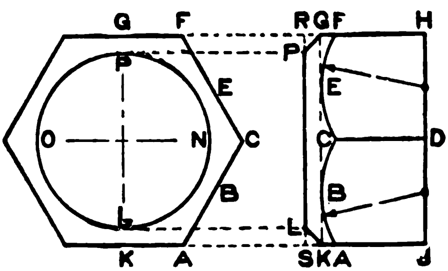


Fig. 37.

Sometimes it is desired to represent the chamfer as being greater, as in Fig. 37. To do this, draw the end view of the hexagon and inside it, of a diameter as much smaller as desired, draw the circle PNLO. Next draw the side view of the hexagonal prism as if there were no chamfer, as shown at the right (partly in dotted lines). Then from P and L, the upper and lower points of the circle in the other view, draw lines perpendicular to RS and meeting it at P and L. From P and L draw PG and LK, either at an angle of 45 degrees or 30 degrees (the latter being preferable) with RS, and meeting the lines RH and SJ at G and K. Join G and K by a construction line GK (shown dotted but not to be left in the finished drawing). Draw the arcs ABC and CEF with center on line HJ as shown, and tangent to GK.

Fig. 38 shows the proper way of representing the head which was shown in Fig. 36 if the view is taken in the direction of the arrow M. The dotted construction lines show how the widths are obtained. Fig. 39 shows the corresponding view of the head shown in Fig. 37. The radius with which the middle arc representing the chamfer is drawn in these two figures is apparent. Various rules are given for finding a radius for small arcs, but they can be found near enough by trial, after a little experience. The line TV, Fig. 39, to which the tops of the arcs are tangent, is drawn parallel to RS and at a distance from it equal to RG in Fig. 37.

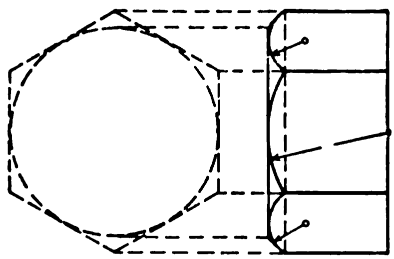


Fig. 38.

The nut, Fig. 35, is drawn in exactly the same way as the head, so that what has just been said will apply equally well to the nut. The hole in the nut is indicated by the four parallel dotted lines as explained for Fig. 29.

The shank of the bolt is represented with the thread upon it as explained above for conventional threads. The point is drawn chamfered a little in the figure, so that it appears as the frustum of a cone. Bolts often have round points, in which case they would be shown as in Fig. 40. The lines which represent the thread should not cross the line which is drawn square across the bolt to indicate where the chamfer or the rounding of the point begins.

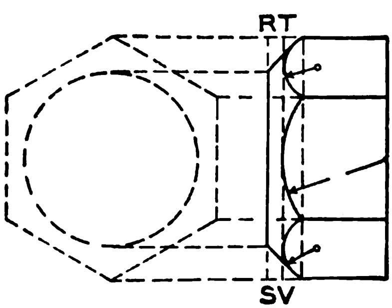
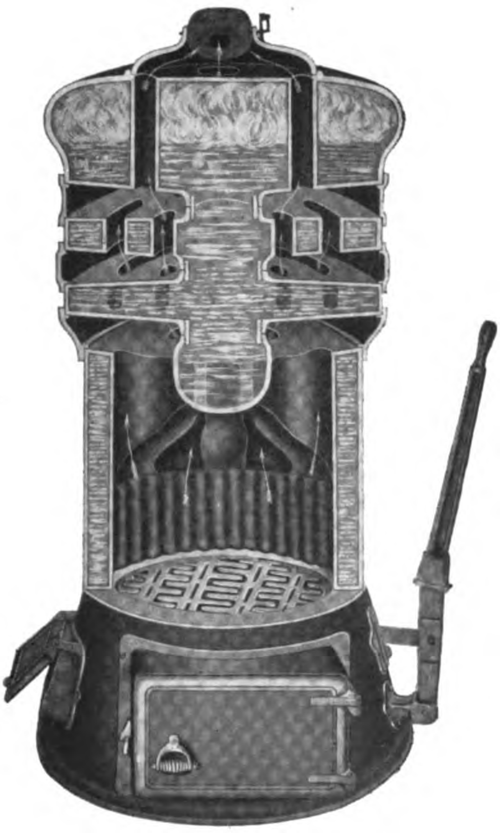


Fig. 39

Fig. 41 shows three views of a square head or nut with chamfer corresponding to that on the hexagonal head in Fig. 36: and Fig. 42 shows the square head or nut chamfered to correspond to



INTERIOR VIEW OF TOURAINE BOILER
Pierce, Butler & Pierce Mfg. Co., Syracuse, N. Y.

Fig. 37. Referring first to Fig. 41 the arc on the side view which shows the short diameter of the nut is drawn with a radius A, equal to two and one-quarter times the diameter of the bolt on which the head or nut belongs. The arcs on the other side view are drawn with a radius B, equal to one-half of A. The lines EF are drawn from points E tangent to the arcs, and it will be found that the points of tangency will come almost at the points where the arcs cut the lines CD. Points E are found by projecting from the plan view as indicated by the dotted lines. In

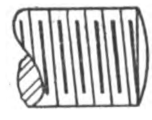


Fig. 40

Fig. 42, the construction is similar. The points N are first found by projecting from the top and bottom of the circle in the plan view; then the lines NL are drawn making angles of 30 degrees with line NN. (The proportions for the radii which are given, hold good only when the angle of 30 degrees is used). Next draw the construction line LL and draw the arc tangent to it with a

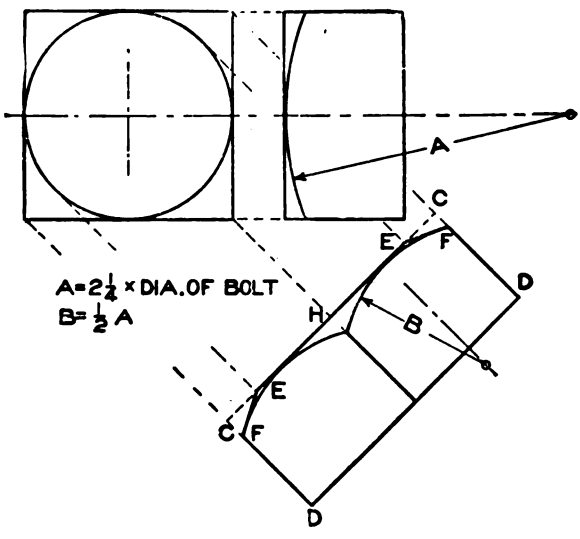


Fig. 41.

radius A equal to two and one-quarter times the diameter of the bolt, the same as in Fig. 41. To draw the chamfer in the other side view, draw the construction line parallel to and at a distance from CC equal to the distance LL from NN and draw the arcs tangent to this line with radius B equal to one-half of A. The lines EF are then drawn as explained for Fig. 41.

Referring again to Fig. 35, the dimension which shows the length of the bolt under the head should be given to the extreme point of the bolt, as should also the dimension which shows how much of the bolt is threaded.

Most of the bolts in common use are made of standard sizes, that is, for a certain diameter of bolt there is a corresponding standard diameter and thickness for the head and the nut, and a standard number of threads per inch, so that if the bolt which the

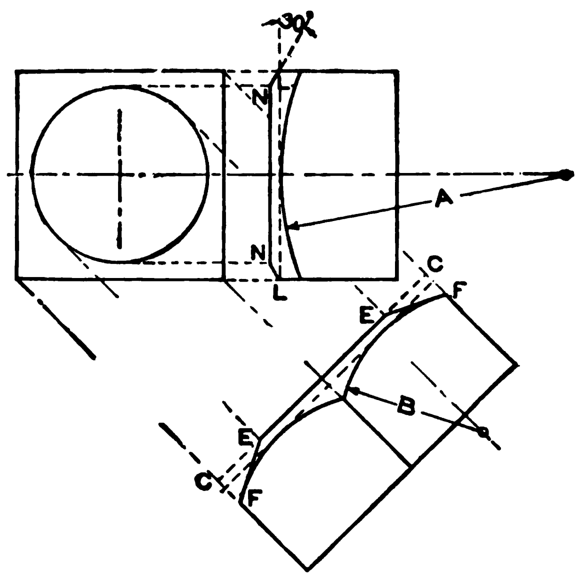


Fig. 42.

draftsman wishes to use has these standard dimensions they may be omitted from the drawing and a note made that the bolt is standard. Then the only dimensions necessary to be given are the diameter, the length under the head, and the length of the threaded part.

The following tables give the United States standard sizes of square and hexagonal heads and nuts for bolts. The columns headed "Width of Nut" and "Width of Head" give the shortest dimension of the square or hexagon, that is, the diameter of the inscribed circle. The standard number of threads per inch can be found from the table already given.

SQUARE BOLT HEADS. U. S. STANDARD (Franklin Institute).

Dia. of Bolt.	Width of Head.	Thickness of Head.	Dia. of Bolt.	Width of Head.	Thickness of Head.
1/4	1/2	1/4	1	1 5/8	13/16
5/16	19/32	19/64	1 1/8	1 13/16	29/64
3/8	11/16	11/32	1 1/4	2	1
7/16	25/32	25/64	1 3/8	2 3/16	1 3/32
1/2	7/8	7/16	1 1/2	2 3/8	1 3/16
9/16	31/32	31/64	1 5/8	2 9/16	1 9/32
5/8	1 1/16	17/32	1 3/4	2 3/4	1 3/8
3/4	1 1/4	5/8	1 7/8	2 15/16	1 15/32
7/8	1 7/16	23/32	2	3 1/8	1 9/16

HEXAGON BOLT HEADS. U. S. STANDARD (Franklin Institute).

Dia. of Bolt.	Width of Head.	Thickness of Head.	Dia. of Bolt.	Width of Head.	Thickness of Head.
1/4	1/2	1/4	1	1 5/8	13/16
5/16	19/32	19/64	1 1/8	1 13/16	29/64
3/8	11/16	11/32	1 1/4	2	1
7/16	25/32	25/64	1 3/8	2 3/16	1 3/32
1/2	7/8	7/16	1 1/2	2 3/8	1 3/16
9/16	31/32	31/64	1 5/8	2 9/16	1 9/32
5/8	1 1/16	17/32	1 3/4	2 3/4	1 3/8
3/4	1 1/4	5/8	1 7/8	2 15/16	1 15/32
7/8	1 7/16	23/32	2	3 1/8	1 9/16

SQUARE AND HEXAGON NUTS. U. S. STANDARD (Franklin Institute).

Dia. of Bolt.	Width of Nut.	Thickness of Nut.	Dia. of Bolt.	Width of Nut.	Thickness of Nut.
1/4	1/2	1/4	1	1 5/8	1
5/16	19/32	5/16	1 1/8	1 13/16	1 1/8
3/8	11/16	3/8	1 1/4	2	1 1/4
7/16	25/32	7/16	1 3/8	2 3/16	1 3/8
1/2	7/8	1/2	1 1/2	2 3/8	1 1/2
9/16	31/32	9/16	1 5/8	2 9/16	1 5/8
5/8	1 1/16	5/8	1 3/4	2 3/4	1 3/4
3/4	1 1/4	3/4	1 7/8	2 15/16	1 7/8
7/8	1 7/16	7/8	2	3 1/8	2

Pipes and Pipe Threads. The various kinds of pipe in common use are made to standard sizes, and as the draftsman very often comes in contact with piping we will consider it briefly. The kinds most often used are wrought-iron or steel pipe, brass pipe made to the size of wrought-iron pipe, and cast-iron pipe. The cast-iron pipe is made of different weights and form, according to the purpose for which it is to be used. Standard weight iron pipe is rated by its nominal inside diameter, although the actual diameter does not in most cases quite agree with the nominal diameter. A $\frac{1}{4}$-inch pipe is a pipe, the hole in which is supposed to be $\frac{1}{4}$ inch in diameter, but if carefully measured it will be found to be a few hundredths of an inch larger.

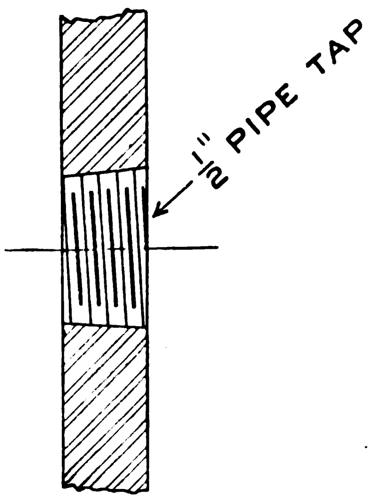


Fig. 43.

The threads on pipes and pipe fittings are also made to standard; taps and dies are made for various sizes of pipe. These taps and dies are spoken of or described by stating the size of the pipe for which they are intended For example, a $\frac{1}{4}$-inch pipe-tap is a tap of the proper size, shape, and number of threads per inch to cut the thread in a hole to receive a $\frac{1}{4}$-inch pipe. Threaded holes are made tapering for pipes, the standard taper being $\frac{3}{4}$ inch per foot, that is, the diameter of the hole decreases at the rate of $\frac{3}{4}$ inch per foot. In representing a hole which is threaded with a pipe tap, the hole is drawn of a diameter at its larger end about equal to the outside diameter of the pipe which is to be screwed into it, and is drawn tapering. It is well to make the taper considerably greater than the actual taper, so that the person looking at the drawing may see at a glance that the hole is for a pipe.

The thread is indicated in one of the conventional ways previously explained, but the number of threads per inch and the diameter of the hole need not be given; instead, a note is made that the hole is tapped for a certain size pipe. Fig. 43 illustrates this.

The following tables of standards for wrought-iron pipe may be found convenient:

STANDARD SIZES OF WROUGHT IRON PIPE.

Nominal Size.	1/8	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2
Actual Inside Diameter.	.27	.364	.494	.623	.824	1.048	1.38	1.610	2.067
Outside Diameter.	.405	.54	.675	.84	1.05	1.315	1.66	1.90	2.375
Nominal Size.	2 1/2	3	3 1/2	4	4 1/2	5	6	7	8
Actual Inside Diameter.	2.468	3.067	3.548	4.026	4.508	5.045	6.065	7.023	7.982
Outside Diameter.	2.875	3.50	4.00	4.50	5.00	5.563	6.625	7.625	8.625

STANDARD THREADS FOR WROUGHT IRON PIPE.

Nominal Size of Pipe.	1/8	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2
Threads per Inch.	27	18	18	14	14	11 1/2	11 1/2	11 1/2	11 1/2
Nominal Size of Pipe.	2 1/2	3	3 1/2	4	4 1/2	5	6	7	8
Threads per Inch.	8	8	8	8	8	8	8	8	8

Scale Drawings. When the object which is to be drawn is not so large but that it can be easily actual size, or full size as it is called, on a sheet of paper which is of convenient dimensions, it is well, usually, to draw the piece full size. In most cases, however, the machine, or the building, or whatever is to be drawn is so large that it would be impossible to draw it full size. Then the drawing is made to some reduced scale, that is, all the dimensions are drawn smaller than the actual dimensions of the object itself; all dimensions being reduced in the same proportion. For example, if a piece is to be drawn half size, the distance from one point to another on the drawing would be one-half what it is on the piece itself; if the drawing is one-fourth size, the distance on the drawing would be one-fourth what it is on the piece itself, and so on. In dimensioning such a drawing the dimension which is written on the drawing is the *actual dimension* of the piece, and not the distance which is measured on the drawing. This fact must be very clearly understood by the student.

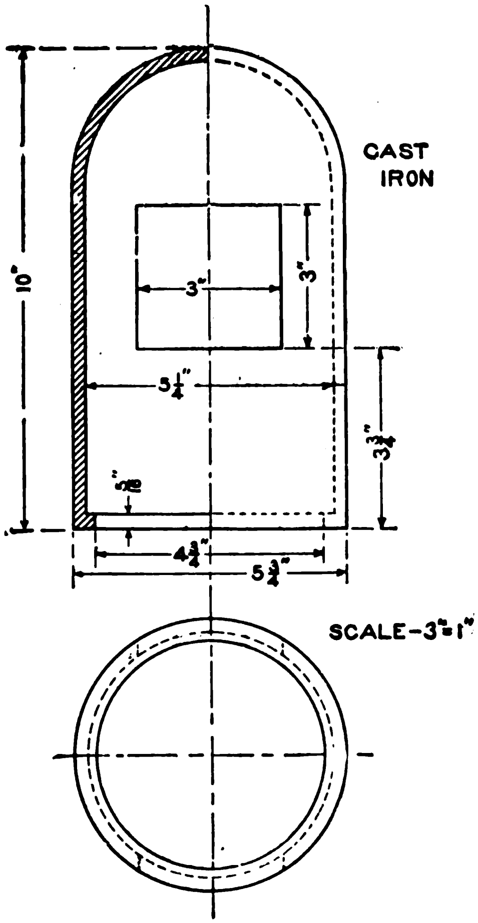


Fig. 44.

The common method of reducing all the dimensions in the same proportion is to choose a certain distance and let that distance represent one foot, this distance is then divided into twelve parts and each one of these parts represents an inch; then if half and quarter inches are required these twelfths are subdivided into halves, quarters, etc., until the subdivisions become so small that they cannot be used. We now have a scale which represents the common foot rule with its subdivisions into inches and fractions; but our new foot is smaller than the ordinary distance which we call a foot, and of course its subdivisions are proportionately smaller. When we make a measurement on the drawing we make it with our reduced foot rule and when we make a measurement on the machine itself we make it with the common foot rule.

Draftsmen's scales can be bought which have different distances thus divided, so that if the draftsman wishes to draw a piece one-fourth size he looks over his scale until he finds a distance of three inches (which is of course one-fourth of a foot) divided as explained above, and he uses this to measure with on his drawing. His drawing would then be made to a scale of three inches to the foot. In the same way, if he wishes to make his drawing one-twelfth size he finds on his scale one inch divided into twelfths and fractions of twelfths and uses this as his standard of measurement; if he wishes to make his drawing one forty-eighth size he uses a quarter inch with its subdivisions. Sometimes if the piece to be drawn is very small, the drawing is made at an enlarged scale, such as twice size, three times size, etc.

The mistake of choosing the wrong distance to use on a scale is often made. For example, if he wishes to draw a piece $\frac{1}{4}$ size, he will look over his scale for a place marked $\frac{1}{4}$, and use this for his standard for $\frac{1}{4}$ size, which is wrong. The figure on the scale indicates the distance which is divided up to represent one foot, so

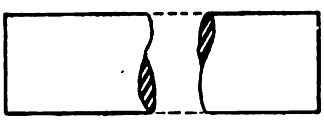


Fig. 45.

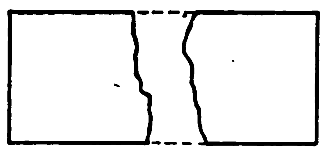


Fig. 46.

that the part of the scale which has $\frac{1}{4}$ marked on it means that $\frac{1}{4}$ of an inch is divided up into twelfths, or in other words, if a drawing is made according to that scale it will be $\frac{1}{48}$th size.

Every drawing which is made at any other scale than full size should have the scale marked on it plainly.

Fig. 44 shows a piece drawn to a scale of 3 inches per foot, that is, $\frac{1}{4}$ size.

Long Pieces. A piece which is very long in proportion to its diameter or width is often difficult to draw complete, especially if there is much detail to any part of it, for if the scale is made so small that the length will go on a sheet of paper of convenient size the small part is so reduced that it is very small. If such a piece is plain the whole or part of its length, a portion of the plain part may be broken out on the drawing thus shortening the drawing of the piece so that a larger scale may be used. Of course in giving the dimension for the length, the *actual* length must be given. Fig. 45 shows a round piece thus broken out and Fig. 46 a rectangular piece

It is a good idea to connect by dotted lines the two parts thus broken, although this is not essential.

"Turning Up" a Section. Sometimes a second view of a piece may be avoided by drawing on the first view a partial view showing the shape of the cross-section at the place where drawn. This partial view or "turned-up section" may be drawn in either full or dotted lines and should be cross hatched. If it comes where there are other lines of the original view, as is usually the case, the original lines would be drawn in regardless of the fact that they conflicted with the auxiliary view. Fig. 47 is an illustration.

In General. A working drawing will usually belong to one of the three following classes: *first*, a design of an entirely new machine; *second*, a drawing of a machine which is already built; *third*, a drawing of a new part to fit a machine which is already built, or a drawing of an old machine remodelled.

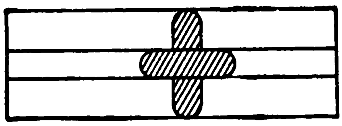


Fig. 47.

In order to design a new machine or a part of a machine, the draftsman must understand the principles of drawing and must also have a clear understanding of the work which the machine is to perform, and must know something of the principles of machine design and the strength of materials. A study of the general manner of proceeding with the drawing, when these things are known, will come later in this course. The draftsman may make a drawing of a machine which is already built, even if he has no understanding of the working of the machine, although under such conditions he works at a great disadvantage. In any case, he must know the principles of drawing.

If the student has learned thoroughly what has preceded in this course, he should be ready to take up the drawing from a machine, and we will now consider the general system to be followed in making such a drawing.

Sketches. In most cases it would be inconvenient for the draftsman to take his drawing board and instruments to the machine and make his careful drawing with the machine close at hand; preferably, he makes what are called sketches, carries his sketches to the drafting room and makes his drawing from them. In making the sketches, each piece of the machine should be taken separately and a complete working drawing made of it, the only difference between these sketches and the finished drawing being that they are made largely without the use of instruments, triangles, etc.; that is, they are made free hand. The experienced draftsman will draw some lines and circles free hand, and use his instruments on some, according as he may think that he will save time by doing the one or the other; but it is well for the beginner to gain practice by making the sketches, almost wholly free hand, except large circles, and long lines.

The sketches should be neat and perfectly clear, so that if they are laid aside for a long time they can be clearly understood without depending at all upon memory. There is a strong tendency for the beginner to make his sketches hurriedly, thinking that when he comes to finish his drawing he can supply the details from memory. This is a bad plan and will lead to many mistakes. The sketches must be so clear and complete that anyone can read them who has never seen the machine. No attempt need be made to draw them to scale, but **all dimensions**, carefully measured from the machine, should be placed on the sketch.

After every piece of the machine has been thus sketched separately, it is well to make a rough, general sketch of the whole machine, to show how the various pieces fit together, a few of the most important over-all dimensions, distances between centers, etc.

All sketching should be done as rapidly as possible without sacrificing clearness. Before starting to sketch a piece, the draftsman must decide what views are necessary to describe the piece clearly. All sketches should be made large to avoid confusion.

Detail Drawing. After the sketches are made, the next step is the making of the pencil drawing from the sketches, accurately to scale. The size of the plate on which the drawing is to be made is usually fixed by some standard. Where many drawings are made and kept in an office, it is desirable to keep the plates of uniform size, as far as possible. It is good practice to have two or three standard sizes of plates, one for small drawings, one for ordinary-sized work, and one for large drawings; then, whenever a drawing is made, make it on one of these standard plates.

Assuming, then, that we have our paper stretched on the drawing board and the plate laid out, the next step will be to arrange the drawings of the various pieces on the plate so that there will be room for all and so that they may be properly placed with relation to each other. It may happen that there will not be room on one plate for all the pieces, but that two or more plates will be required. When the parts must be thus arranged on different plates, an effort should be made to keep on the same plate those parts which belong together. For example, if we were drawing a lathe, the details of the parts of the head stock might form one plate, the apron another, and so on.

In locating the various pieces on a plate, they should be placed as nearly as possible in the same relative position to each other that they bear in the machine, except that they are separated. For example: if a nut belongs on the end of a screw, it is desirable to draw it on the same center line with the screw and at the end where it belongs. If a piece is vertical in the machine it should be vertical on the plate, and if horizontal in the machine, it should be horizontal on the plate.

The approximate location of the pieces on the plate may be easily decided by taking a small sheet of paper of about the same proportion as the plate, but perhaps one-fourth or one-half size, and sketching on it roughly the outline of the various pieces. The arranging of the plate should not be allowed to take much time, but should be done as rapidly as possible. After the location of each view of each piece is determined, the pencil drawing should begin (to scale) with one of the principal pieces. In almost all cases a center line is first drawn. It is better to carry along all the views of a piece at once, instead of completing one view at a time. The piece started should have all its views finished and completely dimensioned before another piece is begun; exceptions to this are sometimes necessary for special reasons. The lines should be drawn accurately, but no attempt need be made to obtain finish; that is, in order to save time, the lines may be run past the point where they should properly stop, etc. Nothing should be omitted, however.

Each plate of details should have a title, stating of what machine it is a drawing, and, if there are several plates, it is well to state also of what part of the machine the plate in question is a drawing. It is also a good idea to print its name beside each of the principal pieces.

Tracing. Having finished the pencil drawing, the next step is the inking. In some offices the pencil drawing is made on a thin. tough paper, called board paper, and the inking is done over the pencil drawing, in the manner with which the student is already familiar. It is more common to do the inking on thin, transparent cloth, called tracing cloth, which is prepared for the purpose. This tracing cloth is made of various kinds, the kind in ordinary use being what is known as "dull back," that is, one side is finished and the other side is left dull. Either side may be used to draw upon, but most draftsmen prefer the dull side. If a drawing is to be traced it is a good plan to use a 3H or 4H pencil, so that the lines may be easily seen through the cloth.

The tracing cloth is stretched smoothly over the pencil drawing and a little powdered chalk rubbed over it with a dry cloth, to remove the slight amount of grease or oil from the surface and make it take the ink better. The dust must be carefully brushed or wiped off with a soft cloth, after the rubbing, or it will interfere with the inking.

The drawing is then made in ink on the tracing cloth, after the same general rules as for inking the paper, but care must be taken to draw the ink lines exactly over the pencil lines which are on the paper underneath, and which should be just heavy enough to be easily seen through the tracing cloth. The ink lines should be firm and fully as heavy as for ordinary work. In tracing, it is better to complete one view at a time, because if parts of several views are traced and the drawing left for a day or two, the cloth is liable to stretch and warp so that it will be difficult to complete the views and make the new lines fit those already drawn and at the same time conform to the pencil lines underneath. For this reason it is well, when possible, to complete a view before leaving the drawing for any length of time, although of course on views in which there is a good deal of work this cannot always be done. In this case the draftsman must manipulate his tracing cloth and instruments to make the lines fit as best he can. A skillful draftsman will have no trouble from this source, but the beginner may at first find difficulty.

Inking on tracing cloth will be found by the beginner to be quite different from inking on the paper to which he has been accustomed, and he will doubtless make many blots and think at first that it is hard to make a tracing. After a little practice, however, he will find that the tracing cloth is very satisfactory and that a good drawing can be made on it quite as easily as on paper.

The necessity for making erasures should be avoided, as far as possible, but when an erasure must be made a good ink rubber or typewriter eraser may be used. If the erased line is to have ink placed on it, such as a line crossing, it is better to use a soft rubber eraser. All moisture should be kept from the cloth.

Blue Printing. The tracing, of course, cannot be sent into the shop for the workmen to use, as it would soon become soiled and in time destroyed, so that it is necessary to have some cheap and rapid means of making copies from it. These copies are made by the process of blue printing in which the tracing is used in a manner similar to the use made of a negative in photography.

Almost all drafting rooms have a frame for the purpose of making blue prints. These frames are made in many styles, some simple, some elaborate. A simple and efficient form is a flat surface usually of wood, covered with padding of soft material, such as felting. To this is hinged the cover, which consists of a frame similar to a picture frame, in which is set a piece of clear glass. The whole is either mounted on a track or on some sort of a swinging arm, so that it may readily be run in and out of a window.

The print is made on paper prepared for the purpose by having one of its surfaces coated with chemicals which are sensitive to sunlight. This coated paper, or blue-print paper, as it is called, is laid on the padded surface of the frame with its coated side uppermost; the tracing laid over it right side up, and the glass pressed down firmly and fastened in place. Springs are frequently used to keep the paper, tracing, etc., against the glass. With some frames it is more convenient to turn them over and remove the backs. In such cases the tracing is laid against the glass, face down; the coated paper is then placed on it with the coated side against the tracing cloth.

The sun is allowed to shine upon the drawing for a few minutes, then the blue-print paper is taken out and thoroughly washed in clean water for several minutes and hung up to dry.

If the paper has been recently prepared and the exposure properly timed, the coated surface of the paper will now be of a clear, deep blue color, except where it was covered by the ink lines, where it will be perfectly white.

The action has been this: Before the paper was exposed to the light the coating was of a pale yellow color, and if it had then been put in water the coating would have all washed off, leaving the paper white. In other words, before being exposed to the sunlight the coating was soluble. The light penetrated the transparent tracing cloth and acted upon the chemicals of the coating, changing their nature so that they became insoluble; that is, when put in water, the coating, instead of being washed off, merely turned blue. The light could not penetrate the ink with which the lines, figures, etc., were drawn, consequently the coating under these was not acted upon and it washed off when put in water, leaving a white copy of the ink drawing on a blue background. If running water cannot be used, the paper must be washed in a sufficient number of changes until the water is clear. It is a good plan to arrange a tank having an overflow, so that the water may remain at a depth of about 6 or 8 inches.

The length of time to which a print should be exposed to the light depends upon the quality and freshness of the paper, the chemicals used and the brightness of the light. Some paper is prepared so that an exposure of one minute, or even less, in bright sunlight, will give a good print and the time ranges from this to twenty minutes or more, according to the proportions of the various chemicals in the coating. If the full strength of the sunlight does not strike the paper, as, for instance, if clouds partly cover the sun, the time of exposure must be lengthened.

Assembly Drawing. We have followed through the process of making a detail drawing from the sketches to the blue print ready for the workmen. Such a detail drawing or set of drawings shows the form and size of each piece, but does not show how the pieces go together and gives no idea of the machine as a whole. Consequently, a general drawing or assembly drawing must be made, which will show these things. Usually two or more views are necessary, the number depending upon the complexity of the machine. Very often a cross-section through some part of the machine, chosen so as to give the best general idea with the least amount of work, will make the drawing clearer.

The number of dimensions required on an assembly drawing depends largely upon the kind of machine. It is usually best to give the important over-all dimensions and the distance between the principal center lines. Care must be taken that the over-all dimensions agree with the sum of the dimensions of the various details. For example, suppose three pieces are bolted together, the thickness of the pieces according to the detail drawing, being one inch, two inches, and five and one-half inches respectively; the sum of these three dimensions is eight and one-half inches and the dimensions from outside on the assembly drawing, if given at all, must agree with this. It is a good plan to add these over-all dimensions, as it serves as a check and relieves the mechanic of the necessity of adding fractions.

FORMULA FOR BLUE-PRINT SOLUTION.

Dissolve thoroughly and filter.

A.	Red Prussiate of potash	2½ ounces,
	Water	1 pint.
B.	Ammonio-Citrate of iron	4 ounces,
	Water	1 pint.

Use equal parts of A and B.

FORMULA FOR BLACK PRINTS

Negatives. White lines on blue ground; prepare the paper with

Ammonio-Citrate of iron	40 grains,
Water	1 ounce.

After printing wash in water.

Positives. Black lines on white ground; prepare the paper with:

Iron perchloride	616 grains,
Oxalic Acid	308 grains,
Water	14 ounces.

Develop in	Gallic Acid	1 ounce,
	Citric Acid	1 ounce,
	Alum	8 ounces.

Use 1¼ ounces of developer to one gallon of water. Paper is fully exposed when it has changed from yellow to white.

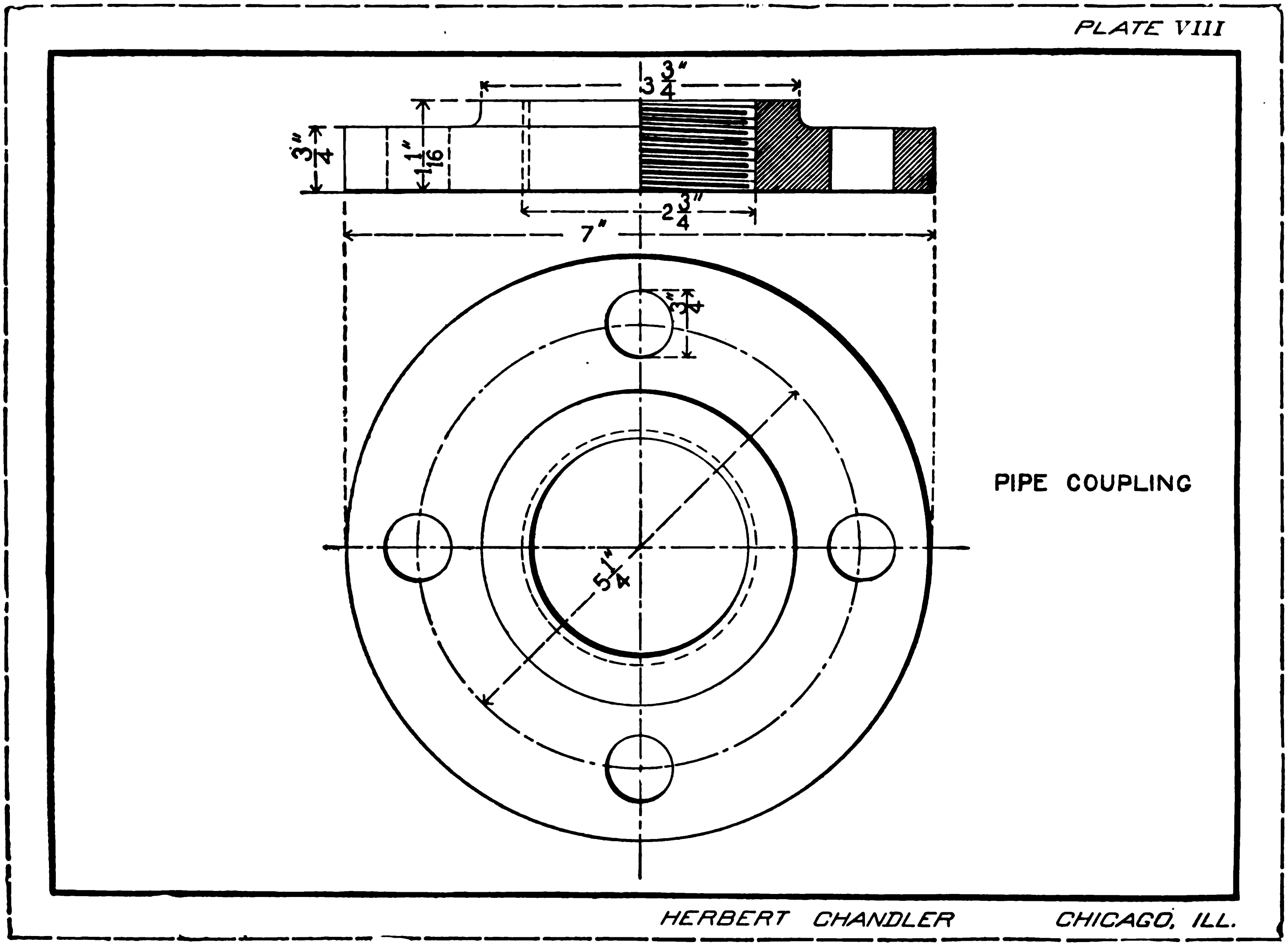
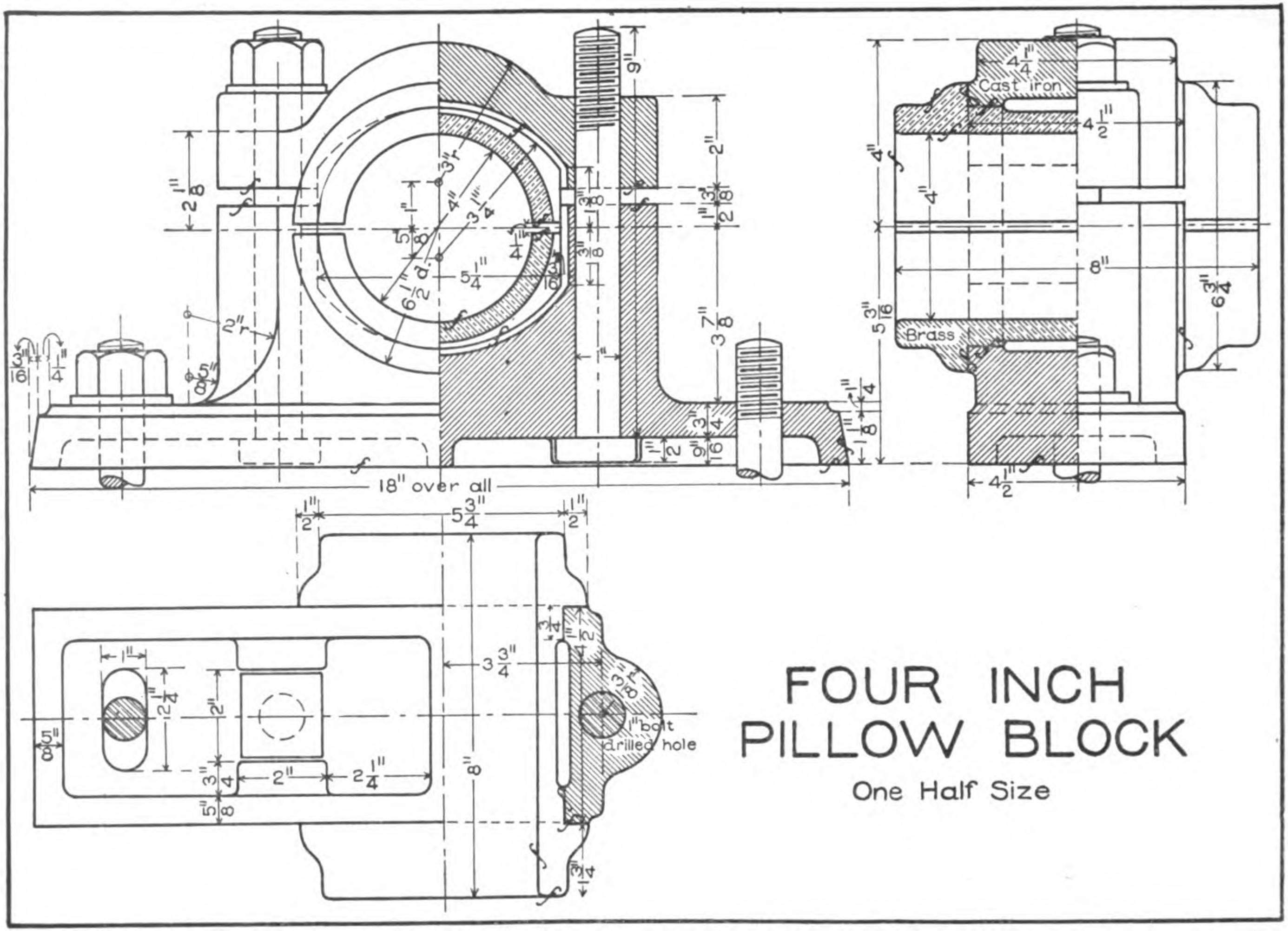
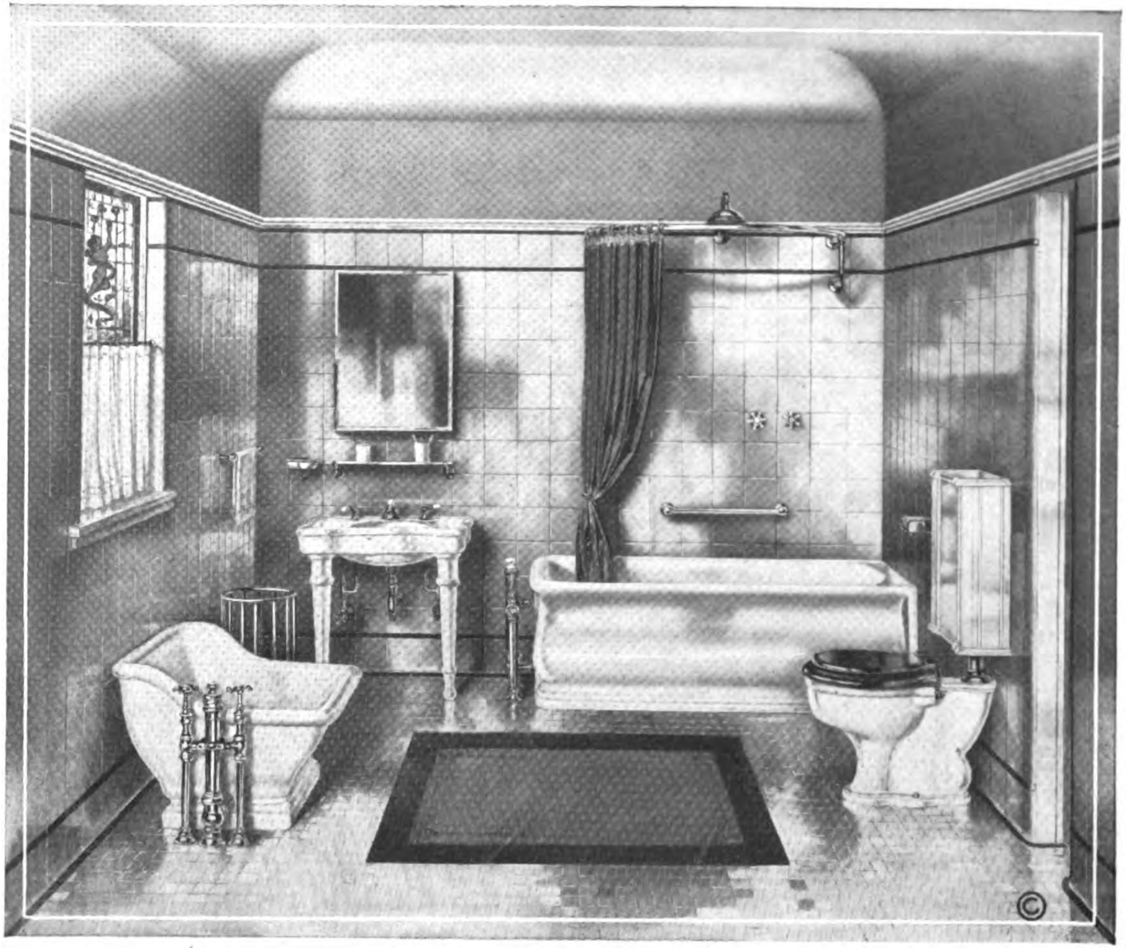


PLATE VIII
3 3/4"
3/4"
1 1/16"
2 3/4"
7"
3/4"
5 1/4"
PIPE COUPLING
HERBERT CHANDLER
CHICAGO, ILL.

PLATE IX



HERBERT CHANDLER CHICAGO ILL.



A TYPICAL MODERN BATH-ROOM
Notice Combination of Shower Bath and Tub
James B. Clow & Sons, Chicago

PLATES.

PLATE VIII.

Pipe Coupling. The drawing represents one of a pair of cast-iron couplings used for connecting two lengths of pipe. It is threaded for a right-handed thread, but appears left-handed because the back part of the thread is visible in the section.

The vertical center line of the coupling is in the center of the plate; the center of the plan is $3\frac{7}{8}$ inches from the lower border and the bottom of the elevation $1\frac{7}{8}$ inches from the top border line. The elevation is made in half section, that is, the right-hand half. It is made by imagining that the front right quarter of the coupling is cut away by vertical planes. If the cutting plane passes through a hole or opening the cross-hatching is omitted. The dotted lines at the left of the hole show that it is threaded. The distance between these lines is $\frac{3}{32}$ inch, the depth of the thread. The threaded or tapped portion is shown in plan by the two circles, the dotted circle representing the outside and the full circle the inside or root of the thread.

The boss or hub adds to the strength and allows more threads. The shade lines should be placed on the drawing following the custom for shop drawings. The title "Pipe Coupling" should be placed as shown and made with letters $\frac{1}{4}$ inch high. The letters may be either vertical or inclined Gothic capitals.

PLATE IX.

Pillow Block. The drawings for this plate are three views—side, plan and end—of a 4 inch-pillow block. Each view is half in section. The drawing should be one-half size. Make the vertical center line of the side and plan views $4\frac{3}{4}$ inches from the left-hand border. The horizontal center line of the side view should be $2\frac{5}{8}$ inches from the top border line and the horizontal center line of the plan $2\frac{1}{4}$ inches from the bottom border line. Locate the vertical center line of the end view $2\frac{1}{4}$ inches from the right-hand border line; the horizontal center line will of course be a continuation of that of the side view. Note that the left-hand half of the plan represents what is seen by looking up from below. The cutting plane for the right-hand half passes horizontally through the center of the shaft.

The student should put on shade lines and finish marks; also the notes and dimensions. Make the letters of the title vertical Gothic capitals ⅜ inch high.

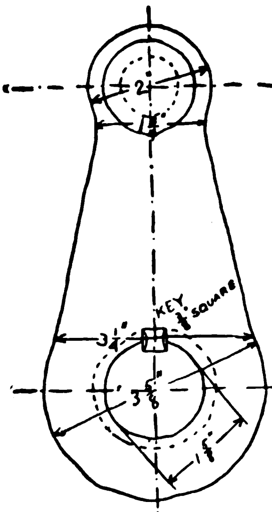


Fig. 48.

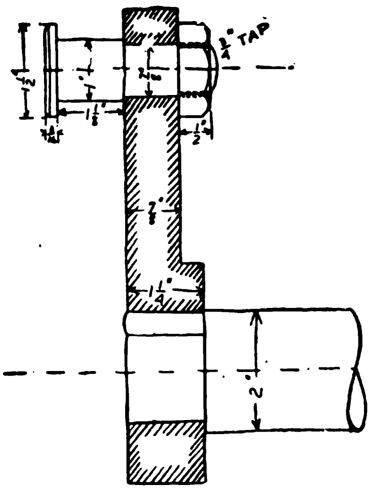


Fig. 49.

PLATE X.

Overhung Crank. The two drawings on this plate are to be made full size from the free-hand sketches Figs. 48 and 49. These are such as would be given the draftsman or such he would make for his own work. Place the two views so that they will look well on the plate. Put on shade lines and dimensions.

PLATE XI.

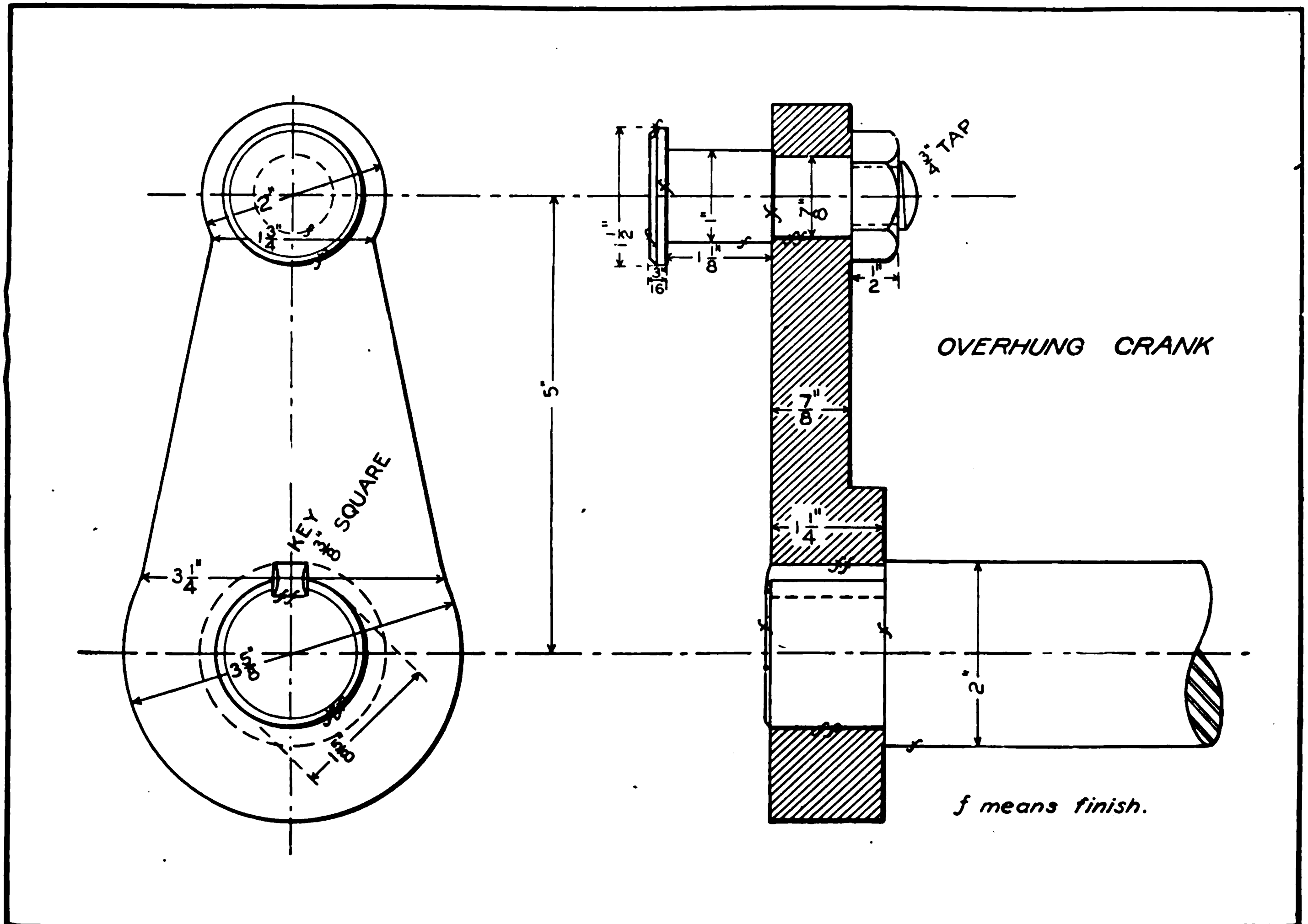
Cylinder Head. This plate consists of a plan view and a cross-section of the cylinder head of a small engine. The center line for the two views is drawn half way between the upper and lower border lines. Always allow sufficient space for dimensions.

The shade lines should be placed on the drawing, following the methods described for machine drawing. Locate the title and explanatory notes to make the plate appear well balanced.

PLATE XI A.

Blue Print. Make a tracing on tracing cloth and (optional) a blue print of one of these plates.

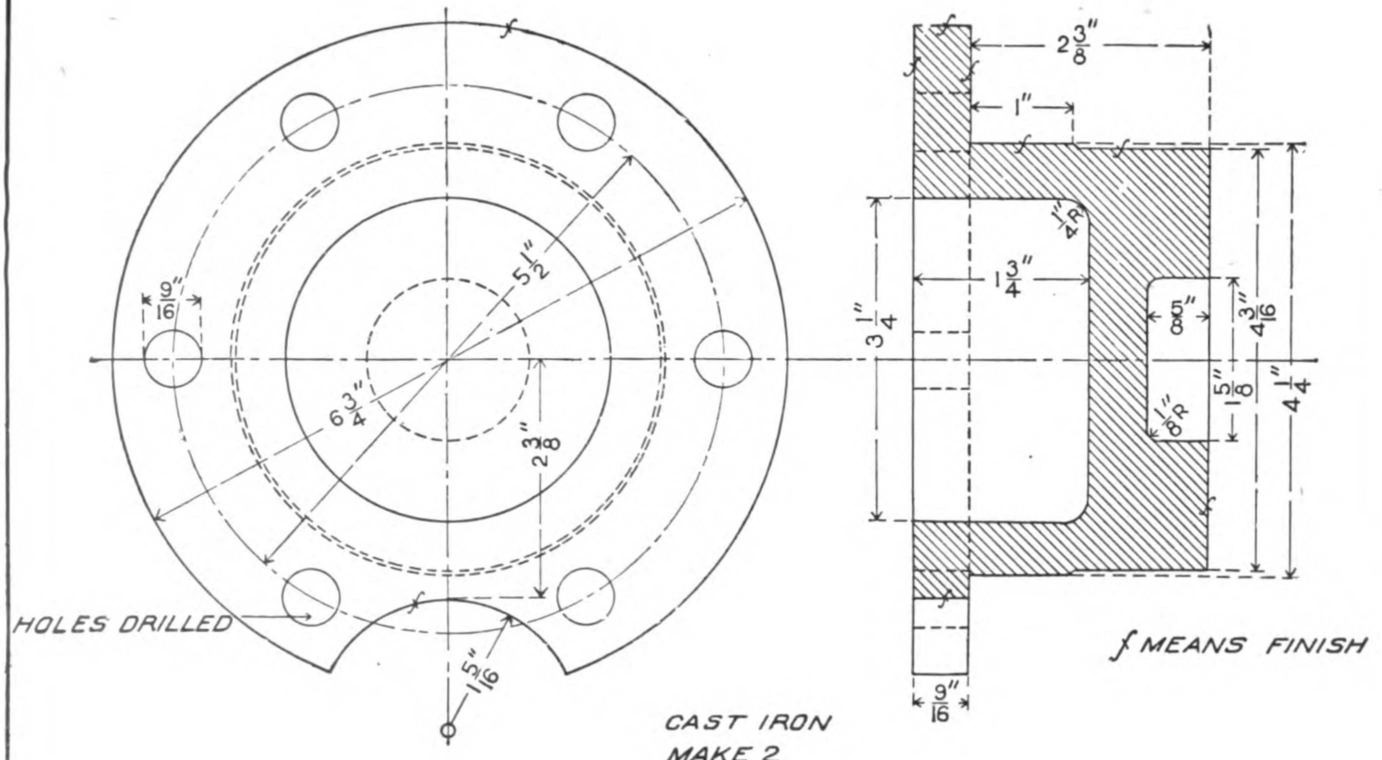
PLATE X.



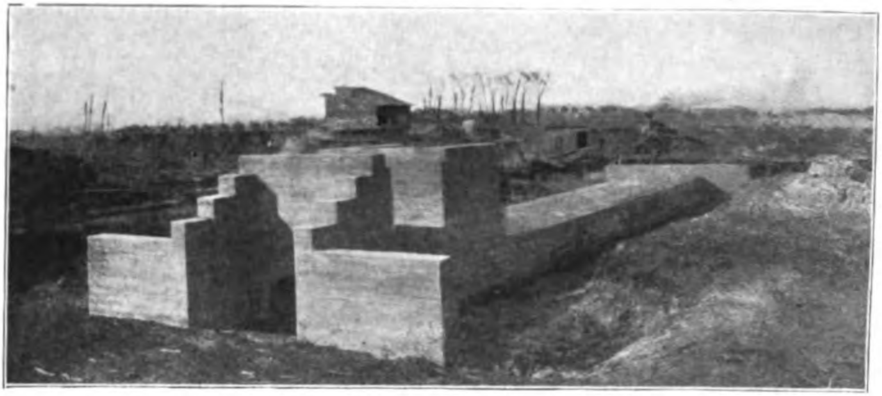
HERBERT CHANDLER, CHICAGO, ILL.

PLATE XI.

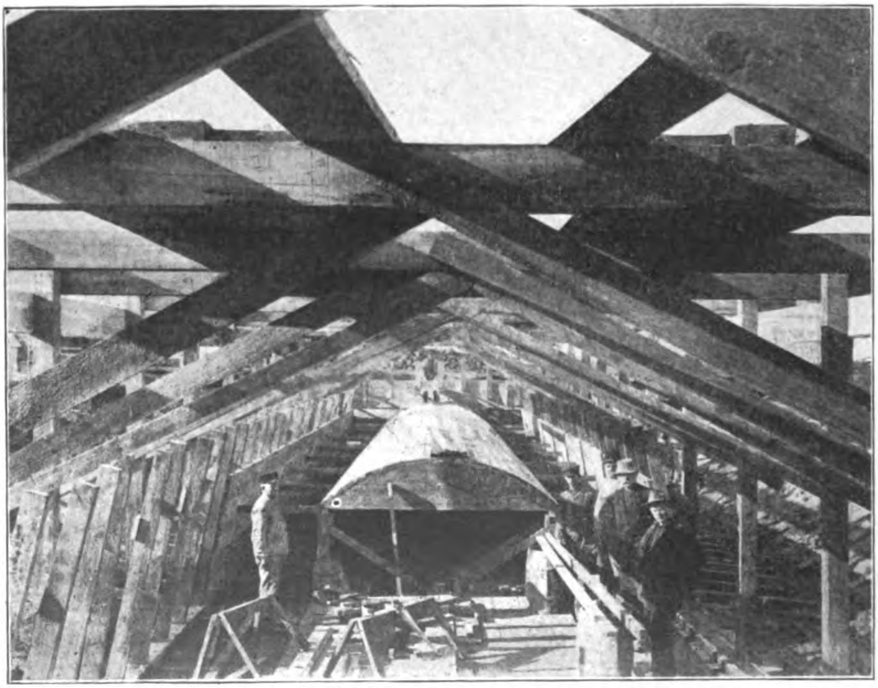
CYLINDER HEAD



HERBERT CHANDLER CHICAGO, ILL.



Reinforced-Concrete Arch Culvert, Completed.



Forms for Construction of Arched Culvert Shown Above.

VIEWS OF CONSTRUCTION ON LINE OF ILLINOIS AND MISSISSIPPI CANAL

MECHANICAL DRAWING.

PART IV.

WORKING SHOP DRAWINGS.

In Parts I to III, inclusive, the fundamental principles of Mechanical Drawing were explained and illustrated. The production of working drawings has also been discussed to some extent, and the usual characters and symbols explained and applied. The elementary work already outlined has been treated chiefly from the standpoint of correctness of line representation considered by itself, without a detailed study of the use to which the drawings so produced are to be applied.

Evidently this is the proper method, for the student should gain a thorough understanding of the principles which underlie line representation before attempting to apply them to any extended practical use. In all of this preceding work it is intended that the theoretical principles shall overshadow any incidental references made to practical application, however true and pertinent the latter may be for purposes of illustration. Hence, before taking up any advanced work, the student should fully realize the importance, in fact, the absolute necessity, of thoroughly understanding the fundamental principles which have been outlined in the books which have preceded Part IV.

At this point the student must realize that a lack of proper elementary and fundamental training will make him "go lame" at every point of his course, and probably prevent the attainment of proficiency which otherwise would naturally and almost instinctively come with advanced study. It is the thorough and ready knowledge, always at his fingers' ends, of *all* the principles of Mechanical Drawing, which makes the expert draftsman.

Plan and Scope of Advanced Work. It is now intended to throw an entirely different light on the matter, and view the subject of Mechanical Drawing from a purely practical standpoint; viz., that of Utility. It is assumed that the student understands and can use the principles which have been previously discussed.

If in a working shop drawing we choose to modify any of these theoretical principles, it will be because of increased value in *Utility* of the drawing. For example, we may desire to omit some portions of an elevation or plan or side view of a complicated casting, because certain details will thus be more clearly brought out. We may make a "zigzag" section to show construction which, by absolute fidelity to theoretical principle, would be confused, or hidden in a maze of dotted lines. We may find it convenient to place in some unoccupied corner of a drawing a layout which could not be in the least justified by any rule of projection. A multitude of transgressions like these occur on good drawings, and they are certainly justifiable from the standpoint of *Utility*, which is the true ultimate end sought for in a practical shop drawing.

These variations from the theoretical are not strictly conventionalities, because they are not classified or established, so far as we know, but are the spontaneous outgrowth, as the occasion demands, of the draftsman's purpose to make his drawing one of greatest *Utility*. He can, however, safely transgress a principle only when he thoroughly knows the principle; otherwise a blind deviation from the theoretical path will inevitably lead to difficulty.

All of the above is intended to impress the student with the idea that theoretical principles are his best, in fact, his only tools to work with; but they are not "self-hardening," like "mushet" steel; they are like the finest grade of tool steel, which must be tempered and ground and used with the best judgment of the operator, to secure the most satisfactory results.

Student Drawings. A student's early drawings are usually unsatisfactory, even to himself. Somehow they do not look like those seen in shops, and as a rule he is unable to see why this is so. Of course the difference is to some extent due to the experience of the professional draftsman. However, the superior results of the latter's work are attained largely through his systematic and workmanlike habits of execution. It should encourage the student in his early attempts to know that these essentials to the infusion of life and shop spirit into a drawing can be analyzed, outlined and grasped at the outset by earnest, intelligent effort, and really good workmanlike results obtained. To discuss, and if possible to impart these essentials of a working shop drawing to the student, is the purpose of the present book.

Essentials. The two chief essentials of a shop drawing, under which general heads a multitude of detail requirements can be summed up, are:

(1.) Absolutely complete and definite instructions from designer to workman.

(2.) Least possible cost in dollars and cents of production of the drawing measured by the draftsman's time.

It makes no difference how much we may attempt to disguise these two elements, the fact will still be apparent that "*complete instructions furnished for the least money*" is what the manufacturing shop is after, and what will be assumed as a basis for judgment as to highest commercial utility.

Completeness of Drawings. As to the first point, that of completeness and definiteness of instruction, there must be no question of degree. If the information which the drawing furnishes is positive and complete, the drawing is good. If doubt arises in the workman's mind as to what the designer intended by a certain line or dimension, or if the dimension be omitted, the drawing is bad. There is no middle ground. The instructions are either present or absent, and the drawing good or bad accordingly.

The workman of to-day is not permitted to assume dimensions or shape. It is his business to execute the draftsman's orders; it is, however, often his privilege to choose his own way of doing it, but further than this modern practice does not allow him to go. He is held as rigidly to the orders specified by the drawing as the locomotive engineer is held to his bit of tissue telegraphic order to proceed, without which he dare not enter the next block. The drawing is supreme; it is official; it must be plain, direct and all-sufficient. It is the draftsman's business to make it thus, and he is not a draftsman until he does.

This idea of positiveness must be thoroughly absorbed by the student. Positive action must be a habit which controls his every move, which marks every dimension he prints, which directs every line he draws. Every line must mean something, must have a definite reason for existence, must be necessary to illustrate the idea which he wishes to convey to the workman, and every line must be a definite measurable distance from every other line, so that its location is fixed beyond a doubt. Lines which mean nothing, and cannot be measured, have no place on the drawing; they only confuse it.

A good picture of a machine could scarcely be called to the same service as a good drawing of it. The picture might give us an excellent idea of the machine, but for the purpose of the actual construction the picture is useless, while the drawing is of positive value. This value exists simply because of, and in proportion to, the completeness of detail which it shows. Hence in making a shop drawing the picture idea is entirely subordinate to the idea of *Utility*, the latter in fact being the measure of its value.

There are certain classes of drawings—of which the Patent Office drawing is a good example—in the making of which the picture idea is predominant. Here the purpose is to illustrate mechanisms, not construct them; hence the function of the drawing is in no wise that of the working shop drawing, and as such does not fall within our discussion.

Cost of Producing Drawings. The second general element involved in producing shop drawings is their cost, as measured by the draftsman's time. It is somewhat subordinate to the first element, for the drawing must be a good one, judged by an absolute standard, whatever the time or cost necessary to produce it. Cost, however, is an important item, and cannot well be overlooked. It is inevitable that in any enterprise economy will ultimately be sought, whatever extravagance an imperative original demand may have permitted. This is as true in the production of drawings as in the case of manufactured articles of trade. Drafting-room labor is a relatively high-priced service, and the salary list easily assumes considerable proportions, so that wasteful excesses count up rapidly. One of the qualifications of proficiency invariably required for this department of shop organization is rapidity of execution. This is not as dependent upon personal traits as at first might be supposed. A man may so husband his time and direct his efforts that he will easily distance his neighbor of more rapid motion. The latter may have less ability to make his energies count, and lack of judgment as to when just enough, and no more than enough, energy has been expended on his drawings. From the standpoint of *Utility*, the function of a drawing is fulfilled when it has reached the stage that it *completely* instructs; more time spent in elaboration is wasted, and is an unnecessary and therefore extravagant expenditure. The student must fully realize this. In his earnestness to produce finished and complete work he must constantly strive to accomplish results in the least possible time. This does not mean careless haste; far from it. A complete shop drawing cannot be made by short cuts, but through a systematic building of line on line, dimension on dimension. This is in sharp contrast to a haphazard habit of developing a drawing, first a line here and then a figure there, with no definite purpose in mind, and no hint as to when the drawing is actually completed.

The one method constitutes the efficient draftsman who works easily, receives a high salary, and is worth it, because he wastes no time in unnecessary labor. The other marks his unfortunate brother, plodding laboriously far behind, receiving a small pittance per hour, and worth less, because he does uncalled-for labor, and loses his definiteness of purpose in a maze of unexplainable lines and figures.

A working shop drawing, commercially considered, may well be defined as being "*Complete instruction from designer to workman issued at minimum expense.*"

This definition should be memorized by the student, and constantly kept in mind while making a drawing. The preceding pages should be re-read with this in view until the full spirit is appreciated.

The maxim as given above, if faithfully adhered to without modification, answers nearly every question that can be raised as to the excellence of a drawing. It can be used as a standard of judgment, whatever system of lines or symbols may be in vogue. It permits a draftsman to adjust himself to the rules of any shop or drawing-room, and yet produce a good drawing and satisfy his employer.

A drawing which is cheaply produced and at the same time does perfectly that for which it was made, that is, convey complete instruction, is beyond commercial criticism.

Method of Procedure. As the general objects to be attained in a working shop drawing have now been presented, it is necessary to indicate in detail how the work may be properly accomplished. In order to do this, it is proposed to produce systematically a full set of working drawings of a familiar and comparatively simple machine. The methods used will be those of a designing detail draftsman, producing commercial work fit for shop use. In the progress of the work, from its beginning in the rough, though accurate, pencil layout, to the completion of the tracings and the order sheets, the same bold style, clearness, directness and businesslike spirit which the shop atmosphere and surroundings would naturally supply, will be emphasized, and so far as possible imparted to the student. It is expected that the student will follow the text closely and study the plates carefully, endeavoring to familiarize himself with every detail illustrated. The more closely he is able to apply himself in this respect the more will he be able to partake of the life and spirit which is intended to be conveyed, and without which the true character of the work can be but poorly developed.

Incidentally, several purposes will be fulfilled by this treatment.

Ability to read drawings quickly and intelligently is almost as important as making them, and it is expected that the study of the plates, with a view to thoroughly understanding every line, will develop proficiency in the art of reading drawings.

The discussion in the text, of not only the form of the machine parts themselves, but also the tools and shop processes to produce them, affords considerable insight into the influences affecting good machine design. Without introducing any mathematical analysis or investigation, which is beyond the province of this book, much practical consideration as to the restrictions imposed by existing shop methods upon theoretical construction will be suggested, and the student encouraged to use his judgment thereon.

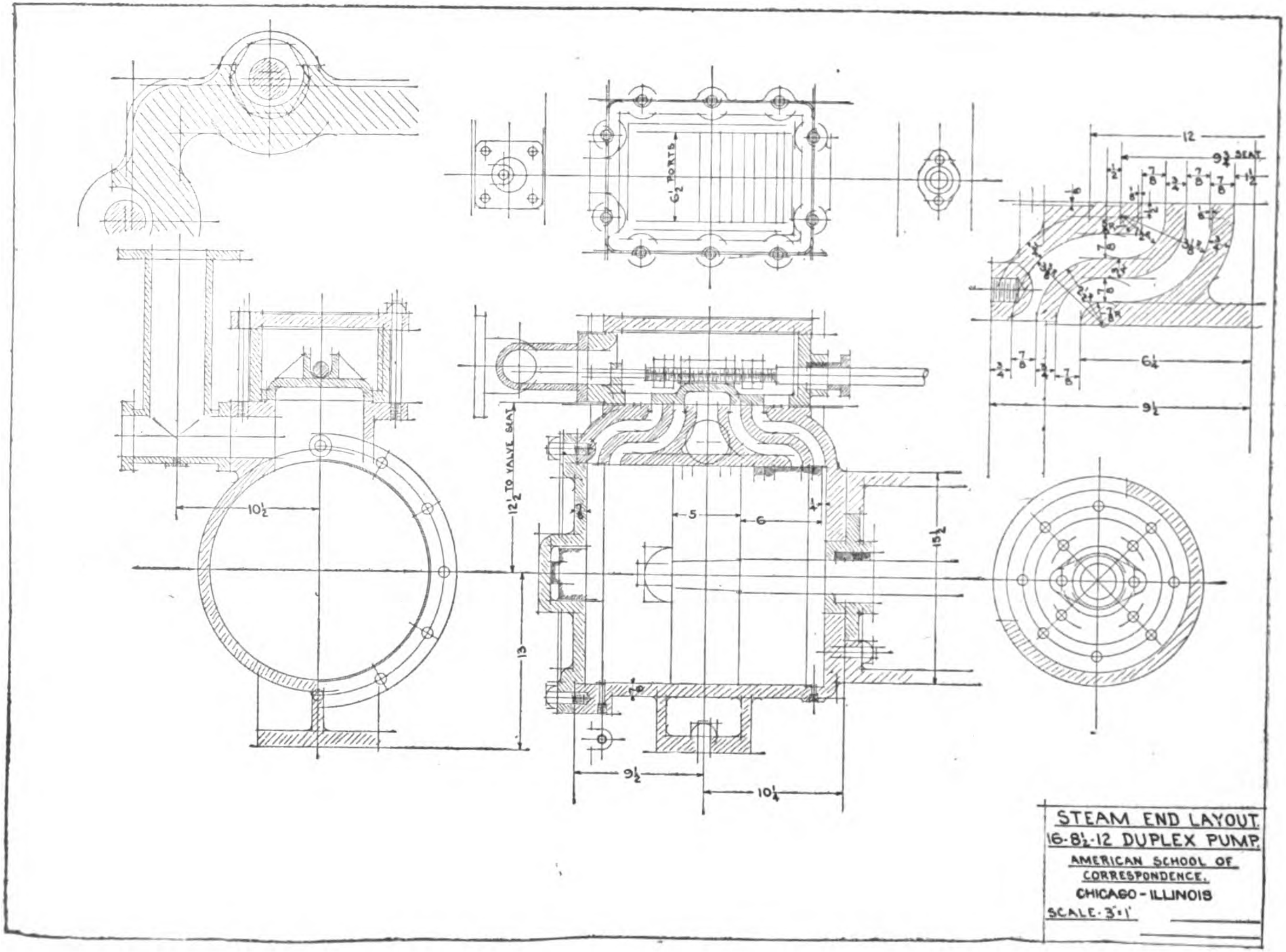
In the preliminary layouts the actual "sketchy" appearance of the pencil drawing will be imitated as far as possible, so that the student himself may imitate and catch the bold dash, yet fine accuracy, of the line-work, which is characteristic of the expert draftsman.

The completeness of a *set* of drawings is as important a lesson as the completeness of each drawing itself. In this is involved the proper arrangement and classification of details, the foundation layout, and the system of order sheets for getting work into and through the shops. This is a feature which very strongly affects some of the finishing touches to a drawing, for it is so easy to omit a "few last things" and turn in an uncompleted sheet. Every draftsman knows how many little things come up toward the close of a job involving complete drawings of a machine, and how strong the tendency is to omit them, and relieve himself of somewhat tedious details. The result is irritation and delay when the drawings get into the shop, and they return to the drawing room to be fixed up at a time probably inconvenient for all parties concerned. A good draftsman will turn in a *complete* set of *complete* drawings. It is highly important that the student grasp this idea, and study his work accordingly.

DUPLEX PUMP PLATES.

The typical set of plates chosen for this book in fulfillment of the above purposes, takes up the study of a simple, duplex steam pump. This particular type of machine represents the simplest and most elementary form of the steam engine in modern use in respect to valve gear and controlling devices. It is not an economical machine, yet its principles lie at the foundation of the economical high-speed engine, the latter being produced through a modification of the uneconomical valve gear such as is found on a pump of the type chosen, rather than through any radical change of construction as to the body of the machine. Hence the study of a steam pump may well precede that of higher forms of the steam engine. It is hoped that the study will so interset the student that he will be led to further investigation and development not only of the steam engine itself, but of that highly important division of modern engineering,—pumping machinery.

Thus we note another point of advantage in the study as out-


STEAM END LAYOUT.
16-8½-12 DUPLEX PUMP.
AMERICAN SCHOOL OF CORRESPONDENCE.
CHICAGO - ILLINOIS
SCALE - 3" = 1'
6½ PORTS
12½ TO VALVE SEAT
9¾ SEAT
12
6¼
9½
10½
13
15½
10¼
5
6

lined. The power end of the machine introduces us to the steam engine; the load end is the beginning of the engineering of pumping machinery.

Rating of Pump. A steam pump is rated by the bore of its cylinders and length of stroke, all being given in inches. A "$16 \times 8\frac{1}{2} \times 12$ pump" means that the steam cylinder is 16 inches in diameter, the water plunger $8\frac{1}{2}$ inches in diameter, and the nominal length of stroke 12 inches. These sizes are always given in the same order, beginning with the diameter of the smallest cylinder (in case there is more than one), then the diameter of water plunger, the common stroke of both being placed last. This expresses to the mechanic the rating of the pump in the clearest style and briefest language.

The pump illustrated here is designed for standard service, operating under a steam pressure not to exceed 100 pounds per square inch, water pressure not to exceed 150 pounds per square inch, and the rated capacity based on an average piston speed of 100 feet per minute being about 550 gallons. This requires that each side of the pump shall handle 275 gallons, and being double acting, shall make 100 reversals or 50 double strokes per minute.

Plate A. Steam End Layout. This plate illustrates, as nearly as reproduction can accomplish, the pencil layout of the steam end. It is the first work of the designing draftsman. The drawing as shown is exactly the type of layout which he would turn over to a detail draftsman, whose duty it would be to work up detail shop drawings therefrom.

The character of this drawing should be carefully studied. Remember that it is a layout, nothing more; also bear in mind that it is an exact, measurable working sketch. Attention is called to the sharpness of the lines, especially to the clean-cut intersections. Note the boldness, dash and businesslike style, the freehand cross-section lines roughly put in. There is no hesitation or worry as to where the end of a line shall be, or whether it crosses other lines which it theoretically should not. The intersections are allowed to indicate the termination of lines, and the rough section lines pick out the parts and separate them clearly to the eye. There is the spirit in this layout of confident, definite and rapid action, with no thought for absolute finish in line-work, but with every thought for absolute results as to measurable dimensions.

The data for the production of Plate A by the student are rather more complete than he would usually find in practice. Plates E, F and G show many details fully.

The steam cylinder and head, however, as shown in Plate G, are not dimensioned, and the student's problem is to produce this plate complete, with finish marks, dimensions and necessary data for a working drawing. In order to do this it is first necessary to work up Plate A with exactness, in pencil, and see that all parts go together properly. Then the detail of cylinder and head may be made separately by measurement of the layout drawing, and Plate G produced.

For this work the ordinary brown detail paper is very satisfactory. A hard lead pencil is necessary, as hard as 6H, and the point must be kept well sharpened.

There are two general rules of action in producing a drawing which give the answer to the question which oftenest confronts the beginner: "What is to be done first?" or "What is to be done next?" These rules are:

1. Draw everything that is positively known.
2. Work from the inside to the outside.

Every problem has some positive data, assumed or calculated, to start with. The first thing to do in every case is to get this data represented by lines on the paper. An expert designer has been heard to say that until he had spoiled the blankness of his sheet of paper by some lines, he could not design. There is something in this: and almost invariably the first line to draw is a horizontal center line somewhere near the middle of the sheet; draw it! Draw it at once without hesitation, and the layout is begun. We now have something about which to build.

In this case the designer would first calculate the size of the piston rod, and determine the fastening to the piston. He would then draw the rod and build a hub around it. He would next calculate the width or thickness of piston and size of packing rings, and draw the two vertical lines 5 inches apart, to indicate the piston faces. These lines would be limited by the cylinder bore, which he knows to be 16 inches; hence horizontal lines 16

ROCOCO ORNAMENTAL THREE COLUMN PATTERN RADIATOR FOR WARMING BY HOT WATER.
American Radiator Company.

inches apart, parallel to and symmetrical with the center line, are the next to be drawn. Short vertical lines indicate the location of the packing rings. As the nominal travel of the piston is to be 12 inches, the location of the piston and rings can be shown on both sides of the central vertical line at the limits of travel. A clearance must exist between the heads and the piston (in this case $\frac{1}{4}$ inch is allowed), hence the lines of the heads can be drawn, and the general inside outline of the cylinder barrel is complete.

This is all in direct application of the foregoing rules, and is so simple, natural and direct that it hardly requires such explicit statement. We have simply taken such data as we had and put it on paper, placing it where it can be seen from all sides, and where the mind is relieved of the labor of carrying it.

If the student will only appreciate this one rule and draw all he knows about the problem, he is well on his way to its solution. *Draw everything you know, and work for what you don't know,* is what these two rules say, and the first question to arise should be: "Have I drawn everything that is known about the problem?" before he asks himself or any one else: "What shall I do next?"

One other rule might be added to these two: *Keep dimensions in even figures, if possible.* This means that small fractions should be avoided. It is just as easy to bear this point in mind, and save the workman much annoyance and chance of error, as it is to disregard this matter. Even figures constitute one of the trade-marks of an expert draftsman. Of course a few small fractions, and sometimes decimals, will be necessary. Remember, however, that fractions must in every case be according to the common scale; that is, in sixteenths, thirty-seconds, sixty-fourths, etc.; never in thirds, fifths, sevenths, or such as do not occur on the common machinist's scale.

A systematic, definite mode of treatment on these lines must become a habit, so that all problems, however complicated, can be approached with confidence in the same way. It is the drawing of one line which makes clear the drawing of the next and subsequent lines; and the most serious obstacle which the student is likely to set for himself is trying to see the whole problem through from the beginning. Even an expert cannot do this, but allows the layout to develop results as he proceeds.

The details of the piston and rod being given in Plate E, the foregoing work is very easy for the student. The thickness of the barrel and heads being determined ($\frac{7}{8}$ inch in this case), the exterior outline may be partially drawn. The fixed head at the yoke end must be thicker than this, in order to receive the yoke and stuffing-box bolts without breaking through. The recesses or counterbores at either end of the cylinder should be so located that the packing rings run over the edge a little at the end of the stroke, thus preventing the wearing of a shoulder by the piston stopping in the same place every time. The counterbore should be deep enough to allow reboring the cylinder without the counterbore being touched by the tool. In this way the counterbore is retained to center the cylinder at its original location.

The size of steam ports having been calculated, they may be drawn in, the turns being made easy and as direct as possible. The height to valve seat must be kept at the lowest limit consistent with sufficient metal between and outside of the ports. As the detail of the ports might be somewhat troublesome, it is shown in an enlarged sketch for the student's benefit. Chipping or filing strips $\frac{1}{8}$ inch high are left on the port edges, which must be true, in order to finish them up easily.

The three inner ports are for exhaust, the outer ones for admission of steam. This five-ported cylinder is peculiar to the direct acting steam pump, it being a device to effect the cushioning of the piston at the end of the stroke, thus preventing the piston from striking the heads. This is necessary, since no positive limit of motion exists, as is the case in machines with crank and connecting rod.

When the edge of the piston has passed the outer edge of the exhaust port, as shown in Fig. 1, the steam, which has been exhausting through port A, is confined in space B and port C, and, being compressed by the piston, acts like a spring to retard its motion. If the point P is properly determined for a given speed, the piston will always compress the steam just enough to cause it to stop at the end of the nominal stroke; in this case, $\frac{1}{4}$ inch from the head. It is evident, however, that at different speeds the piston will have more or less power to compress the steam, and will not stop at the point desired. This causes the trouble of "short stroke," and consequent inability to make the pump work to its full capacity. Now if we connect ports A and C by a small opening shown dotted at D, and control this opening by a plug valve operated by hand from the outside, we can let a little steam leak by into port A, thus reducing the cushion and allowing full stroke.

In order to avoid complicating the drawing, no cushion valves are shown or required to be put on by the student. They are not customary in small pumps, but might advantageously be put on the present illustration.

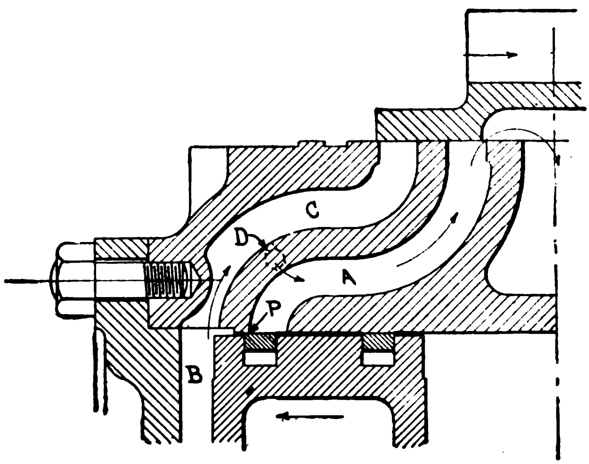


Fig. 1.

The valve seat must be a scraped surface, while the chest face need not be; hence the latter is finished $\frac{1}{8}$ inch lower. This also gives a ledge against which the steam chest fits, thus securing positive location.

The bolting of the heads and the steam chest should allow a width of packing inside of the bolts of $\frac{1}{2}$ to $\frac{5}{8}$ inch, otherwise there is danger of the steam blowing out the packing and causing leakage around the bolts. The bolts do not fill the holes, the latter being drilled large, from $\frac{1}{16}$ to $\frac{1}{8}$ inch. The spacing, if wider than 5 or 6 inches, is likely to permit springing of the flanges between the bolts, and consequent leakage. Bolts less than $\frac{5}{8}$ inch diameter are not desirable, as they can be easily twisted off with an ordinary wrench. In this case the cylinder head takes $\frac{7}{8}$-inch bolts, the yoke, stuffing-box and gland, $\frac{3}{4}$-inch.

The flanges of heads and cylinders are usually from 25 per cent to 50 per cent thicker than the body of the casting.

Drips, $\frac{1}{2}$-inch pipe tap, to be fitted with cocks, are necessary at both ends of the cylinder to readily drain the cylinder of water.

Molding of Steam Cylinder. The design is often influenced by the way in which the piece is to be cast. It often takes but a slight change of design to save many dollars in pattern making and foundry work. Hence the habit should be formed of always judging the design of a piece from the foundry standpoint. In this case it is evident that the ports and cylinder bore must be cored out, and the most obvious position of molding is to lay the cylinder on its side, the parting line of the flask being along a vertical plane running lengthwise through the middle of the cylinder. This permits the chest flanges to draw nicely, likewise the ribs on the foot, and allows the thin curving port cores to stand edgewise in the mold.

Another method of molding would be with the valve seat down. This would involve loose pieces for the chest flanges, and setting of cores for the cylinder foot. It would, however, assure sound metal beyond question at the valve seat. Spongy metal at the important wearing surfaces, the valve seat and cylinder bore, is not permissible in any case, and care in molding, and good design, is necessary for good results.

All corners must be carefully filleted, and chunks of metal must be avoided, especially where several walls or ribs join. The metal must be kept of average uniform thickness, so that the whole casting will cool uniformly.

Machining of Steam Cylinder. The boring may be done on a vertical boring mill, the heavy arm carrying the tool being thrust down unsupported into the cylinder, the latter being rotated by the table to which it is clamped. If the horizontal boring machine be used, the hole through the inside head for the stuffing box must be large enough to permit a stiff boring bar to be passed through. This allows a support at each end of the bar, to take the strain of the cut.

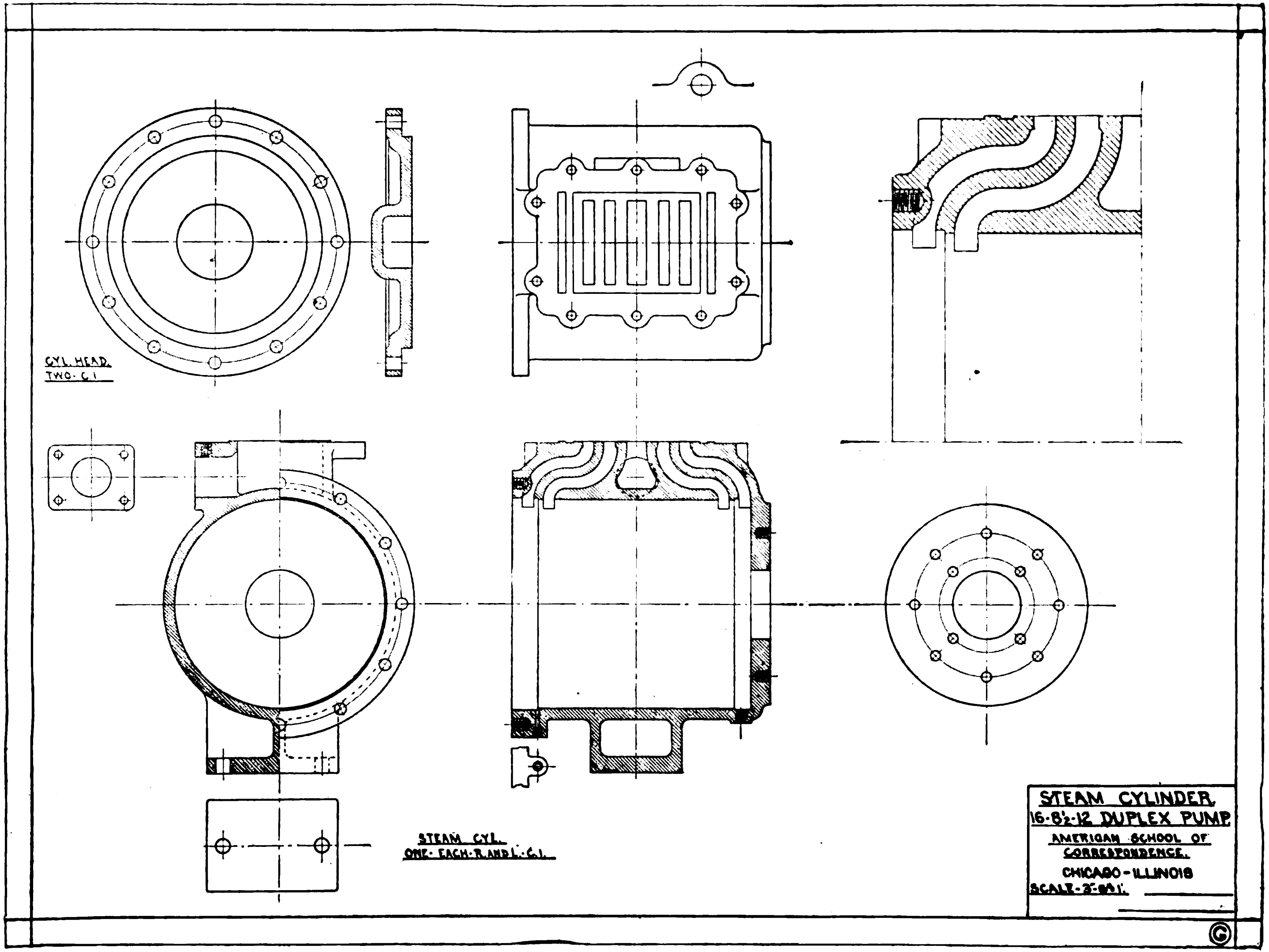
The plane surfaces may be finished on a reciprocating planer or a rotary planer. In the latter case it is desirable to keep all lugs or projections back from finished surfaces, to permit the large round head which carries the cutters to pass over them without interference.

The drilling of standard machine parts of this character is usually done through jigs, or plates carrying hardened steel bushings laid out to correspond with the holes required, and through which the drill is guided. These plates are located by some fixed line or lug on the casting, and then clamped fast, thus assuring exact duplication and rapid drilling, and avoiding the tedious laying out of the holes. In order to save changing the drill it is desirable, if possible, to maintain the same size of hole on any given surface. Of course it is not always admissible to do this.

Plate G. Steam Cylinder. After the exact and complete development of the steam-end layout, the student should be pretty thoroughly acquainted with the details of the cylinder. All the work thus far has been entirely for *his own* information, to get his ideas in visible shape, so that he himself can have a permanent record of them. This layout, however, is not in suitable form to finish up into a detail drawing. Its sketchy nature and the confusion of parts, especially if attempt were made to add dimensions, would render it somewhat difficult to be read by a workman taking it up as an unfamiliar subject. Hence it is now necessary to separately detail the parts, with the object in view of transferring, in the simplest and most direct manner, specific information to the workman which will enable him to construct the several parts. It is not enough now that the drawing be clear to the man who makes it; it must be clear, *absolutely clear*, to the shop mechanic, who has no means of knowing the designer's plans except through the information which the drawing gives on its face.

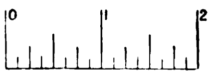
This requires that the draftsman should put himself in the workman's place, and forestall, by the explicit nature of his drawing, all possible questions which may arise in the shop. In this way only can he hope to avoid errors of construction and the continual annoyance of endless explanation of his orders.

Plate G is to be a finished drawing, and the first thing to do is to lay out the sheet. The standard sheet for details which has

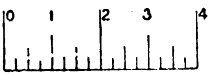

CYL. HEAD.
TWO. C.I.
STEAM CYL.
ONE. EACH. R. AND L. C.I.
STEAM CYLINDER
16-8½-12 DUPLEX PUMP
AMERICAN SCHOOL OF
CORRESPONDENCE.
CHICAGO - ILLINOIS
SCALE 3″ = 1′.

been adopted is 18 × 24 inches trimming size, with $\frac{1}{2}$ inch margin all round, so that the working space is 17 × 23 inches. The rectangle for the title is to be laid off $2\frac{1}{2}$ × 4 inches in the lower right-hand corner, and must never be altered, either in size or position. This does not mean that other sizes are wrong, but once a standard system is adopted it must be strictly adhered to, both for artistic and commercial reasons. The scale to which the drawing is to be made is indicated in the title corner on every plate.

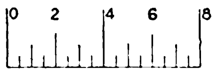
The scales permissible for shop drawings in the United States are those readily derived from the common foot rule, such as full size, 6 inches = 1 foot, 3 inches = 1 foot, $1\frac{1}{2}$ inches = 1 foot. These are the most common, most easily read from an ordinary scale, and one of these can usually be adopted. The student should learn to read these from an ordinary scale without being confined to a special graduation. To do this it is not necessary to divide each dimension by 2, 4 and 8 to get half size, quarter size, or eighth size, and then lay down the result. For half size, or 6 inches = 1 foot, $\frac{1}{2}$ inch on an ordinary rule represents 1 inch. Hence, each half inch may be read as 1 inch, and its subdivisions accordingly, thus:



For 3 inches = 1 foot, or quarter size, $\frac{1}{4}$ inch represents 1 inch, and looks thus:



For $1\frac{1}{2}$ inches = 1 foot, or eighth size, $\frac{1}{8}$ inch represents 1 inch, and looks thus:



It is very easy to get accustomed to this, and it saves much time and trouble hunting up a special scale every time.

The other allowable scales, less common, but sometimes necessary on large work, are 1 inch = 1 foot, $\frac{3}{4}$ inch = 1 foot, $\frac{1}{2}$ inch = 1 foot, $\frac{3}{8}$ inch = 1 foot, $\frac{1}{4}$ inch = 1 foot, and $\frac{1}{8}$ inch = 1 foot. To use these scales conveniently, special graduation is desirable.

The general arrangement of the sheet, number of views and approximate space occupied, should be blocked out first. This can easily be done from the original layout. In general, several cross-sections are preferable to a single view, which involves many dotted lines. Dotted lines are very convenient for showing invisible parts of an object, but they are often abused, and the drawing of a complicated piece made indefinite and confused thereby. As already stated, a working shop drawing is solely to convey information to the workman at the least possible cost. A careful consideration of this will settle the question of the number of views necessary, their character, and the amount of dotted line work desirable.

Never let the drawing become the master; always be master of the drawing. Do not draw an extra view if no use can be seen for it. Do not put in dotted lines if the detail is completely shown without them. Full lines, or lines which show visible portions must, of course, be shown completely.

The nature of the pencil work on Plate G should be the same as on the original layout; viz., sharp, definite lines and positive intersections. Above all things learn the habit of accurate workmanship, for it will save many errors and a vast amount of time. The draftsman must check himself at every line he draws. Slight errors in scaling will often throw parts out of proper relation to each other, and interferences, which the drawing does not show, will become apparent only when the parts get into the machinist's hands.

It is dangerous practice to project across from one view to the other. It only takes a slight irregularity or spring in the T-square to vary the location of lines very perceptibly from where they should be, and once out of scale from this reason it is almost impossible to work a view with any certainty. Rather than project across from view to view, the principal lines, at least, should be scaled off on each view, and it will be found that in the end time will be saved and greater accuracy secured.

It is not economical of time to finish one view before beginning another. It is better to take some single detail of the drawing and develop it in all views, in order to study it from all sides. What is completed in one view may be found to be totally wrong when developed from another side, and the time spent on the first view will be wholly wasted. For example, in the present case the steam ports should be drawn in side elevation, end elevation and plan, and when thus completed the mind can leave them and in a similar fashion take up the study of the flanges, then the cylinder foot, and so on. Thus again the draftsman is master of his drawing, for he is continually making it tell him whether he is right or wrong. If, on the contrary, he allows himself to look at but one side at a time, and works from that standpoint alone, it may lead him into many difficulties from which he cannot readily extricate himself.

Do not be afraid to use the eraser. The draftsman who hesitates to draw until he is positive that no change will be necessary, is likely to spend the greater portion of his time in unprofitable dreams, for he is attempting the impossible. A drawing is a means, not an end; and, as has been already pointed out, it greatly assists the draftsman in clearing up many doubtful questions which the imagination alone cannot do.

A bold attack of a problem shows the quickest path to its solution, even if lines must be erased again and again. It is a sign of serious lack of ability to hesitate in the use of pencil and eraser.

Attention is called to the simple, straightforward character of Plate G. Notice the almost entire absence of dotted lines; the enlarged section through the ports, giving ample opportunity for dimensions without confusion; the use of a half end elevation and a half cross-section,— the one to make clear the flange and bolt layout; the other to show the exhaust opening, the small auxiliary views (drawn at convenient points) of the exhaust flange layout, the cylinder foot and the drip boss.

A steam cylinder is a fairly complicated casting; and it would be an easy matter, by the use of elaborate views, the dotting in of parts already completely shown, and careless line work, to rob this drawing almost entirely of its clearness and directness of illustration. *Just what is necessary* (for clearness' sake) *and no more* (for cheapness' sake), is the whole matter in a nutshell, and is what determines its shop and commercial value.

Dimensions and Letters. A good line drawing can be spoiled by poorly arranged dimensions and hasty lettering. The five principal points to be kept in mind to develop excellence in this respect are:

(1) System.
(2) Accuracy.
(3) Clearness.
(4) Completeness.
(5) Character.

System. The habit of system in placing figures and letters on a drawing is the one element which, to a large extent, controls all the others. If the systematic habit is established early, the other requirements will be fulfilled more easily. A haphazard method will, on the contrary, just as surely prevent the successful cultivation of the ability to figure a drawing. In fact, if the haphazard habit is continued it will itself, by the dissatisfaction which it causes, soon compel the draftsman to change his occupation.

In the first place, whatever part of a machine detail is to be dimensioned, that particular part should receive attention until it has been completely figured. Do not jump from one point to another, putting in a figure here and another there. Stick to one thing until it is done.

For example, take Plate F and the simple detail of the steam pipe. Suppose we start with one of the square flanges. The first question is: "Where is this flange located?" This is answered by the dimensions 5 inches and 21-inch centers, which refer the face of the flange to the center of the pipe and the flanges to each other. The next question is: "What are the three dimensions of the flange,— length, breadth and thickness?" This is readily answered as shown on the drawing. The next question is: "What further description is necessary to completely specify the shape of the flange?" This is answered by the radius of the corners, $\frac{3}{4}$ inch R. Next, "What drilling or special feature exists in the flange?" This is answered by $1\frac{1}{16}$-inch drill, $3\frac{1}{2}$-inch centers, and the letter *f* to denote that the face is to be finished.

The round flange of this pipe is approached and figured in the same way, except that the location of the face is preferably referred to the face of the square flange by the figure $8\frac{1}{4}$ inches, instead of to the center of the pipe, because the planer hand will more naturally use this figure.

These flanges are now to be connected by a pipe involving two sizes. The main pipe is 3 inches diameter inside, 4 inches outside, and $\frac{1}{2}$ inch thick, running into the two branches by fillets and radii, as figured. The two branches are really one pipe, $2\frac{1}{2}$ inches inside, $3\frac{1}{2}$ inches outside, $\frac{1}{2}$ inch thick, and sweeping down into the square flanges by 4-inch radius.

This systematic method takes longer to explain than to actually execute, but it is typical of the train of thought which must be followed on all pieces, simple or complicated, in order to properly place dimensions.

In general, it may be stated that all parts of a piece must be referred either to each other, or to some common reference line, or to both. Each part so referred must then be figured as a piece by itself, and then its connections to the principal structure. Thus, figuring a machine detail involves three things:

(1) Relative location of its parts.
(2) Proportions of these parts.
(3) Proportions of connecting members.

As in the original design of a piece so in the figuring of it, the draftsman must as far as possible put himself in the place of the workman, judging the methods and processes of construction and available tools. This will largely influence the arrangement of the dimensions. Of course it implies considerable experience in shop work, which some students do not possess. He can begin none too early, however, to learn to look at his work from the shop standpoint, and surely make it some better on that account.

Pieces must not only be systematically dimensioned, but regularly specified and called for by suitable titles.

A title should specify at least three things:

(1) Name of piece.
(2) Number wanted for one machine.
(3) Material.

To these might be added a fourth; viz., pattern or piece number. The latter is not specified on the drawings under discussion, because systems of pattern and piece numbering are so varied that little would be gained by developing one for this special study.

These titles should always be put on in the same way, as the workmen become used to a certain system and are likely to misunderstand directions if a regular plan is not followed. A good way to arrange titles is suggested on the plates, although there are others which might be used.

Bolts are usually specified by diameter and length under the head, the length of thread being to some standard system in use by the shop, unless otherwise called for. Bolts are specified on the sheet containing the piece into which they are tapped. In the case of through bolts, tapped into neither piece, they are preferably called for in connection with the principal member.

Accuracy. Of course the dimensions on a drawing must be accurate. It is, however, a very easy matter to make errors. To insure accuracy a figure must *never* be put down carelessly, and a constant watch must be kept that scaled figures add up to over-all dimensions. It will not do to rely on scaling alone, as a very slight variation from exact scale may throw two dimensions out with each other. In spite of all the care that can be exercised errors will creep in, and a final thorough checking must be given a drawing before it is pronounced complete. A good rule to follow in checking up is to "assume everything wrong until it is proved to be right."

Clearness. As in the line drawing itself, there must be absolute clearness of instruction by the dimensions. Any doubt as to what a figure is, or what it means, rules out that figure as part of the drawing. If a piece is made wrong because doubt of this character is transmitted to the workman, the draftsman is always held responsible for the error.

Figures should, in all cases, be placed where they can be most clearly read. They should be bunched on a single view as far as possible, but not when greater clearness demands that another view be used. It hinders the reading of a drawing materially if the eye is forced to jump over large spaces of the sheet from view to view, to catch the several dimensions of a small detail. Usually it is easy to so group figures as to avoid this.

It is a good plan to keep dimensions off the body of the drawing, when it can be done so conveniently. It is not worth while, however, to go out of one's way to do this, as figures in the open spaces of a detail do not at all destroy its clearness.

Extended notes on a drawing to make it clear should not be required, but they should be used without hesitation if any doubt exists. An explicit note of instruction is the final resource for clearness when the art of drawing fails of its purpose, as it sometimes does.

Completeness. A detail is completely dimensioned when it shows *all* the figures necessary for the workman. Anything short of this is incompleteness. As modern shops hold the draftsman solely responsible for the design, the mechanic is not allowed to modify it by filling in any omitted dimensions. The only way to be sure that all the dimensions are on is to systematically go all round a piece inside and out, according to the method suggested under the paragraph on "System."

It is a good plan to always bear in mind that not only the machinist is to use the drawing, but also the pattern maker. For the benefit of the latter, special attention is desirable in figuring the cores. This saves him some addition and subtraction. In general, it has been found that less chance of error exists if mathematical work is not required of the shopman, all necessary data being furnished on the face of the drawing.

Character. By character in figures and letters is meant uniform style, height and slope, and a certain boldness peculiar to the work of the expert draftsman. The last is difficult for the novice to acquire. The student should not be discouraged because his efforts do not look like impressions from printers' type. Artistic excellence is the result of long experience, but is based on character. If the student can once get character into his work, the artistic feature will, with careful and constant practice, gradually develop. It is safe to say that there is no one element of a drawing which more positively stamps it as the work of an amateur than the character of the lettering, and every attention should be paid to getting out of the apprenticeship stage in this respect. Freehand lettering only is permitted in the drawings illustrated herewith. Ruled letters are seldom found on any working drawings, as the element of time involved is so great that few shops are willing to pay for it.

Uniform style requires that if capitals only are used in titles, they only must be used in notes and elsewhere on the drawing. If lower-case letters are used, they must be used in every part of the drawing. One style should not be mixed with another. The height of the letters should be limited by two horizontal lines, and though practice may render the upper line unnecessary, it takes but an instant to draw it, and uniform height is then assured. A good height for titles of details such as are illustrated is $\frac{5}{32}$ inch. The height once chosen should be adhered to throughout the whole set. A medium, not a hard, grade of pencil (3H) will give the hand greater freedom. A great temptation exists to omit titles from the pencil drawing, simply inking them on the tracing. This is false economy of time, for in the end it will be found that enough time will be saved by the certainty with which the tracing can be made to more than pay for the labor on the pencil drawing. Again, it permits the tracing, in regular shop practice, to be made by cheaper labor than that which produced the pencil drawing.

Uniform slope is most easily acquired by the use of guide lines put in at frequent intervals. A small wooden triangle can be made, giving the required angle. The angle of the letters shown on the plates is 9 degrees, or about 1 inch slope in 6 inches. The question as to whether letters should incline backwards, forwards, or stand vertical, does not enter this discussion. Character is not affected by the slope. The student may choose whatever comes most natural to him, but having chosen, the character of his work will be spoiled if he varies it. The most difficult of the three is the vertical style; hence most draftsmen incline their letters. The backward slope is used on the plates of this shop drawing paper, thus giving the student opportunity to compare with plates in the earlier books, and follow his preference.

The effect of change of style, height and slope is shown in Figs. 2, 3 and 4, respectively. Attention is called to Fig. 5, which is a sample title, in which these points are corrected.

Principal Titles. The principal title of a drawing should contain at least seven items:

(1) Name of principal details shown.
(2) Name of machine.
(3) Firm name and location.
(4) Scale of drawing.
(5) Date of completion.
(6) Draftsman's signature.
(7) Filing number.

To these are often added others, but for purposes of filing and reference the above at least *must* be put on. The filing number may or may not be put in the title frame, but it is really a part of it. It is often put in the margin below the title.

An arrangement of title should be established and then followed exactly, without variation either as to location on sheet or detail make-up. Abbreviated words are always permissible in titles, provided the meaning is clear. Special care must be taken in punctuation, however, as a title, whether abbreviated or not, has an unfinished appearance if the periods, commas and other necessary punctuation marks are not included.

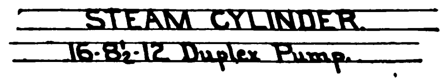


Fig. 2.

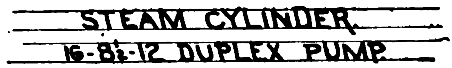


Fig. 3.

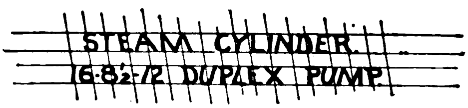


Fig. 4.

The sample title illustrated in Fig. 5 indicates the arrangement chosen for the drawings of Part IV. Note that it is necessary in this special case to add an extra subject to the seven given above; viz., the residence of the student draftsman.

This style of title must be put with care on every drawing, even on the rough pencil layouts. In the latter case it may of course be left in pencil, as the rough layouts are not to be inked.

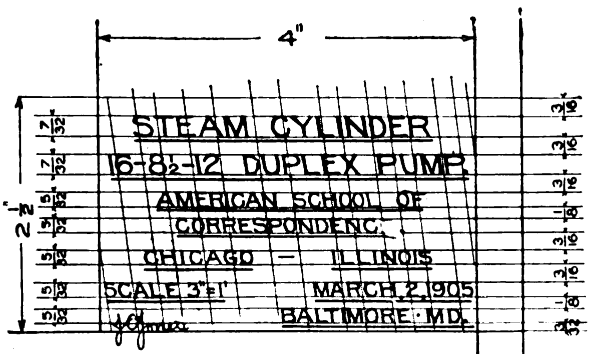


Fig. 5.

Inking and Tracing. Both bond paper and tracing cloth are used in business practice for finished drawings. It is desirable to keep a stock of both in any drawing office, so that either may be used as occasion requires. Bond paper stretched on the board gives a beautiful surface to take the ink, and very handsome and effective detail or assembled drawings can thus be produced.

Changes are not quite as readily made on bond paper as on tracing cloth, and it takes a little longer to make the blue print. In other ways the bond paper is not quite as flexible to use as the tracing cloth. However, one must be guided entirely by shop conditions to settle the question of preference. As the tracing cloth is generally used, and suits the purpose of the student better, it will be required in this work.

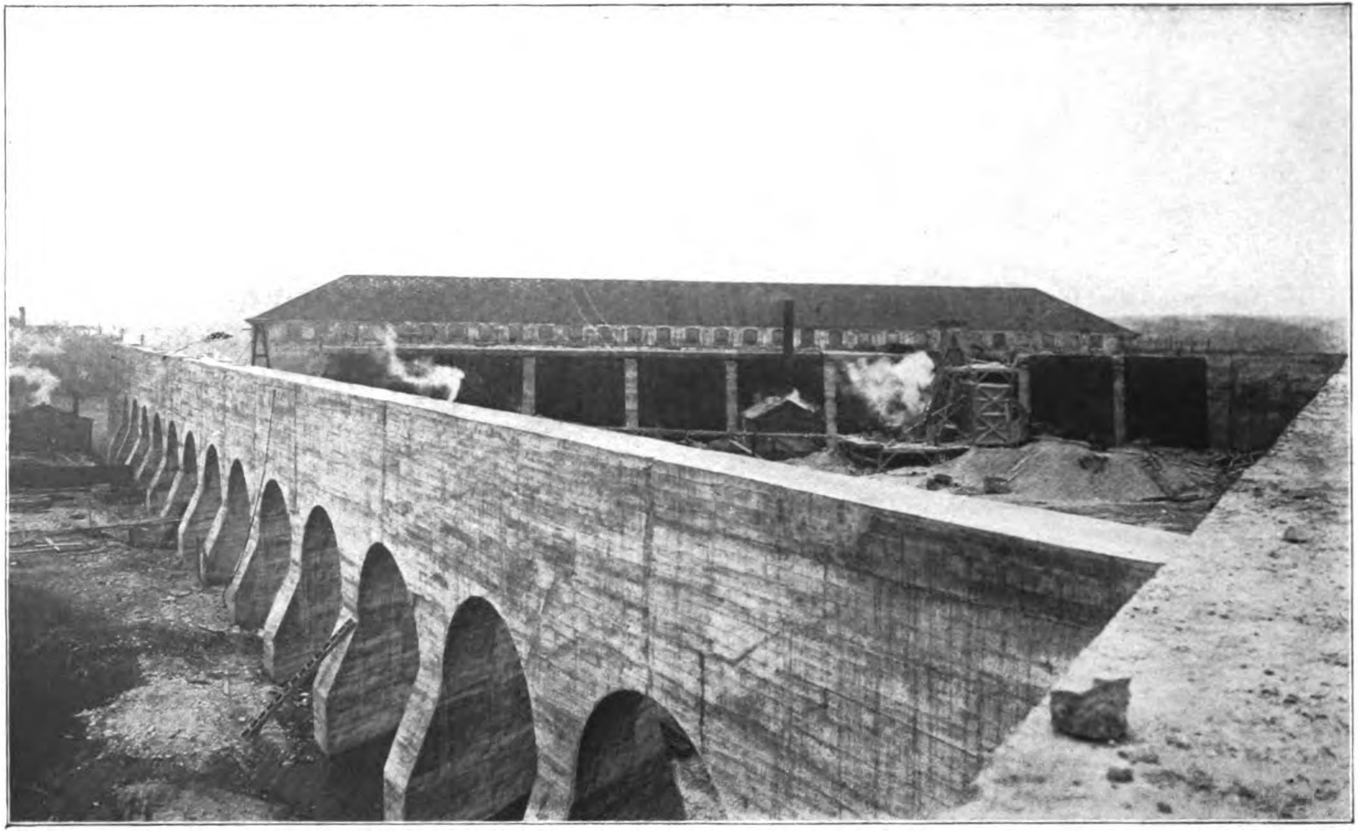
The inking should be done on the *rough* side of the cloth. One reason for choosing this side is that as the cloth tends to curl under toward the glazed side, the drawing as it lies right side up will tend to straighten itself. This seems to be a small point, but it is a very important advantage for filing and for the convenience of those who are to handle the drawings. Also the rough side takes colors and inks better than the glazed side. To trace on the glazed side is not wrong, for it is often done, but it possesses no advantages of its own, and has the disadvantage mentioned above.

Chalk dust scattered over the surface of the cloth after it is tacked down will remove the slightly greasy coating which prevents the ink from flowing well from the pen. This is always necessary if the glazed side be used, and usually for the rough side. The chalk must be carefully removed from the cloth before inking.

The first step in inking is to draw the center lines. Remember that *accurate intersections* are of the utmost importance. No circle is complete without two intersecting lines, preferably at 90 degrees, to determine its center, and these lines should be inked before the circle. When this is done a definite point exists for the needle point of the compasses. If the circle is drawn first the needle point may not be placed accurately at the center on the pencil drawing beneath, and the location be thrown out.

Likewise the principal center lines of pieces, the lines around which the pencil drawing was built up, should be at once put in.

The main body of the drawing, the full lines, should be taken next. In general, circles and arcs should be inked first, but there



POWER HOUSE ON CHICAGO DRAINAGE CANAL AT LOCKPORT, ILLINOIS

Power House in background; in front of it is the forebay, with screens protecting the conduits leading to the turbine chambers; in foreground is the arched concrete fender wall.

Courtesy of R. Isham Randolph.

are cases where it is easier to run the arcs into the straight lines than to match the straight lines to the arcs. They are exceptions. however, and can be judged only as the case arises.

Straight lines, horizontal and vertical, should be inked with the T-square and triangle *in position*. It is a common practice to dispense with the use of the T-square entirely in inking in, using the triangle to match the lines to the arcs already drawn. A necessity for this implies very poor work on the arcs, for with any reasonable care true horizontal and vertical lines will match the arcs all right. With regard to time required, the accuracy with which the T-square may be brought up to a line, or the triangle set on the T-square, more than makes up for the time gained in even an approximate setting of the triangle without a guide. It is just as easy to cultivate the habit of holding the T-square and triangle with the left hand and the pen with the right, and draw an exact line, as to lapse into the other method, which is not workmanlike.

The lines of the body of the drawing depend for their width upon the size of the detail. For a large piece they may be $\frac{1}{32}$ inch wide, and the shade lines $\frac{3}{64}$ inch. For a small detail such widths would be too great. Remember that *contrast* is the principal aim, and to produce it is the only reason why we use different kinds of lines on a drawing. Hence the greatest care must be exercised to prevent body lines from becoming confused with center or dimension lines, and *vice versa*. Also thick lines are desirable for the production of a bold blue-print.

Shade lines are shown on Plates I, K and N only. They are put on according to principles already explained. They certainly improve the drawing from an artistic standpoint, and the student should know how to put them on when desired. Whether or not it is desirable to adopt them on all working drawings is not the purpose of this book to decide, or even discuss. Almost always drawings can be made perfectly clear without them, and are so made and satisfactorily used in probably the majority of shops. Some shops are willing to pay for the extra time necessary to put on shade lines; this, however, is purely their own investment.

Cross-section lines are usually drawn at an angle of 45 degrees with the horizontal, and on sections which are adjacent to each other the slope should be in different directions. If three or more sections come together the width between section lines can be so changed as to indicate clearly the different parts. An example of this is shown in Fig. 6.

The spacing of section lines must not be too fine, rarely closer than $\frac{1}{16}$ inch, more often from $\frac{3}{32}$ to $\frac{1}{8}$ inch, else the labor involved is too great and uniformity practically impossible. It is a waste of time to rule in section lines on the pencil drawing; they may be sketched in freehand, as shown on the original layout of the steam cylinder. Even spacing concerns the tracing alone, and the student should train his eye to regularity as he traces The thickness of section lines may be intermediate between that of center lines and body lines of the drawing.

Inking Dimensions and Letters. Extension lines may be dotted, as explained in Part III, or they may be fine, full lines, the latter method being illustrated in the series of pump plates in this paper. Dimension lines are also often made fine, full lines. If these lines are made full they should be made as fine as it is possible to draw them and still have them firm, clear lines. The same width should be used as for center lines.

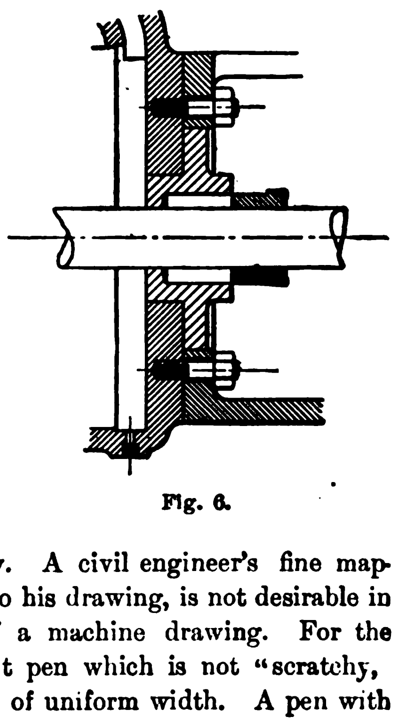


Fig. 6.

Character in inked figures and letters is more difficult to attain than in pencil work. In the first place a pen suitable to the style of drawing is necessary. A civil engineer's fine mapping pen, which gives character to his drawing, is not desirable in producing the bold character of a machine drawing. For the latter choose a rather stiff, blunt pen which is not "scratchy, but runs smoothly, making a line of uniform width. A pen with a round, or ball-shaped nib, recently put on the market, answers the purpose well for ordinary details. A bold, free stroke should be made with the idea of producing a smooth, even line, finished at the first trial. The hesitating uncertainty of the beginner's hand produces a "shaky" letter, and going over a letter or figure twice or more to smooth it up usually makes it worse.

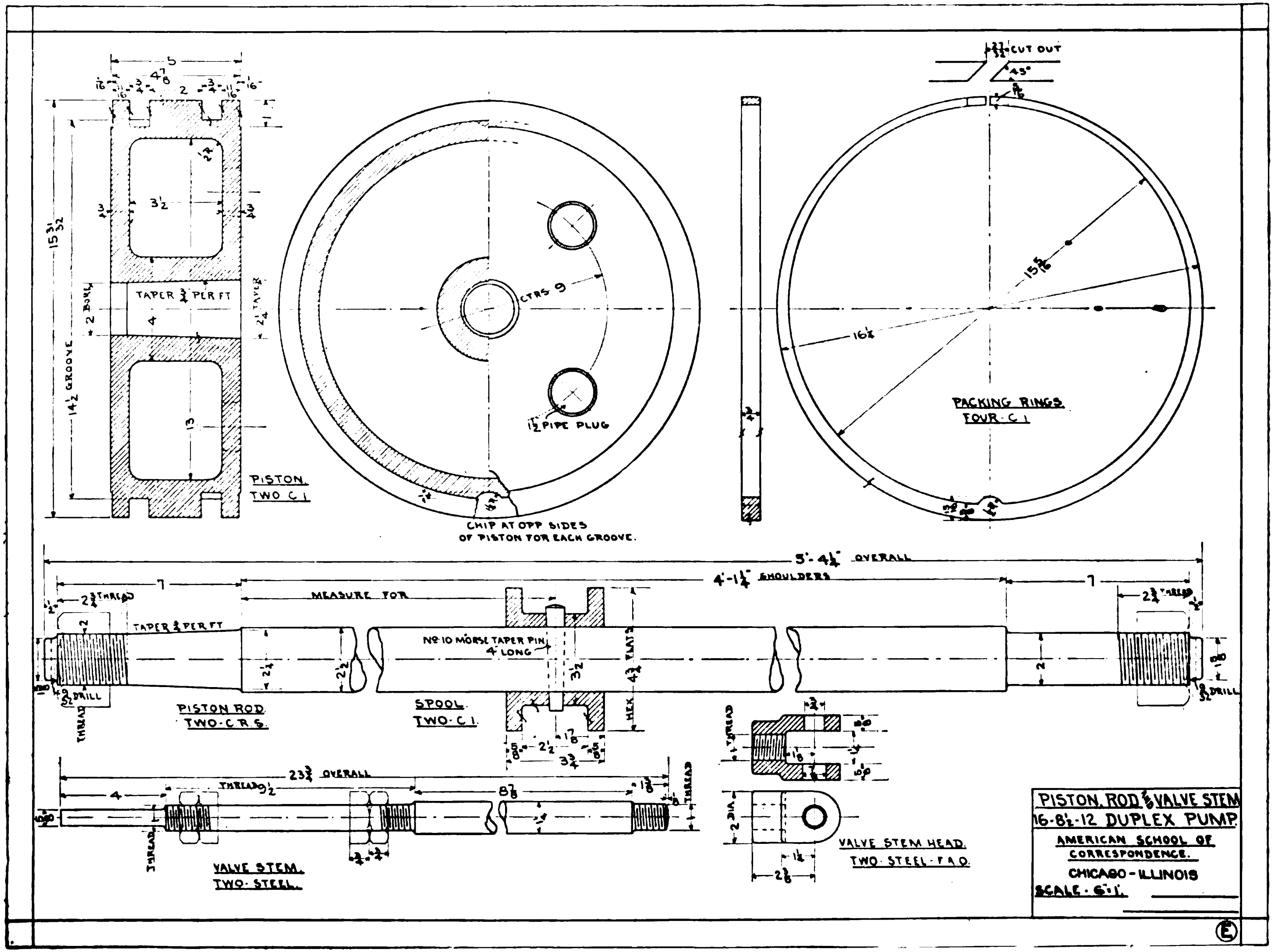
Figures and letters which are broad in proportion to height are easier to make, and have more character. It should never for a moment be forgotten that uniform *height* and *slope* carefully followed will develop character and quickly lead to artistic excellence.

Foot and inch marks are often put after figures according to the common usage. In cases where feet and inches are expressed, thus: 3′ — 6″, or 4′ — 0″, they are, of course, absolutely necessary, and the dash between the figures must be very positively indicated. In cases of inch dimensions alone the marks may be put on if desired, but where there can be no doubt that inches, and not feet, are meant, the inch marks are not necessary. This practice is followed on the plates of this paper.

Abbreviations. A list of the most common abbreviations in use on working drawings follows. This list has been adopted for the plates in Part IV:

F. A. O.	finished all over.
f.	finished surface.
R.	radius.
D.	diameter.
R. H.	right hand.
L. H.	left hand.
P. R.	piston rod.
P. TAP.	pipe tap.
CTRS.	centers.
C. I.	cast iron.
S. C.	steel casting.
Bz.	bronze.
C. R. S.	cold rolled steel.
T. S.	tool steel.
O. H. S.	open hearth steel.
W. I.	wrought iron.

Plate E. Piston Rod and Valve Stem. The piston is of the one-piece box type, with sprung-in rings. The width is reduced to $4\frac{1}{8}$ inches at the outside, so that if the piston strikes the cylinder heads it will not tend to spring and break off the narrow ridge of metal outside of the packing ring. The piston rod is fastened to the piston on a taper drawn in by a nut, and the


PISTON
TWO C.I.
TAPER ¾ PER FT
14½ GROOVE
CTRS 9
1½ PIPE PLUG
CHIP AT OPP SIDES OF PISTON FOR EACH GROOVE.
CUT OUT
45°
PACKING RINGS
FOUR C.I.
5'-4½" OVERALL
4'-1¼" SHOULDERS
MEASURE FOR
№ 10 MORSE TAPER PIN 4 LONG
HEX 4½ FLATS
PISTON ROD
TWO C.R.S.
SPOOL
TWO C.I.
23¾ OVERALL
VALVE STEM
TWO STEEL
VALVE STEM HEAD
TWO STEEL F.A.O.
PISTON ROD & VALVE STEM
16-8½-12 DUPLEX PUMP
AMERICAN SCHOOL OF CORRESPONDENCE.
CHICAGO - ILLINOIS
SCALE 6"-1'
E

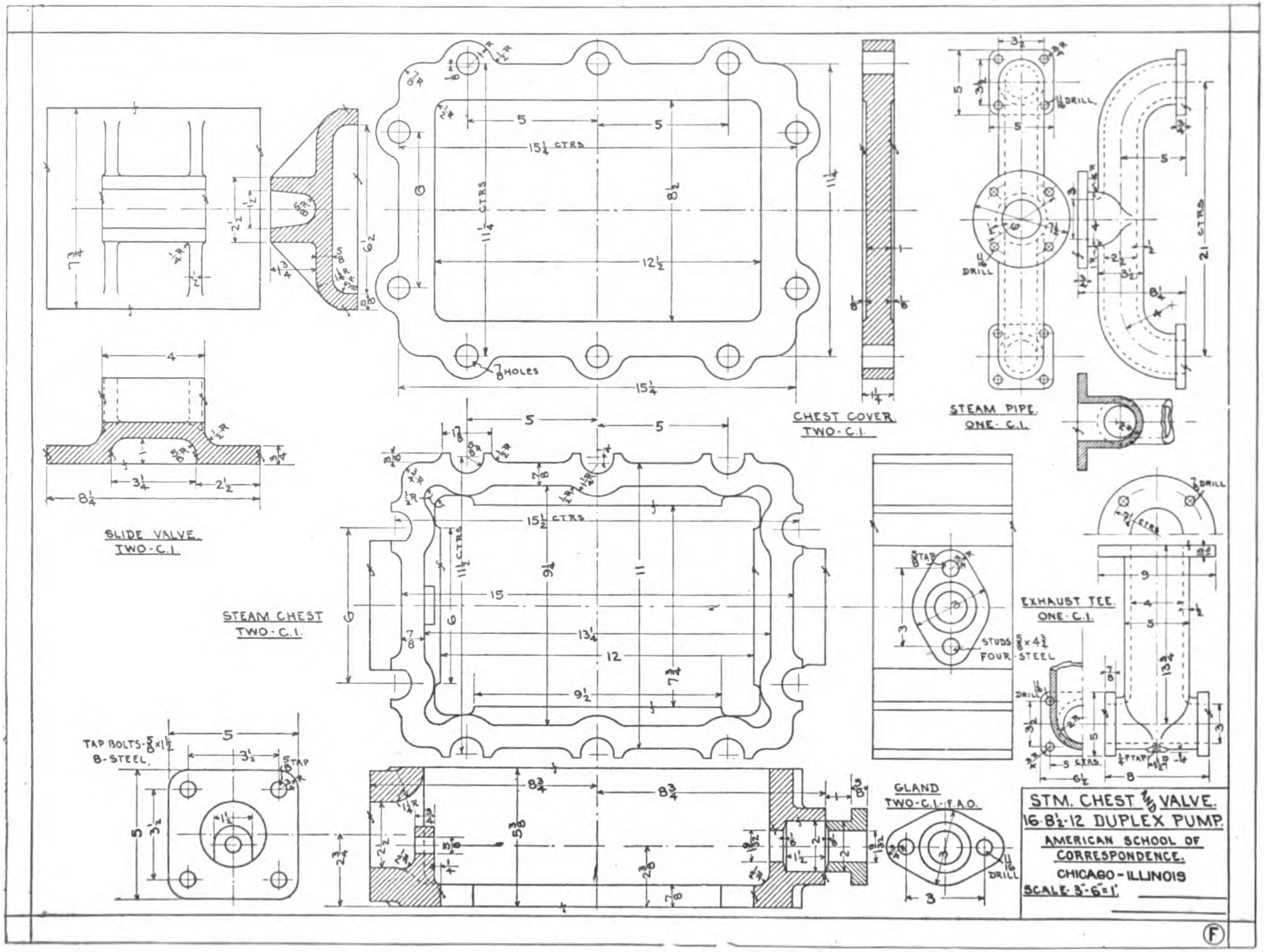
nut is checked by a $\frac{1}{4}$-inch split pin. The packing rings are prevented from slipping round the piston by lugs fitting loosely in chipped recesses in the groove. These being at opposite sides for each groove, the leakage of steam through the split in the ring is minimized, for it must pass half way round the piston before it can pass through the split in the other ring. This is a simple, but fairly effective, device.

The packing rings are usually cast in the form of a cylinder of some length, turned to a diameter a little larger than the cylinder bore, cut off, to the required width, and sufficient space cut out to permit being sprung in to the size of cylinder bore.

The location of the spool on the piston rod is not positively known, as the setting of the valve bracket may be slightly different from what the drawing calls for. Hence, instead of a dimension, the words "measure for" are put on, to indicate that the spool be located during the erection of the pump. The hexagonal flanges of the spool are convenient to hold the rod from turning while screwing on the piston and plunger nuts.

Molding and Machining. There are no special features connected with the molding and machining of parts on Plate E. The holes in the piston side walls are necessary to give supports for the core, the piston being cast on its side. These holes, after the core is cleaned out through them, are plugged as indicated.

Plate F. Steam Chest and Valve. The steam chest in this instance is located on the cylinder by fitting down over the ledge made by the valve seat. The side flanges also serve the purpose of guiding the valve. It will be noticed that the steam chest cover is $15\frac{1}{4}$ inches $\times$ $11\frac{1}{4}$ inches, while the steam chest is 15 inches $\times$ 11 inches. This allows a ledge of $\frac{1}{8}$ inch, all around which the cover overhangs the walls of the chest. The steam cylinder flange in order to correspond must likewise be $15\frac{1}{4}$ inches $\times$ $11\frac{1}{4}$ inches. The reason this is done is because of the difficulty of making good matched joints between the cylinder flange, chest and cover. The practice of thus leaving a little ledge all round is by no means universal, and often the irregularity in the joints is smoothed off by chipping. This is the case with the other flanges on this pump. The steam chest, however, was thought less likely to match properly, and the slight overhang gives the finished appearance of a sort of beaded edge.


SLIDE VALVE.
TWO-C.I.
CHEST COVER.
TWO-C.I.
STEAM PIPE.
ONE-C.I.
STEAM CHEST
TWO-C.I.
EXHAUST TEE.
ONE-C.I.
GLAND
TWO-C.I.-F.A.O.
TAP BOLTS-5/8x1 1/2
8-STEEL.
STUDS 5/8x4 1/2
FOUR-STEEL
STM. CHEST AND VALVE.
16-8 1/2-12 DUPLEX PUMP.
AMERICAN SCHOOL OF
CORRESPONDENCE.
CHICAGO-ILLINOIS
SCALE 3"-6"=1'
F

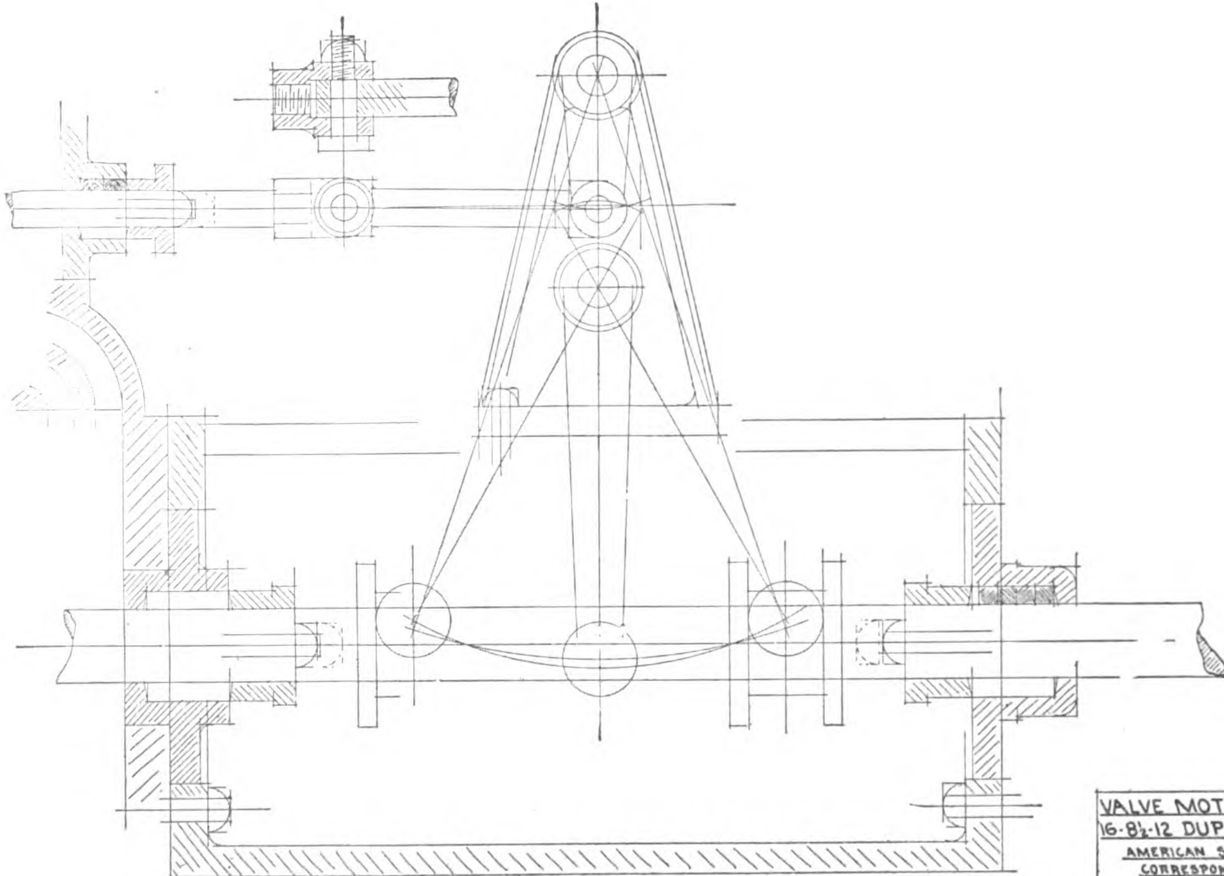
The valve is what is known as a "square" slide valve. This means that when the valve is placed central on the ports its working edges are "square" with the ports; that is, in exact line with them. If the valve be moved either way from this position, the slightest travel will admit steam to one end of the cylinder and exhaust it from the other. (See Plate A.) Another way of stating this is to say that a "square" slide valve is a slide valve without "lap."

The valve is driven from the valve stem by the striking of the nuts against the lug on its top. Since the valve is already guided on its edges by the steam-chest flange, the valve stem, to avoid springing, must be perfectly free in the slot cast for it, as is shown by the $\frac{5}{8}$-inch radius of the bottom, the stem being 1 inch in diameter.

The steam-pipe flange is made square to keep the height of the chest as low as possible. The radius of the bend should be ample; in this case 4 inches is considered sufficient.

The exhaust tee must have its upper flange high enough so that the chest cover can be lifted and slipped off the studs without interfering with it. The lower flanges should be made wide enough to permit the tap bolts to be put in without striking the 4-inch vertical pipe, 5-inch centers being necessary. The $\frac{1}{4}$-inch drip-cock, as located, readily drains the steam chest and exhaust passage of both cylinders, as well as the exhaust tee.

Molding. It is evident that the steam chest will be molded in the position shown on the drawing. The parting line of the mold will be through the centers of the steam-pipe opening and the stuffing-box. These holes must be cored out. The main body of the chest could be made to leave its own core, but it may not be made in this way. It may be cheaper to fashion the pattern solid, and make one large core-box for the inside. In this way the pattern will probably hold its shape better and require less repairs, than if it were made in green sand. The core-box will be an extra piece to make, but it probably will cost no more than to carve out the inside of the pattern, and is a rather more substantial job when done. The molding can be satisfactorily done by either method, shop conditions being the controlling element. As far as the labor of molding alone is concerned, the first method is probably easier, as it saves handling large cores.



VALVE MOTION LAYOUT
16-8½-12 DUPLEX PUMP.
AMERICAN SCHOOL OF CORRESPONDENCE.
CHICAGO - ILLINOIS
SCALE - 6" = 1'.

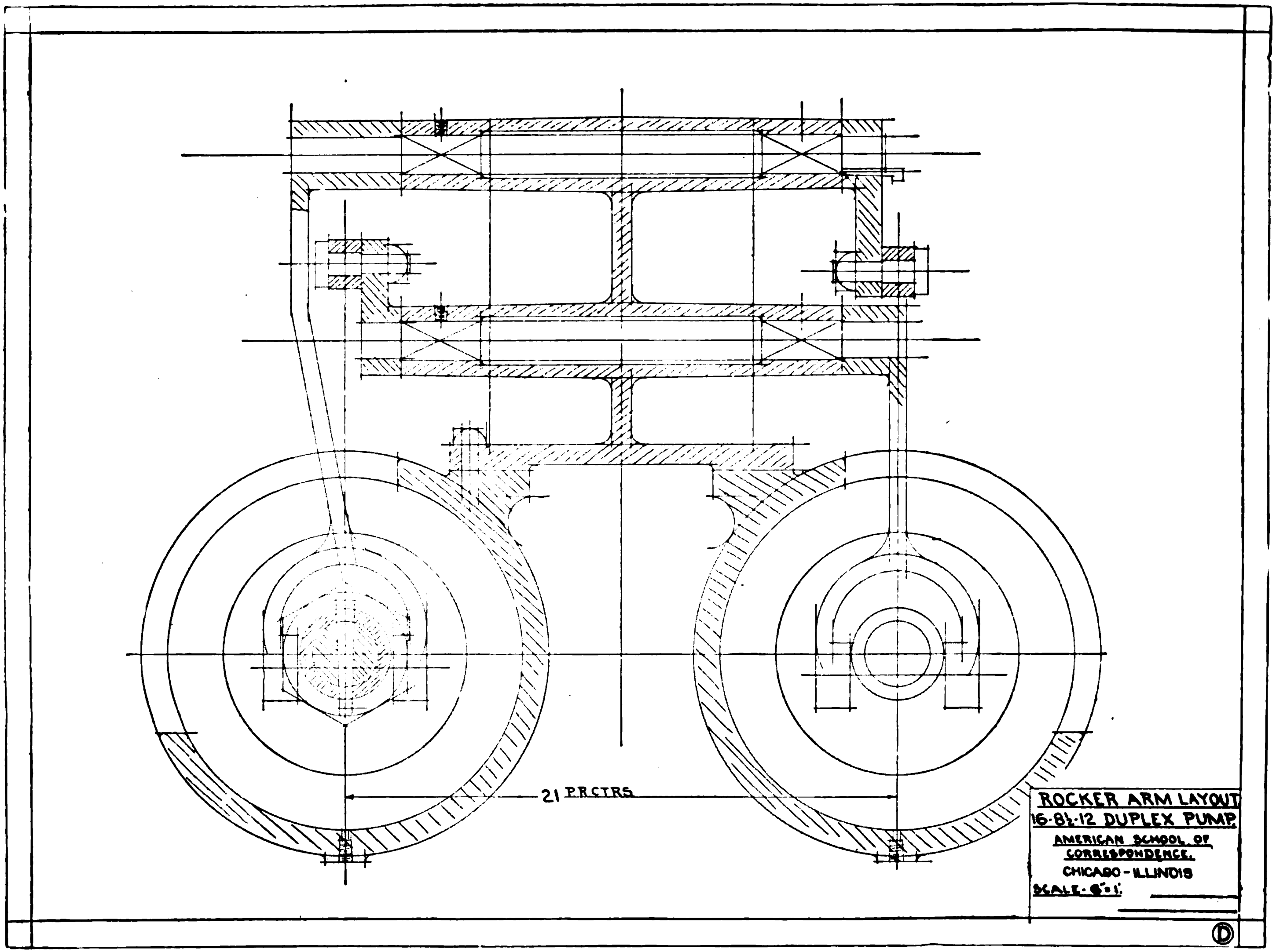
©

The other parts in Plate F are very simple in their molding, and require no special attention.

Machining. Most of the surface work on this plate is adapted to the planer. The slide valve may, perhaps, if finished in lots of considerable number, be more satisfactorily handled on the milling machine. The final finish of the face of the valve must be a scraped fit to its seat.

The drilling of the cover and pipe flanges is to actual layout on the casting, or preferably, through jig plates. A templet for laying out is at least desirable, even though the expense of a jig plate be not deemed necessary.

Plates C and D. Valve Motion Layout. These plates represent the layout of the valve motion, and are necessary in order to find the length of the levers and rocker arms. It will be noticed in Plate D that the valve stem of one side of the pump is controlled by the movement of the piston-rod of the other side, the proper direction of motion being given to the valve by placing the rocker shaft above or below the valve stem as required. By reference to Plate A it will be further noticed that the nuts on the valve stem inside the chest, which abut against the faces of the lug on the valve, do not rest against the faces of the lug in the position shown, but have considerable lost motion. This lost motion is one of the essential features of the valve motion of a duplex pump, and permits the valve to remain at rest for a short period at the end of the stroke, though the valve stem may have reversed its motion and begun its return stroke. When this lost motion is taken up by the movement of the stem and the nuts abut against the lug on the valve, the valve will move, and from this point to the end of the stroke be positively controlled by the motion of the stem. At the end of the stroke the stem will reverse, when the lost motion will again permit the valve to rest for the same period as at the other end, and then move on as before. The time of rest of the valve, and consequently the pistons and plungers, is approximately one-third the period of the stroke. This means that the piston on one side travels one-third of its stroke before it picks up, through the valve levers, the valve on the other side. During the second third of its travel it is bringing the

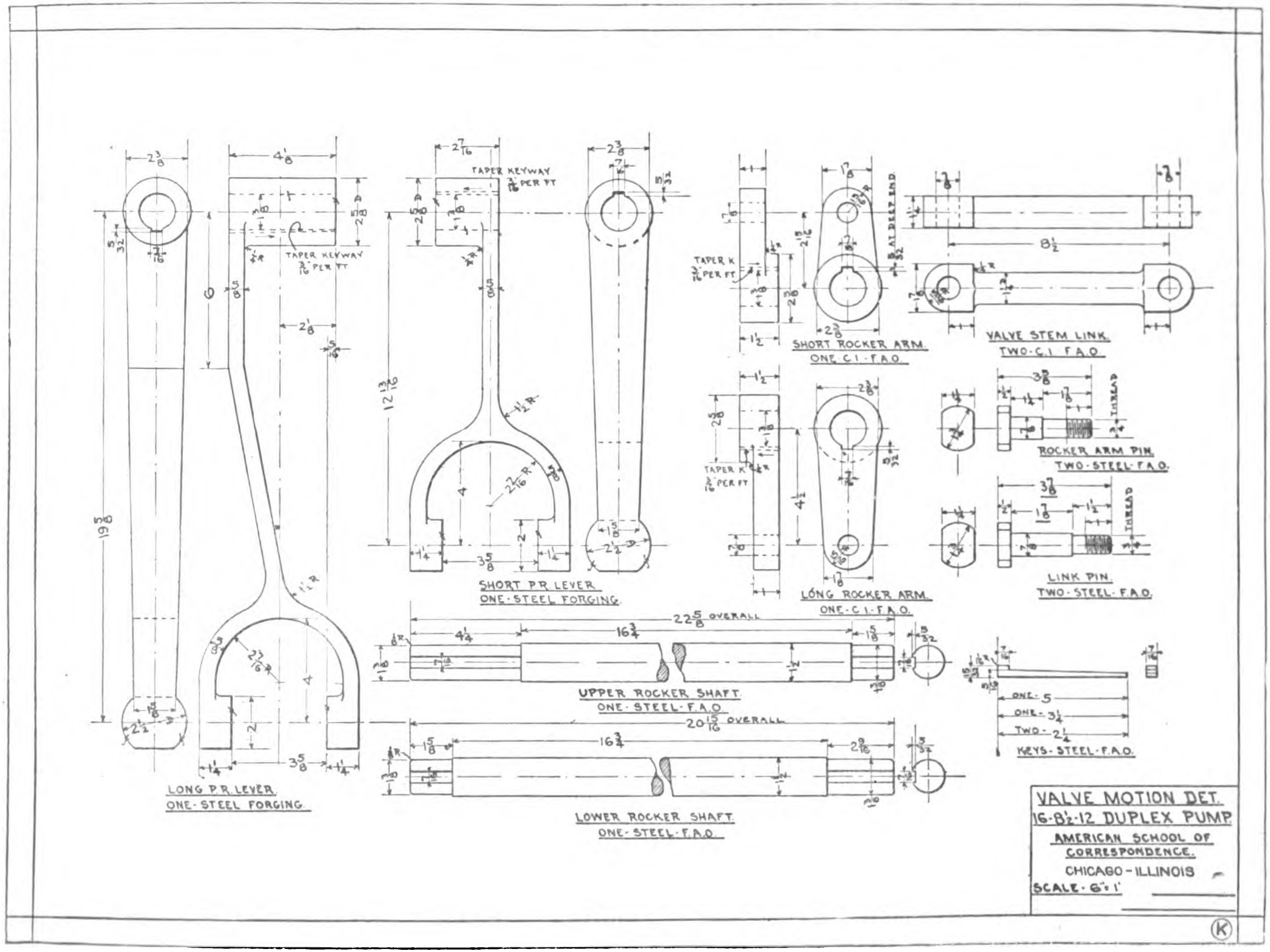

21 P.R.CTRS
ROCKER ARM LAYOUT
16·8½·12 DUPLEX PUMP
AMERICAN SCHOOL OF CORRESPONDENCE.
CHICAGO - ILLINOIS
SCALE · 6" = 1'
D

valve to the point of opening. During the last third of its travel it is opening the port, wider and wider, to steam. Thus the opposite piston will start when the first piston has covered two-thirds of its stroke, and there will be only one-third of the stroke when both pistons are moving at the same time.

This relative period of rest to motion is not always made in this exact ratio, but is at least approximate to it. The period of rest at the end of the stroke is to allow the water end to adjust itself quietly to the reversal of motion about to take place at the end of the stroke. When the plunger stops, the water valves must be given time to seat themselves, and the flow of water through the passages checked. It is much easier to start the flow in the opposite direction if the reversal of plunger motion is not instantaneous. Hence for handling long columns of water, which, once in motion, tend by considerable energy to remain in motion, the duplex pump by this peculiar delayed action has been found to be well suited.

It will be found that for complete uncovering of port, and motion divisible into thirds as described, the travel of the valve stem should be three times the width of port, or $3 \times \frac{7}{8}$ inch $= 2\frac{5}{8}$ inches. A little more than this is allowed, and the travel made $2\frac{7}{8}$ inches in this case. Referring to Plate C, this distance is laid off as shown by the two limiting vertical lines across the line of the valve stem, the central vertical line of mid-position being drawn. The problem then is to find such centers for the rocker arms that the travel of the piston-rod spool will, through proper leverage, produce travel of the valve stem between these two vertical lines. This can readily be done by a few trials, the only requirement for this case being that the extremes of the arc of swing of both piston-rod lever and rocker arm shall be equally above and below the center of piston rod and valve stem respectively. The greatest possible travel of the piston-rod spool, $12\frac{1}{2}$ inches, is usually laid out in this case, not the nominal 12 inches.

From this layout the lengths of the levers and arms may be scaled off for the detail drawing, also the location of the rocker-arm centers. The student has the former given him on Plate K, but the latter, which is necessary for the development of Plate L, must be determined by his own layout. Plate D must also be



LONG P.R. LEVER
ONE-STEEL FORGING.
SHORT P.R. LEVER
ONE-STEEL FORGING.
TAPER KEYWAY
3/16" PER FT
SHORT ROCKER ARM.
ONE-C.I.-F.A.O.
LONG ROCKER ARM.
ONE-C.I.-F.A.O.
VALVE STEM LINK.
TWO-C.I. F.A.O.
ROCKER ARM PIN.
TWO-STEEL-F.A.O.
LINK PIN.
TWO-STEEL-F.A.O.
UPPER ROCKER SHAFT.
ONE-STEEL-F.A.O.
LOWER ROCKER SHAFT.
ONE-STEEL-F.A.O.
22 5/8 OVERALL
20 15/16 OVERALL
ONE-5
ONE-3 1/4
TWO-2 1/4
KEYS-STEEL-F.A.O.
VALVE MOTION DET.
16-8½-12 DUPLEX PUMP
AMERICAN SCHOOL OF CORRESPONDENCE.
CHICAGO-ILLINOIS
SCALE-6"=1'
K

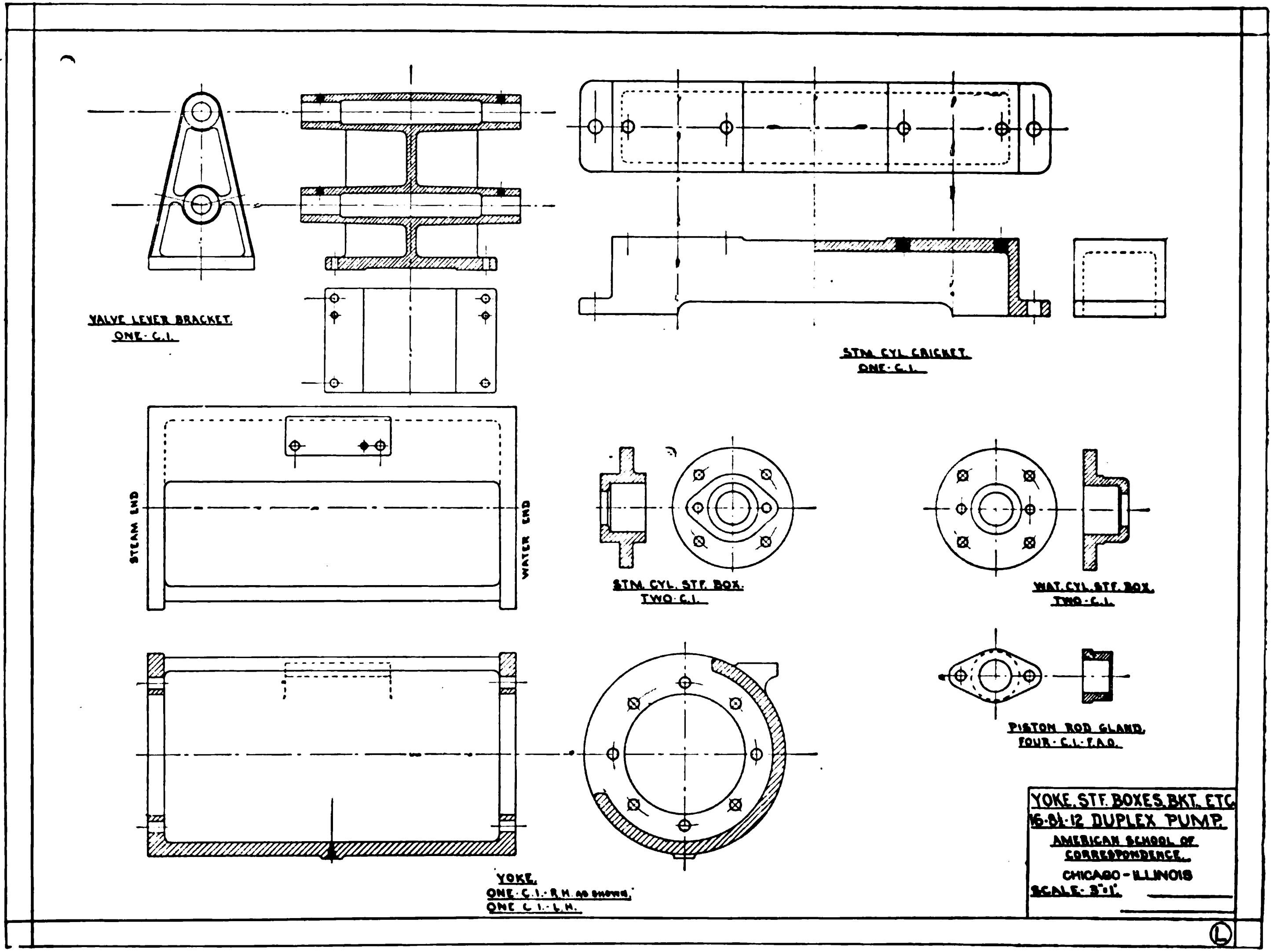
laid out before developing the cross-section of the valve bracket.

The design of stuffing boxes for both steam and water ends, and the length of the yoke, should be determined next. A safe method of assuming clearance between the spool and the gland studs at the end of the stroke, is to imagine that the gland stud nuts have accidentally worked off the studs, so that they are about to drop. They are thus shown by dotted lines on Plate C. A good clearance, say $\frac{1}{4}$ inch to $\frac{1}{2}$ inch, is then allowed, and the gland drawn in. The length of the gland is determined by the number of rings of packing necessary in the stuffing box; it is usually provided that the gland may compress the packing to about one-half its original depth before bringing up against the face of the box. Packing $\frac{5}{8}$ inch square will do for this size of piston rod, hence the faces of the yoke are easily determined, and its detail, with the stuffing boxes, proceeded with as on Plate L. The length of yoke may be brought to an even figure; and proceeding on the above plan the length can be conveniently made in even inches without any fractions; viz., 28 inches.

It will be noticed that the stuffing-box flanges serve to center the yoke in line with the steam and water cylinders. This is a desirable feature of construction, and forms a simple and easy method for lining up the steam and water ends.

Plate K. Valve Motion Details. The piston-rod levers on this plate are specified to be steel forgings. Forgings of this kind are expensive, but are light, neat and reliable for the important service which they have to perform. Castings, whether steel or iron, are much cheaper, and perhaps more commonly used for this detail. When sound they are equally serviceable, though of more clumsy proportions; but the danger in castings of this form is the existence of hidden flaws or pockets, which frequently occur at the points where the hub or the fork joins the arm. These flaws cannot be readily detected from the outside, and breakage may occur at some critical time, when the disability of the pump may be a serious matter.

The use of shade lines is illustrated on this plate. The increased artistic effect is noticeable, but it would seem that absolute clearness would still exist, even if shade lines were not used.


VALVE LEVER BRACKET.
ONE · C.I.
STM. CYL. CRICKET.
ONE · C.I.
STEAM END
WATER END
STM. CYL. STF. BOX.
TWO · C.I.
WAT. CYL. STF. BOX.
TWO · C.I.
PISTON ROD GLAND.
FOUR · C.I. · F.A.O.
YOKE.
ONE · C.I. · R.H. AS SHOWN.
ONE C.I. · L.H.
YOKE, STF. BOXES, BKT. ETC.
16·8½·12 DUPLEX PUMP.
AMERICAN SCHOOL OF CORRESPONDENCE.
CHICAGO - ILLINOIS
SCALE · 3" = 1'
L

It will be noticed that on the detail of the "link pin" two of the dimensions have a short "wavy" line beneath the figures. This is one of the several ways of indicating that the dimension is "out of scale." Some draftsmen use a straight dash beneath the figure; some draw a circle about it; some print after the figure, "out of scale." Although workmen are not allowed to scale drawings, but are required to "work to figures only," yet for general safety's sake, and for the sake of the draftsmen who consult the drawings frequently, attention must be called to any variation of the figure from the measured distance on the drawing. Nothing makes a workman, or any one else who reads a shop drawing, lose confidence in it more quickly than to discover that it does not "scale"; but when no indication exists that the draftsman himself is aware of it, then every dimension is viewed with doubt and hesitation, and the drawing becomes practically worthless.

Dimensions seldom should be out of scale; but if they are, through error or necessary change, a carefully worded note should be added.

Molding and Machining. No special features of molding or machining are noteworthy on Plate K.

Plate L. Yoke, Stuffing-boxes, Bracket, etc. Having worked up the layouts of Plates C and D, the student has enough information to proceed with Plate L. This, like Plate G, is without dimensions, the student's work being to make the drawing and fill in the necessary shop data.

The valve-lever bracket is bolted down to its lug on the yoke through holes larger than the bolt, thus permitting slight adjustment. When the proper location is determined, the bracket is positively fixed in position by two dowels, $\frac{1}{2}$ inch in diameter. The holes in both bracket and yoke are drilled through both pieces at the same operation. This very common method of fixing bolted parts of machinery in absolute position not only assures firmness, but also in case of removal, permits the part to be readily and positively replaced in its exact original position.

If possible, the steam cylinder cricket should be of such height that the stone or brick work upon which it rests shall be at the same level as that beneath the water cylinder. The tapped holes in the top surface receive bolts from the cylinder foot. These bolts are often used only for shipping purposes, the cylinder foot when the pump is set up being allowed to slide freely on the cricket, thus permitting free expansion and contraction. In such cases the water end is rigidly fastened to the foundation by holding down bolts.

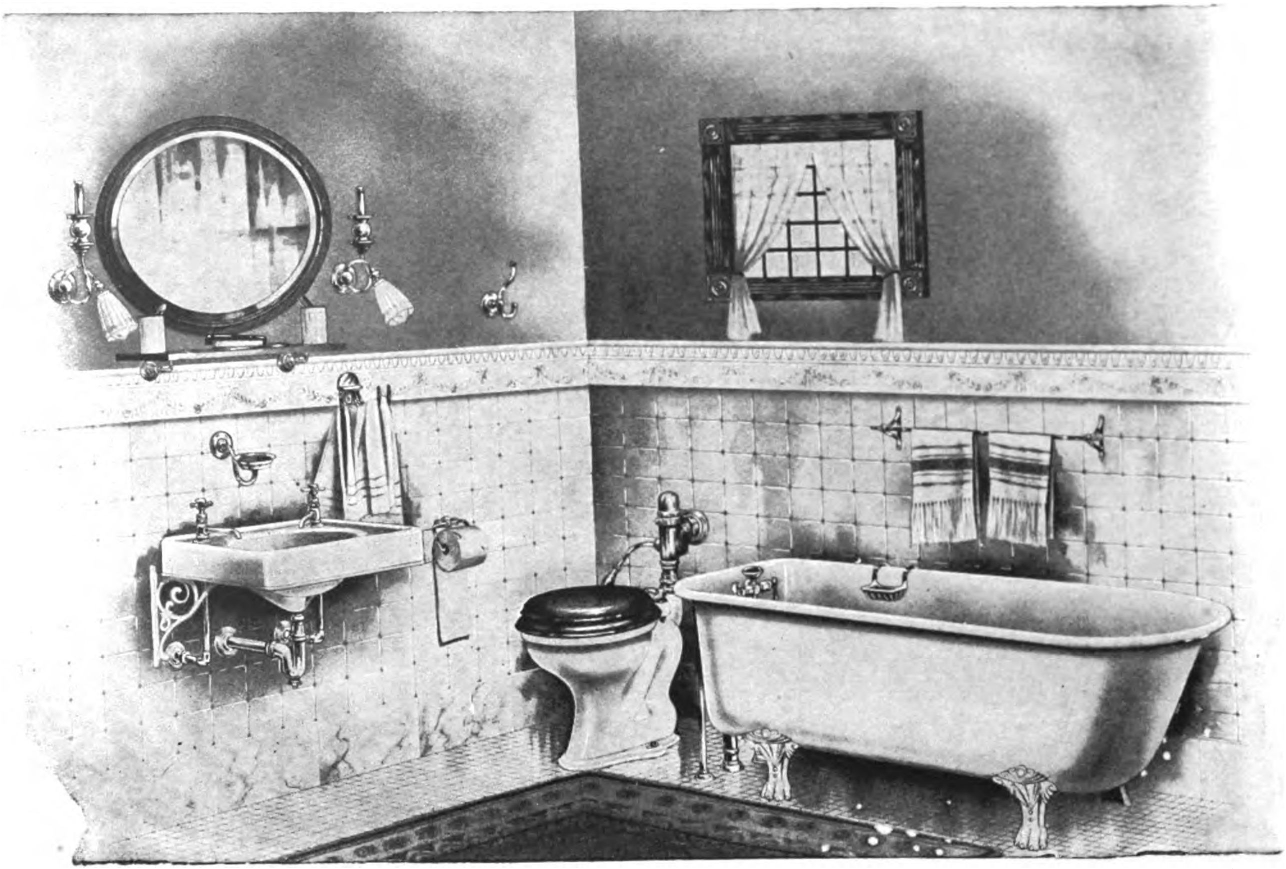
Molding and Machining. The valve lever-bracket would most naturally be molded with the axes of the shafts vertical, the parting line of the mold being the center line of the middle web. This makes quite a long "draw" for the shaft bosses, but the ample taper on the outside overcomes this difficulty. The space between the side webs leaves its own core. The shaft cores stand on end in the mold, which is the best position for strength and stability.

Another method is to have the parting line of the mold on the vertical center line of the bracket, as shown in the end view. In this case the bracket would be cast on its side, and cores must be set for each side of the middle web. The shaft cores are set as easily as before, but in this case lie flat. As with the steam chest, each method has its advantages, which depend largely upon existing conditions. As cored work is generally avoided whenever possible, the first method would probably be chosen.

The shaft bosses are "chamber-cored," to save labor in boring, the bearing surface for the shaft being only a short distance at the ends. The chamber-core diameter should be enough larger than the shaft so that by no possibility can the cutter run into the rough scale, even if the hole be bored slightly out of line. If it should do this, the labor of caring for the cutters more than offsets the attempted saving of labor.

The yoke is simply a barrel open at each end, and with a piece cut out of its side. The inside evidently must be cored out, and the core is satisfactorily supported at the ends on its horizontal axis. The parting line of the mold may be either the vertical or horizontal axis of the end view, the only difference being that in one case the ledge for the valve bracket will "draw," and in the other case it must be loose on the pattern and "pulled in" after the main pattern is drawn.

The cricket and stuffing boxes present no difficulties. The



REPRESENTATIVE TYPE OF MODERN AMERICAN BATHROOM bore of the stuffing boxes and glands should be from $\frac{1}{32}$ inch to $\frac{1}{16}$ inch larger than the rod, to allow the fit to be entirely between the rod and the packing.

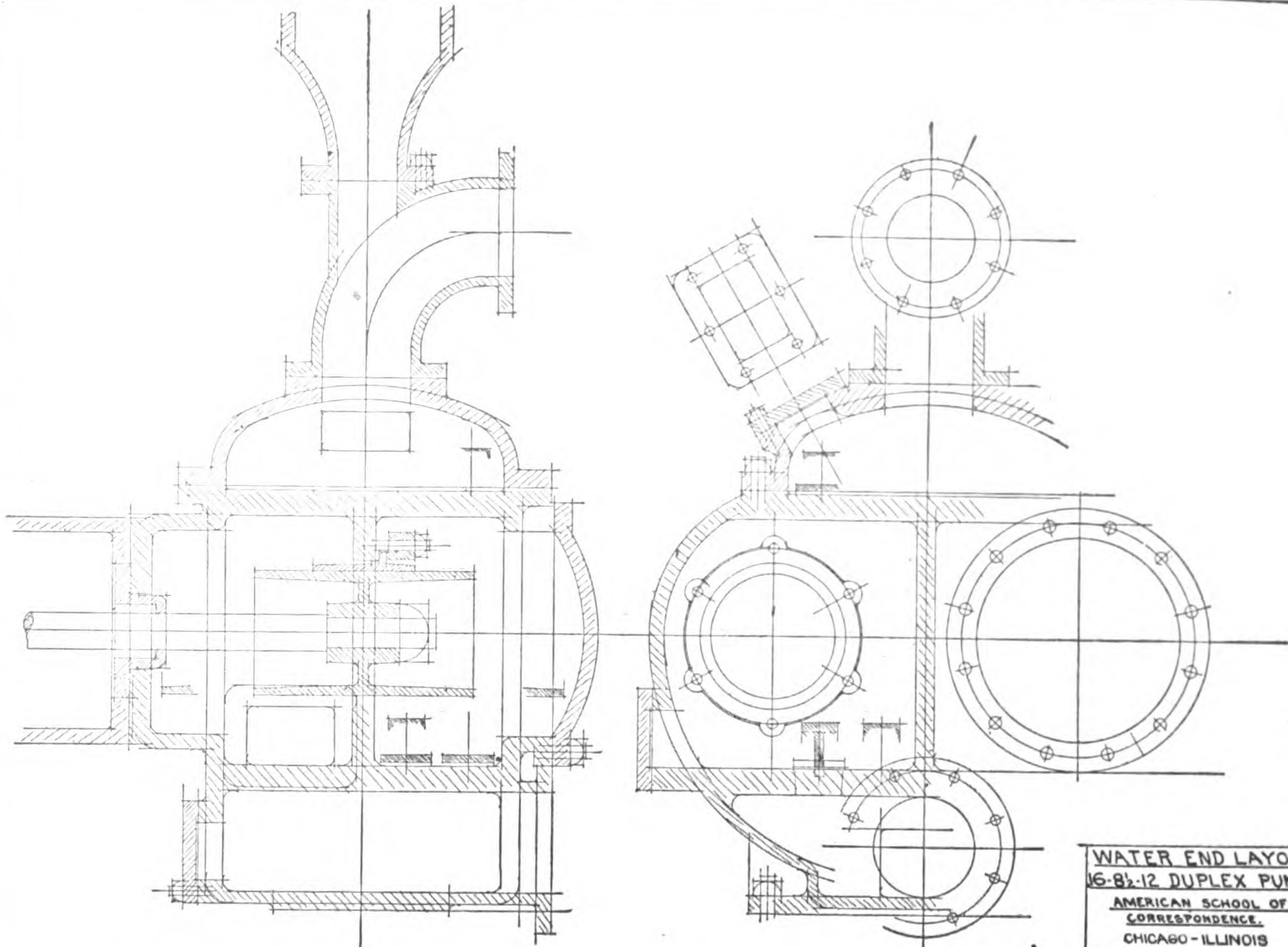
The horizontal boring machine with a double facing head is adapted to boring and facing the yoke flanges. The drilling is accomplished as before by templet or jig.

Attention is called to the tapped holes for oil or grease cups on the valve-lever bracket. The holes on the lower boss cannot be drilled strictly as shown, because the drill shank will not clear the upper boss. They should be swung around the boss at such an angle as will allow the drill to clear. This is a good instance of the common error of drawing details which cannot be made, and constant watch must be kept to avoid such mistakes.

Plate B. Water End Layout. As in the preceding work, Plates II and I being given in full detail offer a good start for the develcpment of the water cylinder, which is the purpose of Plate B. As before, work should begin at the inside and progress outwards. Thus the piston rod with its nut should be drawn first, the hub of the plunger built around it, then the plunger barrel, the bushing, and ring to clamp the bushing. The limits of the plunger travel should be sketched in, and the valve outline shown in order to determine clearances. The progress of Plate B is on exactly the same basis as that stated in detail for the steam cylinder layout; hence it need not be repeated.

The points controlling the design of the water end must, however, be studied to enable the student to work intelligently. The fit of the rod into the plunger hub is loose, $\frac{1}{16}$-inch play being allowed, in order to permit the plunger to be guided solely by its bushing, and thus be independent of any change of alignment of the piston rod.

The relative length of plunger and bushing should allow the end of the plunger to overrun the edge of the bushing at the termination of the stroke, to prevent the formation of a shoulder. The bushing is made of brass because of the better bearing of the two dissimilar metals, brass and iron. Of course there is no lubrication except the water, and the dissimilar metals tend to "cut" less than if both were alike. The brass bushing also prevents the plunger from "rusting in" in case of long periods of



WATER END LAYOUT
16-8½-12 DUPLEX PUMP
AMERICAN SCHOOL OF CORRESPONDENCE.
CHICAGO - ILLINOIS
SCALE- 3"=1'.

(B)

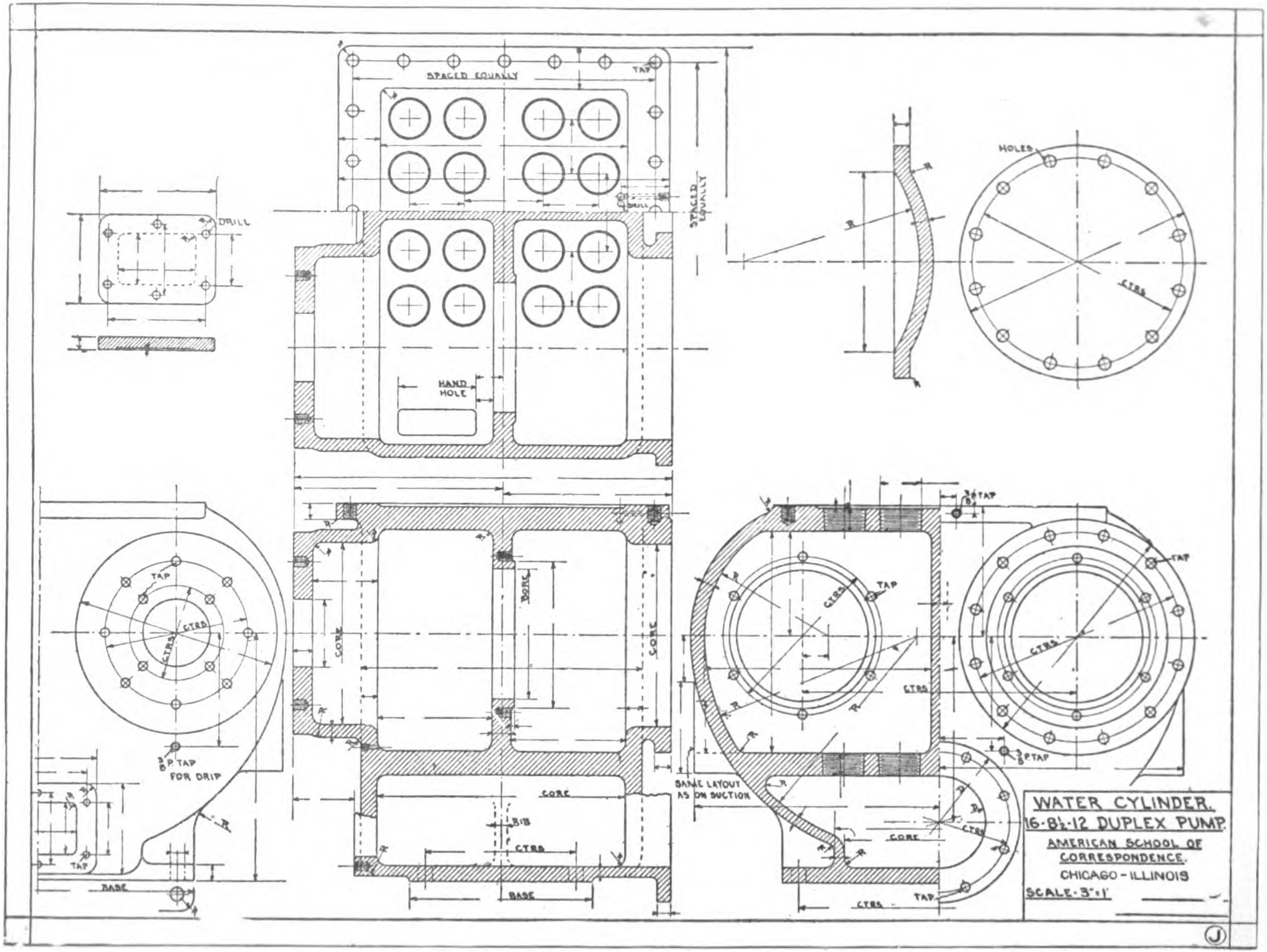
disuse. The bushing being of expensive material is made as light as possible, hence it has no stiffness of its own. Therefore it is reinforced by a deep cast-iron ring, which also takes the bolts and clamps the bushing tightly to its ground seat. These stud bolts are usually made of "tobin bronze," a rust-proof material, possessing strength almost as great as that of steel. This arrangement permits ready removal of the bushing when necessary.

As the parts of the common pump valve illustrated in detail on Plate H must be often replaced during service of the pump, provision must be made for unscrewing the stem and substituting a new one. This must be done through the hand holes provided on the cylinder. The lower valve deck must be located so that the inner valves when unscrewed will not strike the clamp ring. As shown in Plate B the clearance is pretty small, almost too small, but as it affects only two valves, it will probably cause no inconvenience. No hand holes are necessary for the end chambers, as access to the valves is had by removing the outer heads. The upper deck may be placed at a height giving sufficient clearance to allow the upper nuts of the clamp ring to be unscrewed with a socket wrench from the end of the pump. These decks are subjected to a severe pounding from the pulsations of the pump, and should be amply strong; $1\frac{3}{4}$ inches is deemed thick enough for this case.

The middle transverse wall may be $1\frac{1}{2}$ inches thick and the middle longitudinal wall a little thinner, about $1\frac{1}{4}$ inches. With high pressures these walls, being flat surfaces and the valve decks likewise, are likely to fracture under the heavy pounding. To avoid making them excessively heavy they are often strongly ribbed, either on the inside or outside, usually the former.

The curving side walls are of better form to withstand pressure, and need not be as thick, 1 inch being sufficient. This can be decreased to $\frac{3}{4}$ inch in the suction passage below the deck, where little pressure exists.

The outer head is also considered strong enough at 1 inch thickness, on account of its curved shape. It requires $\frac{7}{8}$-inch studs. Studs are preferred to tap bolts in this case, as in all other similar cases, on account of the frequent unscrewing of the nuts for purpose of removal. One or two unscrewings of a tap bolt in cast



SPACED EQUALLY
TAP
DRILL
HAND HOLE
HOLES
CTRS
CORE
BORE
B.I.B
BASE
TAP
CTRS
3/8 P. TAP FOR DRIP
SAME LAYOUT AS ON SUCTION
3/8 P. TAP
WATER CYLINDER.
16-8½-12 DUPLEX PUMP.
AMERICAN SCHOOL OF CORRESPONDENCE.
CHICAGO - ILLINOIS
SCALE - 3" = 1'
J

iron will destroy the tightness of the thread, while the stud, being steel, stands the wear better.

The valve seats are taper screwed into the deck; they are sometimes forced in on a plain taper fit. They are located as closely as strength of the deck between the holes will permit. It is not well to place the edge of the valve closer than $\frac{1}{2}$ inch from the cylinder walls. The valve holes in the lower deck should be in line, or nearly so, with the holes in the upper deck, in order to allow the shank of the mill to pass through when milling the lower holes.

The suction opening is 7 inches in diameter, $12\frac{1}{2}$-inch flange, $10\frac{1}{2}$-inch bolt circle, $\frac{3}{4}$-inch tapped holes.

By means of the hand hole at the end of the suction passage, any dirt which may have been brought in through the suction pipe may be removed.

The water cylinder cap, discharge ell and air chamber may be laid out from the detail Plate I, and the student must do this to see that the parts actually go together properly.

With the foregoing discussion the student should be able to produce Plate B, which is the preliminary step to the detail drawing of the water cylinder as shown on Plate J.

Plate J. Water Cylinder. The water cylinder is, perhaps the most complicated detail that the student will meet in this set of plates. Fundamentally, it is simply a box with curved sides, divided by the several walls into five compartments, each of which communicates with the outside by a round nozzle or flange. If this basic idea be kept constantly in mind, the student will have no trouble in building up the detailed design.

This fundamental conception of a complicated piece is a very important idea, and should be developed carefully by the student. It is one of the great secrets of good design, both from an artistic and a commercial standpoint. We often see a machine which seems to begin anywhere and end nowhere; it appears to be a miscellaneous collection of bosses, lugs, ribs and flanges. There is no general prevailing shape to the structure, no harmony of the lines. This is because the designer, if he may be so called, did not have the fundamental notion of shape, to which all minor details should have been subordinated. He simply grouped parts together, without considering the fundamental structure.

In this water cylinder the box is the basic part of the structure, and its lines must be first developed; they should be designed to convey a smooth, regular and consistent surface to the eye. Then the nozzles and flanges may be added as subordinate parts; they will merely interrupt, but not destroy, the prevailing outline of the box. The dotted lines in the cross-section views of Plate J show the general shape behind and beneath the nozzles.

The hand holes are the same as on Plate I, and the detail of the cover should specify the number required for both places.

Provision for draining the four chambers of the water cylinder is made by the $\frac{3}{8}$-inch pipe tap holes at the lower deck, and the cap, likewise, by the single hole at the upper deck. Drip cocks are screwed into these holes.

The holding-down bolts should not be less than 1 inch diameter; $1\frac{1}{4}$ inch would perhaps be better; and the holes in the foot should be drilled at least $\frac{1}{8}$ inch large.

Dimensions. It will be noticed that this plate has dimension lines, but no figures. This is because the cylinder is rather difficult to figure, and it is desired to guide the student in arrangement of the figures without lessening the benefit of his study of them. Special attention should be paid to this feature of the plate. Notice that although space for dimensions is restricted, a clear opening is always found for the figures; and when one view seems to offer no space for a figure, another view gives the desired opportunity.

No finish marks or titles are shown on this plate, these being left entirely to the student for insertion.

Molding. The centers of the curves for the sides being on the main horizontal axis of the nozzles, the cylinder, if molded to be cast vertically as shown, will draw readily both ways from this line. The exceptions to this easy draw are the foot, suction nozzle and flange, and hand-hole boss. On account of the inside of the cylinder being cored, these pieces if made loose on the pattern have ample space to be "pulled in" after the main pattern is withdrawn.

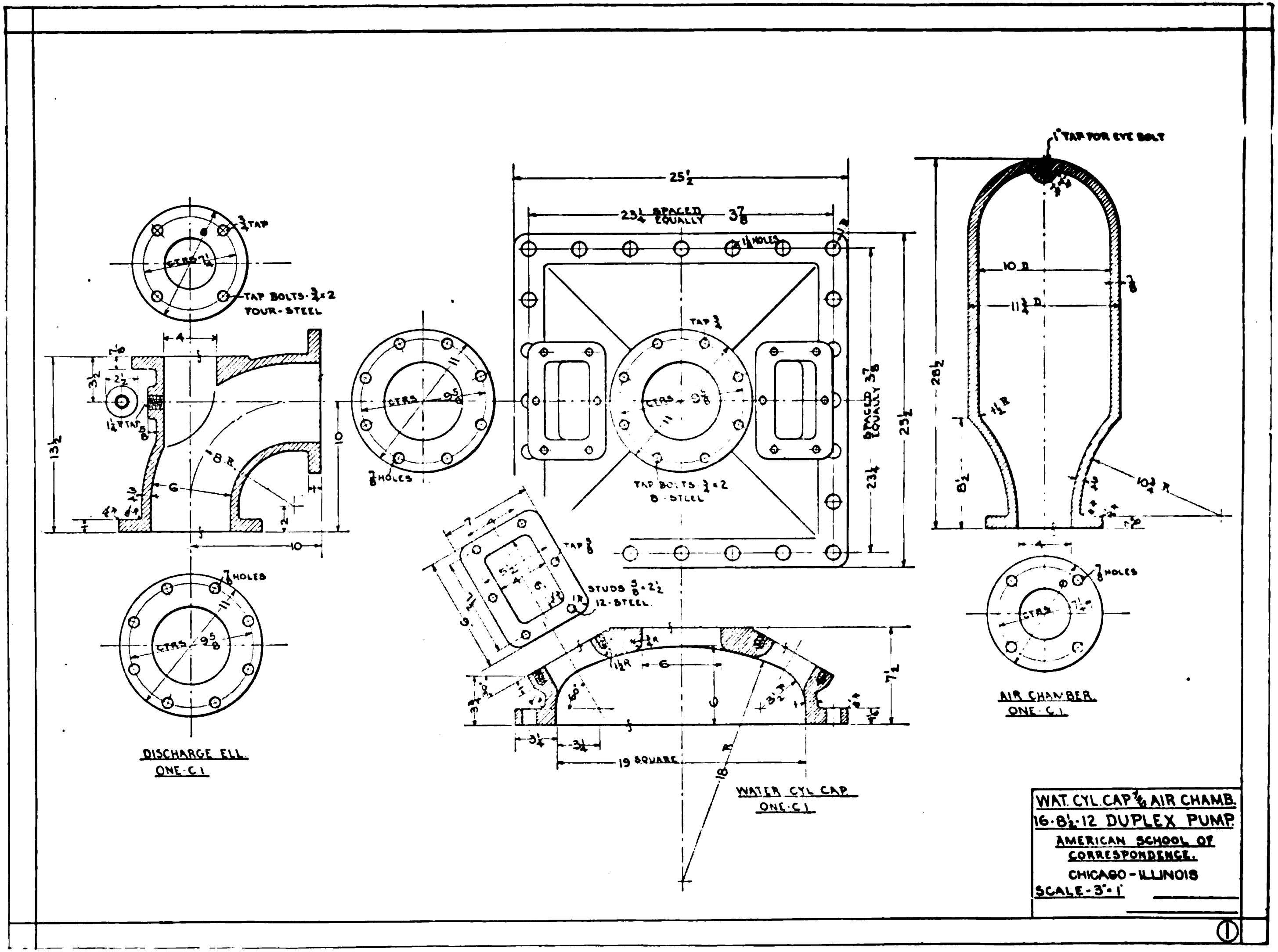
The suction passage below the deck communicates with the main core through the valve holes, hence it may be supported from the main core. This involves some difficulty, however. If a three-part flask be used, and another parting established at the center of the suction flange, in addition to the previous one, the problem becomes much simplified.

It is desirable to make the four chambers of the cylinder alike in general proportions. It is then possible to make a single core-box, and by the use of loose pieces change the length of the nozzle cores and transpose from right to left, thus saving labor on the pattern. This, however, multiplies the loose pieces on the pattern. The many pieces are likely to become lost and make frequent repair necessary. Hence it is not always wise to use a single core box too much, and good judgment is required to fix the limit.

Machining. Special double horizontal boring machines are now in common use for such cases as this water cylinder. The centers are made adjustable, so that within limits any distance between piston-rod centers can be met. The advantages of double boring are, of course, most obvious for a considerable number of duplicate cylinders.

It will be noticed that the face of the suction flange is carried out flush with the cylinder head face. This affords opportunity for finishing all the end surfaces at a single setting of the tool, whether the work be done on the rotary or reciprocating planer. This same point might have been observed on the small hand-hole boss at the other end of the cylinder, but the advantage gained did not seem to warrant extending the "reach" through the hand hole.

Plate I. Water Cylinder, Cap and Air Chamber. For a water cylinder cap of this size, the most difficult problem is to find room for the hand-hole bosses. A hand hole 4 inches × 6 inches is about as small as can be used, and this calls for a flange at least 7 inches × 9 inches. These are the proportions shown on the plate, and since the boss overhangs the bolts in the main-cap flange, it must be cut away underneath to clear the nuts. If three stud bolts are used on each side, this overhang also requires that the nut be "fed on"; that is, screwed on little by little as the end of the stud protrudes above the flange when the cap is being lowered into place. This is an awkward process, but is sometimes necessary.



DISCHARGE ELL.
ONE-C.I.
TAP BOLTS-¾×2
FOUR-STEEL
TAP BOLTS-¾×2
8-STEEL
STUDS ⅝×2½
12-STEEL.
23¼ SPACED EQUALLY 3⅞
WATER CYL. CAP.
ONE-C.I.
19 SQUARE
1" TAP FOR EYE BOLT
AIR CHAMBER.
ONE-C.I.
WAT. CYL. CAP & AIR CHAMB.
16-8½-12 DUPLEX PUMP.
AMERICAN SCHOOL OF CORRESPONDENCE.
CHICAGO-ILLINOIS
SCALE-3"=1'

The discharge ell should have an easy bend; usually the radius is somewhat more than the outside diameter of the pipe, in this case 50 per cent greater. It is customary on this piece to provide an opening for the attachment of a relief valve as shown, $1\frac{1}{4}$-inch pipe tap. This valve can be set to open at a desired pressure, so that the water end may be relieved in case of accidental excessive pressure.

The air chamber provides an air cushion for the water to make the delivery more constant, and take the shock which would otherwise come with hammer-like force and full intensity upon the cylinder. Being placed at the highest point of the water end, air will naturally tend to collect in the air chamber and keep it charged. In some cases, however, a special charging device is necessary.

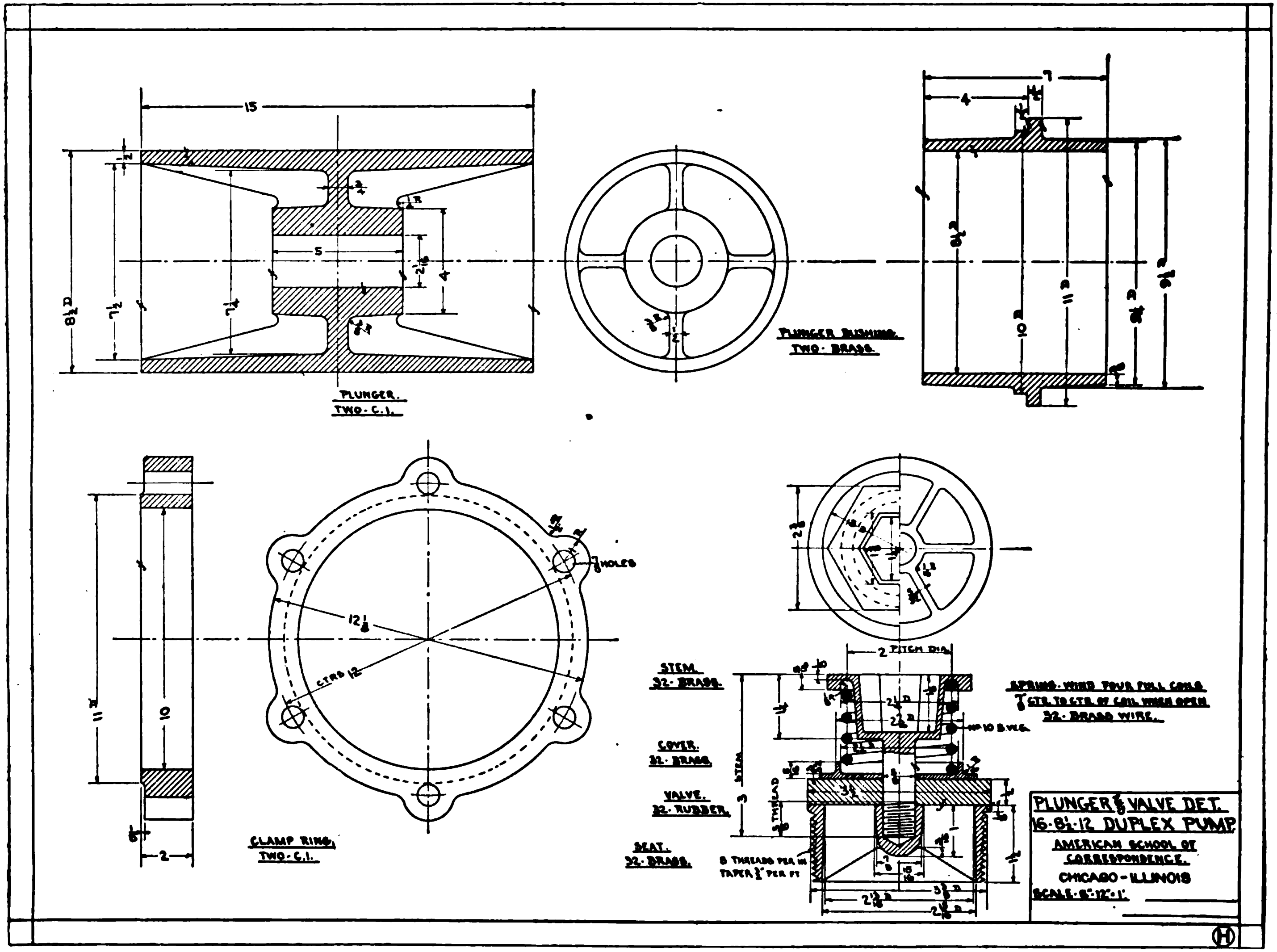
Molding and Machining. The hand holes being at an angle will not "draw." Hence cores must be set for these openings at least, and it may be desirable to core out the whole inside of the cap for the sake of keeping the pattern in good shape by making it solid. Otherwise it is easy to let it leave its own core.

The overhang of the hand-hole bosses requires loose pieces for the overhanging part. They are "pulled" in after the pattern is drawn.

The molding and machining which are further required on details of Plate I are simple, and require no special discussion.

Plate H. Plunger and Valve Details. This plate is noticeable for illustrating a method of drawing details not used elsewhere in this set of plates. On the other plates each piece is separately detailed. On Plate H the details of the valve, cover, seat, stem and spring are shown assembled, and dimensioned without separation. This is an allowable method when clearness is not sacrificed, but it is usually found desirable only with simple construction. It concentrates parts on the drawing, and probably saves some time, besides showing the workman just how the parts go together. The only test which the student need to apply in this, as in any method of detailing, is the test for absolute clearness.

It is believed in the case of the valve as shown that the details are completely illustrated without sacrificing clearness. Special care in putting in dimensions is of necessity required.



PLUNGER.
TWO-C.I.
PLUNGER BUSHING.
TWO-BRASS.
CLAMP RING.
TWO-C.I.
STEM.
32-BRASS.
COVER.
32-BRASS.
VALVE.
32-RUBBER.
SEAT.
32-BRASS.
SPRING-WIND FOUR FULL COILS
$\frac{7}{8}$ CTR. TO CTR. OF COIL WHEN OPEN
32-BRASS WIRE.
8 THREADS PER IN
TAPER $\frac{3}{4}$" PER FT
PLUNGER & VALVE DET.
16-8½-12 DUPLEX PUMP.
AMERICAN SCHOOL OF CORRESPONDENCE.
CHICAGO-ILLINOIS
SCALE-6"=1'-1".
H

The valve stem can be unscrewed either with a socket wrench on the inside or an ordinary fork wrench on the outside.

The seat, after being screwed to position in the deck, is often faced off, to true up any distortion caused by screwing in.

The valve itself, of rubber, can be bought of any desired grade of hardness. The specification for any given set of valves depend upon the quality of the water, the pressure and the general service of the pump.

Molding and Machining. By reason of the simple nature of the parts on this plate, the molding and machining is left entirely to the original consideration of the student.

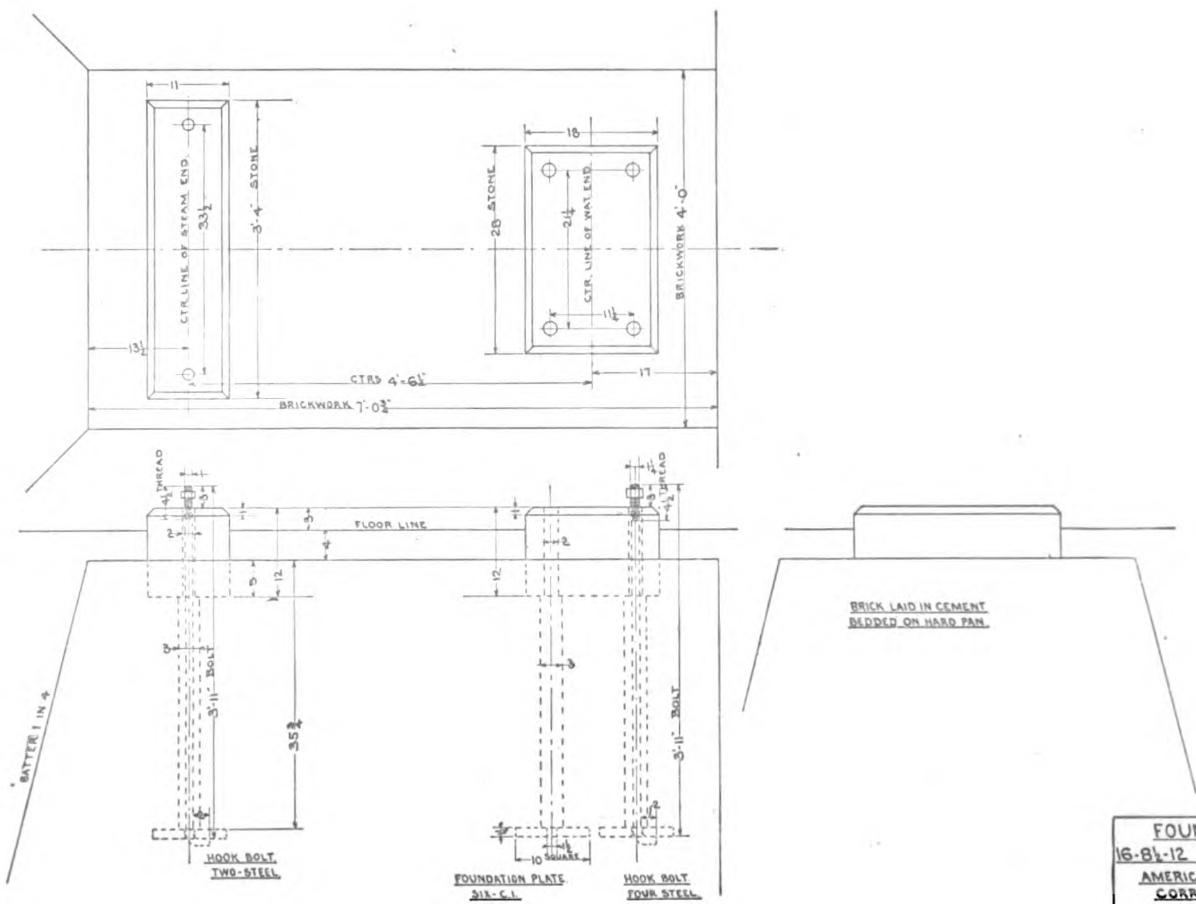
Plate M. Foundation. Pumps are often set directly upon a foundation of brick, but it makes a better job to bed stones, with surfaces dressed plane and true, into the main foundation, and rest the pump feet upon these stones. The simplest form of holding down bolts are shown on Plate M, a plain hook at the lower end, pulling up against a flat cast-iron plate, to distribute the pressure into the brickwork. These plates are of course bedded, and the bolts set as the foundation is built up. As the subsequent courses are laid some little space is left around the bolts, which may be afterwards filled with cement, thus making the bolts rigid with the foundation.

The water end of the foundation has no batter, because the suction pipe often drops vertically down from the end of the pump, and clearance is therefore necessary.

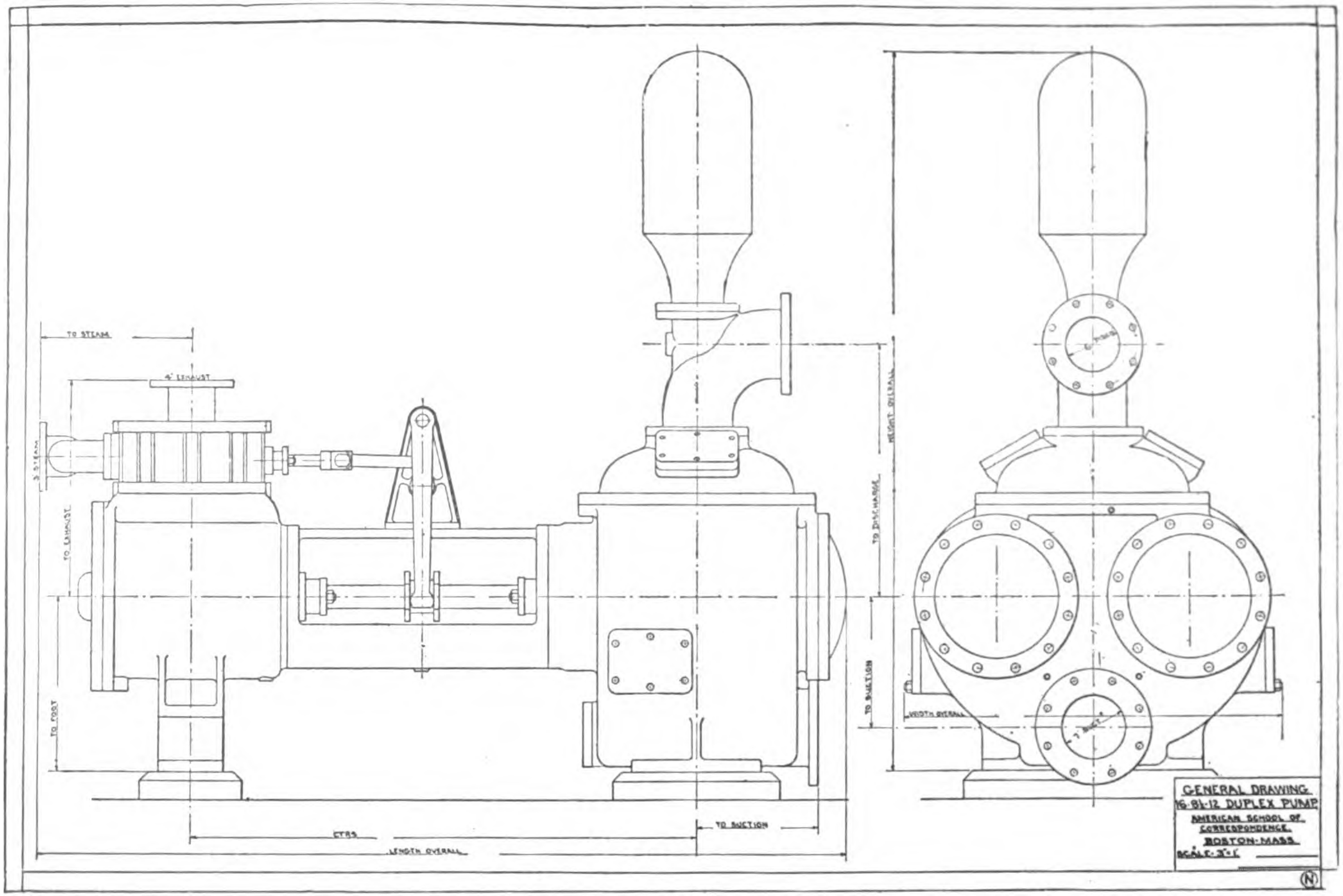
The floor line is placed 4 inches above the brickwork, to allow for the usual 1-inch top floor and 2-inch plank beneath, and still have a space left for shims to level the floor.

Plate N. General Drawing. This is an example of a plain, everyday shop drawing, to show the relation of parts and the extreme space occupied by the pump. A great deal of time can be needlessly wasted in producing a drawing of this character, by trying to make too faithful a picture. For example: If all the bolt heads were put in, it is safe to say that several hours' extra time would be required for this one item alone. But the drawing would be no better for shop use. Hence all bolt heads and nuts have been left out, except when necessary to show clearance.

Shade lines have been put on for no special reason except



FOUNDATION.
16-8½-12 DUPLEX PUMP.
AMERICAN SCHOOL OF
CORRESPONDENCE.
CHICAGO-ILLINOIS
SCALE-1½"=1'.


TO STEAM
4" EXHAUST
3" STEAM
TO EXHAUST
TO FOOT
CTRS
LENGTH OVERALL
TO SUCTION
TO DISCHARGE
HEIGHT OVERALL
WIDTH OVERALL
GENERAL DRAWING
16·8½·12 DUPLEX PUMP
AMERICAN SCHOOL OF
CORRESPONDENCE
BOSTON·MASS
N

that if they are desirable on any drawing they are especially desirable on a general drawing, where one part overlaps another, as they make it easier to pick out and separate one surface from another. Some lines are shaded in this drawing which are not strictly sharp edges. It is held, however, that the rounding of a corner ought not to destroy its character as an edge casting a shadow, and such lines are treated accordingly.

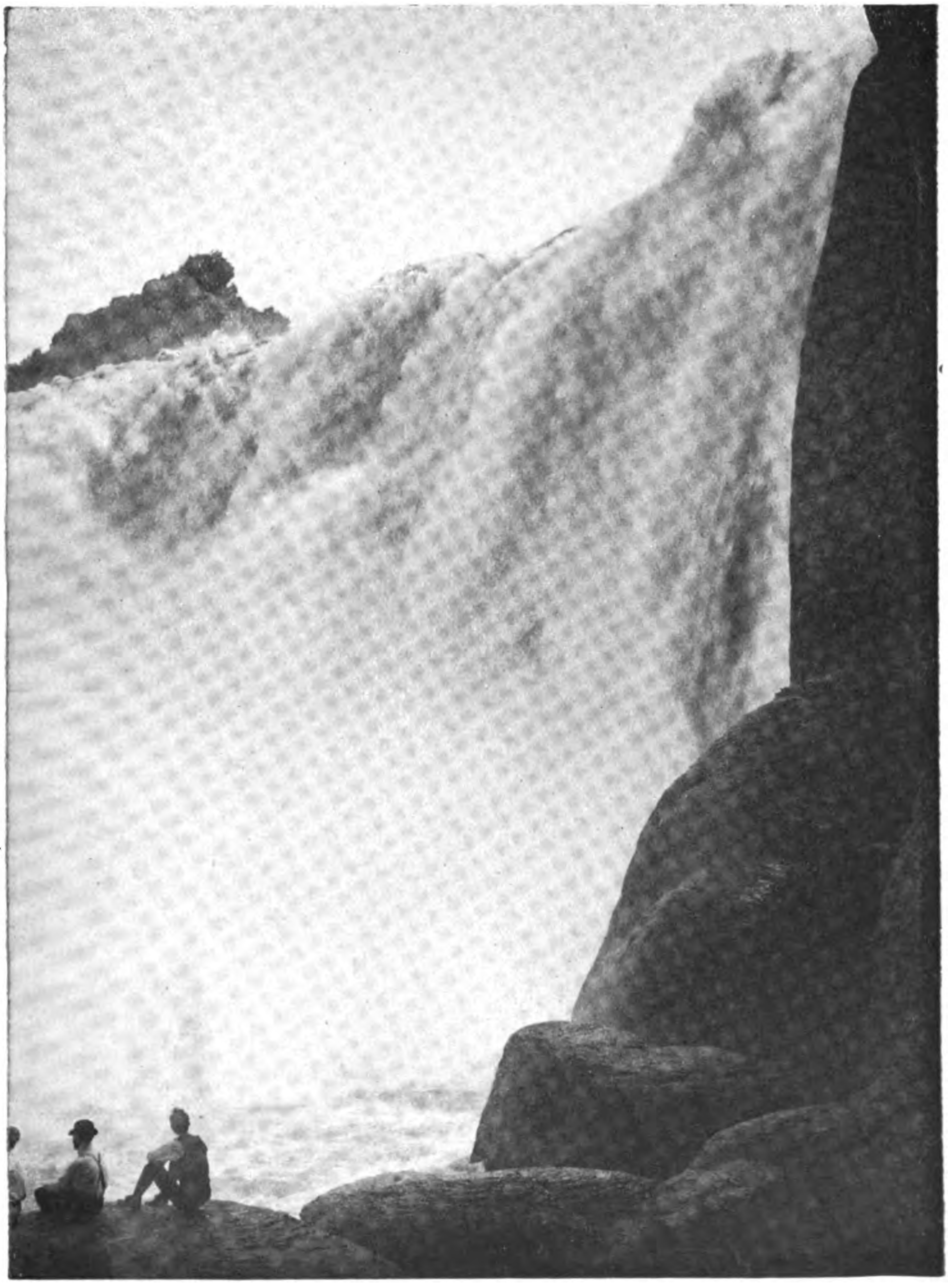
An assembled or general drawing of this character should be laid out strictly from the dimensions shown by the details. It thus serves a valuable purpose in checking up figures, and showing whether or not the parts will go together. The method or character of the work in no respect differs from that suggested for the detail drawings.

If a scale of 3 inches = 1 foot be used, the size of sheet must be 24 inches × 36 inches. The student, however, will perhaps find it easier to use a scale of $1\frac{1}{2}$ inches = 1 foot, in which case the ordinary size, 18 inches × 24 inches, will suffice. For such a small scale it will be found undesirable to attempt to put in any very small fillets and corners, although those that can be readily handled by the ordinary bow pen ought not to be omitted. As a matter of fact, the expert draftsman either leaves the corners sharp, as suggested, or puts in the smallest curves freehand.

Order Sheets. Any set of drawings is incomplete unless in connection with it a statement is made in tabular form of the complete make-up of the machine. An infinite variety of ways exists for making the specifications. Sometimes the tabulated data are placed on the general drawing. Most often, however, printed blanks are provided, usually of bond paper, arranged with special reference to the individual shop system and methods of handling work; these blanks are filled in by the draftsman, indexed and filed as a part of the set of drawings. They can be blue printed for use in the shops the same as a drawing. From these sheets stock is ordered, checked off, and watched in its process of manufacture.

Order sheets are indispensable in any well-ordered shop. Hence they are illustrated on pages 59, 60, 61 and 62 as the final step in the set of pump drawings. They are made as simple as possible, and are not intended to fit any special shop system. As previously stated, the exact form and method of classification can be determined only when the shop conditions are known.

The student, having carefully followed through the preceding pages, must not think that he is master of pump construction, for even the type illustrated has been but touched upon. The object of the detailed discussion is to get the student in close touch with the spirit of construction, to make his drawings real serious work. It is hoped that the student will work just as though a machine were to be built from his drawings, and built to sell at a profit. Only in this way can advanced work in mechanical drawing be of benefit to him, for after becoming expert in the use of the instruments, no other advance is possible except advance in *thought.*



SHOSHONE FALLS OF THE SNAKE RIVER, IDAHO

Height 210 feet. The bed of the Snake river canyon lies at a general level of 700 feet below the valley which its waters irrigate through the Twin Falls project. The Shoshone Falls, Twin Falls (187 feet), and Augur Falls (140 feet)—three of the six large falls in the canyon—all lie within five miles of the town of Twin Falls, center of an area of 250,000 acres of rich soil to be reclaimed. The waters are impounded by means of a dam at Milner, at the head of the canyon, 35 miles upstream from Twin Falls.

DATE. MAY 20, 1907 — AMERICAN SCHOOL OF CORRESPONDENCE — TYPE. INSIDE PLUNGER.

CHICAGO, ILL.

LIST OF CASTINGS

FOR

16—8½—12 DUPLEX PUMP.

No. Wanted.	Name.	Drawing No.	Patt. or Piece No.	Material.	Remarks.
2	Steam Cylinder	G		C. I.	R. & L.
2	Steam Cylinder Head	G		C. I.	
2	Steam Chest	F		C. I.	
2	Steam Chest Cover	F		C. I.	
2	Slide Valve	F		C. I.	
1	Steam Pipe	F		C. I.	
1	Exhaust Tee	F		C. I.	
2	Valve Steam Gland	F		C. I.	
2	Piston	E		C. I.	
8	Piston Pipe Plug, 1½″	E		C. I.	
4	Piston Packing Ring	E		C. I.	
2	Spool	E		C. I.	
1	Steam Cylinder Cricket	L		C. I.	
2	Steam Cylinder Stuffing Box	L		C. I.	
2	Water Cylinder Stuffing Box	L		C. I.	
4	Piston Rod Gland	L		C. I.	
1	Valve Lever Bracket	L		C. I.	
2	Yoke	L		C. I.	R. & L.
1	Short Rocker Arm	K		C. I.	
1	Long Rocker Arm	K		C. I.	
2	Valve Stem Link	K		C. I.	
1	Water Cylinder	J		C. I.	
2	Water Cylinder Head	J		C. I.	
3	Hand Hole Cover	J		C. I.	
1	Water Cylinder Cap	I		C. I.	
1	Air Chamber	I		C. I.	
1	Discharge Ell	I		C. I.	
2	Plunger	H		C. I.	
2	Plunger Bushing	H		Brass	
2	Clamp Ring	H		C. I.	
32	Valve Stem	H		Brass	
32	Valve Cover	H		Brass	
32	Valve Seat	H		Brass	
6	Foundation Plate	M		C. I.	

DATE.
MAY 20, 1907.

AMERICAN SCHOOL OF CORRESPONDENCE

TYPE.
INSIDE PLUNGER.

CHICAGO, ILL.

LIST OF STEEL AND MISCELLANEOUS PARTS

FOR

16–8½–12 DUPLEX PUMP.

No. Wanted.	Name.	Drawing No.	Patt. or Piece No.	Material.	Remarks.
2	Valve Steam Head	E		St.	Drop Forging.
2	Piston Rod	E		C. R. S.	
2	Valve Stem	E		St.	
1	Long P. R. Lever	K		St.	Forging
1	Short P. R. Lever	K		St.	Forging
1	Upper Rocker Shaft	K		St.	
1	Lower Rocker Shaft	K		St.	
2	Rocker Arm Pin	K		St.	
2	Link Pin	K		St.	
1	Long P. R. Lever Key	K		St.	Drop Forging
1	Short P. R. Lever Key	K		St.	Drop Forging
2	Rocker Arm Key	K		St.	Drop Forging
32	Valve Spring	H		Brass wire	Spring Temper
32	Valve	H		Rubber	Medium

DATE.
MAY 20, 1907

AMERICAN SCHOOL OF CORRESPONDENCE

TYPE.
INSIDE PLUNGER.

CHICAGO, ILL.

LIST OF BOLTS, NUTS AND PINS

FOR

16–8½–12 DUPLEX PUMP.

No. wanted.	Name.		Drawing No.	Patt. or Piece No.	Material.	Remarks.
24	Cylinder Head	Stud $\frac{7}{8}$ x $3\frac{1}{4}$	G		St.	
20	Steam Chest	Stud $\frac{3}{4}$ x $8\frac{3}{4}$	G		St.	
4	Valve Stem Gland	Stud $\frac{5}{8}$ x $4\frac{3}{4}$	F		St.	
8	Piston Rod Gland	Stud $\frac{3}{4}$ x 4	L		St.	
24	Water Cylinder Head	Stud $\frac{7}{8}$ x $3\frac{1}{4}$	J		St.	
12	Clamp Ring	Stud $\frac{3}{4}$ x $4\frac{1}{2}$	J		Tobin bz.	
24	Water Cylinder Cap	Stud 1 x $3\frac{1}{2}$	J		St.	
18	Hand Hole Cover	Stud $\frac{5}{8}$ x $2\frac{1}{2}$	J		St.	
12	Hand Hole Cover	Stud $\frac{5}{8}$ x $2\frac{1}{2}$	I		St.	
8	Exhaust Tee	Tap Bolt $\frac{5}{8}$ x $1\frac{3}{4}$	G		St.	
16	Yoke	Tap Bolt $\frac{3}{4}$ x 2	G		St.	
8	Steam Cyl. Stf. Box	Tap Bolt $\frac{3}{4}$ x $1\frac{3}{4}$	G		St.	
8	Steam Pipe	Tap Bolt $\frac{5}{8}$ x $1\frac{1}{2}$	F		St.	
4	Valve Lever Bracket	Tap Bolt $\frac{5}{8}$ x $1\frac{3}{4}$	F		St.	
4	Steam Cyl. Cricket	Tap Bolt 1 x $2\frac{1}{4}$	F		St.	
16	Yoke	Tap Bolt $\frac{3}{4}$ x 2	J		St.	
8	Water Cyl. Stf. Box	Tap Bolt $\frac{3}{4}$ x $1\frac{3}{4}$	J		St.	
8	Discharge Ell	Tap Bolt $\frac{3}{4}$ x 2	I		St.	
4	Air Chamber	Tap Bolt $\frac{3}{4}$ x 2	I		St.	
2	Hook Bolt (special)	1 x 3′—11″	M		St.	
4	Hook Bolt (special)	$1\frac{1}{4}$ x 3′—11″	M		St.	
1	Eye Bolt	Standard 1″	I		St.	
34	Standard Nut	$\frac{5}{8}$			St.	
44	Standard Nut	$\frac{3}{4}$			St.	
36	Standard Nut	$\frac{7}{8}$			St.	
26	Standard Nut	1			St.	
4	Standard Nut	$1\frac{1}{4}$			St.	
4	Standard Nut	2			St.	
8	Special Valve Stem Nut	1			St.	$\frac{3}{4}$ Thick
4	Piston Rod Split Pin	$\frac{1}{4}$ x 2	E		St.	
2	Spool Taper Pin	No. 10 Morse Taper	E		St.	4″ long
4	Valve Bracket Dowel Pin	$\frac{1}{4}$ x 2	L		St.	

DATE.
MAY 20, 1907

AMERICAN SCHOOL OF CORRESPONDENCE

CHICAGO, ILL.

TYPE.
INSIDE PLUNGER.

LIST OF SPECIAL FITTINGS, WRENCHES, ETC.

FOR

16–8½–12 DUPLEX PUMP.

No. Wanted.	Name.		Drawing No.	Patt. or Piece No.	Material.	Remarks.
4	Drip Cock	½″	G			
1	Drip Cock	¼″	F			
2	Drip Cock	¼″	L			
4	Oil Cup	¼″	L			
5	Drip Cock	⅜″	J			
1	Relief Valve	1¼″	I			175 lbs. pressure
1	Standard Fork Wrench	[illegible]″				
1	Standard Fork Wrench	¾″				
1	Standard Fork Wrench	⅞″				
1	Standard Fork Wrench	1″				
1	Socket Wrench	¾″				12″ handle
1	Valve Stem Fork Wrench					
1	Valve Stem Socket Wrench					

ELBOW PATTERNS *

In all elbow work the difficulty lies in obtaining the correct rise of the miter line. By the use of a protractor this is overcome and thus the necessity of drawing a complete quadrant is avoided. Following the rule given in the illustration the rise can be easily found, when the throat and diameter of the pipe is known.

In the upper table are shown various pieced elbows, having different degrees when finished, and the various miter lines. There are six miter patterns shown, the first for a 6-pieced elbow having 90° when completed; the second for a 4-pieced 90° elbow; the third for a 3-pieced 90° elbow; the fourth for a 2-pieced 70° elbow; the fifth for a 2-pieced 90° elbow, and the sixth for a 2-pieced 105° elbow.

No matter what size of throat the elbow may have, or what diameter or number of pieces, always follow the rule given in the illustration and obtain the miter line; then place the half profile in its proper position and place the full girth of the pipe on the line shown in the pattern by similar numbers. By reversing the cut opposite the line 1–7–1 the pattern for the middle pieces is obtained, after which one cut can be placed into the other as shown on Page 48 Sheet Metal Work, Part I.

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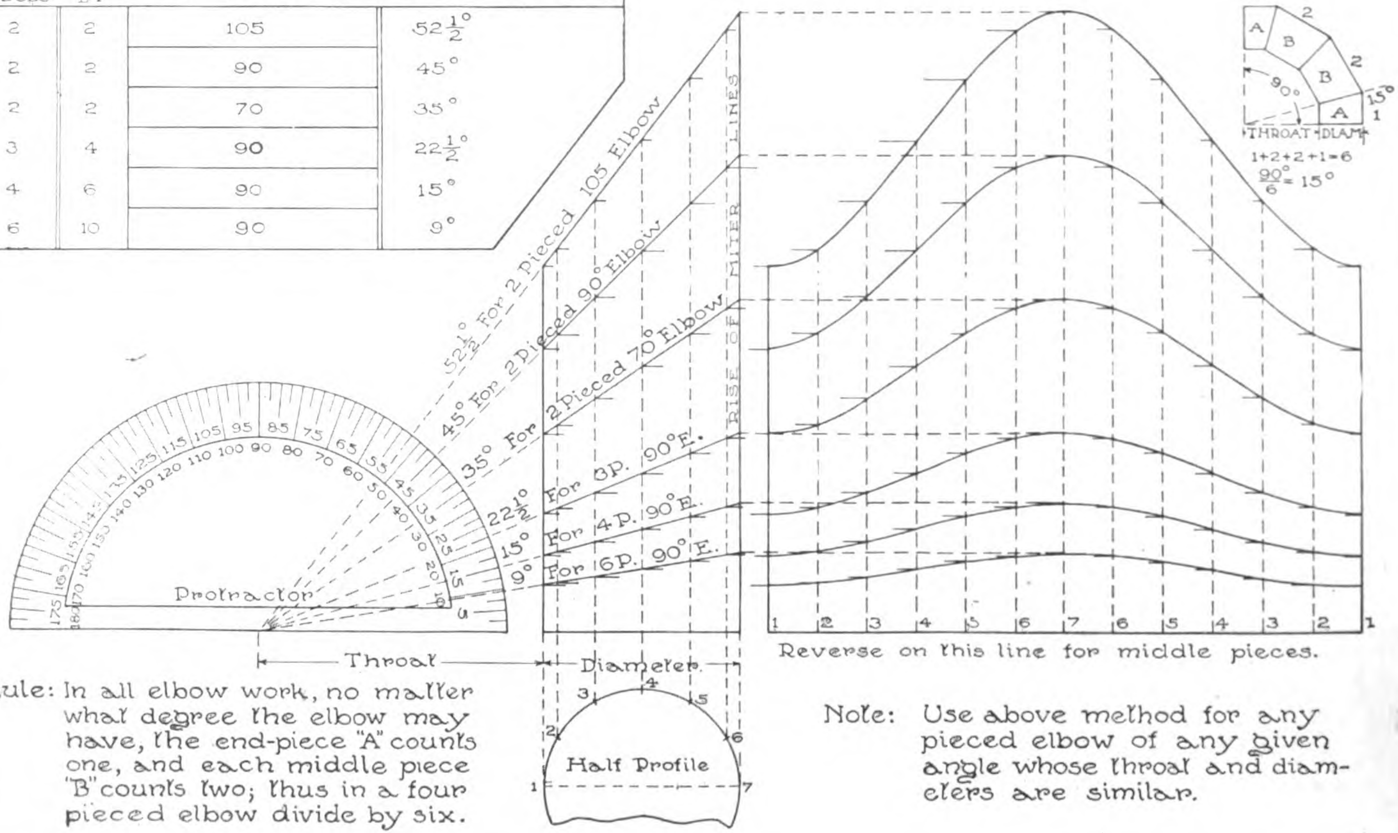
* The illustration referred to will be found on the back of this page.

PATTERNS FOR VARIOUS PIECED ELBOWS OF SIMILAR THROAT AND DIAMETER.

NO. OF PIECES	DIVIDE BY	DEGREE OF ELBOW	RISE OF MITER LINE
2	2	105	$52\frac{1}{2}°$
2	2	90	45°
2	2	70	35°
3	4	90	$22\frac{1}{2}°$
4	6	90	15°
6	10	90	9°



Rule: In all elbow work, no matter what degree the elbow may have, the end-piece "A" counts one, and each middle piece "B" counts two; thus in a four pieced elbow divide by six.

Note: Use above method for any pieced elbow of any given angle whose throat and diameters are similar.

FOR EXPLANATION OF THIS PROBLEM SEE BACK OF PAGE

SHEET-METAL WORK.

PART I.

The sheet-metal worker of today who wishes to succeed must know far more than was necessary years ago. There are many good, practical sheet-metal workers in the trade who are handicapped because they are unable to lay out the patterns that arise in their daily work. Notwithstanding the introduction of labor-saving machinery, the demand for good workmen has increased. While most sheet-metal workers acquire practical knowledge in the shop, they lack the technical education necessary to enable them to become proficient as pattern cutters and draftsmen. In this course, special attention is given to the fundamental principles that underlie the art and science of pattern drafting.

Practical workshop problems will be presented, such as arise in everyday practice, thus giving the student the practical experience that usually comes only after long association with the trade.

CONSTRUCTION.

In constructing the various articles made from sheet metal, various gauges or thicknesses of metal are used. For all gauges from No. 20 to No. 30 inclusive, we assume in the development of the pattern, that we are dealing with no thickness, and we make no allowance for bending or rolling in the machine. But where the metal is of heavier gauge than No. 20, allowance must be made for shrinkage of the metal in the bending and rolling operations, which will be explained in connection with development in heavy sheet-metal work. What has been said about wiring, seaming, and transferring patterns in the Tinsmith's Course is applicable to this course also. It is sometimes the case that the capacity of a vessel or article must be determined, when the rules given in Mensuration should be followed. When figuring on sheet-metal work, the specifications sometimes call for various metals, such as galvanized sheet iron or steel, planished iron, heavy boiler plate, band iron, square or round rods for bracing, etc., zinc, copper, or brass; and the weight of the metal must often be calculated together with that of stiffening rods, braces, etc. On this account it is necessary to have tables which can be consulted for the various weights.

TABLES.

There is a wide difference between gauges in use, which is very annoying to those who use sheet metal rolled by different firms according to the various gauges adopted. It would be well to do away with gauge numbers, and use the micrometer caliper shown in Fig. 1, which determines the thickness of the metal by the decimal or fractional parts of an inch.

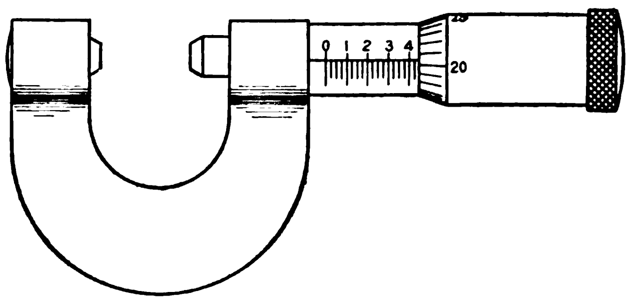


Fig. 1.

This is the most satisfactory method for the average mechanic who works sheet metal manufactured by firms using different gauges. The tables on pages 61 to 74 can be consulted when occasion arises.

SHOP TOOLS.

In allowing edges for seaming and wiring, we must bear in mind that when a seam is to be grooved by hand or machine the allowance to be made to the pattern should conform to the rolls in the machine or the hand tools in use. The edges of the pattern are usually bent on the sheet-iron folder, or brake, while the seam can be seamed or grooved with the hand groover or giant grooving machine. Where round pipe work is done in lengths up to 3 feet, the slip roll former is used, while square or rectangular pipes are bent up on the brake in 8-foot lengths. Where pipes, elbows, stove bodies, furnace shells, metal drums, etc., are made, the sheets are cut square on the large squaring shears, rolled, grooved, and stiffened, by beading both ends in the beading machine, using ogee rolls. There is also a special machine for seaming the cross seams in furnace pipes, also a set of machines for the manufacture of elbows used in sheet-metal work. As before mentioned, if these machines are at hand, it will be well to make slight modifications in the patterns so that both the machines and patterns may work to advantage.

PATTERNS OBTAINED BY VARIOUS METHODS.

In this course will be explained the four methods used in developing patterns for sheet-metal work, namely, parallel line, radial line, triangulation, and approximate developments. What was said on parallel and radial line developments in the Tinsmith's Course is applicable to this course also.

INTERSECTIONS AND DEVELOPMENTS.

The following problems on parallel line developments have been selected because they have a particular bearing on pipe work arising in the sheet-metal trade. All of the problems that will follow should be carefully studied, drawn on cheap paper, and proven by cardboard models. These models will at once show any error in the patterns which might otherwise be overlooked. As only the Examination Plates are to be sent to the School, the student should draw all the other plates given in this course.

The first problem to be drawn is shown in Fig. 2, being the intersection between a cylinder and octagonal prism. In drawing these problems for practice, make the cylinder and octagonal prism both 2 inches in diameter. The height of the cylinder from B to E should be $4\frac{1}{2}$ inches; and the length of the prism from G to H, 3 inches. Let A represent the plan of the cylinder, shown in elevation by B C D E; and F, the section of the prism, shown in plan by G H I J. Number the corners of the section F as shown, from 1 to 4 on both sides; and from these points draw horizontal lines intersecting the plan of the cylinder at $2'3'$ and $1'4'$ on both sides as shown. Establish a convenient intermediate point of intersection between the corners of the prism, as *a* and *a* in A, from which draw horizontal lines intersecting the section F at *a′*, *a′*, *a′*, and *a′*. Take a tracing of the section F with its various intersections, and place it in its proper position as shown by F^1, in the

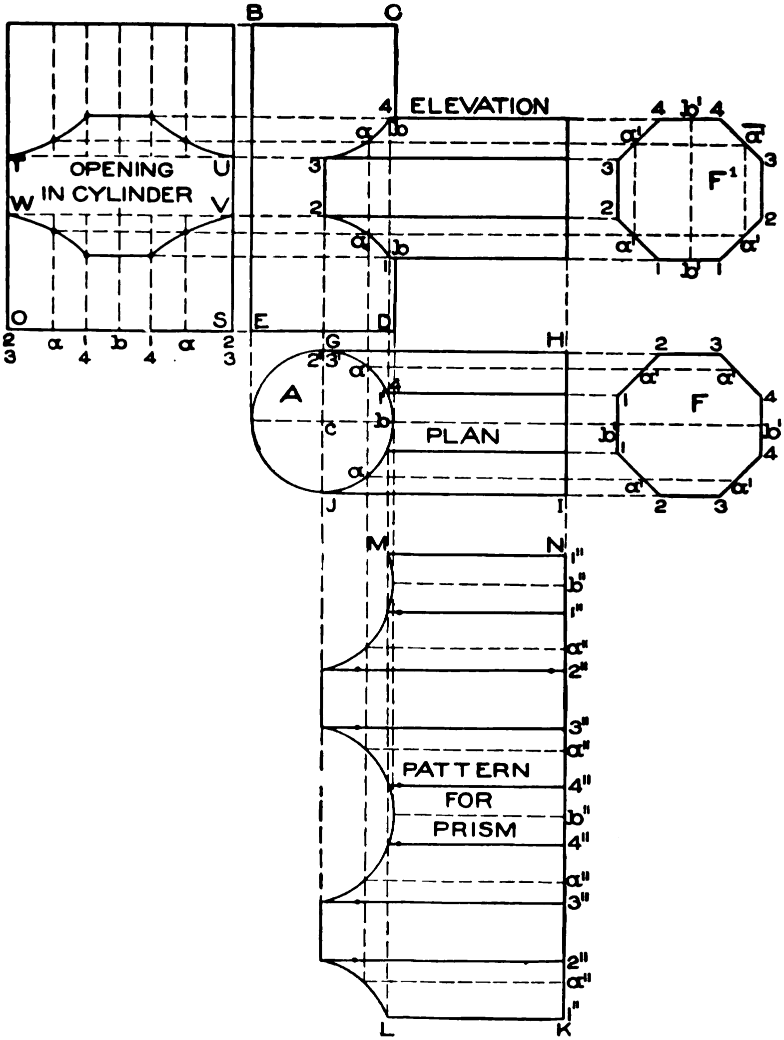


Fig. 2.

center of the cylinder B C D E, allowing the section to make a quarter turn, and bringing the points *b′ b′* at the top and bottom on a vertical line, while in the section F, *b′ b′* are on a horizontal line. From the various intersections in F^1, draw horizontal lines intersecting vertical lines drawn from similarly numbered intersections in the plan A, as shown in elevation. A line drawn through these points will represent the joint between the cylinder and prism.

For the development for the prism, extend the line H I in plan as N K, upon which place the stretchout of all the points contained in the section F, as shown by similar figures and letters on N K. Through these points, at right angles to N K, draw lines which intersect with lines drawn from similarly numbered points and letters in plan, at right angles to J I. Trace a line through points thus obtained, and K L M N will be the desired pattern. To obtain the development for the opening in the cylinder, extend the line D E in elevation as S O, upon which place the stretchout of all the points contained in the half-circle A, as shown by similar numbers and letters on S O. At right angles to S O and through these points, draw lines intersecting horizontal lines drawn from intersections having similar numbers and letters in elevation, thus obtaining the intersections shown by T U V W, which will be the shape of the opening to be cut into one-half of the cylinder.

In Fig. 3 is shown the intersection between a hexagonal and quadrangular prism, the hexagonal prism being placed in elevation at an angle of 45° to the base line. When drawing this problem for practice, make the height of the quadrangular prism 4½ inches, and each of its sides 2 inches. Place the hexagonal prism at an angle of 45° to the base line, placing it in the center of the quadrangular prism in elevation as shown; and inscribe the hexagonal section in a circle whose diameter is 2½ inches. Let A represent the plan of the quadrangular prism placed diagonally as shown, above which draw the elevation B C D E. In its proper position and proper angle, draw the outline of the hexagonal prism as shown by 1^v $1''$ $4''$ 4^v; and on $1''$ $4''$ draw the half section as shown by F, numbering the corners $1''$ $2''$ $3''$ and $4''$. From the corner $1'$ in the plan A, draw the center line $1'$ 4. Take a tracing of the half section F, and place it as shown by F^1, placing the points $1''$ $4''$ in F on the center line in F^1 as shown. From the corners 1, 2, 3, and 4, draw lines parallel to the center line, intersecting the two sides of A (b $1'$ and $1'$ a) at $2'$ $3'$ and $1'$ $4'$, as shown. From these intersections draw vertical lines, which intersect by lines drawn parallel to 4′ 4ᵛ from corners having similar numbers in F, thus obtaining the points of intersection 1^v 2^v 3^v and 4^v. Dropping vertical lines from the intersections on the plane 1′ 4′ in elevation, and intersecting similarly numbered lines in plan, will give the horizontal section of 1′ 4′, as shown by 1° 2° 3° and 4°.

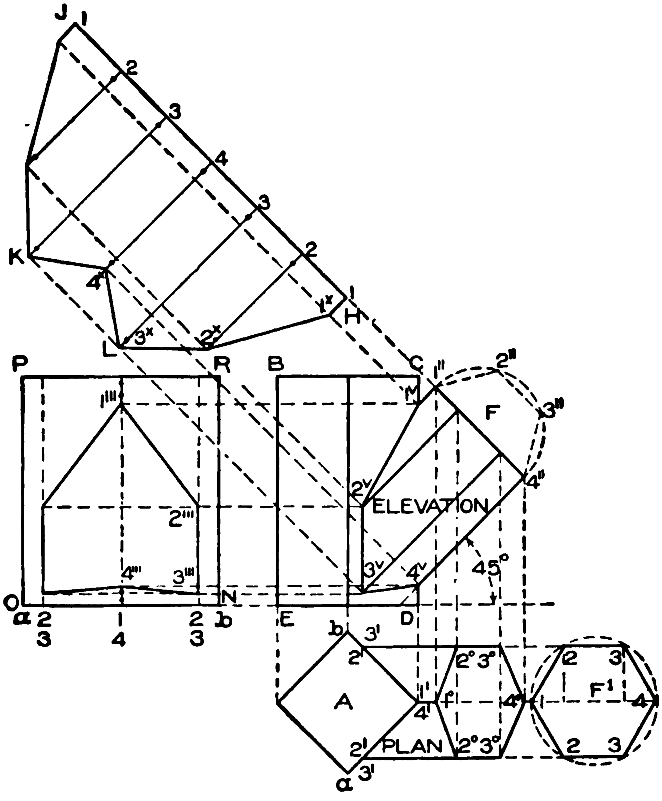
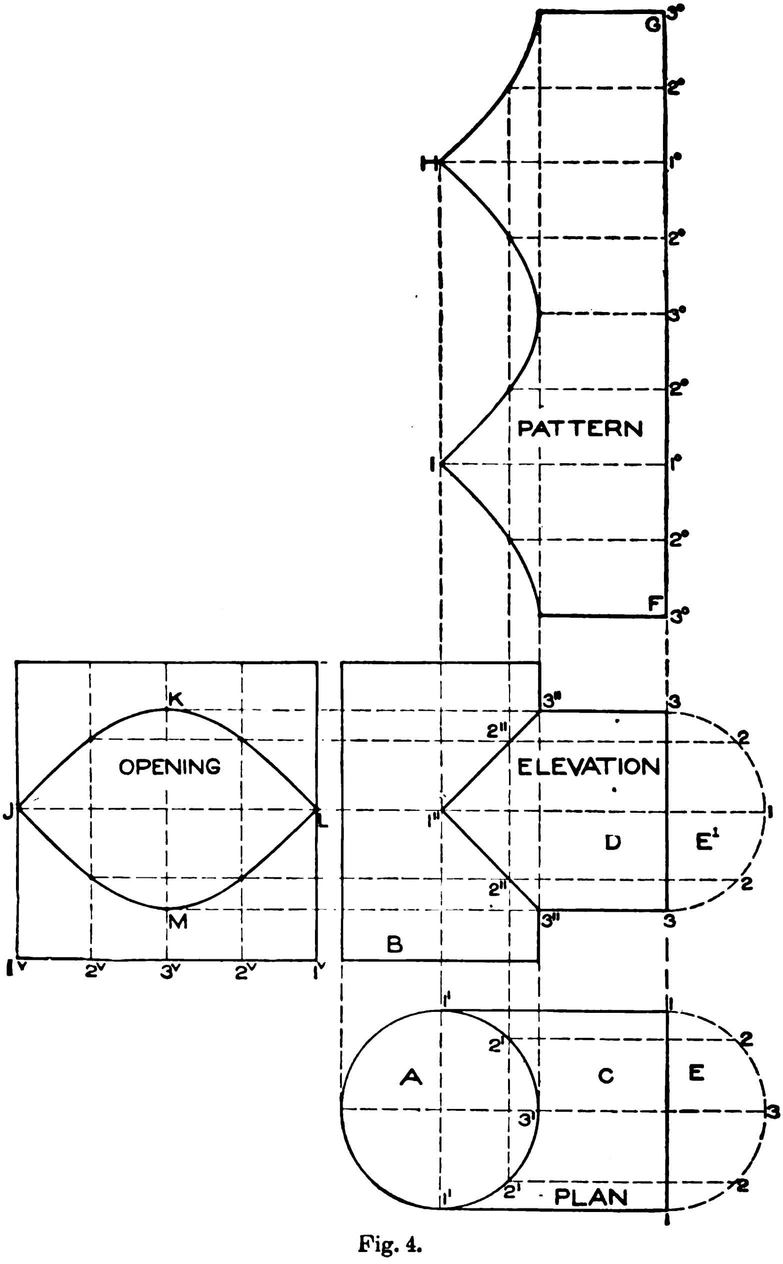


Fig. 3.

For the development of the hexagonal prism, extend the line 4′ 1′ as shown by H J, upon which place the stretchout of twice the number of spaces contained in the half section F, as shown by similar figures on the stretchout line H J. From these points, at right angles to H J, draw lines as shown, which intersect by lines drawn at right angles to the line of the prism from intersections 1^v to 4^v, thus obtaining the points of intersection 1^x to 4^x. Lines traced from point to point as shown by J K L H, will be the required development. The shape of the opening to be cut into the quadrangular prism, is obtained by extending the line D E in elevation as N O, upon which place the stretchout of one-half the section A, with the various points of intersection, as shown by similar figures on O N. At right angles to O N erect lines from these points, which intersect by lines drawn from similarly numbered intersections in elevation at right angles to the quadrangular prism, thus obtaining the points of intersection 1‴ to 4‴ on both sides. Then N O P R will be the half development.

Fig. 4 shows the intersection between two cylinders of equal diameters at right angles. Make the height of the vertical cylinder 3 inches, that of the horizontal cylinder 1¼ inches, and the diameters of both 2 inches. Let A represent the plan of the vertical cylinder, and B its elevation. Draw the plan of the horizontal cylinder C, shown in elevation by D placed in the center of the vertical cylinder. Draw the half section E in plan and divide it into equal parts, as shown from 1 to 3 to 1. In a similar manner draw the half section E^1 in elevation, which also divide into the same number of spaces as E, reversing the numbers as shown.

The following suggestions are given to avoid confusion in numbering the points or corners of irregular or round sections in plan and elevation. If the half section E were bent on the line 1–1 and turned upward toward the reader, and we should view this section from the front, the point 3 would be at the top, or, if bent downward, would be at the bottom; therefore the points 3 and 3 in elevation are placed at top and bottom. Now if the section E^1 in elevation were bent on the line 3-3 either toward or away from the reader, the point 1 when looking down would show on both sides as shown in plan, which proves both operations. No matter whether the form is simple, as here shown, or complicated as that which will follow, the student should use his imaginative power. Study the problem well; close your eyes and imagine you see the finished article before you, or, failing in this, make a rough model in the shop or a cardboard model at home, which will be of service. Now from the intersections in E, draw horizontal lines intersecting the circle A at 1′, 2′ and 3′ on both sides. From these points erect perpendicular lines and intersect them with horizontal lines drawn


PATTERN
ELEVATION
OPENING
PLAN
G
F
H
I
J
K
L
M
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D
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2''
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2°
3°
1ᵛ
2ᵛ
3ᵛ

Fig. 4.

from similarly numbered intersections in E^1. Lines traced through these points 3″ 2″ 1″ and 1″ 2″ 3″ will be straight because both branches are of equal diameters.

For the development of the cylinder D in elevation, extend the line 3-3 as shown by F G, upon which place the stretchout of twice the number of spaces contained in E^1, as shown by similar numbers 3° to 1° to 3° to 1° to 3° on the stretchout line F G. From these points, at right angles to G F, draw lines, and intersect them by lines drawn parallel to the cylinder B from similar numbers in the joint line. Trace a line through these points in the development, when F G H I will be the desired shape.

For the opening to be cut into the cylinder B to receive the cylinder D, extend the base of the cylinder B as shown by 1^v 1^v, upon which place the stretchout of the half circle A in plan, as shown by similar figures on the stretchout line 1^v 1^v. From these points erect perpendiculars, which intersect by lines drawn from similarly numbered intersections in elevation at right angles to the line of the cylinder B. Trace a line through the intersections thus obtained; J K L M will be the shape of the opening.

Fig. 5 shows the intersection of two cylinders of unequal diameters at an angle of 45°. Make the diameters of the large and small cylinders 2 inches and 1¼ inches respectively; the height of the large cylinder 3 inches; and the length of the small cylinder measured from its shortest side in elevation, 1 inch, placed at an angle of 45° in the center of the cylinder B. A represents the plan of the large cylinder struck from the center *a* and shown in elevation by B. Draw the outline of the small cylinder C at its proper angle, and place the half section D in its position as shown; divide it into a number of equal spaces, as shown from points 1 to 5. Through the center *a* in plan. draw the horizontal line *a* 5; and with *b* as a center describe a duplicate of the half section D with the various points of intersection, as shown by D^1, placing the points 1 and 5 on the horizontal line *a* 5. From the intersections in D^1 draw horizontal lines intersecting the large circle A at 3′ to 3′ as shown, from which points erect perpendicular lines; intersect them by lines drawn parallel to the lines of the smaller pipe from similarly numbered intersections in D. A line traced through the points thus obtained will represent the intersection or miter joint between the two pipes.

These same principles are applicable no matter what diameters the pipes have, or at what angle they are joined, or whether the

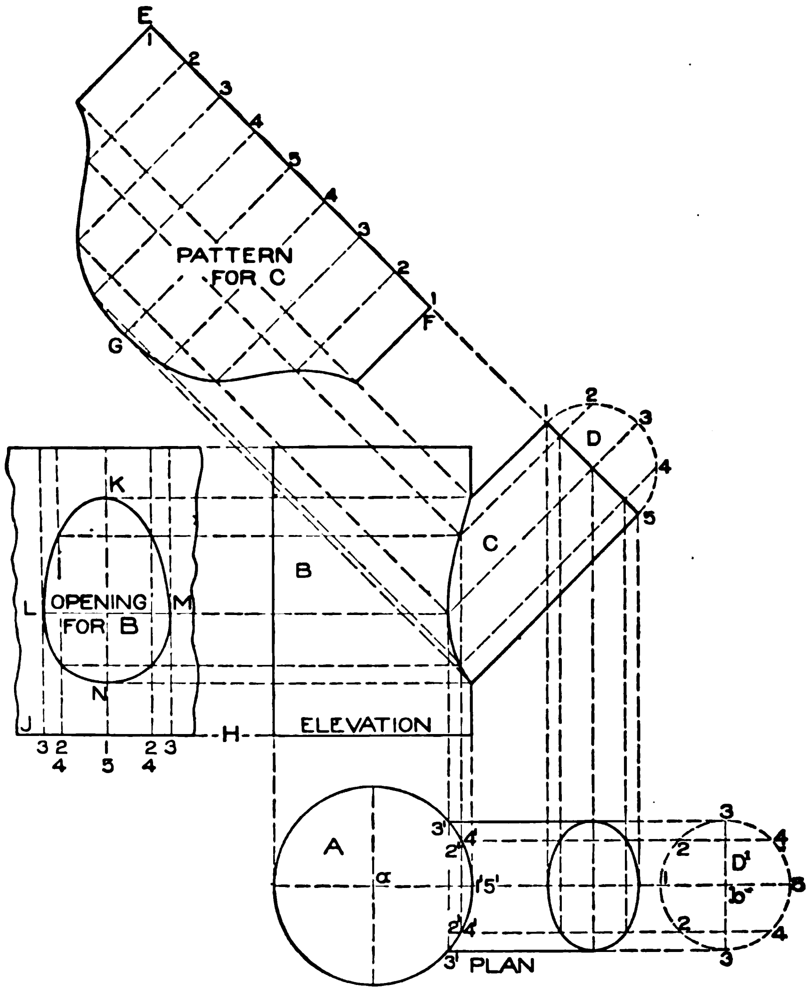
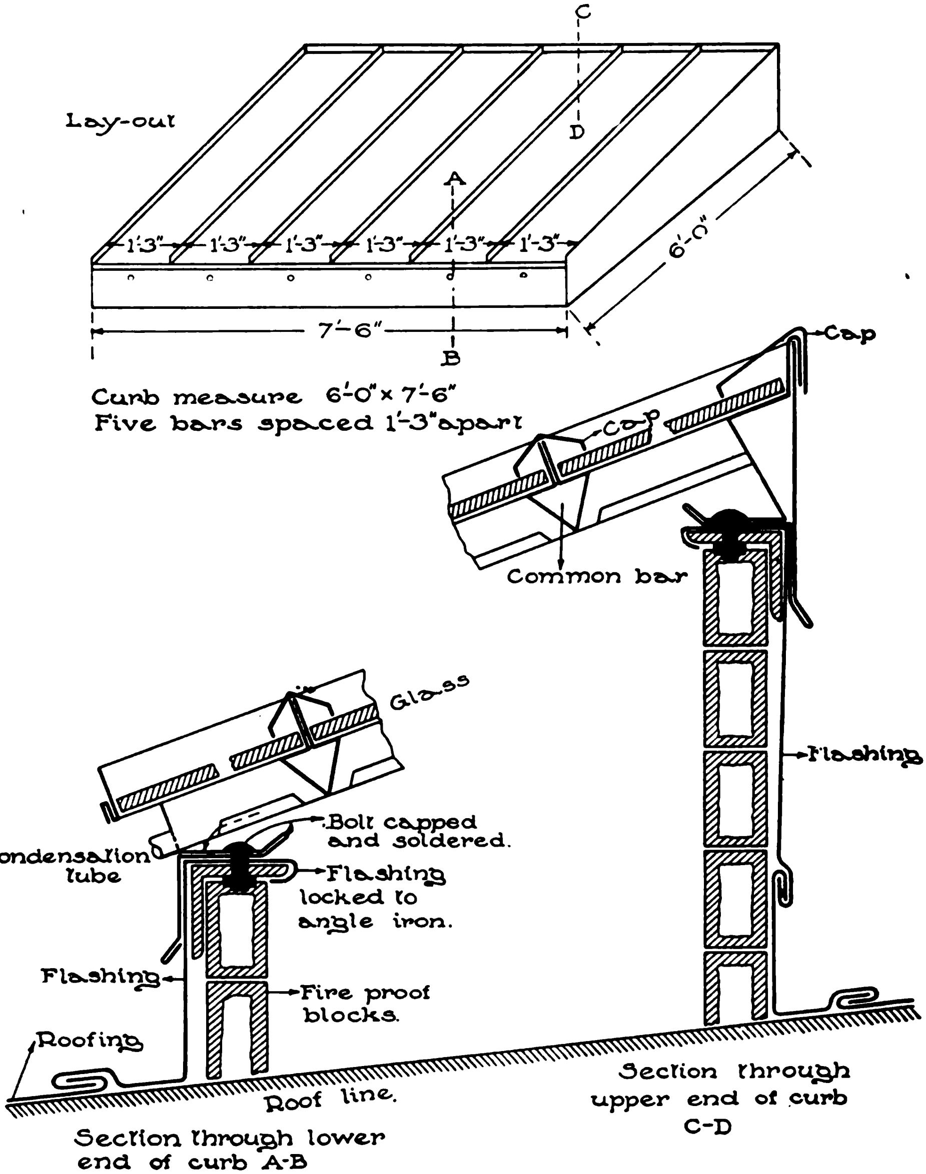


Fig. 5.

pipe is placed as shown in plan or at one side of the center line.

For the development of the small cylinder extend the line 5 - 1 in elevation as shown by F E, upon which place the stretchout

CONSTRUCTION DRAWING SHOWING LAYOUT OF FLAT SKYLIGHT AND METHOD OF FASTENING FLASHING ON ANGLE IRON CONSTRUCTION.



of the circle D' in plan, or twice the amount of D in elevation, as shown by similar figures on the stretchout line F E. At right angles to F E and through these small figures, draw lines which intersect with lines drawn at right angles to the lines of the small cylinder from similarly numbered intersections in the miter line in elevation. Trace a line through the points thus obtained; E F G will be the development for the cylinder C.

To obtain the opening in the large cylinder extend the lines of the large cylinder in elevation as shown at the base by H J, upon which place the stretchout of the intersections contained in the circle A, being careful to transfer each space separately (as they are unequal) to the stretchout line H J. Through these points and at right angles to H J erect lines which intersect with horizontal lines drawn from similar points in the miter line in elevation A line traced through the points thus obtained, as shown by K L M N, will be the desired development.

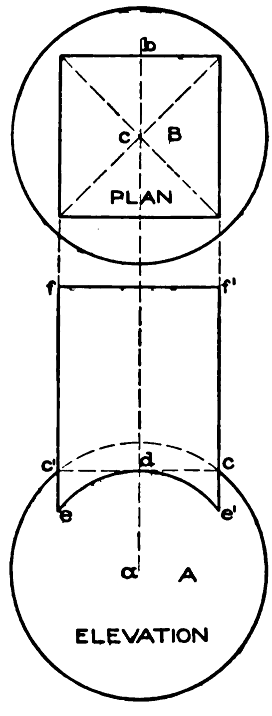


Fig. 6.

Fig. 6 shows the intersection between a quadrangular prism and sphere, the center of the prism to come directly over the center of the sphere. Make the diameter of the sphere 2½ inches, the sides of the prism 1½ inches, and the height from *f* to *c'* 2⅝ inches. Draw the elevation of the sphere A which is struck from the center *a*, from which erect the perpendicular *a b*. With any point, as *c*, as a center and using the same radius as that used for A, describe the plan B. Through *c* draw the two diagonals at an angle of 45°, and draw the plan of the prism according to the measurements given. Now draw the elevation of the prism *f c'* and *f' c*, the sides of the prism intersecting the sphere at *c* and *c'*. From either of these points draw a horizontal line intersecting the center line *a b* at *d*. Then using *a* as a center and *a d* as the radius, describe the arc *e e'* intersecting the sides of the prism extended at *e* and *e'*; *f e e' f'* will be the development for one of the sides of the prism. In practice the four sides are joined in one.

Fig. 7 shows the intersection of a quadrangular prism and sphere when the center of the prism is placed to one side of the center of the sphere. Make the diameter of the sphere the same as in the preceding figure; through *x* in the plan draw the 45° diagonal, and make the distance from *x* to A $\frac{1}{8}$ inch, the sides of the prism 1 inch, and the height from E to *c* in elevation $1\frac{1}{2}$ inches. Having drawn the elevation and plan of the sphere, construct the plan of the prism as shown by A B C D. Parallel to the center line *x y* project the prism in elevation intersecting the sphere at *a* and *c*. Now since the center of the sphere is on one of the diagonals of the prism in plan, either two of the sides meeting at one end of that diagonal, as B C and C D, will be alike, and both will be different from the other two sides A B and A D, meeting at the opposite end of the diagonal. Therefore the line F *a* in elevation will be used in obtaining the development of D C in plan, while the line E *c* will be used in obtaining the development for the two sides D A and A B in plan.

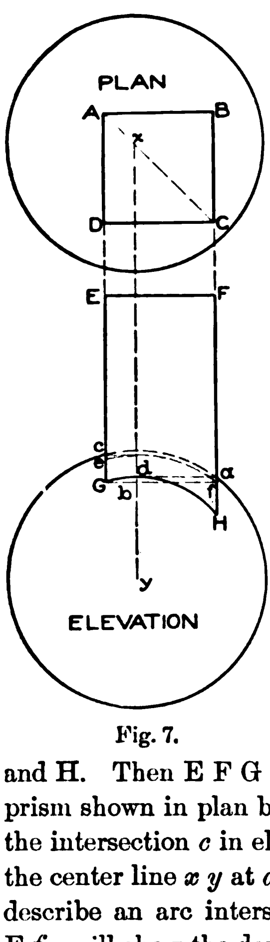


Fig. 7.

Now from *a* draw a horizontal line intersecting the center line *x y* at *b;* and using *y* as a center and *y b* as the radius, describe the arc G H intersecting the sides of the prism extended to G and H. Then E F G H is the development for each side of the prism shown in plan by D C and C B. In a similar manner, from the intersection *c* in elevation draw a horizontal line intersecting the center line *x y* at *d*. Then using *y* as center and *y d* as radius, describe an arc intersecting the sides of the prism at *e* and *f*. E F *f e* will show the development for either side of the prism shown in plan by D A and A B. By connecting the points G and *f* it will be found that the line is a true horizontal line, which proves the two developments. Should the plan of the prism be so placed on the sphere that all sides would be different, then two elevations would be necessary so that the intersections of all the sides could be shown.

Developments by Triangulation. In developing sheet-metal work of irregular forms, patterns are required which cannot be developed by either the parallel or radial-line methods. These irregular shapes are so formed that although straight lines can be drawn upon them the lines would not run parallel to one another, nor would they all incline to a common center. In the methods previously described, the lines in parallel developments run parallel to one another, while in radial-line developments all the lines meet at a common center. Hence in the development of any irregular article, it becomes necessary to drop all previous methods, and simply proceed to measure up the surface of the irregular form, part by part, and then add one to another until the entire surface is developed. To accomplish this, one of the simplest of all geometrical problems is made use of and shown in Part II of Mechanical Drawing, Plate V, Problem 11, entitled "To construct a triangle having given the three sides." To carry out this method it is necessary only to divide the surface of the plan or elevation of any irregular article into a number of equal parts. Use the distances in plan as the bases of the triangles, and the distances in elevation as the altitudes or heights of the triangles, or *vice versa;* and then find the hypothenuse by connecting the two given lengths.

To illustrate this simple principle Fig. 8 has been prepared. Let A B C D represent the plan of a plane surface, shown in elevation by A^1 B^1. We know that the true length of the plane is equal to A^1 B^1 and the true width is equal to A D or B C in plan. We also know that the vertical height from the bottom of the plane A^1 to the top B^1 is equal to B^1 *b* as shown. But suppose we want to obtain the true length of the diagonal line B D in plan on the developed plane. To obtain this it will be necessary only to take the length of B D, place it from *b* to D^1, and draw a line as shown from B^1 to D^1, which is the length desired.

While this may look very simple, it is all that there is to triangulation, and if the student thoroughly understands the simple principle and studies the problems which will follow, he will have no trouble in applying this principle in complicated work. To make it still clearer we will prove the length of the line $B^1 D^1$. Take the distance of $A^1 B^1$, place it in plan as shown by $A B^2$, and complete the rectangle $A B^2 C^2 D$. Draw the diagonal $B^2 D$, being the length sought, which will be found to equal $B^1 D^1$ in elevation. When drawing this problem in practice, make the plan 4 by 6 inches and the vertical height in elevation 5 inches.

In obtaining developments by triangulation. the student should use all of his conceptive powers as previously explained. Before making any drawing, he must see the article before him in his mind's eye, so to speak, before he can put it down on paper. Therefore we want to impress upon the student the necessity of drawing all the problems that will follow in this part and in the Practical Workshop Problems. It should be understood that triangulation is not given as an alternative method, but is used when no other method can be employed, and without it no true pattern could be obtained for these irregular shapes; hence the necessity of close study.

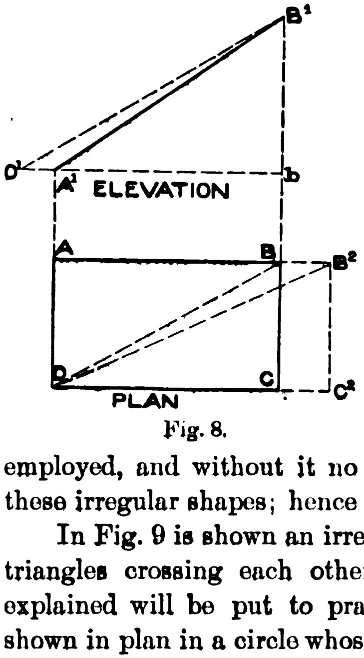


Fig. 8.

In Fig. 9 is shown an irregular solid whose base and top are triangles crossing each other. and in which the principle just explained will be put to practical test Inscribe the triangles shown in plan in a circle whose radius is equal to a 1, or $1\frac{1}{2}$ inches, and make the height of the article in elevation 2 inches. The dotted triangles 1 2 3 in plan represent the section of the article on the line 2–3 in elevation: and the solid triangle $1^1 2^1 3^1$ in plan, the section on the line $2^1 3^1$ in elevation. Now connect the two sections in plan by drawing lines from 1 to 2^1 and to 3^1, from 2 to 2^1 and to 1^1, and from 3 to 1^1 and to 3^1. In a similar manner connect the points in elevation as shown. It now becomes necessary to obtain a triangle giving the true length of the lines connecting the corners of the triangle in plan, and as all of these lines are equal only one triangle is necessary Therefore take the distance from

1 to 2^1 in plan and place it on the line 3–2 extended in elevation, as shown from 2 to 1°, and draw a line from 1° to 2^1, which is the desired length.

For the pattern, proceed as is shown in Fig. 10. Take the distance of any one of the sides in the triangle, as 1–2 in Fig. 9, and place it on the horizontal line 1–2 in Fig. 10. Then using 1 and 2 as centers, with 1° 2^1 in elevation in Fig. 9 as radius, describe the arcs in Fig. 10 intersecting each other in 2^1. Then 1 2 2^1 will be the pattern for one of the sides shown in plan in Fig. 9 by 1 2 2^1. Proceed in this manner in Fig. 10 as shown by the small arcs; or a tracing may be taken of the one side 1 2 2^1, and traced as shown until six sides are obtained, which will be the full pattern and which is numbered to correspond to the numbers in plan.

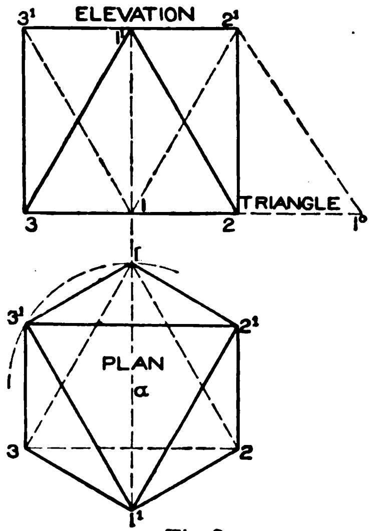


Fig. 9.

In Figs. 11, 12, and 13 are shown the methods used in developing a scalene cone. The method of obtaining the development of any scalene cone, even though its base is a perfect circle, is governed by the same principle as employed in the last problem on triangu-

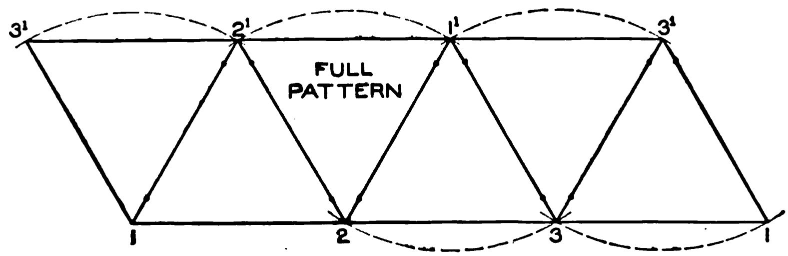


Fig. 10.

lation It is well to remember that any section of a scalene cone drawn parallel to its base will have the same shape (differing of course in size) as the base. This is equally true of articles whose bases are in the shape of a square, rectangle, hexagon, octagon, or any other polygon. What has just been explained will be proven in connection with Fig. 11, in which A B C represents a side elevation of a scalene cone, whose plan is shown by 1 4¹ 7 4 C¹. Draw any horizontal line, as A D, on which set off the distances

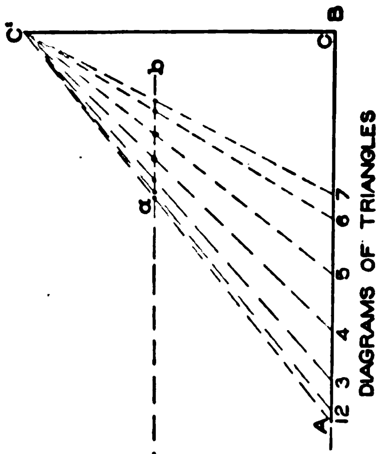


Fig. 12.

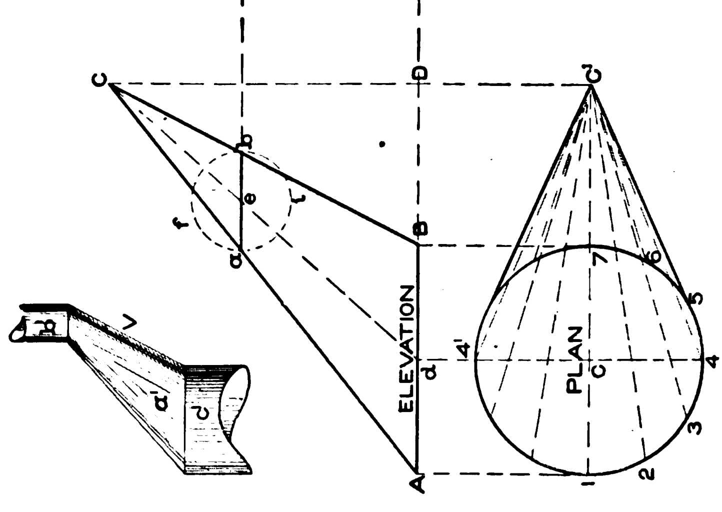


Fig. 11.

A B equal to 3 inches and B D equal to 2½ inches, and the vertical height D C equal to 4½ inches. Draw lines from B and A to C, which completes the elevation. In its proper position below the line A B, draw the plan of A B as 1 4 7 4¹ struck from the center C. Through C draw the horizontal line C C¹, and intersect it by a vertical line drawn from the apex C in elevation, thus obtaining the apex C^1 in plan. Draw lines from 4 and 4^1 to C^1, which completes the plan.

As both halves of the scalene cone are symmetrical, it is necessary only to divide the half plan 1 4 7 into a number of equal spaces as shown by the small figures 1 to 7, and from points thus obtained draw radial lines to the apex C^1. Then these lines in plan will represent the bases of triangles which will be constructed, whose altitudes are all equal to D C in elevation. Therefore in Fig. 12 draw any horizontal line, as A B, and from any point, as C, erect the perpendicular line C C^1 equal in height to D C in Fig. 11. Now from C^1 in plan take the various lengths of the lines 1 to 7 and place them on the line A B in Fig. 12, measuring in every instance from the point C, thus obtaining the intersections 1 to 7, from which lines are drawn to the apex C^1. Then these lines will represent the true lengths of similarly numbered lines in plan in Fig. 11.

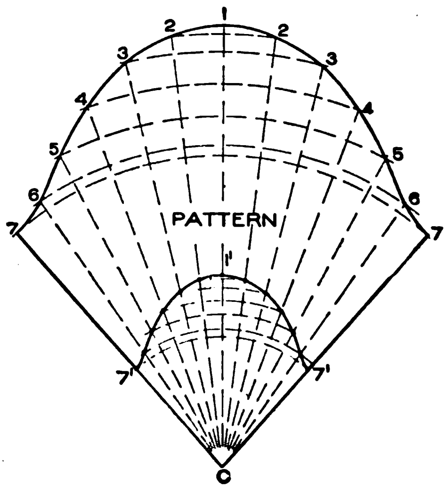


Fig. 13.

For the pattern proceed as is shown in Fig. 13. With C as center and radii equal to C^1 7, 6, 5, 4, etc., in Fig. 12, describe the arcs 7–7, 6–6, 5–5, 4–4, etc., in Fig. 13 as shown. Now assuming that the seam is to come on the short side of the cone, as C B in Fig. 11, set the dividers equal to one of the equal spaces in the plan; and starting on the arc 7–7 in Fig. 13, step from arc 7 to arc 6, to arcs 5, 4, 3, 2, and 1, and then continue to arcs 2, 3, etc., up to 7. Trace a line through these intersections as shown by 7–1–7, and draw lines from 7 and 7 to C, which completes the pattern.

Now to prove that any section of an oblique or scalene cone cut parallel to its base, has a similar shape to its base (differing in size), draw any line as *a b* in Fig. 11 parallel to A B. From C in plan erect a vertical line intersecting the base line A B at *d*, from which draw a line to the apex C, cutting the line *a b* at *e*. Then the distances *e a* and *e b* will be equal; and using *e* as a center and *e b* as radius, describe the circle *a f b i*, which is the true section on *a b*. Then *a b* B A will be the frustum of a scalene cone. Extend the line *a b* parallel to A D, cutting the diagram of triangles in Fig. 12 from *a* to *b*. Then with radii equal to the distances from C^1 to the various intersections on the line *a b*, and using C in Fig. 13 as center, intersect similarly numbered radial lines drawn from 7 to 1 to 7 to the apex C. A line traced as shown from 7′ to 1′ to 7′ will be the desired cut, and 7–7–7′–7′ will be the pattern for the frustum. The practical use of this method is shown in diagram V in Fig. 11; *a′* is the frustum of the oblique cone, on the ends of which are connected round pipes *b′* and *c′*.

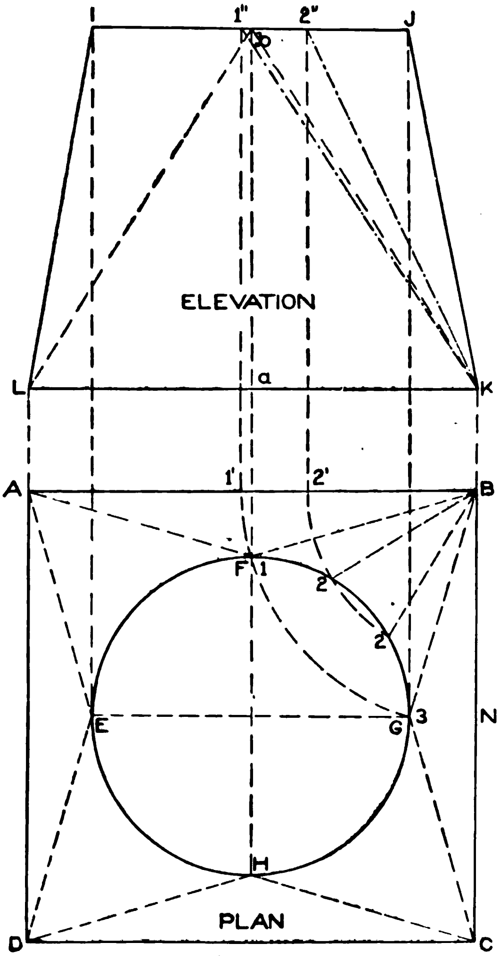


Fig. 14.

It is shown in Fig. 14 how in an irregular solid whose base is square and top is round, both top and bottom on horizontal planes are developed. The corners in plan F B G, G C H, H D E and E A F should be considered as sections of scalene cones. Proceed by drawing the plan A B C D 3½ inches square, which represents the plan of the base of the article; and the circle E F G H $2\frac{1}{2}$ inches in diameter, which shows the plan of the top of the article; the vertical height to be 3 inches, shown from *a* to *b*. As the circle is in the center of the square, making the four corners symmetrical, it is necessary only to divide the one-quarter circle into a number of equal parts as shown by the small figures 1, 2, 2, 3, from which draw lines to the apex B. Complete the elevation as shown by I J K L. Now using B as center, and radii equal to B 1 and B 2 in plan, describe arcs intersecting A B at 1′ and 2′ as shown. From these points erect perpendiculars intersecting the top of the article I J

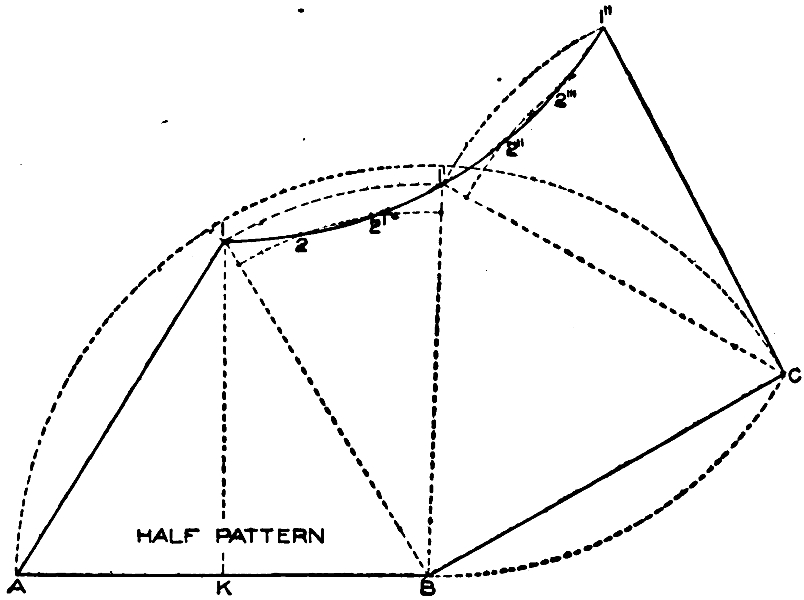


Fig. 15.

in elevation at 1″ and 2″, from which draw lines to K. Then K 1″ and K 2″ will be the true lengths of the lines shown in plan by B 1 and B 2 respectively on the finished article.

For the half pattern proceed as follows: In Fig. 15 draw any horizontal line, as A B, equal in length to A B in plan in Fig. 14. Now with K 1″ as radius and A and B in Fig. 15 as centers, describe arcs intersecting each other at 1 From 1 drop a vertical line intersecting A B at K. Then 1 K should equal J K in elevation in Fig. 14, which represents the true length through G N in plan.

Now with radii equal to K 1″ and K 2″ in elevation, and with B in Fig. 15 as center, describe the arcs 1–1′ and 2–2′. Now set the dividers equal to one of the spaces in G F in plan in Fig. 14; and starting at 1 in Fig. 15, step off arcs having similar numbers as shown by 1, 2, 2′, 1′. Now using 1 B as radius, and 1′ as center, describe the arc B C, and intersect it by an arc struck from B as center and with B A as radius, as shown at C. Take a tracing of 1 B 1′ and place it as shown by 1′ C 1″. Now connect the various intersections by drawing lines from 1 to A to B to C to 1″ to 1′ to 1, which completes the half pattern. The triangular pieces 1 A B or 1′ B C will represent the flat sides of the article shown in plan by 1 A B or 3 B C respectively in Fig. 14; and the cone patterns 1–1′ B and 1′–1″ C in Fig. 15, the sections of the scalene cones 1–3–B and H–G–C respectively in plan in Fig. 14. This same rule is applicable whether the top opening of the article is placed exactly in the center of the base or at one side or corner. Various problems of this nature will arise in Practical Workshop Problems; and if the principles of this last problem are thoroughly understood, these will be easily mastered.

Approximate Developments. In developing the blanks or patterns for sheet-metal work which requires that the metal be hammered or raised by hand, or passed between male and female dies in foot or power presses, circular rolls, or hammering machines, the blanks or patterns are developed by the approximate method, because no accurate pattern can be obtained. In all raised or pressed work in sheet metal, more depends upon the skill that the workman has with the hammer, than on the patterns, which are but approximate at their best. While this is true, it is equally true that if the workman understands the scientific rule for obtaining these approximate patterns a vast amount of time and labor can be saved in bringing the metal to its proper profile. If the true rule for averaging the various shapes and profiles in circular work is not understood, the result is that the blank has either too little or too great a flare and will not form to its proper profile and curve. Before proceeding to describe the approximate development methods, attention is called to the governing principle underlying all such operations. We have previously shown how the patterns are developed for simple flaring ware; in other words, how to develop the frustum of a cone. The patterns for curved or any other form of circular or hammered work are produced upon the same principle. The first illustration of that principle is shown in Fig. 16, in which A B C D represents a sphere 3 inches in diameter composed of six horizontal sections, struck from the center *a*.

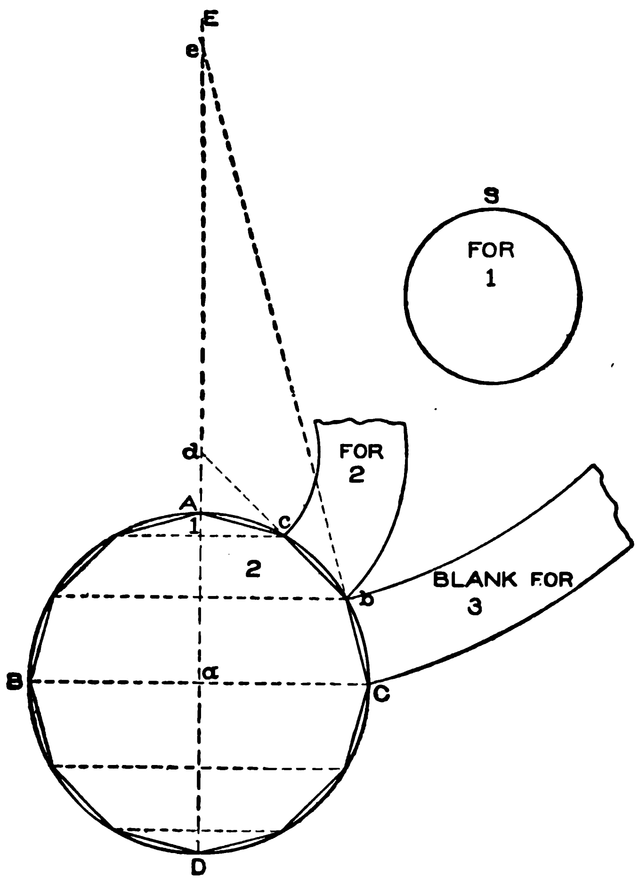


Fig. 16.

Divide the quarter circle A C into as many parts as there are sections required in the half sphere (in this case three), and draw horizontal lines through the ball as shown. The various radii for the patterns are then obtained by drawing lines through C *b*, *b c*, and *c* A. Thus C *b* extended meets the center line E D at *e*, which is the center for striking the blank for number 3, using the radii *e b* and *e* C. In similar manner draw a line from *b* to *c*, extending it until it meets E D at *d*. Then *d c* and *d b* will be the radii for blank number 2, while A *c* is the radius for blank 1 shown at S. The lengths of the pattern pieces are determined in the same manner as would be the case with an ordinary flaring pan in producing the patterns for tin ware, and will be explained

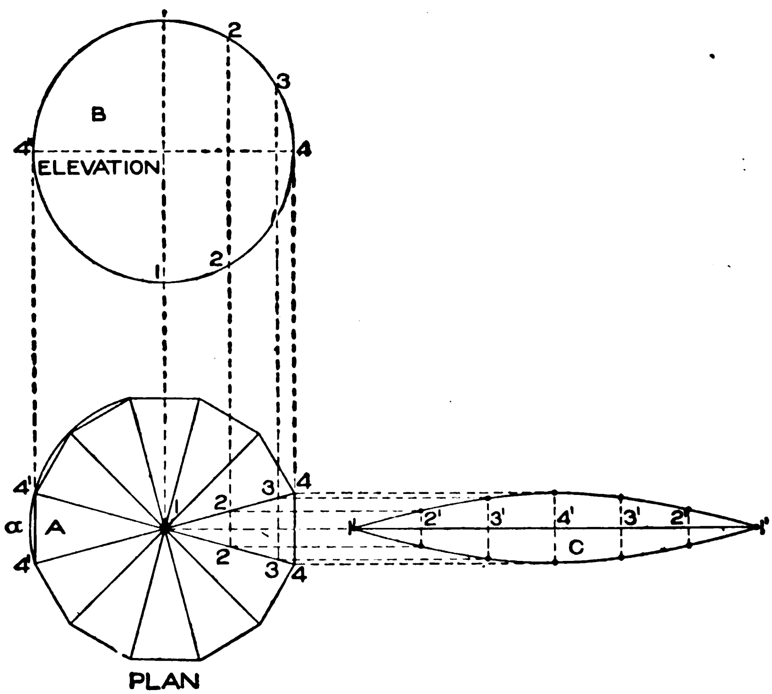


Fig. 17.

thoroughly in the Practical Workshop Problems which will shortly follow.

In Fig. 17 is shown another elevation of a sphere composed of twelve vertical sections as shown in plan view. While the method used for obtaining the pattern is by means of parallel lines, and would be strictly accurate if the sections in plan remained straight as from 4 to 4, the pattern becomes approximate as soon as we start to raise it by means of machine or hammer to conform to the profile B in elevation, because the distance along the curve *a* from 4′ to 4′

in plan is greater than a straight distance from 4 to 4. The pattern by this method is obtained as follows: Let B represent the elevation of the sphere, and A the plan of the same, which is divided into as many sides as the sphere is to have vertical sections, in this case 12, being careful that the two opposite sides 4–4 and 4′ 4′ in plan run parallel to the center line as shown. Make the diameter of the sphere 4–4″ 3 inches. Divide the half elevation into an equal number of spaces as shown from 1 to 4 to 1, and from these points drop lines at right angles to 4–4″ intersecting the miter lines 1–4 in plan as shown. Now draw any horizontal line, as 1′–1′, upon which place the stretchout of 1–4–1 in elevation as shown by 1′–4′–1′ on the line 1′–1′ in C. Through these points draw lines at right angles to 1′–1′, which intersect by lines drawn from similarly numbered intersections on the miter lines 1–4 in plan, at right angles to 4–4. A line traced through points thus obtained as shown by C will be the desired pattern.

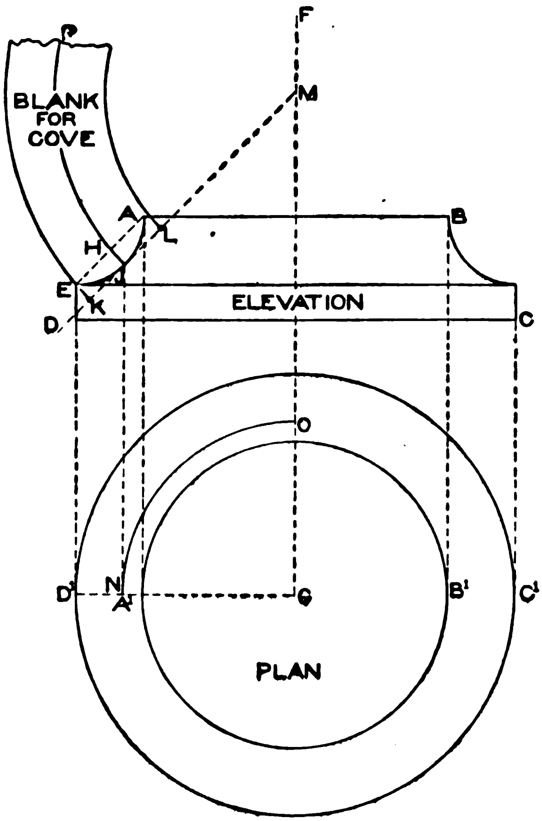


Fig. 18.

In Fig. 18 is shown the principle used in obtaining the radii with which to develop the blank for a curved or circular mould when it is to be hammered by hand. In this connection, only the principle employed will be shown, leaving the full development and also the development for patterns which are to be raised by hand

and hammered by machine, to be explained in problems which will follow in Practical Workshop Problems. Draw this problem double the size shown. First draw the elevation A B C D, and through the elevation draw the center line F G. Then using G as a center, draw the circles A^1 B^1 and C^1 D^1 representing respectively the horizontal projections of A B and C D in elevation. Now draw a line from A to E in elevation, connecting the corners of the cove as shown. Bisect A E and obtain the point H, from which at right angles to A E draw a line intersecting the cove at J. Through J parallel to A E draw a line intersecting the center line F G at M. Take the stretchout from J to A and from J to E and place it on the line J M as shown respectively from J to L and from J to K. Then will M L and M K be the radii with which to strike the pattern or blank for the cove. From J drop a vertical line intersecting the line D^1 G in plan at N. Then with G as center strike the quarter circle N O. Now using M as center and M J as radius, strike the arc J P. Then on this arc, starting from J, lay off 4 times the stretchout of N O in plan for the full pattern. It should be understood that when stretching the cove A E, the point J remains stationary and the metal from J to L and from J to K is hammered respectively toward J A and J E. For this reason is the stretchout obtained from the point J.

PRACTICAL WORKSHOP PROBLEMS.

In presenting the 32 problems which follow on sheet-metal work, practical problems have been selected such as would arise in every-day shop practice.

In this connection we wish to impress upon the student the necessity of working out each and every one of the 32 problems. Models should be made from stiff cardboard, or, if agreeable to the proprietor of the shop, the patterns can be developed at home, then cut out of scrap metal in the shop during lunch hour, and proven in this way.

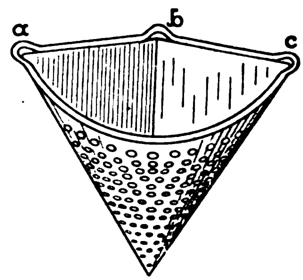


Fig. 19.

Our first problem is shown in Fig. 19, and is known as a sink drainer. It is often the case that the trap under the kitchen sink is choked or blocked, owing to a collection of refuse matter. To avoid this a sink drainer is used, and is fastened in position through the wire loops *a*, *b* and *c*. The refuse matter is poured into the drainer, from which it is easily removed after the fluid has passed through the perforations. These drainers may be made of tin or of black or galvanized iron, but where a good job is wanted 16-ounce copper should be used. To obtain the pattern for any sized drainer, proceed as follows: First draw the plan of the drainer A B C in Fig. 20, making A B and B C each two inches and forming a right angle. Then using B as center and A B as radius, draw the arc A C. In its proper position above the plan construct the side elevation, making E D 2 inches high, and draw the line F D. Then will F E D be the side elevation. Divide the arc A C into equal spaces as shown by the small figures 1 to 5. For the pattern use F D as radius, and with D in Fig. 21 as center strike the arc 1 5. From 1 draw a line to D and step off on 1–5 the same number of spaces as contained in A C in plan in Fig. 20, as shown by similar figures in Fig. 21. Draw a line from 5 to D. Then will 1–5–D be the pattern for the front of the strainer, in which perforations should be punched as shown. To join the sides of this pattern, use 1 and 5 as centers, and with either F E or A B in Fig. 20 as radius, describe the arcs E and E[1] in Fig. 21. Now using D as center and D E in Fig. 20 as radius, intersect the arcs E and E[1] as shown in Fig. 21. Draw lines from 1 to E[1] to D to E to 5, which completes the pattern, to which edges must be allowed for wiring at the top and seaming at the back.

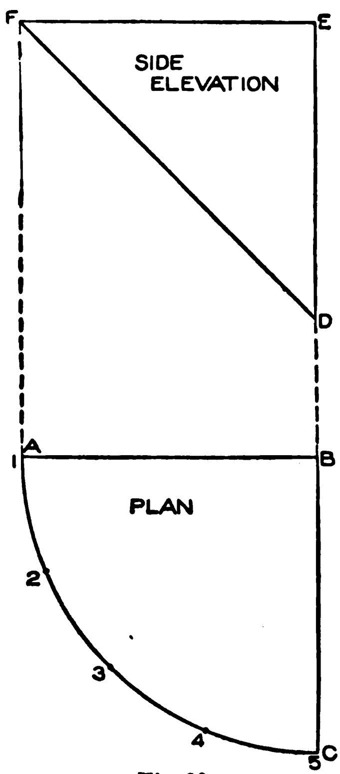


Fig. 20.

When joining a faucet or stop cock to a sheet-metal tank it is usual to strengthen the joint by means of a conical "boss," which is indicated by A in Fig. 22. In this problem the cone method is employed, using principles similar to those used in developing a frustum of a cone intersected by any line. Therefore in Fig. 23 let

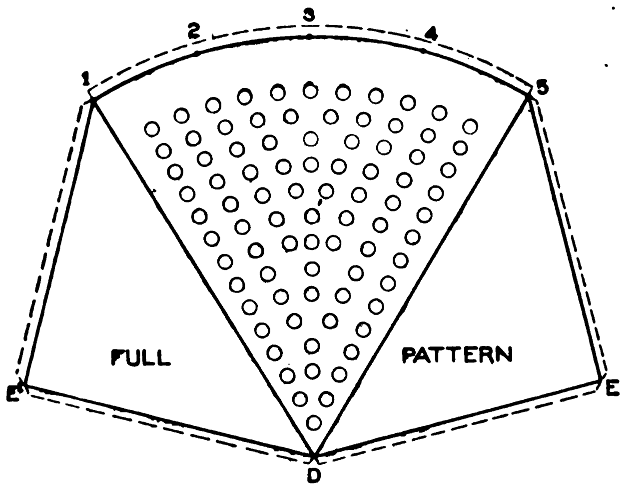


Fig. 21.

A B represent the part plan of the tank, C portion of the faucet extending back to the tank line, and F G H I the conical "boss" to fit around a faucet. When drawing this problem make the radius of the tank D A equal to 3½ inches, and from D draw the vertical line D E. Make the distance from G to H equal to 2¾ inches, the diameter of the faucet F I 1¼ inches and the vertical height K C 1½ inches Draw a line from G to H intersecting the center line D E at K. Then using K as center describe the half section G J H as shown. Divide J H into equal parts shown from 1 to 4, from which drop vertical lines intersecting the line G H as shown, from which draw radial lines to the apex E cutting the plan line

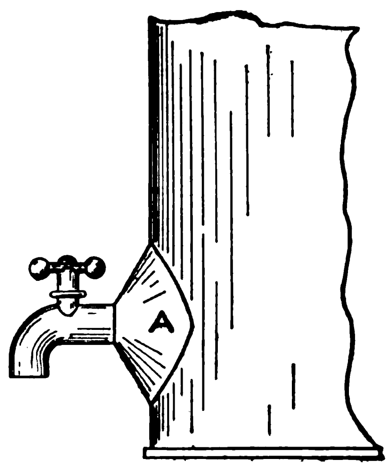


Fig. 22.

LOCOMOTIVE CRANE USED IN SEWER TRENCH CONSTRUCTION
Metropolitan Water and Sewerage System of Boston, Mass.

of the tank A B as shown. From these intersections draw horizontal lines intersecting the side of the cone H I at 1, 2′, 3′, and 4′. Now use E as center, and with radius equal to E 1 describe the

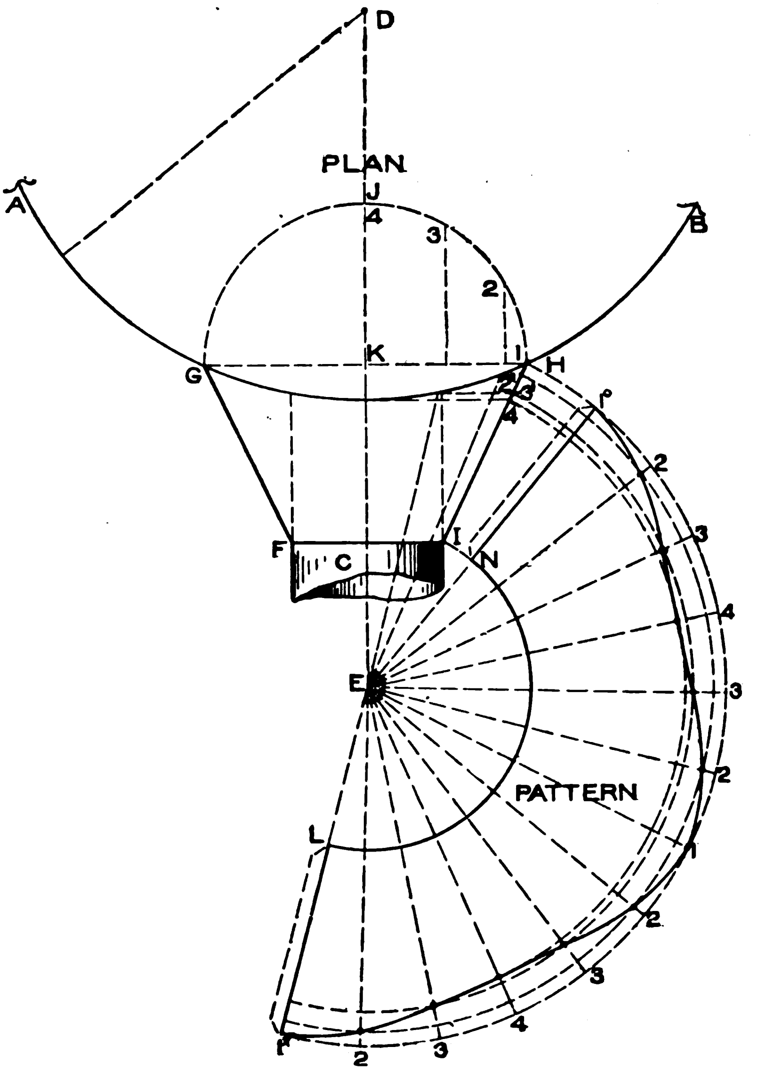


Fig. 23.

arc 1°–1^x as shown. Draw a line from 1° to E, and starting from 1° set off on 1°–1^x four times the number of spaces contained in

J H in plan, as shown by similar numbers on 1° 1^x. Draw a line from 1^x to E, and with E I as radius describe the arc N L intersecting the radial lines 1° E and 1^x E at N and L respectively. From the various numbers on the arc 1° 1^x draw radial lines to the apex E; and using E as center and with radii equal to E 4′, E 3′, and E 2′, draw arcs intersecting similarly numbered radial lines as shown. Trace a line through points thus obtained; then will N 1° 1 1^x L be the pattern for the "boss."

In Fig. 24 is shown what is known as a hip bath. In drawing out the problem for practice the student should remember that it is similar to the preceding one, the only difference being in the outline of the cone. Make the top of the cone I B in Fig. 25 equal to 3¼ inches, the bottom C D 1¾ inches, the vertical height from K to 5′ 2⅓ inches, the diameter of the foot E F 2¼ inches, and the vertical height 5′–5″ ¼-inch. Through the center of the cone draw the center line K L, and at pleasure draw the outline of the bath as shown by A J B. It is immaterial of what outline this may be, the principles that follow being applicable to any case. Thus, in the side elevation, extend the lines B C and A D until they intersect the center line at L. In similar manner extend the sides of the foot piece E D and F C until they intersect the center line at R. Now with 5′ as center and with radius equal to 5′ D or 5′ C, describe the half section C H D, which divide into equal spaces as shown by the small figures 1 to 9. From the points of division erect vertical lines meeting the base line of the bath D C at points 1, 2′, 3′, etc., to 9. From the apex L and through these points draw radial lines intersecting the outline B J A, from which horizontal lines are drawn intersecting the side of the bath B C as shown from 1 to 9. For the pattern for the body use L as center, and with L C as radius draw the arc F L^1. Now starting at any point, as 1, set off on F L^1 twice the stretchout of D H C as shown by similar numbers on the arc F L^1. From the apex L and through the small figures draw radial lines, which intersect by arcs

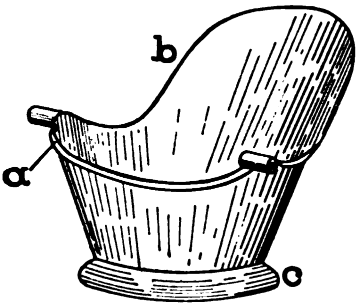


Fig. 24.

struck from L as center with radii equal to similarly numbered intersections on B C. Trace a line through points thus obtained, and L^1 M N P F will be the pattern for the body of the bath, to which laps should be added at the bottom and sides for seaming.

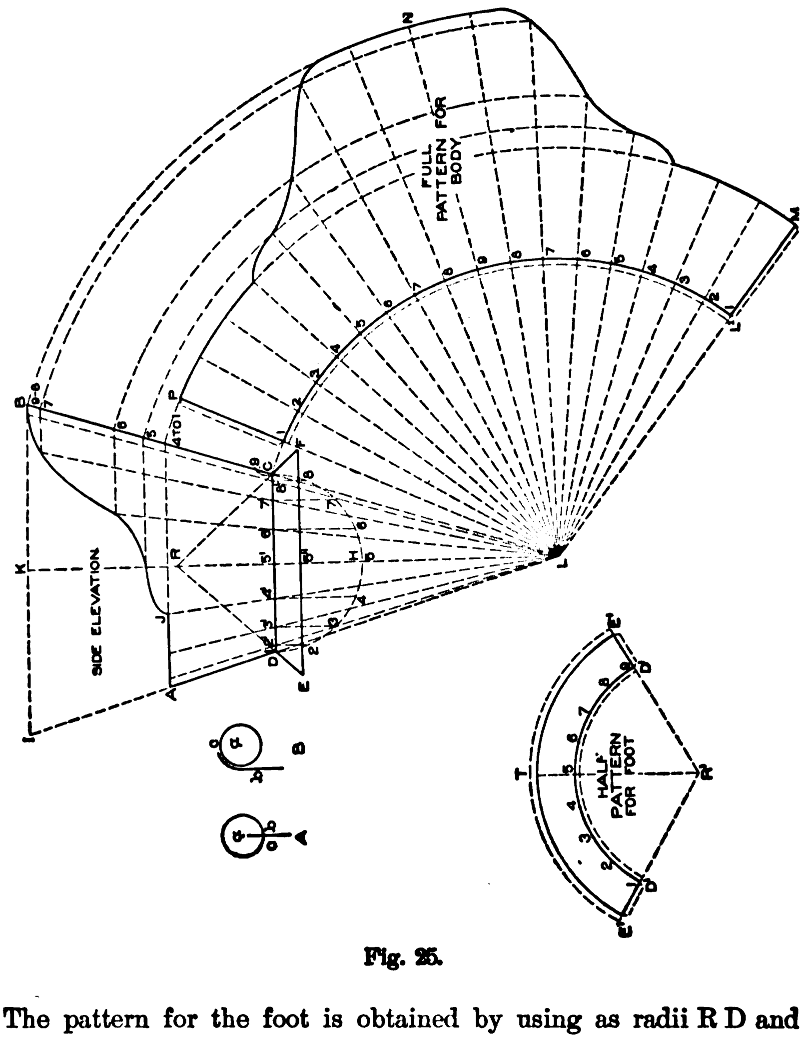


Fig. 25.

The pattern for the foot is obtained by using as radii R D and R E, and striking the pattern using R^1 as center, the half pattern being shown by E^1 T E^1 D^1 D^1, and the distance D^1 D^1 being equal to the stretchout of the half section D H C in side elevation.

It is usual to put a bead along the edges of the top of a bath as shown at *a* and *b* in Fig. 24. For this purpose tubing is sometimes used, made of brass, zinc, or copper and bent to the required shape; or zinc tubes may be rolled and soldered by hand, filled with heated white sand or hot rosin, and bent as needed. The tube or bead can be soldered to the body as shown in (A) in Fig. 25. Here *a* represents the bead, in which a slot is cut as *c*, and which is then slipped over the edge of the bath and soldered. Another method is shown in (B), in which the bath body *b* is flanged over the bead *a* and soldered clean and smooth at *c*, being then scraped and sandpapered to make a smooth joint. A wired edge is shown at *c* in Fig. 24, for which laps must be allowed as shown in Fig. 25 on the half pattern for foot.

In Fig. 26 is shown the perspective view of a bath tub; these tubs are usually made from IX tin or No. 24 galvanized iron. The bottom and side seams are locked and thoroughly soldered, while the top edge is wired with handles riveted in position as shown at A. The method used in developing these patterns will be the cone method and triangulation. In drawing this problem for practice (Fig. 27), first draw the center line W 8 in plan; and using *a* as center with a radius equal to 1½ inches draw the semicircle C–12 D. Now make the distance *a* to *b* 4 inches; and using *b* as center with a radius of 1⅝ inches draw the semicircle E–7–H. Draw lines from E to D and from C to H. D E 7 H C 12 D will be the plan of the bottom of the bath. In this case we assume that the flare between the top and bottom of the narrow end of the bath should be equal; therefore using *a* as center and with a radius equal to 1⅝ inches draw the semicircle A W B. At the upper end of the bath the flare will be unequal; therefore from *b* measure a distance on line W 8 of 1 inch and obtain *c*, which use as center, and with a radius equal to 2 inches describe the arc F 8 G. Draw lines from F to A and from B to G; and A F 8 G B W A will be the plan of the top of the bath. Now project the side elevation from the plan as shown by the dotted lines, making the slant height from I to R 2⅛ inches and from J to K 3⅛ inches; draw a line

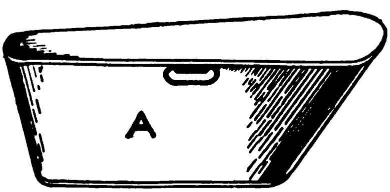


Fig. 26.

from K to R, and J K R I will be the side elevation of the bath tub. In constructing the bath in practice, seams are located at H G, F E,

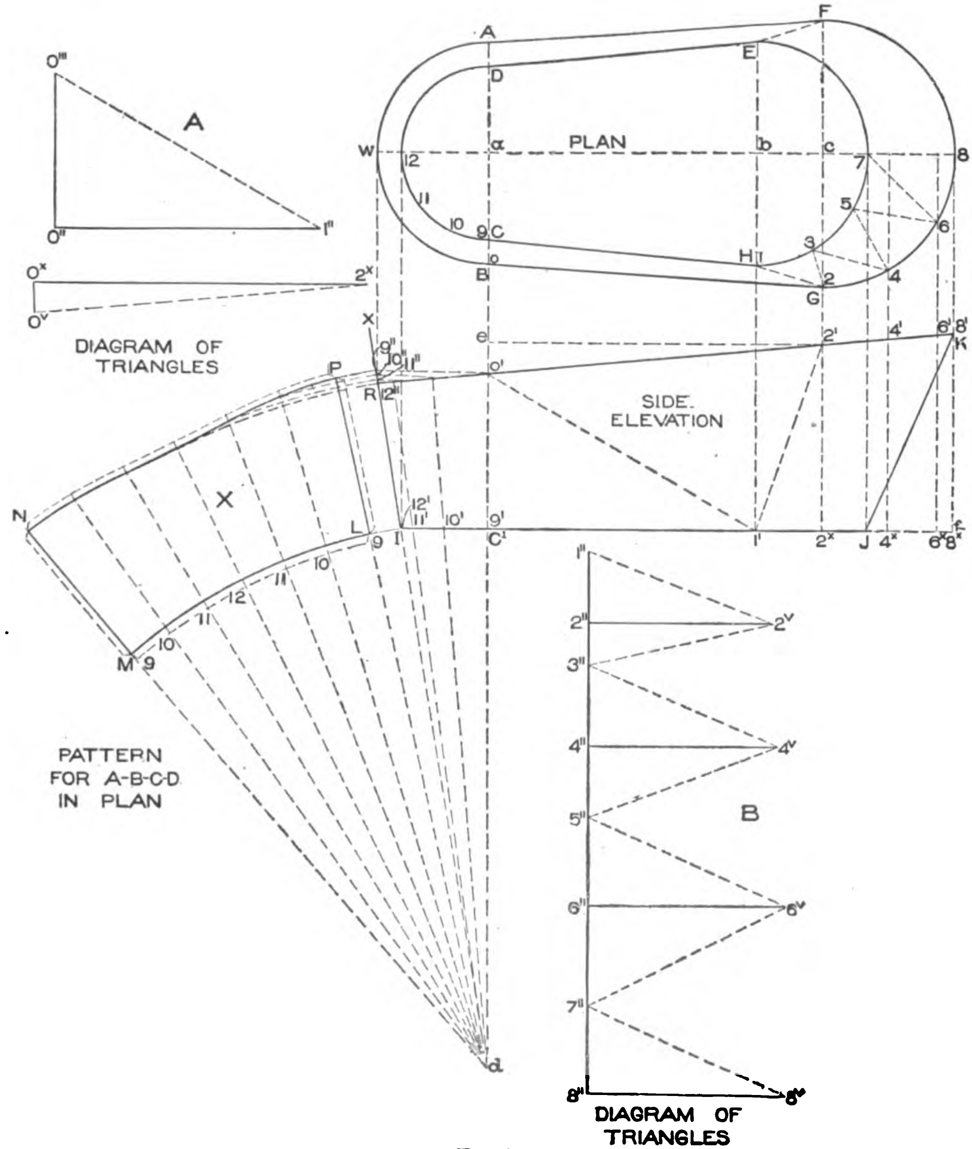


Fig. 27.

A D, and C B in plan, thus making the tub in four pieces

The lower end of the bath will be developed by the cone method as in the last two problems. From the center *a* drop a line indefinitely as shown. Extend the side R I of the side elevation until it meets the center line *a d* at *d*. Now divide the quarter circle 12–9 in plan into equal spaces as shown by the small figures 9, 10, 11, and 12, from which drop vertical lines (not shown) intersecting the bottom of the bath tub in elevation from 9′ to 12′. Then through these points from *d* draw lines intersecting the top line of the bath R K as shown, from which draw horizontal lines intersecting the side I–R extended as I X at points 9″ to 12″. Then using *d* as center and *d* I as radius, describe the arc I M, upon which place the stretchout of D 12 C in plan, as shown by similarly numbered points on L M. Through these points from *d* draw radial lines, which intersect by arcs drawn from similarly numbered intersections on I R extended, using *d* as center. Trace a line as shown, and L M N P will be the pattern for the lower end of the tub A B C D in plan. Laps should be allowed for wiring and seaming.

As the patterns for the upper end and sides will be developed by triangulation, diagrams of triangles must first be obtained, for which proceed as follows: Divide both of the quarter circles H 7 and G 8 in plan into the same number of spaces as shown respectively from 1 to 7 and from 2 to 8. Connect these numbers by dotted lines as shown from 1 to 2, 2 to 3, 3 to 4, etc. From the various points 2, 4, 6, and 8 representing the top of the bath, drop lines meeting the base line J *f* in elevation at 2^x, 4^x, 6^x, and 8^x, and cutting the top line of the bath at 2′, 4′, 6′, and 8′. Then will the dotted lines in plan represent the bases of the triangles, which will be constructed, whose altitudes are equal to the various heights in elevation. Take the various distances 1 to 2, 2 to 3, 3 to 4, 4 to 5, etc., in plan up to 8, and place them on the vertical line 1″–8″ in (B) as shown from 1″ to 2″, 2″ to 3″, 3″ to 4″, 4″ to 5″, etc., up to 8″. For example, to obtain the true length of the line 6–7 in plan, remembering that the points having even numbers represent the top line of the bath and those having uneven numbers the base line, draw at right angles to 1″–8″ in (B), from 6″, a line equal in height to 6^x–6′ in elevation, and draw a line from 6^v to 7″ in (B), which is the length desired. For the true length of 6–5 in plan it is necessary only to take this distance place it from 6″ to 5″ in (B) and draw a line from 6^v to 5″. In this way each altitude answers for two triangles. In plan draw a line from 1 to 0. Then will two more triangles be necessary, one on the line 1–0, and the other on B G or 0–2. From 2′ in elevation draw a horizontal line, as 2′ *e*, intersecting the vertical line dropped from 0 at *e*. Now take the distances 0 1 and 0 2, and place them in (A) as shown by the horizontal lines 0″–1″ and 0^x–2^x respectively. At right angles to both lines at either end draw the vertical lines 0″–0‴ and 0^x–0^v equal in height respectively to C^1 0′ and *e* 0′ in elevation. Draw in (A) lines from 2^x to 0^v and from 1″ to 0‴, which are the desired lengths. Before proceeding with the pattern, a true section must be obtained on 2′–8′ in side elevation. Take the various distances 2′ to 8′ and place them on the line 2′–8′ in Fig. 28. At right angles to 2′–8′ and through the small figures draw lines as shown. Now measuring in each and every instance from the center line in plan in Fig. 27, take the various distances to points 2, 4, and 6 and place them on similarly numbered lines in Fig. 28, measuring in each case on either side of the line 2′–8′, thus obtaining the intersections 2–4–6. A line traced through these points will be the true section on 2′–8′ in elevation in Fig. 27.

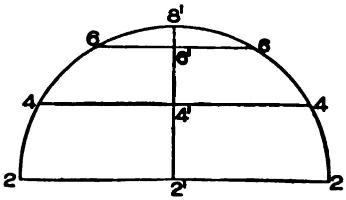


Fig. 28.

For the pattern for the upper end of the tub proceed as follows: Take the distance of 7″–8^v in (B) and place it on the vertical line 7–8 in Fig. 29. Then using 8 as center and with a radius equal to 8′–6 in Fig. 28, describe the arc 6 in Fig. 29, which intersect by an arc struck from 7 as center and with 7″–6^v in (B) in Fig. 27 as radius. Then using 7–5 in plan as radius, and 7 in Fig. 29 as center, describe the arc 5, which intersect by an arc struck from 6 as center and with 6^v–5″ in (B) in Fig. 27 as radius. Proceed in this manner, using alternately as radii first the divisions in Fig. 28, then the length of the slant lines in (B) in Fig. 27, the divisions on 7 H in plan, then again the slant lines in B, until the line 1–2 in Fig. 29 is obtained. Trace a line through points thus obtained, as shown by 2–8–7–1. Trace this opposite the line 8–7, as shown by 2′ 1′. Then will 2–8–2′–1′–7–1 be the desired pattern, to which laps must be allowed.

For the pattern for the side of the bath draw any line 9–1 in Fig. 30 equal to 9–1 in plan in Fig. 27. Now with a radius equal

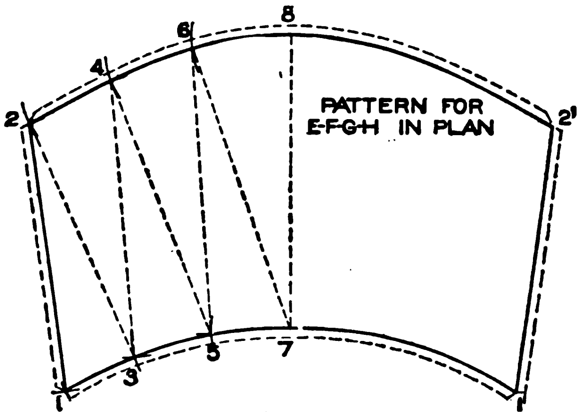


Fig. 29.

to 9–P in the pattern X and with 9 in Fig. 30 as a center, describe the arc 0, which intersect by an arc struck from 1 as center and with 1′–0‴ in (A) in Fig. 27 as radius. Now taking a radius equal to 0^v–2^x in (A) with 0 in Fig. 30 as center, describe the arc 2, which intersect by an arc struck from 1 as center, and with 1–2 in Fig. 29 as radius. Draw lines from corner to corner in Fig. 30, which gives the desired pattern, to which laps are added for seaming and wiring.

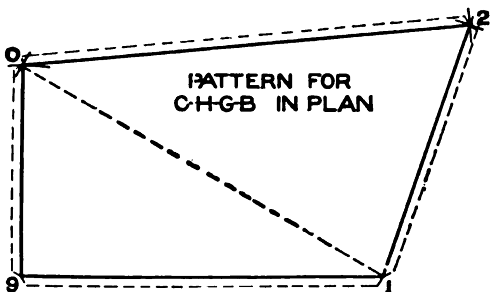


Fig. 30.

In Fig. 31 is shown a perspective view of a funnel strainer pail. These pails are usually made from IX bright tin, and the same principles as are used in the development of the pattern are applicable to similar forms, such as buckets, coal hods, chutes, etc. This problem presents an interesting study in triangulation, the principles of which have been explained in previous problems. First draw the center line C I in Fig. 32, at right angles to which draw H E and H F each equal to $1\frac{1}{4}$ inches. Make the vertical height H C $3\frac{1}{4}$ inches and C D 2 inches. Now make the vertical heights measuring from C G, to A, and to B respectively $1\frac{1}{4}$ inches, and $1\frac{1}{8}$ inches. Make the horizontal distance from C to G $2\frac{3}{4}$ inches, the diameter from G to A $1\frac{5}{8}$ inches, and from A to B $\frac{3}{4}$-inch, and draw a line from B to C. Connect points by lines; then will A B C D E F G be the side elevation of the pail. In its proper position below F E, with J as center, draw the plan K L M N. Also in its proper position draw the section on A G as O P R S Now draw the rear elevation making G^1 U and G^1 V each equal to H E, and 1″ T and 1″–1′ each equal to C D. Project a line from B in side, intersecting the center line in rear at 4′. Then through the three points 1′ 4′ T draw the curve at pleasure, which in this case is struck from the center *a*. W Y X Z represents the opening on G A in side obtained as shown by the dotted lines but having no bearing on the patterns. Pails of this kind are usually made from two pieces, with seams at the sides, as in Fig. 31. The pattern then for the back shown by C D E H in side elevation in Fig. 32 will be obtained by the cone method, struck from the center I, the stretchout on E^1 E^2 in the pattern being obtained from the half plan. The pattern for C D E H is shown with lap and wire allowances by D^1 D^2 E^2 E^1 and needs no further explanation.

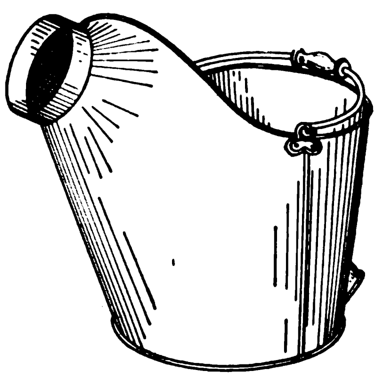


Fig. 31.

The front part of the pail shown by A B C H F G will be developed by triangulation, but before this can be done a true section must be obtained on B C, and a set of sections developed as follows: Divide one-half of 1′ 4′ T in rear elevation into equal parts as shown from 1′ to 4′, from which draw horizontal lines intersecting the line B C as shown. From these intersections lines are drawn at right angles to B C equal in length to similarly numbered lines in rear as 3′–3″, 2′–2″, and 1′–1″. Trace a line as shown, so that C 1‴ 2‴ 3‴ 4‴ will be the true half section on B C. To avoid a confusion of lines take a tracing of A B C H F G and place it as shown by similar letters in Fig. 33. Now take tracings of the half sections in Fig. 32, as H E D C, C 1‴ B, P O S, and the quarter plan N J M, and place them in Fig. 33 on similar lines on which they represent sections as shown respectively by H 9′ 8′ C, C 8 B, A 3 G, and F 9 H. Divide the half section

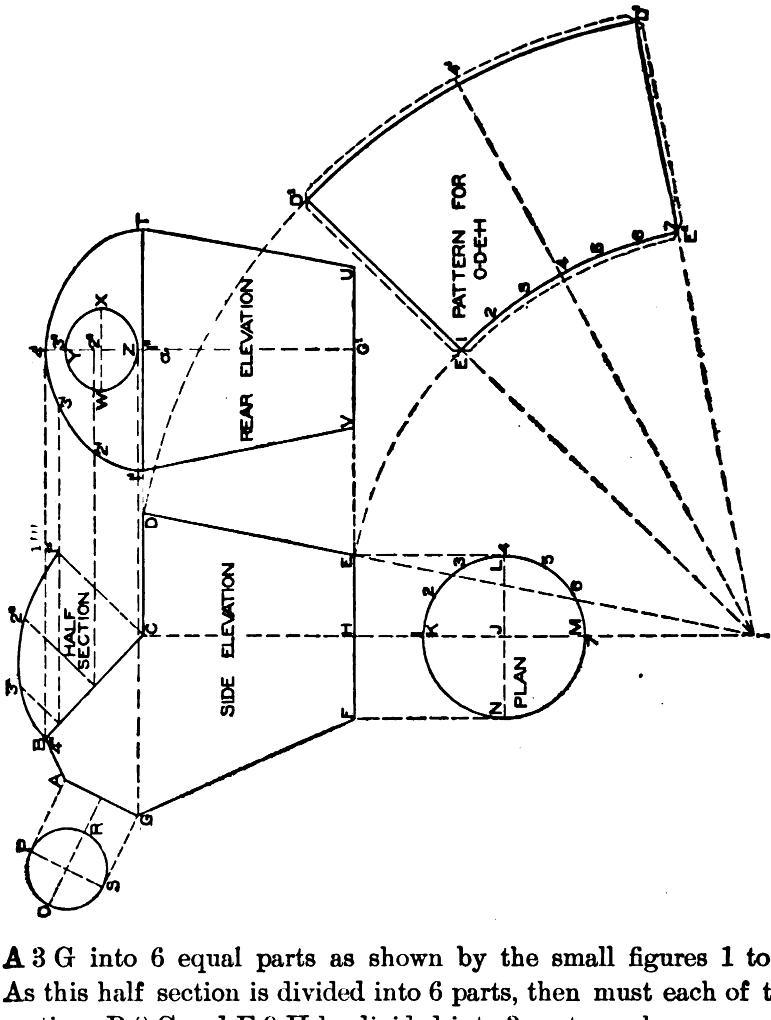


Fig. 32.

A 3 G into 6 equal parts as shown by the small figures 1 to 5. As this half section is divided into 6 parts, then must each of the sections B 8 C and F 9 H be divided into 3 parts as shown respectively from 6 to 8 and 9 to 11. As C 8′ and H 9′ are equal respectively to C 8 and H 9 they are numbered the same as shown.

Now at right angles to G A, B C, C H, and H F, and from the various intersections contained in the sections G 3 A, B 8 C, C 8′ 9′ H, and H 9 F, draw lines intersecting the base lines of the sections G A, B C, C H, and H F at points shown from 1′ to 11′. Now draw dotted lines from B to 5′ to 6′ to 4′ to 7′ to E to C, and then from H to E to 10′ to 2′, etc until all the points are

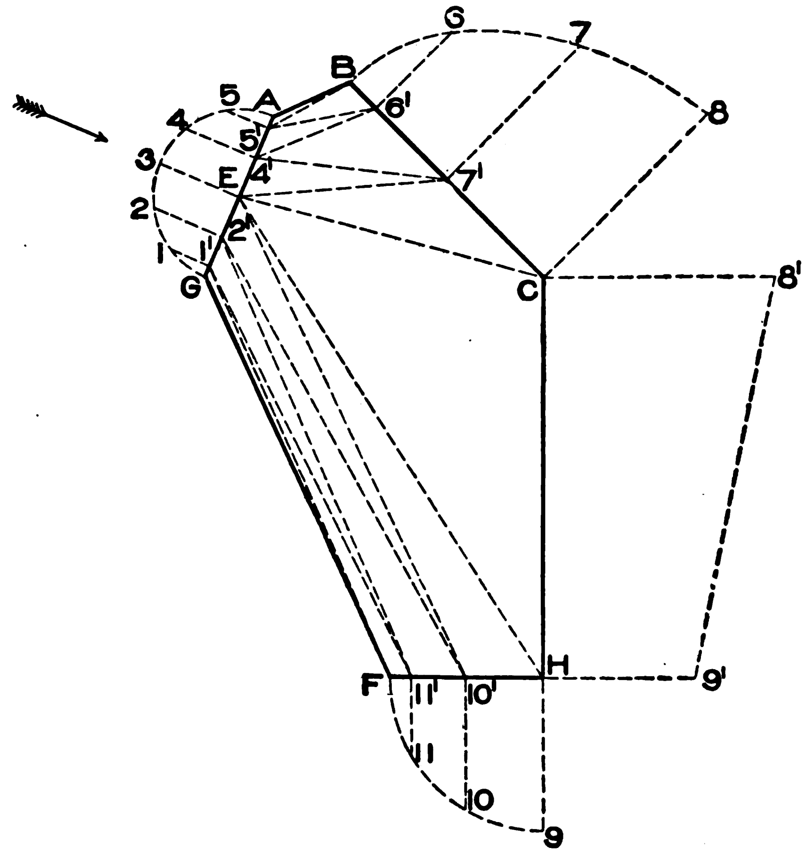


Fig. 33.

connected as shown. These dotted lines represent the bases of the sections whose altitudes are equal to similar numbers in the various sections.

In order that the student may thoroughly understand this method of triangulation as well as similar methods that will follow in other problems, the model in Fig. 34 has been prepared, which shows a perspective of Fig. 33 with the sections bent up in their proper positions. This view is taken on the arrow line in Fig. 33, the letters and figures in both views being similar. For the true sections on the dotted lines in C E A B in Fig. 33, take the lengths of the dotted lines C E, E 7', 7' 4', etc., and place them on the horizontal line in Fig. 35 as shown by similar letters and figures. From these small figures, at right angles to the horizontal line, erect the vertical heights C 8, E 3, 7' 7, etc., equal to similar

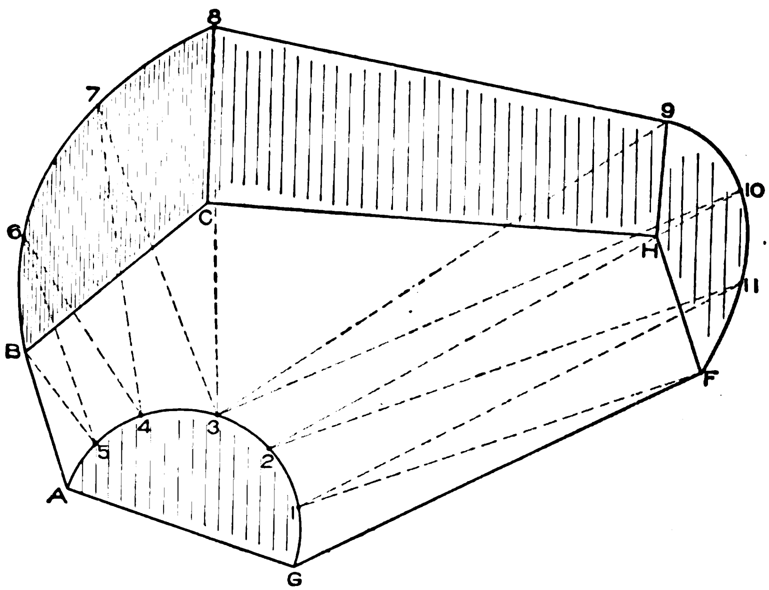


Fig. 34.

vertical heights in the sections in Fig. 33. Connect these points in Fig. 35 by dotted lines as shown, which are the desired true distances.

In Fig. 36 are shown the true sections on dotted lines in G E H F in Fig. 33, which are obtained in precisely the same manner, the only difference being that one section is placed inside of another in Fig. 36. For the pattern proceed as is shown in Fig. 37. Draw any vertical line as G F equal to G F in Fig. 33. With radius equal to G 1 and with G in Fig. 37 as center describe the arc 1, which intersect by an arc struck from F as center and with a radius equal to F 1 in Fig. 36. Now with F 11 in Fig. 33 as radius and F in Fig. 37 as center, describe the arc 11, which is intersected by an arc struck from 1 as center and with 1–11 in Fig 36 as radius. Proceed in this manner until the line 3–9 in Fig. 37 has been obtained. Then using 8′–9′ in Fig. 33 as radius and 9 in Fig. 37 as center, describe the arc 8, which is intersected by an arc struck from 3 as center and with 3–8 in Fig.

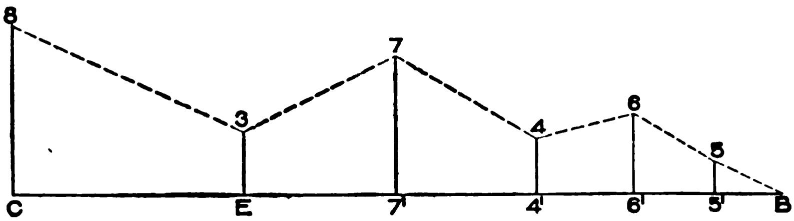


Fig. 35.

35 as radius. Now use alternately as radii, first the divisions in B 8 C in Fig. 33, then the length of the slant lines in Fig. 35, the divisions in E 3 A in Fig. 33, and again the distances in Fig. 35, until the line B A in Fig. 37 has been obtained, which is obtained from B A in Fig. 33. Trace a line through points thus obtained in Fig. 37 as shown by A B 8 9 F G A. Trace this half pattern opposite the line G F. Then will B A G A^1 B^1 8^1

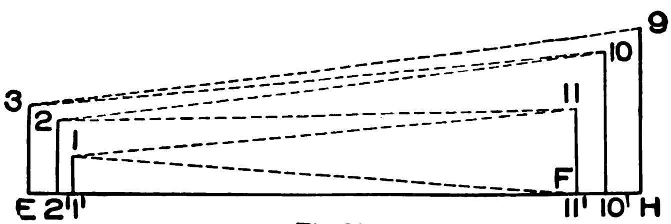


Fig. 36

9^1 F 9 8 be the pattern for the front half of the pail. If for any reason the pattern is desired in one piece, then trace one-half of D^1 D^2 E^2 E^1 in Fig. 32 on either side of the pattern in Fig. 37 as shown by the dotted lines 8′ D^1 E^1 9^1 and 9 E D 8. Allow edges for wiring and seaming.

Fig 38 shows the method for obtaining the pattern for an Emerson ventilator shown in Fig. 39.

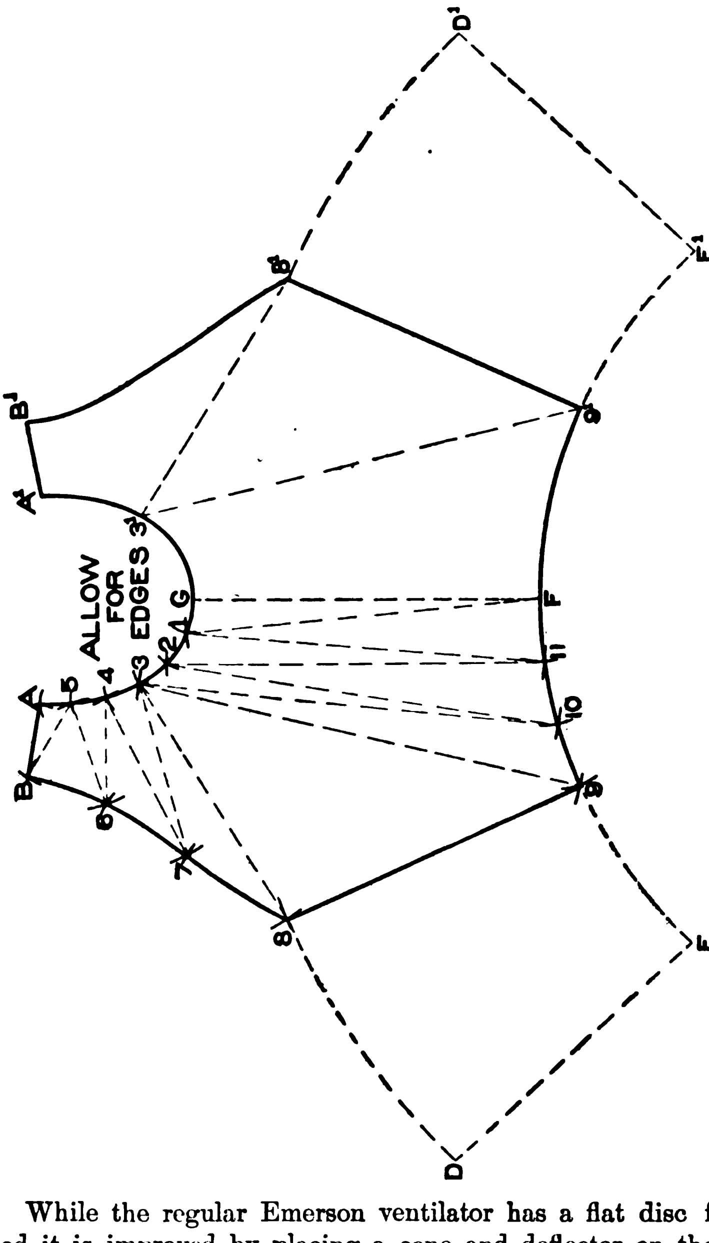


Fig. 37.

While the regular Emerson ventilator has a flat disc for a hood it is improved by placing a cone and deflector on the top as shown. To make the patterns, proceed as shown in Fig. 38. First draw the center line *a b*, on either side of which lay off

1½ inches, making the pipe A, 3 inches in diameter. The rule usually employed is to make the diameter of the lower flare and upper hood twice the diameter of the pipe. Therefore make the diameter of *s d* 6 inches. From *s* and *d*, draw a line at an angle of 45° to intersect the line of the pipe at *t* and *i*; this completes B. Measure 2 inches above the line *t i* and make *u m* the same diameter as *s d*. Draw the bevel of the deflector so that the apex will be ½ inch above the line *t i* and make the apex of the hood the same distance above *u m* as the lower apex is below it. Then draw lines as shown which complete C and D.

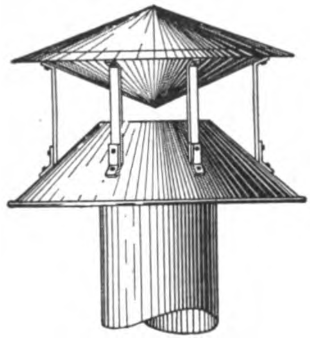


Fig. 39.

Now with *c* as a center and radii equal to *c e* and *c d* draw the quarter circles *e f* and *d h* respectively, which represent the one-

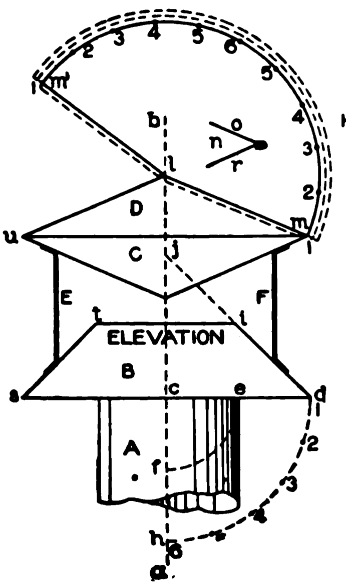


Fig. 38.

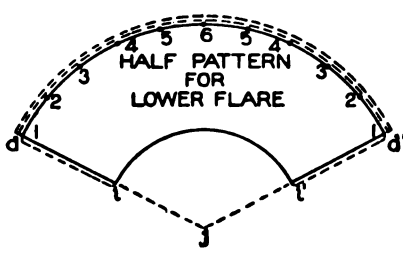


Fig. 40.

quarter pattern for the horizontal ring closing the bottom of the lower flare. For the pattern for the hood, use *l* as a center and *l m* as a radius. Now draw the arc *m m'*. Take the stretchout of the quarter circle 1 to 6 on *d h*, and place twice this amount on *m m'* as shown from 1–6–1. Draw a line from 1 to *l*. Then *m'* 6 *m l*, will be the half pattern for the hood. As the deflector has the same bevel as the hood, the hood pattern will also answer for the deflector.

When seaming the hood and deflector together as shown at *n*, the hood *o* is double-seamed to the deflector at *r*, which allows the water to pass over; for this reason allow a double edge on the pattern for the hood as shown, while on the deflector but a single edge is required. Edges should also be allowed on *e d h f*.

For the pattern for the lower flare, extend the line *d i* until it intersects the center line at *j*. Then with radii equal to *j i* and *j d* and with *j* in Fig. 40 as center describe the arcs *i i'* and *d d'*. On one side as *d* draw a line to *j*. Then set off on the arc *d d'*

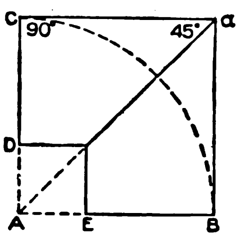


Fig. 41.

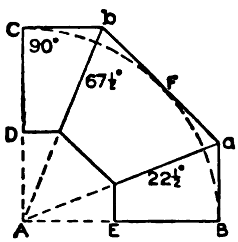
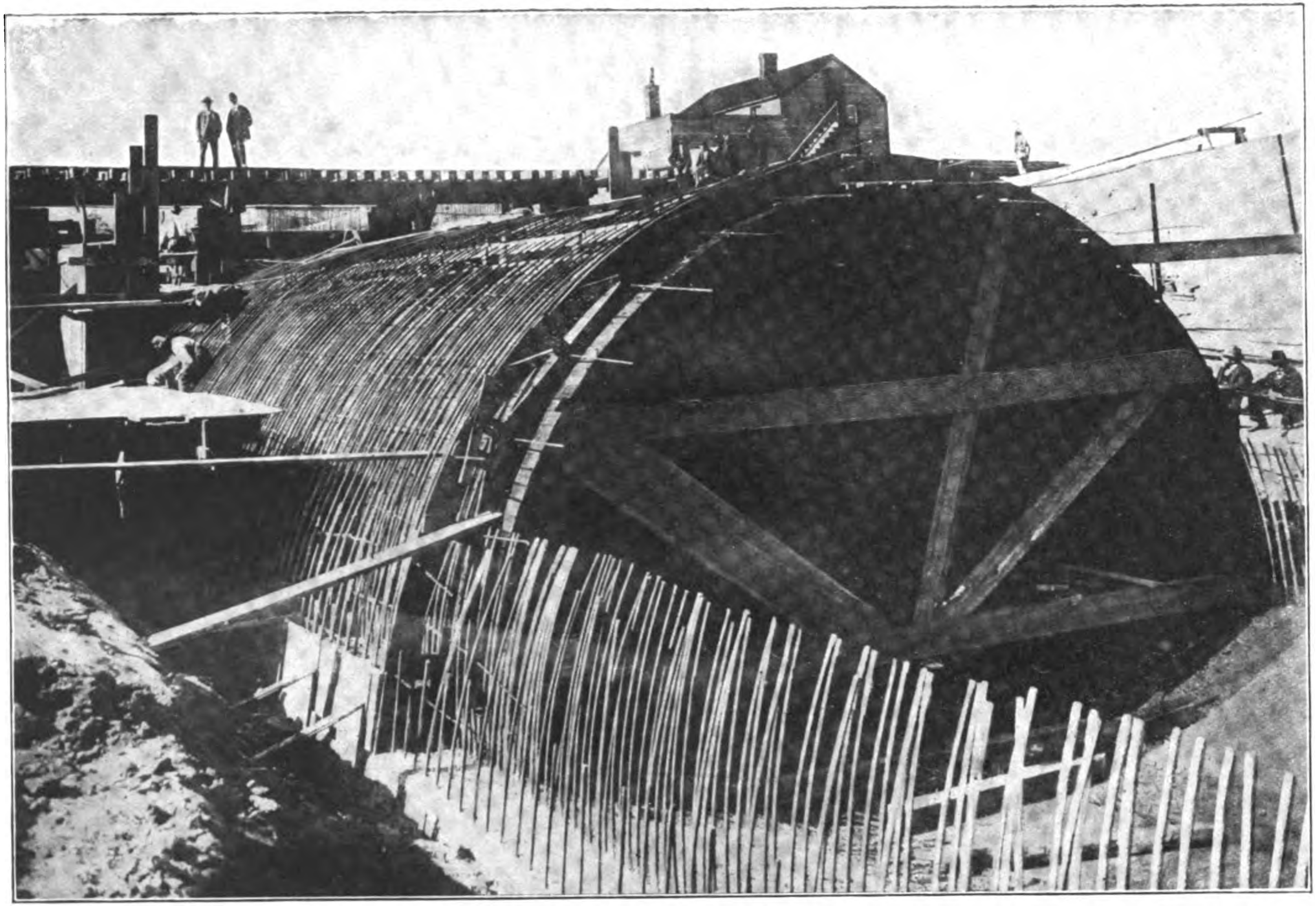


Fig. 42.

twice the number of spaces contained in *d h* in Fig. 38 as shown in Fig. 40. Draw a line from *d'* to i and allow edges for seaming. Then *d d' i' i* will be the half pattern for the lower flare.

The braces or supports E and F, Fig. 38, are usually made of galvanized band iron bolted or riveted to hood and pipe. The hood D must be water tight. or the water will leak into the deflector, from which it will drip from the apex inside the building.

Elbows. There is no other article in the sheet-metal worker's line, of which there are more made in practice than elbows. On this account rules will be given for constructing the rise of the miter line in elbows of any size or diameter, also for elbows whose sections are either oval, square or round, including tapering elbows Before taking up the method of obtaining the patterns, the rule will be given for obtaining the rise of the miter line for any size



HARLEM CREEK PUBLIC SEWER, ST. LOUIS, MISSOURI

View showing forms and reinforcing bars in place. Length of sewer, 4,800 ft. Clear span at lower end, 29 ft.; at upper end, 25 ft. Height, from 19 to 18 ft. Designed for 15-ft. fill.

Courtesy of Expanded Metal & Corrugated Bar Company, St. Louis, Mo.

or number of pieces. No matter how many pieces an elbow has, they join together and form an angle of 90°. Thus when we speak of a two-pieced, three-pieced, four, five or six-pieced elbow, we understand that the right-angled elbow is made up of that number of pieces. Thus in Fig. 41 is shown a two-pieced elbow placed in the quadrant C B, which equals 90° and makes C A B a right angle. From A draw the miter line A *a* at an angle of 45° to the base line A B. Then parallel to A B and A C and tangent to the quadrant at C and B draw lines to intersect the miter line, as shown. Knowing the diameter of the pipe as C D or E B draw lines parallel to the arms of the pipe, as shown. Then C B E D will be a two-pieced elbow, whose miter line is an angle of 45°.

In a similar manner draw the quadrant B C, Fig. 42, in which it is desired to draw a three-pieced elbow. Now follow this simple

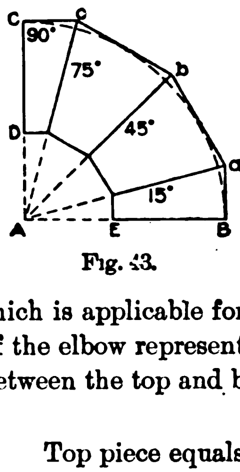


Fig. 43.

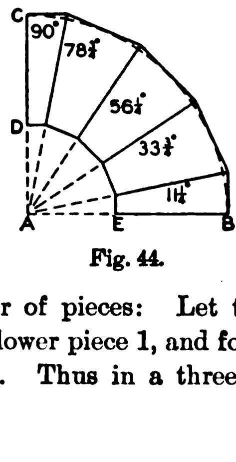


Fig. 44.

rule, which is applicable for any number of pieces: Let the top piece of the elbow represent 1, also the lower piece 1, and for every piece between the top and bottom add 2. Thus in a three-pieced elbow:

Top piece equals	1
Bottom piece equals	1
One piece between	2
Total equals	4

Now divide the quadrant of 90° by 4 which leaves $22\frac{1}{2}°$. As one piece equals $22\frac{1}{2}°$, draw the lower miter line A *a* at that angle to the base line A B. Then as the middle piece represents two by the above rule and equals 45°, add 45 to $22\frac{1}{2}$ and draw the second miter line A *b*, at an angle of $67\frac{1}{2}°$ to the base line A B. Now tangent to the quadrant at C and B draw the vertical and horizontal lines shown, until they intersect the miter lines, from which intersections draw the middle line, which will be tangent to the quadrant at F. C D and B E show the diameters of the pipe, which are drawn parallel to the lines of the elbow shown.

Fig. 43 shows a four-pieced elbow, to which the same rule is applied. Thus the top and bottom piece equals 2 and the two middle pieces equal 4; total 6. Now divide the quadrant of 90° by 6. $\frac{90}{6} = 15$. Then the first miter line A *a* will equal 15°, the second A *b* 45°, the third A *c* 75°, and the vertical line A C 90°.

The last example is shown in Fig. 44, which shows a five-pieced elbow, in which the top and bottom pieces equal 2, the 3 middle pieces 6; total 8. Divide 90 by 8. $\frac{90}{8} = 11\frac{1}{4}$. Then the first miter line will equal $11\frac{1}{4}$°, the second $33\frac{3}{4}$°, the third $56\frac{1}{4}$°, and the fourth $78\frac{3}{4}$°. By using this method an elbow having any number of pieces may be laid out. When drawing these miter lines it is well to use the protractor shown in Fig. 45, which illustrates how to lay out a three-pieced elbow. From the center point A of the protractor draw lines through $22\frac{1}{2}$°, and $67\frac{1}{2}$°. Now set off A *a*, and the diameter of the pipe *a b*. Draw vertical lines from *a* and *b* to the miter line at *c* and *d*. Lay off similar distances from A to *a'* to *b'* and draw horizontal lines intersecting the $67\frac{1}{2}$° miter line at *c'* and *d'*. Then draw the lines *d d'* and *c c'* to complete the elbow. In practice, however, it is not necessary to draw out the entire view of the elbow; all that is required is the first miter line, as will be explained in the following problems.

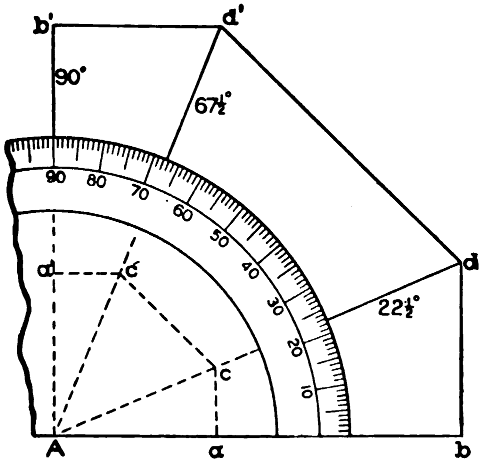


Fig. 45.

EXERCISES FOR PRACTICE.

1. Make the diameter of the pipe $1\frac{3}{4}$ inches and the distances from A to E $1\frac{1}{2}$ inches in Figs. 41 to 44 inclusive.

To obtain the pattern for any elbow, using but the first miter

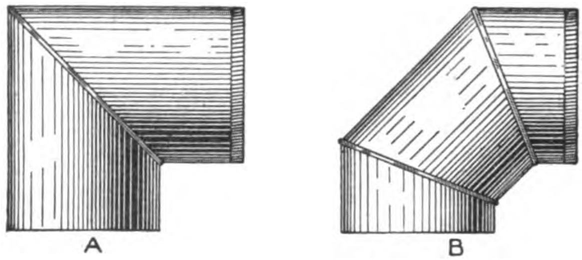


Fig. 46.

line, proceed as follows: In Fig. 46 let A and B represent respectively a two- and three-pieced elbow for which patterns are desired. First draw a section of the elbow as shown at A in Fig. 47 which

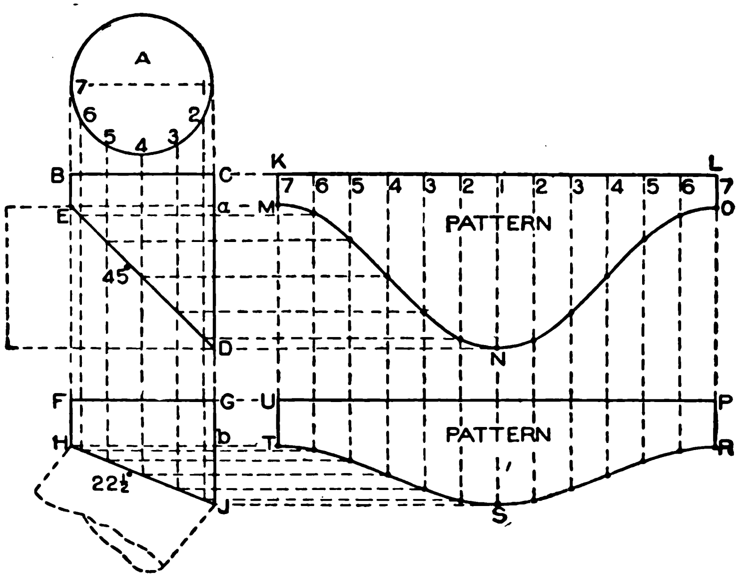


Fig. 47.

is a circle 3 inches in diameter; divide the lower half into equal spaces and number the points of division 1 to 7. Now follow the rule previously given: The top and bottom piece equals 2; then for a two-pieced elbow divide 90 by 2. In its proper position below the section A draw B C D E making E D 45°. From the various points of intersection in A drop vertical lines intersecting E D as

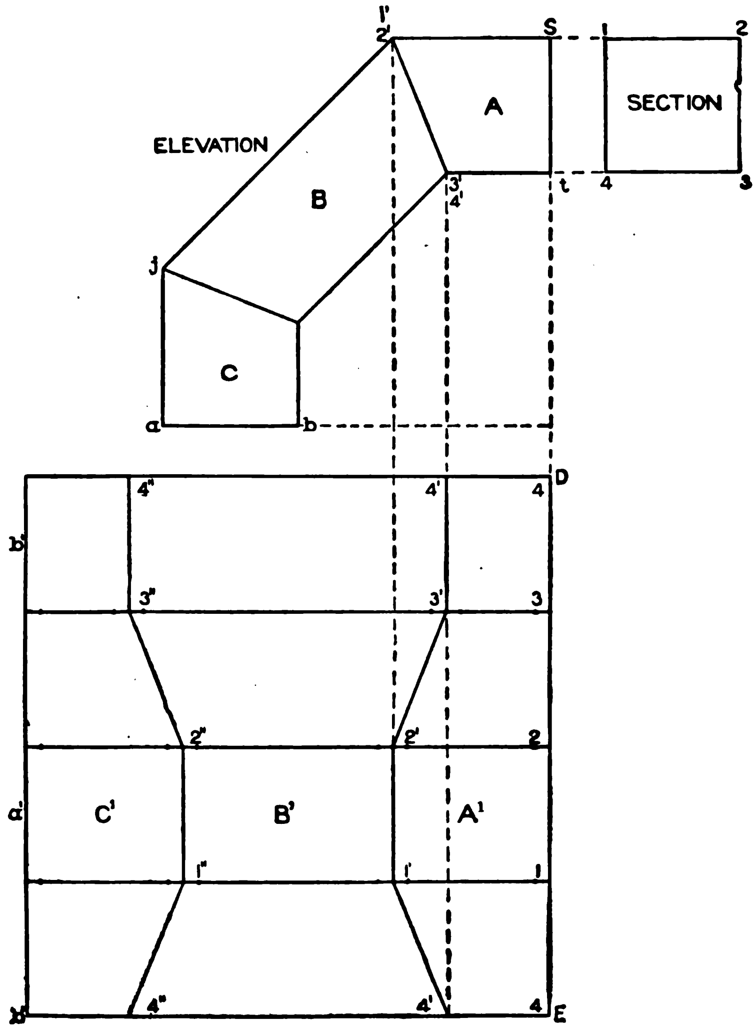


Fig. 48.

shown. In line with B C draw K L upon which place twice the number of spaces contained in the section A as shown by similar figures on K L; from these points drop perpendiculars to intersect with lines drawn from similar intersections on E D, parallel to K L. Trace a line through points shown; then K L O N M will be the pattern. To this laps must be allowed for seaming.

Now to obtain the pattern for a three-pieced elbow, follow the rule. Top and bottom pieces equal 2, one middle piece equals 2; total 4. $\frac{90}{4} = 22\frac{1}{2}$. Therefore in line with the section A below the two-pieced elbow draw F G J H, making H J at an angle of $22\frac{1}{2}°$ to the line H *b*. Proceed as above using the same stretchout lines; then U P R S T will be the desired pattern. It should be understood that when the protractor is used for obtaining the angle as shown in Fig. 45, the heights *a c* and *b* d measured from the horizontal line form the basis for obtaining the heights of the middle pieces, inasmuch as they represent one-half the distance; for that reason the middle pieces count 2 when using the rule. Therefore, the distances F H and G J (Fig. 47), represent one-half of the center piece and U T S R P one-half the pattern for the center piece of a three-pieced elbow.

Fig. 48 shows how the patterns are laid into one another, to prevent waste of metal when cutting. In this example we have a three-pieced elbow whose section is 2 × 2 inches. It is to be laid out in a quadrant whose radius is 5 inches. Use the same principles for square section as for round; number the corners of the section 1 to 4. In line with S *t* draw D E upon which place the stretchout of the square section as shown by similar numbers on D E; from which draw horizontal lines which intersect lines drawn parallel to D E from the intersections 1′ 2′ and 3′ 4′ in A in elevation, thus obtaining similar points in the pattern. Then A^1 will be the pattern for A in elevation. For the pattern for B simply take the distance from 2′ to *j* and place it on the line 4 4′ extended in the pattern on either side as shown by 4′ 4″ on both sides. Now reverse the cut 4′ 2′ 4′ and obtain 4″ 2″ 4″. By measurement it will be found that 4′ 4″ is twice the length of 2′ 2 as explained in connection with Figs. 45 and 47. Make the distance from 1″ to *a′* the same as *j* to *a* in C and draw the vertical line *b′ b′* intersecting the lines 4 4″ extended on both sides. Then A^1, B^1, and C^1 will be the patterns in one piece minus the edges for seaming which must be allowed between these cuts; this would of course make the lengths b′ 4″, 4″ 4′ and 4′ 4 as much longer as the laps would necessitate.

This method of cutting elbows in one piece, from one square is applicable to either round, oval or square sections.

In Figs. 49 and 50 are shown three-pieced elbows such as are

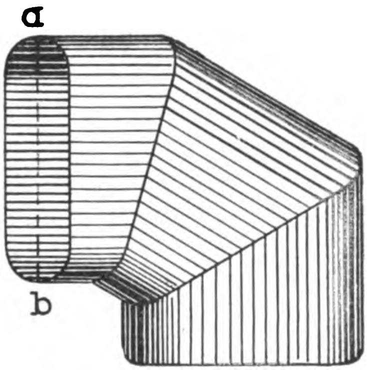


Fig. 49.

Fig. 50.

used in furnace-pipe work and are usually made from bright tin. Note the difference in the position of the sections of the two elbows. In Fig. 49 *a b* is in a vertical position, while in Fig. 50 it is in a horizontal position. In obtaining the patterns the same rule is employed as in previous problems, care being taken when developing the patterns for Fig. 49 that the section be placed as in Fig. 51 at A; and when developing the patterns for Fig. 50, that the section be placed as shown at A in Fig. 52.

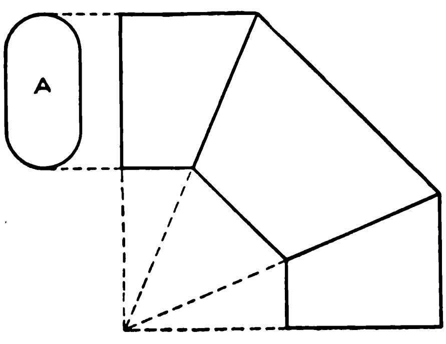


Fig. 51.

Fig. 53 shows a tapering two-pieced elbow, round in section. The method here shown is short and while not strictly accurate, gives good results. It has been shown in previous problems on Intersections and Developments that an oblique section through the opposite sides of a cone is a true ellipse. Bearing this in mind it is evident that if the frustum of the cone H I O N, Fig. 54, were a solid and cut obliquely by the plane J K and the several parts placed side by side, both would present true ellipses of exactly the same size, and if the two parts were placed together again turning the upper piece half-way around as shown by J W M K, the edges

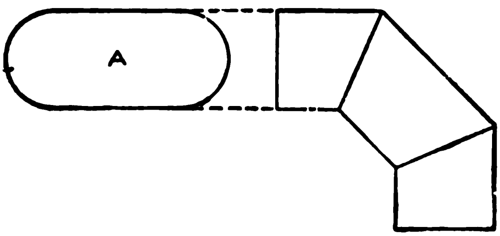


Fig. 52.

of the two pieces from J to K would exactly coincide. Taking advantage of this fact, it is necessary only to ascertain the angle of the line J K, to produce the required angle, between the two pieces of the elbow, both of which have an equal flare. The angle of the miter line, or the line which cuts the cone in two parts, must be found accurately so that when joined together an elbow will be formed having the desired angle on the line of its axis.

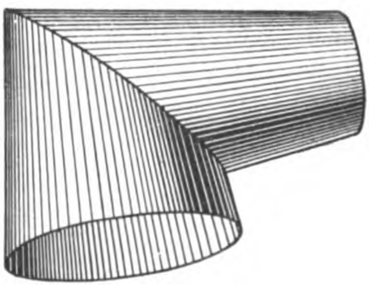


Fig. 53.

Therefore draw any vertical line as A B. With C as a center describe the plan of the desired diameter as shown by E D F B. At right angles to A B draw the bottom line of the elbow H I equal to E F, or in this case, 3 inches. Measuring from the line H I on the line A B the height of the frustum is 5 inches. Through X′ draw the upper diameter O N, 1½ inches. Extend the contour lines of the frustum until they intersect the center line at L. Divide the half plan E D F into a number of equal parts as shown; from these points erect lines intersecting the base line H I from which draw lines to the apex L. As the elbow is to be in two pieces, and the axis at right angles, draw the angle T R S, bisect it at U and draw the line R V. No matter what the angle of the elbow, use this method. Now establish the point J at some convenient point on the cone, and from J, parallel to R V, draw the miter line J K intersecting the radial lines drawn through the cone; from these points and at right angles to the center line A B draw lines intersecting the side of the cone J H from 1 to 7. If it is

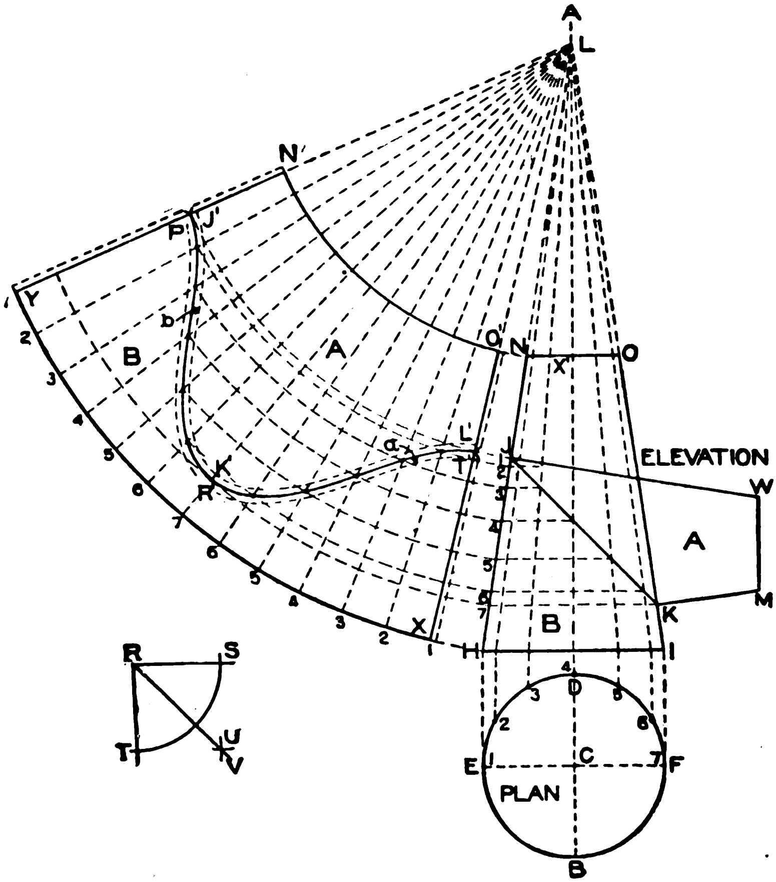


Fig. 54.

desired to know how the side of the tapering elbow would look, take a tracing of N O K J, reverse it and place it as shown by J W M K.

For the pattern proceed as follows: With L as a center and L H as a radius describe the arc 1 1. Starting from 1 set off on this arc twice the stretchout of 1 4 7 in plan, as shown by similar figures on 1 1, from which draw radial lines to the apex L. Again using L as center with radii equal to L N, L 1, L 2 to L 7, draw arcs as shown intersecting radial lines having similar numbers. Through these intersections draw the line J′ L′. Then O′ N′ J′ K′ L′ or A will be the pattern for the upper arm (A) in elevation, and P′ R′ T′ X Y or B the pattern for the lower arm (B) in elevation.

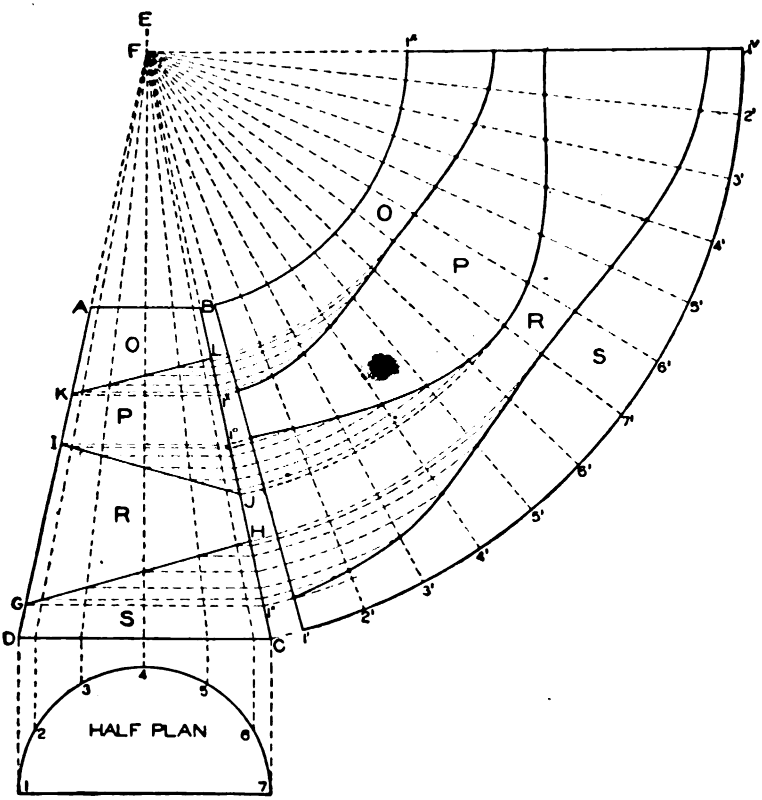


Fig. 55.

The pattern should be developed full size in practice and then pricked from the paper on to the sheet metal, drawing the two patterns as far apart as to admit allowing an edge to A at *a*; also an edge at *b* to B for seaming.

When a pattern is to contain more than two pieces the method of constructing the miter lines in the elevation of the cone is slightly different as shown in Fig. 55. Assume the bottom to be 3 inches in diameter and the top $1\frac{1}{4}$ inches. Let the vertical height be 4 inches. In this problem, as in the preceding, the various pieces necessary to form the elbow are cut from one cone whose dimensions must be determined from the dimensions of the required elbow. The first step is to determine the miter lines, which can be done the same as if regular pieced elbows were being developed. As the elbow is to consist of four pieces in 90°, follow the rule given in connection with elbow drafting. The top and bottom piece equal 2; the two middle pieces equal 4; total 6. $\frac{90}{6} = 15$. Lay off A B C D according to the dimensions given, and draw the half plan below D C; divide it into equal parts as shown. From the points of division erect perpendiculars intersecting D C, from which draw lines meeting the center line E 4 at F.

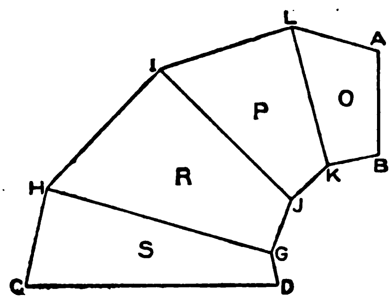


Fig. 56.

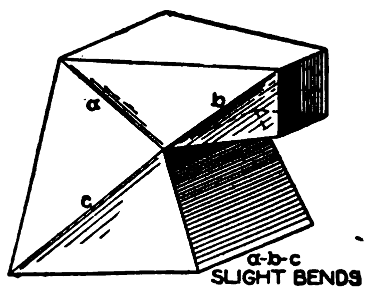


Fig. 57.

We assume that the amount of rise and projection of the elbow are not specified, excepting that the lines of axis will be at right angles. Knowing the angle of the miter line, it becomes a matter of judgment upon the part of the pattern draftsman, what length shall be given to each of the pieces composing the elbow. Therefor establish the points G, I and K, making D G, G I, I K and K A $\frac{1}{2}$, $1\frac{7}{8}$, $\frac{3}{4}$ and 1 inch respectively. From G, I and K draw the horizontal lines G 1′, I 1° and K 1ˣ. To each of these lines draw the lines G H, I J and K L respectively at an angle of 15° intersecting the radial lines in the cone as shown. From these intersections draw horizontal lines cutting the side of the cone. Then using F as a center, obtain the various patterns O, P, R and S in the manner already explained.

In Fig. 56 is shown a side view of the elbow, resulting from preceding operations; while it can be drawn from dimensions obtained in Fig. 55, it would be impossible to draw it without first having these dimensions.

In Fig. 57 is shown a perspective view of a tapering square elbow of square section in two pieces. This elbow may have any given taper. This problem will be developed by triangulation and parallel lines; it is an interesting study in projections as well as in developments. First draw the elevation of the elbow in Fig. 58 making 1–6 equal to $3\frac{1}{2}$ inches, the vertical height 1–2, $4\frac{1}{2}$ inches, and 6–5, $2\frac{1}{2}$ inches; the projection between 1 and 2 should be $\frac{5}{8}$ inch and between 5 and 6, $\frac{3}{8}$ inch. Make the horizontal distance

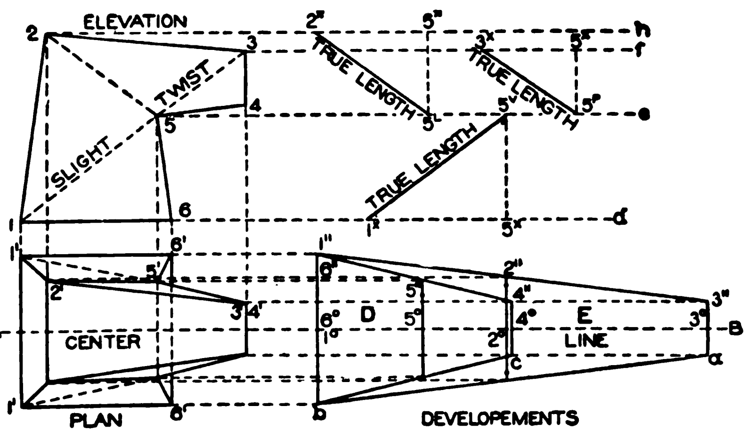


Fig. 58.

from 5 to 4, 2 inches, and the rise at 4 from the horizontal line $\frac{1}{4}$ inch, and the vertical distance from 4 to 3, $1\frac{1}{4}$ inches. Then draw a line from 3 to 2 to complete the elevation.

In its proper position below the line 1–6, draw the plan on that line, as shown by 1′ 1′ 6′ 6′. Through this line draw the center line A B. As the elbow should have a true taper from 1 to 3 and from 4 to 6, we may develop the patterns for the top and bottom pieces first and then from these construct the plan. Therefore, take the distances from 1 to 2 to 3 and from 4 to 5 to 6 in elevation and place them on the line A B in plan as shown respectively from 1° to 2° to 3° and from 4° to 5° to 6°; through these points draw vertical lines as shown. While the full developments

E and D are shown we shall deal with but one-half in the explanation which follows. As the elbow is to have the same taper on either side, take the half distance of the bottom of the elbow 1–6 and place it as shown from 1°–6° to 1″–6″, and the half width of the top of the elbow 3–4 and place it as shown from 3° to 3″ and 4° to 4″. Then draw lines from 3″ to 1″ intersecting the bend 2° at 2″, and a line from 4″ to 6″ intersecting the bend 5° at 5″. Trace these points on the opposite side of the line A B. Then 1″ 3″ *a b* will be the pattern for the top of the elbow and 6″ 4″ *c b* the pattern for the bottom. From these various points of intersection draw horizontal lines to the plan, and intersect them by lines drawn from similarly numbered points in the elevation at right angles to A B in plan. Draw lines through the points thus obtained in plan as shown by 1′, 2′, 3′, 4′, 5′ and 6′ which will represent the half plan view. For the completed plan, trace these lines opposite the line A B as shown. It will be noticed that the line 3–4 in elevation is perpendicular as shown by 3′ 4′ in plan while the points 2′ and 5′ project from it, showing that the piece 2–3–4–5 in elevation must be slightly twisted along the line 5–3 when forming the elbow. Similarly slight bends will be required along the lines 1–5 and 5–2.

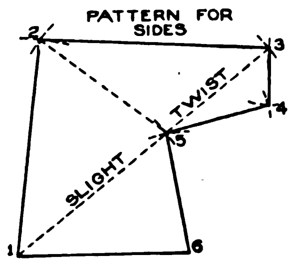


Fig. 59.

It will now be necessary to obtain the true lengths or a diagram of triangles on the lines 1–5, 5–2 and 5–3. Connect similar numbers in plan as shown from 1′ to 5′, 5′ to 2′ and 5′ to 3′, the last two lines being already shown. From similar points in elevation draw horizontal lines as shown by 2-*h*, 3-*f*, 5-*e* and 6-*d*. Take the distances from 1′ to 5′, 5′ to 2′ and 5′ to 3′ in plan and place them on one of the lines having a similar number in elevation, as shown respectively by 1^x 5^x, 5^x 2^x and 5^x 3^x. From the points marked 5^x draw vertical lines intersecting the horizontal line drawn from 5 at 5^v, 5^L and 5^p respectively. Now draw the true lengths 1^x 5^v, 2^x 5^L, and 3^x 5^p. For the pattern draw any line as 1–6 in Fig. 59 equal to 1–6 in Fig. 58. Now with 6″ 5″ in D as a radius and 6 in Fig. 59 as a center, describe the arc 5 which is intersected by an arc struck from 1 as a center and the true length

$1^x 5^v$ in Fig. 58 as radius. Then using the true length $5^L 2^x$ as radius and 5 in Fig. 59 as center, describe the arc 2, which is intersected by an arc struck from 1 as center and 1′ 2′ in E in Fig. 58 as radius. Using the true length $5^p 3^x$ as radius and 5 in Fig. 59 as center, describe the arc 3, and intersect it by an arc struck from 2 as center and 2′ 3′ in E in Fig. 58 as a radius. Now with 5′ 4′ in D as a radius and 5 in Fig. 59 as a center, describe tht arc 4, and intersect it by an arc struck from 3 as center and 3–4 in the elevation in Fig. 58 as a radius. Draw lines from point to point in Fig. 59 to complete the pattern. Laps should be allowed on all patterns, for seaming. Slight bends will take place as shown on the pattern, also as is shown by *a b* and *c* in Fig. 57. If the joint is to be on the line 2–5 in elevation in Fig. 58, the necessary pieces can be joined together.

In Fig. 60 is shown a perspective view of a five-piece tapering elbow, having a round base and an elliptical top. This form is generally known as a *ship ventilator.* The principles shown in this problem are applicable to any form or shape no matter what the respective profiles may be at the base or top. The first step is to draw a correct side view of the elbow as shown in Fig. 61. The outline A B C D E F can be drawn at pleasure, but for practice, dimensions are given. First draw the vertical line A F equal to 4½ inches. On the same line extend measure down 1¼ inches to *f* and draw the horizontal line H B. From *f* set off a distance of 1¼ inches at G, and using G as a center and G F as a radius describe the arc F E intersecting H B at E, from which draw the vertical line E D equal to 1 inch. Draw D C equal to 1¾ inches, then draw C B. From B lay off 5¾ inches, and using this point (H) as a center and H B as a radius describe the arc B A. The portion shown B E D C is a straight piece of pipe whose section is shown by I J K L. Now divide the two arcs B A and E F into the same number of parts that the elbow is to have pieces (in this case four) and draw the lines of joint or miter lines as shown by U V, etc

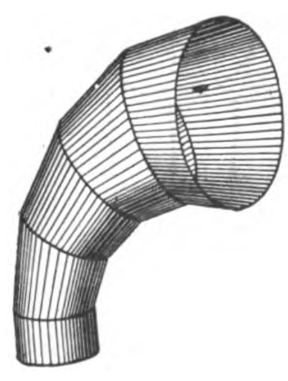


Fig. 60.

Bisect each one of the joint lines and obtain the points *a b c d* and *e*. Then A B C D E F will be the side view.

The patterns will be developed by triangulation, but before this can be done, true sections must be obtained on all of the lines in side elevation. The true sections on the lines B E and C D are shown by I J K L. The length of the sections are shown by the joint lines, but the width must be obtained from a front outline of the elbow, which is constructed as follows: In its proper relation to the side elevation, draw the center line M R upon which draw

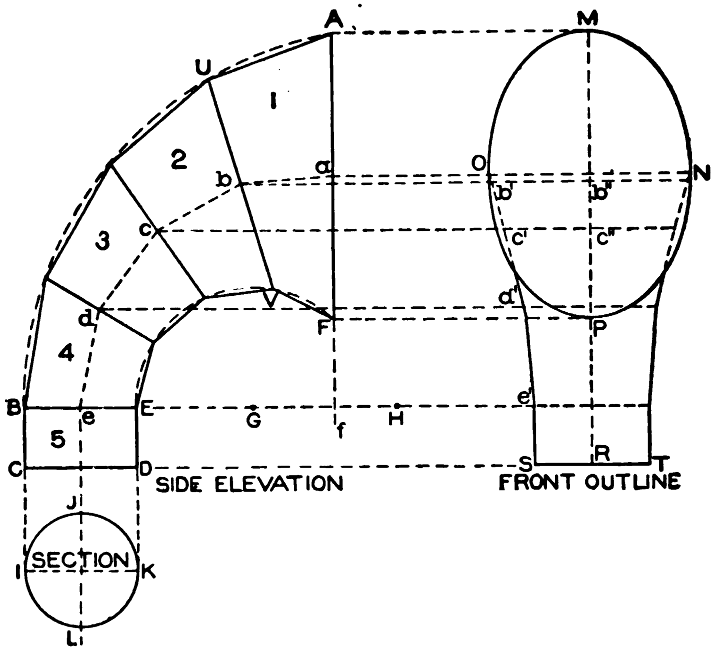


Fig. 61.

the ellipse M N O P (by methods already given in Mechanical Drawing) which represents the section on A F in side. Take half the diameter I K in section and place it on either side of the center line M R as R T or R S. Then draw the outline O S and T N in a convenient location. While this line is drawn at will, it should be understood that when once drawn, it becomes a fixed line. Now from the various intersections *a b c d* and *e* in the side elevation, draw lines through and intersecting the front outline as shown on one side by O, b', c', d' and e'. Then these distances will represent the widths of the sections shown by similar letters in side. For example, the method will be shown for obtaining the true section on U V, and the pattern for piece 1 in side elevation. To avoid a confusion of lines take a tracing of A F V U and place it as shown by 1, 13, 12, O in Fig. 62. On 1–13 place the half profile M N P of Fig. 61. Bisect O–12 in Fig. 62 and obtain the point 6; at a right angle to O–12 from 6 draw the line 6 6′ equal to b' b'' in front outline in Fig. 61. Then through the three points O, 6′ and 12 in Fig. 62, draw the semi-ellipse, which will represent the half section on U V. The other sections on the joint lines in side elevation are obtained in the same manner.

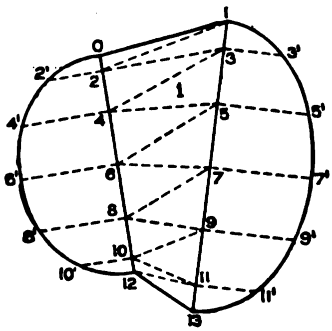


Fig. 62.

If the sections were required for piece 2 in side it would be necessary to use only O 6′ 12 in Fig. 62 and place it on U V in Fig. 61, and on a perpendicular line erected from c, place the width c' c'' shown in front and through the three points obtained again draw the semi-elliptical profile or section. Now divide the two half sections (Fig. 62) into equal parts as shown by the small figures, from which at right angles to 1–13 and O–12 draw lines intersecting these base lines from 1–13. Connect opposite points as 1 to 2 to 3 to 4 to 5, etc., to 12. Then these lines will represent

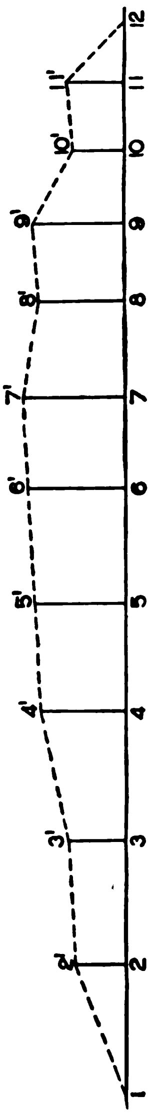


Fig. 63.

the bases of sections whose altitudes are equal to the heights in the half section. For these heights proceed as follows:

Take the various lengths from 1 to 2, 2 to 3, 3 to 4, 4 to 5, etc., to 11 to 12 and place them on the horizontal line in Fig. 63 as shown by similar figures; from these points erect vertical lines equal in height to similar figures, in the half section in Fig. 62 as shown by similar figures in Fig. 63. For example: Take the distance from 7 to 8 in Fig. 62 and place it as shown from 7 to 8 in Fig. 63 and erect vertical lines 7–7′, and 8–8′ equal to 7–7′ and 8–8′ in Fig. 62. Draw a line from 7′ to 8′ in Fig. 63 which is the true length on 7–8 in Fig. 62. For the pattern take the distance of 1–O and place it as shown by 1–O in Fig. 64. Now using O as a center and O 2′ in Fig. 62 as a radius, describe the arc 2 in Fig. 64

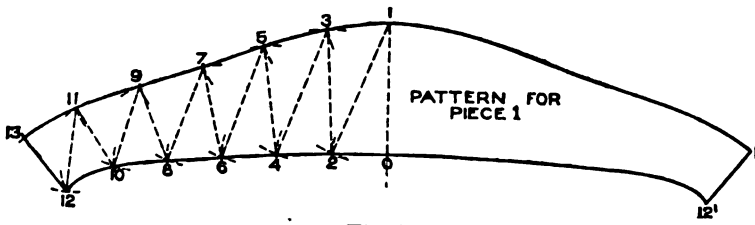
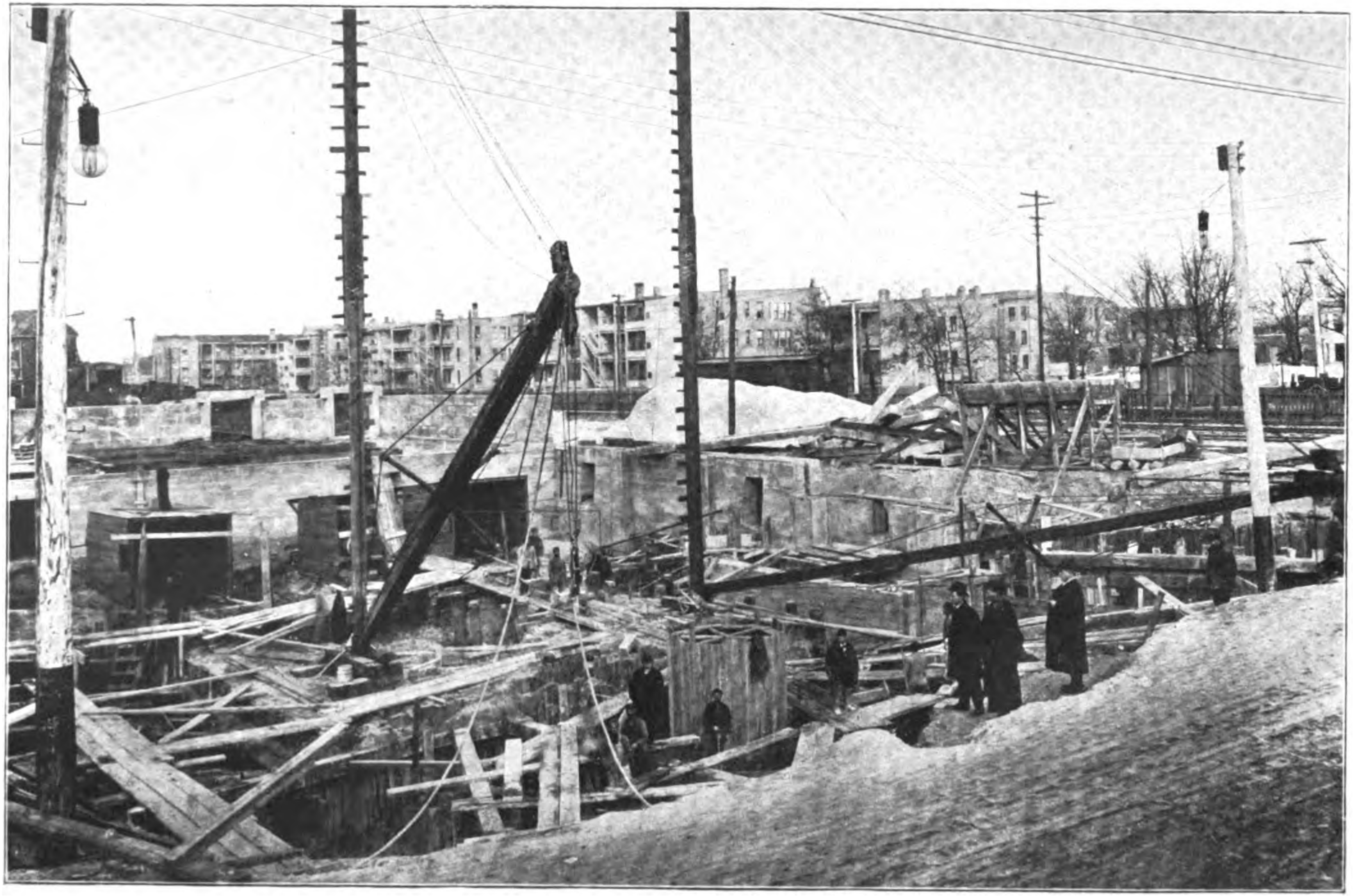


Fig. 64.

and intersect it by an arc struck from 1 as a center with 1–2′ in Fig. 63 as a radius. Now with 1–3′ in Fig. 62 as a radius and 1 in Fig. 64 as a center, describe the arc 3, and intersect it by an arc struck from 2 as center and 2′–3′ in Fig. 63 as a radius. Proceed thus, using alternately as radii, first the divisions in O–6′–12 in Fig. 62, then the proper line in Fig. 63, the divisions in 1–7′–13 in Fig. 62 and again the proper line in Fig. 63, until the line 12–13 in Fig. 64 is obtained, which equals 12–13 in Fig. 62. In this manner all of the sections are obtained, to which laps must be allowed for wiring and seaming.



LAWRENCE AVENUE PUMPING STATION, SYSTEM OF INTERCEPTING SEWERS, CHICAGO, ILL., UNDER CONSTRUCTION

The intercepting sewers run parallel to the shore of Lake Michigan, preventing egress of sewage to the lake. At certain points the sewage is pumped to higher levels, and allowed to flow by gravity westward into the new outlet afforded by the Drainage Canal.

TABLES.

The following tables will be found convenient for the Sheet-Metal Worker:

WEIGHT OF A SQUARE FOOT OF CAST AND WROUGHT IRON, COPPER, LEAD, BRASS AND ZINC.

FROM $\frac{1}{16}$ INCH TO ONE INCH IN THICKNESS.

THICKNESS.	CAST IRON.	WROUGHT IRON.	COPPER.	LEAD.	BRASS.	ZINC.
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1-16	2.346	2.517	2.89	3.691	2.675	2.34
1-8	4.693	5.035	5.781	7.382	5.35	4.68
3-16	7.039	7.552	8.672	11.074	8.025	7.02
1-4	9.386	10.07	11.562	14.765	10.7	9.36
5-16	11.733	12.588	14.453	18.456	13.375	11.7
3-8	14.079	15.106	17.344	22.148	16.05	14.04
7-16	16.426	17.623	20.234	25.839	18.725	16.34
1-2	18.773	20.141	23.125	29.53	21.4	18.72
9-16	21.119	22.659	26.016	33.222	24.075	
5-8	23.466	25.176	28.906	36.923	26.75	
11-16	25.812	27.694	31.797	40.604	29.425	
3-4	28.159	30.211	34.688	44.296	32.1	
13-16	30.505	32.729	37.578	47.987		
7-8	32.852	35.247	40.469	51.678		
15-16	35.199	37.764	43.359	55.37		
1	37.545	40.282	46.25	59.061		

NOTE.—The wrought iron and the copper weights are those of hard-rolled plates.

SHEET COPPER.

Official table adopted by the Association of Copper Manufacturers of the United States. Rolled copper has specific gravity of 8.93. One cubic foot weighs 558.125 pounds. One square foot, one inch thick, weighs 46.51 pounds.

Stubs' Gauge, (nearest number).	Thickness in decimal parts of an inch.	Ounces per sq. ft.	Sheets 14"x48" Weight in pounds.	Sheets 24"x48" Weight in pounds.	Sheets 30"x60" Weight in pounds.	Sheets 36"x72" Weight in pounds.	Sheets 48"x72" Weight in pounds.
35.......	.00537	4	1.16	2	3.12	4.50	6
33.......	.00806	6	1.75	3	4.68	6.75	9
31.......	.0107	8	2.33	4	6.25	9	12
29.......	.0134	10	2.91	5	7.81	11.25	15
27.......	.0161	12	3.50	6	9.37	13.50	18
26.......	.0188	14	4.08	7	10.93	15.75	21
24.......	.0215	16	4.66	8	12.50	18	24
23.......	.0242	18	5.25	9	14.06	20.25	27
22.......	.0269	20	5.83	10	15.62	22.50	30
21.......	.0322	24	7	12	18.75	27	36
19.......	.0430	32	9.33	16	25	36	48
18.......	.0538	40	11.66	20	31.25	45	60
16.......	.0645	48	14	24	37.50	54	72
15.......	.0754	56	16.33	28	43.75	63	84
14.......	.0860	64	18.66	32	50	72	96
13.......	.095	70	....	35	55	79	105
12.......	.109	81	....	40½	63	91	122
11.......	.120	89	....	44½	70	100	134
10.......	.134	100	....	50	78	112	150
9.......	.148	110	....	55	86	124	165
8.......	.165	123	....	61	96	138	184
7.......	.180	134	....	67	105	151	201
6.......	.203	151	....	75½	118	170	227
5.......	.220	164	....	82	128	184	246
4.......	.238	177	....	88½	138	199	266
3.......	.259	193	....	96	151	217	289
2.......	.284	211	....	105½	165	238	317
1.......	.300	223	....	111½	174	251	335
0.......	.340	253	....	126½	198	285	380

SHEET ZINC.

Numbers		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Weight per sq. foot		.30	.37	.45	.52	.60	.67	.75	.90	1.05	1.20	1.35	1.50	1.68	1.87	2.06	2.25	2.62	3.00	3.37
Approximate thickness in inches		.008	.010	.012	.014	.016	.018	.020	.024	.028	.032	.036	.040	.045	.050	.055	.060	.070	.080	.090
Size of sheet.	Sq. ft. per sheet.	APPROXIMATE WEIGHT PER SHEET.																		
24 x 84 in.	14.	4.2	5.2	6.3	7.3	8.4	9.4	10.5	12.6	14.7	16.8	18.9	21.	23.5	26.2	28.9	31.5	36.7	42.	47.2
26 x 84	15.2	4.6	5.6	6.9	7.9	9.1	10.2	11.4	13.7	16.	18.3	20.5	22.8	25.6	28.4	31.3	34.2	39.9	45.6	51.2
28 x 84	16.3	4.9	6.	7.4	8.5	9.8	10.9	12.2	14.7	17.1	19.6	22.	24.5	27.4	30.5	33.6	36.7	42.7	48.9	54.9
30 x 84	17.5	5.3	6.5	7.9	9.1	10.5	11.8	13.2	15.8	18.4	21.	23.6	26.2	29.4	32.8	36.1	39.4	45.8	52.5	59.
32 x 84	18.7	5.6	6.9	8.4	9.7	11.2	12.6	14.1	16.9	19.7	22.5	25.3	32.8	31.4	35.	38.5	42.	49.	56.1	63.
34 x 84	19.9	6.0	7.4	9.	10.4	12.	13.4	15.	18.	20.9	23.9	26.9	29.9	33.4	37.2	41.	44.8	52.2	59.7	67.
36 x 84	21.	6.3	7.8	9.5	10.9	12.6	14.1	15.8	18.9	22.	25.2	28.4	31.5	35.3	39.3	43.3	47.2	55.	63.	70.8
36 x 96	24.	7.2	8.9	10.8	12.5	14.4	16.1	18.	21.6	25.2	28.8	32.4	36.	40.3	44.9	49.5	54.	62.8	72.	80.9
36 x 108	27.	8.1	10.	12.2	14.1	16.2	18.1	20.3	24.3	28.4	32.4	36.5	40.5	45.4	50.5	55.6	60.7	70.7	81.	91.
40 x 84	23.4	7.	8.7	10.6	12.2	14.1	15.7	17.6	21.	24.6	28.1	31.6	35.1	39.3	43.8	48.2	52.6	61.3	70.2	78.8
40 x 96	26.8	8.	9.9	12.1	14.	16.1	18.	20.1	24.1	28.1	32.2	36.2	40.2	45.	50.1	55.2	60.3	70.2	80.4	90.3
44 x 84	25.7	7.7	9.5	11.6	13.4	15.4	17.2	19.3	23.1	27.	30.8	34.7	38.6	43.2	48.1	53.	57.8	67.4	77.1	86.6
46 x 90	28.7	8.6	10.6	12.9	14.9	17.2	19.2	21.5	25.8	30.1	34.4	38.7	43.	48.2	53.7	59.1	64.6	75.2	86.1	96.7
48 x 84	28.	8.4	10.4	12.6	14.6	16.8	18.8	21.	25.2	29.4	33.6	37.8	42.	47.	52.4	57.7	63.	73.4	84.	94.4
48 x 96	32.	9.6	11.9	14.4	16.7	19.2	21.5	24.	28.8	33.6	38.4	43.2	48.	53.8	59.9	65.9	72.	83.9	96.	107.8
50 x 108	37.5	11.3	13.9	16.9	19.5	22.5	25.1	28.2	33.8	39.3	45.	50.7	56.3	63.	70.1	77.3	84.4	98.3	112.5	126.4
52 x 84	30.4	9.1	11.3	13.7	15.8	18.3	20.4	22.8	27.4	31.9	36.5	41.	45.6	51.	56.9	62.6	68.4	79.6	91.2	102.5

Casks average about 600 pounds each. No. 4 to No. 17. Boxes average about 500 pounds. No. 18 and heavier.

UNITED STATES STANDARD GAUGE FOR SHEET AND PLATE IRON AND STEEL

COPY [Public—No. 137]

An act establishing a standard gauge for sheet and plate iron and steel.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That for the purpose of securing uniformity the following is established as the only standard gauge for sheet and plate iron and steel in the United States of America, namely:

Number of Gauge	THICKNESS		WEIGHT		Number of Gauge
	Approximate thickness in fractions of an inch	Approximate thickness in decimal parts of an inch	Weight per square foot in OUNCES avoirdupois	Weight per square foot in POUNDS avoirdupois	
0000000	1-2	.5	320	20.	0000000
000000	15-32	.46875	300	18.75	000000
00000	7-16	.4375	280	17.5	00000
0000	13-32	.40625	260	16.25	0000
000	3-8	.375	240	15.	000
00	11-32	.34375	220	13.75	00
0	5-16	.3125	200	12.5	0
1	9-32	.28125	180	11.25	1
2	17-64	.265625	170	10.625	2
3	1-4	.25	160	10.	3
4	15-64	.234375	150	9.375	4
5	7-32	.21875	140	8.75	5
6	13-64	.203125	130	8.125	6
7	3-16	.1875	120	7.5	7
8	11-64	.171875	110	6.875	8
9	5-32	.15625	100	6.25	9
10	9-64	.140625	90	5.625	10
11	1-8	.125	80	5.	11
12	7-64	.109375	70	4.375	12
13	3-32	.09375	60	3.75	13
14	5-64	.078125	50	3.125	14
15	9-128	.0703125	45	2.8125	15
16	1-16	.0625	40	2.5	16
17	9-160	.05625	36	2.25	17
18	1-20	.05	32	2.	18
19	7-160	.04375	28	1.75	19
20	3-80	.0375	24	1.5	20
21	11-320	.034375	22	1.375	21
22	1-32	.03125	20	1.25	22
23	9-320	.028125	18	1.125	23
24	1-40	.025	16	1.	24
25	7-320	.021875	14	.875	25
26	3-160	.01875	12	.75	26
27	11-640	.0171875	11	.6875	27
28	1-64	.015625	10	.625	28
29	9-640	.0140625	9	.5625	29
30	1-80	.0125	8	.5	30
31	7-640	.0109375	7	.4375	31
32	13-1280	.01015625	6½	.40625	32
33	3-320	.009375	6	.375	33
34	11-1280	.00859375	5½	.34375	34
35	5-640	.0078125	5	.3125	35
36	9-1280	.00703125	4½	.28125	36
37	17-2560	.0066406	4¼	.265625	37
38	1-160	.00625	4	.25	38

And on and after July first, eighteen hundred and ninety-three, the same and no other shall be used in determining duties and taxes levied by the United States of America on sheet and plate iron and steel. But this act shall not be construed to increase duties upon any articles which may be imported.

SEC. 2. That the Secretary of the Treasury is authorized and required to prepare suitable standards in accordance herewith.

SEC. 3. That in the practical use and application of the standard gauge hereby established a variation of two and one-half per cent either way may be allowed.

Approved, March 3, 1893.

WEIGHTS OF FLAT ROLLED IRON PER LINEAR FOOT.

Iron weighing 480 pounds per cubic foot.

Thickness in Inches.	1"	1¼"	1½"	1¾"	2"	2¼"	2½"	2¾"	12"
1/16	.208	.260	.313	.365	.417	.469	.521	.573	2.50
1/8	.417	.521	.625	.729	.833	.938	1.04	1.15	5.00
3/16	.625	.781	.938	1.09	1.25	1.41	1.56	1.72	7.50
1/4	.833	1.04	1.25	1.46	1.67	1.88	2.08	2.29	10.00
5/16	1.04	1.30	1.56	1.82	2.08	2.34	2.60	2.86	12.50
3/8	1.25	1.56	1.88	2.19	2.50	2.81	3.13	3.44	15.00
7/16	1.46	1.82	2.19	2.55	2.92	3.28	3.65	4.01	17.50
1/2	1.67	2.08	2.50	2.92	3.33	3.75	4.17	4.58	20.00
9/16	1.88	2.34	2.81	3.28	3.75	4.22	4.69	5.16	22.50
5/8	2.08	2.60	3.13	3.65	4.17	4.69	5.21	5.73	25.00
11/16	2.29	2.86	3.44	4.01	4.58	5.16	5.73	6.30	27.50
3/4	2.50	3.13	3.75	4.38	5.00	5.63	6.25	6.88	30.00
13/16	2.71	3.39	4.06	4.74	5.42	6.09	6.77	7.45	32.50
7/8	2.92	3.65	4.38	5.10	5.83	6.56	7.29	8.02	35.00
15/16	3.13	3.91	4.69	5.47	6.25	7.03	7.81	8.59	37.50
1	3.33	4.17	5.00	5.83	6.67	7.50	8.33	9.17	40.00
1 1/16	3.54	4.43	5.31	6.20	7.08	7.97	8.85	9.74	42.50
1 1/8	3.75	4.69	5.63	6.56	7.50	8.44	9.38	10.31	45.00
1 3/16	3.96	4.95	5.94	6.93	7.92	8.91	9.90	10.89	47.50
1 1/4	4.17	5.21	6.25	7.29	8.33	9.38	10.42	11.46	50.00
1 5/16	4.37	5.47	6.56	7.66	8.75	9.84	10.94	12.03	52.50
1 3/8	4.58	5.73	6.88	8.02	9.17	10.31	11.46	12.60	55.00
1 7/16	4.79	5.99	7.19	8.39	9.58	10.78	11.98	13.18	57.50
1 1/2	5.00	6.25	7.50	8.75	10.00	11.25	12.50	13.75	60.00
1 9/16	5.21	6.51	7.81	9.11	10.42	11.72	13.02	14.32	62.50
1 5/8	5.42	6.77	8.13	9.48	10.83	12.19	13.54	14.90	65.00
1 11/16	5.63	7.03	8.44	9.84	11.25	12.66	14.06	15.47	67.50
1 3/4	5.83	7.29	8.75	10.21	11.67	13.13	14.58	16.04	70.00
1 13/16	6.04	7.55	9.06	10.57	12.08	13.59	15.10	16.61	72.50
1 7/8	6.25	7.81	9.38	10.94	12.50	14.06	15.63	17.19	75.00
1 15/16	6.46	8.07	9.69	11.30	12.92	14.53	16.15	17.76	77.50
2	6.67	8.33	10.00	11.67	13.33	15.00	16.67	18.33	80.00

WEIGHTS OF FLAT ROLLED IRON PER LINEAR FOOT.

(Continued)

Thickness in Inches.	3″	3¼″	3½″	3¾″	4″	4¼″	4½″	4¾″	12″
1/16	.625	.677	.729	.781	.833	.885	.938	.990	2.50
1/8	1.25	1.35	1.46	1.56	1.67	1.77	1.88	1.98	5.00
3/16	1.88	2.03	2.19	2.34	2.50	2.66	2.81	2.97	7.50
1/4	2.50	2.71	2.92	3.13	3.33	3.54	3.75	3.96	10.00
5/16	3.13	3.39	3.65	3.91	4.17	4.43	4.69	4.95	12.50
3/8	3.75	4.06	4.38	4.69	5.00	5.31	5.63	5.94	15.00
7/16	4.38	4.74	5.10	5.47	5.83	6.20	6.56	6.93	17.50
1/2	5.00	5.42	5.83	6.25	6.67	7.08	7.50	7.92	20.00
9/16	5.63	6.09	6.56	7.03	7.50	7.97	8.44	8.91	22.50
5/8	6.25	6.77	7.29	7.81	8.33	8.85	9.38	9.90	25.00
11/16	6.88	7.45	8.02	8.59	9.17	9.74	10.31	10.89	27.50
3/4	7.50	8.13	8.75	9.38	10.00	10.63	11.25	11.88	30.00
13/16	8.13	8.80	9.48	10.16	10.83	11.51	12.19	12.86	32.50
7/8	8.75	9.48	10.21	10.94	11.67	12.40	13.13	13.85	35.00
15/16	9.38	10.16	10.94	11.72	12.50	13.28	14.06	14.84	37.50
1	10.00	10.83	11.67	12.50	13.33	14.17	15.00	15.83	40.00
1 1/16	10.63	11.51	12.40	13.28	14.17	15.05	15.94	16.82	42.50
1 1/8	11.25	12.19	13.13	14.06	15.00	15.94	16.88	17.81	45.00
1 3/16	11.88	12.86	13.85	14.84	15.83	16.82	17.81	18.80	47.50
1 1/4	12.50	13.54	14.58	15.63	16.67	17.71	18.75	19.79	50.00
1 5/16	13.13	14.22	15.31	16.41	17.50	18.59	19.69	20.78	52.50
1 3/8	13.75	14.90	16.04	17.19	18.33	19.48	20.63	21.77	55.00
1 7/16	14.38	15.57	16.77	17.97	19.17	20.36	21.56	22.76	57.50
1 1/2	15.00	16.25	17.50	18.75	20.00	21.25	22.50	23.75	60.00
1 9/16	15.63	16.93	18.23	19.53	20.83	22.14	23.44	24.74	62.50
1 5/8	16.25	17.60	18.96	20.31	21.67	23.02	24.38	25.73	65.00
1 11/16	16.88	18.28	19.69	21.09	22.50	23.91	25.31	26.72	67.50
1 3/4	17.50	18.96	20.42	21.88	23.33	24.79	26.25	27.71	70.00
1 13/16	18.13	19.64	21.15	22.66	24.17	25.68	27.19	28.70	72.50
1 7/8	18.75	20.31	21.88	23.44	25.00	26.56	28.13	29.69	75.00
1 15/16	19.38	20.99	22.60	24.22	25.83	27.45	29.06	30.68	77.50
2	20.00	21.67	23.33	25.00	26.67	28.33	30.00	31.67	80.00

WEIGHTS OF FLAT ROLLED IRON PER LINEAR FOOT.

(Continued)

Thickness in Inches.	5″	5¼″	5½″	5¾″	6″	6¼″	6½″	6¾″	12″
1/16	1.04	1.09	1.15	1.20	1.25	1.30	1.35	1.41	2.50
1/8	2.08	2.19	2.29	2.40	2.50	2.60	2.71	2.81	5.00
3/16	3.13	3.28	3.44	3.59	3.75	3.91	4.06	4.22	7.50
1/4	4.17	4.38	4.58	4.79	5.00	5.21	5.42	5.63	10.00
5/16	5.21	5.47	5.73	5.99	6.25	6.51	6.77	7.03	12.50
3/8	6.25	6.56	6.88	7.19	7.50	7.81	8.13	8.44	15.00
7/16	7.29	7.66	8.02	8.39	8.75	9.11	9.48	9.84	17.50
1/2	8.33	8.75	9.17	9.58	10.00	10.42	10.83	11.25	20.00
9/16	9.38	9.84	10.31	10.78	11.25	11.72	12.19	12.66	22.50
5/8	10.42	10.94	11.46	11.98	12.50	13.02	13.54	14.06	25.00
11/16	11.46	12.03	12.60	13.18	13.75	14.32	14.90	15.47	27.50
3/4	12.50	13.13	13.75	14.38	15,00	15.63	16.25	16.88	30.00
13/16	13.54	14.22	14.90	15.57	16.25	16.93	17.60	18.28	32.50
7/8	14.58	15.31	16.04	16.77	17.50	18.23	18.96	19.69	35.00
15/16	15.63	16.41	17.19	17.97	18.75	19.53	20.31	21.09	37.50
1	16.67	17.50	18.33	19.17	20.00	20.83	21.67	22.50	40.00
1 1/16	17.71	18.59	19.48	20.36	21.25	22.14	23.02	23.91	42.50
1 1/8	18.75	19.69	20.63	21.56	22.50	23.44	24.38	25.31	45.00
1 3/16	19.79	20.78	21.77	22.76	23.75	24.74	25.73	26.72	47.50
1 1/4	20.83	21.88	22.92	23.96	25.00	26.04	27.08	28.13	50.00
1 5/16	21.88	22.97	24.06	25.16	26.25	27.34	28.44	29.53	52.50
1 3/8	22.92	24.06	25.21	26.35	27.50	28.65	29.79	30.94	55.00
1 7/16	23.96	25.16	26.35	27.55	28.75	29.95	31.15	32.34	57.50
1 1/2	25.00	26.25	27.50	28.75	30.00	31.25	32.50	33.75	60.00
1 9/16	26.04	27.34	28.65	29.95	31.25	32.55	33.85	35.16	62.50
1 5/8	27.08	28.44	29.79	31.15	32.50	33.85	35.21	36.56	65.00
1 11/16	28.13	29.53	30.94	32.34	33.75	35.16	36.56	37.97	67.50
1 3/4	29.17	30.63	32.08	33.54	35.00	36.46	37.92	39.38	70.00
1 13/16	30.21	31.72	33.23	34.74	36.25	37.76	39.27	40.78	72.50
1 7/8	31.25	32.81	34.38	35.94	37.50	39.06	40.63	42.19	75.00
1 15/16	32.29	33.91	35.52	37.14	38.75	40.36	41.98	43.59	77.50
2	33.33	35.00	36.67	38.33	40.00	41.67	43.33	45.00	80.00

WEIGHTS OF FLAT ROLLED IRON PER LINEAR FOOT.

(Continued)

Thickness in Inches.	7"	7¼"	7½"	7¾"	8"	8¼"	8½"	8¾"	12"
1/16	1.46	1.51	1.56	1.61	1.67	1.72	1.77	1.82	2.50
1/8	2.92	3.02	3.13	3.23	3.33	3.44	3.54	3.65	5.00
3/16	4.38	4.53	4.69	4.84	5.00	5.16	5.31	5.47	7.50
1/4	5.83	6.04	6.25	6.46	6.67	6.88	7.08	7.29	10.00
5/16	7.29	7.55	7.81	8.07	8.33	8.59	8.85	9.11	12.50
3/8	8.75	9.06	9.38	9.69	10.00	10.31	10.63	10.94	15.00
7/16	10.21	10.57	10.94	11.30	11.67	12.03	12.40	12.76	17.50
1/2	11.67	12.08	12.50	12.92	13.33	13.75	14.17	14.58	20.00
9/16	13.13	13.59	14.06	14.53	15.00	15.47	15.94	16.41	22.50
5/8	14.58	15.10	15.63	16.15	16.67	17.19	17.71	18.23	25.00
11/16	16.04	16.61	17.19	17.76	18.33	18.91	19.48	20.05	27.50
3/4	17.50	18.13	18.75	19.38	20.00	20.63	21.25	21.88	30.00
13/16	18.96	19.64	20.31	20.99	21.67	22.34	23.02	23.70	32.50
7/8	20.42	21.15	21.88	22.60	23.33	24.06	24.79	25.52	35.00
15/16	21.88	22.66	23.44	24.22	25.00	25.78	26.56	27.34	37.50
1	23.33	24.17	25.00	25.83	26.67	27.50	28.33	29.17	40.00
1 1/16	24.79	25.68	26.56	27.45	28.33	29.22	30.10	30.99	42.50
1 1/8	26.25	27.19	28.13	29.06	30.00	30.94	31.88	32.81	45.00
1 3/16	27.71	28.70	29.69	30.68	31.67	32.66	33.65	34.64	47.50
1 1/4	29.17	30.21	31.25	32.29	33.33	34.38	35.42	36.46	50.00
1 5/16	30.62	31.72	32.81	33.91	35.00	36.09	37.19	38.28	52.50
1 3/8	32.08	33.23	34.38	35.52	36.67	37.81	38.96	40.10	55.00
1 7/16	33.54	34.74	35.94	37.14	38.33	39.53	40.73	41.93	57.50
1 1/2	35.00	36.25	37.50	38.75	40.00	41.25	42.50	43.75	60.00
1 9/16	36.46	37.76	39.06	40.36	41.67	42.97	44.27	45.57	62.50
1 5/8	37.92	39.27	40.63	41.98	43.33	44.69	46.04	47.40	65.00
1 11/16	39.38	40.78	42.19	43.59	45.00	46.41	47.81	49.22	67.50
1 3/4	40.83	42.29	43.75	45.21	46.67	48.13	49.58	51.04	70.00
1 13/16	42.29	43.80	45.31	46.82	48.33	49.84	51.35	52.86	72.50
1 7/8	43.75	45.31	46.88	48.44	50.00	51.56	53.13	54.69	75.00
1 15/16	45.21	46.82	48.44	50.05	51.67	53.28	54.90	56.51	77.50
2	46.67	48.33	50.00	51.67	53.33	55.00	56.67	58.33	80.00

WEIGHTS OF FLAT ROLLED IRON PER LINEAR FOOT.

(Continued)

Thickness in Inches.	9″	9¼″	9½″	9¾″	10″	10¼″	10½″	10¾″	12″
1/16	1.88	1.93	1.98	2.03	2.08	2.14	2.19	2.24	2.50
1/8	3.75	3.85	3.96	4.06	4.17	4.27	4.38	4.48	5.00
3/16	5.63	5.78	5.94	6.09	6.25	6.41	6.56	6.72	7.50
1/4	7.50	7.71	7.92	8.13	8.33	8.54	8.75	8.96	10.00
5/16	9.38	9.64	9.90	10.16	10.42	10.68	10.94	11.20	12.50
3/8	11.25	11.56	11.88	12.19	12.50	12.81	13.13	13.44	15.00
7/16	13.13	13.49	13.85	14.22	14.58	14.95	15.31	15.68	17.50
1/2	15.00	15.42	15.83	16.25	16.67	17.08	17.50	17.92	20.00
9/16	16.88	17.34	17.81	18.28	18.75	19.22	19.69	20.16	22.50
5/8	18.75	19.27	19.79	20.31	20.83	21.35	21.88	22.40	25.00
11/16	20.63	21.20	21.77	22.34	22.92	23.49	24.06	24.64	27.50
3/4	22.50	23.13	23.75	24.38	25.00	25.62	26.25	26.88	30.00
13/16	24.38	25.05	25.73	26.41	27.08	27.76	28.44	29.11	32.50
7/8	26.25	26.98	27.71	28.44	29.17	29.90	30.63	31.35	35.00
15/16	28.13	28.91	29.69	30.47	31.25	32.03	32.81	33.59	37.50
1	30.00	30.83	31.67	32.50	33.33	34.17	35.00	35.83	40.00
1 1/16	31.88	32.76	33.65	34.53	35.42	36.30	37.19	38.07	42.50
1 1/8	33.75	34.69	35.63	36.56	37.50	38.44	39.38	40.31	45.00
1 3/16	35.63	36.61	37.60	38.59	39.58	40.57	41.56	42.55	47.50
1 1/4	37.50	38.54	39.58	40.63	41.67	42.71	43.75	44.79	50.00
1 5/16	39.38	40.47	41.56	42.66	43.75	44.84	45.94	47.03	52.50
1 3/8	41.25	42.40	43.54	44.69	45.83	46.98	48.13	49.27	55.00
1 7/16	43.13	44.32	45.52	46.72	47.92	49.11	50.31	51.51	57.50
1 1/2	45.00	46.25	47.50	48.75	50.00	51.25	52.50	53.75	60.00
1 9/16	46.88	48.18	49.48	50.78	52.08	53.39	54.69	55.99	62.50
1 5/8	48.75	50.10	51.46	52.81	54.17	55.52	56.88	58.23	65.00
1 11/16	50.63	52.03	53.44	54.84	56.25	57.66	59.06	60.47	67.50
1 3/4	52.50	53.96	55.42	56.88	58.33	59.79	61.25	62.71	70.00
1 13/16	54.38	55.89	57.40	58.91	60.42	61.93	63.44	64.95	72.50
1 7/8	56.25	57.81	59.38	60.94	62.50	64.06	65.63	67.19	75.00
1 15/16	58.13	59.74	61.35	62.97	64.58	66.20	67.81	69.43	77.50
2	60.00	61.67	63.33	65.00	66.67	68.33	70.00	71.67	80.00

WEIGHTS OF FLAT ROLLED IRON PER LINEAR FOOT.

(Concluded)

Thickness in Inches.	11"	11¼"	11½"	11¾"	12"	12¼"	12½"	12¾"
1/16	2.29	2.34	2.40	2.45	2.50	2.55	2.60	2.66
1/8	4.58	4.69	4.79	4.90	5.00	5.10	5.21	5.31
3/16	6.88	7.03	7.19	7.34	7.50	7.66	7.81	7.97
1/4	9.17	9.38	9.58	9.79	10.00	10.21	10.42	10.63
5/16	11.46	11.72	11.98	12.24	12.50	12.76	13.02	13.28
3/8	13.75	14.06	14.38	14.69	15.00	15.31	15.63	15.94
7/16	16.04	16.41	16.77	17.14	17.50	17.86	18.23	18.59
1/2	18.33	18.75	19.17	19.58	20.00	20.42	20.83	21.25
9/16	20.63	21.09	21.56	22.03	22.50	22.97	23.44	23.91
5/8	22.92	23.44	23.96	24.48	25.00	25.52	26.04	26.56
11/16	25.21	25.78	26.35	26.93	27.50	28.07	28.65	29.22
3/4	27.50	28.13	28.75	29.38	30.00	30.63	31.25	31.88
13/16	29.79	30.47	31.15	31.82	32.50	33.18	33.85	34.53
7/8	32.08	32.81	33.54	34.27	35.00	35.73	36.46	37.19
15/16	34.38	35.16	35.94	36.72	37.50	38.28	39.06	39.84
1	36.67	37.50	38.33	39.17	40.00	40.83	41.67	42.50
1 1/16	38.96	39.84	40.73	41.61	42.50	43.39	44.27	45.16
1 1/8	41.25	42.19	43.13	44.06	45.00	45.94	46.88	47.81
1 3/16	43.54	44.53	45.52	46.51	47.50	48.49	49.48	50.47
1 1/4	45.83	46.88	47.92	48.96	50.00	51.04	52.08	53.13
1 5/16	48.13	49.22	50.31	51.41	52.50	53.59	54.69	55.78
1 3/8	50.42	51.56	52.71	53.85	55.00	56.15	57.29	58.44
1 7/16	52.71	53.91	55.10	56.30	57.50	58.70	59.90	61.09
1 1/2	55.00	56.25	57.50	58.75	60.00	61.25	62.50	63.75
1 9/16	57.29	58.59	59.90	61.20	62.50	63.80	65.10	66.41
1 5/8	59.58	60.94	62.29	63.65	65.00	66.35	67.71	69.06
1 11/16	61.88	63.28	64.69	66.09	67.50	68.91	70.31	71.72
1 3/4	64.17	65.63	67.08	68.54	70.00	71.46	72.92	74.38
1 13/16	66.46	67.97	69.48	70.99	72.50	74.01	75.52	77.03
1 7/8	68.75	70.31	71.88	73.44	75.00	76.56	78.13	79.69
1 15/16	71.04	72.66	74.27	75.89	77.50	79.11	80.73	82.34
2	73.33	75.00	76.67	78.83	80.00	81.67	83.33	85.00

The weights for 12" width are repeated on each page to facilitate making the additions necessary for plates wider than 12". Thus, to find the weight of 15¼" x ⅞", add the weights to be found in the same line for 3¼" x ⅞" and 12" x ⅞" = 9.48 + 35.00 = 44.48 lbs.

SQUARE AND ROUND IRON BARS.

Thickness or Diameter in Inches.	Weight of □ Bar One Foot long.	Weight of ○ Bar One Foot long.	Area of □ Bar in sq. inches.	Area of ○ Bar in sq. inches.	Circumference of ○ Bar in inches.
0					
1/16	.013	.010	.0039	.0031	.1963
1/8	.052	.041	.0156	.0123	.3927
3/16	.117	.092	.0352	.0276	.5890
1/4	.208	.164	.0625	.0491	.7854
5/16	.326	.256	.0977	.0767	.9817
3/8	.469	.368	.1406	.1104	1.1781
7/16	.638	.501	.1914	.1503	1.3744
1/2	.833	.654	.2500	.1963	1.5708
9/16	1.055	.828	.3164	.2485	1.7671
5/8	1.302	1.023	.3906	.3068	1.9635
11/16	1.576	1.237	.4727	.3712	2.1598
3/4	1.875	1.473	.5625	.4418	2.3562
13/16	2.201	1.728	.6602	.5185	2.5525
7/8	2.552	2.004	.7656	.6013	2.7489
15/16	2.930	2.301	.8789	.6903	2.9452
1	3.333	2.618	1.0000	.7854	3.1416
1/16	3.763	2.955	1.1289	.8866	3.3379
1/8	4.219	3.313	1.2656	.9940	3.5343
3/16	4.701	3.692	1.4102	1.1075	3.7306
1/4	5.208	4.091	1.5625	1.2272	3.9270
5/16	5.742	4.510	1.7227	1.3530	4.1233
3/8	6.302	4.950	1.8906	1.4849	4.3197
7/16	6.888	5.410	2.0664	1.6230	4.5160
1/2	7.500	5.890	2.2500	1.7671	4.7124
9/16	8.138	6.392	2.4414	1.9175	4.9087
5/8	8.802	6.913	2.6406	2.0739	5.1051
11/16	9.492	7.455	2.8477	2.2365	5.3014
3/4	10.21	8.018	3.0625	2.4053	5.4978
13/16	10.95	8.601	3.2852	2.5802	5.6941
7/8	11.72	9.204	3.5156	2.7612	5.8905
15/16	12.51	9.828	3.7539	2.9483	6.0868
2	13.33	10.47	4.0000	3.1416	6.2832
1/16	14.18	11.14	4.2539	3.3410	6.4795
1/8	15.05	11.82	4.5156	3.5466	6.6759
3/16	15.95	12.53	4.7852	3.7583	6.8722
1/4	16.88	13.25	5.0625	3.9761	7.0686
5/16	17.83	14.00	5.3477	4.2000	7.2649
3/8	18.80	14.77	5.6406	4.4301	7.4613
7/16	19.80	15.55	5.9414	4.6664	7.6576
1/2	20.83	16.36	6.2500	4.9087	7.8540
9/16	21.89	17.19	6.5664	5.1572	8.0503
5/8	22.97	18.04	6.8906	5.4119	8.2467
11/16	24.08	18.91	7.2227	5.6727	8.4430

SQUARE AND ROUND IRON BARS.
(Concluded)

Thickness or Diameter in Inches.	Weight of □ Bar One Foot long.	Weight of ○ Bar One Foot long.	Area of □ Bar in sq. inches.	Area of ○ Bar in sq. inches.	Circumference of ○ Bar in inches.
3/4	25.21	19.80	7.5625	5.9396	8.6394
13/16	26.37	20.71	7.9102	6.2126	8.8357
7/8	27.55	21.64	8.2656	6.4918	9.0321
15/16	28.76	22.59	8.6289	6.7771	9.2284
3	30.00	23.56	9.0000	7.0686	9.4248
1/16	31.26	24.55	9.3789	7.3662	9.6211
1/8	32.55	25.57	9.7656	7.6699	9.8175
3/16	33.87	26.60	10.160	7.9798	10.014
1/4	35.21	27.65	10.563	8.2958	10.210
5/16	36.58	28.73	10.973	8.6179	10.407
3/8	37.97	29.82	11.391	8.9462	10.603
7/16	39.39	30.94	11.816	9.2806	10.799
1/2	40.83	32.07	12.250	9.6211	10.996
9/16	42.30	33.23	12.691	9.9678	11.192
5/8	43.80	34.40	13.141	10.321	11.388
11/16	45.33	35.60	13.598	10.680	11.585
3/4	46.88	36.82	14.063	11.045	11.781
13/16	48.45	38.05	14.535	11.416	11.977
7/8	50.05	39.31	15.016	11.793	12.174
15/16	51.68	40.59	15.504	12.177	12.370
4	53.33	41.89	16.000	12.566	12.566
1/16	55.01	43.21	16.504	12.962	12.763
1/8	56.72	44.55	17.016	13.364	12.959
3/16	58.45	45.91	17.535	13.772	13.155
1/4	60.21	47.29	18.063	14.186	13.352
5/16	61.99	48.69	18.598	14.607	13.548
3/8	63.80	50.11	19.141	15.033	13.744
7/16	65.64	51.55	19.691	15.466	13.941
1/2	67.50	53.01	20.250	15.904	14.137
9/16	69.39	54.50	20.816	16.349	14.334
5/8	71.30	56.00	21.391	16.800	14.530
11/16	73.24	57.52	21.973	17.257	14.726
3/4	75.21	59.07	22.563	17.721	14.923
13/16	77.20	60.63	23.160	18.190	15.119
7/8	79.22	62.22	23.766	18.665	15.315
15/16	81.26	63.82	24.379	19.147	15.512
5	83.33	65.45	25.000	19.635	15.708

ANGLE IRON.

Weight Per Linear Foot.

6 x 6 x 5/8	24	Lbs.	2 x 2 x 1/4	3 1/2	Lbs.
5 x 5 x 9/16	16 1/2	"	1 3/4 x 1 3/4 x 3/16	2 3/4	"
4 x 4 x 1/2	12 1/2	"	1 1/2 x 1 1/2 x 3/16	2	"
3 1/2 x 3 1/2 x 7/16	9	"	1 1/4 x 1 1/4 x 3/16	1 1/2	"
3 x 3 x 3/8	7	"	1 x 1 x 1/8	1	"
2 1/2 x 2 1/2 x 5/16	5	"	3/4 x 3/4 x 1/8	5/8	"
2 1/4 x 2 1/4 x 1/4	4 1/4	"			

TEE IRON.

Weight Per Linear Foot.

5 x 8 x 5/8	30	Lbs.	2 1/4 x 2 1/4 x 1/4	4	Lbs
7 x 6 x 5/8	30	"	2 x 2 x 1/4	3 1/4	"
6 x 3 x 1/2	16 1/2	"	1 3/4 x 1 3/4 x 1/4	3	"
4 x 4 x 1/2	14	"	1 1/2 x 1 1/2 x 1/4	2 3/4	"
3 1/2 x 3 1/2 x 1/2	12 1/2	"	1 1/4 x 1 1/4 x 1/4	2 1/4	"
3 x 3 x 3/8	7 3/4	"	1 x 1 x 1/8	1	"
2 1/2 x 2 1/2 x 1/2	8	"	3/4 x 3/4 x 1/8	3/8	"
2 1/2 x 2 1/2 x 5/16	5	"			

VENTILATION WORK *

In the illustration is shown a system of ventilation, in which the various pipes are led from brick or metal flues to the attic as shown, and connected to the sheet metal drum.

This drum is made in size equal to the combined area of all pipes entering same. The drum is set upon a wooden platform as shown and has a clean-out door made large enough to admit a man's body. Steam coils are placed inside to create a suction, when the heated air rises through the ventilator. The drum is connected to the ventilator as shown, the bracing of the ventilator being fastened to the inside of the curb.

The detail at the right shows the connection joint between the pipe and drum, while that at the left shows the construction of the metal door and frame, with method of fastening to the body of the drum.

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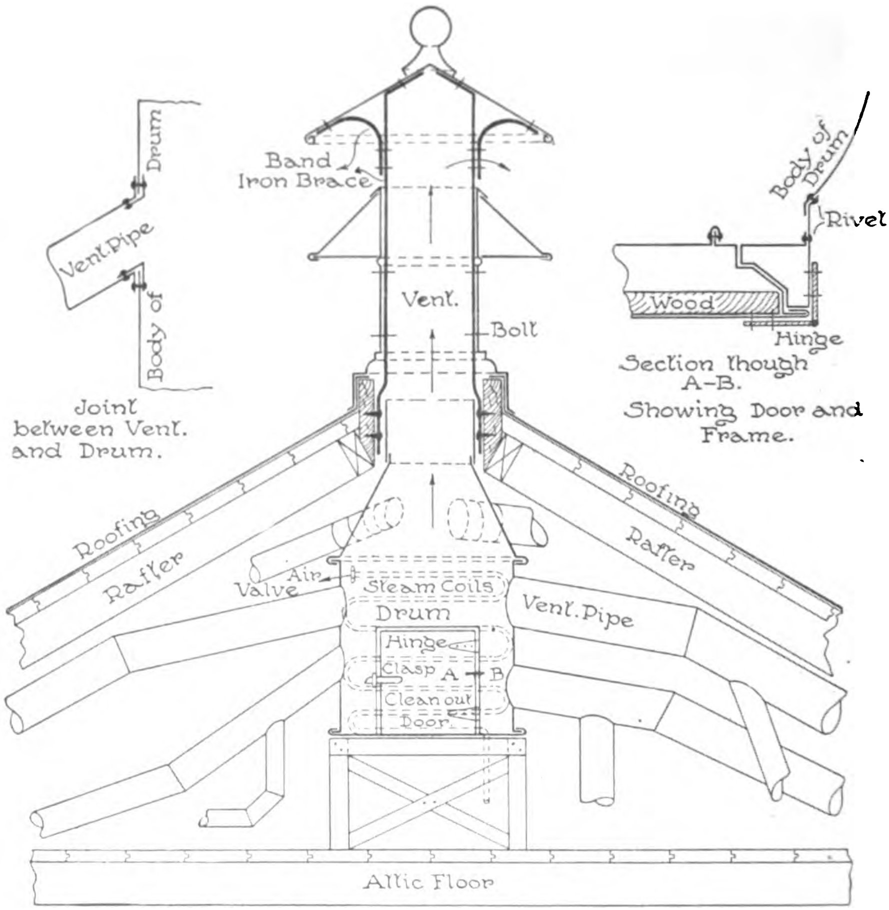
* The illustration referred to will be found on the back of this page.

CONSTRUCTION DRAWING
SHOWING

SHEET METAL DRUM AND VENTILATOR IN VENTILATION WORK



Sectional view showing ventilation pipes connected to drum in attic also steam coils in drum to create suction.

FOR EXPLANATION OF THIS PROBLEM SEE BACK OF PAGE

SHEET METAL WORK.

PART II.

PROBLEMS FOR LIGHT GAUGE METAL.

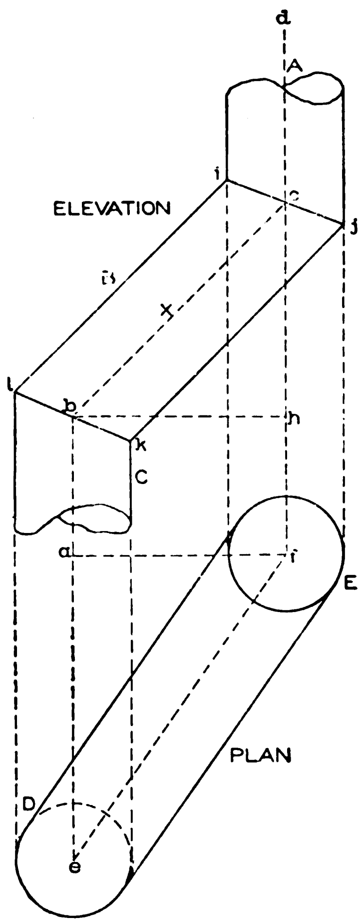


Fig. 65.

It is often the case that the sheet metal worker receives plans for vent, heat, or blower pipes to be constructed, in which the true lengths and angles are not shown but must be obtained from the plans or measurements at the building.

Figs. 65 and 66 show the principles employed for obtaining the true angles and lengths in oblique piping, it being immaterial whether the piping is round, square, or oval in section. The only safe way in obtaining these angles is to use the center line as a basis and after this line has been obtained, build the pipe around it, so to speak. In Fig. 65 let A B C represent the elevation of the elbow shown in plan by D E. Through the center of the pipes draw the center line *a b c d* which intersect the center lines of the pipe in plan at *e* and *f*. In elevation the rise of the middle piece B on the center line is equal to *h c* and projects to the right a distance equal to *b h*, shown in plan by *e f*; this same pipe projects forward in plan a distance equal to *e a*. While the miter lines in elevation *i j* and *k l* have been drawn straight, they would in reality show curved lines; those lines have not been projected as there is no necessity for doing so.

With the various heights and projections in plan and elevation the true length and true angles are obtained as shown in Fig.

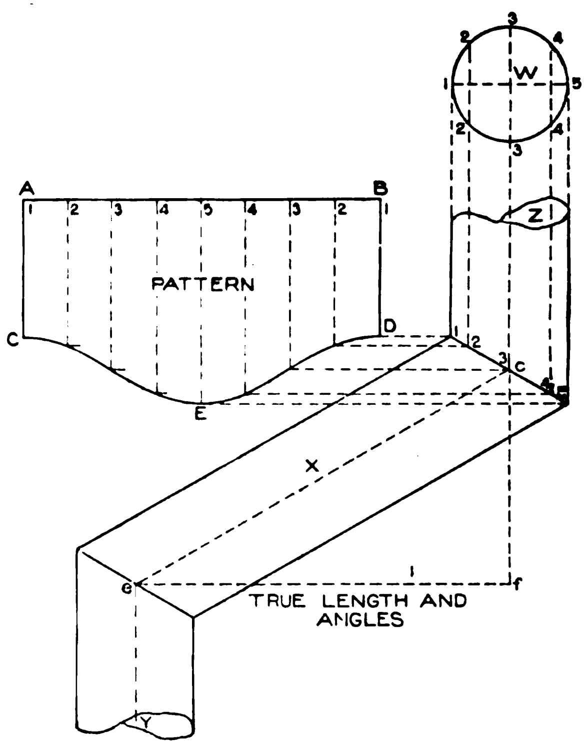


Fig. 66.

66, in which draw the horizontal line *e f* equal to *e f* in plan in Fig. 65. Take the height from *h* to *c* and place it from *f* to *c* in Fig. 66 on a vertical line erected from *f*. Draw a line from *e* to *c* which is the true length on the center line of the pipe shown by B in elevation in Fig. 65. From the points *c* and *e* in Fig. 66 draw perpendicular lines, making Y *e* X and X *c* Z = the true angles shown by *a b* X and X *c d* respectively in Fig. 65. On either side of the center line in Fig. 66 lay off the half diameter of the pipe as shown, and in its proper position draw the profile W.

Divide this into equal spaces and obtain the pattern A B D E C in the usual manner. As both angles are similar the miter cut C E D can be used for all of the patterns. In drawing this problem for practice make the diameter of the pipe 2 inches, the height from *h* to *c* 3¾ inches in Fig. 65, the projection *b* to *h* 3¾ inches, and the projection in plan *e* to *a* 5¼ inches.

Our next problem is that of a rain-water cut-off, a perspective view of which is shown in Fig. 67. While the miter cuts in this problem are similar to elbow work the intersection between the two beveled arms, and the cut-off or slide on the inside require attention. Make the diameter of the three openings each 2 inches; A to B (Fig. 68) 1½ inches. From B at an angle of 45° draw B C 3¼ inches and C D 2 inches. From G draw the vertical miter line G *h*. Make the distance from B to T ½ inch. Place the line *d e* of the cut-off ⅛ inch above the line T U as indicated at *a* and the line *e c* to the right of *h* G, as indicated by *b*, a distance of $\frac{3}{16}$ inch. Parallel to G H draw *c d* giving slight play room between G H, intersecting *e d* and *e c* at *d* and *c* respectively. From *c* at right angles to *d c*, draw a line as shown, intersecting *h* G at *f*, which is the pivot on which the cut-off *c d e* will turn either right or left. The angles of the pipes on opposite sides are constructed in similar manner; A B C D E F G H I J K L M will be the elevation, N, the section on A M and O P R S the section on I J. B T U L shows how far the upper tube projects into the body under which the scoop *e d c* turns right and left to throw the rain water into either elbow as desired. The pattern for the upper piece A T U M is a straight piece of metal whose circumference is equal to N.

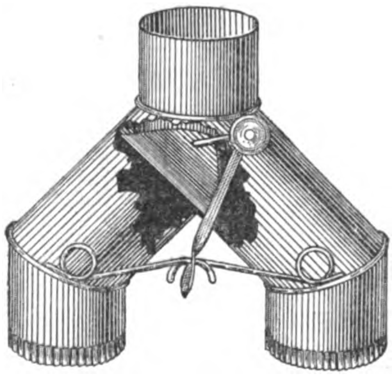


Fig. 67.

For the pattern for (A), divide the half section O P R into equal spaces as shown, from which erect lines intersecting the miter line H K as shown, and from which, parallel to K L and H G, draw lines intersecting the joint lines G *h* L as shown. As none of the lines just drawn intersect the corner *h*, it will be necessary to obtain this point on the half section O P R from which the stretchout of the pattern is taken. Therefore from *h*, parallel to L K draw *h h'* intersecting H K at *h'*, from which, parallel to K J, drop a line intersecting the profile O P R S at *h''*. At right angles to L K draw stretchout of O P R S as shown by similar numbers on T¹ U¹, through which at right angles to T¹ U¹ draw lines which are intersected by lines drawn at right angles to L K from similar in-

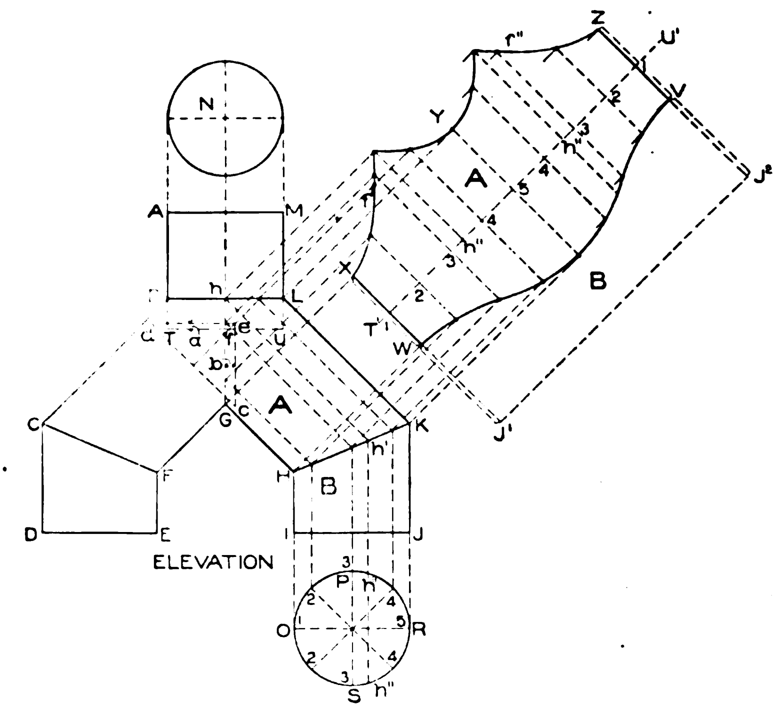


Fig. 68.

tersections on G *h* L and H K. A line traced through points thus obtained as shown by X Y Z V W will be the pattern for (A). From *f* in the elevation at right angles to L K project a line intersecting the miter cut X Y Z at *f'* and *f''*. At *f'* and *f''* holes are to be punched in which the pivot *f* of the scoop *c d e* in elevation will turn.

While the pattern for (B) can be obtained as that for (A) was obtained, a short method is to take the distance K to J and place it as shown from W to J^1 and V to J^2 on the lines of the pattern X W and Z V respectively extended. W V J^2 J^1 will be the pattern for B.

To avoid a confusion of lines in the development of the scoop or cut-off *c d e*, this has been shown in Fig. 69 in which *d e c* is a reproduction of *d e c* in Fig. 68. A true section of the scoop must now be drawn on *x e* in Fig. 69 so that its dimensions will allow it to turn easily inside of the joint line G *h* in elevation in Fig. 68. Therefore draw any horizontal line as 4 5 in Fig. 69, at right angles to which from *f* draw a vertical line intersecting 4 5 at *f*. Now take a distance $\frac{1}{16}$ inch less than one-half the diameter of O R in Fig. 68, and place it in Fig. 69 on either side of the line 4 5 on the vertical line just drawn as shown from *f* to 2 and *f* to 2′. Extend *d e* till it intersects 4 5 at 4. Draw a line from 4 to 2′; by bisecting this line we obtain the line *a b* intersecting 4 5 at *i*. Then with *i* as center and *i* 2′ as radius, describe the arc 2′ 2.

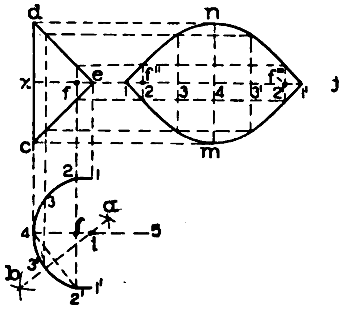


Fig. 69.

From 2 and 2′ draw horizontal lines equal to *f e* as shown by 2 1 and 2′ 1′. Then will 1 4 1′ be the true section on *x e*. Divide the half section into equal spaces as shown from 1 to 4, from which erect lines intersecting *c e* and *e d*. Extend *x e* as *x j*, upon which place the stretchout of 1 4 1′ as shown by similar numbers on *x j*, through which draw vertical lines. These lines intersect with horizontal lines drawn from similar intersections on *d e c*. Through points thus obtained draw the line 1 *n* 1′ *m* which is the desired pattern. As the pivot hole *f* falls directly on line 2, then *f‴ f″* will be the position of the holes in the pattern. Laps must be allowed to all patterns.

In putting up rectangular hot air pipe it is often the case that the pipe will be placed in the partition of one story, then has to fall forward and twist one quarter way around to enter the partition of the upper story which runs at right angles to the lower one. A perspective view showing this condition is shown in Fig. 70, where the upper opening turns one quarter on the lower one and leaning to the right as much as is shown in Fig. 71 in plan. This problem is known as a transition piece in a rectangular pipe.

Full size measurements are given in Fig. 71 which should be drawn one-half size. The height of the transition piece is 1 foot 8 inches, the size of the openings, each 4×10 inches turned as shown, two inches to the left and two inches above the lower section as shown. From the plan construct the front and side elevations as shown by the dotted lines. A B C D and E F G H will then be the front and side elevations of the transition piece respectively

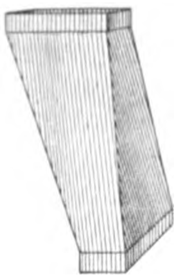


Fig. 70.

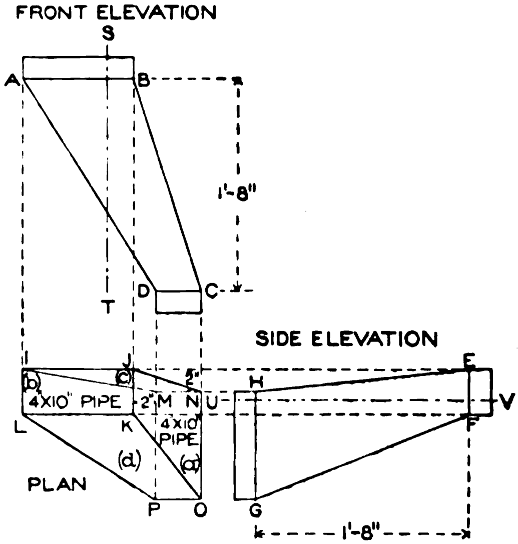


Fig. 71.

equal to 20 inches or 10 inches for practice. Number each side of the plan (*a*), (*b*), (*c*), and (*d*). Through the front and side elevations draw the vertical and horizontal lines S T and U V respectively at pleasure. These lines are only used as bases for measurements in determining the patterns. For the pattern for the side marked (a) in plan take the length of B C and place it on the vertical line B C in Fig. 72. Through the points B and C draw the horizontal lines E F and H G, making B F and B E, and C G and C H equal respectively to the distances measured from the line U V in Fig. 71 to points F, E, G, H. Draw lines from E to H and F to G in Fig. 72, which is the pattern for (a).

For the pattern for (b) in Fig. 71 take the distance of A D, and place it as shown by A D in Fig. 72; through A and D draw E F and H G, making A F and A E, and D G and D H equal

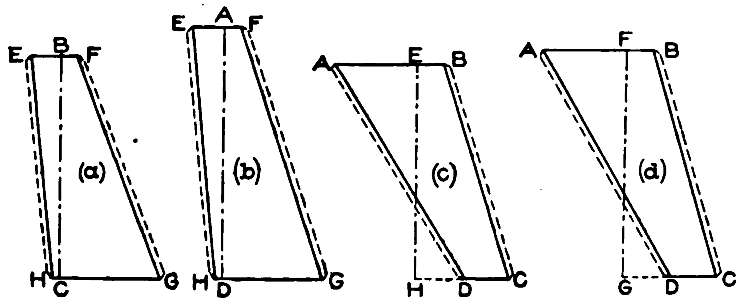


Fig. 72.

respectively to the distances measured from the line U V in side elevation in Fig. 71 to points F, E, G, H. Draw lines from E to H and F to G in Fig. 72, which will be the pattern for (b). In similar manner obtain the patterns for (c) and (d) in plan in Fig. 71. The lengths of E H and F G are placed as shown by similar letters

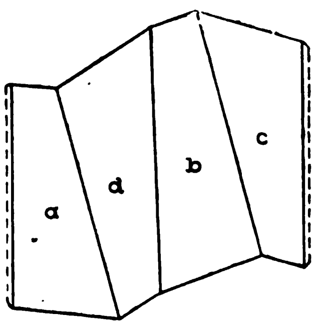


Fig. 73.

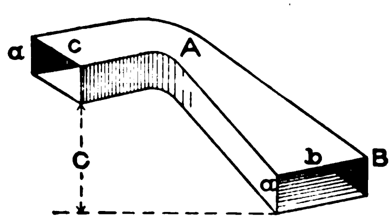


Fig. 74.

in Fig. 72, while the projections to A, B, C, D are obtained from A, B, C, D in front elevation in Fig. 71, measuring in each instance from S T.

If desired the top and lower flange shown in the perspective in Fig. 70 can be added to the patterns in Fig. 72. Laps are allowed to the patterns to allow for double seaming at corners, if, however, the pattern should be required in one piece, it would only be necessary to join the various pieces in their proper positions as shown by *a d b c* in Fig. 73, which would bring the seam on the line J N in plan in Fig. 71.

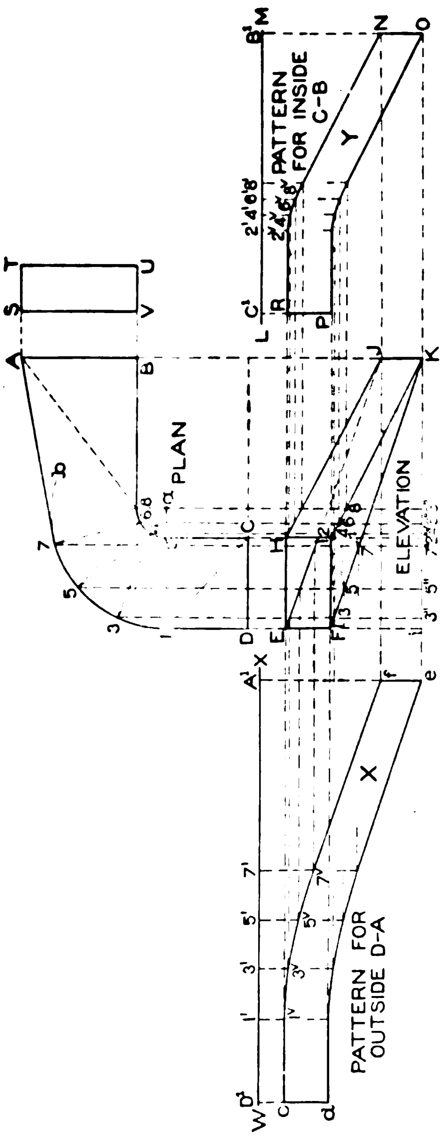


Fig. 75.

In Fig. 74 is shown a perspective view of a curved rectangular chute the construction of which arises in piping and blower work. The problem as here presented shows the sides *a* and *a* in vertical planes having the same height, while the bottom *b* has more width than the top *c*. The top opening is to rise above the bottom opening a given distance equal to C. First draw the plan and elevation as shown in Fig. 75, make A B equal to 2 inches, B 8 $2\frac{1}{2}$ inches; with a radius equal to $\frac{1}{2}$ inch, with *a* as center draw the quarter circle 8 2. From 2 draw the vertical line 2 C equal to $1\frac{3}{8}$ inches and draw C D equal to $1\frac{1}{2}$ inches. Make D 1 equal to C 2 and using *a* as center and *a* 1 as radius draw the arc 1 *b*. From A draw a line tangent to 1 *b* as A 7. A B C D will be the plan of the chute. In line with A B draw the section S T U V. In line with D C draw the section E F I H as shown. Place the desired rise of the chute as shown by F *i* in elevation and from *i* draw a horizontal line as *i* K, which intersect by a line drawn from A B in plan as shown. Make K J equal to F E and draw the lines F K, K I, and E J, J H. F E J K is the elevation of the outside curve, H I K J the inside curve, F I K the bottom, and E H J the top.

Having the plan and elevation in position we will first draw the pattern for the two vertical sides. For the pattern for the side of the chute shown by B C in plan proceed as follows: Divide the inner curve 2 to 8 into equal parts as shown by 2-4-6 and 8, from which points drop lines intersecting the inside of the chute in plan H J K I as shown. At right angles to J K draw L M, upon which place the stretchout of B C in plan as shown by similar letters and numbers on L M, through which draw vertical lines which intersect lines drawn parallel to L M from H J. Through points thus obtained draw the line R 2^V 4^V 6^V 8^VN. The same method can

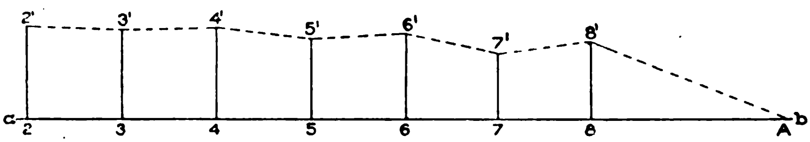


Fig. 76.

be employed for the curve P O, but as the height H I and J K are equal, having a common profile B C, take the height of H I or J K and place it on vertical lines as R P and N O and trace the curve R N as shown by P O. N O P R is the pattern for C B in plan; To obtain the pattern for the outside curve divide the curve 1-7 into equal parts as shown, from which drop vertical lines intersecting similar points in E J K F, in elevation at right angles to E F draw W X, upon which place the stretchout of D A in plan as shown. From the divisions on W X drop vertical lines, which intersect by lines drawn from similar numbered intersections on E J. Trace a line through these points as shown by *c f* and draw *d e* as explained in connection with the inside pattern. *c d e f* is the pattern for the outside of the chute shown in plan by D A.

As both the top and bottom of the chute have the same bevel, the pattern for one will answer for the other. Connect opposite points in plan as shown from C to 1 to 2 to 3 up to 8, then to A. In similar manner connect similar points on the bottom in elevation as shown from 1 to 2 up to K. The lines in plan represent the bases of the sections whose altitudes are equal to the various heights in elevation, measured from i K. Take the various lengths from 2 to 3 to 4 to 5 to 6 to 7 to 8 to A in plan and place them as shown by similar numbers on the horizontal line *a b* (Fig. 76); through *a b* draw vertical lines, equal in height to similar numbers in elevation, in Fig. 75, measured from the line *i* K. For example take the distance 4 5 in plan and place it as shown by 4 5 in Fig. 76. Erect perpendiculars 4 4′ and 5 5′ equal to 4″ 4 and 5″ 5 in elevation in Fig. 75. Draw a line from 4′ to 5′ in Fig. 76, which is the true length of 4 5 in plan in Fig. 75. Proceed in similar manner for the balance of the sections. Take a tracing of 1 2 C D in plan and place it as shown by 1, 2, C, D in Fig. 77. Now using 1 as

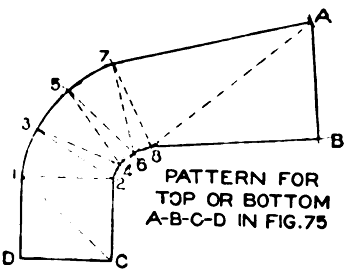


Fig. 77.

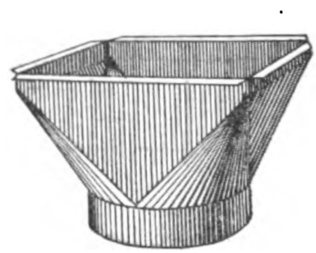


Fig. 78.

center and 1^V 3^V in (*x*), in Fig. 75, as radius, describe the arc at 3, in Fig. 77, which is intersected by an arc, struck from 2 as center, and 2′ 3′, in Fig. 76, as radius. Now with radius equal to 2^V 4^V in (Y) in Fig. 75 and 2 in Fig. 77 as center, describe the arc at 4 which is intersected by an arc, struck from 3 as center and 3′ 4′, Fig. 76, as radius. Proceed in this manner, using alternately as radius, first the divisions in the pattern (X), Fig. 75, then the slant lines in Fig. 76, the divisions in the pattern (Y), Fig. 75, then again the lines in Fig. 76 until the line 7 8, Fig. 77, has been obtained. Then using 7 as center, with a line equal to $7^V f$ in (X), Fig. 75, as radius, describe the arc A, Fig. 77, which is intersected by an arc struck from 8 as center and 8′ A, Fig. 76, as radius. Then with radius, equal to 8^V N in (Y), Fig. 75, and 8, Fig. 77, as center, describe the arc B, which is intersected by an arc, struck from A as center and A B in plan in Fig. 75 as radius. Trace lines through points thus obtained in Fig. 77, and A B C D will be the desired pattern. Laps must be allowed on all patterns for double seaming the corners.

In Fig. 78 is shown a perspective view of a hopper register box usually made from bright tin or galvanized iron in hot air piping. In drawing this problem, the student should first draw the half plan, making the semicircle $3\frac{3}{4}$ inches diameter, and placing it directly in the center of the rectangular top, which is $3\frac{3}{4}$ inches wide and $5\frac{3}{4}$ inches long. Draw the elevation from the plan as shown by A B C D E F G H, making the vertical height V W, $2\frac{1}{4}$ inches, and the flanges at the top and bottom each $\frac{1}{2}$ inch. I K L M in plan is the horizontal section on A B in elevation and O P R the section on E F.

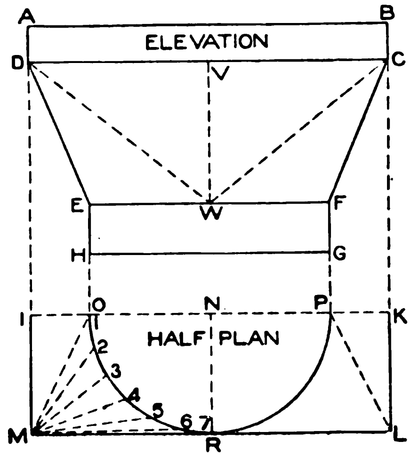


Fig. 79.

The pattern will be developed by triangulation, and the first step is to develop a set of triangles. Divide the quarter circle O R into equal spaces, as shown by the numbers 1 to 7 in plan, from which draw lines to the apex M. These lines represent the bases of triangles whose vertical height is equal to V W in elevation. Therefore, in Fig. 80, draw any horizontal line as T U, upon which place the various lengths M 1, M 2, M 3, etc.) Fig. 79) as shown by similar numbers on T U. From T U erect the line T S equal to the vertical height V W (Fig. 79). Then draw the hypotenuses S 1, S 2, S 3, etc., in Fig. 80, which represent the true lengths of similar numbered lines in plan in Fig. 79. For the half pattern with seams on I O and P K in plan, take a tracing of D V W in elevation and place it as shown by D V 7 in Fig. 81. Now using D as center, and with radii equal to the various slant lines in Fig. 80 from S 1 to S 7 strike small arcs as shown from 1 to 7 in Fig. 81. Set the dividers

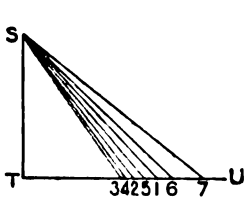


Fig. 80.

equal to the spaces contained in O R, in Fig. 79, and starting from point 7, in Fig. 81, step from one arc to another until 1 is obtained. Then using 1 as center and E D (Fig. 79) as radius describe the arc D′ in Fig. 81. With D as center and M I in plan in Fig.

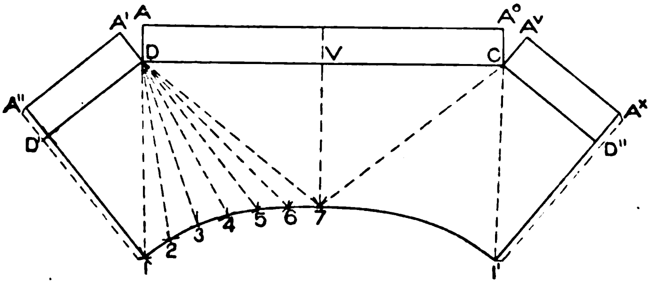


Fig. 81.

79 as radius, draw another arc intersecting the one previously drawn at D′. Draw a line from 1 to D′ to D in Fig. 81, 7 1 D′ D V is the quarter pattern, and the left-hand side of the figure may be made by tracing the quarter pattern reversed as shown by V C D″ 1′ 7. Take the distance of the flange D A in elevation in Fig. 79 and place it at right angles to the line D′ D, D C, C D″ as shown respectively by A″ A′, A A° and Aᵛ Aˣ, which completes the half pattern with laps allowed as shown

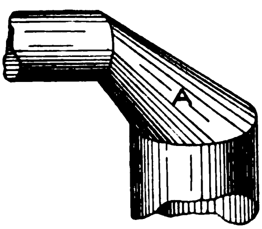


Fig. 82.

The pattern for the collar E F G H in elevation in Fig. 79 is simply a straight strip of metal, equal to the circumference of O P R in plan.

It is often the case that two unequal pipes are to be connected by means of a transition piece as shown by A in Fig. 82, the ends of the pipes being cut at right angles to each other. As the centers of both pipes are in one line when viewed in plan, making both halves of the transition piece equal, the problem then consists of developing a transition piece, from a round base to a round top placed vertically. Therefore in Fig. 83 draw 1 5 equal to $2\frac{1}{4}$ inches, and at an angle of 45° draw 5 6 $1\frac{3}{4}$ inches. At right angles to 1 5 draw 6 10 4 inches long and draw a line from 10 to 1. On 1 5 draw the semicircle 1 3′ 5, and on 6 10 draw the semicircle 6 8′ 10.

Divide both of these into equal spaces as shown, from which draw lines perpendicular to their respective base lines. Connect opposite points as shown by the dotted lines, and construct a diagram of

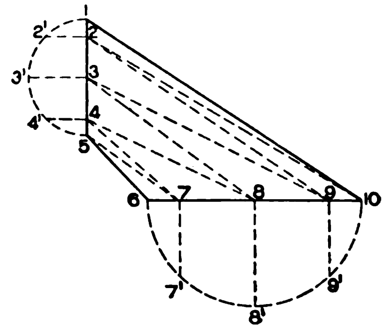


Fig. 83.

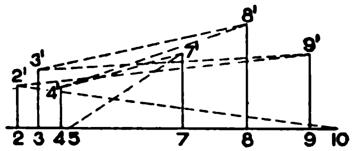


Fig. 84.

sections as shown in Fig. 84 whose bases and heights are equal to similar numbered bases and heights in Fig. 83. For example, take the distance 4 8 and place it as shown by 4 8 in Fig. 84, from which points erect the vertical lines 4 4′ and 8.8′ equal to 4 4′ and 8 8′ in Fig. 83. Draw a line from 4′ to 8′, Fig. 84, which is the true

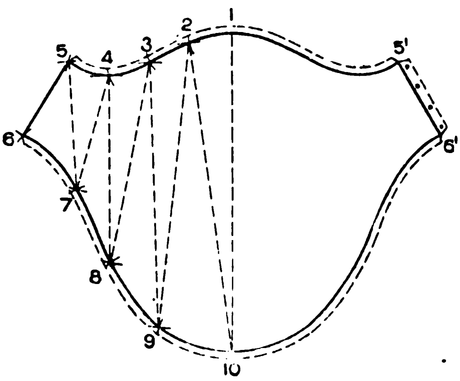


Fig. 85.

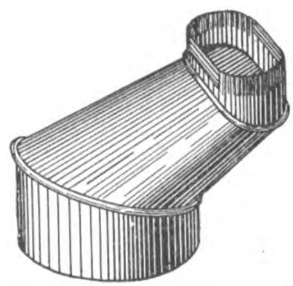


Fig. 86.

length on similar line in Fig. 83. For the pattern take the distance of 1 10 and place it as shown by 1 10 in Fig. 85. Using 1 as center, and 1 2′, Fig. 83, as radius, describe the arc 2 in Fig. 85; intersect it by an arc struck from 10 as center and 10 2′, Fig. 84, as radius. Then using 10 9′ in Fig. 83 as radius, and 10, Fig. 85, as center, describe the arc 9, and intersect it by an arc struck from 2 as center, and 2' 9', Fig. 84, as radius. Proceed in this manner using alternately as radii, first the divisions in the half profile 1 3' 5, Fig. 83, then the length of the proper hypotenuse in Fig. 84, then the divisions in 6 8' 10 in Fig. 83; then again the hypotenuse in Fig. 84 until the line 5 6 in Fig. 85 has been obtained, which is equal to 5 6 in Fig. 83. Laps should be allowed for riveting and seaming as shown.

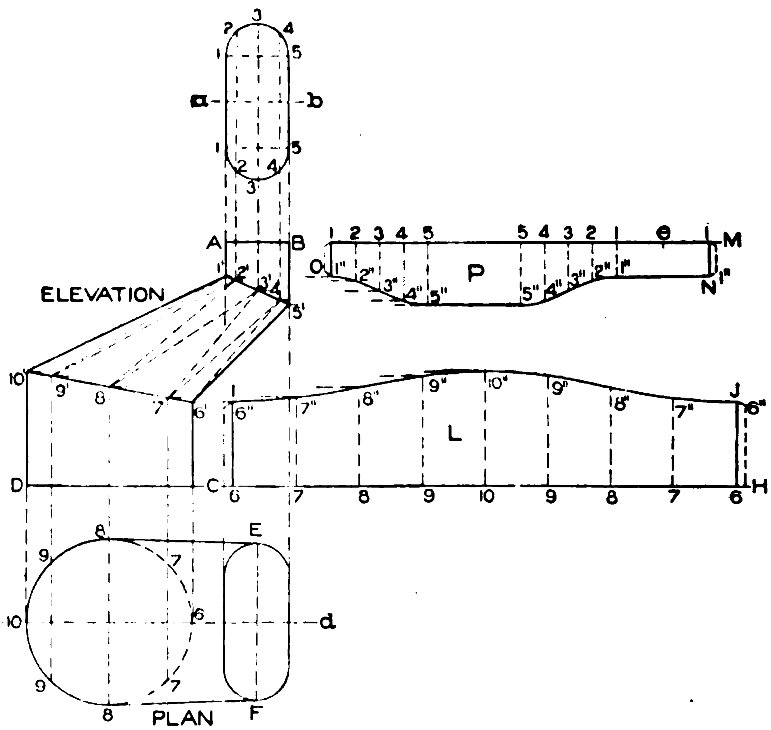


Fig. 87.

In Fig. 86 is shown a perspective of an offset connecting a round pipe with an oblong pipe, having rounded corners.

The first step is to properly draw the elevation and plan as shown in Fig. 87. Draw the horizontal line A B equal to one inch, B 5' one inch, and from 5' at an angle of 45° draw 5' 6' equal to $2\frac{1}{4}$ inches and 6' C $1\frac{1}{4}$ inches. Make the diameter C D $2\frac{3}{4}$ inches and D I 0' $1\frac{3}{4}$ inches. Make A 1' $\frac{1}{2}$ inch and draw a line from 1' to

10′ which completes the elevation. Directly above the line A B draw the section of the oblong pipe, making the sides 1 1 and 5 5 equal to 1½ inches, to which describe the semicircles on each end as shown. In similar manner draw the section on D C, which is shown by 6 8 10 8. A duplicate of the oblong pipe is also shown in plan by E F, showing that the centers of the pipe come in one line, making both halves symmetrical.

The patterns for the pipes will first be obtained. Divide the semicircular ends of the oblong section into equal parts, in this case four, also each of the semicircles of the round pipe in similar number of parts as shown respectively from 1 to 5 and 6 to 10. Draw vertical lines from these intersections cutting the miter line of the oblong pipe at 1′ 2′ 3′ 4′ 5′ and the miter line of the round pipe at 6′ 7′ 8′ 9′ and 10′. In line with A B draw B M, upon which place the stretchout of the oblong pipe as shown by similar numbers; from B M drop vertical lines intersecting the lines drawn parallel to B M from similarly numbered points on 1′ 5′. Trace a line through points thus obtained, and P N O will be the pattern for the oblong pipe. Now take the stretchout of the round pipe, and place it on C H; erect vertical lines as shown intersecting the lines drawn parallel to C H from similar intersections on 6′ 10′. I J H C is the pattern for the round pipe.

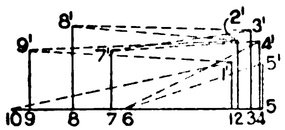


Fig. 88.

The transition piece 1′ 5′ 6′ 10′ will be developed by triangulation, and it is usual to obtain true sections on the lines 1′ 5′ and 6′ 10′; however, in this case it can be omitted because we have the true lengths of the various divisions on the lines 1′ 5′ and 6′ 10′ in the miter cuts in P and L respectively.

The next step is to obtain a diagram of sections giving the true lengths, for which proceed as follows: Connect opposite points in elevation as shown from 1′ to 9′ to 2′ to 8′ to 3′ etc., as shown. For example draw center lines through the oblong and round sections as shown by *a b* and *c d* respectively, and take the length of 1′ 10′ in elevation and place it as shown from 1 to 10 in Fig. 88. From 1 draw the vertical line 1 1′ equal to the height of 1 in the oblong section in Fig. 87 above the center line *a b*. As point 10 in plan has no height, it falls on the center line *c d* in plan, then draw a line from 1′ to 10 in Fig. 88. Now take the distance from 1′ to 9′ in elevation, Fig. 87, and place it as shown from 1 to 9 in Fig. 88. Erect the lines 1 1′ and 9 9′ equal to points 1 and 9 in the oblong and round sections in Fig. 87, measured respectively from the lines *a b* and *c d*. Draw a line from 1′ to 9′ in Fig. 87. Proceed in this manner until all of the sections are obtained. For the pattern proceed as shown in Fig. 89, in which draw any vertical line as *e* 10 equal to 1′ 10′ in elevation in Fig. 87. Now, with one-half of 1 1 in pattern P as *e* 1 as radius, and *e* in Fig. 89 as center, describe the arc 1 which is intersected by an arc struck from 10 as center and 10 1′, in Fig. 88 as radius. With radius equal to 10″ 9″ in pattern L in Fig. 87, and 10 in Fig. 89 as center describe the arc 9, which is intersected by an arc struck from 1 as center and 1′ 9′, in Fig. 88 as radius. Now, using as radius 1″ 2″ in pattern P in Fig. 87 and 1 in Fig. 89 as center, describe the arc 2 which is intersected by an arc struck from 9 as center and 9′ 2′ in Fig. 88 as radius.

Proceed in this manner, using alternately as radii, first the divisions in the pattern cut I J, Fig. 87, then the length of the slant lines in Fig. 88, the divisions in the cut O N in Fig. 87, then again the slant lines in Fig. 88 until the line 5 6 in pattern, Fig. 89, has been obtained. Then using 5 as center and 1 *e* in P, Fig. 87, as radius, describe the arc *e′* in Fig. 89, and intersect it by an arc struck from 6 as center and 6′ 5′ in elevation in Fig. 87 as radius. Draw lines through the various intersections in Fig. 89; 10 *e e′* 6 is the half pattern. By tracing it opposite the line *e* 10, as shown by *e* 1′ 5′ *e″* 6′ 10, the whole pattern, *e′ e e″* 6′ 10 6, is found. Laps should be allowed on all patterns for seaming or riveting both in Figs. 87 and 89.

In Fig. 90 is shown a perspective view of a three-way branch round to round, the inlet A being a true circle, and the outlets B, C, and D also being true circles, the centers of which are in the same vertical plane, thus making both sides of the branch symmetrical.

First draw the elevation and the various sections as shown in Fig. 91. Draw the center line *a b*. From *b* draw the center line of the branch C at an angle of 58° as shown by *b d*. Make the center lines *a b* and *b d* each 3½ inches long. Make the half diameter of the branch B at the outlet ¾ inch, and the full diameter of the branch C at the outlet $1\frac{1}{2}$ inches placed on either side of and at right angles to the center lines. Draw a line from *e* to *f*, and with *i* and *h* as centers and radii equal to $\frac{3}{4}$ inch draw arcs intersecting each other at *c*. Draw lines from *i* to *c* to *h*. In similar manner obtain A and the opposite half of B. A B C is the elevation of the three branches whose sections on outlet lines are shown respectively by G F and E and whose section on the inlet line is shown by D.

The next step is to obtain a true section on the miter line or line of joint *b c*. Knowing the height *b c* and the width at the

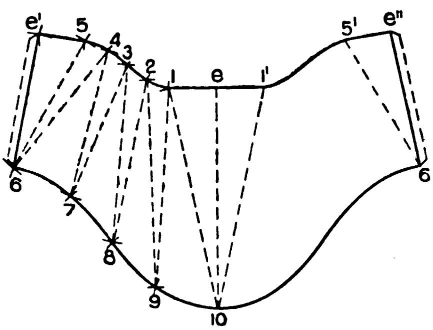


Fig. 89.

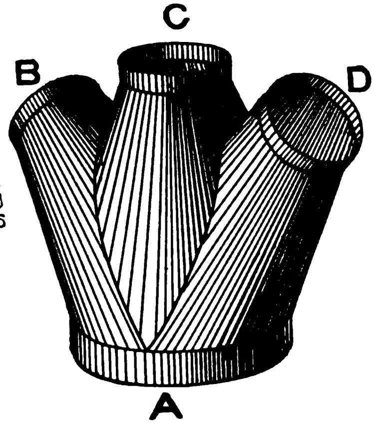


Fig. 90.

bottom, which is equal to the diameter of D, the shape can be drawn at pleasure as shown in Fig. 92, *b c* is drawn equal to *b c*, Fig. 91, while *b d* and *b a* are equal to the half diameter D in Fig. 91. Now through *a c d* in Fig. 92 draw the profile at pleasure as shown, which represents the true section on *c b* in Fig. 91.

As the side branches A and C are alike, only one pattern will be required, also a separate pattern for the center branch both of which will be developed by triangulation. To obtain the measurements for the sections for the center branch B, proceed as shown in Fig. 93 where 1 4 5 8 is a reproduction of one-half the branch B in Fig. 91. As the four quarters of this center branch are alike only one quarter pattern will be developed; then, if desired, the quarter patterns can be joined together, forming one pattern. Now take a tracing of *c b a*, Fig. 92, and place it on the line 5 8 as shown in Fig. 93. Similarly take a tracing of the quarter profile F in Fig. 91 and place it on the line 4 1 in Fig. 93. Divide the two profiles 1′ 4 and 5 8′ each into the same number of spaces as shown respectively by points 1′ 2′ 3′ 4 and 5 6′ 7′ 8′, from which points at right angles to their respective base lines 1 4 and 5 8 draw lines intersecting the base lines at 1 2 3 4 and 5 6 7 8. Now draw solid lines from 3 to 6 and 2 to 7 and dotted lines from 3 to 5, 2 to 6, and 1 to 7. These solid and dotted lines represent

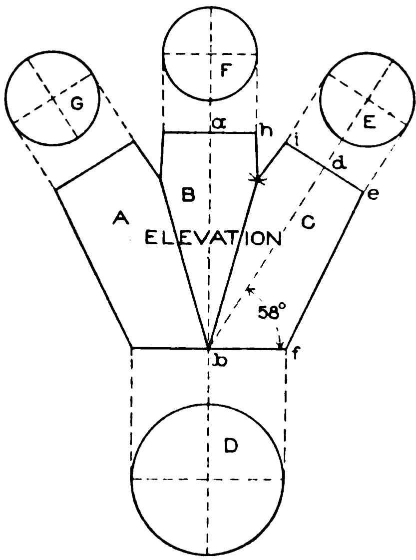


Fig. 91.

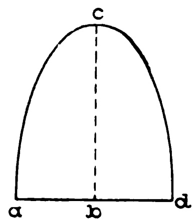


Fig. 92.

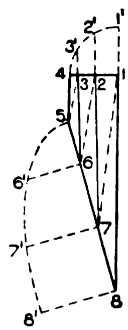


Fig. 93.

the bases of the sections whose altitudes are equal to the various heights of the profiles in Fig. 93. The slant lines in Fig. 94 represent the true distances on similar lines in Fig. 93, as those in Fig. 95 represent the true distances on dotted lines in Fig. 93.

For the pattern take the length of 1′ 8′, Fig. 94, and place it as shown by 1 8 in Fig. 96, and using 8 as center and 8′ 7′ in Fig. 93 as radius draw the arc 7, which intersect by an arc struck from 1 as center and 1′ 7′ in Fig. 95 as radius. Then using 1′ 2′ in Fig. 93 as radius draw the arc 2, which intersect by an arc struck from 7 as center and 7′ 2′ in Fig. 94 as radius. Proceed in this manner until the line 4 5 in Fig. 96 has been obtained which equals 4 5 in Fig. 93. Trace a line through points thus obtained in Fig. 96, then will 1 4 5 8 1 give the quarter pattern.

If the pattern is desired in one piece trace as shown by similar figures, to which laps must be allowed for riveting.

As the two branches A and C in Fig. 91 are alike, one pattern will answer for the two. Therefore let 1 7 8 11 14 in Fig. 97 be a reproduction of the branch C in Fig. 91. Now take a tracing of *a b c* in Fig. 92 and place it as shown by 11′ 11 8 in Fig. 97; also take a tracing of the half section E and the quarter section D in Fig. 91 and place them as shown respectively by 1 4′ 7 and

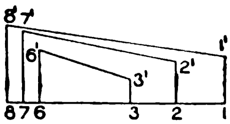


Fig. 94.

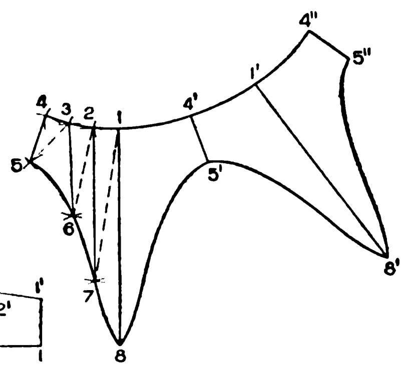


Fig. 96.

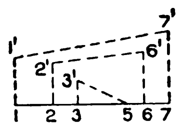


Fig. 95.

11 11′ 14 in Fig. 97. Now divide the two lower profiles 8 11 and 11′ 14 each into 3 equal parts, and the upper profile 7 4′ 1 into 6 equal parts as shown by the small figures 8 to 11′, 11′ to 14 and 1 to 7. From these points, at right angles to the various base lines, draw lines, intersecting the base lines as shown by similar numbers. Draw solid and dotted lines as shown, and construct the sections on solid lines as shown in Fig. 98 and the sections on dotted lines as shown in Fig. 99 in precisely the same manner as described in connection with Figs. 94 and 95.

In Fig. 100 is shown the pattern shape (to which laps must be allowed for riveting) obtained as was the development of Fig. 96. First draw the vertical line 1 14, Fig. 100, equal to 1 14 in Fig. 97. Then use alternately as radii, first the divisions in 1 4′ 7 in Fig. 97, the proper slant line in Figs. 98 and 99 and the divisions in 11′ 14 until the line 4 11, Fig. 100, is obtained. Starting from the point 11 use as radii in their regular order the distances marked off between 11′ and 8, Fig. 97, then the proper slant lines in Figs. 98 and 99, the distances shown in the semicircle, 1 4′ 7, Fig. 97, until the line 7 8, Fig. 100, is drawn equal to 7 8, in Fig. 97. Then

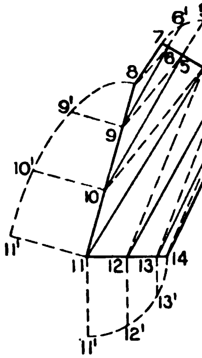


Fig. 97.

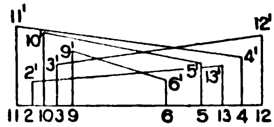


Fig. 98.

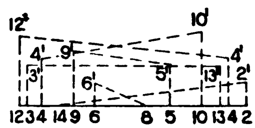


Fig. 99.

1 7 8 11 14, Fig. 100, will be the half pattern. If the pattern is desired in one piece trace 1 7′ 8′ 11′ 14 opposite the line 1 14 as shown.

In Fig. 101 is shown a perspective view of a two-branch fork oval to round, commonly used as breeching for two boilers. As

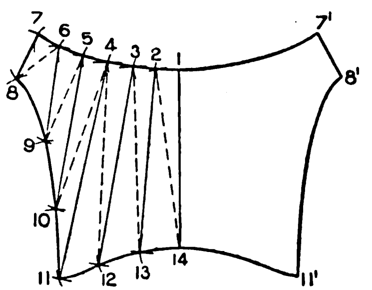


Fig. 100.

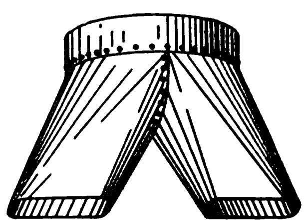


Fig. 101.

both halves of the fork are symmetrical the pattern for one will answer for the other.

While the side elevation shown in Fig. 102 is drawn complete, it is only necessary in practice, to draw one half as follows, and then, if desired, the other half elevation can be traced opposite to the center line E J. First draw J B, 1½ inches, equal to the half diameter of the outlet, and the vertical center height J V, 2¼ inches. Establish the height of the joint J E one inch, and the desired projection V D on the base line 1¼ inches. Draw the length of the inlet D C 2¾ inches, and draw a line from C to B and D to E. Draw a similar figure opposite the line J E, and A B C D E F G shows the side elevation of the fork. In their proper position below A B draw the sections M and N whose semicircular ends are struck from *a b c* and *d* with radii equal to ½ inch. Now draw an end elevation in which the true section on

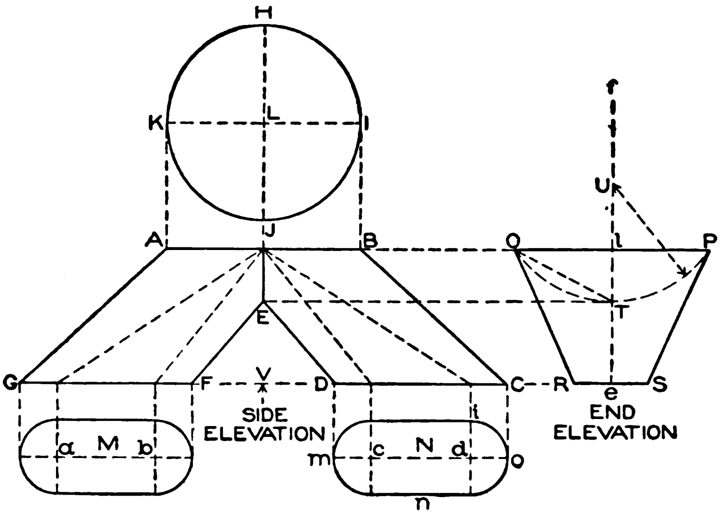


Fig. 102.

J E is obtained. Draw the center line *f e* and extend the lines A B and G C in elevation as A P and G S. Take the half diameter L J and place it on either side of *e f* as shown by O P. In a similar manner take the half diameter of the section N as *d i* and place it on either side of *e f* as shown by R S. Then O P S R shows the end elevation. Draw E T intersecting *e f* at T. Now draw the curve O T P, which in this case is struck from the center U, being obtained by bisecting the line O T. It should be understood that the curve O T P, which represents the true section on J E, can be made any desired shape, but when once drawn, represents a fixed line.

The pattern will be developed by triangulation, for which diagrams of sections must be obtained from which to obtain measurements. These sections are obtained as follows: In Fig. 103 1 4 5 12 13 is a reproduction of J B C D E, Fig. 102. Reproduce the quarter profile H L I, the half profile O T, and the half profile *m n o* as shown by 1′ 1 4, 1″ 13 1 and 12 9′ 8′ 5 in Fig. 103. Divide the round ends in *a* each into 3 parts and the profiles *b* and *c* also each into 3 spaces, as shown by the figures. Drop lines from these figures at right angles to the base lines from 1 to 15 as shown and draw solid and dotted lines in the usual manner. While in some of the previous problems only dotted lines were drawn, we

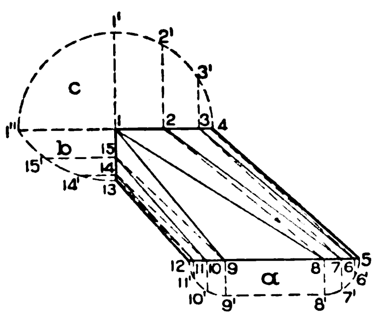


Fig. 103.

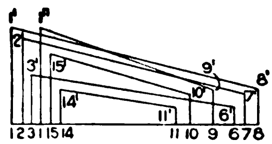


Fig. 104.

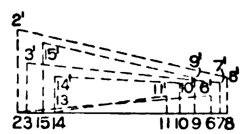


Fig. 105.

have drawn both solid and dotted lines in this case, in order to avoid a confusion of sections. A diagram of sections on solid lines in Fig. 103 is shown in Fig. 104, the figures in both corresponding; while Fig. 105 shows the true sections on dotted lines. The method of obtaining these sections has been described in connection with other problems.

For the pattern draw any vertical line as 4 5, Fig. 106, equal to 4 5 in Fig. 103. Then with 5 6′, Fig. 103, as radius and 5 in Fig. 106 as center draw the arc 6, intersecting it by an arc struck from 4 as center and 4 6′, Fig. 105, as radius. Then using 4 3′, Fig. 103, as radius, and 4 in Fig. 106 as center, describe the arc 3, intersecting it by an arc struck from 6 as center and 6′ 3′ in Fig. 104 as radius. Proceed in this manner, using alternately as radii, first the divisions in *a* in Fig. 103, then the slant lines in Fig. 105; the divisions in *c* in Fig. 103, then the slant lines in Fig.

104, until the line 1 8, Fig. 106, is obtained. Now using 8 as center and 8′ 9′, Fig. 103, as radius draw the arc 9 in Fig. 106, intersecting it by an arc struck from 1 as center and 1″ 9′, Fig. 104, as radius. Then starting at 1 in Fig. 106 use alternately as radii, first the divisions in *b* in Fig. 103, then the slant lines in Fig. 105, the divisions in *a* in Fig. 103, then the length of the slant lines in Fig. 104 until the line 12 13 is obtained in Fig. 106, which equals 12 13 in Fig. 103. Trace a line through points thus obtained in Fig. 106, then will 4 1 13 12 9 8 5 be the half pattern. If the pattern is desired in one piece, trace this half opposite the line 4 5 as shown by 1′ 13′ 12′ 9′ 8′, allowing laps for riveting.

In Fig. 107 is shown a perspective view of a tapering flange around a cylinder passing through an inclined roof, the flange

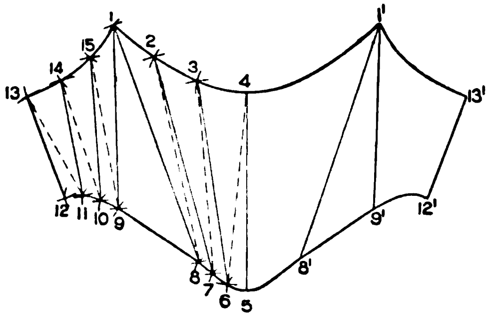


Fig. 106.

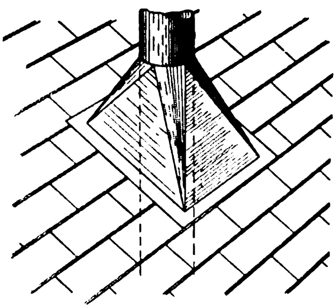


Fig. 107.

being rectangular on the roof line. The problem will be developed by triangulation, a plan and elevation first being required as shown in Fig. 108.

First draw the angle of the roof A B at an angle of 45°, through which draw a center line C D. From the roof line A B on the center line set off *a b* equal to 4 inches and through *b* draw the horizontal line E F, making B F and B E each one inch. Through *d* on the center line draw the horizontal line G H, making *d* H and *d* G each two inches. From H and G erect perpendiculars intersecting the roof line at K and L. Then draw lines from E to K and F to L, completing the elevation. Construct the square in plan making the four sides equal to G H. Bisect H I and draw the center line *e e* intersecting the vertical center at *d*′. Then with radius equal to *b* F or *b* E in elevation and *d*′ in plan as center, draw the circle 1 4 7 4′ representing the horizontal section on E F in elevation, while G H I J is the horizontal section on K L in elevation. As the circle in plan is in the center of the square making the two halves symmetrical it is only necessary to divide the semicircle into equal spaces as shown from 1 to 7 and draw lines

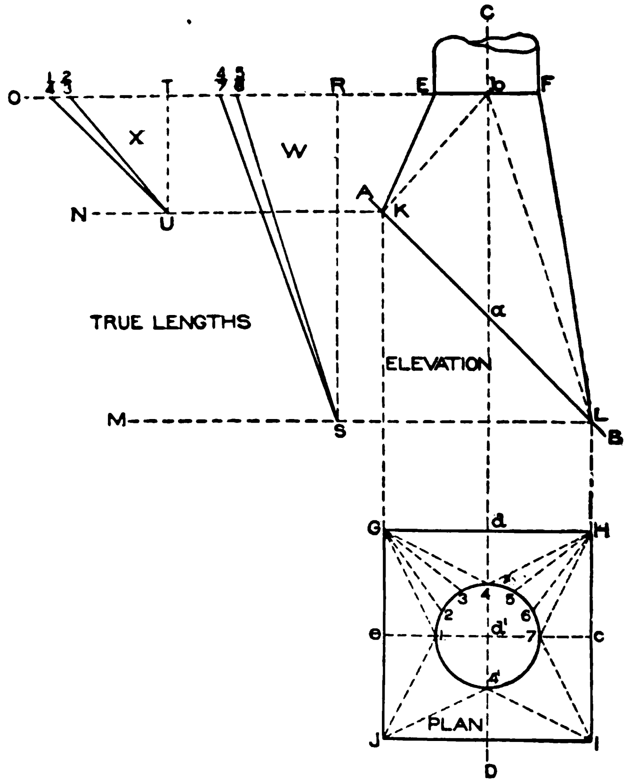


Fig. 108.

from 1, 2, 3 and 4 to G, and 4, 5, 6 and 7 to H. Then will the lines in 1 G 4 and 4 H 7 represent the bases of triangles which will be constructed, whose altitudes are shown respectively by the vertical heights in K E and L F in elevation. Therefore draw horizontal lines through E F, K, and L as shown by F O, K N, and L M. From any point as R and T on F O, draw the perpendiculars R S and T U respectively, meeting the horizontal lines drawn from L and K. Now take the various lengths in plan as G1, G2, G3, and

G4 and place them on the line F O as shown by T1, T2, T3 and T4, from which points draw lines to U which will represent the true lengths on similar lines in plan. In similar manner take the distances in plan from H to 4, to 5, to 6, to 7, and place them on the line F O, from R to 4, to 5, to 6, to 7, from which points draw lines to S which represent the true lengths on similar lines in plan.

For the pattern take the distance F L in elevation and place it on the vertical line 7′ L in Fig. 109. At right angles to 7′ L draw L S equal to *c* H or *c* I in plan, Fig. 108. Draw the dotted

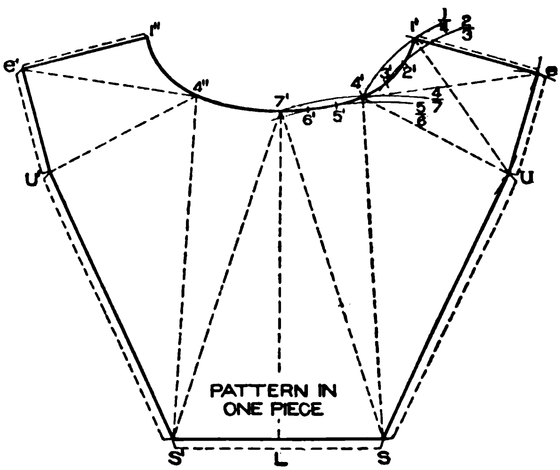


Fig. 109.

line from 7′ to S in Fig. 109, which should be equal to S 7 in W in Fig. 108. Now with radii equal to S $\frac{4}{7}$, and S $\frac{5}{6}$ and S, Fig. 109, as center, draw the arcs indicated by similar numbers. The dividers should equal the spaces in the semicircle in plan in Fig. 108, and starting at 7′ in Fig. 109, step from arc to arc of corresponding numbers as shown by 6′, 5′, 4′. Draw a dotted line from 4′ to S. Then using S as center and L K in elevation, Fig. 108, as radius, describe the arc U in Fig. 109, intersecting it by an arc struck from 4′ as center and U 4, Fig. 108, as radius. Now using U $\frac{1}{4}$, and U $\frac{2}{3}$ in X as radii, and U, Fig. 109, as center, describe arcs having similar numbers. Again set the dividers equal to the spaces in plan in Fig. 108, and starting from 4′ in Fig. 109 step to corresponding numbered arcs as shown by 3′, 2′, 1′.

Draw a dotted line from 4′ to U′ to 1′. With K E in elevation, Fig. 108, as radius, and 1′ in Fig. 109 as center, describe the arc *e* intersecting it by an arc struck from U as center and G *e* in plan in Fig. 108 as radius. Draw a line connecting S, U, *e*, and 1′. 7′ 4′ 1′ *e* U S L 7′ shows the half pattern, which can be traced opposite the line 7′ L to complete the full pattern as shown by 7′ 4″ 1″ *e*′ U′ S′ L.

One of the difficult problems often encountered by the sheet metal worker is that of a cylinder joining a cone furnace top at any angle. The following problem shows the principle to be applied, no matter what size the furnace top has, or what size pipe is used, or at what angle the pipe is placed in plan or elevation, the principles being applicable under any conditions.

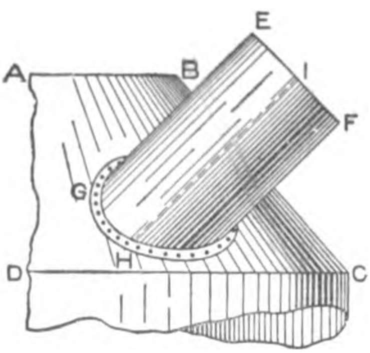


Fig. 110.

Fig. 110 shows a view of a cylinder intersecting a conical furnace top, the top being placed to one side of the center of the top. A B C D represents a portion of the conical top, intersected by the cylinder E F G H, the side of the cylinder H I to intersect at a given point on the conical top as at H. This problem presents an interesting study in projections, intersections, and development, to which close attention should be given.

In Fig. 111 first draw the center line A X. Then draw the half elevation A B C D, making A B $1\frac{5}{8}$ inches, C D $3\frac{1}{2}$ inches and the vertical height A D $2\frac{1}{8}$ inches. Draw the line from B to C. Directly below C D draw the one-quarter plan using Z as center, as shown by Z C^1 D^1 and in line with A B of the elevation draw the quarter plan of the top as Z B^1 A^1. Let *a* in the elevation represent the desired distance that the side of the cylinder is to meet the cone above the base line as H in Fig. 110. From *a*, parallel to C D in Fig. 111, draw *a b*. Then from *a* drop a vertical line intersecting the line Z C^1 in plan at *a*′. Then using Z as center and Z *a*′ as radius, describe the quarter circle *a*′ *b*′. Z *a*′ *b*′

in plan represents the true section on the horizontal plane *a b* in elevation. Now locate the point where the side of the cylinder as H in Fig. 110 shall meet the arc *a′ b′* in plan, Fig. 111, as shown

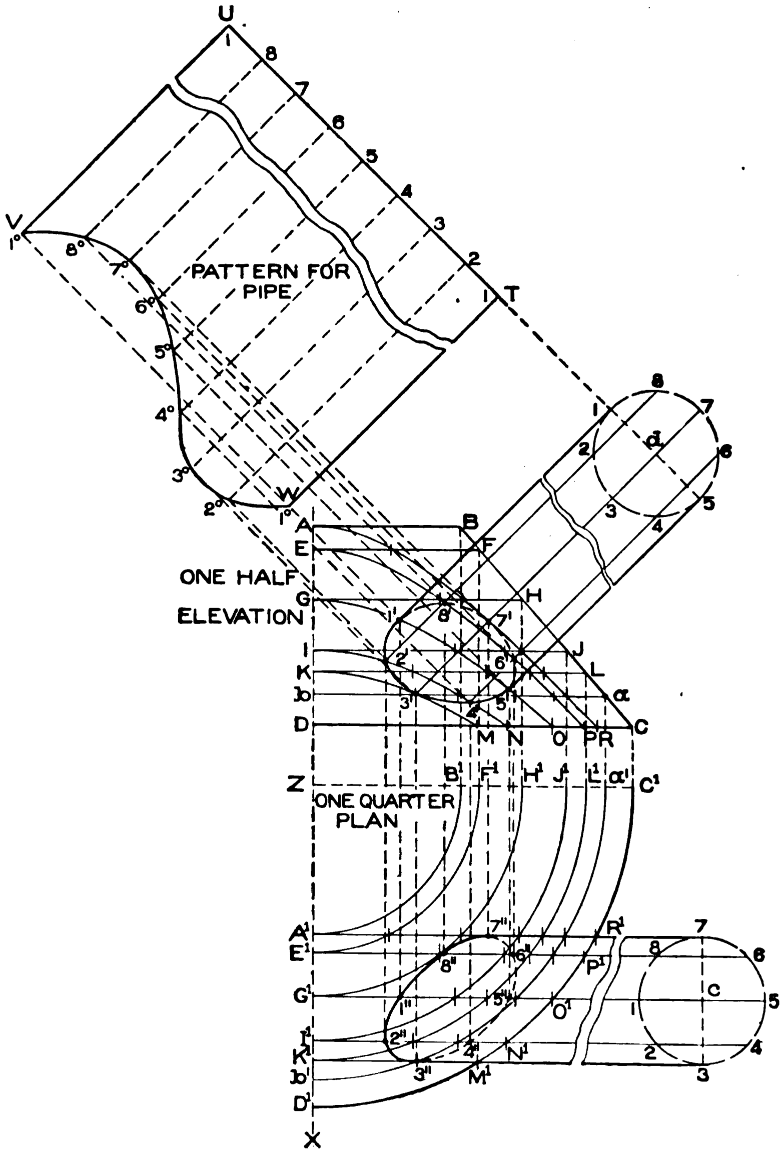


Fig. 111.

at 3″. Through 3″ draw the horizontal line intersecting the center line at K¹, the outer arc at M¹ and extend it indefinitely to 3. From 3 erect the perpendicular equal to the diameter of the cylinder, or 1⅝ inches, bisect it and obtain the center *c*. Using *c* as center with *c* 7 as radius, describe the profile of the cylinder as shown, and divide it into equal parts from 1 to 8. From these points draw lines parallel to 3 K¹, intersecting the outer arc D¹ C¹ at N¹ O¹ P¹ R¹ and the center line Z X at I¹, G¹, E¹, A¹. With Z as center and the various intersections from K¹ to A¹ as radii, describe the arcs K¹ L¹, I¹ J¹, G¹ H¹, E¹ F¹, and A¹ B¹. From the intersection B¹, F¹, H¹, J¹, L¹ erect vertical lines into the elevation intersecting the side of the cone B C as shown by similar letters B F H J L. From these points draw horizontal lines through the elevation as shown respectively by A B, E F, G H, I J, and K L. These lines represent a series of horizontal planes, shown in plan by similar letters. For example, the arc E¹ F¹ in plan represents the true section on the line E F in elevation, while the arc G¹ H¹ is the true section on the line G H in elevation, etc.

The next step is to construct sections of the cone as it would appear, if cut by the lines shown in plan by K¹ M¹, I¹ N¹, G¹ O¹, E¹ P¹, and A¹ R¹. To obtain the section of the cone in elevation on the line A¹ R¹ in plan, proceed as follows: At right angles to the line A¹ R¹ and from the intersections on the various arcs, draw lines upward (not shown) intersecting similar planes in elevation corresponding to the arcs in plan. A line traced through intersections thus obtained in elevation as shown from A to R, will be the true section on the line A¹ R¹ in plan. For example, the line K¹ M¹ of the cylinder intersects the arcs at K¹ 3″ and M¹ respectively. From these intersections, erect vertical lines intersecting K L, *b a*, and D C in elevation at K, 3′, and M respectively. Trace a curve through these points, then will K 3′ M be the section of the cone if cut on the line K¹ M¹ in plan. In similar manner obtain the other sections. Thus the section line E P, G O, and I N in elevation, represent respectively the sections if cut on the lines E¹ P¹, G¹ O¹, and I¹ N¹ in plan. Now from the given point 3″ in plan erect a line which must meet the intersection of the plane *b a* and section K M in elevation at 3′. From 3′ at its desired angle, in this case 45°, draw the line 3′ 7. At any point as *d* at right angles to 3′ 7 draw the line 1 5 through *d*, making *d* 5 and *d* 1 each equal to half the diameter of the cylinder shown in plan. With *d* 5 as radius and *d* as center draw the profile of the cylinder in elevation, and divide it into the same number of parts as shown in C in plan, being careful to allow the circle *d* in elevation to make a quarter turn, bringing the number 1 to the top as shown.

The next operation is to obtain the miter line or line of joint between the cylinder and cone in elevation. By referring to the plan it will be seen that the point 7 in the profile *c* lies in the plane of the section A^1 R^1. Then a line from the point 7 in the profile *d* in elevation, drawn parallel to the lines of the cylinder, must cut the section A R which corresponds to the plane A^1 R^1 in plan as shown by 7′ in elevation. The points 6 and 8 in the profile *c* in plan, are in the plane at the section E^1 P^1, then must the corresponding points 6 and 8 in the profile *d* in elevation, intersect the section E P as shown by 6′ and 8′. As the points 1 5, 2 4, and 3 in the profile *c* in plan, are in the planes of the sections G^1 O^1, I^1 N^1, and K^1 M^1 respectively, the corresponding points 1 5, 2 4, and 3 in the profile *d* in elevation must intersect the sections G O, I N, and K M respectively at points 1′ 5′, 2′ 4′, and 3′ as shown. Trace a line through these points, which will show the line of intersection between the cone and cylinder.

For the pattern for the cylinder, proceed as follows: At right angles to the line of the cylinder in elevation, draw the line T U upon which place the stretchout of the profile *d* as shown by similar figures on T U. In this case the seam of the pipe has been placed at 1 in *d*. Should the seam be desired at 3, 5 or 7, lay off the stretchout on T U starting with any of the given numbers. At right angles to U T from the small figures 1 to 1 draw lines which intersect with lines drawn from similar numbered intersections in the miter line in elevation at right angles to 1′ 1, resulting in the intersections 1 to 5° to 1° in the pattern. Trace a line through points thus obtained, then will U V W T be the development for the cylinder to which laps must be allowed for riveting to the cone as shown in Fig. 110 and seaming the joint T W in pattern in Fig. 111.

While the pattern for the cone is obtained the same as in ordinary flaring ware, the method will be described for obtaining the pattern for the opening to be cut into the cone. Before this can be done a plan view of the intersection between the pipe and cone must first be obtained as follows: From the various intersections 1′ to 8′ in elevation drop vertical lines intersecting lines drawn from similar numbers in the profile *c* in plan, thus obtaining the intersections 1″ to 8″ through which a line is traced which is the desired plan view.

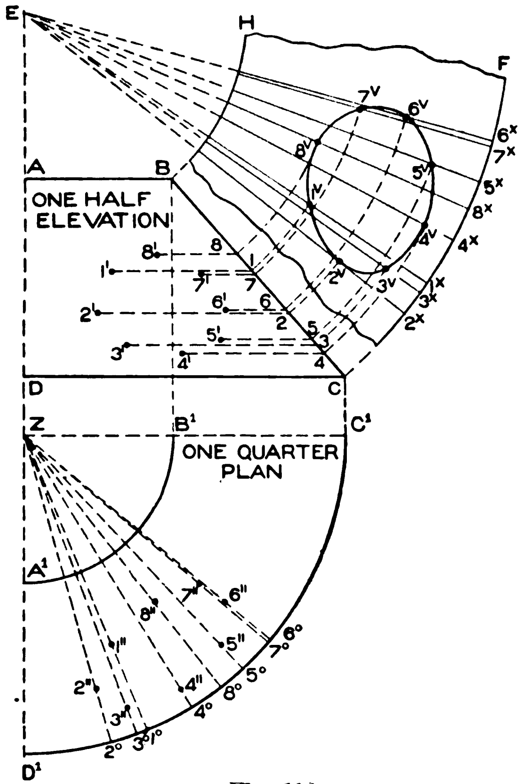


Fig. 112.

For the pattern for the opening in the cone, the outline of the half elevation and one-quarter plan with the various points of intersections both in plan and elevation in Fig. 112 is a reproduction of similar parts in Fig. 111, and has been transferred to avoid a confusion of lines which would otherwise occur in obtaining the pattern. Parallel to D C in Fig. 112 from the various intersections 1′ to 8′ draw lines intersecting the side of the cone B C from 1 to 8. Through the various intersections 1″ to 8″ in plan from the apex Z draw lines intersecting the outer curve from 1° to 8° as shown. Extend the line C B in elevation until it meets the center line D A extended at E. Then using E as center, with E C and E B as radii draw the arcs C F and B H respectively. At any point as 2^x on the arc C F lay off the stretchout of the various points on D^1 C^1 in plan from 2° to 6° as shown by similar figures on C F as shown from 2^x to 6^x. From these points draw radial lines to the apex E, and intersect them by arcs struck from E as center whose radii are equal to the various intersections on B C having similar numbers. Thus arc 4 intersects radial line 4^x at 4^v; arcs 3, 5, and 2 intersect radial lines 3^x, 5^x, and 2^x at 3^v, 5^v, and 2^v, and so on. Trace a line through points thus obtained as shown from 1^v to 8^v which is the desired shape. If a flange is desired to connect with the cylinder, a lap must be allowed along the inside of the pattern.

COPPERSMITH'S PROBLEMS.

In the five problems which will follow, particular attention is given to problems arising in the coppersmith's trade. While all the previous problems given in the course can be used by the coppersmith in the development of the patterns where similar shapes are desired, the copper worker, as a rule, deals mostly with hammered surfaces, for which flaring patterns are required. The principles which will follow, for obtaining the blanks or patterns for the various pieces to be hammered, are applicable to any size or shape of raised work. The copper worker's largest work occurs in the form of brewing kettles, which are made in various shapes, to suit the designs of the different architects who design the work. In hammering large brewing kettles of heavy copper plate, the pieces are developed, hammered, and fitted in the shop, then set together in the building, rope and tackle being used to handle the various sections for hammering, as well as in construction at the building. While much depends upon the skill the workman has with the hammer, still more depends upon the technical knowledge in laying out the patterns.

In all work of this kind the patterns are but approximate, but no matter what size or shape the work has, the principles contained in the following problems are applicable to all conditions.

In Fig. 113 is shown a perspective of a sphere which is to be constructed of horizontal sections as shown in Fig. 114, in which for practice draw the center line A B, on which, using *a* as center, and with radius equal to $2\frac{1}{4}$ inches, describe the elevation of the sphere B C D E. Divide the quarter circle D C into as many spaces as the hemi-sphere is to have sections, as shown by C F G D. From these points draw horizontal lines through the elevation, as shown by C E, F H, and G I. Now through the extreme points as E H, H I, and I D draw lines intersecting the center line B A at J, K, and D respectively. For the pattern for the first section Z, take D I as radius, and using D^1 in Z^1 as center, describe the circle shown. For the pattern for the second section Y, use K I and K H as radii, and with K^1 as center draw the arcs I^1 I^2 and H^2

Fig. 113.

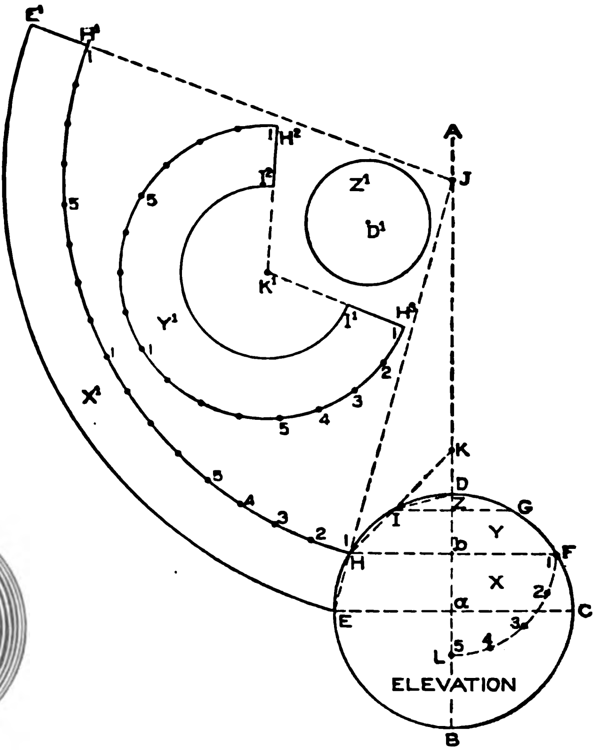
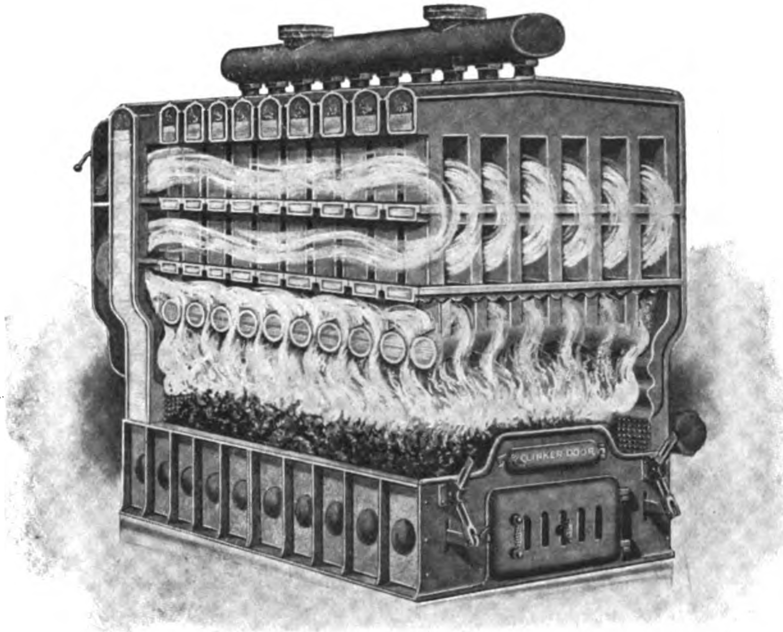
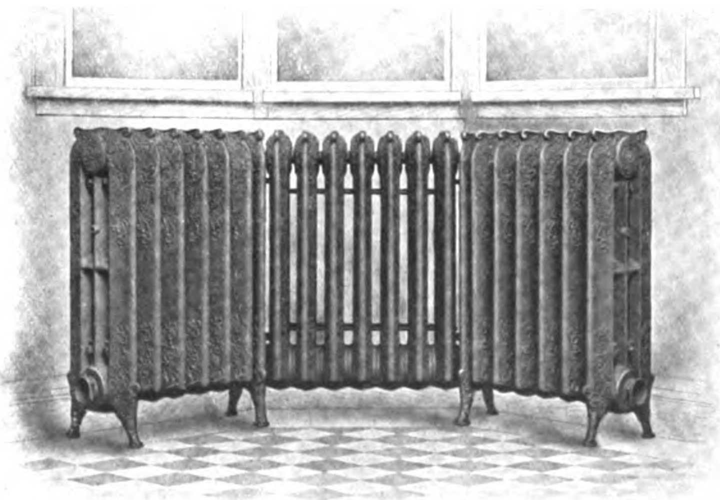


Fig. 114.

H^3. From any point as H^3 draw a line to the center K^1. It now becomes necessary to draw a section, from which the true length of the patterns can be obtained. Therefore with *b* F as radius, describe the quarter circle F L, which divide into equal spaces, as shown by the figures 1 to 5. Let the dividers be equal to one of those spaces and starting at H^3 on the *outer arc* in Y^1 step off four times the amount contained in the quarter section F L, as shown from 1



SECTIONAL VIEW SHOWING COURSE OF FIRE THROUGH "MONARCH" HOT-WATER BOILER
James B. Clow & Sons, Chicago



TRITON THREE-COLUMN BAY-WINDOW RADIATOR
United States Radiator Co., Dunkirk, N. Y.

to 5 to 1 to 5 to 1 in Y^1. From 1 or H^2 draw a line to K^1. Then will H^2 I^2 I^1 H^3 be the pattern for the section Y in elevation.

For the pattern for the third section, use J as center, and with radii equal to J H and J E draw the arcs H H^1 and E E^1. Now set the dividers equal to one of the equal spaces in F L and starting from H set off four times the amount of L F as shown from 1 to 5 to 1 to 5 to 1 on the *inner curve* H H^1. From the apex J through H^1 draw a line intersecting the outer curve at E^1. E E^1 H^1 H shows the pattern for the center section. It will be noticed in the pattern X^1 we space off on the inner curve, while on the pattern Y^1 we space off on the outer curve. These two curves must contain the same amount of material as they join together when the ball is raised. To all of the patterns laps must be allowed for brazing or soldering. The patterns shown are in one piece; in practice where the sphere is large they are made in a number of sections.

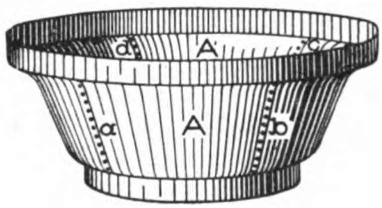


Fig. 115.

In Fig. 115 is shown the perspective view of a circular tank whose outline is in the form of an ogee. The portion for which the patterns will be described is indicated by A A, made in four sections, and riveted as shown by *a b c d*.

Fig. 116 shows how the pattern is developed when the center of the ogee is flaring as shown from 3 to 4 in elevation. First draw the elevation A B C D, making the diameter of A B equal to 7 inches, the diameter of D C 4 inches, and the vertical height of the ogee $1\frac{3}{4}$ inches. Through the center of the elevation draw the center line *f h*, and with any point upon it as *i*, draw the half plan through A B and C D in elevation as shown respectively by E F and H G. Now divide the curved parts of the ogee into equal spaces as shown from 1 to 3 and 4 to 6. Draw a line through the flaring portion until it meets the center line *f h* at *j*. *j* will, therefore, be the center with which to strike the pattern. Take the stretchout of the curve from 3 to 1 and 4 to 6 and place it on the flaring line from 3 to 1′ and 4 to 6′ as shown by the figures. Then will 1′ 6′ be the stretchout for the ogee. It should be understood that no hammering is done to that part shown from 3 to 4. The portion shown from 3 to 1′ is stretched to meet the required profile 3 2 1, while the lower part 4 to 6′ is raised to conform with the lower curve 4 5 6. Therefore, knowing that the points 3 and 4 are fixed points, then from either of these, in this case point 4,

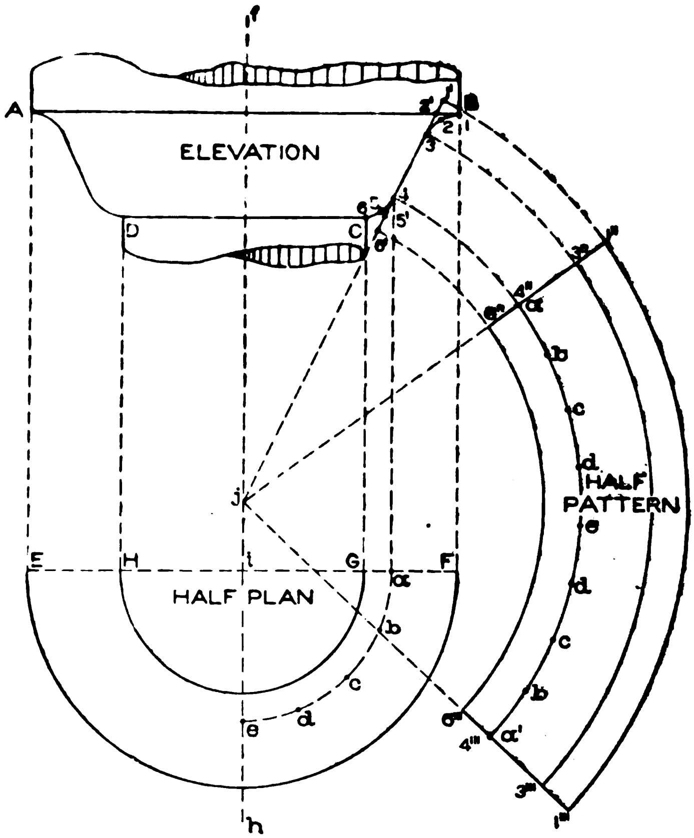


Fig. 116.

drop a vertical line intersecting the center line E F in plan at *a*. Then with *i* as center and *i a* as radius, describe the quarter circle *a e*, and space it into equal parts as shown by *a*, *b*, *c*, *d*, *e*, which represent the measuring line in plan on the point 4 in elevation. Using *j* as center, and *j* 6′, *j* 4, *j* 3 and *j* 1′ as radii, draw the arcs 1″-1‴, 3″-3‴, 4″-4‴ and 6″-6‴ as shown. From 1″ draw a radial line to *j* intersecting all the arcs as shown. Now starting at 4″ step off on the arc 4″-4‴ twice the stretchout of the quarter circle *a e* as shown by similar letters *a* to *e* to *a′* in pattern. From *j* draw a line through *a′* intersecting all of the arcs as shown. 1″-1‴-6‴-6″ shows the half pattern for the ogee.

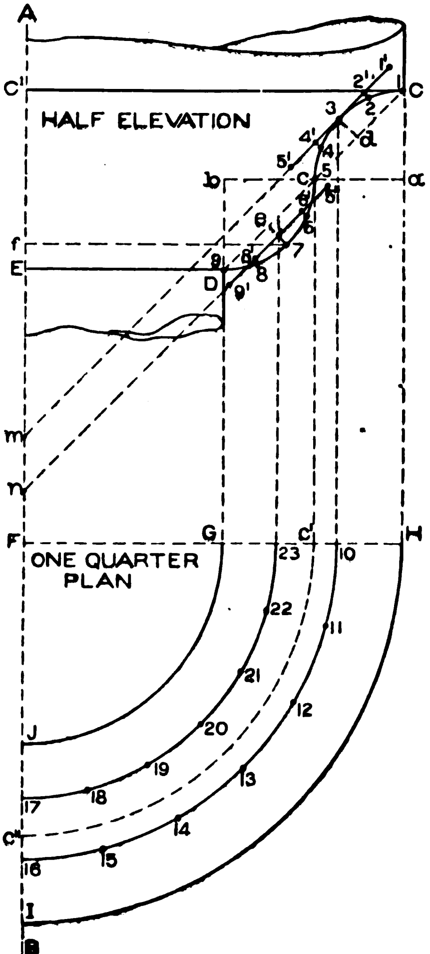


Fig. 117.

While in the previous problem the greater part of the ogee was flared, occasion may arise where the ogee is composed of two quarter circles struck from centers as shown in Fig. 117. First draw the center line A B, then draw the half diameter of the top C' C equal to 3¼ inches and the half diameter E D 1¾ inches. Make the vertical height of the ogee 1½ inches, through the center of which draw the horizontal line *a b*. From C and D draw vertical lines intersecting the horizontal line *a b*, at *a* and *b* respectively. Then using *a* and *b* as centers with radii equal respectively to *a* C and *b* D draw the quarter circles shown completing the ogee. In the quarter plan below which is struck from the center F, G J and H I are sections respectively on D E and C C' in elevation. The methods of obtaining the patterns in this case are slightly different than those employed in the previous problems. The upper curve shown from C to *o* will have to be stretched, while the lower curve shown from *o* to D will have to be raised. Therefore in the stretchout of the pattern of the upper part from 1′ to 3 and 3 to 5′ the edges must be stretched so as to obtain more material to allow the metal to increase in diameter and conform to the desired shape shown from 1 to 3 and 3 to 5. In the lower curve the opposite method must be employed. While in the upper curve the edges had to be stretched to increase the diameters, in the lower curve the edges must be drawn in by means of raising, to decrease the diameter, because the diameters to the points 5″ and 9′ are greater than to points *c* and *d*.

To obtain the pattern for the upper curve C *c* which must be stretched, draw a line from C to *c*; bisect it and obtain *d*, from which erect the perpendicular *d* 3 intersecting the curve at 3. Through 3 draw a line parallel to C *c* intersecting the center line A B at *m*. Now divide the curve C *c* into equal spaces as shown from 1 to 5 and starting from the point 3 set off on the line just drawn on either side of 3 the stretchout shown from 3 to 1′ and 3 to 5′. 1′ 5′ shows the amount of material required to form the curve C *c*. In this case 3 represents the stationary point of the blank on which the pattern will be measured. Therefore from 3 drop a vertical line intersecting the line F H at 10. Then using F as center and F 10 as radius, describe the arc 10 16, and divide it into equal spaces as shown from 10 to 16. Now with radii equal to *m* 5′, *m* 3 and *m* 1′, Fig. 117, and with *m* in Fig. 118 as center, describe the arcs 5 5′, 3 3′ and 1 1′. Draw the radial line *m* 1 intersecting the two inner arcs at 3 and 5. As the arc 3 3′ represents the stationary point 3 in elevation in Fig. 117, then set the dividers equal to the spaces 10 16 in plan and step off similar spaces in Fig. 118 on the arc 3 3′, starting at 3 as shown by similar numbers 16 to 10. Through 10 draw a line to the apex *m*, intersecting the inner curve at 5′ and the outer curve at 1′. 1 1′ 5′ 5 is the quarter pattern for the upper curve or half of the ogee, to which laps must be allowed for riveting and brazing.

For the pattern for the lower curve in elevation in Fig. 117 draw a line from *c* to D; bisect it at *e* and from *e* erect a perpendicular intersecting the curve at 7. From 7 draw a horizontal line intersecting the center line at *f*. Now the rule to be followed in "raising" is as follows: Divide the distance from *e* to 7 into as many parts, as the half diameter F 7 is equal to inches. In this case 7 *f* equals 2¼ inches; (any fraction up to the ⅛ inch is not taken into consideration, but over $\frac{1}{8}$ inch one is added). Therefore for $2\frac{1}{4}$ inches use 2. Then divide the distance from *e* to 7 into two parts as shown at *i* and through *i* parallel to *e* D draw a line as shown intersecting the center line at N. Now divide the curve *e* to D into equal spaces as shown by the figures 5 to 9. Let off on either side of *i* the stretchout from 5 to 9 as shown from 5″ to

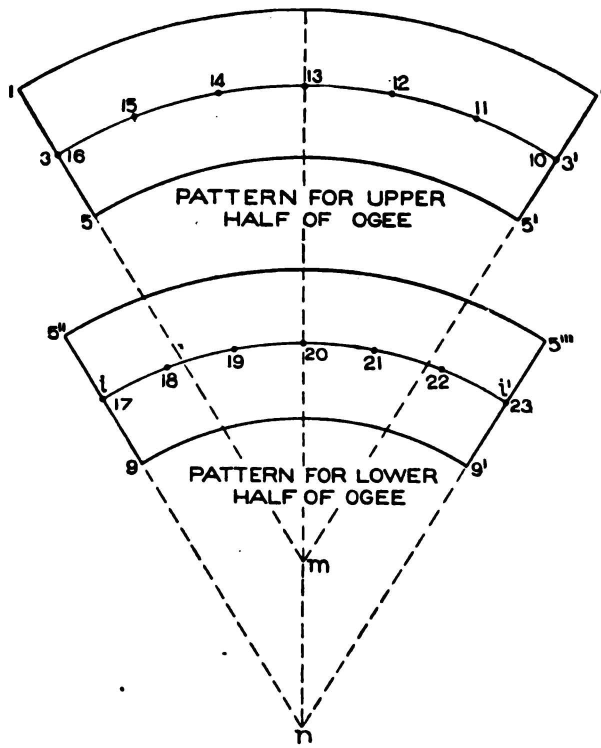


Fig. 118.

9′. From *i* drop a vertical line intersecting F H in plan at 23. Then using F as center draw the arc 23 17 as shown, which represents the measuring line in plan on *i* in the stretchout.

The student may naturally ask, why is *i* taken as the measuring line in plan, when it is not a stationary point, for when "raising" *i* will be bulged outward with the raising hammer until it meets the point 7. In bulging the metal outward, the surface at *i* stretches as much as the difference between the diameter at *i* and

7. In other words, if the measuring point were taken on 7 it would be found that after the mould was "raised" the diameter would be too great. But by using the rule of dividing *e* 7 into as many parts as there are inches in *f* 7 the diameter will be accurate while this rule is but approximate. In this case *e* 7 has only been divided into two equal parts, leaving but one point in which a line would be drawn through parallel to *c* D. Let us suppose that the semi-diameter 7 *f* is equal to eleven inches. Then the space from *e* to 7 would be divided into just so many parts, *and through the first part nearest the cove* the line would be drawn parallel to *c* D and used as we have used *i*. Now with radii equal to *n* 9′, *n i*, and *n* 5″ and *n* in Fig. 118 as center, describe the arcs 5″ 5‴ *i i′* and 9 9′. From any point as 5″ draw a line to *n* intersecting all the arcs shown. Now take the stretchout from 17 to 23 in plan, Fig. 117, and starting from 17 in Fig. 118 mark off equivalent distances on the arc *i i′* as shown. Draw a line through 23 to the apex *n*, intersecting the inner and outer arcs at 9′ and 5‴. Then will 9 5″ 5‴ 9′ be the greater pattern for the lower part of the ogee.

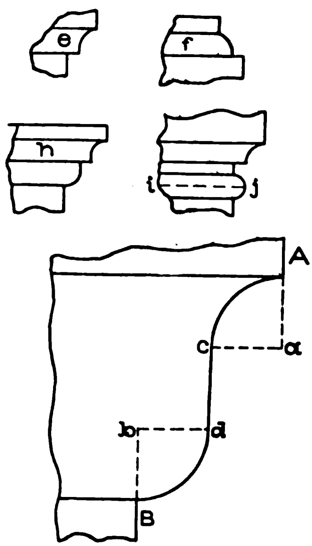


Fig. 119.

Another case may arise where the center of the ogee is vertical as shown from *c* to *d* in Fig. 119 in A B. In this case the same principles are applied as in Fig. 117; the pattern for *c d* in Fig. 119 being a straight strip as high as *c d* and in length equal to the quarter circumference *c′ c″* in plan in Fig. 117 which is the section on *c* in elevation. These rules are applicable to any form of mould as shown in Fig. 119, by *e*, *f*, *h*, and *j*. The bead *i* in *j* would be made in two pieces with a seam at *i* as shown by the dotted line, using the same method as explained in connection with *c* D in elevation in Fig. 117.

The coppersmith has often occasion to lay out the patterns for curved elbows. While the sheet metal worker lays them out in pieces, the coppersmith's work must form a curve as shown in Fig. 120 which represents a curved elbow of 45°.

In Fig. 121 is shown how an elbow is laid out having 90°, similar principles being required for any degree of elbow. First draw the side elevation of the elbow as shown by A B C D, mak-

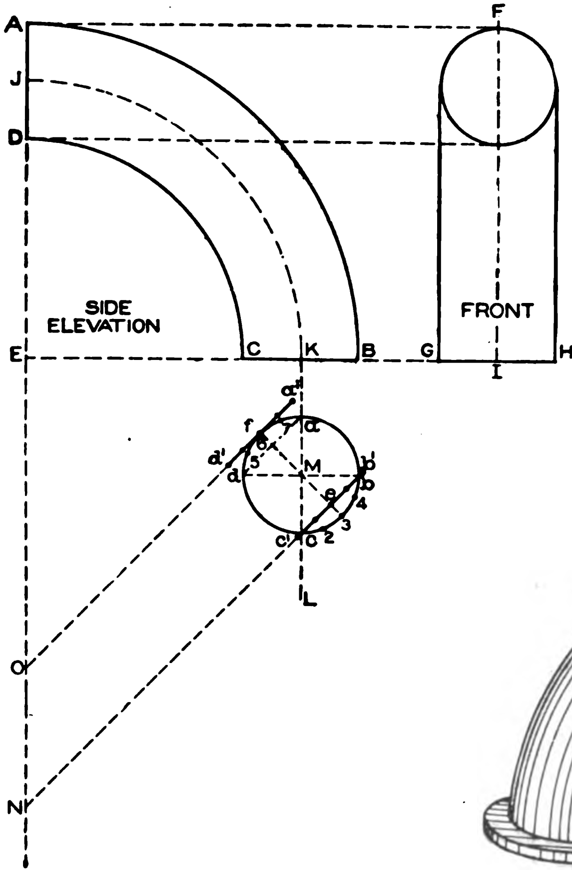


Fig. 121.

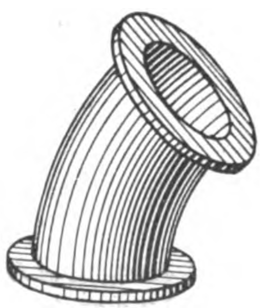


Fig. 120.

ing the radius E B equal to 4½ inches and the diameter B C 2 inches. Bisect C B at K. Then with E as center and E K as radius draw the arc K J representing the seam at the sides. Draw the front view in its proper position as F G H, through which draw the center line F I representing the seam at back and front, thus making the elbow in four pieces. Directly below C B draw the section of the elbow as shown by *a b c d* struck from M as center. Through M draw the diameters *b d* and *a c*. The inner curve of the elbow *a d c* in plan will be stretched, while the outer curve *a b c* in plan will be raised. Through M draw the diagonal 3 6 intersecting the circle at 3 and *f* respectively. Now draw *a d;* through *f* parallel to *a d* draw a line intersecting the center

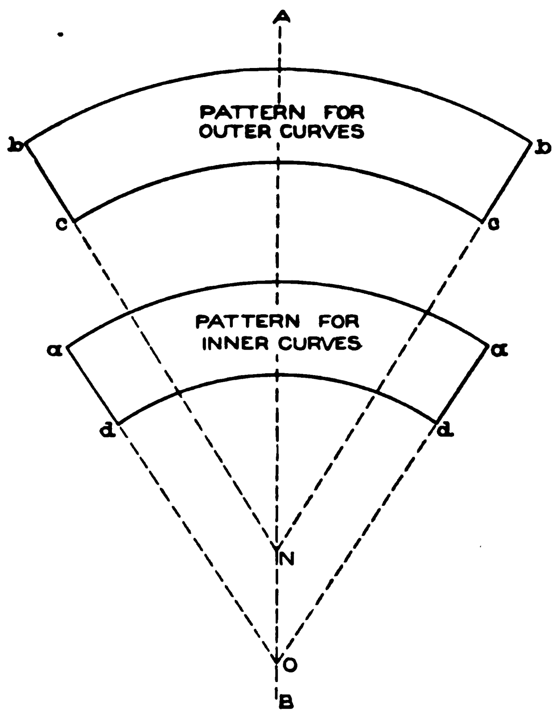


Fig. 122.

line A E extended at O. On either side of *f* place the stretchout of 6 *a* and 6 *d* as shown by *f a'* and *f d'*. Then with radii equal to O *d'* and O *a'* and with O on the line A B, Fig. 122, as center describe the arcs *d d* and *a a*. Make the length of *d d* equal to the inner curve D C in Fig. 121. From *a* and *d* in Fig. 122 draw lines to the apex O extending them to meet the outer curve at *a* and *a*. Then will *a d d a* be the half pattern for the inner portion of the elbow for two sides. The radius for the pattern for the outer curve is shown in Fig. 121 by N *c'*, N *b'*, placing the stretchout of the curve on either side of the point *e*. *b b c c* in Fig. 122 shows the pattern for the outer curve, the length *b b* being obtained from A B in elevation in Fig. 121.

In work of this kind the patterns are made a little longer, to allow for trimming after the elbow is brazed together. Laps must be allowed on all patterns for brazing.

Fig. 123 shows a perspective view of a brewing kettle, made in horizontal sections and riveted. The same principles which were employed for obtaining the patterns for a sphere in Fig. 114 are applicable to this problem. Thus in Fig. 124, let A B C represent a full section of a brewing kettle as required according to architect's design. Through the middle of the section draw the center line D E. Now divide the half section B to C into as many parts as the kettle is to have pieces as shown by *c*, *d*, *e*, *f*. From these small letters draw horizontal lines through the section, as shown by *c* A, *d d'*, *e e'*, and *f f'* and in its proper position below the section, draw the plan views on each of these horizontal lines in elevation, excepting *d' d*, as shown respectively by I F G H, *e'' e'''* and *f'' f'''*, all struck from the center *a*. Now through the points *c d* draw a line which if extended would meet the center line. Then this intersection would be the center with which to draw the arcs *c c'* and *d d''*; the flange *c b* would be added to the pattern as shown by *b'*. The stretchout for this pattern 1' would be obtained from the curved line F G H I in plan and stepped off on the outer arc *c c'*. In similar manner through *d e*, *e f*, and *f* C draw the lines intersecting the center line D E at K, L, and C. Then using the points as center, describe the patterns 2', and 3', and the full circle 4'.

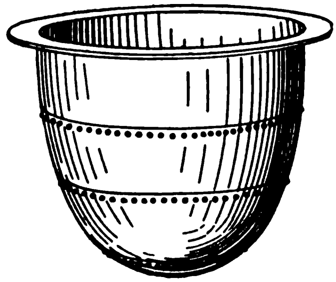


Fig. 123.

The stretchout for the patterns 2' and 3' is obtained from the circle *e'' e'''* in plan and placed on the inner curve of the pattern 2', and on the outer curve of the pattern 3'. If desired the stretchout could be taken from *f'' f'''* in plan, and placed on the inner curve of 3' which would make the pattern similar as before.

In large kettles of this kind, the length of the pattern is guided by the size of the sheets in stock, and if it was desired that each ring was to be made in 8 parts then the respective circle in plan from which the stretchout is taken would be divided into 8 parts, and one of these parts transferred to the patterns, to which laps must be allowed for seaming and riveting.

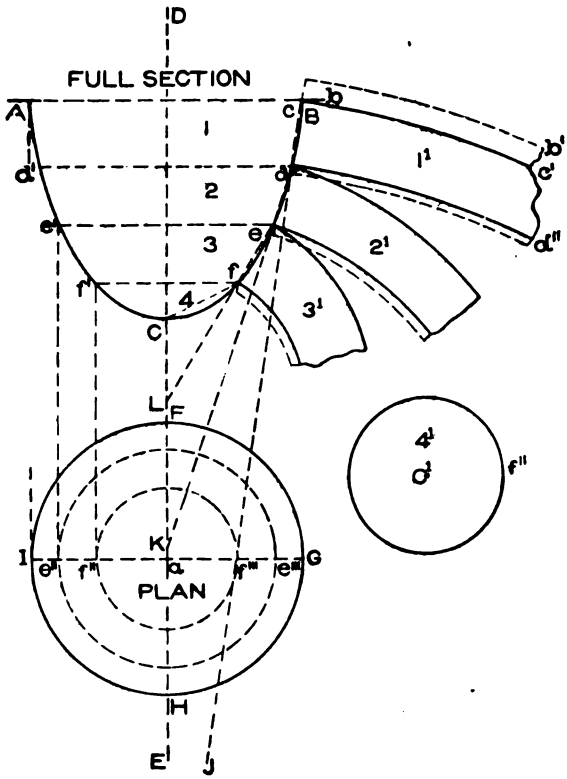


Fig. 124.

PROBLEMS FOR WORKERS IN HEAVY METAL.

While all of the problems given in this course are applicable to developments in heavy metal as well as in that of lighter gauge, the following problems relate to those forms made from boiler plate.

When using metal of heavier gauge than number 20, for pipes, elbows, or any other work, it is necessary to have the exact inside diameter. It is customary in all shops working the heavier metal, to add a certain amount to the stretchout to make up for the loss incurred in bending, in order that the inside diameter of the article (pipe, stack, or boiler shell) may be kept to a uniform and desired size. This amount varies according to different practice of workmen, some of whom allow 7 times the thickness of the metal used, while others add but 3 times the thickness. Theoretically the amount is 3.1416 times the thickness of the metal.

For example, suppose a boiler shell or stack is to be made 48 inches in diameter out of ½-inch thick metal. If this shell is to measure 48 inches on the inside, add the thickness of the metal, which is ½ inch, making 48½ inches. Multiply this by 3.1416 and the result will be the width of the sheet. If, on the other hand, the outside diameter is to measure 48 inches, subtract the thickness of the metal, which would give 47½ inches and multiply that by 3.1416 which would give the proper width of the sheet. It is well to remember that no matter what the thickness of the plate may be, if it is not added, the diameter of the finished article will not be large enough; for where no account is taken of the thickness of the metal, the diameter will measure from the center of the thickness of the sheet. While this rule is theoretically correct there is always a certain amount of material lost during the forming operations. It is, therefore, considered the best practice to use seven times the thickness of the metal in question. The circumference for a stack 48 inches in diameter inside using ½ inch metal would be, on this principle, $3.1416 \times 48 + (7 \times \frac{1}{2})$ to which laps would have to be allowed for riveting. Where the stack has both diameters equal a butt joint is usually employed with a collar as shown at either *a* or *b* in Fig. 125, but where one end of the stack is to fit into the other, a tapering pattern must be obtained which will be described as we proceed.

In putting up large boiler stacks it is usual to finish at the top with a moulded cap, and while the method of obtaining the patterns is similar to parallel line developments, the method of developing such a pattern will be given showing how the holes are punched for a butt joint.

In Fig. 126 a view of the moulded cap on a stack is shown. On a large size stack the cap is often divided into as many as 32 pieces. If the stack is to be made in horizontal sections the rules given in the problems on coppersmithing apply. While in obtaining the patterns for a cap in vertical sections, the plan is usually divided into 16 to 32 sides, according to the size of the stack; we have shown in Fig. 127 a quarter plan so spaced as to give 8 sides to the full circle. This has been done to make each step distinct, the same principles being applied no matter how many sides the plan has.

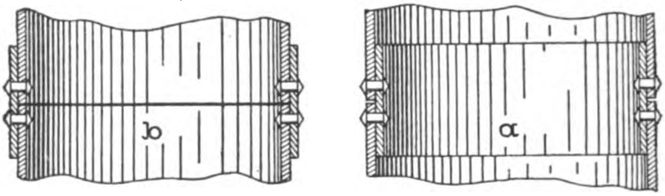


Fig. 125.

First draw the center line A B and with any point as C with radius equal to $4\frac{1}{2}$ inches draw the quadrant D E. Now tangent to D and E, draw the line D F and E G, and at an angle of 45°, tangent to the curve at Y, draw G F intersecting the previous lines drawn at G and F. C D F G E shows the plan view of the extreme outline of the cap. Directly above the plan draw a half section of the cap, the curve 5 8 being struck from *b* as center and with a radius equal to *b* 8 or $1\frac{3}{4}$ inches. Then using the same radius with *a* as center describe the quarter circle 5 2. Make 2 1 equal to $\frac{5}{8}$ inch, and 8 9 one inch. From the corners F and G in plan draw the miter lines F C, C G. Divide the profile of the cap into equal spaces as shown by the figures 1 to 9, from which drop vertical lines, intersecting the miter line F C as shown. On C D extended as C H place the stretchout of the profile of the cap as shown by similar numbers. At right angles to D H draw lines as shown, and intersect them by lines drawn parallel to D H from the intersections on C F. Trace a line through points thus obtained as shown by J I and trace this outline on the opposite side of the

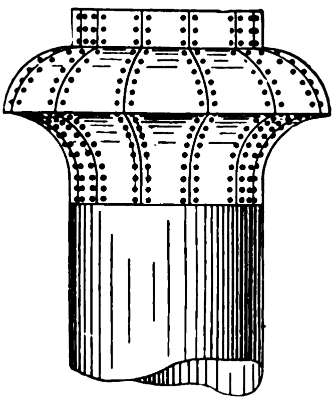


Fig. 126.

line D H as shown by J¹ I¹. Then will J I I¹ J¹ be the complete pattern for one side.

When riveting these pieces together an angle is usually placed on the inside and the miters butt sharp, filing the corners to make a neat fit. This being the case the holes are punched in the pattern before bending as shown by X X X etc. Assuming that the

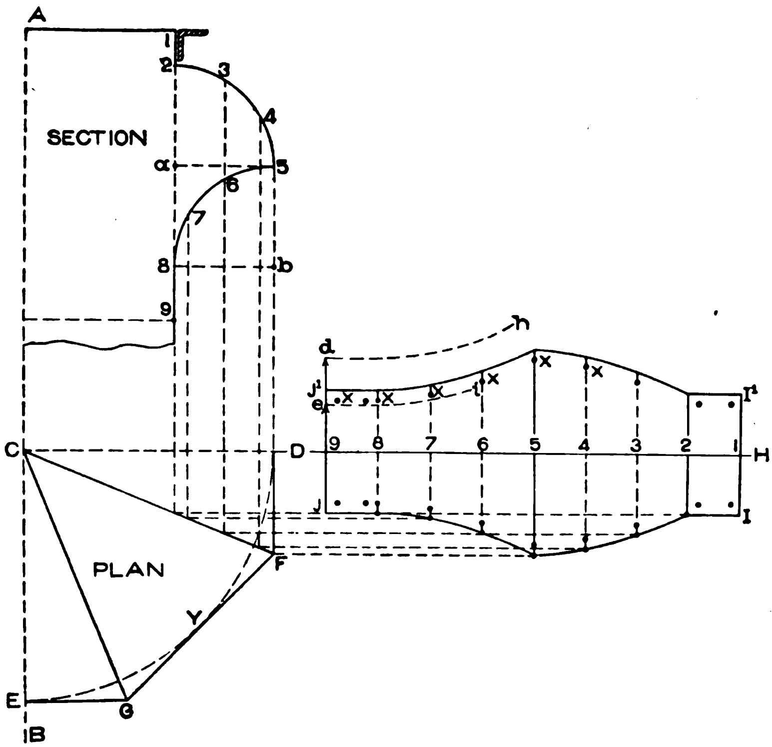


Fig. 127.

stack on which the cap is to fit is 48 inches in diameter, obtain the circumference as previously explained and divide by 8 (because the plan is composed of 8 pieces) placing one-half of the distance on either side of the center line D H in pattern. Assuming that $\frac{1}{16}$ of the circumference is equal to 9 *e*, trace from *e* the entire miter cut, as partly shown by *e i* to the line I¹ I. If the $\frac{1}{16}$ circumference were equal to 9 *d*, the cut would then be traced as shown in part by *d h* until it met the line I I¹. This, of course, would be done on the half pattern 9 J I I before tracing it opposite the center line D H. Should the plan be divided into 32 parts, divide the circumference of the stack by 32 and place $\frac{1}{64}$ of the circumference on 9 J in pattern, measuring from the center line D H, and after obtaining the proper cut, trace opposite the line D H.

In constructing a stack where each joint tapers and fits inside of the other, as shown in Fig. 128, a short rule is employed for obtaining the taper joints without having recourse to the center. In the illustration *a b* represents the first joint, the second C slip-

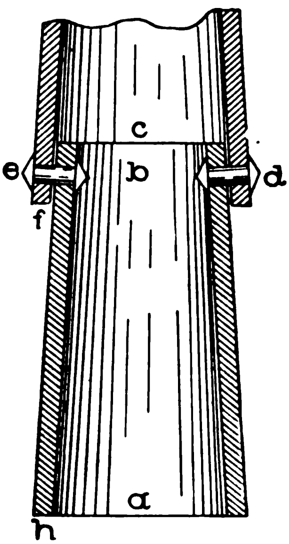


Fig. 128.

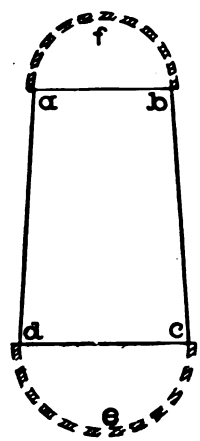


Fig. 129.

ping over it with a lap equal to *f*, the joint being riveted together at *e* and *d*. When drawing the first taper joint *a b*, care must be taken to have the diameter at *f* on the outside, equal to the inside diameter at the bottom at *h*. This allows the second joint to slip over a certain distance so that when the holes are punched in the sheets before rolling, the holes will fit over one another after the pipe is rolled.

In Fig 129 *a b c d* is a taper joint drawn on the line of its inside diameter, as explained in Fig. 128 *f*, and *e* in Fig 129 represents respectively the half sections on *a b* and *d c*. By the short rule the radial lines of the cone are produced without having recourse to the apex, which, if obtained in the full-size drawings, would be so far away as to render its use impracticable. A method similar to the following is used for obtaining the arcs for the pattern in all cases where the taper is so slight as to render the use of a common apex impracticable.

Let *a b c d*, Fig. 130, be a reproduction of *a b c d* in Fig. 129. On either side of *a d* and *b c*, in Fig. 130, place duplicates of *a b c d* as shown by *b' c'* and *a' d'*. This can be done most accurately by using the diagonals *d b* and *c a* as radii, and with *d* and *c* as centers describe the arcs *b b'* and *a a'* respectively, and intersect

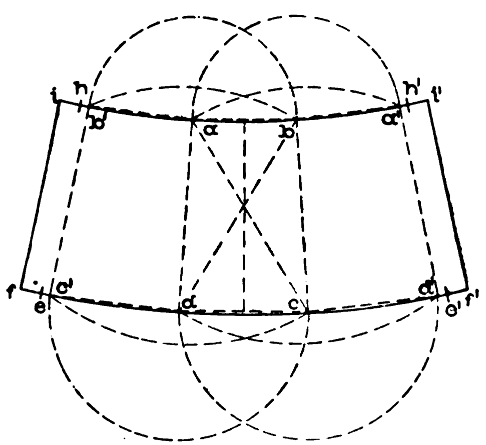


Fig. 130,

them by arcs struck from *a* and *b* as centers, with radii equal respectively to *a b* and *b a* as shown. In precisely the same manner obtain the intersection *c'* and *d'* at the bottom. Now through the intersections *b' a b a'* and *d' c d c'* draw the curve as shown by bending the straight-edge or any straight strip of wood placed on edge and brought against the various intersections, extending the curves at the ends and top and bottom indefinitely. Since the circumference of the circle is more than three times the diameter, and as we only have three times the diameter as shown from *c'* to *d'* and *b'* to *a'*, then multiply .1416 times the bottom and top diameter *d c* and *a b* respectively, and place one-half of the amount on either side of the bottom and top curves as shown by *e*, *e'*, and *h*, *h'*. Now take one-half of seven times the thickness of the metal in use and place it on either side on the bottom and top curves as shown by f, f' and i, i', and draw a line from i to f and i' to f'. To this lap must be allowed for riveting. The desired pattern is shown by $i\ i'\ f'\ f$.

Fig. 131 shows a three-pieced elbow made from heavy metal, the two end pieces fitting into the center pieces, to which laps are allowed for riveting. The principles which shall be explained to cut these patterns and make the necessary allowance for any thickness of metal is applicable to any elbow.

In Fig. 132 draw as previously described the elbow A B C, below G H draw the section of the inside diameter as D which is struck from a, and divide into equal spaces as shown by the figures 1 to 5 on both sides. Through these figures draw vertical lines intersecting the miter line $b\ c$, and from these intersections parallel to $c\ d$ draw lines intersecting the line $d\ e$ as shown.

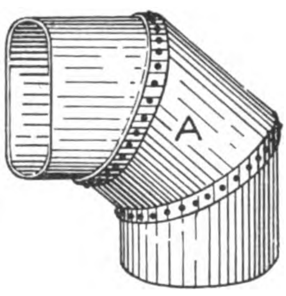


Fig. 131.

Before obtaining the stretchout for these elbows, a preliminary drawing must be constructed, in which an allowance is made for the thickness of the material that is to be used. This drawing makes practical use of a principle well known to draughtsmen from its application to the proportional division of lines and is clearly shown at (R). In allowing for the thickness of the metal in use, it is evident that we cannot allow it at one end, but must distribute it uniformly throughout the pattern. In (R) draw any horizontal line as E F, upon which place the stretchout of the inside diameter of the pipe D, as shown by similar figures on E F. From 1^o on E F lay off the distance $1^o\ m$ equal to 7 times the thickness of the metal in use as before explained. Then using E as center and E m as radius, draw the arc m 1' intersecting the vertical line drawn from 1^o, and from the various intersections from 1 to 1^o on E F erect perpendiculars intersecting the slant line 1 1' at 2' 3' 4', etc., as shown. The slant line 1 1, with the various intersections is now the correct stretchout for the elbow made of such heavy material called for by the specifications. On G H extended, as H I, place the stretchout of the slant line 1 1' as shown from 1 to 1' on H I. At right angles to H I and

CONSTRUCTING THE LARGEST SEWER IN THE UNITED STATES

View of men at work in tunneling shield; wooden forms also shown. Sewer lined with brick laid in "Utica" hydraulic cement. View of 39th Street intercepting sewer, Chicago, Ill.

Courtesy of Meacham & Wright, Chicago, Ill.

from the various intersections, erect lines, which are intersected by lines drawn parallel to H I from similar numbered intersections on the miter line *b c*. Trace the curve L M. L M I H shows the pattern for the two end pieces of the elbow.

As the middle section A in Fig. 131 is to overlap the two end pieces, it is unnecessary to allow for any additional thickness on

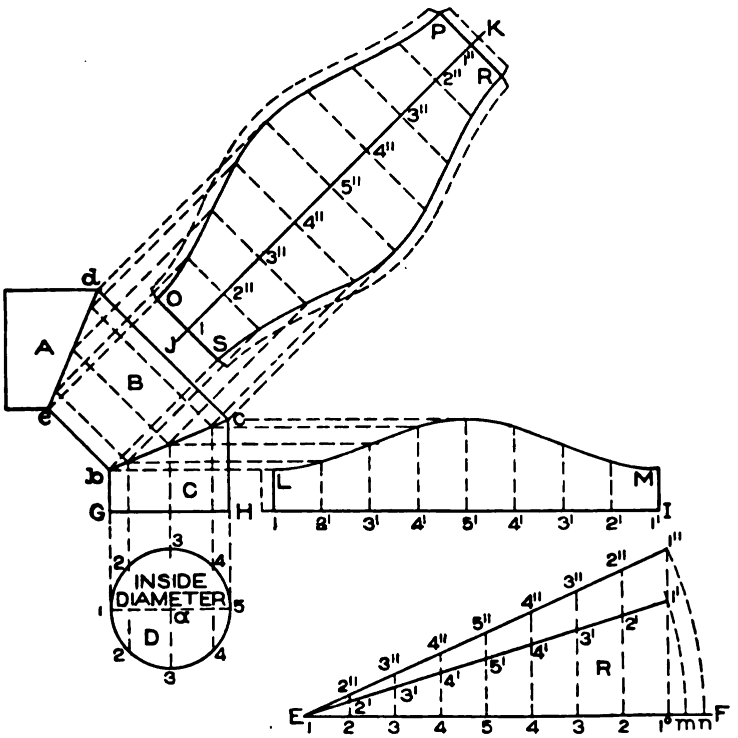


Fig. 132.

account of this lap when suitable flanging machines are available; but since it is desirable, in some instances, to make an allowance in the pattern for riveting, the method of allowing for this lap will be explained.

In (R), Fig. 132, lay off on the line E F the distance *m n* equal to 7 times the thickness of the metal in use, and with radius equal to E *n* draw an arc intersecting the line 1° 1′ extended at 1″. Draw the slant line from 1″ to 1 and extend all the vertical lines to intersect 1 1″ at 2″ 3″ 4″, etc. The slant line 1 1″ is the correct stretchout for the middle section B. At right angles to *d e* draw J K equal to 1 5″ 1″ in (R), as shown by similar figures in J K, through which draw lines at right angles to J K, and intersect them by lines drawn at right angles to *d e* as shown. Trace the curved lines to produce O P R S, which is the pattern for the middle section, to which flanges are allowed as shown by dotted lines.

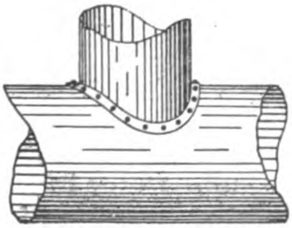


Fig. 133.

The perspective of an intersection between pipes having different diameters in boiler work is shown in Fig. 133. While the method of obtaining the patterns is similar in principle to parallel line developments, a slight change is required in obtaining the allowance in the stretchout for the thickness of the metal in use.

Let A B, Fig. 134, represent the part section of a boiler struck with a radius equal to $3\frac{3}{8}$″ and let 1 7 7° 1° be the elevation of the intersecting pipe, whose inside diameter is $4\frac{7}{8}$″, as shown by 1 7.

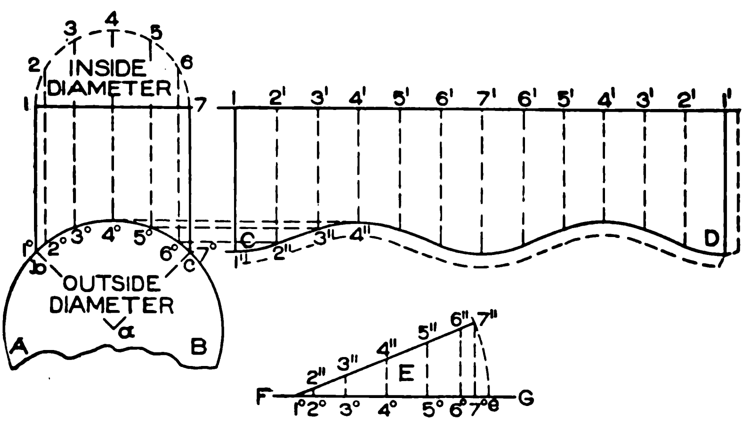


Fig. 134.

Divide the half section 1 4 7 into an equal number of spaces, as numbered, from which drop vertical lines intersecting the outside line of the boiler at 1° to 7° as shown. A true stretchout must now be obtained in which allowance has been made for the thickness of the metal in use. Therefore, in Fig. 135, on the horizontal line A B lay off the stretchout of twice the inside section of the pipe in Fig. 134, as shown by similar figures on A B in Fig. 135, adding 1^x *a*, equal to 7 times the thickness of the metal in use. For example, supposing $\frac{1}{4}$-inch steel was used; the distance $1^x a$ would then be equal to $7 \times \frac{1}{4}$, or $1\frac{3}{4}$ inches. Now draw the arc *a* 1′, using 1 as center, which is intersected by the vertical line drawn from 1^x. From 1′ draw a line to 1, and from the various points on A B erect perpendiculars intersecting 1 1′ at 2′ 3′ 4′, etc. 1 1′ shows the true stretchout to be be laid off on the line 1 7 extended in Fig. 134 as 1 1′, and from the various intersections on 1 1′ drop vertical lines and intersect them by lines drawn parallel to 1 1′ from similar intersections on the curve 1° 7° as shown. Trace a curved line as shown from C to D. 1 C D 1′ shows the pattern for the vertical pipe to which a flange must be allowed for riveting as shown by the dotted line.

It is now necessary to obtain the pattern for the shape to be cut out of the boiler sheet, to admit the mitering of the vertical pipe. In some shops the pattern is not developed, only the vertical pipe is flanged, as shown in Fig. 133, then set in its proper position on the boiler and line marked along the inside diameter of the pipe, the pipe is then removed and the opening cut into the boiler with a chisel. We give, however, the geometrical rule for obtaining the pattern, and either method can be used.

As A B in Fig. 134 represents the outside diameter of the boiler, to which 7 times the thickness of the metal used must be added to the circumference in laying out the sheet, and as the vertical pipe intersects one-quarter of the section as shown by *a b c*, take the stretchout from 1° to 7° and place it from 1° to 7° on F G in (E), to which add 7° *e*, equal to $\frac{1}{4}$ of 7 times the thickness of the plate used. Draw the arc *e* 7″, using 1° as center, intersecting it by the vertical line drawn from 7°. Erect the usual vertical lines and draw 7″ 1°, which is the desired stretchout. Now place this stretchout on the line A B in Fig. 136, erecting vertical lines as shown. Measuring in each and every instance from the line 1 7 in Fig. 134, take the various distances to points 2, 3, 4, 5, and 6 and place them in Fig. 136 on lines having similar numbers, measuring in each instance from A B on either side, thus obtaining the points 2, 3, 4, 5, and 6. Trace the curve 1° 4 7″ 4, which is the desired shape.

Fig. 137 shows a perspective of a gusset sheet A on a locomotive, the method of obtaining this pattern in heavy metal is shown in Fig. 138. First draw the end view A B C, the semicircle 4 1 4 being struck from *a* as center with a radius equal to 2

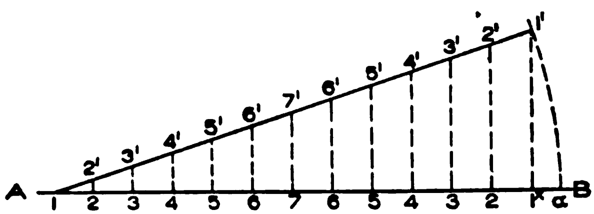


Fig. 135.

inches. Make the distance 4 to C and 4 to B both 3¾ inches and draw C B. Draw the center line A F, on which line measure up 2¼ inches and obtain *b*, which use as center with radius equal to *a* 4, draw the section of the boiler D E F G. In its proper position draw the side view H I J K L M N. H I L M N H shows the side view of the gusset sheet shown in end view by G A E D G.

Divide the semicircle 4 1 4 in end view into equal spaces as shown, from which draw horizontal lines intersecting H N in side

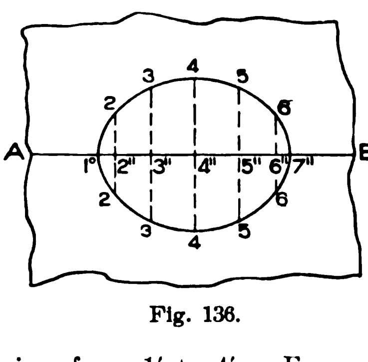


Fig. 136.

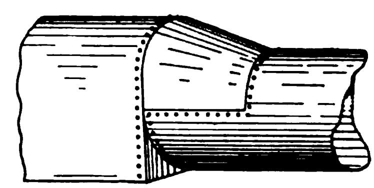


Fig. 137.

view from 1′ to 4′. From these intersections parallel to H I, draw lines indefinitely intersecting I L from 1″ to 4″. At right angles to N L produced draw the line at *c d*, on which a true section must be obtained at right angles to the line of the gusset sheet. Measuring from the line A D in end view, take the various distances to points 2, 3, and 4 and place them on corresponding lines measuring from the line *c d* on either side, thus obtaining the intersections 1° to 4°, a line traced through these points will be the true section. In (Y) on any line as O P lay off the stretch-out of the true section as shown from 4°, 1°, 4°. As the gusset sheet only covers a portion equal to a half circle, add the distance 4° *e* equal to ½ of 7 times the thickness of the metal in use and

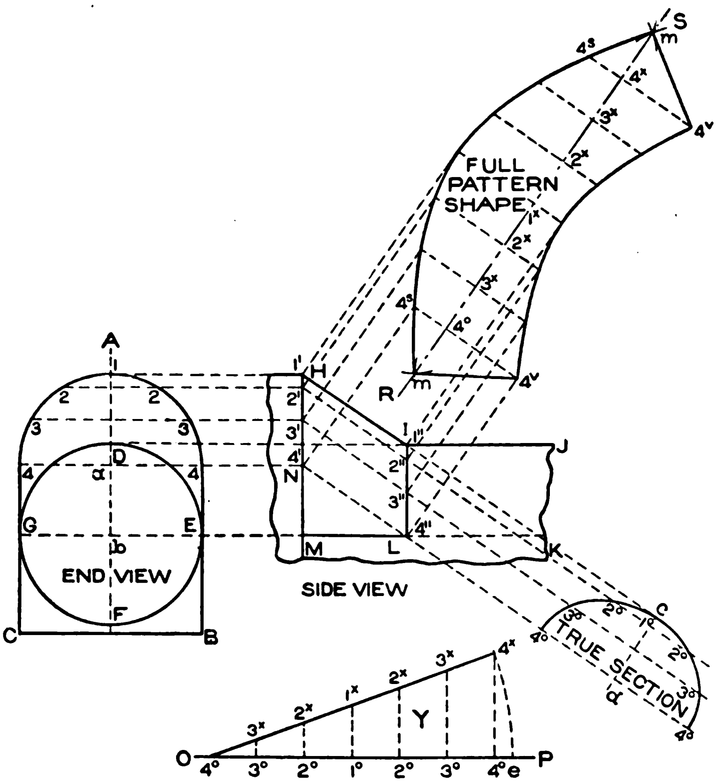


Fig. 138.

using 4° at the left, as center with 4° *e* as radius, describe the arc *e* 4ˣ, intersecting it at 4ˣ by the vertical line drawn from 4°. From O P erect vertical lines intersecting the line drawn from 4ˣ to 4° at 3ˣ, 2ˣ, 1ˣ, etc. 4° 4ˣ is the true stretchout, and should be placed on the line R S drawn at right angles to H I. Through the numbers on R S and at right angles draw the lines shown and intersect them by lines drawn from similarly numbered intersections on H N and I L at right angles to H I. Through points thus obtained trace a curved line 4^S, 4^S, and 4^V, 4^V. It now becomes necessary to add the triangular piece shown by L M N in side view, to the pattern which can be done as follows: Using L M in side view as radius and 4^V at either end of the pattern as centers, describe the arcs *m* and *n*; intersect them by arcs struck from 4^S and 4^S as centers, and M N in side view as radius. Then draw lines from 4^S to *m* to 4^V in the pattern on either side. The full pattern shape for the gusset sheet will then be shown by *m* 4^S 4^S *m* 4^V 4^V, to which laps must be allowed for riveting.

Fig. 139 shows a conical piece connecting two boilers with the flare of A such that the radial lines can be used in developing the pattern. In all such cases this method should be used in preference to that given in connection with Fig. 130. Thus in Fig. 139 the centers of the two boilers are on one line as shown by *a b*. While the pattern is developed the same as in flaring work, the method of allowing for the metal used is shown in Fig. 140.

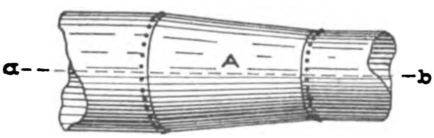


Fig. 139.

A B C D is the elevation of the conical piece, the half inside section being shown by 1 4 7 which is divided into equal spaces. 1 7 1 in (E) is the full stretchout of the inside section A 4 D in elevation, and 1 *e* is equal to 7 times the thickness of the metal used. The line 1 1′ is then obtained in the usual manner as are the various intersections 2′ 3′ 4′, etc. Now extend the lines A B and D C in elevation until they meet the center line *a b* at *a*. Then using *a c* and *a d* draw the arcs 1′ 7′ and 1″ 7″. From 1′ draw a radial line to *a*, intersecting the inner arc at 1″. Now set the dividers equal to the spaces on 1 1′ in (E) and starting from 1′ in the pattern step off 6 spaces and draw a line from 7′ to *a* intersecting the inner arc at 7″. 1′ 7′ 1″ 7″ shows the half pattern to which flanges must be allowed for riveting.

Fig. 141 shows a view of a scroll sign, generally made of heavy steel, heavy copper, or heavy brass. So far as the sign is concerned it is simply a matter of designing, but what shall be given attention here is the manner of obtaining the pattern and elevation of the scroll. As these scrolls are usually rolled up in form of a spiral, the method of drawing the spiral will first be shown.

Establish a center point as *a'* in Fig. 142, and with the desired radius describe the circle shown, which divide into a polygon of

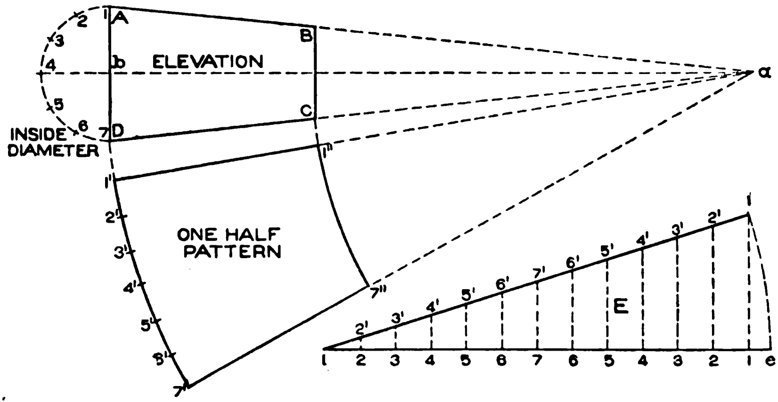


Fig. 140.

any number of sides, in this case being 6 sides or a hexagon. The more sides the polygon has, the nearer to a true spiral will the figure be. Therefore number the corners of the hexagon 1 to

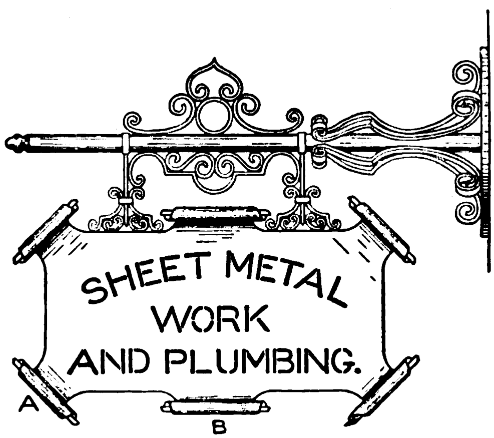


Fig. 141.

5 and draw out each side indefinitely as 1 *a*, 2 *b*, 3 *c*, 4 *d*, 5 *e*, and 6 *f*. Now using 2 as center and 2 1 as radius, describe the arc 1 A; then using 3 as center and 3 A as radius, describe the arc

A B, and proceed in similar manner using as radii 4 B, 5 C, 6 D, and 1 E, until the part of the spiral shown has been drawn. Then using the same centers as before continue until the desired spiral is obtained, the following curves running parallel to those first drawn. The size of the polygon *a'*, determines the size of the spiral.

In Fig. 143 let A B C D represent the elevation of one corner of the flag sign shown in Fig. 141. In its proper position in Fig. 143 draw a section of the scroll through its center line in elevation as shown by *a* 17 to 1, which divide into equal spaces as shown from 1 to 17. Supposing the scroll is to be made of $\frac{1}{8}$ inch thick

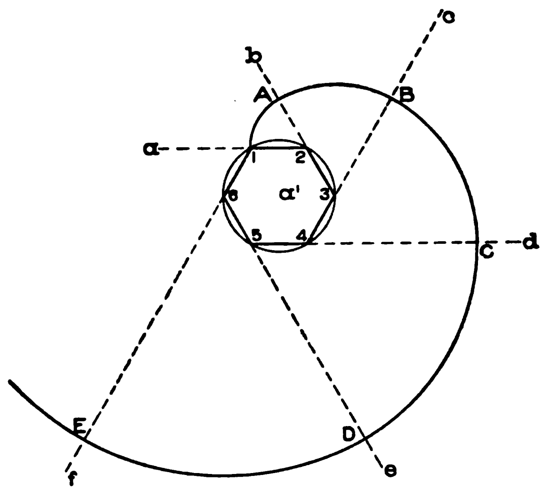


Fig. 142.

metal, and as the spiral makes two revolutions then multiply $\frac{1}{8}$ by 14, which would equal $1\frac{3}{4}$ inches. Then on E F in Fig 144 place the stretchout of the spiral in Fig. 143, as shown by similar numbers, to which add 17 E equal to 14 times the thickness of metal in use, and draw the arc E 17' in the usual manner and obtain the true stretchout with the various intersections as shown. Through the elevation of the corner scroll in Fig. 143 draw the center line E F, upon which place the stretchout of 17' E, Fig. 144, as shown by similar numbers on E F in Fig. 143. At right angles to E F, through 1' and 17', draw 17° 17° equal to A B and 1° 1° equal to the desired width of the scroll at that point. Then at pleasure draw the curve 1° 17° on either side, using the straight-

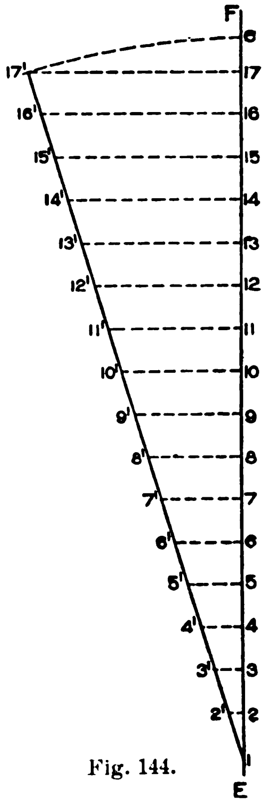
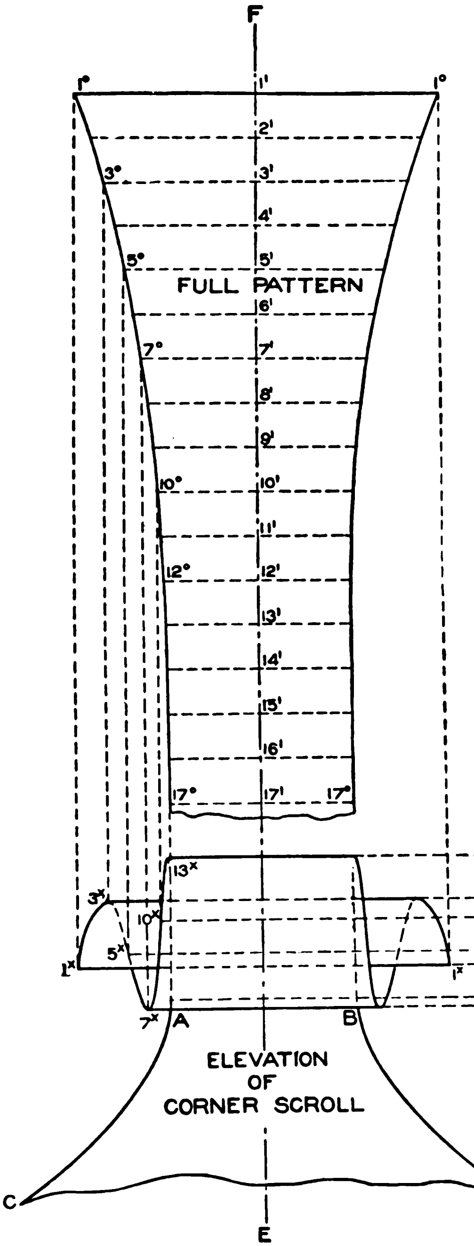


Fig. 144.



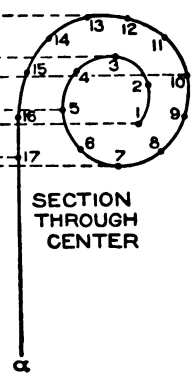


Fig. 143.

edge and bending it as required. Then will 1° 1° 17° 17° be the pattern for the scroll using heavy metal.

If it is desired to know how this scroll will look when rolled up, then at right angles to E F and through the intersections 1′ to 17′ draw lines intersecting the curves of the pattern 1°-17° on both sides. From these intersections, shown on one side only, drop lines intersecting similar numbered lines, drawn from the intersections in the profile of the scroll in section parallel to A B. To avoid a confusion of lines the points 1^x, 3^x, 5^x, 7^x, 10^x, 12^x, and 17^x have only been intersected. A line traced through points thus obtained as shown from 1^x to 17^x in elevation gives the projections at the ends of the scroll when rolled up.

GENERAL INDEX

GENERAL INDEX

In this index the *Volume number* appears in Roman numerals—thus, I, II, III, IV, etc.; and the *Page number* in Arabic numerals—thus, 1, 2, 3, 4, etc. For example Volume IV, Page 327, is written IV, 327.

In addition to this "General Index," the reader is referred to the more exhaustive analytical index to be found in each volume.

The page numbers of each volume will be found at the bottom of the pages; the numbers at the top refer only to the section.

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