THE
UNITED
COKE AND GAS
COMPANY
NEW YORK

UNITED-OTTO SYSTEM

A SHORT TREATISE ON THE DESTRUCTIVE DISTILLATION
OF BITUMINOUS COAL.

WITH REFERENCE TO

THE UNITED-OTTO SYSTEM OF BY-PRODUCT COKE OVENS.

PREFATORY NOTE

THIS PUBLICATION IS INTENDED TO AFFORD GENERAL INFORMATION CONCERNING THE BY-PRODUCT COKE OVEN AND ITS OPERATION, TO THOSE NOT FAMILIAR WITH THE SUBJECT. IT, THEREFORE, AVOIDS DETAILS OF A TECHNICAL CHARACTER. IT WILL BE FOLLOWED BY OTHER PAMPHLETS IN WHICH THE VARIOUS SUBJECTS HERE OUTLINED WILL BE TREATED IN A MORE EXHAUSTIVE MANNER.

WE SOLICIT CORRESPONDENCE WITH REFERENCE TO RETORT COKE OVENS, WITH OR WITHOUT BY-PRODUCT RECOVERY, AND WILL GLADLY FURNISH ANY FURTHER INFORMATION ON SUCH MATTERS TO INTERESTED PARTIES OF RESPONSIBILITY.

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PORTRAITS.

I AM bold enough to go so far as to say that raw coal should not be used as fuel for any purpose whatsoever, and that the first step toward the judicious and economic production of heat is the gas-retort or gas-producer, in which coal is converted either entirely into gas, or into gas and coke, as is the case at our ordinary gas works.

SIR WILLIAM SIEMENS.

COAL

The NATURE of COAL

OAL is a remnant of the flora of past geological periods; consequently it is organic matter (chiefly cellulose) that has undergone chemical changes, and to which mineral impurities have been added. These chemical changes are indicated in a general way by the following table of average ultimate analyses of cellulose, wood, peat, lignite, bituminous coal and anthracite, the sulphur and ash being eliminated.

ULTIMATE ANALYSES OF FUELS.

	Carbon	Hydrogen	Oxygen	Nitrogen
Cellulose	44.4	6.2	49.4	0.
Wood	50.	6.	43.	1.
Peat	59.	6.	33.	2.
Lignite	69.	5.5	25.	0.8
Bit. Coal	82.	5.	13.	0.8
Anth. Coal	95.	2.5	2.5	trace

These figures show that the transformation of wood to anthracite is accompanied by an increase in the carbon, and a decrease in the hydrogen and oxygen, the loss in the latter element being the more pronounced. As, however, these analyses show only the elementary substances that go to compose the coal, they do not give a fair idea of the complex chemical nature of the coal itself. The precise manner in which the chemical elements are combined is unknown to us. We know only the proportion in which they are present.

FLORA OF CARBONIFEROUS PERIOD.

Arising from the decomposition of different plants, and exposed to an infinite variety of geological conditions, it is hardly possible to find two coals that are exactly alike. We are only concerned here with the behavior of coal when heated under exclusion of air.

DESTRUCTIVE DISTILLATION OF COAL.

IF bituminous coal be subjected to heat, the complex organic compounds will be decomposed ("cracked") and a part of the resulting products will pass off as gas. If this process is carried out under the exclusion of air, it is known as destructive distillation, and there will remain the non-volatile or "fixed" carbon and the mineral impurities as residue.

Certain coals, when subjected to heat, become a viscous mass, rendered porous by the gas evolved, and finally attaining a cellular structure of which the cell walls are exceedingly hard. The contraction following the escape of the gas, from a sufficiently large body of coal, causes the mass to separate in pieces of more or less uniform size, which, on cooling, exhibit a silvery-grey color, and have a metallic ring. This is known as coke; therefore, the coals which yield a residue of this nature are classified as "coking" coals, as distinguished from those which leave a non-coherent sandy or gritty residue, and which are classified as "non-coking."

CRUCIBLE TEST.

THE only method of determining the coking qualities of a coal is by actual experiment. Chemical analyses furnish no rule of general application. The usual form of

laboratory test is known as the crucible test, and is shown in Figure 1. It consists in placing a known weight of dried coal in a covered platinum crucible and heating it till the volatile matter is driven off, combustion of the residue being prevented by the close-fitting lid which keeps out the air. The nature of the residue indicates approximately the coking properties of the coal, and its weight the approximate yield of coke to be expected, while the loss of weight corresponds to the " volatile" matter. This process corresponds on a small scale with the treatment of coal in the coke oven. The re-heating of the coke in the crucible without the lid, until all the carbon is consumed, leaves the ash as the sole residue, the loss of weight, in this case, indicating the " fixed carbon." This crucible test, together with separate determinations of sulphur and phosphorus, are the usual tests made to ascertain the character of a coal under investigation. Such tests of the coking coals of this country, ranging from those of low to those of higher volatile matter, would be as follows:
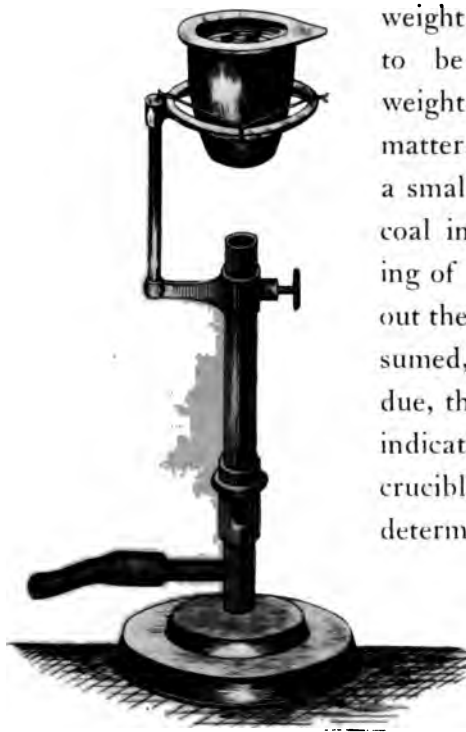
FIGURE 1. CRUCIBLE TEST.

CRUCIBLE TESTS OF BITUMINOUS COALS AND COKE.

KIND OF COAL.	Low Volatile Coal.	⌐— Coking Coals. ——⌐		High Volatile or Gas Coal.	
BEHAVIOR WHEN HEATED.	Expanding.	Neutral.	Moderately Shrinking	Strongly Shrinking.	
CHARACTER OF COKE.	Very Dense and Firm.	Dense and Firm.	Larger Cells But Firm.	Spongy and Brittle.	Typical Blast Furnace Coke.
CRUCIBLE TEST.					
Vol. Mat. . .	18.0	25.0	32.0	38.0	1.5
Fix. Carb. . .	74.0	67.0	60.0	54.0	87.5
Ash.	8.0	8.0	8.0	8.0	11.0
	100.0	100.0	100.0	100.0	100.0

The ash in bituminous coal varies from 3 to 15 per cent. and more, but for a better comparison of the coals it is taken uniformly at 8 per cent. The sulphur varies between .5 and 2.5 per cent. and phosphorus between .007 and .025 per cent.

The coal gases given off during destructive distillation are inflammable in their nature, and besides water vapor contain tar, ammonia, cyanides, benzol, naphthalene and other compounds which may be recovered from them by condensing and scrubbing operations.

THREE TYPES OF APPARATUS USED IN THE DESTRUCTIVE DISTILLATION OF COAL.

THERE are three forms in which the destructive distillation of coal is practiced on a large commercial scale in this country, namely:

1. The *bee-hive coke oven*, for coke alone.
2. The *coal gas retort*, chiefly for illuminating gas (coke and by-products of subordinate value).
3. The *by-product coke oven*, yielding metallurgical coke, together with illuminating gas and other by-products.

1. BEE-HIVE OVEN.

2. GAS RETORT.

3. UNITED-OTTO
   BY-PRODUCT
   COKE OVEN.

The BEE-HIVE OVEN
Evolution of the Meiler

THE bee-hive form of coke oven has been evolved from the primitive mode of charcoal burning in a mound or meiler. This method was practiced in some parts of the United States in the inception of the coke-making industry.

A variation of this method was the use of a rectangular kiln, built of brick, having sides but no top. The yield of coke obtained by these means was small, and the quality inferior.
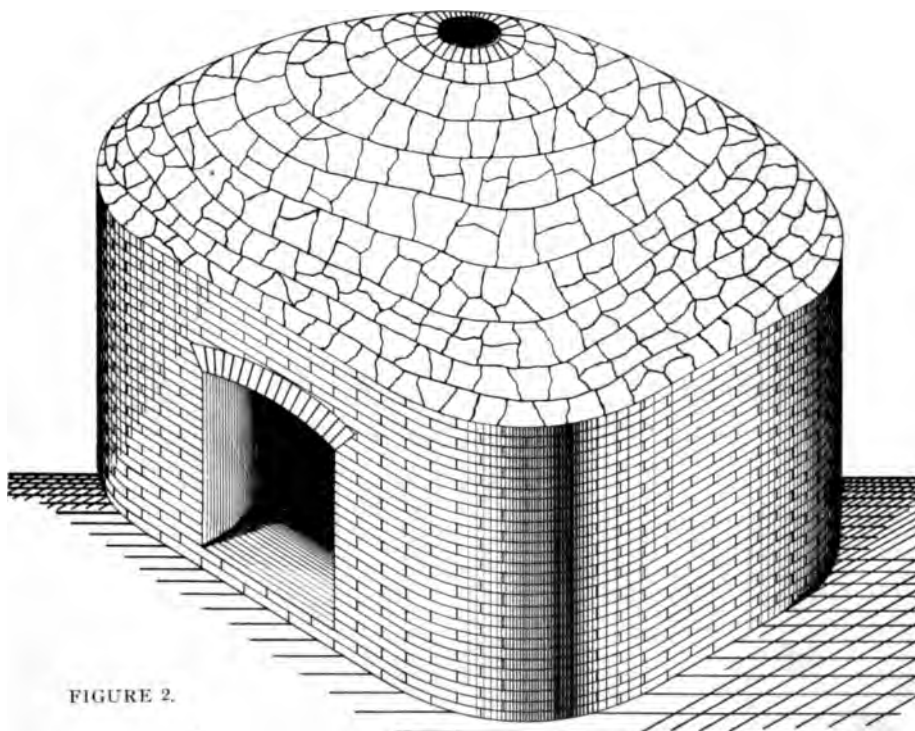
FIGURE 2.

Early Form of Bee-Hive Oven.

ORIGINAL TYPE OF BEE-HIVE OVEN.
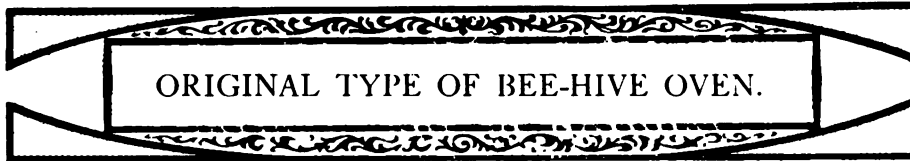
THE original form of the bee-hive oven is shown in Figure 2 as patented in England as early as 1620. From its shape the origin of the name "bee hive" is readily apparent. Its dimensions were less than those of the present standard bee-hive oven.

CONSTRUCTION OF STANDARD AMERICAN BEE-HIVE OVEN.
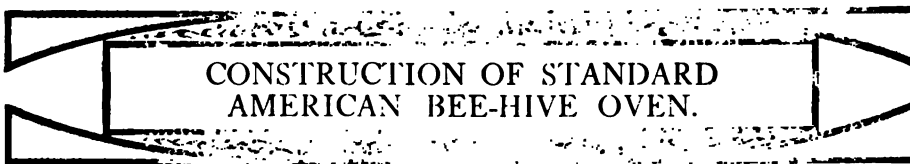
THIS oven, as shown in Figure 3, is 12 to 12½ feet in diameter, and 6 to 7 feet high inside, and is built of a good quality of refractory materials, having jambs, door arches and charging hole of shaped clay blocks, and an iron door frame built in to hold the temporary brick wall with which the opening is closed while in operation. The coal is charged into the oven through the top opening from a car or larry, running on tracks resting on the filling above the oven dome.

OPERATION OF BEE-HIVE OVEN.
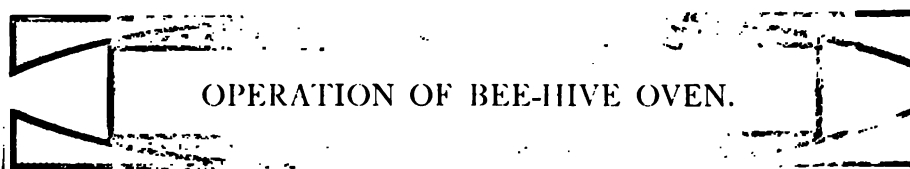
THE coal is levelled off in the oven by a rake worked by hand, after which the door is closed by bricking up, leaving a small air space at the top above the level of the coal charge. The heat remaining in the oven brick work from previous charges or from preliminary heating starts the evolution of gas, which is ignited and burns with the air enter-
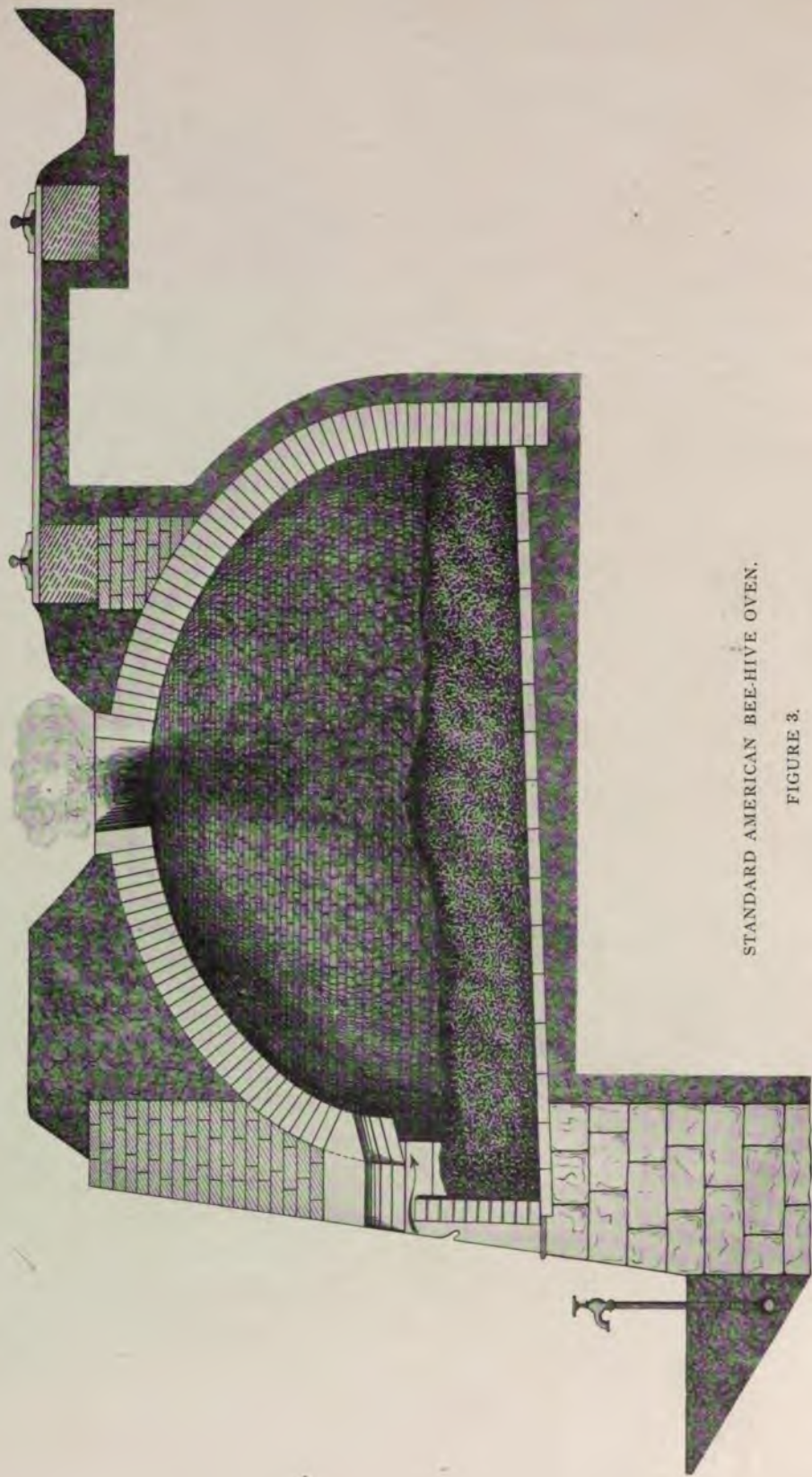
STANDARD AMERICAN BEE-HIVE OVEN.

FIGURE 3.

ing at the opening in the top of the door. The combustion heats the arched dome of the oven, which reflects the heat to the coal charge below, causing it to become coke. When all the gas is burned off, the oven is opened and the coke quenched by throwing water into the oven from a hose. The coke is then raked out by hand and loaded into cars for shipment. The charge is from $4\frac{1}{2}$ to 5 net tons of coal for a 48-hour coking period, and somewhat more for a 72-hour coking period, which is usually arránged so as to avoid drawing coke on Sunday, two 48-hour charges and one 72-hour charge constituting a week's work.

As the coke is watered in the oven, the steam evolved during the quenching period practically excludes the air, which gives the coke a silvery grey lustre, to which in former times the blast furnace operators were wont to attribute great virtue as a protection from the dissolving action of the gases in the upper portion of the blast furnace charge. This virtue, however, has been found to reside more particularly in the hardness of the cell walls forming the coke structure, which is dependent on the degree of heat during the coking operation, and the compactness of the coal in the charge, as well as upon the nature of the coal itself, and not at all on the color and mode of watering.
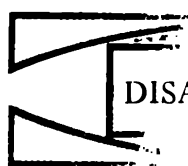
DISADVANTAGES OF THE BEE-HIVE OVEN.

LIMITED TO CERTAIN COALS.

A LARGE proportion of the bituminous coals classed as coking coals do not yield a satisfactory coke for blast furnace use when coked in the bee-hive oven. Those having in the neighborhood of 32 per cent. volatile matter give the best results. The higher volatile coals yield a coke that is apt to be brittle or spongy, while the low volatile coals give a low yield, as a portion of their " fixed carbon " must be burned to maintain the required oven heats. Until the advent of the by-product oven, the iron manufacturers who desired to use coking coals from mines outside the recognized cok-

ing fields, as the Connellsville or Pocahontas, labored under a serious handicap.

LOW YIELD.

THE average yield of coke in the bee-hive oven from Connellsville coal with 32 per cent. of volatile matter is not over 60 to 65 per cent. of the coal charged, under the most favorable circumstances. With Pocahontas coal, having 22 per cent. volatile, the coke yield is not over 50 per cent. This loss is due to the crude nature of the process, from the standpoint of heat economy, and the imperfect regulation of the air admitted to the coking chamber.

MANUAL LABOR.

IT has not as yet been found practicable to replace the manual labor necessary in the operation of the bee-hive oven with machinery to any great extent. The work of levelling the coal, quenching and drawing the coke and loading it on cars, are operations of a laborious character, and are still done by hand labor.

WASTE OF BY-PRODUCTS.

NOT alone is the yield of the coal in coke reduced by a considerable percentage below that theoretically and practically possible to obtain, but gas, tar, ammonia and other volatile by-products are entirely wasted as well. The extent of this loss will be discussed further on.

SMOKE NUISANCE.

THE smoke and soot arising from a bee-hive coke oven plant is so great as to make its banishment to the more thinly populated regions a necessity. No city or town of any pretensions would admit such a nuisance in its vicinity.

BECAUSE of the above-mentioned smoke nuisance, it is necessary to ship the coke from the coal mining districts to the points of consumption. The by-product coke oven, as will be seen further on, does not produce any such nuisance, and can therefore be located at the consuming plant, even if it be in or near a large city. With the advent of the by-product oven there would therefore come a change in traffic, as coal would be shipped instead of coke.

The shipment of coke as necessitated under the bee-hive practice has however the following disadvantages:

1. Coke is bulky; its shipment by water is therefore impracticable.

2. Its shipment by rail requires special cars. These cars are of special design and are not adapted to the shipment of any other bulk freight; consequently they have to go back empty from the point of coke consumption to the point of coke production.

3. The transportation of coke in railroad cars results in the production of a considerable percentage of breeze.

4. The standard coke cars hold only 20 tons of coke, or at most 30 tons. Standard coal cars hold 50 tons. Even if it be taken into consideration that 1.25—1.35 tons of average coking coal is necessary for the production of 1 ton of coke it would still be preferable to ship the coal. The railroads have recognized the advantage of shipping coal by making very much lower freight rates than on coke.

5. A blast furnace which depends upon bee-hive coke depends also on the smooth operation of the railroad system. It has repeatedly happened that furnaces had to bank and lie idle for a long period of time, on account of inability to obtain coke deliveries. If a by-product plant were operated in immediate proximity to a blast furnace, a sufficient amount

of coal could be stored to tide over railroad blockades, whereas storage of coke is too expensive to be considered. This difference arises from the low cost of handling coal as compared with coke.

COKE OUTPUT.

A BEE-HIVE oven taking a coal charge of 5 net tons and coking it in 48 hours, yielding a maximum of 65 per cent. in coke, delivers 1.61 net tons of coke per day. A by-product coke oven of the United-Otto type, coking a charge of 7—12 net tons per day of 24 hours, yields 75 per cent. of the coal in coke. In order to make this comparison clearer the accompanying illustration, Figure 4, shows a United-Otto oven of a daily charging capacity of 10.5 net tons of coal yielding 7.9 net tons of coke per day and a bee-hive oven drawn to the same scale.

The contrast in the returns from two plants of this character would be even greater, when the yield of by-products is taken into account, as the following table will show:

COMPARATIVE RETURNS.

THE results from coking 100 net tons of coal are as follows:

BEE-HIVE OVENS.	BY-PRODUCT OVENS.
65 net tons coke.	75 net tons coke.
	1,000 gallons tar.
	2,300 lbs. sulphate of ammonia.
	450,000 cu. ft. illuminating gas.

According to the usual method of operating bee-hive oven plants it would take a plant of 200 such ovens to equal in coke output a block of 50 United-Otto by-product ovens.
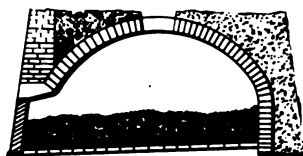
BEE-HIVE OVEN.
Charges 5 Net Tons Coal –Coking Time 48 Hours.
Output Per 24 Hours:
1.6 NET TONS COKE.
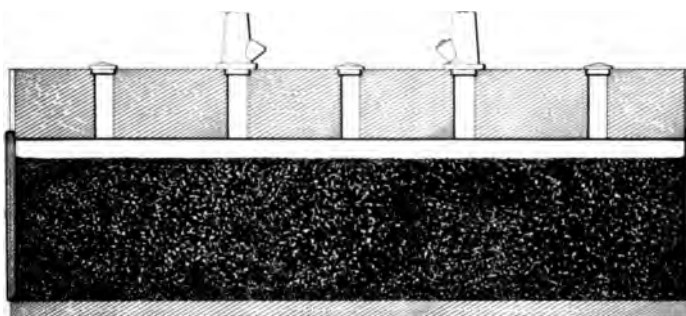
UNITED-OTTO OVEN.
Charge 10.5 Net Tons Coal—Coking Time 24 Hours.
Output Per 24 Hours:
7.9 NET TONS COKE.

[FIGURE 4. COMPARISON OF BY-PRODUCT AND BEE-HIVE OVENS.]

SUMMARY.

IT is therefore clear that the bee-hive oven is a crude and wasteful device, inherited from the pioneering period of the iron industry and destined to be abandoned in its more complete development. It has disappeared in Continental Europe and is condemned in Great Britain. It will soon be extinct in the United States. The present enormous loss of national wealth entailed by the destruction of by-products must come to an end.

H E coal gas retort is designed primarily for the manufacture of illuminating gas, just as the bee-hive coke oven is particularly adapted to the manufacture of coke, there being a difference, however, in that the gas retort permits the recovery as well of the subsidiary products, coke, tar, ammonia, etc.

INTRODUCTION.

THE introduction of the gas retort is ascribed to Murdoch, an Englishman, who in 1798 made use of the gas obtained from the distillation of coal in a closed retort for illuminating purposes. In its various improved types it forms an integral part of most of the gas works now in existence.

WILLIAM MURDOCH
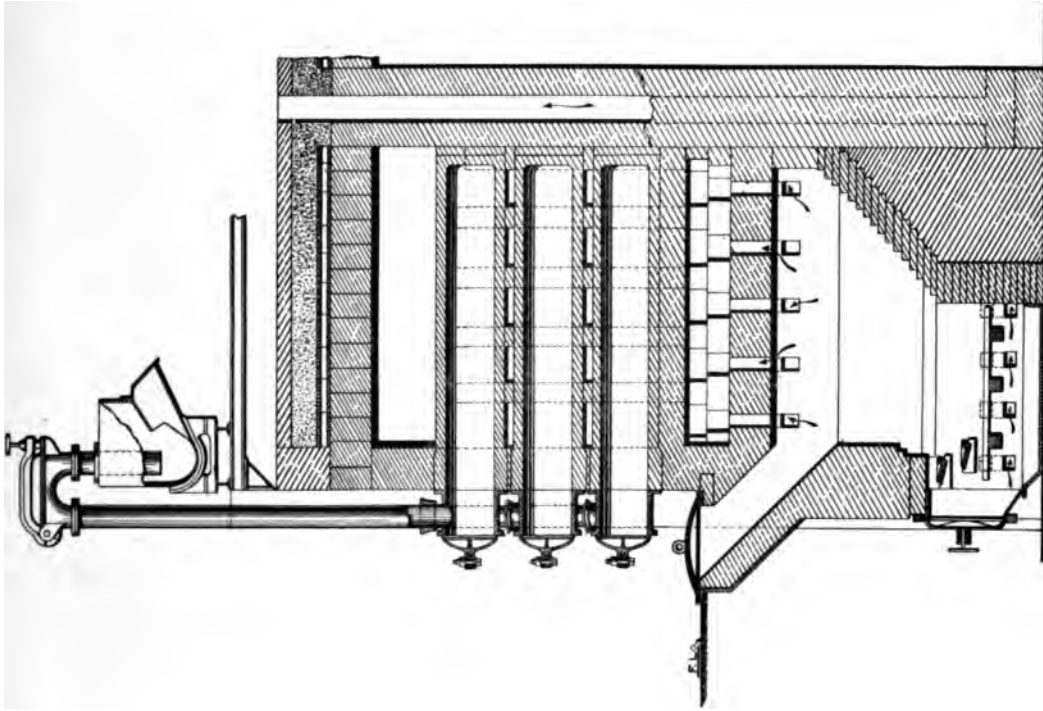
5b. Longitudinal Section Through Retorts.
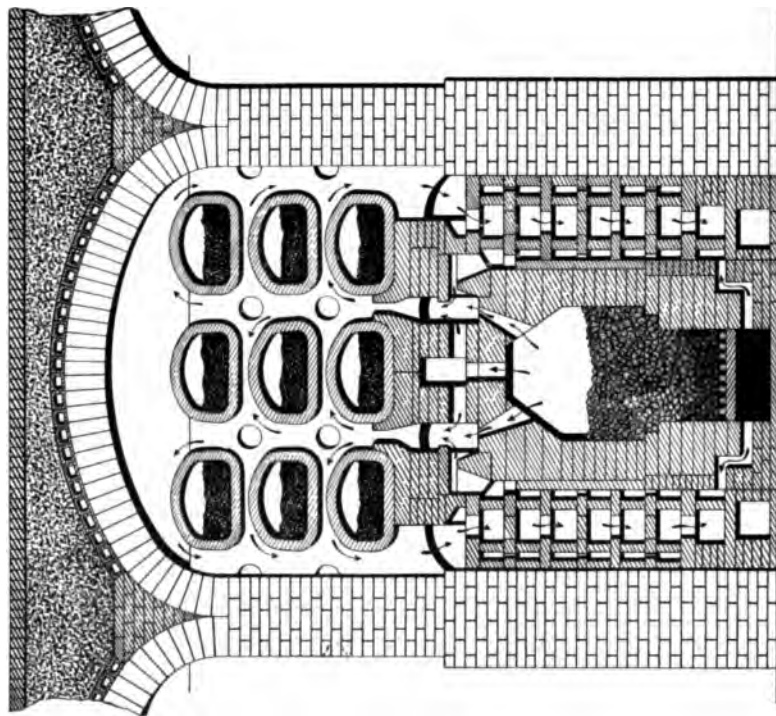
5a. Transverse Section Through Retorts.

FIGURE 5. BENCH OF GAS RETORTS.
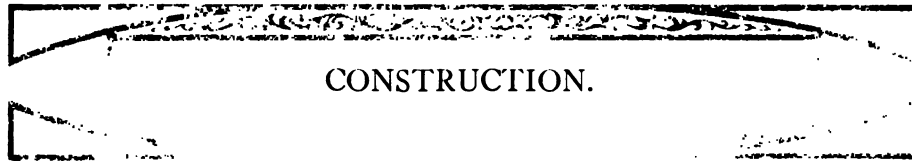
CONSTRUCTION.

THE present form of the gas retort is shown in Figures 5a and 5b which give the details of a modern retort setting. This consists essentially of an arched chamber of fire brick construction containing a gas producer below, and nine fire clay retorts in the upper section, each retort approximately 26 x 16 inches inside and from 8 to 10 feet long. They are moulded of refractory clay, and have walls from $2\frac{1}{2}$ to 3 inches thick.

The nine retorts, each containing a charge of coal, are shown in the upper portion of the transverse section, Figure 5a, the gas producer beneath them being shown partly filled with coke in this view. In the longitudinal section, Figure 5b, the retorts and producer are shown without the charges. As shown in the latter view, each retort has a tightly closing cast iron mouth piece and lid, and has a separate pipe connection leading up to the so-called hydraulic main above. Immediately below the retort lids is an opening closed by a lid, through which coke taken from the retorts can be fed to replenish the fire in the gas producer. On the floor, level with this lid, the coal for charging the gas retorts is handled, either by shovel or by machinery, and the coke drawn from the retorts is quenched and wheeled away. On the floor below this the producer is "clinkered" or cleaned and the ashes removed.

OPERATION.

EACH retort is charged with approximately 400 lbs. of coal at a time, and the lid is closed. The heating of the retorts is done in the following manner. The fuel gas from the gas producer below rises through the openings in the producer roof, indicated by

arrows in the illustrations, and mixes with the hot air which rises through the narrow passages shown at each side of Figure 5a. The burning air and gas then rise to the retort chamber and circulate between the retorts, heating them to a high temperature, and subjecting the coal inclosed in them to destructive distillation. The heating gases then pass downwards through the large passages at each side of the producer as shown by the arrows, transmitting their heat to the incoming air moving upwards in the adjoining narrow passages; the waste gases then pass to the stack flue, shown in Figure 5b at the rear of the retorts.

The gases from the coal enclosed in the retorts are kept entirely separate from the heating gases, and are led upwards through the pipes to the hydraulic main, and thence pass through the cooling and condensing operations necessary to prepare them for illuminating purposes.

After the completion of the distillation period, which is 4 hours or

FIGURE 6. PLANT OF GAS RETORTS.

longer, according to the weight of the charge, the retort is opened and the coke is withdrawn, the retort then being ready for a fresh charge. The operation is in every respect similar to that going on in a by-product coke oven, except that it is in miniature, each retort with its connection to the gas main constituting a unit similar to a by-product oven, the bench of nine retorts corresponding to the battery of fifty coke ovens. Gas retorts, however, are nearly always protected from the elements by a substantial retort house, whereas for by-product coke ovens experience has proved this expense unnecessary. An interior view of such a retort house, showing the gas retorts, is given in Figure 6.

DISADVANTAGES OF THE GAS RETORT.
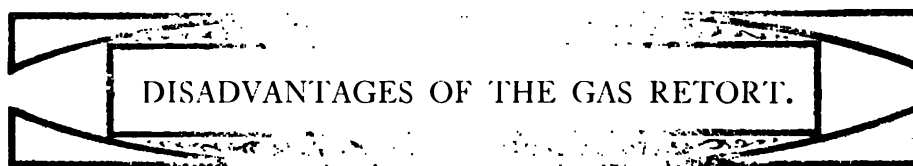
SUITABLE COALS.

A S the whole yield of gas from the gas retort must be of marketable quality, only specially selected gas coals can be used. Such coals are few in number and high in price. As the existing mines are becoming depleted, the price is not likely to decrease.

QUALITY OF COKE.

T HE coke from a gas retort is not, however, to be compared to that from a by-product coke oven, as it is of a soft, spongy nature, unfit for blast furnace or foundry use, and not as adaptable to domestic purposes as is the properly prepared coke-oven article. The reason of this inferiority of the coke is the shallow layer in which it is formed; this allows the free expansion of the gas in the semi-fluid coal mass and results in excessively large cells. As stated above, a part of the coke is used as fuel for heating the retort benches. The amount of coke thus used varies between 15 and 25 per cent. of the coal carbonized.

MAINTENANCE.

THE retorts, consisting as they do of a single piece, are expensive to replace, and are liable to crack. Those experienced in the operation of gas retorts can vouch for the difficulty and expense of maintaining them.

SMALL UNITS UNECONOMICAL.

IT is apparent that the labor cost of handling coal in such small quantities as 400 to 500 lbs. must be greater than in charges of 14,000 to 24,000 lbs., as is the practice in a modern coke oven. In the older retort installations the coal is actually shovelled into the retorts by hand, an operation requiring no little skill as well as strength, and the coke is raked out on the floor by hand. In the more modern retort houses charging and coke drawing machines of complicated character are used. The advantage gained by such machinery is, however, relatively slight, since the small charges must be adhered to. The use of inclined retorts, taking coal charges of from 600 to 750 lbs., has been resorted to more recently, but the opinion of the gas fraternity in general is very much divided as to the economy resulting from their use, in comparison to horizontal retorts with machines for charging and drawing them.

CONTRAST BETWEEN BY-PRODUCT OVENS AND GAS RETORTS.

IN order to show more clearly the relation between the size of the gas retort and the by-product oven, the two are shown in Figure 7 drawn to the same scale. The gas retort takes a charge of from 400 to 500 lbs. of coal, carbonizing five or six such charges in 24

Transverse Section.

Gas Retort.

Longitudinal Section.

CHARGE 400 Lbs. of COAL.

DAILY CARBONIZATION 2400 Lbs.

Transverse Section.

By-Product Oven.

Longitudinal Section.

DAILY CARBONIZATION 21000 Lbs.

CHARGE 21000 Lbs. of COAL.
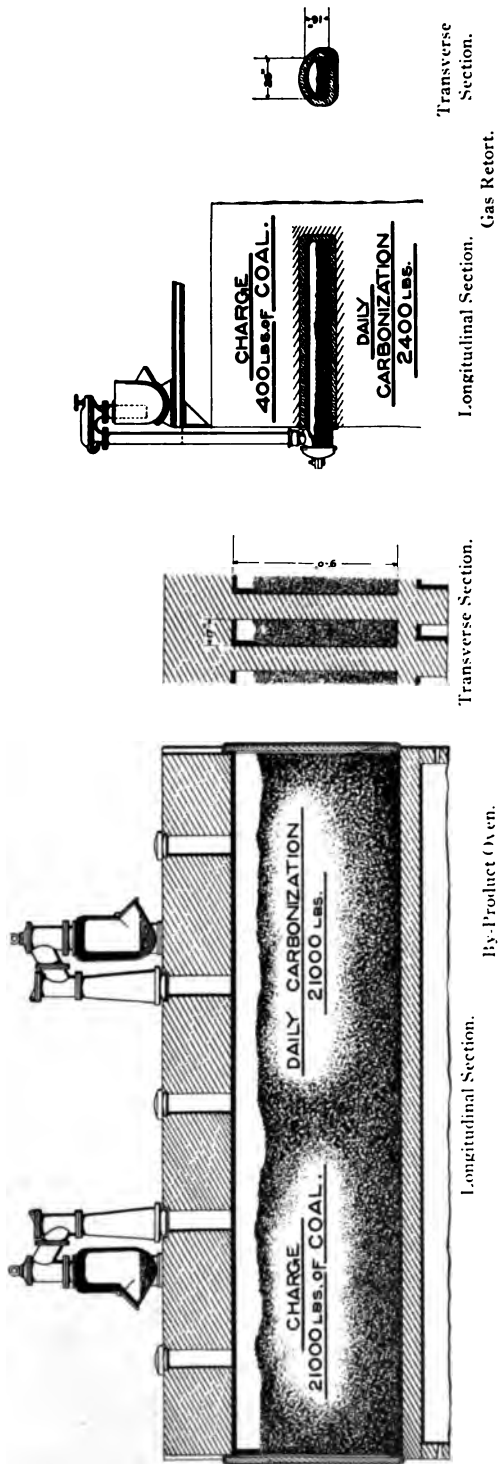
FIGURE 7. COMPARISON OF BY-PRODUCT OVEN AND GAS RETORT.

A Bench of 9 Retorts Carbonizes 9 Net Tons of Coal Per Day.

A Battery of 50 United-Otto Ovens Carbonizes 525 Net Tons of Coal Per Day.
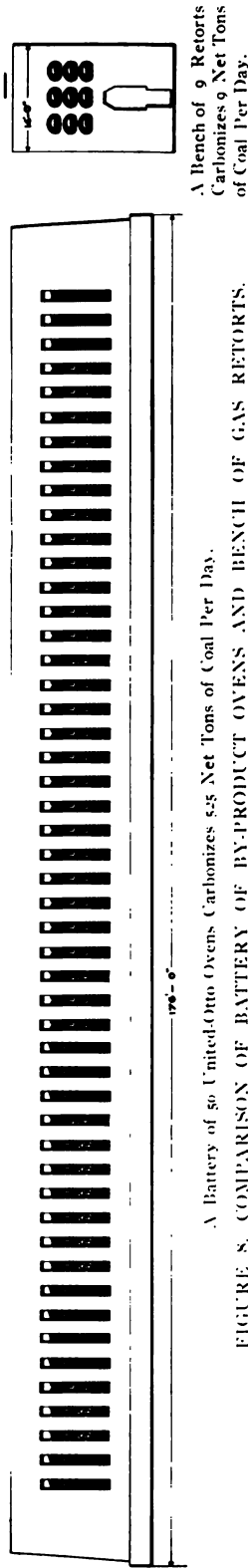
FIGURE 8. COMPARISON OF BATTERY OF BY-PRODUCT OVENS AND BENCH OF GAS RETORTS.

hours, or about 2,400 lbs. of coal. The United-Otto coke oven takes a charge of 21,000 lbs. of coal once in 24 hours. It would therefore take one bench of 9 retorts to equal the daily carbonizing capacity of one United-Otto oven. The contrast between the two is graphically shown in Figure 8 in which a bench of 9 retorts and a battery of 50 ovens are drawn to the same scale.

SUMMARY.

FROM the foregoing it is apparent that the gas retort is at a serious disadvantage, when compared with the by-product coke oven, because of the smaller scale on which it works, and the higher cost of operation and repairs. The restrictions as to coal quality, and the low grade of the coke made, circumscribe its field to the illuminating gas supply of cities and towns in favored localities. The larger function referred to by Sir William Siemens in his prophetic words, quoted on the opening page, namely, the economical transformation of all raw coal to gas and smokeless coke, recovering all the impurities in the form of useful by-products, has never been realized by the gas retort process, nor by the gas producer, to which he also refers. It remains for the modern by-product coke oven to make good his prescient words.

The By-Product COKE OVEN

N order to trace the evolution of the by-product coke oven, we will first briefly indicate the steps which produced an oven of the present retort form, without provision for the recovery of by-products.

THE RETORT OVEN WITHOUT BY-PRODUCT RECOVERY.

INTRODUCTION.

THE disadvantages under which the bee-hive oven labored became apparent to the Belgian and German coke makers earlier than to those in England and America. The original round or square oven of moderate size was increased to one of oblong shape, closed with a door of fire brick extending its whole width. This construction is typified by the Welsh "drag" oven, still existing in England, in which the coke was drawn out all at one time by an iron device put in with the coal charge, and operated by a windlass and cable. The need of increased heat for coking larger charges, and the desire to improve the yield led to the expedient of conducting the flaming gases escaping from the oven top, through flues built in the oven sides and bottom, and thence to a smoke stack. This device appeared in various forms, and was applied to ovens of both round and rectangular section. Among the latter were those of Fabry, François, Rexroth, Coppée and Smet. The result in Germany, Belgium and France was the ultimate abandonment of the

round oven, and the tendency towards greater height and length of oven chamber combined with less width.

CONSTRUCTION.

THIS oven was practically what is now known as the non-by-product retort oven. It had the long and narrow coking chamber characteristic of the modern retort oven, closed by doors at either end, the coal being charged through openings in the oven top. The coke was removed from the oven by a ram or pusher and quenched on a wharf in order to prevent the cooling of the oven. The ovens were arranged side by side in batteries of 20 to 30. The heating was done entirely by the combustion of the gases evolved from the coal, in passages situated in the walls separating the adjacent coking chambers.

ADVANTAGES.

THE advantages gained in this type of oven over the bee-hive were the following: The ability to coke coals of lower volatile matter by virtue of the more economical utilization of the heat; the outside quenching; the economy of labor in using mechanical pushers in place of hand drawing; an increased coke yield due to the more perfect exclusion of air from the coking chamber, and finally a gain in the strength of the coke produced because of the greater depth of the oven, and the consequent closer packing of the coal charge.

OTTO-COPPÉE OVEN.

THE Otto-Coppée oven may be considered as typical of this form. It is shown in its later form in the drawing, Figures 9a and 9b. Its dimensions were, in general, 30 feet long, 5 feet high, and

24 inches in average width, the ovens being 4 inches wider at the coke side than at the pusher side. The walls separating the ovens were provided with vertical heating flues, as shown in Figure 9a. These flues were connected directly with the adjacent oven chamber
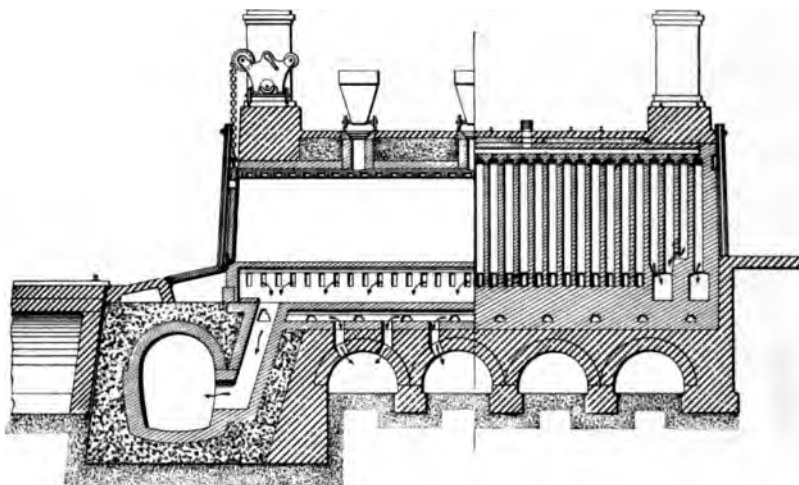
Longitudinal Sections.

FIGURE 9a. OTTO-COPPÉE, NON BY-PRODUCT RETORT OVEN.

by a small opening at the top, and a second opening was provided from an air flue in the brick work, above each vertical heating flue. Thus the gas distilled from the coal in the oven would pass directly to the wall flues and meeting the air, would burn and heat the wall on its downward passage. As may be seen by the arrows on the transverse section, Figure 9b, the ovens worked in pairs, the gas from two adjacent walls passing to the flue beneath one oven, traversing this flue horizontally, and then passing through an opening to the flue beneath the other oven of the pair, reaching the stack flue by the down-take passage as indicated by the arrows. The ovens were charged

Transverse Sections.
FIGURE 9b.

on alternate days, so that a fresh oven was always next to one from which the gas was nearly exhausted. A damper on top of
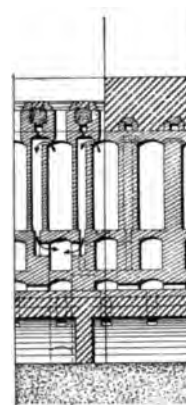
the ovens regulated the air for combustion for each separate oven. A great improvement in the regularity of heating was made by Dr. C. Otto & Co., who, in order to overcome the inequality due to the decreasing gas evolution, placed a gas equalizing opening of small diameter beside each gas port, so that surplus gas in any one oven could find its way to the adjacent oven unconsumed and assist to maintain the heats. This device resulted in the reduction of the coking time in the Otto-Coppée oven from the prevailing 48-hour period to 33-36 hours.

DR. CARL OTTO.

Over 8,000 ovens of the Otto-Coppée type have been built by Dr. C. Otto & Co. in Germany and elsewhere. None as yet have been constructed in the United States.*

*Note.—These ovens are built by the United Coke and Gas Company, who would be glad to furnish information to interested parties.

THE RETORT OVEN WITH BY-PRODUCT RECOVERY.

INTRODUCTION IN GERMANY.

IN 1856 Knab attempted to obtain gas and by-products as well as strong coke from an externally heated retort at Commentry, France. Later Carvès improved the Knab oven, and built several plants. The results attracted the attention of Huessener, who in 1881 built a plant of by-product ovens at Gelsenkirchen, Westphalia, Germany, the design being a modification of the Knab-Carvès construction. At the same time Dr. C. Otto was experimenting on similar lines with a plant of ten Otto-Coppée ovens at Wattenscheid, Germany, with the avowed intention of evolving an oven of the true by-product type, *i. e.*, one in which the coal was heated in a closed retort with no combustion whatever in the coking chamber, the heat being supplied entirely by cleaned gas burning in flues surrounding the coking chamber.

Up to this time the attempts made to construct and operate such an oven had met with only moderate success, and cannot be said to have achieved any general approval or introduction. This was, however, the turning point of the industry. As a result of the Wattenscheid experiments the firm of Dr. C. Otto & Co. in 1881 constructed and exploited a form of oven in which the Siemens regenerator was adapted to recover the heat from the waste gases, and furnish heated air for combustion, the oven construction being in general of the well-known Otto-Coppée type. This form of oven, known as the Otto-Hoffmann, came rapidly into use, and on its merits the introduction of the by-product oven into Germany may be said to rest.

Up to 1894, when the oven was introduced into America, there had been over twelve hundred of these ovens constructed on the European Continent, more than three times as many as existed there of any other type of by-product oven. This oven is shown in detail in Figure 10 and is described on page 43.
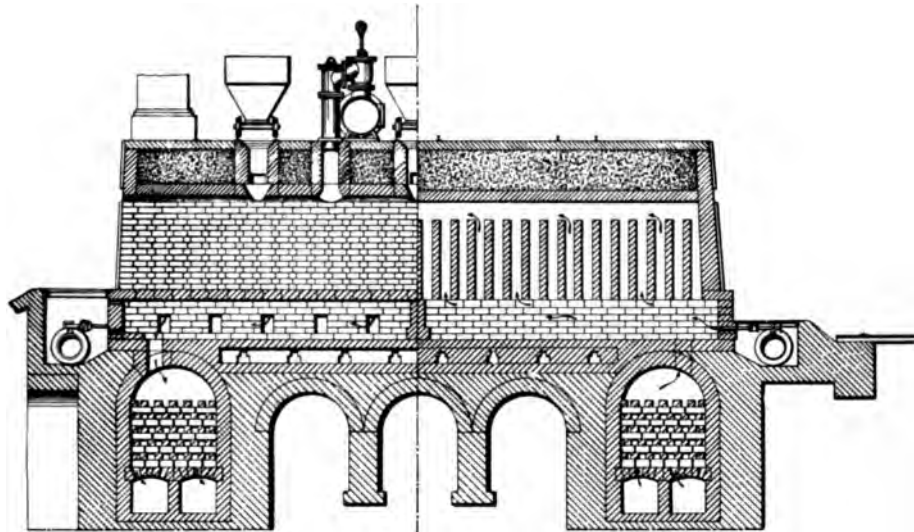
Figure 10a. Longitudinal Sections.
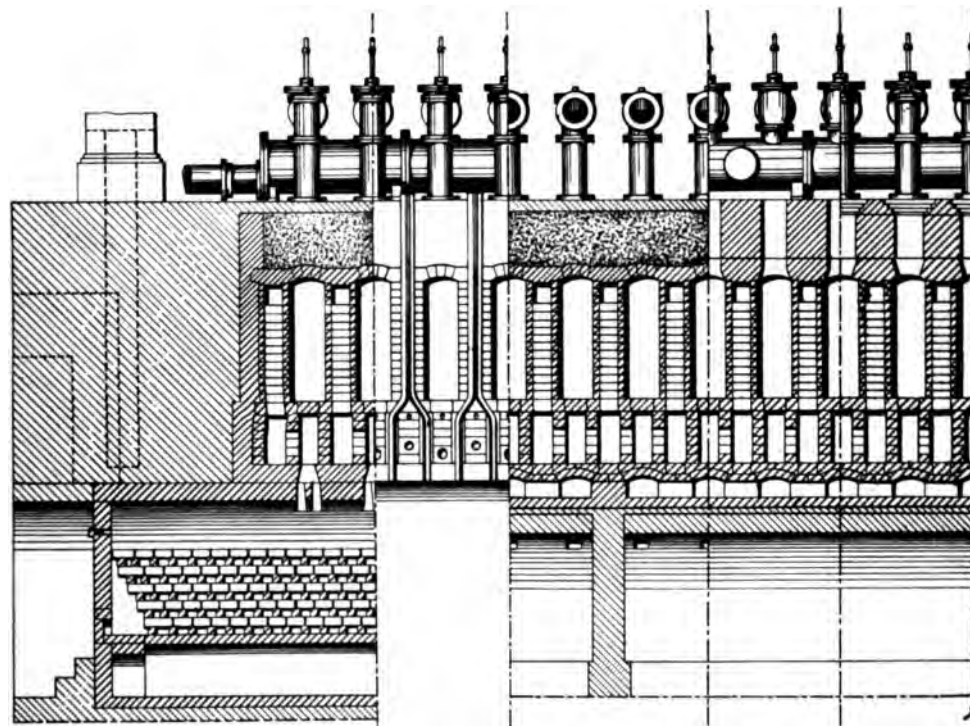
Figure 10b. Section Through Regenerator.   Elevation   Transverse Sections.

FIGURE 10. EARLY TYPE OF OTTO-HOFFMANN BY-PRODUCT COKE OVEN.

INTRODUCTION IN AMERICA.

IN 1894 The Otto Coke and Chemical Company acquired the American and Canadian rights for Dr. C. Otto & Co.'s oven types, and built a plant of 60 Otto-Hoffmann by-product coke ovens for the Cambria Steel Company at Johnstown, Pa. This was the first by-product oven plant operated in conjunction with a blast-furnace built in this country. It is in successful operation to-day, though more than quadrupled in size.

WILLIAM L. ELKINS. Jr.

With the discovery of the great value of the surplus gas from the Otto-Hoffmann ovens the field of the Otto Coke and Chemical Co. was enlarged and they operated thereafter under the name of The United Coke and Gas Company, which company was created by the late William L. Elkins, Jr., who remained its President until his untimely death in 1902.

A list is given herewith of the by-product oven plants installed by The United Coke and Gas Company up to the present time.

BY-PRODUCT COKE OVENS BUILT AND UNDER CONTRACT BY THE UNITED COKE AND GAS COMPANY IN THE UNITED STATES AND CANADA, 1905.

COMPANY	Instal-ments	LOCATION	No. of Ovens	Use of Coke	Use of Surplus Gas.
Cambria Steel Co.	1st	Johnstown, Pa.	60	Blast Furnace.	Fuel and Power.
Cambria Steel Co.	2nd	Johnstown, Pa.	100	Blast Furnace.	Fuel and Power.
Cambria Steel Co.	3d	Johnstown, Pa.	100	Blast Furnace.	Fuel and Power.
Cambria Steel Co.	4th	Johnstown, Pa.	112	Blast Furnace.	Fuel and Power.
Pittsburgh Gas and Coke Co.		Glassport, Pa.	120	Blast and Domestic.	Illumin't'g and Fuel
New England Gas and Coke Co.		Everett, Mass.	400	Domestic and Locomotive	Illumin't'g and Fuel
Dominion Iron and Steel Co.		Sydney, N. S.	400	Blast Furnace.	Fuel.
Hamilton Otto Coke Co.		Hamilton, O.	50	Foundry and Domestic.	Illumin't'g and Power
Lackawanna Steel Co.		Lebanon, Pa.	232	Blast Furnace.	Fuel.
Lackawanna Steel Co.		Buffalo, N. Y.	564*	Blast Furnace.	Fuel.
South Jersey Gas, Electric and Traction Co.	1st	Camden, N. J.	100	Foundry and Domestic.	Illumin't'g and Power
South Jersey Gas, Electric and Traction Co.	2nd	Camden, N. J.	50*	Foundry and Domestic.	Illumin't'g and Power
Maryland Steel Co.		Sparrow's Pt., Md.	200	Blast Furnace.	Illuminating.
Michigan Alkali Co.	1st	Wyandotte, Mich.	15	Lime Kilns.	Fuel.
Michigan Alkali Co.	2nd	Wyandotte, Mich.	15*	Lime Kilns.	Fuel.
Sharon Coke Co.		South Sharon, Pa.	212	Blast Furnace.	Fuel.
Zenith Furnace Co.		Duluth, Minn.	50	Blast Furnace.	Illuminating.
		Total,	2780		

* Not Completed.

FIGURE II.—SECTIONAL VIEW OF OTTO HOFFMANN BY-PRODUCT OVEN
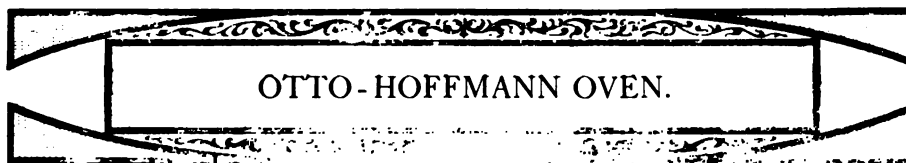
OTTO-HOFFMANN OVEN.

THE Otto-Hoffmann oven in its early form, as built in America by The United Coke and Gas Company, is shown in sectional perspective in Figure 11. This is practically the construction adopted at the first and second Cambria installations and at Glassport, Everett, Sydney, Hamilton and Camden.

CONSTRUCTION.

THE coking chamber itself consists of a long, narrow retort of firebrick construction, a number of such retorts, at first 30, later 50, being placed side by side to form a battery. The dimensions of this retort are 33 feet long, 6½ feet high, and from 17 to 22 inches in average width, containing 6 to 7 net tons of coal at a charge. The walls of the retort are sometimes built with a taper, so that the oven is wider at the discharge side than at the pusher side, this taper being given in order to facilitate the discharge of the coke, and varying from 4 inches for swelling coals to 1 inch or nothing for those of a shrinking nature. The walls are provided with vertical internal flues heated by gas. The ends of the retorts are closed by iron doors lined with fire brick, fitting closely to the retort walls and luted with clay. These are raised and lowered in the older plants by a winch, and in later plants by electrical devices. The coal was at first charged into the ovens from three larries moved by hand along tracks laid on the oven tops, or in the later plants by a single electrically-operated larry as shown in Figure 11. The single larry has spouts which deliver the coal through corresponding charging holes in the oven top to the coking chamber below. This larry, in the case of the Everett, Hamilton, Camden and Duluth plants, is carried on an overhead steel trusswork so as to relieve the oven walls of the weight of the larry and track.

OPERATION.

THE coke is pushed out of the oven by a pusher operated by steam or in the later plants by electricity, and is received and quenched on a wharf, from which it is loaded by hand into railroad cars on a depressed track alongside. The later plants have quenching devices of different design, described more fully further on. The heating of the oven is done by gas returned from the condensing house through mains running along each side of the battery, there being a burner at either end of each oven (see Figure 10). Only one burner for each oven is used at a time. The air for combustion is taken in at the end of the battery, where the gas and air reversing valves are located, (see Figure 11) and is led through the underground passages shown in the figure to the flues beneath the regenerative chambers. These extend the whole length of the oven battery and are filled with checker brick. The air rising through this checkerwork is heated to about 1800 Fahr. passing then through uptake connections to the space beneath the floor of the oven chambers (see Figure 10) and through lateral ports to the combustion chamber, where it meets the gas from the burner. The burning gases rise through the vertical flues of half the wall, pass along the horizontal connecting flue above, and down the remaining vertical flues to the horizontal flues below, thence passing to the regenerator, where their sensible heat is absorbed by the checkerwork. From there they are led to the lower regenerator flue, past the reversing valve, to the draught stack. On the reversal of the air and gas, the gas burner on the other end of the oven comes into use, the air passing up through the heated regenerator on that side, and to the gas burner and combustion chamber, the heated gases passing in reverse direction through the wall flues, downwards through the regenerator and so to the stack. The amount of checker work in the regenerators is so calculated that the waste gases escape to the stack with only sufficient temperature to secure ample draught, viz. about 550° Fahr. The period of reversal is usually 30 minutes.

The gas evolved from the coal is led from the oven through uptake pipes and valves to the gas-collecting mains, of which there are two shown in Figure 11. This part of the process will be discussed more fully further on.

THE OTTO-HILGENSTOCK OVEN.
GENERAL DESIGN.
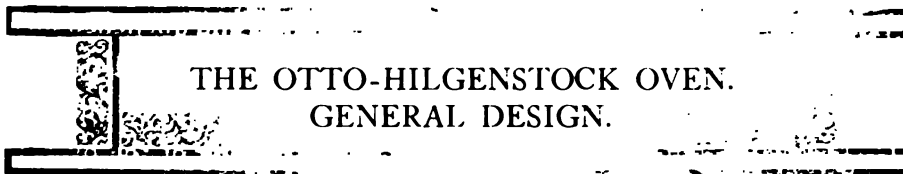
A TYPE known as the underfired or Otto-Hilgenstock* oven has come into prominence in Germany, principally because of its simplicity and its adaptation to local conditions. In it the regenerators have been discarded, and the heating burners are applied through openings placed beneath the vertical flues in the oven walls. The somewhat lower cost of these ovens and the advantage of the location of the burners, in comparison to the Otto-Hoffmann ovens, have given this construction considerable vogue, particularly where the waste heat can be advantageously used for raising steam.

CONSTRUCTION.

THE details of this oven are shown in Figure 12. The coking chamber is similar in construction to the Otto-Hoffmann oven, the main points of difference lying in the arrangement of the heating flues and the waste gas outlets. As may be seen in Figure 12a, the heating gas enters through 10 burners, passing upwards through specially designed ports. The air is admitted at the same opening, drawn from the foundation arches, and hence taking up the heat radiated from the ovens above. The course of the heating gases is similar in each half of the wall, rising from the burners through the vertical flues, passing horizontally along the upper canal to the middle of the oven, and thence down on either side of the division wall there shown, to the lateral openings into the oven sole canal, and from this to the waste heat canal leading to the

* U. S. Patent 619159 assigned to the United Coke Co. and Gas Company.

Figure 12b. Transverse Sections.

Figure 12a. Longitudinal Sections.

FIGURE 12. THE OTTO-HILGENSTOCK OVEN.

boilers and stack. This flame course is constant, there being no reversal as in the Otto-Hoffmann oven.

ADVANTAGES.

THE advantage gained in this type of oven is the superior distribution of the heat, and the consequent increase in uniformity of coking over the Otto-Hoffmann oven. This is due to the method of under-firing. The combination of this feature with an oven retaining the regenerators essential to secure the maximum amount of surplus gas gave rise to the United-Otto type of oven.* A similar combination has since been adopted by Dr. C. Otto & Co., who have built a plant of underfired ovens with regenerators at the Centrum mine in Wattenscheid, Germany.

THE UNITED-OTTO OVEN.
PRINCIPLES OF CONSTRUCTION.
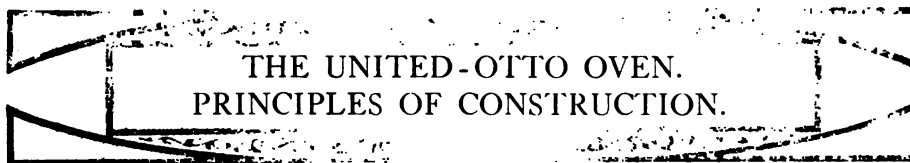
THE principles which guided the design of this oven may be briefly summed up as follows:

1. The retention of the general form and wall construction of the eminently successful Otto-Coppée and Otto-Hoffmann ovens.

2. The adherence to the regenerative system as the most economical heating method known, hence as essential to a maximum recovery of surplus gas.

3. The adoption of the underfired system in so far as it would aid in the uniform distribution of heat throughout the oven.

4. The absolute prevention of any damage to the coking chamber from the contraction and expansion inevitable to the brickwork of the regenerative chambers.

5. The arrangement of the supporting sub-structure so as to admit of thorough anchoring of the oven masonry.

6. Perfect accessibility of the foundations, regenerators, heating system and reversing apparatus.

* United States Patents Nos. 673928 and 644369.
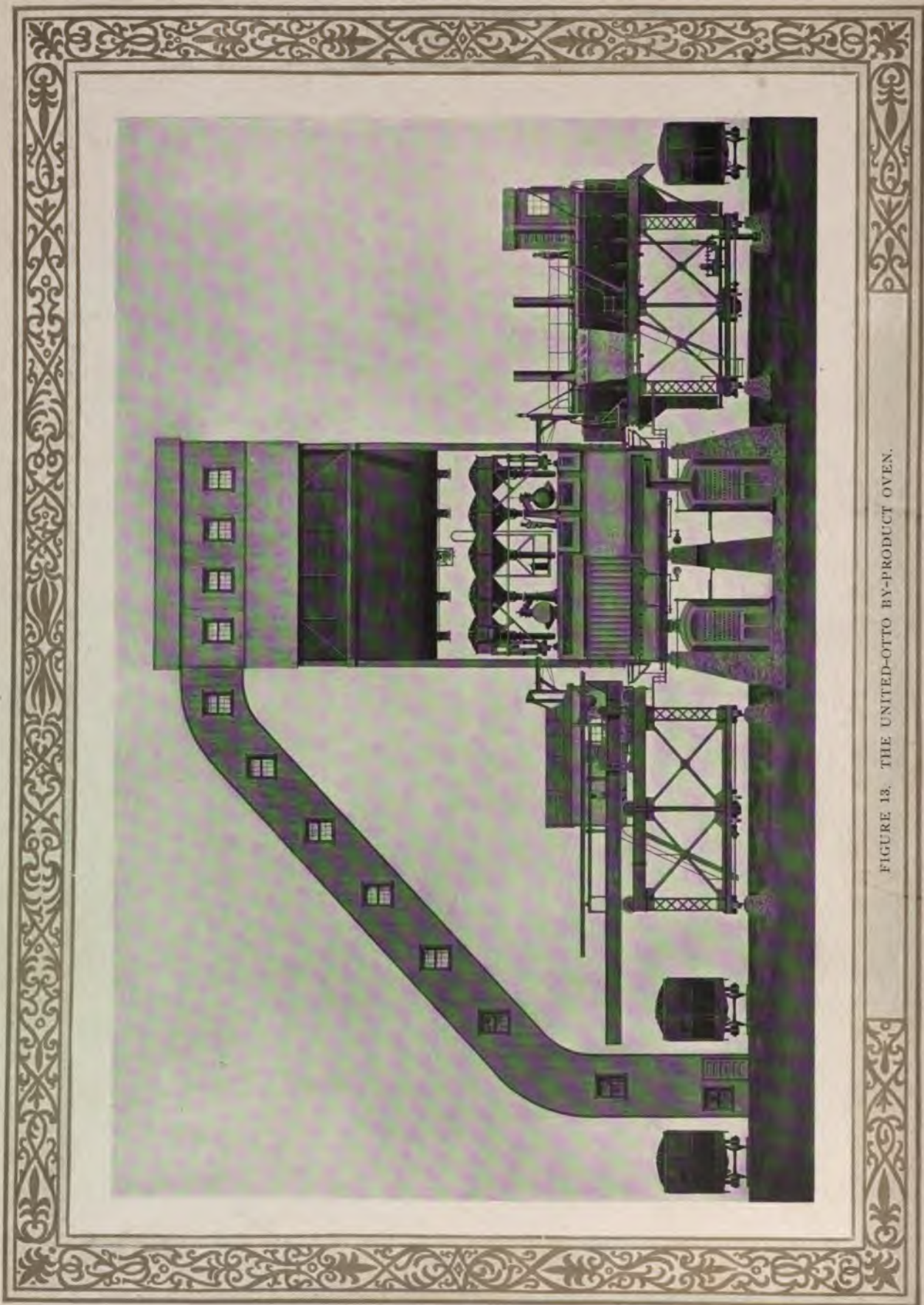
FIGURE 13. THE UNITED-OTTO BY-PRODUCT OVEN.

7. The increase of the oven dimensions to admit of the largest carbonizing capacity within conservative limits of regular and economical operation.

8. The adaptation of the ovens and accessories to the production of high candle power illuminating gas, and a maximum yield of by-products, without affecting the quality of the coke produced.*

9. The use of automatic labor-saving machinery wherever practicable.†

The embodiment of these principles in the plants most recently constructed has met with a gratifying measure of success.

GENERAL DESIGN.

THE details of this type of oven are shown in the cross section in Figure 13, which also gives the arrangement of the coal conveyors, coal bin, pusher and quencher. The oven itself is a rectangular retort from 33 feet to 43 feet long, 7 to 9 feet high and 17 inches average width, with or without taper, the dimensions varying with the characteristics of the coal that is to be used. The retort walls, top and bottom are composed of refractory material, and the masonry is supported on a steel and concrete substructure so as to be entirely independent of the regenerative chambers below. This avoids the cracking of the oven walls and the consequent loss of gas, liable to occur from the expansion and contraction of the heated regenerator walls beneath the oven structure. Access is also given to all parts of the oven for inspection and incidental repairs. The open substructure admits of a complete anchoring system joining the buckstays above and below, and holding the oven walls securely in place. The steel work of the substructure is properly protected from the heated brickwork above, this protection also serving to retain the heat in the ovens themselves.

The oven chamber is closed at either end by doors, as in the Otto-Hoffmann oven.

*U. S. Patents, Nos. 627595, 644368, 668225.
† U. S. Patents, Nos. 639570, 723493, 723479, 725471, 725745, 725746, 725747, 755154, 755155.

WALL CONSTRUCTION.

THE construction of the oven walls is a point of vital importance. Shaped brick of the best grade of refractory material, of moderate size and simple design, are used; complicated and irregular shapes and those of larger size being avoided as being more liable to cracks and distortion. The time-honored method of laboriously chipping bricks of uneven thickness to form an even course in laying the oven walls has been abandoned entirely, and all cutting is done to exact dimensions by large grinding wheels, which economize the high-priced masons' labor and result in a quality of workmanship far beyond anything previously considered possible. A practically gas-tight wall of great strength is thus obtained.

The resistance of the wall is enhanced by the vertical flue system. As will be seen on the drawing, the heating flues run perpendicularly along all that portion of the oven wall against which the coal can exert any pressure. The divisions between the flues form vertical strengthening ribs. This is of especial advantage when coals of only slightly shrinking or even expanding nature are to be coked, such as is the case with all low volatile coals.

Other arrangements of flues have been tried on expanding coals, for instance, horizontal flues built of hollow tiles, but the weaker flue walls are more easily crushed in by the pressure exerted by the coal. The strength of the United-Otto vertical flue construction has been demonstrated by the long life of ovens, charged with highly-expanding coals.

A further advantage of the vertical flue system is its ability to withstand the compression loads, due to the weight of the oven superstructure. This does away with the necessity of supporting walls built between the heating flue systems of each adjacent oven, and serving to carry the load of the superstructure. These have been found essential in the horizontal flue system, as might readily be expected from the weakness under compression of the thin horizontal

flue walls extending the whole length of the oven. These division walls add to the cost of the masonry and to the length of the gas mains, railroad tracks, platforms and other equipment, as well as increasing the space required for a given block of ovens by about 65 per cent.

HEATING SYSTEM.

THE heating of the ovens is accomplished by the use of gas returned from the condensing house through the two mains shown beneath the middle portion of the ovens in figure 13. The air for combustion is supplied to the regenerator by a fan, this method aiding in the equal distribution of the supply to each oven, and reducing the amount of stack draft necessary. This not only allows the use of a smaller stack, but makes a more even balance of the pressure in the flues. The gas is admitted through a burner at each end and four or six burners in the bottom, placed symmetrically on each side of the middle line. This avoids the use of bottom burners above the regenerative chambers, where they are less easy of access for cleaning and regulation. At the same time it makes it possible to properly heat ovens up to 43 feet in length, instead of 33 feet, which was the limit of the Otto-Hoffmann oven heated with the end burners alone. This results in an increase of oven output of approximately 30 per cent., and a corresponding saving in the operating cost per ton of product.

The surface of the checkerbrick in the regenerators is so proportioned as to render the most efficient service in absorbing the heat from the waste gases.

OPERATION.

IT is worthy of notice that from the time the coal is unloaded from the car into the elevator, until it is in the oven, it is handled
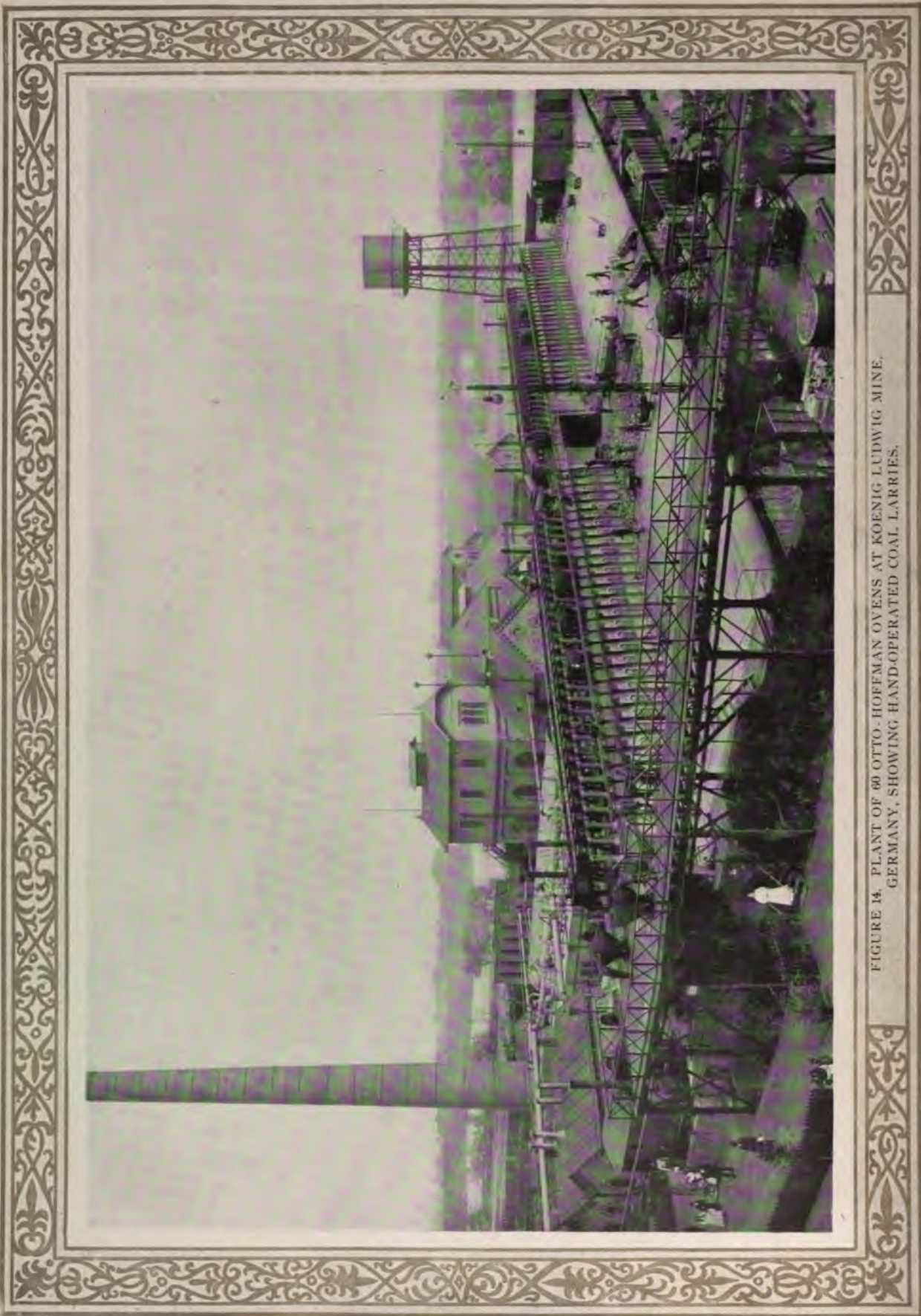
FIGURE 14. PLANT OF 60 OTTO-HOFFMAN OVENS AT KOENIG LUDWIG MINE, GERMANY, SHOWING HAND-OPERATED COAL LARRIES.

FIGURE 15. ELECTRICALLY OPERATED CHARGING LARRY AND SUPPORTING
BRIDGE AT THE CAMDEN PLANT.

by machinery. The railroad cars usually employed are of the modern self-dumping type, and discharge into a hopper below the track as shown in Figure 13. An automatic feeder delivers the coal to a conveyor in regular amounts, thus preventing choking. If the coal is to be crushed, as is usually the case, this conveyor delivers it to the crusher, and from there an elevator takes it to the bin above. If several varieties of coal are used, the mixing is effected by suitable equipment before the coal enters the crusher. The discharge of the coal into the bin is regulated by an automatic device that ensures a regular distribution. The discharge from the bin to the coal larry below is by gravity through a number of chutes, and is controlled by a single lever, the larry being provided with stops so that about the proper quantity of coal is drawn. This amount may be checked by scales with which the larry may be provided, so that an accurate weight of each coal charge is obtained. This is done by one man, who also operates the motors transferring the larry to the oven to be

charged, and dumps the coal into it through the separate spouts which correspond with openings in the oven top. The contrast between these methods and the older ones is seen by comparing Figure 14, where the small larries are pushed by hand from a distance along an elevated track to the ovens, with Figures 15, 16 and 17, which show the electrically-driven charging larry in use at different plants.

The mechanical leveller, which evens off the irregular surface of the coal as it is dropped into the oven, has done away with hand levelling, which was manual labor of the severest kind. The levelling bar is carried on the pusher and is operated through an opening in the oven door. It consists of a light steel beam carrying a head of special design, and provided with a rack on the under side, and is driven in and out of the oven by gears operated by a motor. The travel of the levelling head back and forth through the piles of coal serves to reduce it all to an even height, and tends to increase the actual amount of coal charged by eliminating voids. It is operated by the
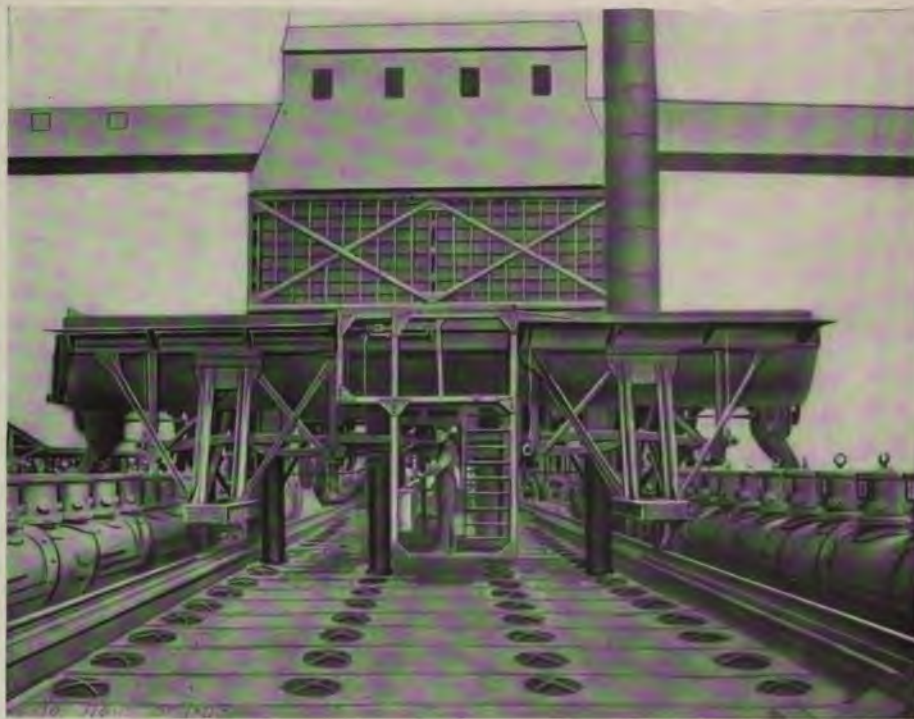
FIGURE 16.   ELECTRICALLY OPERATED CHARGING LARRY
AT THE SPARROWS POINT PLANT.
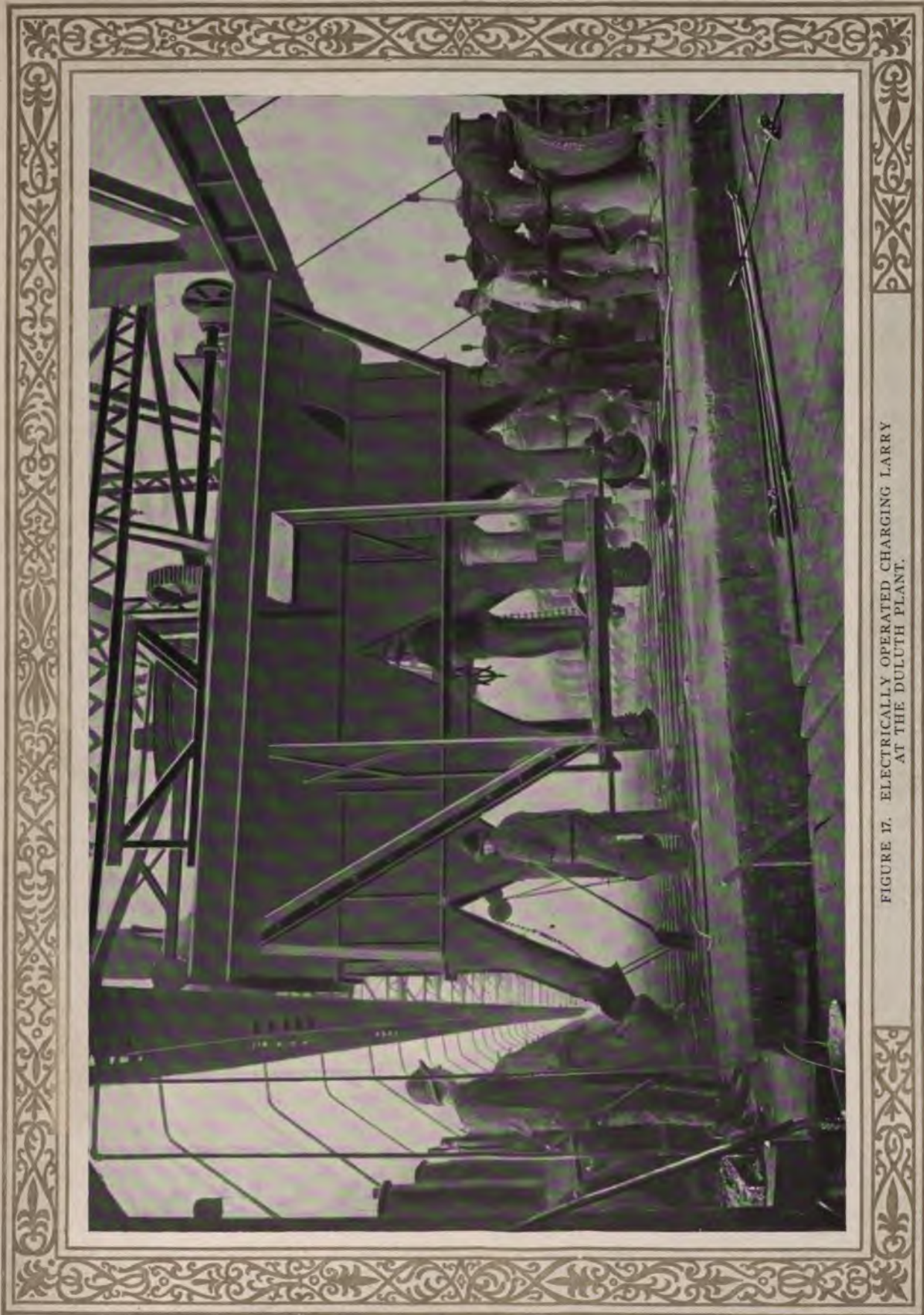
FIGURE 17. ELECTRICALLY OPERATED CHARGING LARRY
AT THE DULUTH PLANT.

FIGURE 18. MECHANICAL LEVELLING DEVICE ON PUSHER.

pusher man without loss of efficiency. This device is shown in Figure 18 in detail. When this levelling is completed, the oven is sealed up and the valve leading to the gas main is opened. There are two of these mains provided, the one for the rich gas and the other for the fuel gas. When the coking period has elapsed, the ovens are disconnected from the gas mains, the doors are removed, usually by an electric hoist, and the coke charge pushed out of the oven by the ram or pusher shown on the left hand side of Figure 13.
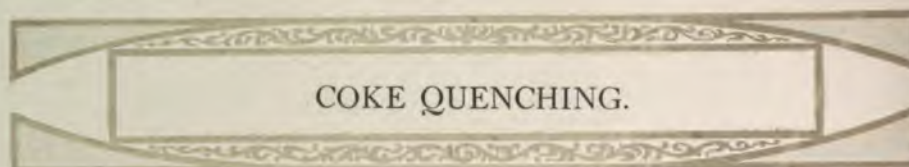
COKE QUENCHING.

THE coke on being pushed from the oven may be received and quenched in one of several ways.
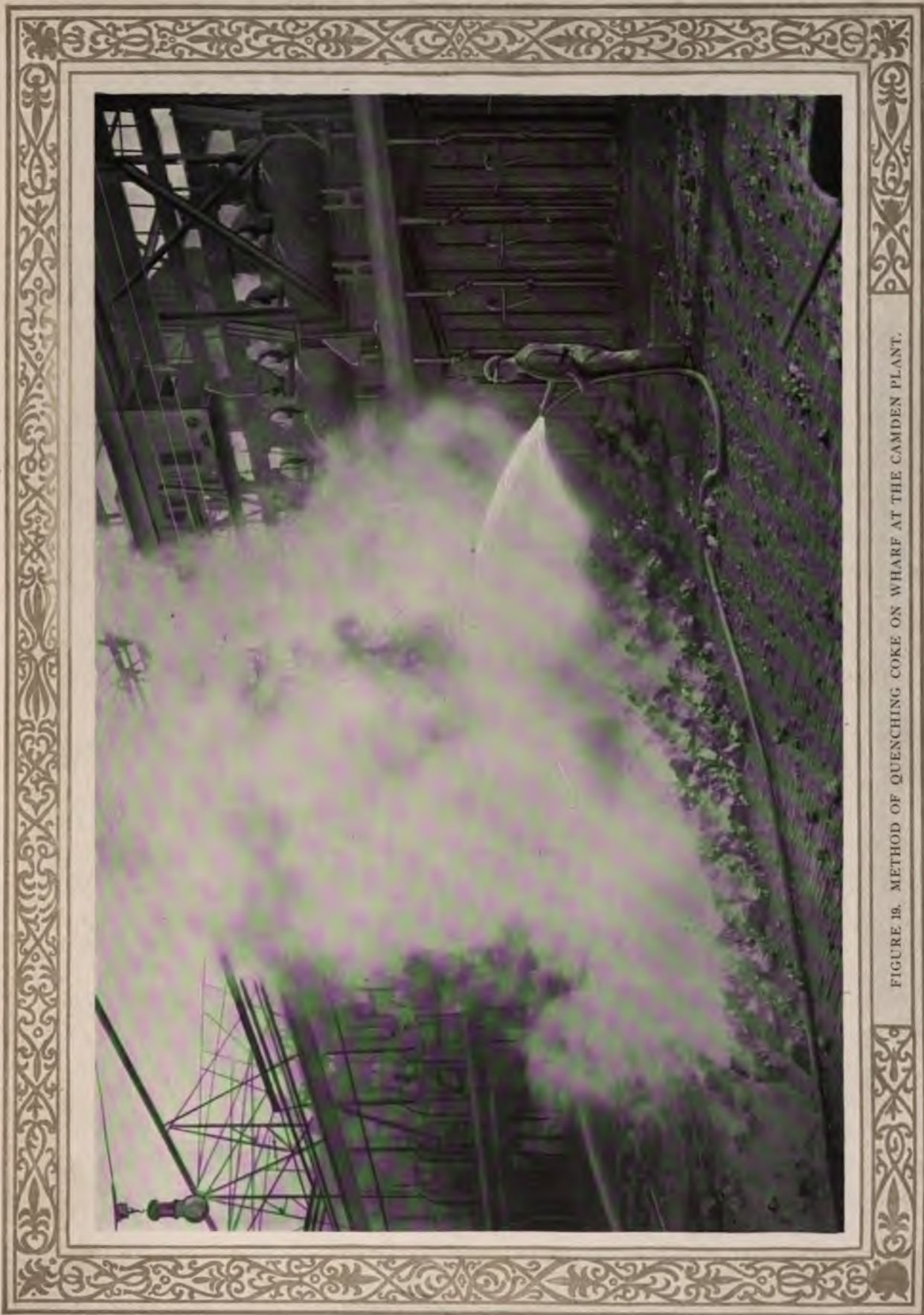
FIGURE 19. METHOD OF QUENCHING COKE ON WHARF AT THE CAMDEN PLANT.

COKE WHARF.

IN this method of quenching, a wharf or platform wide enough to take the whole charge of coke is built at the level of the oven floor, and when the coke is pushed out onto it, the mass is pulled down by hooks and quenched by a hose. After sufficient time is allowed for it to cool and drain, it is loaded by hand into barrows, and dumped into cars standing on a depressed track at the outer edge of the wharf. This method of quenching has the advantage of simplicity and low initial cost, and allows a selection of coke for various purposes, but is high in labor cost. It is practiced in nearly all German and English plants, and in several plants in America. Figure 19 shows this method in operation at the Camden plant. In some cases the approximately level platform is replaced by an inclined wharf, as is shown in Figure 20.

INCLINED CAR.

IN order to avoid the high labor cost of the wharf, an inclined car has been used as shown in Figure 21, which represents the type of car used at the works of The New England Gas and Coke Company, at Everett, Mass. A similar type of car is in successful operation at the Duluth plant, and is shown in Figure 22. The platform level with the oven floor is wide enough to serve as a gallery for the attendants, and beneath the outer edge of the gallery the upper edge of the car moves in a direction parallel with the length of the oven battery. The car itself is built of cast-iron plates carried on a steel or timber frame work and runs on a railroad track below. It is operated by electricity, and is long enough to take a whole charge of coke. When an oven is to be pushed, the car is brought to a position opposite the door, and the coke pushed out across the gallery falls into one end of the car, being kept in by the sides and bottom gate. During the pushing operation the car is moved along so that the coke is distributed over the inclined bottom in an approximately even layer, which is cooled by water from a hose.
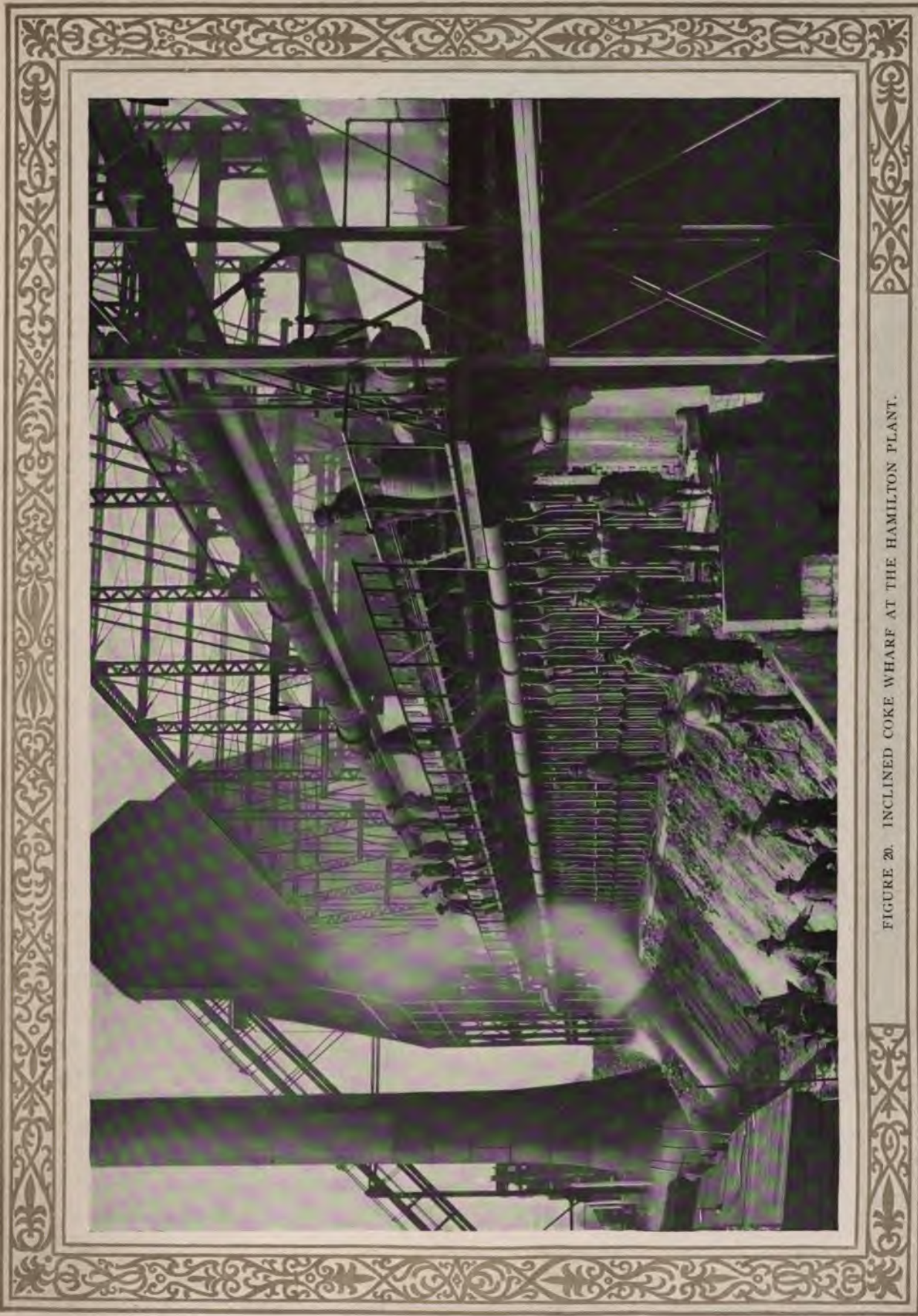
FIGURE 20.   INCLINED COKE WHARF AT THE HAMILTON PLANT.
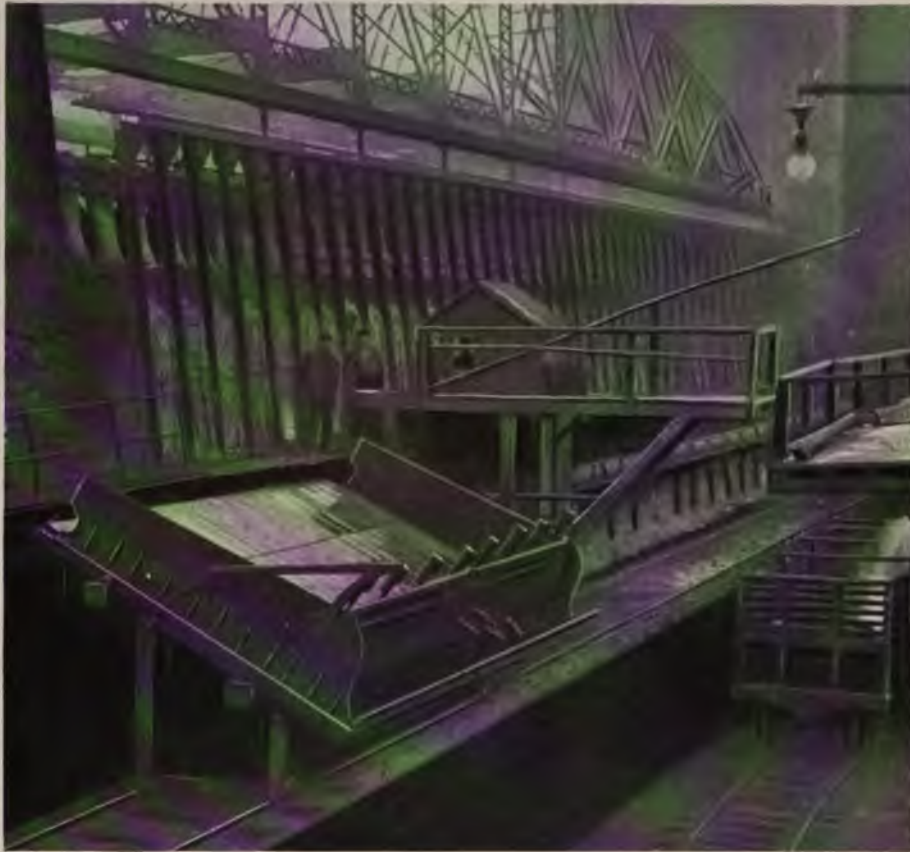
FIGURE 21.   INCLINED COKE QUENCHING CAR AT THE EVERETT PLANT.

When the quenching is complete, the door at the bottom of the slope is opened and the coke runs by gravity into the railroad car placed on the track adjoining. These quenching cars effect a considerable saving in labor and handle the coke with rapidity, but suffer seriously from depreciation and require special protection, because of the alternate heating and cooling and the corrosion by the waste water which becomes acid by the oxidation of part of the sulphur in the coke. They do not improve the appearance of the coke over that quenched on the wharf, as the coke is exposed to the air during the quenching, which causes it to be dark in color in both cases.
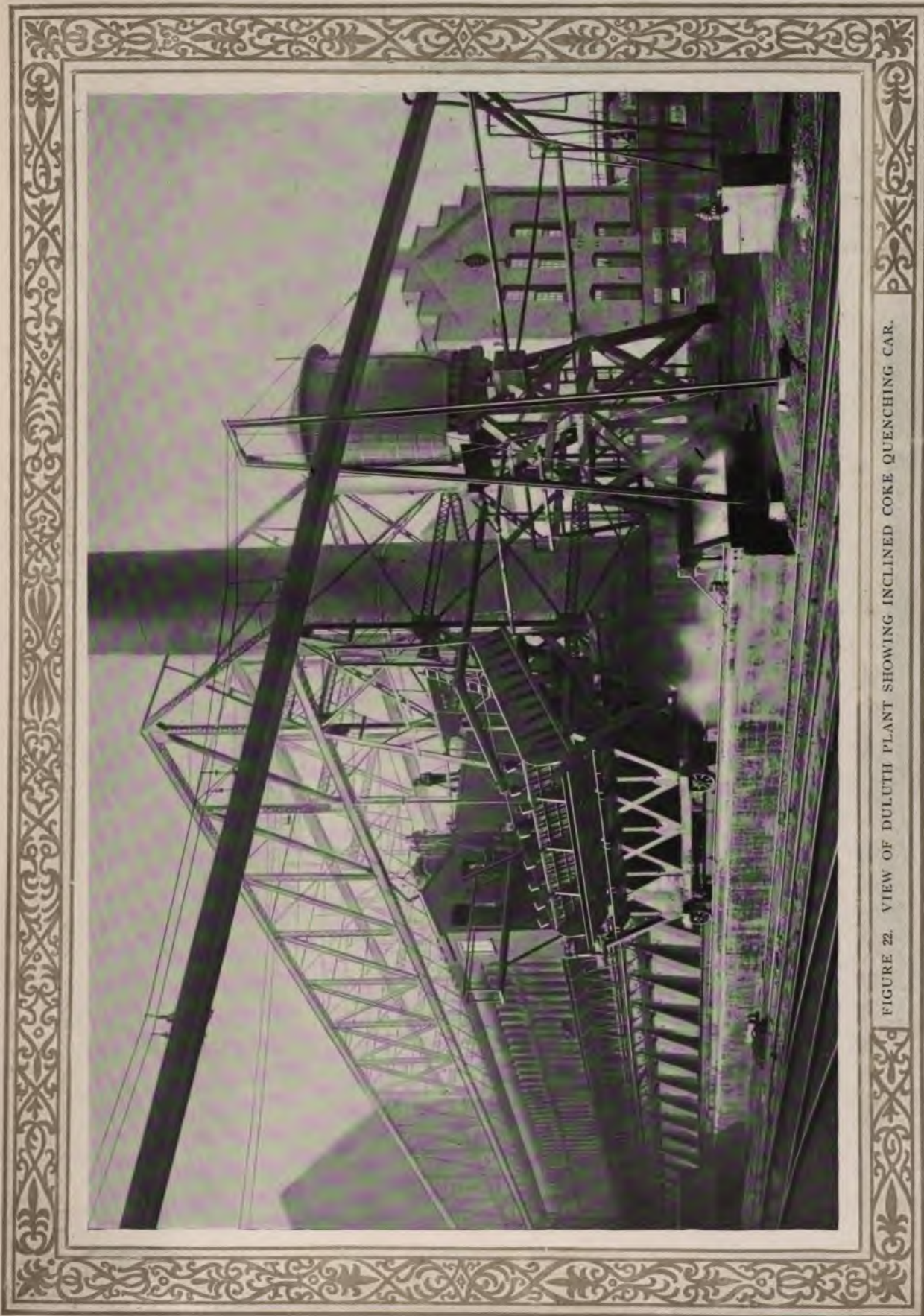
FIGURE 22. VIEW OF DULUTH PLANT SHOWING INCLINED COKE QUENCHING CAR.

MOORE COKE QUENCHER.

A FORM of coke quencher, shown in Figure 23, known as the Moore Quencher, has recently been introduced.* It consists of a rectangular receiver, of the approximate shape of an oven, and large enough to easily contain the whole coke charge intact. Its walls are of cast iron, and are of cellular construction, so as to admit of water cooling. The top and bottom are tightly covered in with cast-iron plates, and the ends are provided with closely-fitting doors. A cast-iron link conveyor, driven by a motor, runs on the bottom. The whole machine moves on rails parallel to the face of the oven battery and is operated by electric motors. When it is desired to push an oven of coke, the quencher is placed exactly in front of it, and connection is made by means of swinging doors and a drop bottom so as to guide the coke from the oven directly into the receptacle. The movement of the coke is assisted by the motion of the conveyor in the bottom of the quencher chamber.

When the charge has been pushed from the oven into the quencher the doors are closed and the quenching water is admitted. The violent generation of steam is taken care of by the vertical stacks shown on the roof of the quencher. The quenching chamber is completely filled with steam, and remains so until the charge is quenched, practically excluding the air, so that the silvery-grey color of the coke is preserved as in the bee-hive product. When the quenching is complete the door farthest from the ovens is opened and the coke is discharged into the railroad car below by operating the conveyor. The first machines of this type were erected at the Sharon and Cambria plants in 1903 and 1904. The United Coke and Gas Company has now under contract two additional machines for the Cambria plant, and one for the Wyandotte plant. These later machines embody some minor improvements. The operation of the quencher may be clearly seen from Figures Nos. 23 and 24, which show the quencher under actual working conditions at the Cambria plant.

* U. S. Patents 755154 and 755155.
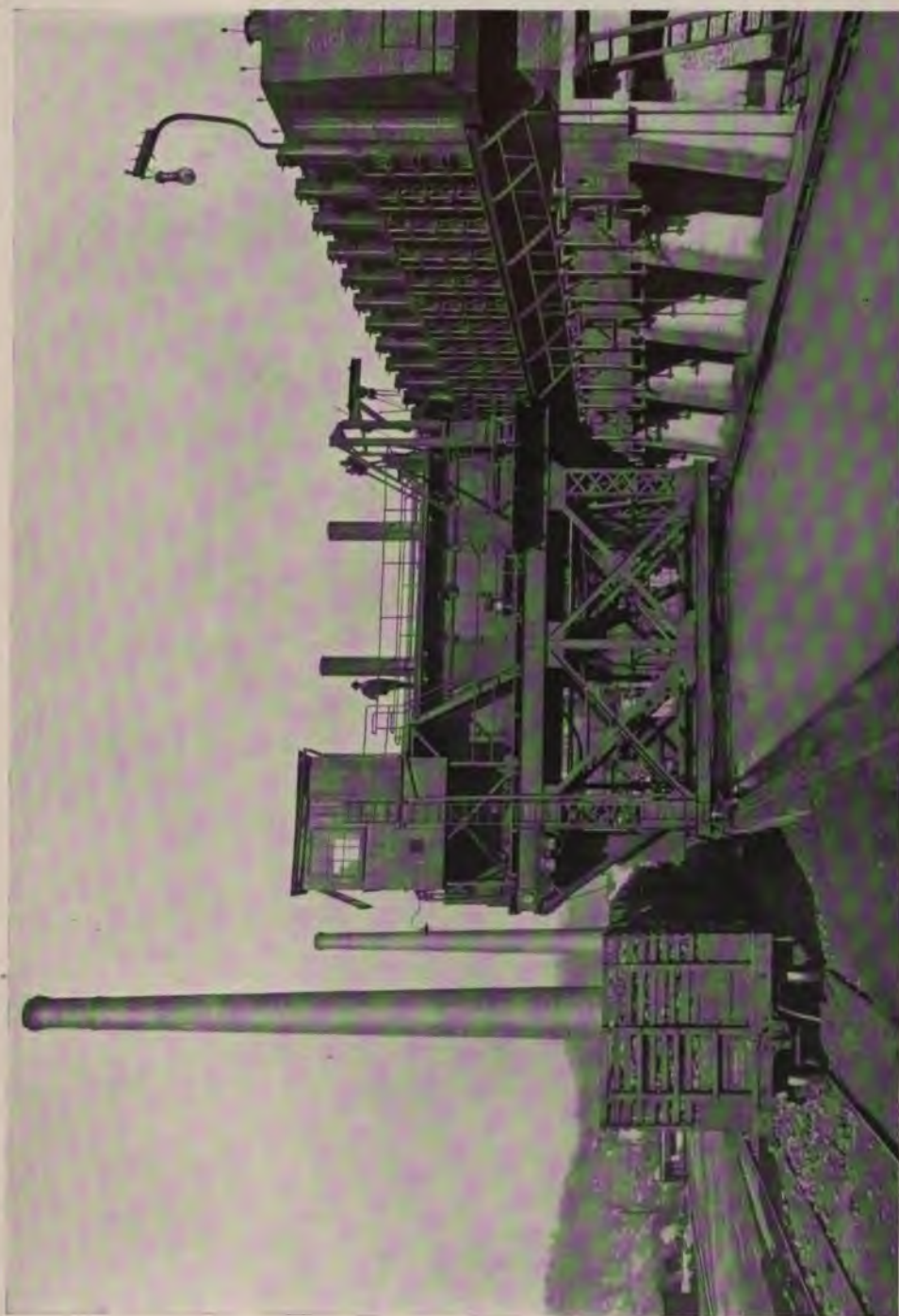
FIGURE 23. THE MOORE COKE QUENCHER AT THE CAMBRIA PLANT.

FIGURE 24. THE MOORE COKE QUENCHER IN OPERATION.

SCHEDULE SHOWING MECHANICAL HANDLING OF
COAL AND COKE IN BY-PRODUCT OVENS.

THE sequence of the mechanical operations through which the raw coal and the resulting coke pass in a modern by-product coking plant is outlined in the accompanying diagram, Figure 25. The scheme for handling the gas and by-products is shown farther on. (See Figure 29).

GAS.

TREATMENT OF GAS.

THE gas given off from the coal during the coking operation is led away from the oven through up-take pipes, furnished with valves, to the gas-collecting mains. If the surplus gas is to be used for fuel purposes, only one gas-collecting main is needed, but if it is required to make illuminating gas two are used, the additional one to take the portion of the gas delivered during the first part of the coking time, known as the rich gas. This fraction is higher in calorific and illuminating value than the last portion of the gas, and is therefore better suited for distribution purposes. The last portion of the gas is led off into the fuel gas mains and after being freed of tar and ammonia is used for heating the ovens. The two portions of the gas are kept absolutely separate through the subsequent cooling and condensing operations, the condensing house being so arranged as to handle them in separate systems usually arranged in parallel. This application of the principle of fractional distillation to the treatment of coke oven gas has been developed by The United Coke and Gas Company,* the first installation on a large scale being that of the Everett plant.

* U. S. Patent 627595.

SCHEDULE SHOWING MECHANICAL HANDLING OF COAL AND COKE IN BY-PRODUCT OVENS.

COAL
IN SELF DUMPING HOPPER CARS DISCHARGING
BY GRAVITY INTO TRACK PIT. CARS WEIGHED BEFORE DUMPING.

STOCK CONVEYOR

STOCK PILE

RETURN CONVEYOR

CRUSHER CONVEYOR

CRUSHER

BIN ELEVATOR

BIN CONVEYOR

DISTRIBUTOR

STORAGE BIN

COAL LARRY (ELECTRICALLY DRIVEN AND DISCHARGING BY GRAVITY, MAY BE PROVIDED WITH WEIGHING SCALES.)

COKE OVEN (COAL LEVELLED BY AUTOMATIC LEVELLER)

COKE PUSHER (ELECTRICALLY OPERATED)

COKE QUENCHER AND LOADER (ELECTRICALLY OPERATED)

COKE CONVEYOR

GAS

ILLUMINATING GAS

COKE CRUSHER

FUEL GAS

CRUSHED COKE ELEVATOR

AMMONIA LIQUOR

COKE SCREEN

TAR

COKE BINS (GRAVITY DISCHARGE)

(SEE SEPARATE SCHEDULE FOR BY-PRODUCTS.) BENZOL

CYANIDES

COKE CARS

FURNACE COKE   **FOUNDRY** COKE   **EGG** COKE   **STOVE** COKE   **NUT** COKE   **BREEZE**

FIGURE 25

[66]

FIGURE 28. DIAGRAM SHOWING CANDLE POWER, CALORIFIC VALUE AND
VOLUME OF COKE OVEN GAS.

SCHEDULE SHOWING MECHANICAL HANDLING OF COAL AND COKE IN BY-PRODUCT OVENS.

COAL
IN SELF DUMPING HOPPER CARS DISCHARGING
BY GRAVITY INTO TRACK PIT. CARS WEIGHED BEFORE DUMPING.

STOCK CONVEYOR

STOCK PILE

RETURN CONVEYOR

CRUSHER CONVEYOR

CRUSHER

BIN ELEVATOR

BIN CONVEYOR

DISTRIBUTOR

STORAGE BIN

COAL LARRY (ELECTRICALLY DRIVEN AND DISCHARGING BY GRAVITY, MAY BE PROVIDED WITH WEIGHING SCALES.)

COKE OVEN (COAL LEVELLED BY AUTOMATIC LEVELLER)

COKE PUSHER (ELECTRICALLY OPERATED)

COKE QUENCHER AND LOADER (ELECTRICALLY OPERATED)

COKE CONVEYOR

COKE CRUSHER

CRUSHED COKE ELEVATOR

COKE SCREEN

COKE BINS (GRAVITY DISCHARGE)

COKE CARS

GAS

ILLUMINATING GAS

FUEL GAS

AMMONIA LIQUOR

TAR

(SEE SEPARATE SCHEDULE FOR BY-PRODUCTS.)

BENZOL

CYANIDES

FURNACE COKE | **FOUNDRY** COKE | **EGG** COKE | **STOVE** COKE | **NUT** COKE | **BREEZE**
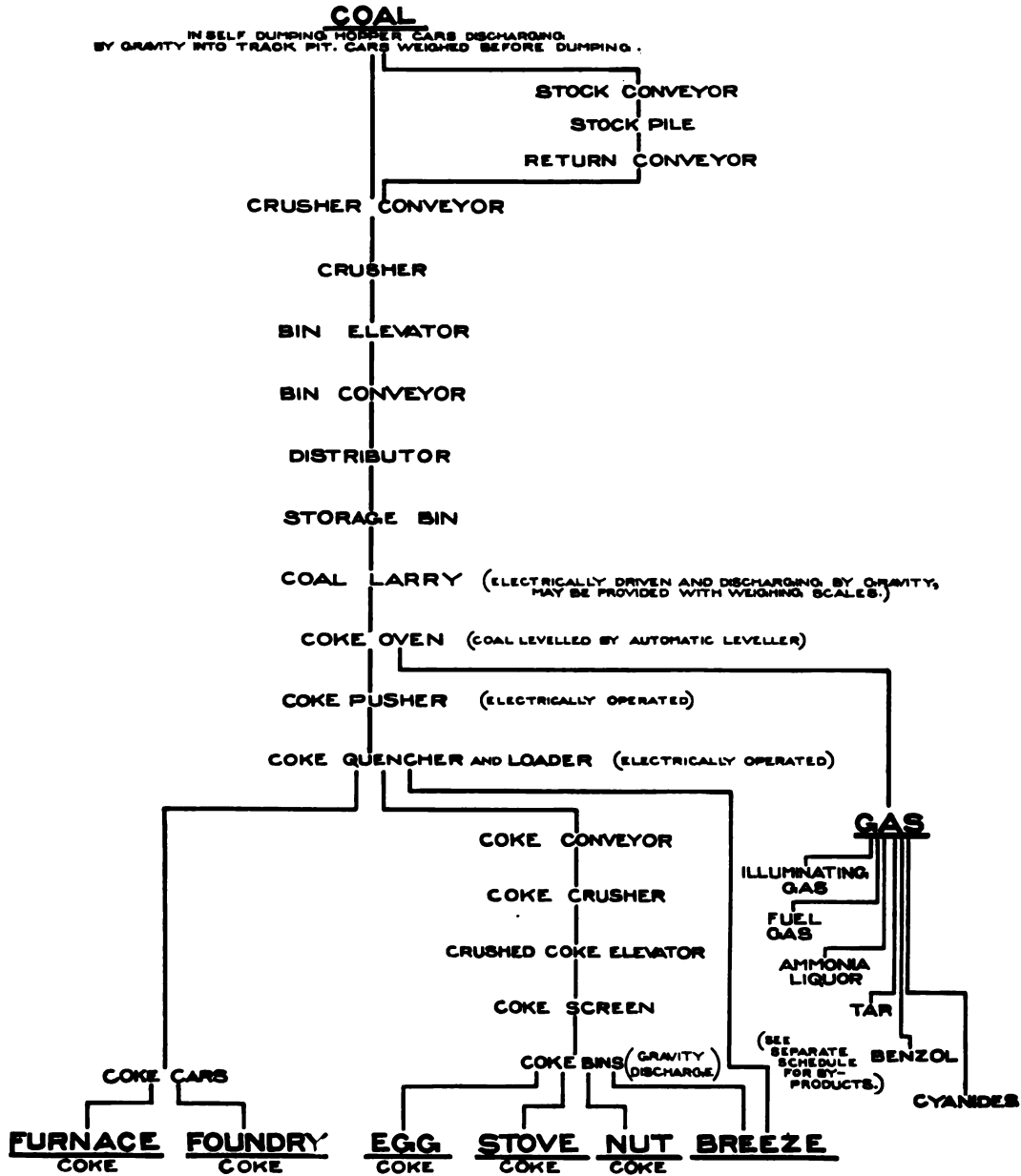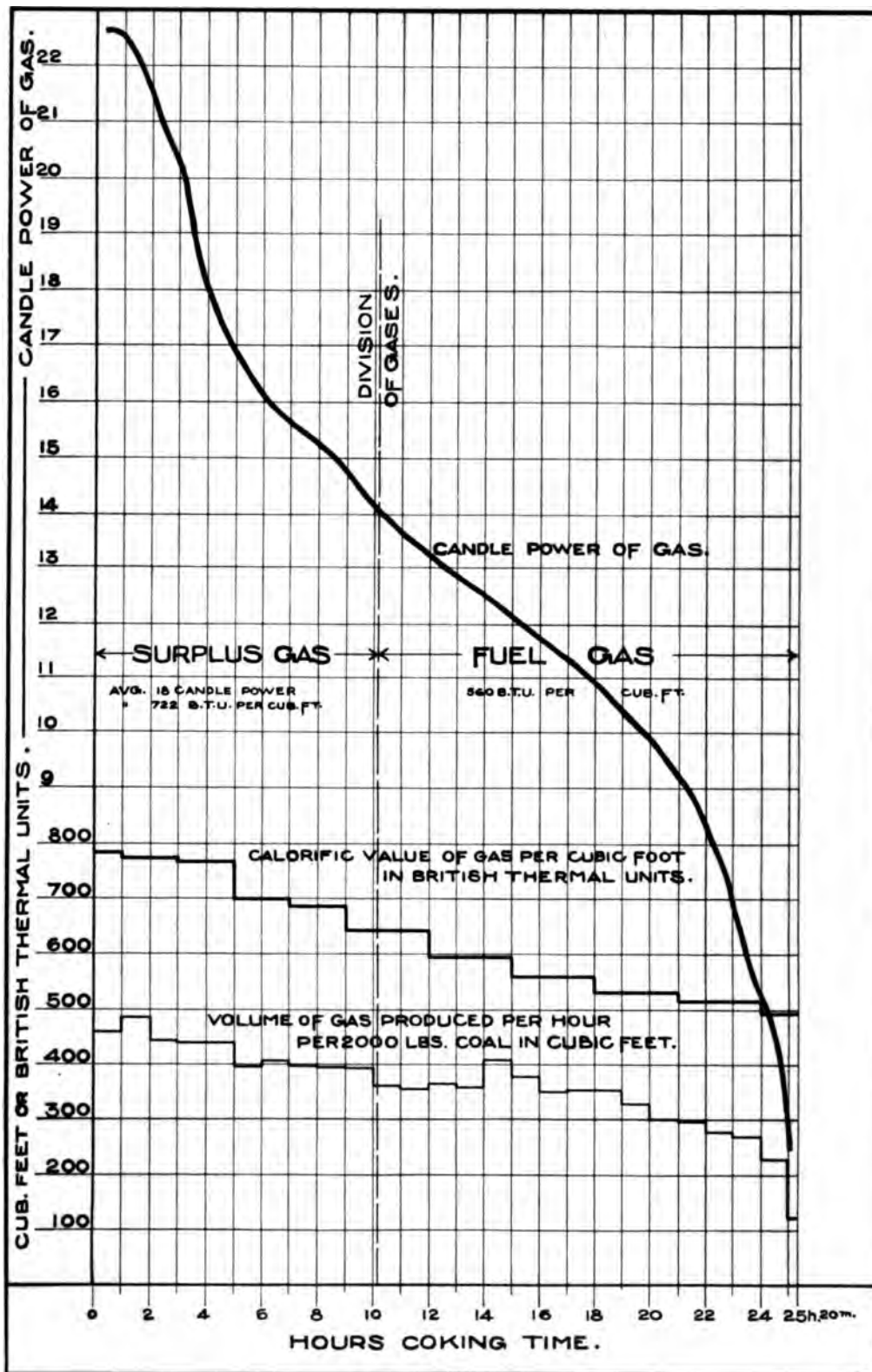
FIGURE 25

FIGURE 28. DIAGRAM SHOWING CANDLE POWER, CALORIFIC VALUE AND
VOLUME OF COKE OVEN GAS.

BY this method gas of a higher candle power can be obtained from a coal than it would yield if distilled in the ordinary manner in coal gas retorts. This is shown by an examination of the preceding diagram, Figure 26, which gives the candle power, calorific power and volume of the gas given off during each hour of the coking period for a medium volatile coal. This coal could not be fairly classed as a gas coal, and it yielded an excellent quality of furnace coke, yet the average illuminating value of the surplus gas, as shown by the upper line on the diagram, would be 18 candle power, which compares favorably with the gas retort practice on gas coals.

The middle line of the diagram shows the calorific value per cubic foot of the gas generated for each hour. This value falls off slowly at first, and more rapidly towards the close of the coking period. The average calorific value of the surplus gas would be 722 British thermal units, and of the fuel gas would be 560 British thermal units.*

The volume of gas evolved per hour per 2,000 lbs. of coal is shown by the lower line. This falls slightly after the first two hours, but remains nearly constant until the latter third of the coking period, when it falls off more rapidly. The point of division of the gas into surplus and fuel gas is shown by the vertical line. The surplus gas amounted to 4,300 cubic feet or 46 per cent. of the whole amount of gas evolved. Calorifically considered, it contained 52 per cent. of the total heat value of the gas.

With a coal of somewhat higher volatile matter, yielding an excellent quality of foundry coke, a surplus of 4,800 cubic feet corrected volume of gas per net ton of coal has been delivered for distribution for months in succession, the illuminating value in this instance being maintained at 18 to 20 candle power by the transfer of the benzol from the fuel to the rich gas portion, described further on.

* The gross heating value of the gas, in which the hydrogen is calculated as burned to liquid water, is given here and elsewhere in this work.
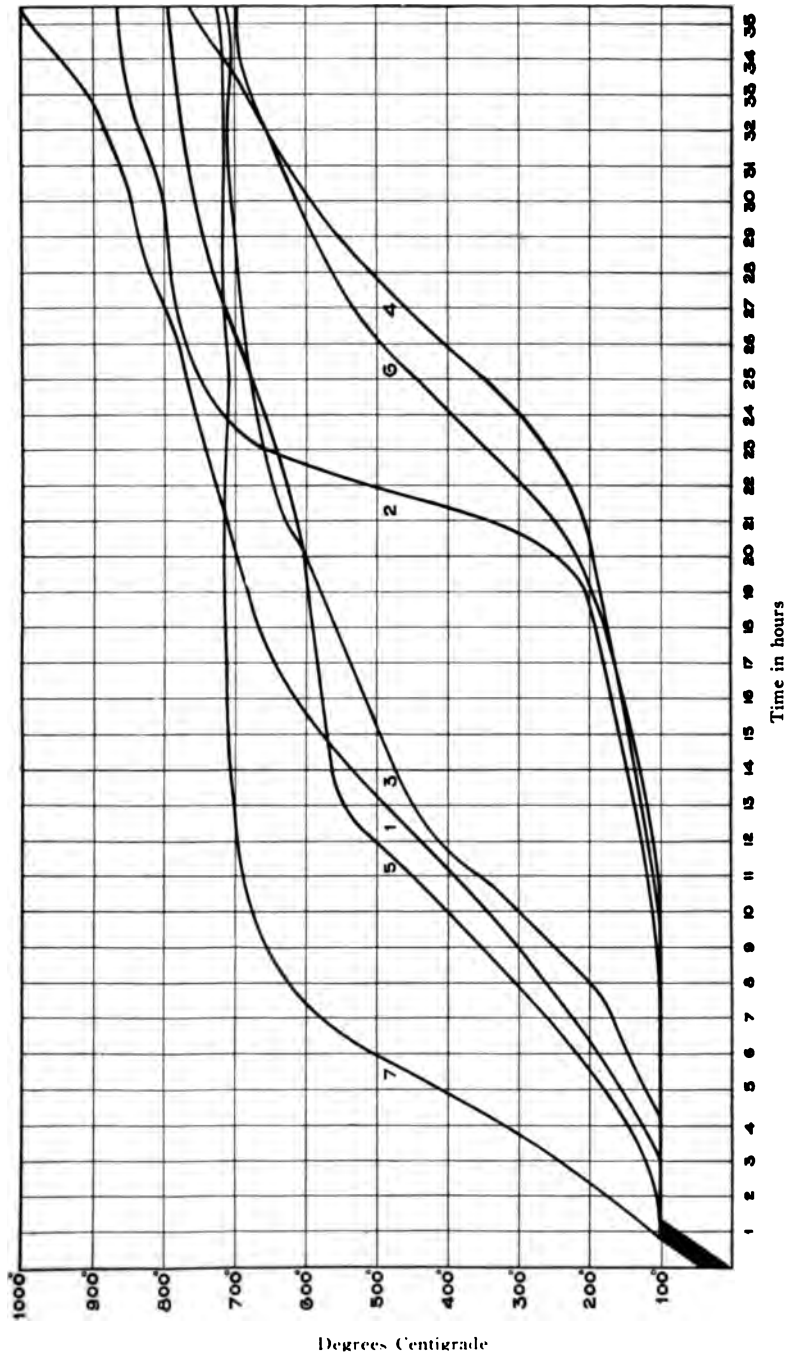
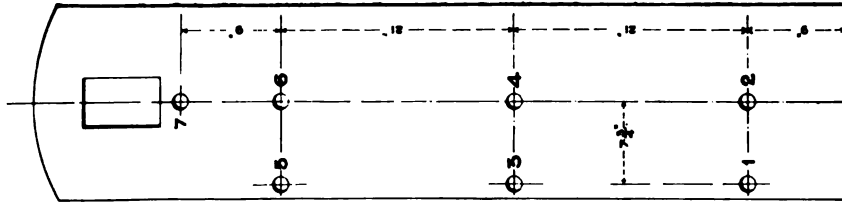DIAGRAM SHOWING TEMPERATURES AT DIFFERENT POINTS IN COKE OVEN CHARGE.

FIGURE 27

DIAGRAM SHOWING LOCATION OF HOLES IN OVEN DOOR.

COKE FORMATION AND
GAS PRODUCTION.

OPERATION OF COKING.

A STUDY of the conditions prevailing in the coal charge during the coking period casts some light upon the quality of gas produced. The coking of the charge proceeds from the hot walls and bottom of the oven towards the center in what may be called a coking zone, leaving behind it finished coke, while in advance of it exists coal as yet practically unchanged. This is shown by the temperature readings of different portions of the oven charge given in Figure 27.* These were obtained by inserting pyrometers in the coal charge through holes bored in an oven door, located as in the figure, the successive temperature readings for each point being given on the curves. These curves group themselves naturally in two sets, those taken near the heating walls, which show a gradual continuous rise, and those near the middle of the oven, which remain but little above the boiling point of water until the latter part of the coking period. The middle part of the charge, then, remains low in temperature, and, far from losing its volatile components early, may even gain by condensation of the heavier tar vapors set free from the distillation. The portion inside the coking zone forms an uncoked core of coal, becoming smaller with the progress of degasification. The lines in Figure 28 show the successive positions of this coking zone and the uncoked portion, near the middle of the coking period.

The early gas, evolved from the coal near the hot walls, is rich in hydrocarbons, and passing upwards through the space left next the walls by the shrunken coal, takes with it considerable of its moisture undissociated, to be deposited in the condensation process. The presence of this moisture in the gas minimizes the breaking down of

* See paper by Mr. C. G. Atwater, entitled "The Development of the Modern By-Product Coke Oven," Trans. American Institute of Mining Engineers, 1903, page 700.

the illuminating hydrocarbons, this effect being aided by its rapid escape, and by the fact that the oven is heated on the sides only, not on top. Later in the coking operation, the distillation zone advances farther into the coal charge, the travel of heat is longer, hence the transmission per unit of time is smaller, the amount of gas decreases, and its way of escape is longer and more difficult; hence there is more dissociation of the hydrocarbons in the gas. This results in a deposit of the carbon atoms as a graphitic glaze on the surface of the coke, and increases the amount of hydrogen in the gas.

Comparing the heating of a coke oven with that of a gas retort, it may be readily seen that the gas space above the coal charge is less highly heated in the coke oven. This causes more cracking of the hydrocarbons in the gas from gas retorts, resulting in a higher percentage of free carbon (soot) in gas house tar.
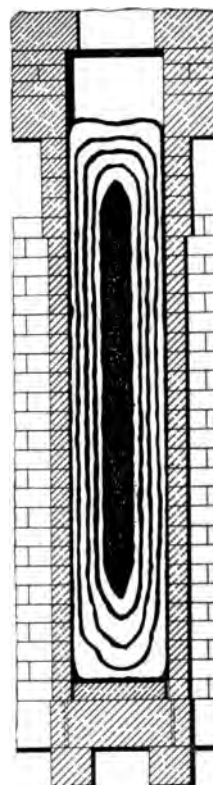
FIGURE 28. DIAGRAM SHOWING PROGRESS OF COKING IN BY-PRODUCT OVEN.

CONDENSATION.

OBJECT.

THE gas as it comes from the oven is at a temperature approximating that of the oven itself, but this is rapidly reduced by radiation in the iron stand pipes and collecting mains. During its passage to the condensing house it undergoes a certain amount of preliminary cooling and condensation, depending upon the length of the mains and the temperature of the surrounding air. At this stage it consists mainly of a mixture of the so-called per-

manent gases, hydrogen, methane, carbon monoxide, carbon dioxide, and nitrogen with the vapors of water and tar. The latter exists partly as a finely divided mist mechanically suspended in the moving gas. There are also present small quantities of ethylene, naphthalene, benzol and the numerous other hydrocarbon compounds usually classed as illuminants, together with impurities, as ammonia, sulphuretted hydrogen, carbon disulphide and cyanides. The function of the condensing house is to cool the gas to a temperature that will facilitate the elimination of the tar and ammonia, which is from 60° to 70° Fahr. and to remove these impurities by scrubbing. To this may be added the scrubbing process for the absorption of benzol and cyanides, as well as the necessary pumps and cisterns for handling or storing the scrubbing liquors, and delivering them to the plants where they are to undergo further treatment.

METHOD OF HANDLING GAS.

THE motive power for moving the gas through the different operations of condensation is supplied by exhausters, usually of the positive rotary type. The generation of gas in the ovens gives rise to considerable pressure, but to rely on this for moving the gas through the system, as was done in the early days of gas retort practice, would not be technically practicable. The exhauster is usually placed midway in the system, so that a part of the apparatus is under suction, the remainder being under pressure. The power required is only that due to the friction of the gas moving at the required speed, and the pressure that must be maintained to overcome the seals incident to the apparatus.

SCHEDULE SHOWING TREATMENT OF GAS AND BY-PRODUCTS.

THE general scheme of handling the gas, and the disposition of the products resulting from it, is shown in the accompanying schedule, Figure 29.
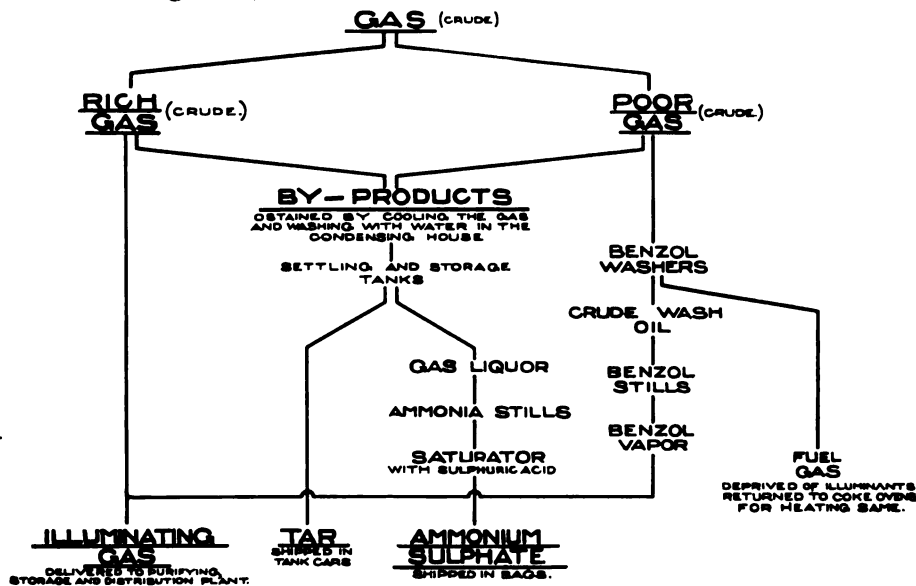
FIGURE 29 SCHEDULE SHOWING TREATMENT OF GAS AND BY-PRODUCTS WITH GAS SEPARATION AND BENZOL TRANSFER.

DISTRIBUTION OF HEAT.

THE heat existing in the gas may be divided into three portions: G, the sensible heat of the gas itself. V, the sensible heat of the water and tar vapor in the gas, and L, latent heat given off when the water and tar vapors in the hot gas are condensed to liquid. Of these L is by far the greatest item. This is shown in the following approximate table, giving the heat diffused in cooling 1000 cu. ft. of gas from 300° Fahr. to 70° Fahr. The original coal is assumed to have about 5 per cent. moisture and tar, and 4 per cent. of water, formed by the destructive distillation of the coal.

Sensible heat of gas   G = 4,195 British thermal units
     "   "   " vapors V = 1,966   "   "   "
Latent heat of   "   L = 16,151   "   "   "
—————
Total,   22,312 British thermal units

SEPARATION OF GASES.

IN case the plant is designed to produce two qualities of gas, rich and poor, the condensation is carried forward in two systems, arranged parallel and similar in type, but kept entirely separate. The methods are the same in either case, the main difference lying in the greater cooling surface necessary per 1000 cubic feet of rich gas, as its moisture exceeds that contained in the poor gas. The proportional yield of tar is usually greater from the rich gas.

CONDENSING APPARATUS.

THERE is wide divergence in the design of apparatus for condensing, cooling and scrubbing gas. Many forms are to be seen in use whose only excuse for existence is their antiquity. In order to handle the large volume of gas generated daily by a by-product coke oven plant of even moderate size, say 10,000,000 cubic feet for 100 ovens, it has become necessary to develop apparatus of types differing somewhat from the prevailing gas works' standards, though following in the main the same general lines. As it would require too much space to discuss condensing apparatus in general, we will confine ourselves to those types used with the United-Otto system. It may here be stated that as the final reduction of the gas temperature and removal of ammonia requires the use of water as a cooling and washing medium, the quality and quantity of the supply at hand will considerably affect the design and dimensions of the condensing plant.
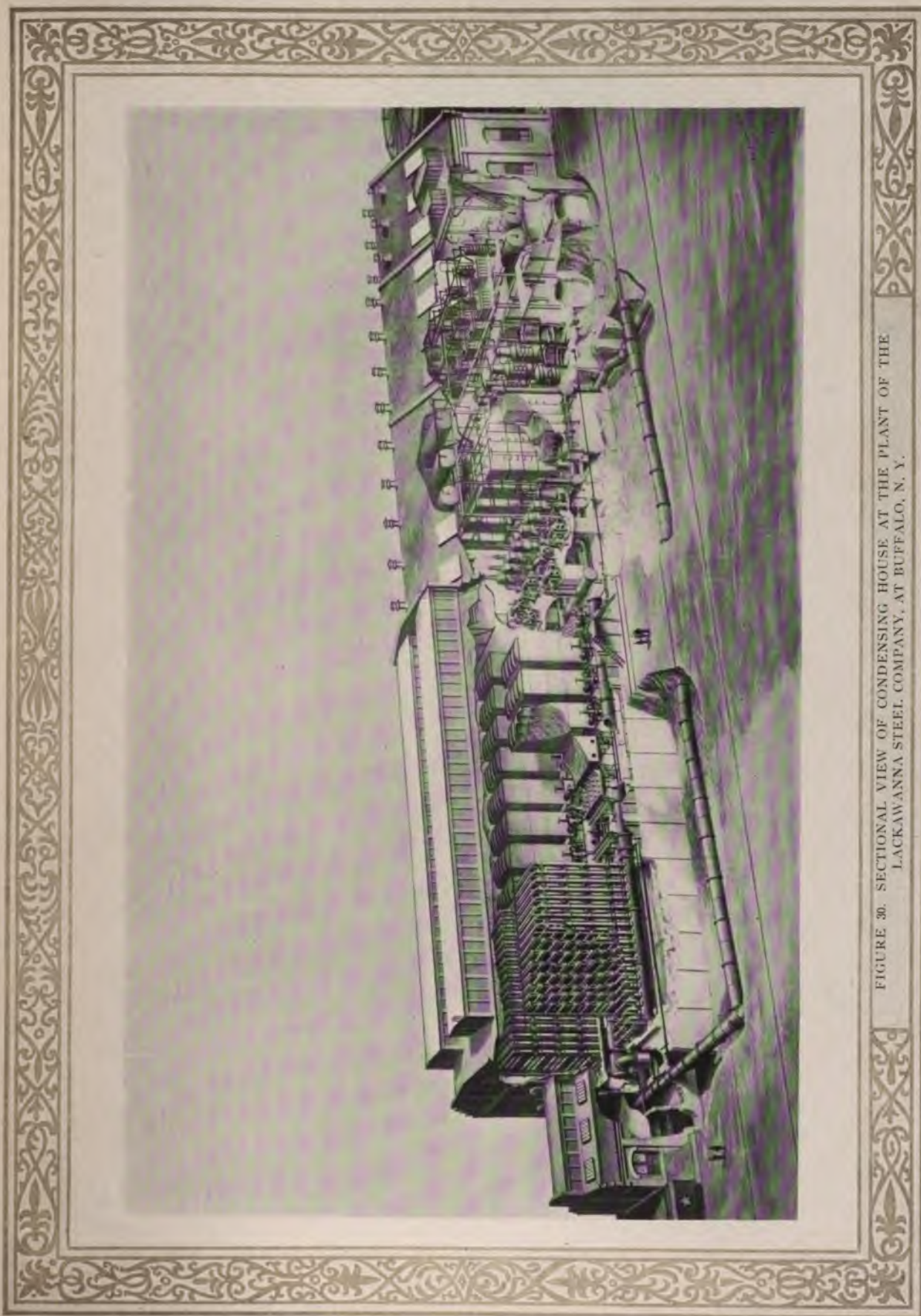
FIGURE 30. SECTIONAL VIEW OF CONDENSING HOUSE AT THE PLANT OF THE
LACKAWANNA STEEL COMPANY, AT BUFFALO, N. Y.

GENERAL ARRANGEMENT.

A SECTIONAL view of a condensing house and apparatus is shown in Figure 30, the general arrangement being similar to that built at the by-product coke oven plant of the Lackawanna Steel Company, at Buffalo, N. Y. The arrangement here adopted lends itself well to the general design of a plant where future extensions must be provided for, without sacrifice of convenience or economy in the immediate installation. The course of the gas is in general from one end of the system to the other, through a number of units working in parallel with conveniently arranged by-passes. This design simplifies the separation of the rich and fuel gases, if the production of illuminating gas is desired, and at the same time allows extension on either side to take care of additional oven capacity.

AIR AND WATER COOLERS.

THE gas enters on the left hand, coming directly from the ovens. It first passes through air and water coolers, which lead the gas to and fro in passages of steel plate construction, exposing a large surface for atmospheric cooling. A number of these cooling units are arranged in parallel, so that any single one may be taken off for cleaning without disturbing the operation of the remainder. All are provided with an external sprinkling system, so that water cooling may be used in hot weather if necessary. The cross-section of the gas passages in this apparatus is long and narrow, so that the cooling surface is large for the volume of gas space, this making it a most efficient cooler for its cost. Its adaptability to either air or water adds flexibility to the system, and its compact construction permits of housing it within a minimum area.

WATER COOLER.

THE further reduction of the gas temperature is accomplished by the use of tubular water coolers of special design. These are of large size and are rectangular in shape. The gas space is divided by successive baffles so that a tortuous path is followed, and the water circulation is made to flow through the tubes in a parallel but opposed direction; this gives the highest efficiency of heat transmission and permits great economy in the use of cooling water.

EXHAUSTERS.

THESE are of the positive rotary type, and are steam driven. Provision is always made for a reserve unit to allow for repairs or adjustment. When two kinds of gas are made it is usually possible to make the spare units serve for either variety of gas, thus avoiding excessive duplication. In order to avoid leakage of air into the ovens, a slight pressure is maintained on them at all times. The control of the gas passing through the system centers in the exhauster room, and here are placed the gauge boards, on which are carried the pressure and vacuum gauges showing the working conditions in the various parts of the apparatus.

TAR SCRUBBERS.

THE gas passing from the exhausters comes to the tar scrubbers, which are of the impact type. In these the gas is led through a series of thin perforated steel plates, the openings in the plates being so arranged that the gas, passing through the first plate, will impinge on an unperforated part of the second plate before arriving at a second opening. Thus the tar, existing in the gas in the form of minute globules like mist, is thrown with high velocity against the
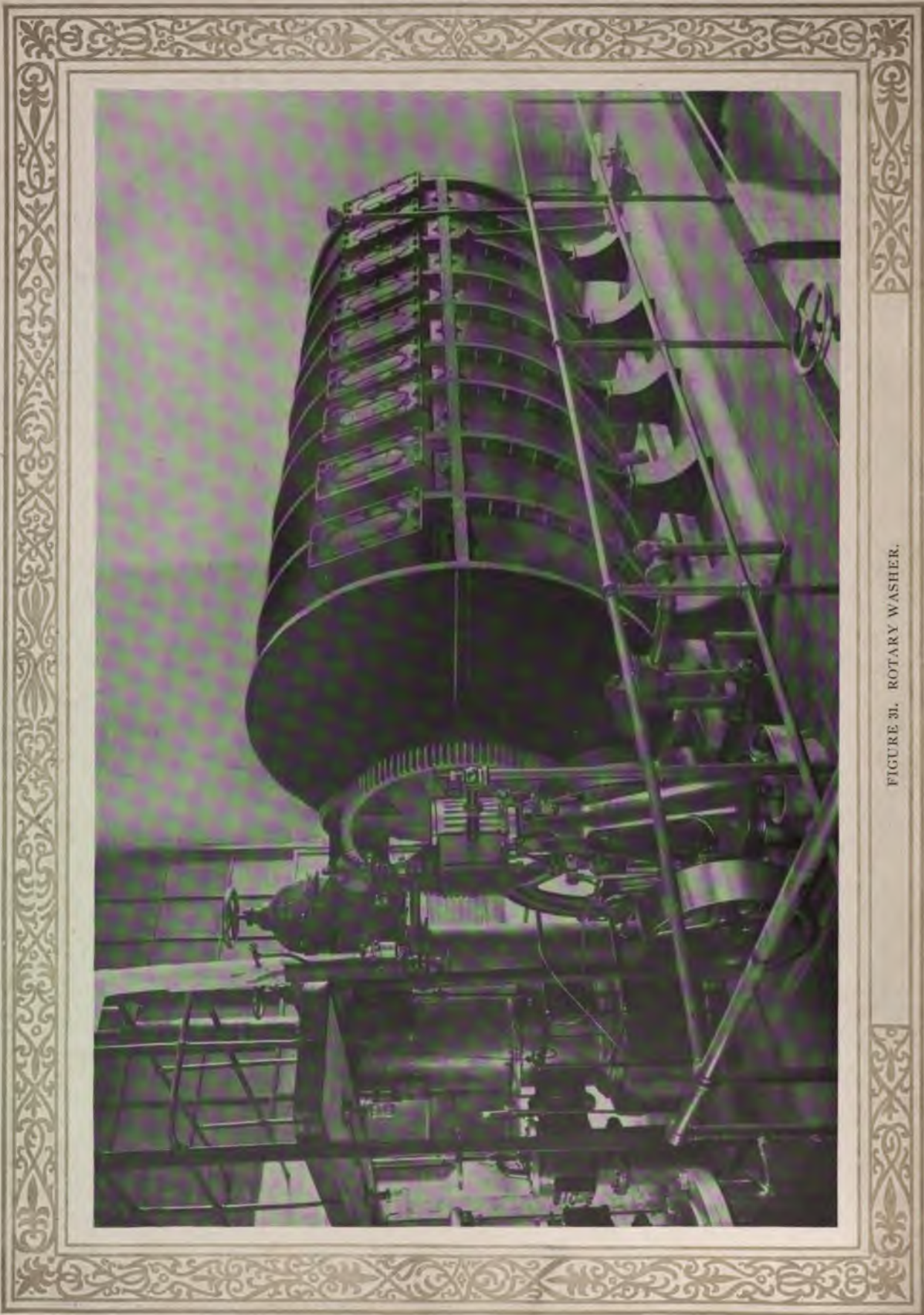
FIGURE 31. ROTARY WASHER.

baffling plates, to which it adheres, and is collected and drawn off through seals to the tar cisterns.

In case a coal yielding considerable naphthalene is used, which deposits on the baffle plates and gives rise to stoppages, the temperature of the gas entering the tar scrubber may be raised high enough to avoid this difficulty; in this case the gas is passed through a final cooler before coming to the ammonia scrubbers. Or a type of submerged tar scrubber may be used in which the gas is caused to bubble through successive water seals of the mushroom form, and is thus deprived of its tar.

AMMONIA SCRUBBERS.

IN all later plants these are of the tower type, as in Figure 30, the gas passing upwards through a lattice work of wooden slats, and the scrubbing water passing downwards, thus presenting a large wetted area for the absorption of the ammonia from the gas. Fresh water is used in the last scrubber, and the weak liquor resulting is successively used in the scrubbers preceding this, until it becomes strong enough for distillation.

The same result may be accomplished by the use of a rotary washer or of bell washers. The rotary washer, of which several types are well known, consists of a horizontal cylinder of cast-iron plates provided with a rotating shaft passing through its axis, the shaft carrying steel plates or wooden grids or similar devices which dip into the liquor contained in the lower half of the cylindrical casing and present a continually-wetted surface. The gas enters at one end and leaves at the other, and in its transit is forced to come into intimate contact with the wetted surfaces, thus parting with its ammonia. The shaft is usually driven by a small independent engine provided for the purpose; an external view of such a washer is shown in Figure 31. The great advantage of this apparatus is that it removes the ammonia thoroughly with but a small amount of back pressure. Its own operating cost to some extent offsets this.

FIGURE 32. BELL WASHERS AT THE EVERETT PLANT.

The bell washer consists of a series of cast-iron sections placed one above another, each section containing a water seal with serrated edges through which the gas must bubble. The gas passes through successively weaker liquors, the last pass being through fresh water. This type of apparatus has the advantage of saving the ammonia down to a small residue, but is objectionable because of the back pressure it causes. The washers in use at the Everett works are of this type, and are shown in Figure 32. The amount of ammonia remaining in the gas leaving the condensing house depends largely upon its temperature. If this be between 60° and 70° Fahr. the loss should be practically negligible.
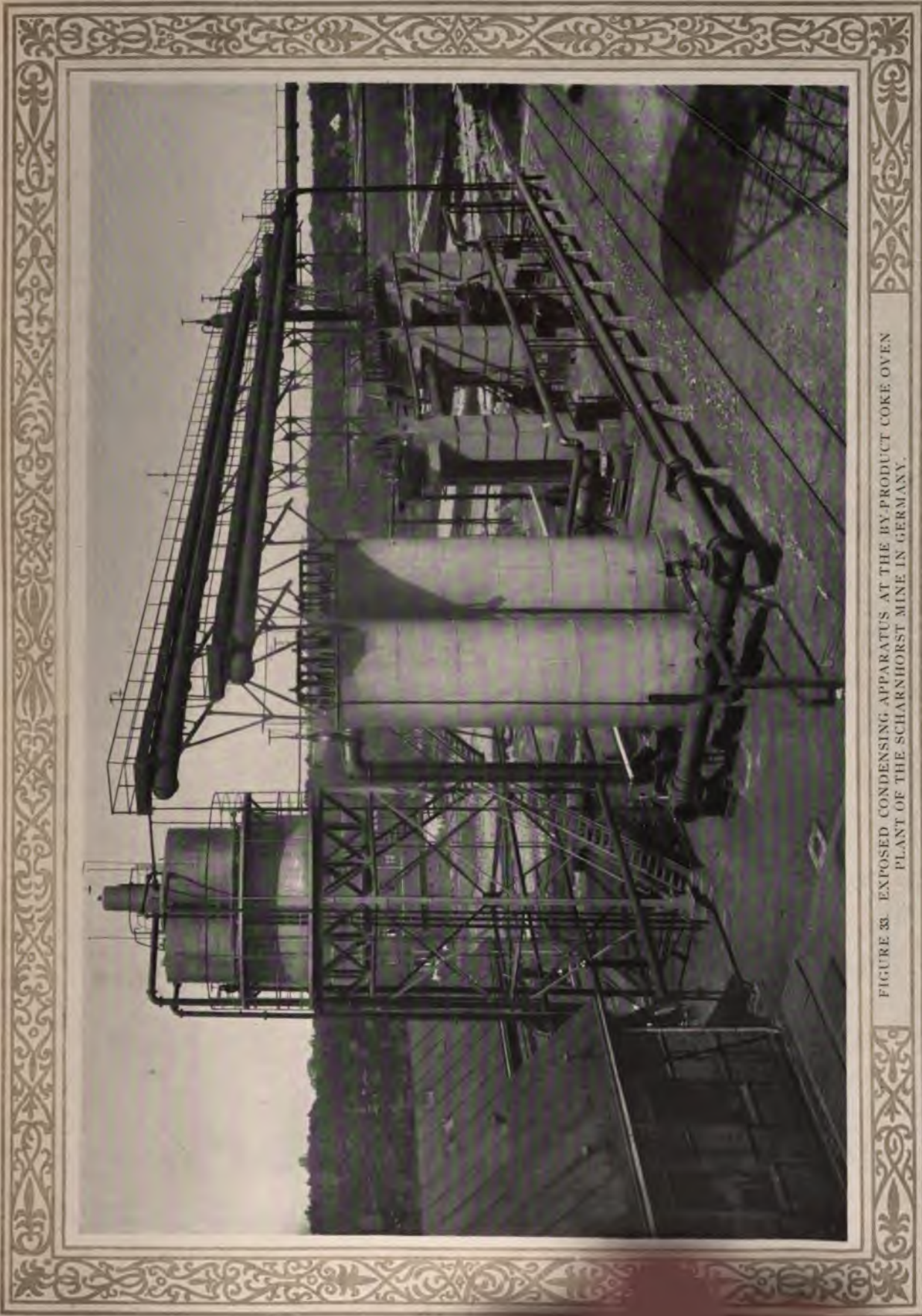
FIGURE 33. EXPOSED CONDENSING APPARATUS AT THE BY-PRODUCT COKE OVEN PLANT OF THE SCHARNHORST MINE IN GERMANY.

EXPOSED CONDENSING APPARATUS.

THE condensing apparatus is usually put under cover, as this measure prolongs its life and saves labor in operating, at the same time protecting it from heating by the direct rays of the sun in summer and from stoppages by freezing in winter. In cases when it is desirable to avoid the cost of the building, and in localities where the climate is not too severe, it is possible to dispense with the condensing house altogether. Such a plant, erected at the by-product coke oven plant of the Scharnhorst mine in Germany, is shown in **Figure 33.** The gas coming directly from the ovens is first cooled by passing through the long, horizontal cooling coil, placed above the water coolers. From this the gas passes in turn to the water coolers, ammonia scrubbers and benzol scrubbers, there being two of each. The motive power for the gas is supplied by Kœrting exhausters, placed between the first and second water coolers. This avoids the need of a steam-engine driven exhauster and the necessary covering. In fact, only the steam pumps for handling the tar and liquor are housed. The plant is of extreme simplicity and of low cost.

AMMONIA PLANT.

TREATMENT OF WEAK LIQUOR.

THE ammoniacal liquor coming from the ammonia washers contains from .5 per cent. to 2 per cent. of ammonia (NH_3), existing in a variety of compounds. The usual method of treating this liquor to obtain the ammonia in marketable form is by distilling it off and reabsorbing it in sulphuric acid, forming ammonium sulphate.
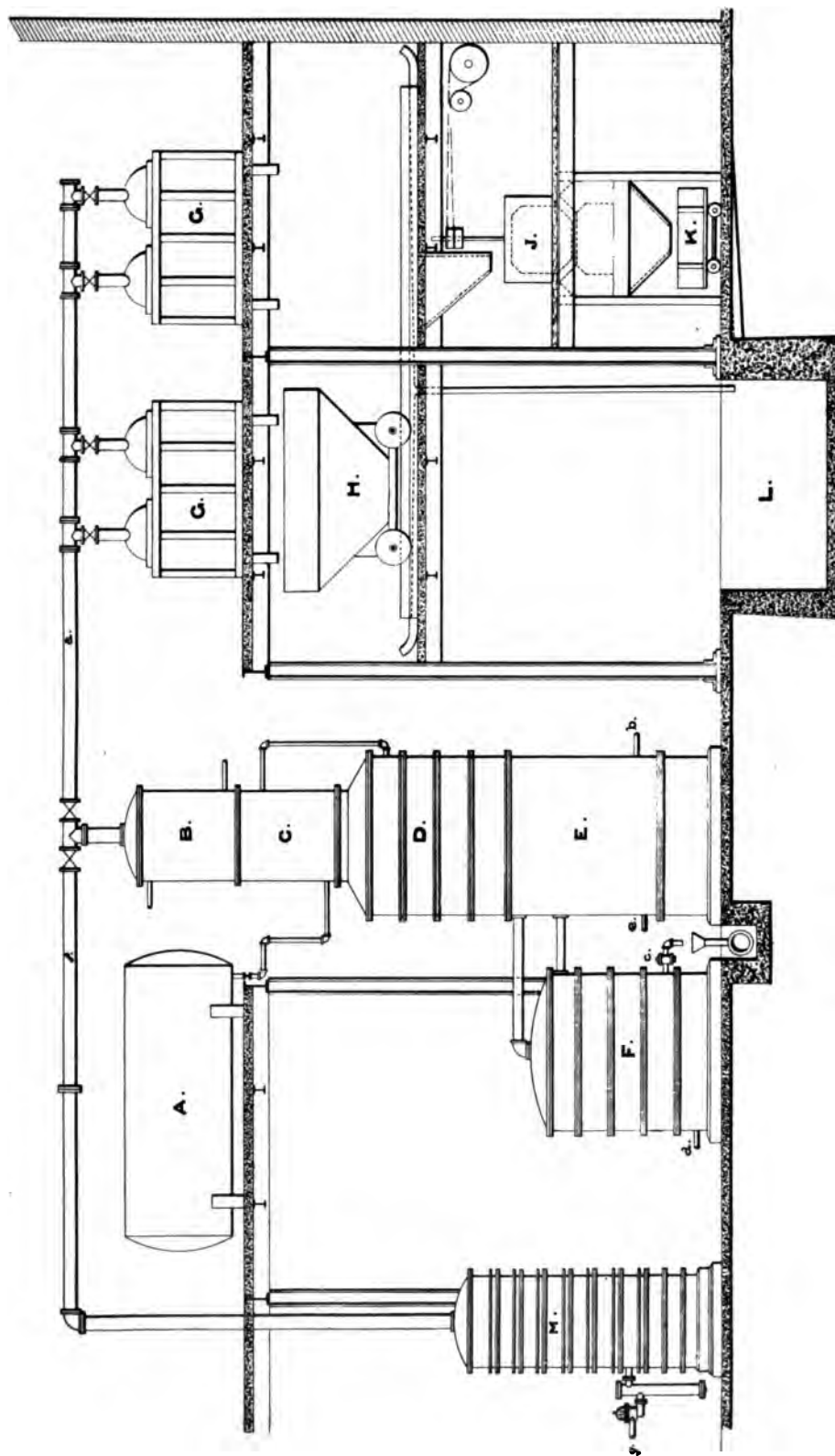
FIGURE 34. APPARATUS FOR MAKING AMMONIUM SULPHATE AND CONCENTRATED AMMONIA LIQUOR.

APPARATUS FOR SULPHATE.

THE apparatus for making sulphate is shown in Figure 34. Part of the ammonia exists in volatile form, and can be driven off by passing steam through the liquor. The remainder exists in forms known as "fixed" and must be decomposed by the action of lime or other alkali, before becoming volatile.

In the apparatus shown, the weak liquor enters the preheater C from the feed tank A, to which it is pumped from the condensing house cisterns, and passing down through the column D, encounters an ascending current of steam, with which it is brought in intimate contact by the baffles and seals in each section of D. The volatile ammonia is liberated in this process, and passes, together with a certain amount of water vapor, to the preheater C, where it heats the incoming feed liquor, and to the cooler B where the temperature is further reduced, if necessary, by cold water circulation. The liquor containing only the fixed ammonia salts passes downwards to the liming chamber E, into which milk of lime is pumped at c. The reaction at this point may be expressed as follows:

Lime + Ammonium Chloride = Calcium Chloride + Water + Ammonia.

$$Ca\ (OH)_2 + 2\ (NH_4)\ Cl = CaCl_2 + 2H_2O + 2NH_3.$$
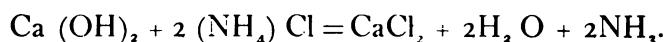
From E the liquor enters the column F, which is known as the "fixed" or "lime" still. Here it is again acted upon by the steam entering F at the steam inlet d. The liquor escapes from F at the waste cock c. The steam for the distillation enters the system at the base of the fixed still F and of the lime chamber E at b.

The ammonia vapors, together with the volatile impurities (carbonic acid, hydrogen sulphide, etc.), leaving the cooler B, pass through the pipe a to the saturators F, in which there is dilute sulphuric acid. The reaction here, which is attended with the evolution of considerable heat, is as follows:

Ammonia + Sulphuric Acid = Ammonium Sulphate.

$$2NH_3 + H_2SO_4 = (NH_4)_2SO_4$$
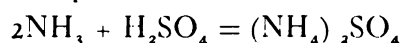
The saturators and all the parts coming in contact with the acid are protected by lead. A discharge opening is furnished from G to the cooling tank H placed below, which is also lead lined. As the neutralization of the acid proceeds, the sulphate crystallizes out in the form of a white salt. When the neutralization is nearly or quite complete, the process is stopped, as to continue beyond this point causes loss of ammonia and discoloration of the salt.

The salt and the mother liquor in G are then dropped into H, where they are cooled, and the salt allowed to settle and drain. The mother liquor is drawn off to the well L for use in further saturation, and the salt is dumped into the centrifugal machine J where it is dried. The dried sulphate is then transported by the car K to the storage room, or to a machine for automatically weighing it and placing it in bags.

The waste gases not absorbed by the acid in the saturators are of a very offensive nature, and may be drawn off through a pipe connection to the fuel gas mains and burned under the ovens, or disposed of in some other suitable way.

APPARATUS FOR STRONG LIQUOR.

THE manufacture of strong crude ammonia liquor is carried on in the same way as ammonium sulphate, except that after leaving the stills, the ammonia vapors pass to the pipe f and downwards to the condenser and saturator M, where they are cooled and condensed by means of water circulation, the concentrated liquor leaving M at g. The strength of the liquor made may be regulated by the temperature of the gases leaving the stills, and is usually between 15 and 20 per cent. of NH_3. The strong liquor is stored in steel tanks, and drawn from there to tank cars or drums for shipment.

The waste gases not condensed in the saturator are often disposed of in the same way as when making sulphate.

The general arrangement of an ammonia plant is shown in Figure 30 in connection with the condensing house adjoining it.

BENZOL RECOVERY
ᴼᴼ BENZOL ᴼᴼ

BENZOL (C_6H_6), or benzine, exists as a vapor in coke oven gas, the larger portion of the illuminating power being due to its presence. It can be removed from the gas by passing through washers in which a certain tar oil is used as the scrubbing liquor. This oil absorbs the benzol and it may be recovered from the oil by fractional distillation and subsequent condensation.

GAS ENRICHMENT BY TRANSFER.

WHEN the rich fraction of the gas is to be used for illuminating purposes, the removal of the benzol is clearly a detriment. It is, however, possible to obtain considerable benzol from the fuel gas fraction, the loss in heating power being negligible. The transfer of this benzol to the rich gas fraction for its further enrichment is carried out by The United Coke and Gas Company.* This is done without the separation and condensation of the benzol, the vapors being absorbed directly by the illuminating gas.

APPARATUS.

THE apparatus for the above operation forms a part of the condensing house. The general arrangement of such a plant is shown in the diagram, Figure 35.

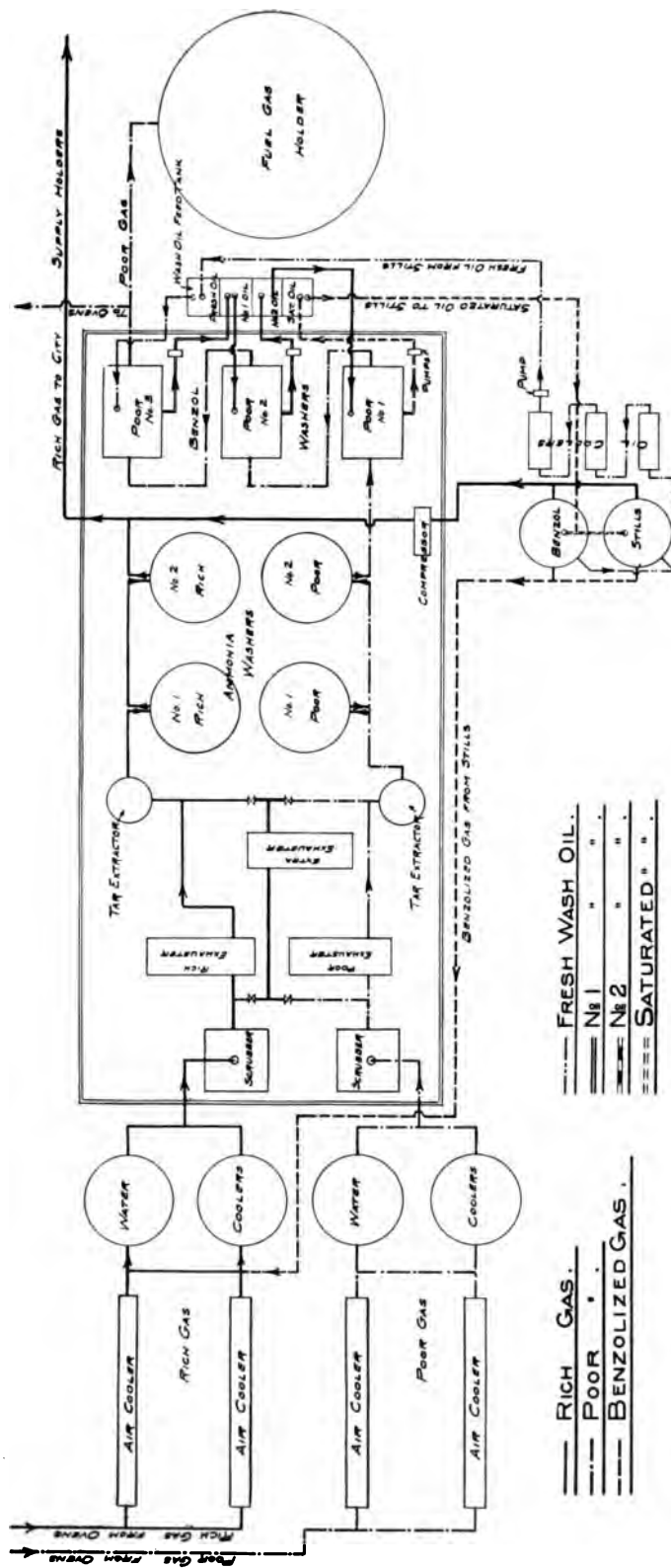* United States patents 684590, 698063, 728991.

FIGURE 35. ARRANGEMENT OF CONDENSING HOUSE FOR COKE OVEN GAS WITH BENZOL ENRICHMENT.

In addition to the usual condensing house apparatus, scrubbing towers are provided in which the fuel gas is scrubbed with tar oil, which absorbs the benzol. The benzolized oil is pumped to steam-heated stills, where the benzol is driven off in a current of rich gas, the composition of the vapors distilled off being easily controlled by the temperature. The benzolized gas is then mixed with the main body of rich gas entering the condensing house, and is thoroughly diffused through it in the subsequent condensing operations.

The process of enrichment by benzol transfer is much less difficult than it is to produce a condensed and rectified liquid benzol, which must be subsequently vaporized in the gas. The simplicity of the operation and the fact that it makes use of the supply of benzol immediately at hand are greatly to its advantage.

RESULTS.

THE results attending the first installation of the above-described apparatus on a working scale at the Camden coke oven plant have been most satisfactory. The gain in illuminating power is over four candles, the daily output of gas enriched under these conditions being in the neighborhood of 2,500,000 — 3,000,000 cubic feet. Gas is pumped to Trenton, thirty-eight miles distant, under ten pounds pressure, without any appreciable drop in candle power, even during extreme winter weather.

The production of the maximum amount of gas of high illuminating value from a by-product coke oven, as from a gas retort, requires regular operation and careful oversight. The results depend largely, therefore, upon the effectiveness and discipline of the operating force. It is but just to give full credit to Mr. G. W. Curtis, the superintendent of the Camden plant, for the admirable results there obtained.

PREPARATION of COAL
for COKING
CRUSHING

I N general, all coke is improved by crushing the coal to a moderate degree of fineness before charging into the by-product oven. In many cases the improvement in the coke is enhanced by dampening the coal, up to say 5 per cent. of water. This facilitates charging the ovens, as the coal is not so fiery.

WASHING.

A COAL that is high in sulphur or ash can usually be much improved by proper washing, for which purpose there are several efficient systems on the market.

IMPURITIES.

I N blast furnace practice the limit for sulphur in coke is usually taken to be 1.2 per cent. though for Bessemer steel making it is specified under 1.00 per cent. The quantity of sulphur permissible in the coal before coking, in order not to exceed the assigned limits in the coke, can only be definitely determined by trial. It frequently happens that the percentage of sulphur in the coal, and in the resulting coke will be found nearly the same. But there are so many exceptions to this rule that it should hardly be considered more than a rough approximation.

Phosphorus in coke is usually limited to .03 per cent. and for Bessemer coke .02 per cent. Practically all of the phosphorus in the coal appears in the resulting coke; therefore, the amount may be closely approximated when the coke yield is known.

The effect of ash in the coke is to reduce its calorific value, and in iron smelting additional fuel must be supplied for melting this ash into slag. The presence of the ash also tends to weaken the structure of coke. The question of the amount that may be tolerated is one for individual consideration. The effect of these impurities on domestic coke is not so marked; therefore, the requirements are not so rigid.

COAL STORAGE.

WHEN the supply of coal is regular and reliable, a capacity of the oven bins for one day's supply is deemed sufficient. Usually circumstances make a greater storage capacity immediately at hand advisable. As increase of oven bin capacity is expensive, this is usually effected by storing on the ground level, coal-handling machinery being resorted to to move the coal to and from the pile. An ample storage capacity is always considered necessary when coal is received by water, or when gas is supplied for city distribution.

COAL COMPRESSION.

A METHOD resorted to in England and Germany, and to some extent in this country as well, to improve the physical structure of the coke from certain coals, is to compress the finely-crushed and wetted coal into a cake of such consistency that it will stand being charged into the oven through the door, supported only on a moving bottom plate or peel. After the charge is in the oven, the door is lowered

and the peel withdrawn, leaving the coal cake inside. The effect of this method of working, on the output of a given oven, is summarized as follows:

Increase in oven capacity per cu. ft.	45 per cent.
Less clearance	15 per cent.
Net increase in amount charged	30 per cent.
Increase in coking time	20 per cent.
Net increase in coke output	10 per cent.

The increase in the coking time is due to the 8 to 10 per cent. water needed to make the cake compact properly, and to the increased amount of coal in the oven. The advantages resulting from the increased output are, however, outweighed by the repairs to the compressing machinery and the additional labor cost, the operation being particularly difficult in cold weather. The process would find its greatest value in the use of coals that could be coked in no other way. The use of such coals under the conditions prevailing in this country presents little attraction. The effect of compression on the quality of the coke wherever tried has been to strengthen it, particularly with poorly coking high volatile coals, but the improvement in quality has not been great enough to justify its general employment. It is inadvisable to use this method with coals which expand strongly during coking, as this tendency is increased by compression and the oven walls are damaged.

PRODUCTS

Relative Importance of Coke and Other Products

N order to make clear the relation between the main product, coke, and the by-products, the following schedule is given, showing the approximate yield of each from a given weight of coal:

YIELD OF COKE AND BY-PRODUCTS.

(From Dry Coal.)

Coke	from	70	to	82	per cent.	by weight.
Heating gas	"	12	"	11	" " "
Surplus	"	7.5	"	2	" " "
Tar	"	5	"	2	" " "
Crude ammonia liquor	"	5.5	"	3	" " "

100.0   100 per cent.

RESULTS OF ACTUAL OPERATION.

THE following figures are taken from the actual records of operation of an existing United-Otto plant for a period of six months, and are representative of the returns that may be expected under the prevailing conditions. A coal mixture averaging 30-32 per cent. of volatile matter, gave the following results:

Average daily coal carbonization	503 net tons.
" yield of coke (per cent. of coal)	74
" " " ammonia (NH_3) per net ton coal	5.20 pounds.
" " " tar per net ton coal	10.17 gallons.
" quantity illuminating gas sold per net ton coal, corrected to 60° F. and 29.92 in. barometrical pressure	4,630 cubic feet
" illuminating value of gas	18.07 candle power.

GAS ANALYSES.

	Illuminating Gas	Fuel Gas (For oven heating).
Illuminants	5.8	2.8
Methane	40.8	29.6
Hydrogen	37.6	41.6
Carbon monoxide	5.6	6.3
Carbon dioxide	3.7	3.2
Oxygen	.4	.4
Nitrogen	6.1	16.1
Total	100.0	100.0
British thermal units (gross) per cu. ft.	730.3	551.3

THE CHARACTERISTICS OF
BY-PRODUCT COKE.

OWING to the method of its production, by-product coke differs somewhat in its characteristics from the product of the bee-hive oven.

Figure 36b. Structure of Bee-Hive Coke.
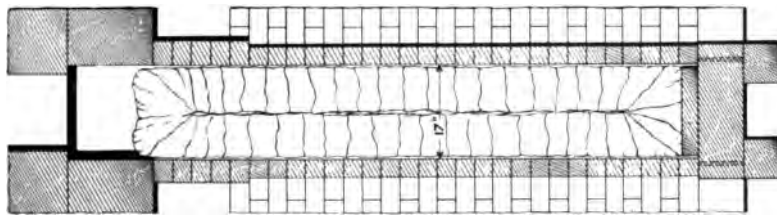
Figure 36a. Structure of By-product Oven Coke.

FIGURE 36. DIAGRAMS SHOWING STRUCTURE OF BY-PRODUCT AND BEE-HIVE COKE.

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APPEARANCE.

IN appearance by-product coke is apt to lack the silvery gloss that the bee-hive coke possesses, due to the smaller amount of graphitic carbon deposited on it and to the method of quenching outside of the oven.

SIZE.

THE pieces of coke are not as long as in the bee-hive product, though apt to be more uniform in size. This arises from the conditions shown in Figure 36, which illustrates the formation of the coke in by-product and bee-hive ovens. In the by-product oven the heat comes from the sides and from the bottom. Therefore, the fingers of coke form perpendicularly to these surfaces, leaving a plane of cleavage in the middle of the charge. This cleavage extends through the whole length of the oven, and is very distinct, so that the coke pieces are invariably divided by it; this results in the block-like appearance of a pile of by-product coke, and in a certain uniformity of size that is conceded by furnace men to be an advantage. The bee-hive oven, on the other hand, cokes from the top downwards through the charge, the coke fingers forming vertically, giving the coke a kind of columnar structure. These pieces of coke are frequently 18 to 20 inches in length, but the majority are of necessity broken in the operation of drawing. This gives a characteristic appearance to a pile of bee-hive coke so that it can readily be distinguished from the by-product article.

PHYSICAL STRUCTURE.

IN general, the physical structure of by-product coke is closer than that of the same coal coked in bee-hive ovens. This is due to the greater depth of the charge and the consequent greater pressure

on the lower strata during the coking process. The closer cell structure, combined with the firmness of body, due to the higher and more uniform coking heats, is a great advantage for the by-product coke, as it renders it able to stand harder driving in the furnace, without breaking up under abrasion or dissolving in the furnace gases.

The upper layer of coke in an oven has not the advantage of compression, and therefore is more on a par with the bee-hive coke. There is, however, this advantage that this relatively softer coke is in separate pieces, and can be divided from the remainder and used for domestic service, if deemed necessary, whereas in the bee-hive coke each piece has a soft end next the oven bottom, which cannot be practically separated from it.

COMPRESSION.

COKE from compressed coal will invariably show a firmer, closer cell structure and a higher specific gravity than coke from the same coal uncompressed. The somewhat spongy appearance of the top coke practically disappears, the improvement being most marked with high volatile coals, There will be less breeze made, and the coke pieces will be of even size and block-like appearance.

CHEMICAL COMPOSITION.

IN chemical composition by-product coke has a slight advantage over the bee-hive coke in general. In any given coal the amount of ash, sulphur and phosphorus present, and the form in which they exist, practically determine the percentages of these undesirable elements in the resulting coke. If a larger yield of coke from a given quantity of coal is obtained, as is the case with the by-product oven, the actual percentage of impurities will be relatively reduced; this is particularly advantageous with the low volatile coals, which give their maximum yield of coke in the by-product oven, but a much lower yield in the bee-hive oven.

THE USES OF COKE.

THE BLAST FURNACE.

THE principal use of coke is for the smelting of iron ore in the blast furnace. Practically all of the pig iron produced in this country in 1904 was made with coke alone, the small amount to which this statement does not strictly apply being made with part coke and part anthracite coal, and, for a special grade of iron made in small quantities, with charcoal. The remarkable increase in the output of the modern blast furnace during the last two decades is intimately connected with the use of coke as a fuel. Its use has been a large factor in the development of the American iron industry and it may be expected to increase in importance in the future. Until the advent of the by-product oven, the coke-making process was the one branch of the iron industry that had undergone no radical improvement. That the by-product oven is recognized as the ultimate possessor of the field is clearly indicated by the advances it has already made. There were over 3,500 by-product ovens in existence in the United States and Canada, in 1905, two-thirds of these having been built by the United Coke and Gas Company. In the United States, the by-product ovens produced over 11 per cent. of the coke made in 1904.

The early prejudice existing against by-product coke for blast furnace use was founded on lack of accurate knowledge of its qualities, and with better acquaintance this feeling will gradually disappear. That this prejudice is unfounded was shown by the results of a test of coke made from Connellsville coal, some 3,000 tons of which were coked at the Glassport plant of Otto-Hoffmann ovens and tested under actual working conditions at the Canal Dover Furnace, in comparison with an equal amount of standard Connellsville bee-hive coke. This test was most thorough in its character, being under the joint super-

vision of Mr. John Fulton and Mr. E. A. Uehling, the well-known blast furnace experts. Mr. David T. Croxton was in charge of the Dover Furnace at this time. The test showed that the by-product coke smelted a ton of pig iron with 98 pounds of coke less than was required of the bee-hive coke after making all allowances, the furnace increasing in output on the by-product coke by 3 per cent. The conclusion drawn was that the Otto-Hoffmann coke is a superior blast furnace fuel.

The evidence of this test is supplemented by the experience of the Cambria Steel Company at Johnstown, Pa., with by-product coke.

During the year 1901, a series of operating tests was made on two furnaces, one using all Connellsville bee-hive coke, and the other using all Otto by-product oven coke, made from local coals. Careful records were kept of the coke consumption, output, and the general behavior of the two furnaces. At the end of two weeks, the coke on the two furnaces was interchanged, and the test was continued. After repeating this operation four or five times, it was concluded that any difference in the results and behavior of the two furnaces, under these conditions, was rather in favor of the Otto coke than otherwise. One of the furnaces in question was 96 feet high, so the test of burden carrying ability on the part of the coke was undoubtedly severe.

Subsequently the Cambria Steel Company added 100 United-Otto ovens to their existing plant of 160 ovens, and these being in successful operation, they have recently broken ground for a fourth installment of 112 United-Otto ovens.

It may therefore be stated as a fact that with any given coal at least as good coke can be made in the by-product oven as in the bee-hive oven. The injustice of comparing bee-hive coke from standard coking coals with by-product coke made from inferior coals, should be apparent to everyone. This, however, has frequently been done in the past, even when the coal which the by-product oven was required to coke would not have received a moment's consideration for bee-hive operations. The ability of the by-product

MODERN BLAST FURNACE.

oven to make a satisfactory blast furnace, or foundry, coke from inferior coals has, however, been repeatedly demonstrated, and is one of its strongest recommendations. The quantity and quality of the coke, together with the return of by-products, can only be determined by exhaustive coking tests under operating conditions. Such tests The United Coke and Gas Company is prepared to make, at the request of interested parties, at their specially equipped testing plant.

FOUNDRY COKE.

THE coke used in melting pig iron in the cupola is usually required to be of a better character than that necessary for blast furnace operations, because, although the depth of the furnace is much less, it has to carry the heavy burden of the pig iron charge. By-product coke is usually denser and stronger than coke made from the same quality of coal in the bee-hive oven, by reason of the greater depth of the charge in the former, as already indicated. It is therefore eminently fitted for foundry use, and has proved itself to be fully equal, if not superior, to other cokes in every instance.

One of the largest companies building engines in the country, whose product is of international reputation, and whose specifications on iron, steel, coke, etc., are quoted as standards of practice, has exhaustively investigated the by-product coke made at the Camden ovens, and after a year's trial is using this coke exclusively in its foundry. The output of this foundry approximates 150 tons of finished castings daily and necessarily covers a wide range of requirements. A more severe test or a more thorough indorsement of the merits of foundry coke from United-Otto ovens could hardly be desired.

Another firm, widely known as extensive iron pipe founders, use and prefer Otto coke to the standard 72 hour Connellsville bee-hive article. They believe it permits of more rapid driving and melts more quickly, while its chemical composition is equally good or better, for reasons already stated. Testimonials from foundry men who have used Otto coke successfully might be multiplied indefinitely.
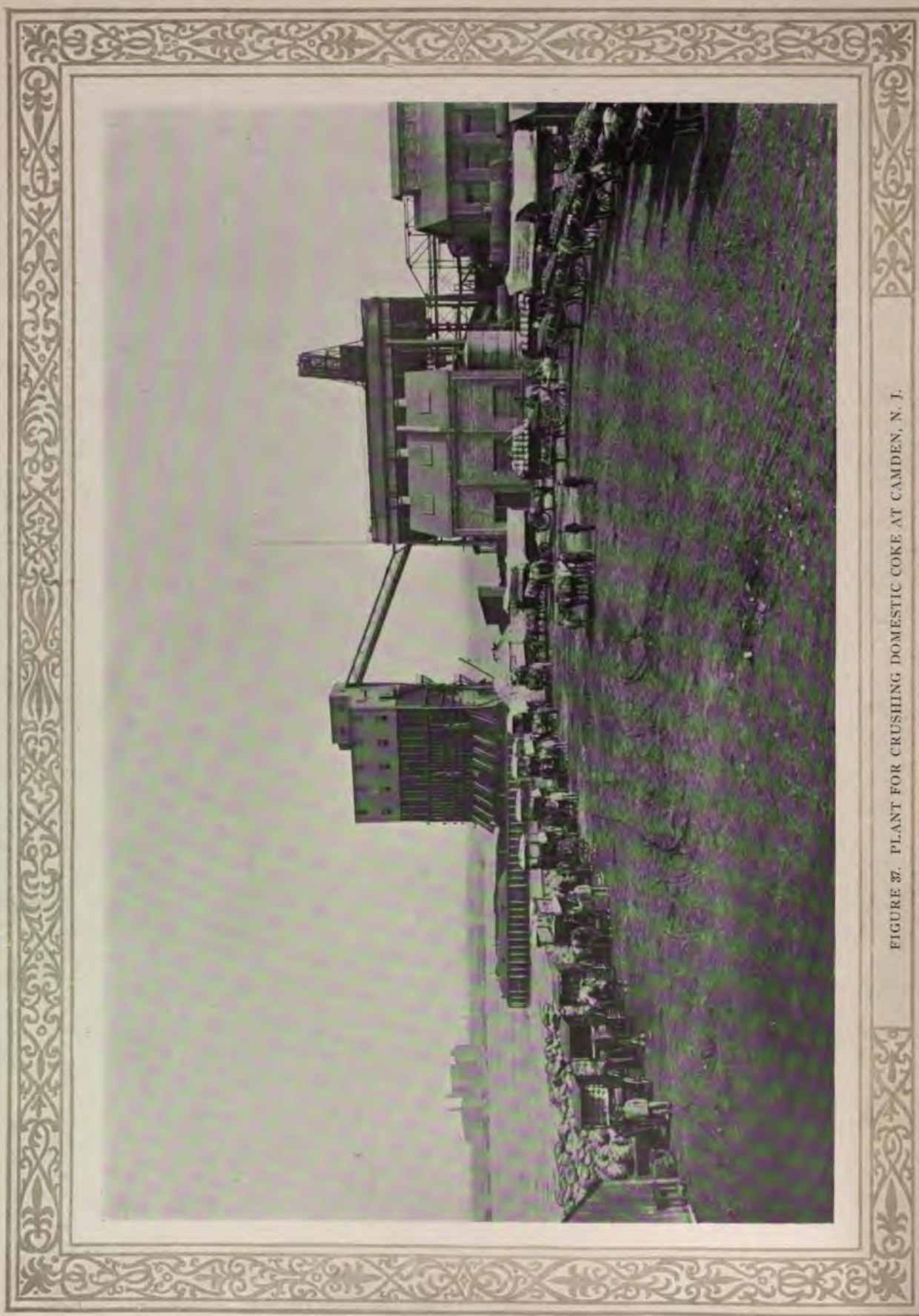
FIGURE 37. PLANT FOR CRUSHING DOMESTIC COKE AT CAMDEN, N. J.

DOMESTIC AND MINOR INDUSTRIAL USES.

THE use of properly crushed and sized coke, as a substitute for bituminous coal, is coming to be recognized as the only real and permanent solution of the smoke question. As a domestic fuel, and for all ordinary industrial uses, such as baking, drying, heating and steam raising, it is fully equal to anthracite coal, weight for weight; it lights quicker and holds the heat as well, while its smokelessness renders it easily superior to bituminous coal. Its moderate cost and the advantages of cleanliness, uniformity and convenience are all in its favor. It requires no special appliances to burn it, and only a slightly different adjustment of draughts. As it is lighter than coal it requires a somewhat larger fire box, but the space in ordinary furnaces is usually ample. Whenever it has been brought to the attention of the public by proper methods and made constantly and conveniently accessible to them through suitable channels, it has uniformly been well received.

Of the large output of the New England Gas and Coke Company, at Everett, Mass., some 200,000 gross tons per year are disposed of for domestic and industrial service, a similar amount being used for firing locomotives, particularly in suburban service, because of its smokeless nature.

The same outlet has been found for the output of the Camden plant, a portion of which, however, is sold for foundry purposes. The plant for the preparation of domestic coke at this plant is shown in Figure 37.

The type of wagon used for domestic coke delivery from the Camden plant is shown in Figure 38.

The output of the Hamilton plant is also absorbed to a great extent by domestic requirements. The ability of gas companies to dispose of an inferior coke for similar purposes, when proper methods are used for its introduction, is further evidence of the field open for by-product coke in this direction.

COKE BREEZE.

THE fine coke, or breeze, made in the handling of the coke and in crushing it, is readily disposed of for boiler fuel. For this purpose a special form of grate bar is necessary, having small circular draught openings and operating under a forced blast, such as is used for burning the smaller sizes of anthracite coal. Coke breeze has also been successfully made into briquettes, and a certain amount has been used in the lining of steel furnaces.

FIGURE 38. TYPE OF WAGON USED FOR DOMESTIC COKE DELIVERIES FROM CAMDEN PLANT.

GAS FOR FUEL AND POWER.

WHERE a by-product oven plant is located near blast furnaces, in districts not sufficiently populated to absorb the surplus gas in domestic service, industrial uses must be sought for. These purposes cover a wide range, as gas is applicable to most of the uses to which coal is put. It has been used as fuel for steam raising, in open hearth furnaces, drying ladles, heating furnaces, lime kilns, glass-melting furnaces, tar stills, chemical works, etc., and for power generation in gas engines. For these purposes a gas of high candle power is not necessary, and there is no need of resorting to the division of the rich and poor gases. Therefore, a single system of gas-collecting mains and condensing apparatus will suffice. Neither is it necessary to remove the small amount of sulphur present in the gas by means of oxide or other purification methods. A properly cleaned gas is suitable for use as it comes from the condensing house. In a number of cases in Germany, where coke-oven gas was used in gas engines of large size, it was found that the action of the sulphur on the engine valves and cylinder was not sufficient to warrant the cost of its removal. Where oxide boxes had been provided for the purpose, their use was abandoned. Records are at hand of some of the above-mentioned engines, operating on electric current generation, which ran without stop, for any cause, for three and four months at a stretch.

With gas having 550 to 600 British thermal units per cubic foot, there should be no difficulty in developing 1 horse power with 16 to 18 cubic feet, or about 10,000 British thermal units per brake horse power. At the plant of the Theresia Colliery in Polnisch-Ostrau, Austria, one of those referred to on page 104, the engines were guaranteed to deliver 1 horse power per hour with 27 cubic feet of gas, of

LIST OF GERMAN AND AUSTRIAN PLANTS USING GAS FROM OTTO-HOFFMANN AND OTTO-HILGENSTOCK BY-PRODUCT OVENS IN GAS ENGINES.

LOCATION	TYPE OF ENGINE	Number of Engines	H. P. of Engines	Purpose
Skalley Colliery, Zaborze, Upper Silesia............	....	1	60	....
Dannenbaum Colliery, near Bochum, Westphalia......	Deutz....	1	60	Power
Mansfield Colliery, near Langendreer, Westphalia......	....	1	100	....
Lothringen Colliery, Gerthe, near Bochum	Nuernberg—Augsburg............	{ 1 1 1 }	10 50 350	....
Neunkircher Ironworks, Neunkirchen....	Nuernberg—Otto Four Cycle.....	1	242	Blowing Engine
Matthias Stinnes Colliery, near Carnap......	Krupp.....................	3	300	....
Julienhuette, Bobrek, Upper Silesia........	Körting Four Cycle........	4	300	Power
Caroline Colliery, Maehrisch Ostrau........	{ Delamare—Debouteville(Cockerill). Twin Four Cycle...... }	{ 1	200	Electric Generators
Theresia Colliery, Maehrisch Ostrau.	Deutz Twin Four Cycle.... ...	{ 3 2 }	300 600	Electric Generators
Cologne Mining Company, Altenessen.	Oechelhauser................	1	550	....
Consolidation Colliery, Gelsenkirchen-Schalke, Westphalia	Nuernberg—Augsburg............	2	650	....
Krenig Ludwig Colliery, near Recklinghausen............	{ Deutz................... Nuernberg—Augsburg....... }	{ 1 1 }	60 550	....
Shamrock III-IV Colliery, Wanne, Westphalia..........	Nuernberg—Augsburg	1	800	....
Minister Achenbach Colliery, Brambauer, Westphalia.....	Deutz................	1	250	....
Gustav Schultz Coke Works, Hofstede-Riemke, Westphalia	Körting (Old Type) Four Cylinders	1	200	Electric Generators

329 British thermal units, or about 8,900 British thermal units per horse power. This guarantee was successfully carried out.

The accompanying table gives the names of a number of German coke oven plants using the gas from Otto-Hoffmann and Otto-Hilgenstock by-product ovens in gas engines.

ILLUMINATING GAS.

THE most advantageous field for the disposal of surplus gas is in ordinary city distribution for illuminating, fuel and power purposes. Such gas, produced by the principle of separation already described, and properly purified by the methods used in all city gas works, is of high candle power and in every way adapted to the purpose. It is capable of being pumped under pressure for long distances, and in such service suffers a minimum loss of candle power by condensation of illuminants.

The results of the Everett plant, which delivers between 6,000,000 and 7,000,000 cubic feet of illuminating gas daily, may be cited. In the case of the plant at Sparrow's Point the gas is pumped eleven miles under pressure to Baltimore, and at Camden it is pumped thirty-eight miles to Trenton, N. J. Mention of this plant has been made in connection with benzol enrichment. (page 88.)

At the Hamilton plant, a large portion of the town is supplied with coke oven gas for illuminating and other purposes; the more recently constructed plant at Duluth supplies gas to the cities of Duluth and Superior.

QUALITY OF COKE OVEN GAS COMPARED WITH OTHER ILLUMINATING GASES.

THE following table of analyses showing a comparison of coke oven gas, ordinary retort coal gas, and carburetted water gas is of interest in this connection.

ANALYSES OF ILLUMINATING GAS FROM UNITED-OTTO COKE OVENS, RETORT COAL GAS AND CARBURETTED WATER GAS.

	Coke Oven Gas	Retort Coal Gas	Carburetted Water Gas
Hydrocarbons - - -	5.8	3.83	11.32
Methane - - - -	40.8	35.90	20.48
Hydrogen - - - -	37.6	48.49	29.35
Carbon Monoxide -	5.6	6.61	33.19
Carbon Dioxide - - -	3.7	.12	.17
Oxygen - - - - -	.4	.00	.32
Nitrogen - - - -	6.1	5.05	5.17
	100.0	100.0	100.0
B. T. U. per cubic foot	730.	669.	719.
Specific Gravity - -	.508	.401	.528
Candle Power - -	17.5	15.5	20.7

In this table the predominance of the carbon monoxide in the carburetted water gas is the most striking feature. There have been many objections made to water gas on account of the highly poisonous character of carbon monoxide, but-this feeling has been largely overcome. The presence of carbon monoxide should be objected to, however, for another reason, viz: that of enriching economy. This point will be discussed further on.

ᵛᴵ The table shows also that rich coke oven gas, as delivered from a number of plants now in operation in the United States, is of exceedingly high heat value. This enhances its advantages for all fuel and power generating purposes.

The analysis of the coke oven gas shows a higher percentage of carbon dioxide than is present in the retort coal gas or carburetted water gas. This carbon dioxide could be removed from the coke oven gas by lime purification in the same manner as has been done in the other two gases. In that event the specific gravity of the coke oven gas would be reduced to about .470 and the illuminating value would

be increased to approximately 20 candle power. The retort gas was evidently made at high temperature, to which is probably due the excess of hydrogen over methane.

Illuminating gas consists of three different elements:

(1) Illuminants; the vapors of benzol, C_6H_6 and its homologues, toluol, C_7H_8, xylol, C_8H_{10}, together with ethylene, C_2H_4, and its homologues, propylene C_3H_6, butylene C_4H_8.

(2) Diluents; marsh gas, hydrogen and carbon monoxide in varying proportions.

(3) Impurities; or accidental mixtures of carbon dioxide, oxygen, nitrogen, etc.

The last mentioned exist only in small quantities in the gas, and have a detrimental action only on the gas flame.

The theory of flame is that the combustion of the so-called diluents generates a body of gas of high temperature. The light is then produced by passing the illuminants through this highly heated gas body, by which the hydrocarbons are decomposed; this segregates the carbon molecules, which reach the temperature of the burning gases in an incandescent state in the inner body of the flame, before combustion on the periphery. The carbon molecules when heated to a high temperature have the property of radiating light.

It is clear that it is of the greatest value to have such a mixture of diluents that not only a flame of very high temperature is produced, (because the light emission increases greatly with the temperature) but also to secure a maximum volume of flame so that the carbon molecules will be exposed to as long a period of incandescence as possible.

It has so far been found that mixtures of marsh gas and hydrogen, such as are found in coke oven gas, and coal gas, are superior to mixtures of hydrogen and carbon monoxide, such as water gas presents. This latter mixture cannot, therefore, be considered as the proper diluent for hydrocarbons, and the water gas industry has therefore found its development only after the admixture of oil gas, rich in gaseous hydrocarbons, has been resorted to.

Benzol is the most valuable enriching hydrocarbon in use. If

added to the water gas diluents (carbon monoxide and hydrogen) it requires 2.5 times as much enriching material for the same illuminating effect as when added to coal gas or coke oven gas diluents (hydrogen and marsh gas). This is of great importance, as the amount of benzol vapors which a gas can carry, is limited for each temperature by the corresponding vapor tension. Hence, blue water gas when enriched with benzol, could not be brought to more than 12-14 candle power in winter time. Any excess of benzol would deposit in the pipe system. On the other hand, the mixture of hydrogen and marsh gas could be enriched to over 30 candle power without danger of loss by condensation.

Coke oven gas and coal gas do not, however, owe all of their illuminating value to benzol vapors, but in part to the ethylene they contain. The following table gives the respective amounts under ordinary circumstances:

	Per cent. of Benzol and Homologues	Per cent of. Ethylene and Homologues
Rich coke oven gas (Everett)	1.05	4.2
Retort coal gas (London)	1.00	3.0

These illuminants are evolved from the coal in varying proportions during the coking process. The candle power due to benzol and ethylene and their respective homologues would be as follows:

	Candle Power due to Benzol.	Candle Power due to Ethylene.	Total Candle Power
Rich coke oven gas	10.5	7.0	17.5
Retort coal gas	10.	5.0	15.

We cannot exhaust this subject in this connection, but propose to take it up more fully in a subsequent pamphlet.

USES OF TAR.

THE tar from by-product coke ovens is worked up into various marketable products. A great deal is used as a coating for pipe, castings and all kinds of iron work, and in the manufacture of waterproof paint. It is also used in lining open hearth steel furnaces. Felt is saturated with it to make various forms of prepared roofing and water-proofing. On distillation it forms pitch (which is used directly in paving, water-proofing and fuel briquette making) and light and heavy oils, which are used as a preservative of wood, and in the manufacture of chemicals. The fuel value of crude tar when burned in a suitable type of liquid fuel burner is equal to that of crude petroleum, weight for weight, and in relation to coal, 5 lbs. of tar may be

FIGURE 39. STEEL TANK BARGE FOR SHIPPING TAR BY WATER.

said to be equivalent to 7 or 8 lbs. of coal, according to the quality of the latter.

Tar is usually shipped by rail in barrels, or in ordinary tank cars. In order to avoid the cost of barreling the tar for shipment by water, the Barrett Manufacturing Company, who handle practically all the tar made in the United-Otto ovens, operate a steel tank barge, shown in Figure 39. This barge has a capacity of 230,000 U. S. gallons.
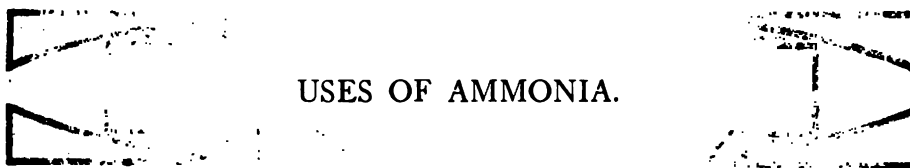
USES OF AMMONIA.

THE ammonia obtained from the coke oven process is transformed by distillation, as already described, into ammonium sulphate, or concentrated crude liquor having 14 to 18 per cent. NH_3. In the latter instance it can be disposed of to manufacturers of alkali, soap and chemicals of various forms.

In the form of ammonium sulphate it is used to some extent in chemical manufacture, but chiefly as a fertilizer. Ammonium sulphate contains approximately 20 per cent. of nitrogen, which is the most valuable constituent of fertilizers. The market for ammonia in this form is practically unlimited, particularly as Chilian nitrate, its only substitute, will soon grow scarcer by reason of the depletion of the mines. The greatly increased yield in crops that can be obtained by the use of artificial fertilizers has long been recognized in the older countries, and the great economical advantages to be obtained by such methods in this country are continually attracting more attention on the part of the agricultural population. The sulphate made in the United-Otto oven plants is placed on the market by the American Coal Products Company, of New York.

USES OF BENZOL.

IF it is not desired to use the benzol for enriching the illuminating gas fraction by direct transfer, as already described, it may be recovered from the absorbing oil by redistillation, condensation and rectification with sulphuric acid and alkali, to be disposed of as commercial benzol. In this form it is a colorless liquid possessing great inflammability, and is usually graded as 50 or 90 per cent. benzol, this designation indicating that 50 or 90 per cent. of the liquid will distill over at 100° Cent., the other hydrocarbons present being chiefly toluol, xylols and cumols. Besides its use as an enricher of coal gas, for which purpose the 90 per cent. benzol is best adapted, it is used in the aniline dye and drug industries. In Germany, where by far the greater proportion of the world's benzol is consumed, the major part goes into these industries. It is also used in the manufacture of paints, as a solvent for rubber, in the making of nitro-benzol for explosives and in the preparation of perfumery.

GENERAL ARRANGEMENT OF PLANT
PLANT of 100 to 200 OVENS

THE general arrangement of a plant of 100 United-Otto ovens, made with a view to subsequent extension to 150 or 200 ovens, is shown in Figures 40 and 41 in plan and cross-section. The ovens are to be ultimately arranged in four 50-oven batteries all in one row, the condensing house and auxiliary apparatus being placed on the pusher side opposite the initial 100 ovens. Between these two batteries and the two future batteries is placed the coal bin, which is designed to supply all four.

On the discharge side of the ovens are the coke quenching car, the coke tracks, the coal receiving tracks and the coal handling apparatus; either the inclined quenching car or the Moore type of quencher may be used, both being shown. Adjacent to the coal receiving hoppers the storage of coal on the ground level may be provided for if desired.

The gas collecting mains of both pairs of batteries lead towards the coal bin, and cross there to the condensing house. This is so arranged that the gas enters at one end and leaves at the other, passing successively through the various operations in their prescribed order. The pump room, liquor cisterns and gas holder are located close to the condensing house, while forming practically an extension to it are the ammonia house, the power house, shops, etc.

Railroad tracks are provided for sulphate shipment and for shipment of tar, the tar and liquor storage tanks being located along the last mentioned track. A separate track raised on a trestle supplies fuel to the boilers.

COAL HOPPERS

COKE TRACKS.

STACK

MOORE QUENCHER

COKE QUENCHER

50 OVENS.

COKE PUSHER.

BY-PRODUCT TRACK

STAND PIPE

STACK

TRESTLE.

ELECTRIC POWER PLANT

BOILERS

SULPHATE STORAGE

BENZOL STILLS

AMMONIA PLANT

PUMPS

BENZOL WASHERS

EXHAUSTERS & WASHERS.

FUTURE COOLERS

COOLERS

AMMONIA LIQUOR TANKS & TAR TANKS

BY-PRODUCT TRACK

50 OVENS.

COAL BIN

GAS HOLDER

OFFICE & LABORATORY

MOORE QUENCHER

FUTURE 50 OVENS.

FUTURE 50 OVENS.

FIGURE 40. GROUND PLAN.

FIGURE 41. CROSS SECTION.

COAL BIN

CONDENSING HOUSE

PUSHER & LEVELLER

PUMPS

MOORE QUENCHER

COKE QUENCHER

CRUSHER & DISINTEGRATOR

COAL HOPPERS

FIGURES 40 AND 41. GENERAL ARRANGEMENT OF 100 UNITED-OTTO OVEN PLANT, WITH PROVISION FOR EXTENSION TO 200 OVENS.
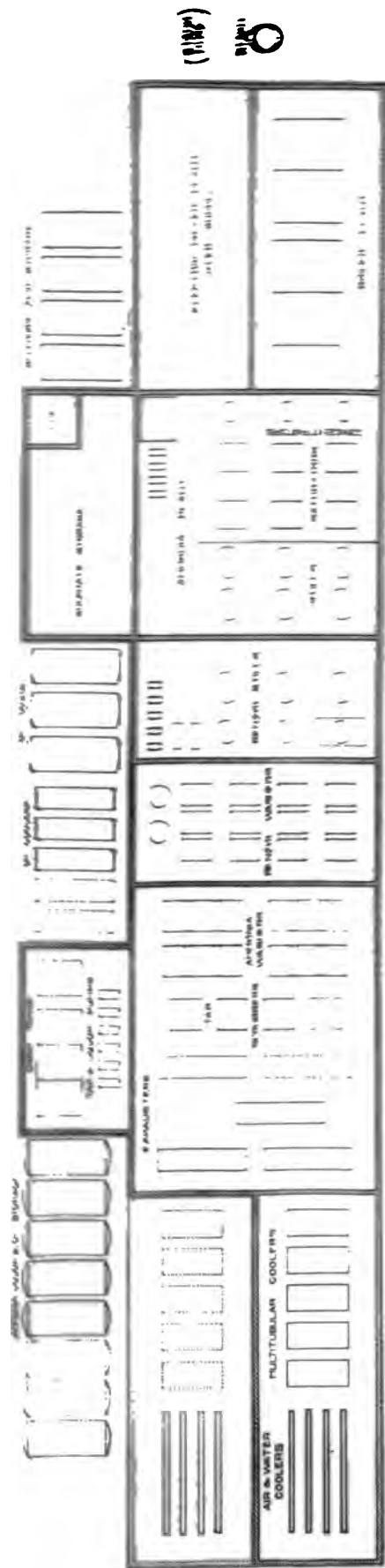
FIGURE 42. GENERAL ARRANGEMENT OF CONDENSING AND AMMONIA HOUSES FOR BENZOLE OVENS WITH PROVISION FOR EXTENDING DEHYDRATION

The office and laboratory building is located near both condensing house and oven batteries for convenience of access.

This general arrangement may be said to provide for the initial installation in a compact and convenient manner, while admitting of extension without sacrifice of future efficiency. It is easily accessible for railroad tracks without long approach curves, and gives ample facilities for rapid switching and coal storage. Furthermore, by avoiding isolated buildings it saves a portion of the construction cost. Lastly, it preserves, as far as possible, the existing ground level without expensive filling in, and with a minimum amount of foundation work.

CONDENSING AND AMMONIA HOUSE.

THE arrangement of the condensing and ammonia houses for 100 ovens, with the extension to 200 provided for, is shown in Figure 42. As will be seen, the original building is made large enough to inclose all the by-product apparatus, power plant, etc., needed for the ultimate extension, with the exception of the gas coolers, for which an addition may be constructed. The additional machinery, storage tanks and other apparatus and their location are shown by dotted lines. Provision is made for handling two qualities of gas, for benzol transfer from the poor to the rich gas, and for the necessary auxiliary power plant, but otherwise the plant is similar to that shown in the sectional view, Figure 30.

ARRANGEMENT
of
EXISTING PLANTS
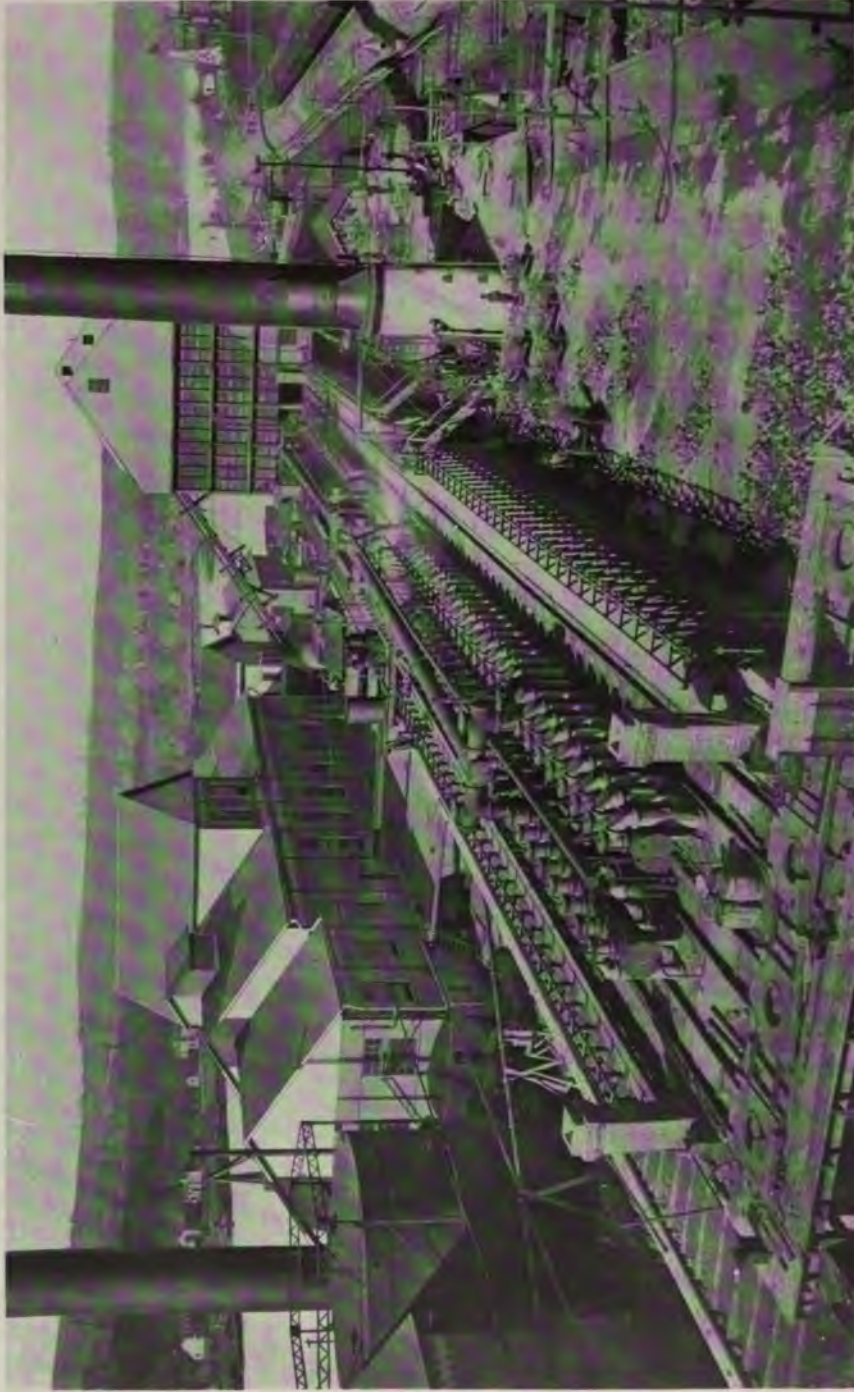
FIGURE 43. PLANT OF THE PITTSBURGH GAS AND COKE COMPANY, AT GLASSPORT, PA.
120 OVENS.

The illustration above shows the installation at Glassport, there being four batteries of thirty ovens in a single line. The condensing house and auxiliaries are placed in the rear of the pusher tracks.
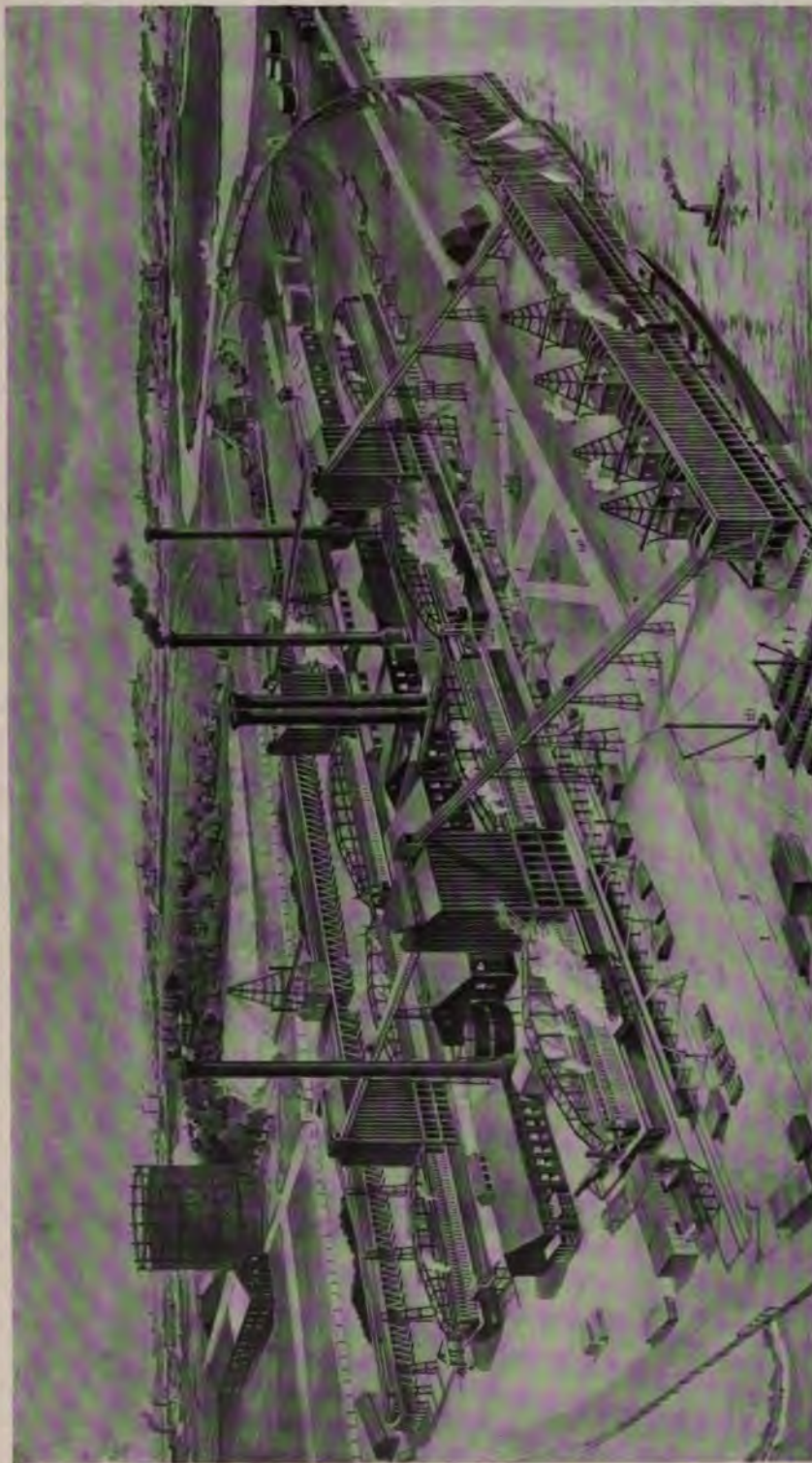
FIGURE 44. PLANT OF THE NEW ENGLAND GAS AND COKE COMPANY, AT EVERETT, MASS.
400 OVENS.

The illustration shows a general view of the Everett plant of 400 ovens, in which the eight batteries of fifty ovens are arranged in a double row. In this case the condensing house and other buildings were placed between the batteries, and the coal supply, being entirely by water, received special treatment. This plant was the first to make general use of electric motors in the operations usually performed by hand or by steam power, among these innovations being electrically-operated pushers coal larries, door hoists, quenching cars, mud mills and various smaller devices.

FIGURE 45. PLANT OF THE DOMINION IRON AND STEEL COMPANY, AT SYDNEY, N. S.
400 OVENS.

The plant at Sydney, shown above, preserved the same general arrangement as at Everett, except that the conditions did not favor the adoption of the labor-saving machinery used there. The method of handling coal is substantially that shown in Figure 13, and has proved advantageous in many ways. As will be noted, the disabling of one elevating system does not necessarily stop the charging of ovens, as coal for one side of the plant may be drawn from either of two bins.

FIGURE 46. PLANT OF THE HAMILTON-OTTO COKE COMPANY, AT HAMILTON, OHIO.
50 OVENS.

The arrangement of the Hamilton plant is shown in this illustration and the two following ones. This plant, being of small size, does not present any novel features.

FIGURE. 47.   PLANT OF THE HAMILTON OTTO COKE COMPANY, AT HAMILTON, OHIO.
50 OVENS.

The scrupulous neatness of this plant and the unobjectionable nature of its surroundings, as shown in Figures 47 and 48, indicate how little annoyance the presence of a properly run by-product coke plant is to those in its vicinity.

FIGURE 48. OFFICE AND VICINITY OF THE HAMILTON OTTO COKE COMPANY AT HAMILTON, OHIO.

FIGURE 49. PLANT OF THE SOUTH JERSEY GAS, ELECTRIC AND TRACTION COMPANY, AT CAMDEN, N. J. 100 OVENS.

The Camden plant is shown in the general view above. This plant receives its coal supply by water and is equipped with coal storage and handling apparatus of modern type. It has also a coke-crushing plant, shown in Figure 37.

FIGURE 50. VIEW DURING CONSTRUCTION OF 50 ADDITIONAL UNITED-OTTO OVENS AT THE CAMDEN PLANT, JUNE 14, 1905.

The illustration above, together with the five succeeding views, show the progress in erection. The excavation has been completed, ready to drive the foundation piling. The relation of the new battery to the existing plant of 100 ovens is also shown in this view. The American Coke and Gas Construction Company are the contractors for the complete installation.
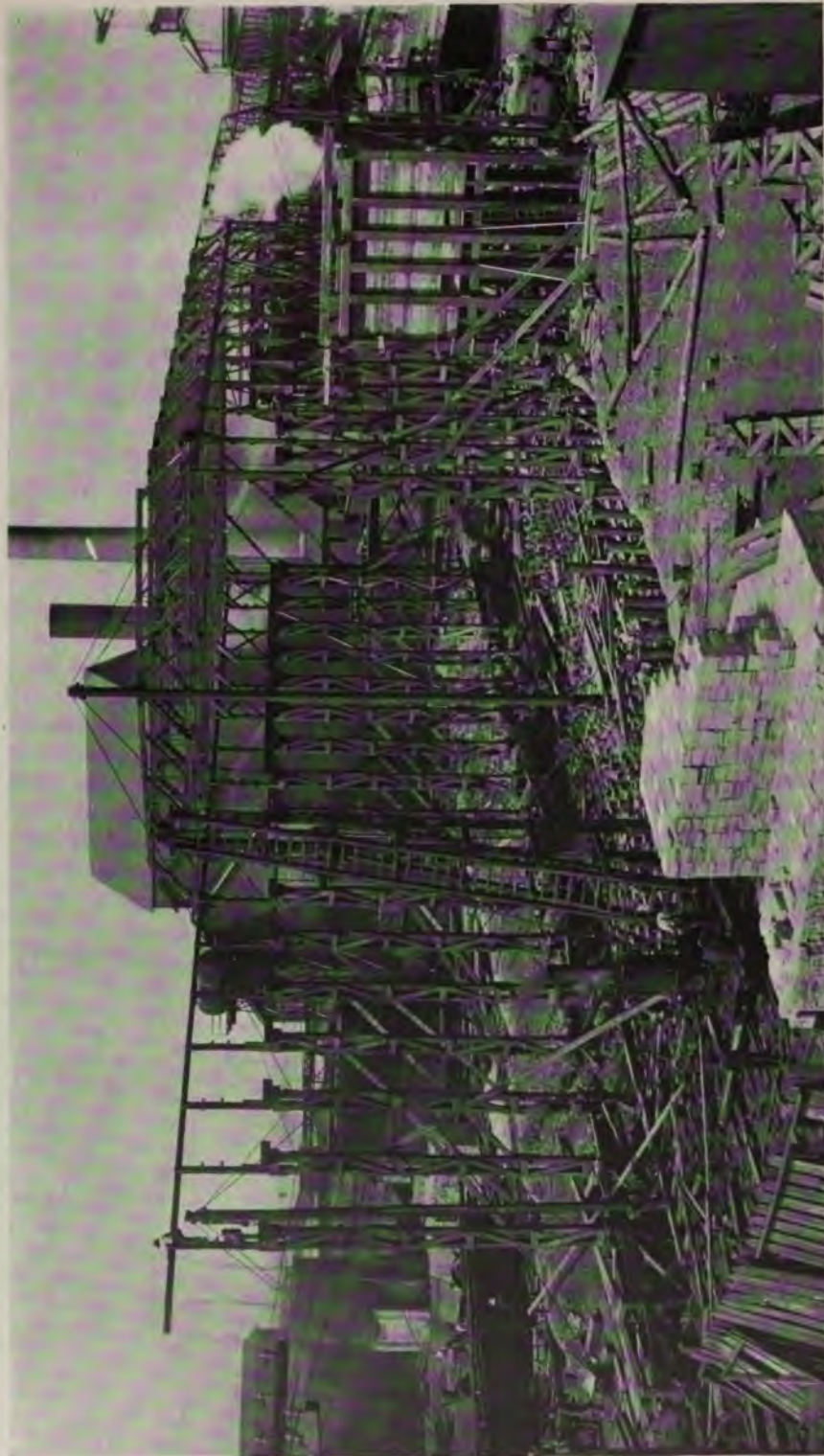
FIGURE 51. VIEW DURING CONSTRUCTION OF 50 ADDITIONAL UNITED-OTTO OVENS AT THE
CAMDEN PLANT, JULY 15, 1905.

The piling has been completed, and the erection of the shed for protecting the construction is under way.

FIGURE 52. VIEW DURING CONSTRUCTION OF 50 ADDITIONAL UNITED-OTTO OVENS AT THE CAMDEN PLANT, SEPTEMBER 15, 1905.

The concrete foundation walls and stack foundations are in place.
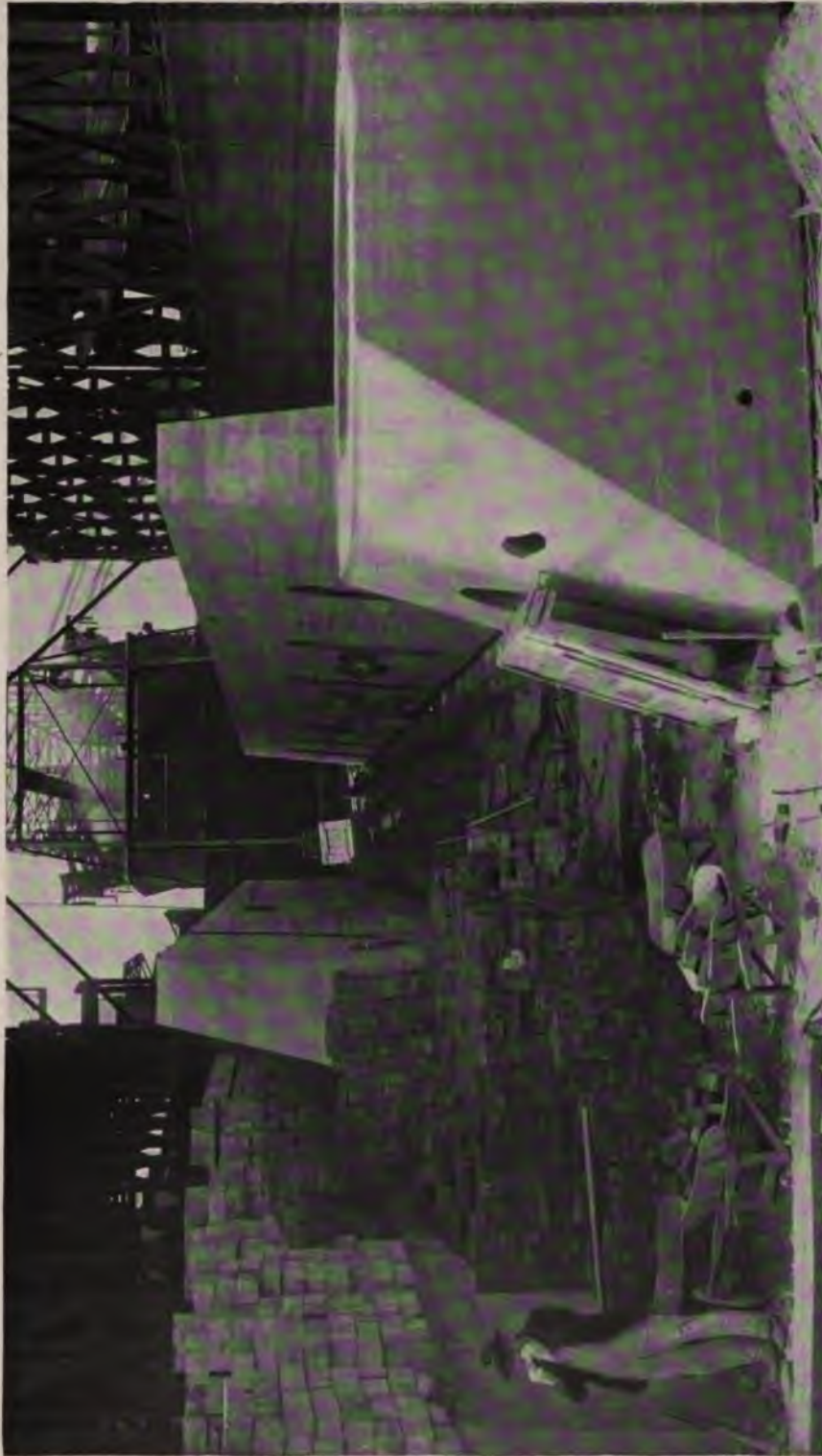
FIGURE 53. VIEW DURING CONSTRUCTION OF 50 ADDITIONAL UNITED-OTTO OVENS AT THE CAMDEN PLANT, OCTOBER 7, 1905.

The iron work for the oven masonry is shown in place on the foundation walls.

FIGURE 54. VIEW DURING CONSTRUCTION OF 50 ADDITIONAL UNITED-OTTO OVENS AT THE CAMDEN PLANT, NOVEMBER 1, 1905.

In this view the method of grinding the brick to exact size for the United-Otto oven walls is shown in detail, see page 50.

FIGURE 55. VIEW DURING CONSTRUCTION OF 50 ADDITIONAL UNITED-OTTO OVENS AT THE CAMDEN PLANT, JANUARY 13, 1906.

The oven masonry is nearly completed, and the iron work is partly in place.

FIGURE 56. PLANT OF THE LACKAWANNA STEEL COMPANY, AT LEBANON, PA. 232 OVENS.

FIGURE 57. CONDENSING HOUSE AND AUXILIARY PLANT AT THE BY-PRODUCT COKE OVENS OF THE LACKAWANNA STEEL COMPANY.

FIGURE 58. FIRST INSTALMENT OF 188 UNITED-OTTO OVENS AT THE PLANT OF THE LACKAWANNA
STEEL COMPANY, AT BUFFALO, N. Y.

The illustration above shows three of the four batteries of 47 ovens each, forming part of the installation of 564 United-Otto ovens contracted for by the Lackawanna Steel Company. The present four batteries are arranged in one row, the ultimate arrangement of the plant providing for twenty-four 47-oven batteries in two rows, with the condensing house and auxiliary plant between.

Owing to the proximity of Lake Erie, and the consequent trouble with ground water, the usual form of horizontal regenerative chamber beneath the oven, was replaced by vertical regenerators enclosed in a steel shell, placed at the ends of each oven battery. The condensing house is shown in Figure 30.

FIGURE 59. PLANT OF THE MICHIGAN ALKALI COMPANY, AT WYANDOTTE, MICHIGAN.
30 UNITED-OTTO OVENS.

The existing plant of 15 ovens is shown above, the additional 15 ovens being under construction in the shed at the right hand of the illustration.

FIGURE 60. PLANT OF THE MARYLAND STEEL COMPANY, AT SPARROWS POINT, MD.
200 UNITED-OTTO OVENS.

The above figure shows the plant at Sparrows Point. The general arrangement comprises four 50-oven batteries, in two rows. The ovens at this plant are of the United-Otto type taking a charge of nine net tons of coal. The gas is divided the rich portion being delivered to Baltimore by a pipe line twelve miles long, for illuminating purposes.
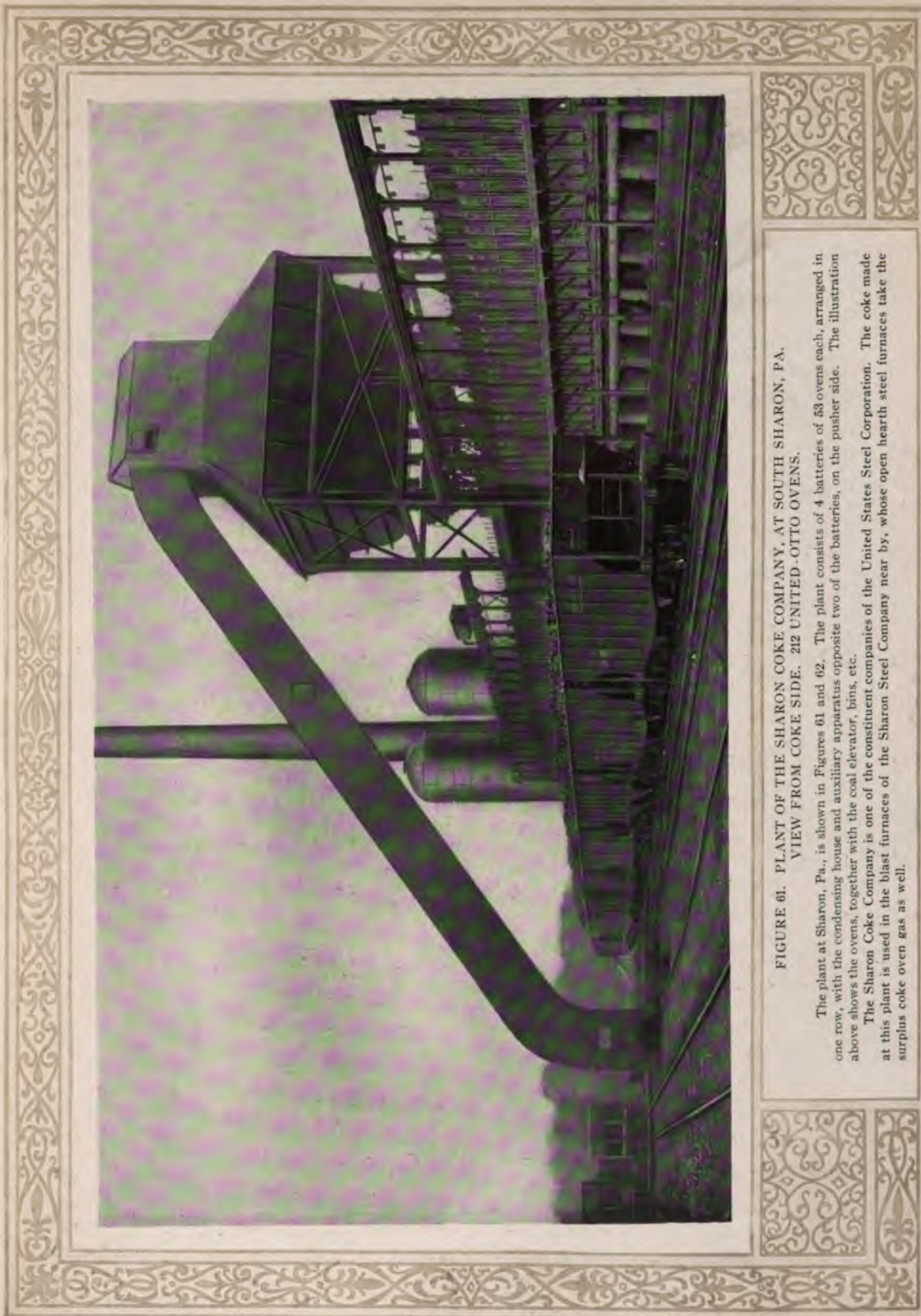
FIGURE 61. PLANT OF THE SHARON COKE COMPANY, AT SOUTH SHARON, PA.
VIEW FROM COKE SIDE. 212 UNITED-OTTO OVENS.

The plant at Sharon, Pa., is shown in Figures 61 and 62. The plant consists of 4 batteries of 53 ovens each, arranged in one row, with the condensing house and auxiliary apparatus opposite two of the batteries, on the pusher side. The illustration above shows the ovens, together with the coal elevator, bins, etc.

The Sharon Coke Company is one of the constituent companies of the United States Steel Corporation. The coke made at this plant is used in the blast furnaces of the Sharon Steel Company near by, whose open hearth steel furnaces take the surplus coke oven gas as well.
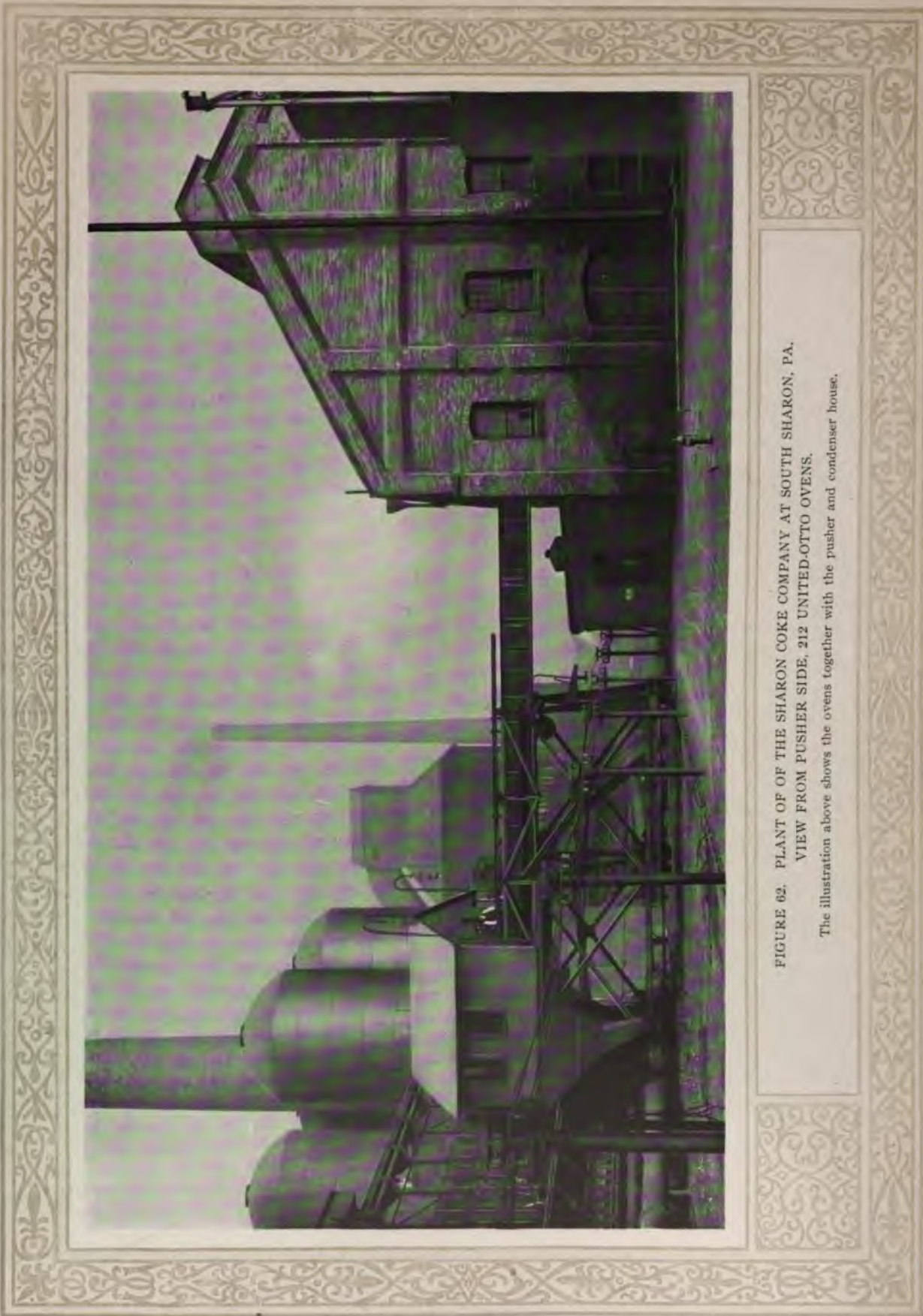
FIGURE 62. PLANT OF OF THE SHARON COKE COMPANY AT SOUTH SHARON, PA.
VIEW FROM PUSHER SIDE, 212 UNITED-OTTO OVENS.

The illustration above shows the ovens together with the pusher and condenser house.

By-Product Coke
Ovens.

Blast Furnace.

Coal Storage and Handling
Plant.

Dock.

FIGURE 63. GENERAL VIEW OF THE PLANT OF THE ZENITH FURNACE COMPANY AT DULUTH, MINN.
50 UNITED-OTTO OVENS.

The plant at Duluth is shown above. Its location on the lake front and the method of coal supply, which is by narrow gauge cable cars, from a coal dock adjacent, governed the arrangement to some extent, but it is, in general, a replica of the Hamilton plant. Extension is provided for by adding two 50-oven batteries on the same line. This plant supplies illuminating gas to the cities of Duluth and Superior, Mich., and its coke output is absorbed by the blast furnace of the Zenith Furnace Company, shown in the background.

The ovens themselves are obscured by the coal bin in this view but are shown in more detail in Figure 22.

FIGURE 64. THIRD INSTALMENT OF 100 UNITED-OTTO OVENS, AT THE PLANT OF THE
CAMBRIA STEEL COMPANY, AT JOHNSTOWN, PA.
View from Coke Side.

The last addition to the Cambria plant is shown above, this making 200 ovens, in all. The location of the original installation of 60 ovens being on a mountain side, only the first extension of 100 could be added in a direct line. The latest addition was therefore laid out at a slight angle, a separate condensing house being provided. The new site, however, permits of 300 additional ovens, making a separate plant of 8 batteries of 50 each, in two lines. The Cambria Steel Company is now excavating for an additional 112 ovens.

Another view of the same plant taken from the pusher side is shown in Figure 65.

FIGURE 65.   THIRD INSTALMENT 100 UNITED-OTTO OVENS AT THE PLANT OF THE
CAMBRIA STEEL COMPANY AT JOHNSTOWN, PA.

View from Pusher Side.

The Field of the By-Product
COKE OVEN

THE by-product coke oven process has already attained a well recognized position in the metallurgical field and is to be reckoned with in all undertakings involving the smelting of ore in the blast furnace or the melting of pig iron in the cupola. It is destined to play an important part as well in the fuel supply of the larger cities and thickly populated districts. To such communities the by-product oven delivers gas for illuminating, fuel and power purposes and at the same time yields smokeless coke suitable for domestic and industrial consumption. The depletion of the anthracite coal mines prohibits any great extension of the output and militates against any decrease in its cost. The consequent increase in the consumption of soft coal is arousing bitter opposition, particularly in those localities hitherto comparatively free from the smoke nuisance. To them the by-product oven offers a ready and complete solution of the fuel problem. The raw coal passing through its transforming process is resolved into its elements of solid and gaseous fuel, its impurities are removed and made into articles of commercial value, with a total loss of efficiency in the conversion that is already less than that of any known gasifying process, and promises to be even further reduced. It seems therefore inevitable that the by-product oven will figure extensively in the industrial development of the country

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