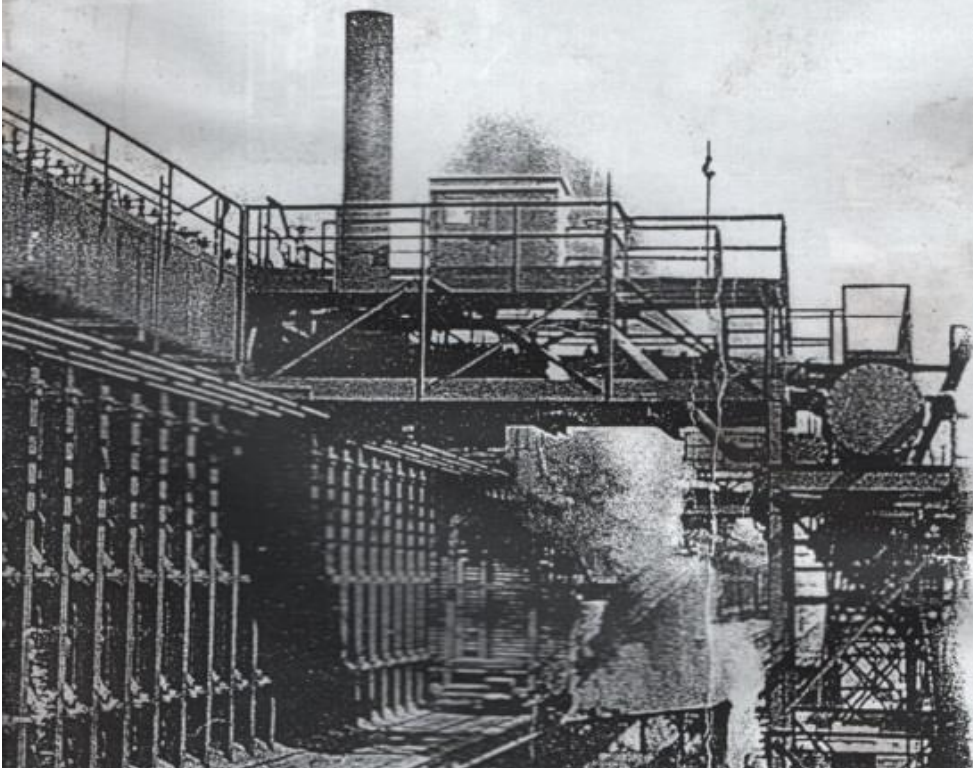
THE STORY OF

COKE AND COAL CHEMICALS



THIS BOOKLET IS PRODUCED BY THE AMERICAN COKE AND COAL CHEMICALS INSTITUTE.

IT ATTEMPTS TO PRESENT IN LAYMEN'S LANGUAGE A DESCRIPTION OF A BASIC INDUSTRY ESSENTIAL TO THE NATIONAL WELFARE.

Coke—SON OF COAL AND PARENT OF MANY INDUSTRIES

This is the story of coke.

It is a little-known story of a giant industry which without fanfare has become, in effect, the father of literally hundreds of other vital enterprises—businesses with a total volume of many billions of dollars a year, employing tens of thousands of American workers.

It is a dramatic story of an industry that almost miraculously extracts from coal the primary chemicals that are used today to manufacture thousands of diverse products ranging from nylon stockings and aspirin tablets to DDT, synthetic rubber and life-saving sulfa drugs.

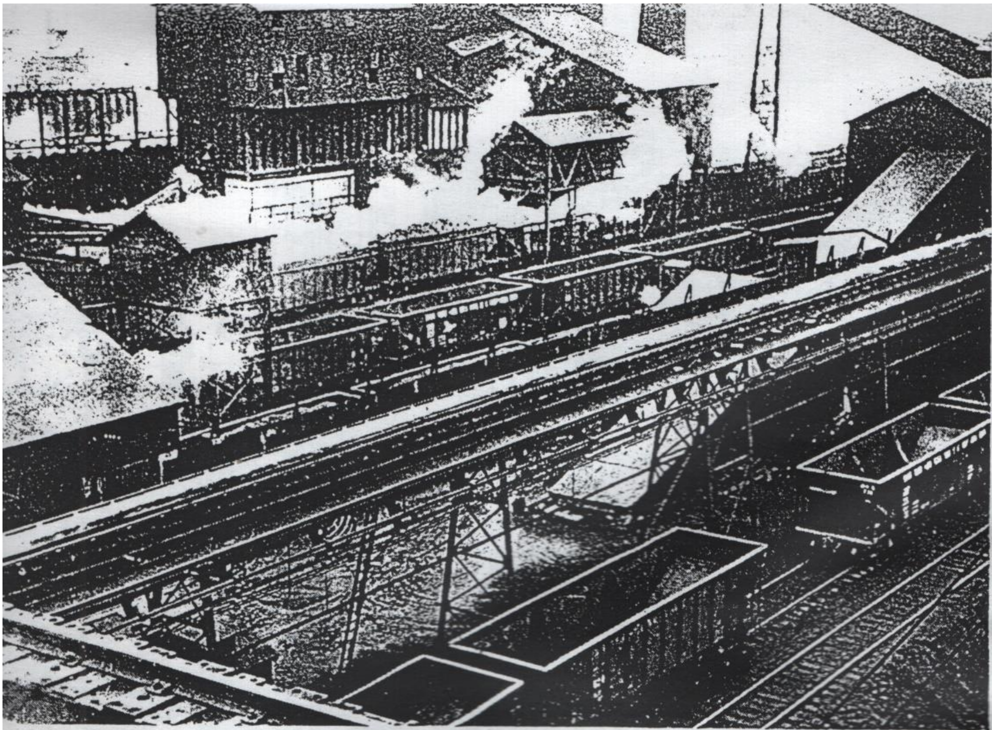
It is a story of vast operations, of complicated manufacturing processes and of a vital part played in the nation's military affairs.

VITAL TO STEEL INDUSTRY

The coke industry today is so important that without it the vital iron and steel industry would be paralyzed. Without it, much of the nation's industrial progress in the last 50 years would have been impossible.

It is a relatively new industry but all of the benefits it has brought to mankind offer only a promise of what still is to come. Science constantly is developing startling new products from chemicals resulting from the manufacture of coke.

Coal moves from the mines to coke plants

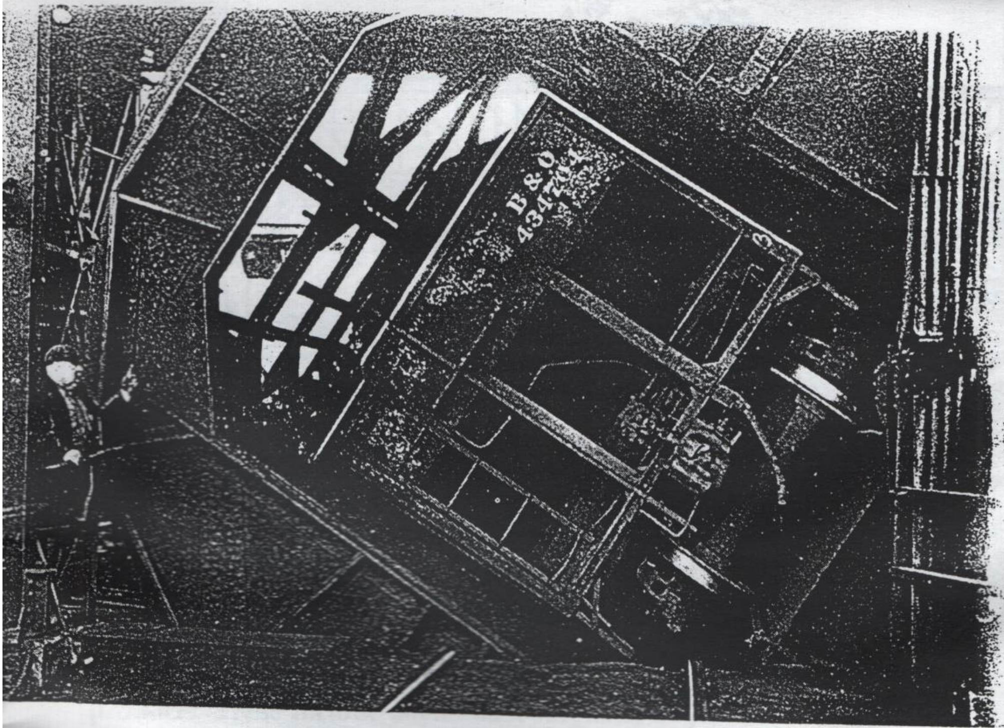


Railroad yards of coke plants are extensive.

In the manufacture of iron and steel, the nation's most vital basic end product, coke is a key ingredient. It is much more important than it is popularly conceived, for it is more than a simple fuel. Coke actually is essential in the metallurgy of the iron-making process, providing the carbon monoxide gas which releases the oxygen from the iron ore, leaving metallic iron.

Charcoal is the only other fuel that has been used for smelting iron with any success and it was substantially discarded by the iron and steel industry many decades ago because of its relatively high cost and its unsuitability to modern mass production.

Coke is used too in the production of gaseous industrial fuels, such as "water gas" and "producer gas", and in the manufacture of low-cost chemical carbon

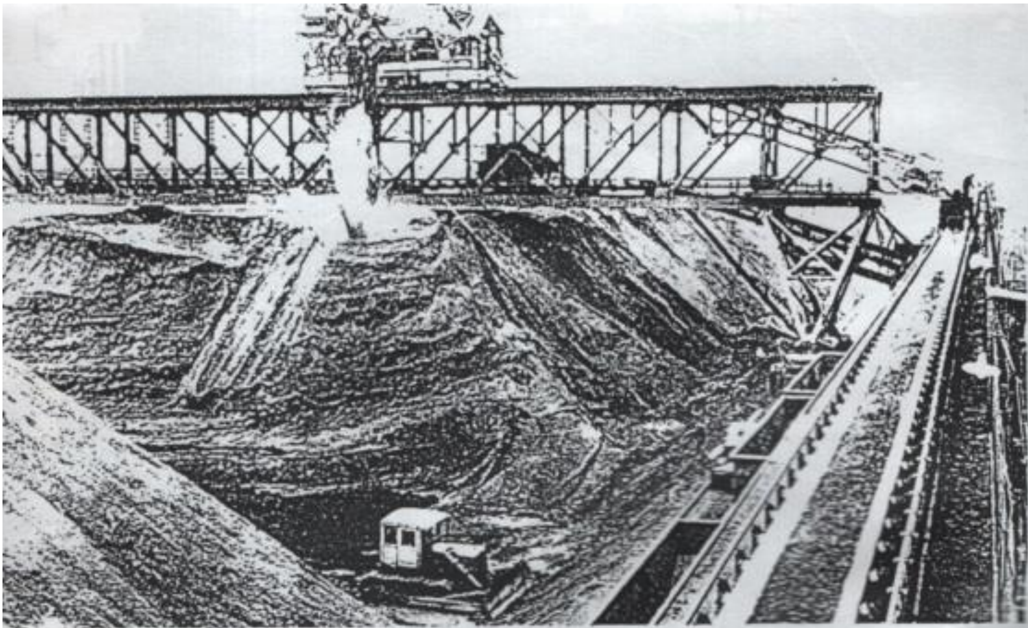


Rotary dumper handles loaded car with ease, tipping it upside down. From a hopper below, coal is carried by conveyor belt either to the crusher or the storage pile.

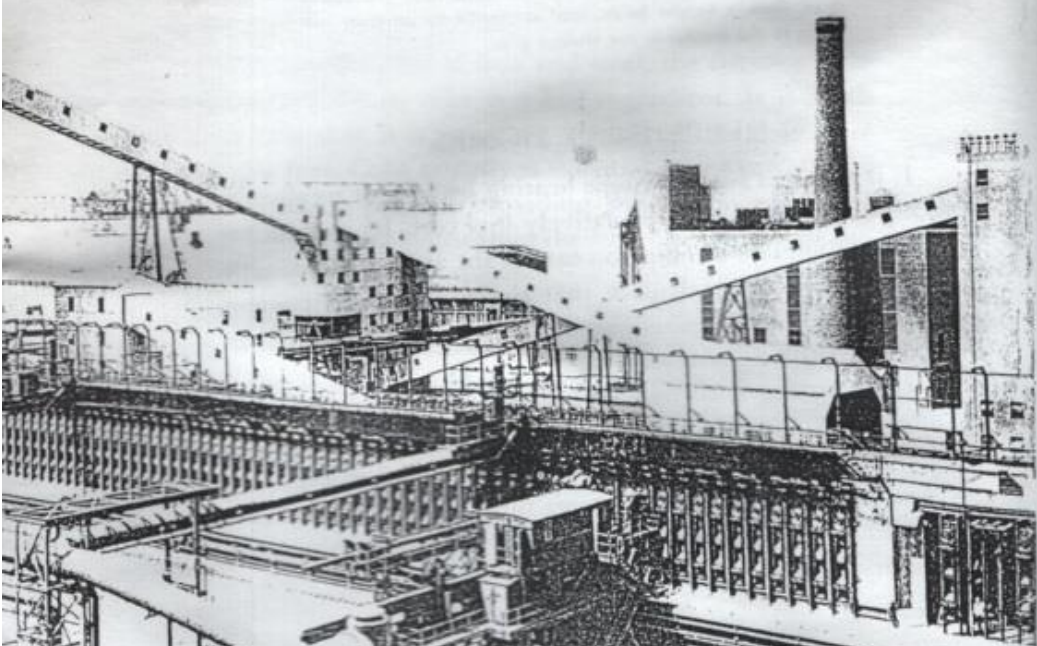
HELPS HEAT HOMES

It is a superb fuel for home heating because of its cleanliness, high heat-content and relatively low cost. Its porous nature makes complete combustion easy in the average home-type furnace. Technicians calculate that the fixed-carbon content (fuel part) of coke is sometimes as much as 10% greater than that of competitive smokeless fuels.

Much of the coke that before 1941 was used for home heating had to go to war and had not returned as recently as early 1949 because of the great need for this fuel in the steel, gas and chemical industries. Greater supplies will be available for homes as soon as abnormal industrial demands are satisfied and additional coke plants completed.



Vast mounds of storage coal are typical of every coke plant. Incoming coal here is carried by conveyor belt to a movable crane bridge which can handle several hundred tons per hour.



PROVIDES PRIMARY CHEMICALS

The coke and coal chemicals industry is proud of the role it plays in providing the primary chemicals that have created so many new industries but only a small fraction—about 15%—of its revenues come from this source. Under present conditions a typical coke plant obtains about 65% of its revenues from coke and around 20% from the sale of gas to industrial plants and city distribution systems.

Generally, it is only after further extensive and expensive processing of the primary coal chemicals that other industries —like chemical and plastics companies—are able to produce their end products.

Actually, the processing of coal results in only eight major items—coke, gas, tar, ammonia, benzol, toluol, xylol, and naphthalene. But from these components, some of which are available economically from no other source, stem many hundreds of other chemicals and literally thousands of end products. These include ammonium sulphate, major source of nitrogen for farm fertilizer, resins for high-grade paints, moth-flakes, dyes, creosote that saves so much of the nation's lumber supply by protecting existing lumber, anti-malarial drug compounds, perfumes, cosmetics, food preservatives, saccharin, and lacquer solvents.

Yields of coal chemicals are relatively small. For instance, a ton of coal yields only 8 gallons of tar, two gallons of benzol, .3 gallon of toluol and 20 pounds of sulphate of ammonia. The sulphate of ammonia yield is obtained only after the coke plant has added 20 pounds of sulphuric acid for each ton of coal. Probably the most extreme example is pyridine, coal-tar derivative used in sulfa drugs and some vitamin compounds, which is recovered at a rate of only one gallon from each 300 tons of coal.

86 PLANTS OPERATING

To make its so-called coal chemicals from which the products are manufactured, the coke industry has invested huge sums. It has been established that the 86 coke plants in the country, most of which are affiliated with iron and steel companies which they supply with coke, have a total investment cost of around $1,000,000,000. The plants would cost more than twice that to reproduce today.

This cost is represented primarily by some 15,000 ovens of a type capable of recovering gas and coal chemicals. The old-fashioned "beehive" ovens, although they cost much less than modern ovens, are utilized today only to meet unusual peak demands for coke because they are uneconomic, requiring comparatively excessive manual labor and are unable to recover the gas and coal chemicals. They were the main source of coke in the late 1800's and early 1900's and were pressed into emergency use during the last war. In the pre-war year of 1938, however, they produced only 2.6% of the nation's coke.

SIZE OF THE INDUSTRY

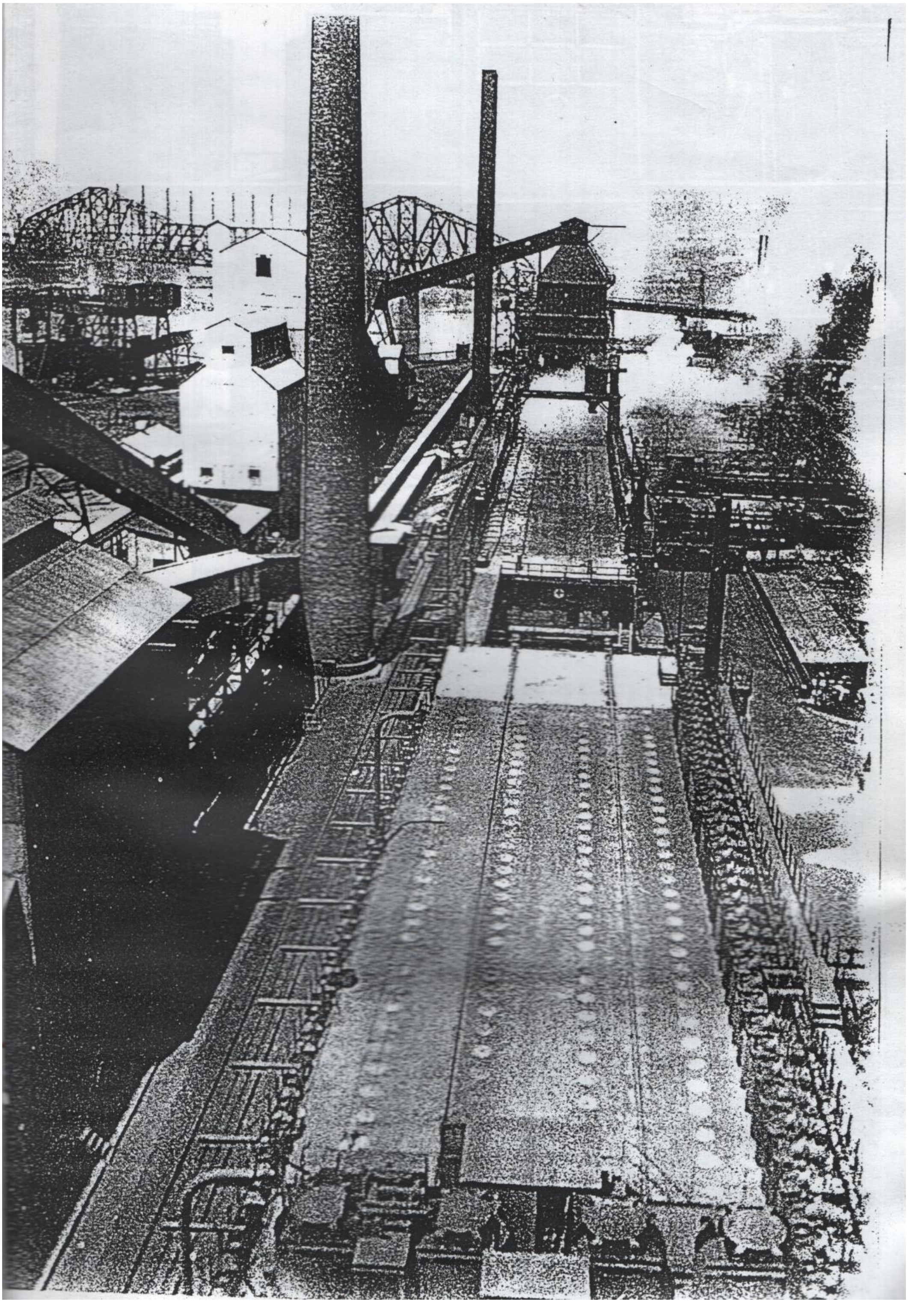
The gigantic size of the coke and coal chemicals industry is shown most effectively with some figures:

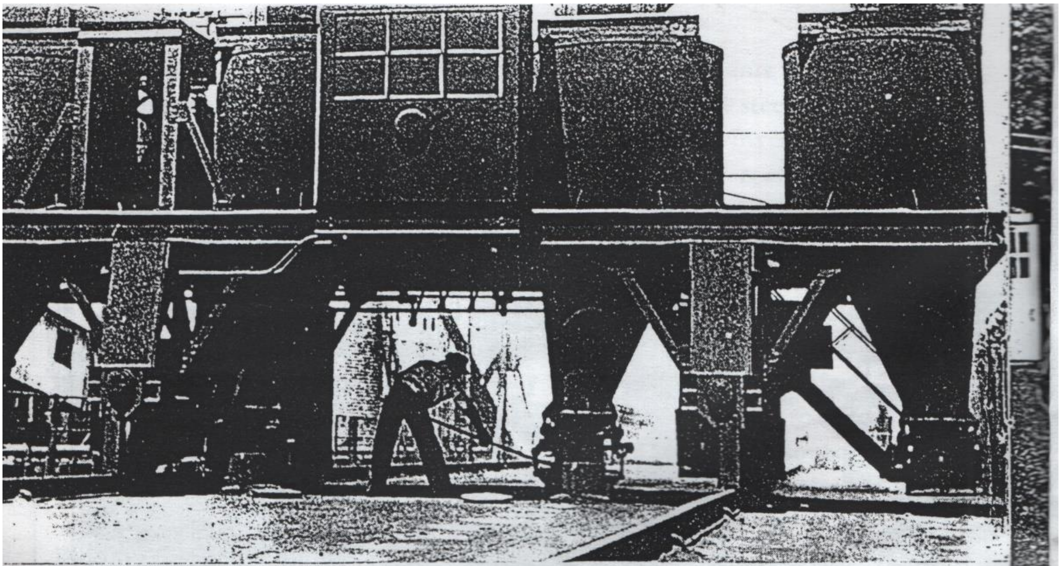
It uses some 97,000,000 tons of bituminous coal annually, about one-sixth of all the bituminous coal mined in the United States. That astronomical figure means the daily consumption, every day in the year, of the contents of about 50 trainloads of 100 cars each. Many of the larger plants use more than 75 carloads a day. Annually, total consumption is equal to more than six solid trainloads stretching from coast to coast.

From this coal, the industry gets about 68,000,000 tons of coke, nearly half a ton for every person in the United States. Approximately 1½ tons of coal are required to make 1 ton of coke.

An average-sized coke plant uses in its manufacturing processes about 10,000,000 gallons of water a day, as much as an entire fair-sized city.

Batteries of modern coke ovens as seen from above. Coke ovens generally average from 14 to 18 inches wide, hold 10 to 22 tons of coal each. Note circular openings for charging ovens. →





A larry car carries coal from the oven storage bin to an oven. Pulverized to an almost sandlike consistency, the coal runs out of the funnels into the oven through circular openings. Note lids for openings near workman.

GAS PRODUCTION HUGE

Total annual gas production by the industry, other than that used to heat its own ovens, amounts to the stupendous figure of 600,000,000,000 cubic feet. This is enough to fill all the average gas needs throughout the year of about 33 cities of a million population each. Substantial additional amounts of "water gas" and "producer gas" are manufactured from coke in stand-by plants. In producing "water gas" or "blue gas", these plants force steam and air through the hot coke. Oil injected into this hot gas vaporizes and increases its heat value. Producer gas is developed by forcing air through hot coke.

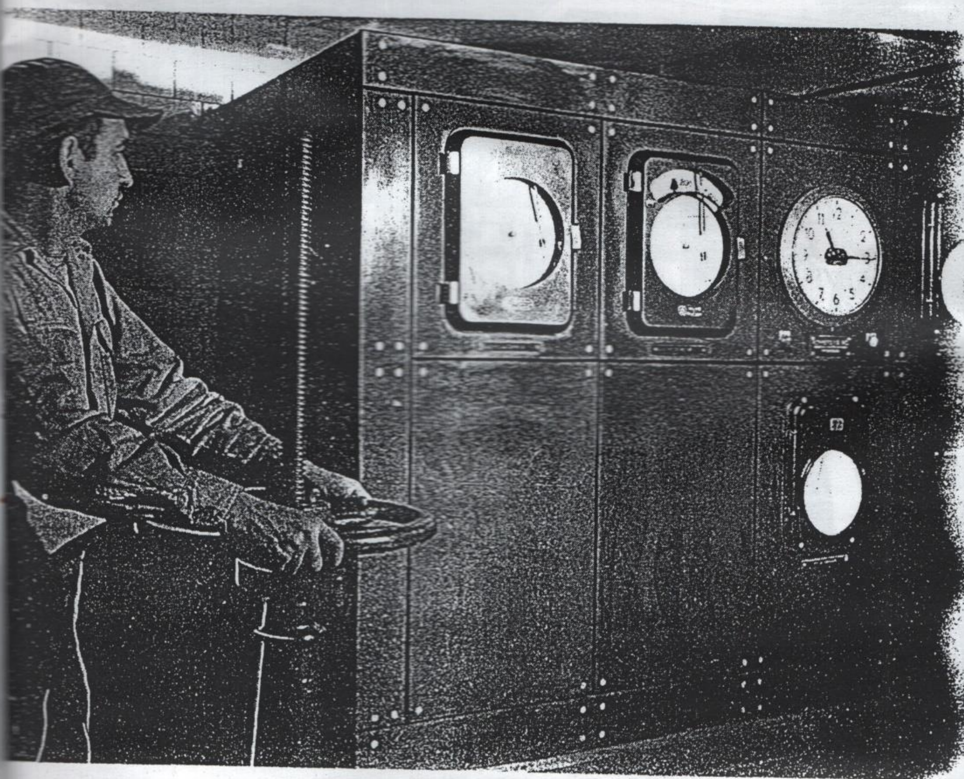
Generally, the smaller sizes of coke are used in these processes. The stand-by plants are operated by many coke and gas companies, which use the resultant gases for heating their ovens, thereby releasing more of the higher-grade coke-oven gas into the mains for public consumption. The lower-grade gases also are used in periods of peak-demand in city mains after they have been enriched with natural gas, or other gases of high heat value. Incidentally, there is no water in the "water gas" produced.

PLANTS BEWILDERING, SPECTACULAR

The manufacture of coke and its co-products is a fascinating operation. The first impression of a modern plant may be one of bewilderment—of pipes and huge tubes running in all directions, of great clouds of steam, of vast piles of coal, of sounds of bells and whistles from unexpected places and of spectacular, flaming slabs of coke being pushed from the narrow openings of glowing ovens.

Soon one gets the pattern of things. The confusing maze of pipes and conveyor belts and bridge cranes quickly resolves itself into an orderly, efficient way of doing things. But the feeling of smallness in this labyrinth may persist—plus a strong

Heat in ovens is registered and controlled from this point.



inclination to run for shelter when one feels the withering heat of one of those white-hot slabs of coke being pushed from an oven. In an average size plant containing approximately 200 ovens, an oven is pushed every 5 minutes—24 hours a a day and 365 days a year. Each oven requires approximately 16 hours to complete the coking process.

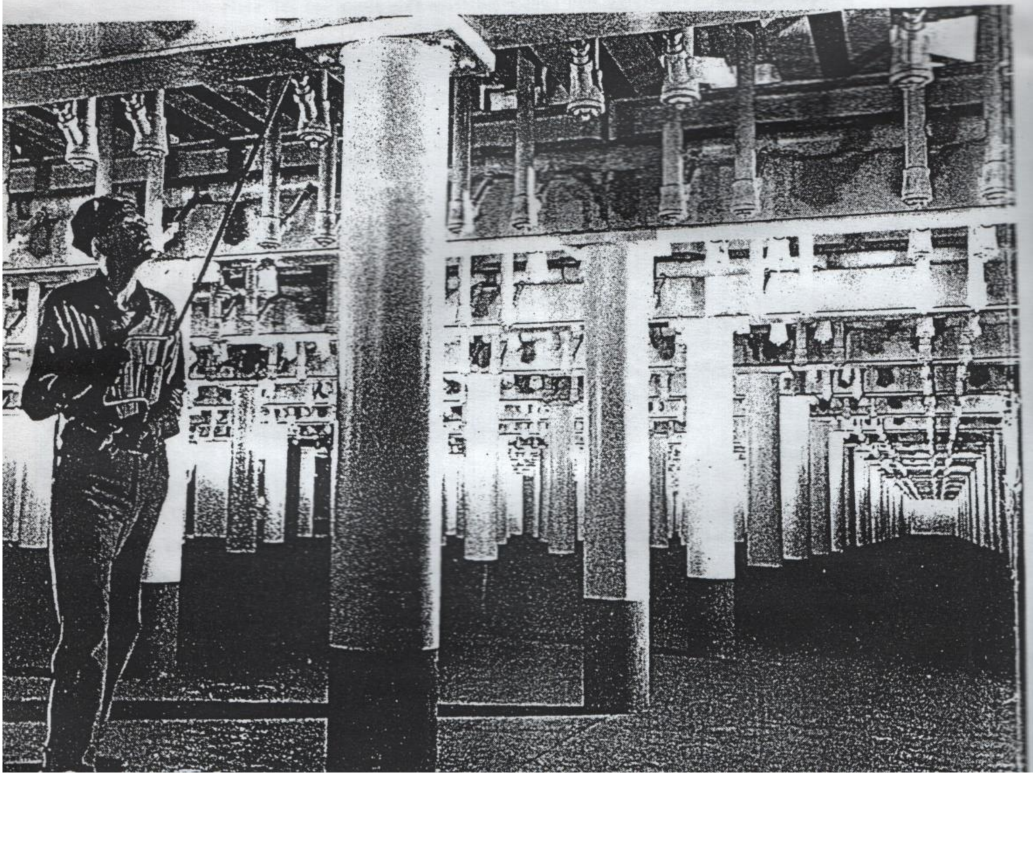
HOW COKE IS MADE

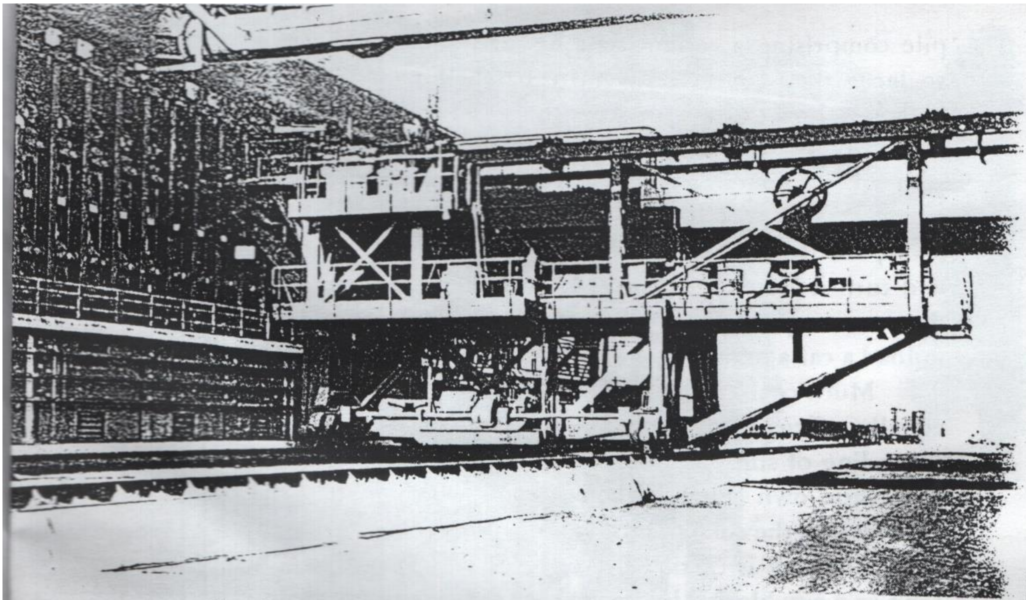
But let's start at the beginning.

Most coke plants aim to have on hand at least a 30-day supply of coal to insure continuous operation because coke production cannot be stopped abruptly without causing damage to the ovens.

It requires a month or more to heat gradually the sensitive ovens when they are first placed in production. This insures uniform expansion of the silica brick ovens. Cooling also has to be done slowly to avoid uneven contraction and consequent

The "basement" of a battery of coke ovens.





Ramming arm of a "pusher" is over 50 feet long. Like a snow-plow, it must push the coke through the entire length of a coke oven.

warping or cracking. Coke plants, therefore, keep ovens in constant production, even though they may reduce output rates by cutting down temperatures.

Much of the temperature flexibility and long life of modern coke ovens results from the adoption by American engineers of silica brick, a product which had been discarded as unsuitable by European coke-oven designers. The American engineers discovered that silica brick expands rapidly while oven temperatures are rising to 1200 degrees but thereafter, up to temperatures of 2900 degrees, is extremely stable. Oven temperatures, they found, can be changed rapidly within the range of 1200 to 2900 degrees without causing any substantial contraction or expansion of the brick. This meant a great reduction of oven cracks and oven repairs. Today, silica brick is used throughout the world.

COAL PILE ENORMOUS

The huge amounts of coal required to keep the ovens in constant operation are stored precisely in separate piles, each pile comprising a certain type of coal. Some of the piles are so large they'd crowd an entire baseball park. Some are as high as a three or four-story building. Collections of these piles may extend for a half-mile or more in several directions.

Many modern plants have equipment which handles arriving cars of coal like so many toys. Powerful clamps seize a car, loaded with 70 tons of coal, lift it easily into the air and turn it upside down to empty its contents into a hopper, then set it gently back onto the track. Such equipment can unload a car a minute.

Much coal arrives at the coke plants by water routes and equally efficient equipment has been devised for the quick unloading of ships and barges. This equipment includes boats with their own conveyor belt systems which unload the coal rapidly into the coke plants' storage piles.

The coal is carried by conveyor belt to bridge cranes as long as a city block. Unless the coal is needed immediately, the cranes distribute it to the different piles. It is essential that the different coals be kept in separate piles. Each pile contains a certain type of coal, each with different characteristics. All types, however, have the ability to "coke" or cake. All coal does not have this ability.

COKING COAL SUPPLIES DWINDLE

The industry is seriously concerned about the use of coking coals for purposes other than the manufacture of coke when such other purposes could use non-coking or poorly-coking coals.

It cannot be emphasized too strongly, the industry feels, that all types of coal will not "coke", or form into a hard, porous lump when it is heated. Known national reserves of high-grade coking coal are sufficient for only about 100 years of operations at the present rate of consumption while re-

Making ready for a "push" of coke. →

serves of non-coking or poorly-coking coals—generally just as good for ordinary purposes—are sufficient for 1,000 years or more.

It seems evident that supplies of coking coals should be conserved and that this highly-specialized fuel should not be used, as it is being used at present, for purposes other than coke-making.

COAL BLENDED CAREFULLY

Most coke plants find that the quality of coke and the quality and quantity of coal chemicals and gas produced can best be controlled on an economical basis by blending various types of high-volatile and low-volatile bituminous coals of the coking type.

The quality of the coke, including its mechanical strength, and the amounts of coal chemicals to be produced also can be regulated to some extent by the temperatures to which the ovens are heated. Considerable strength is required for coke used in blast furnaces where it must support the weight of tons of iron ore and limestone.

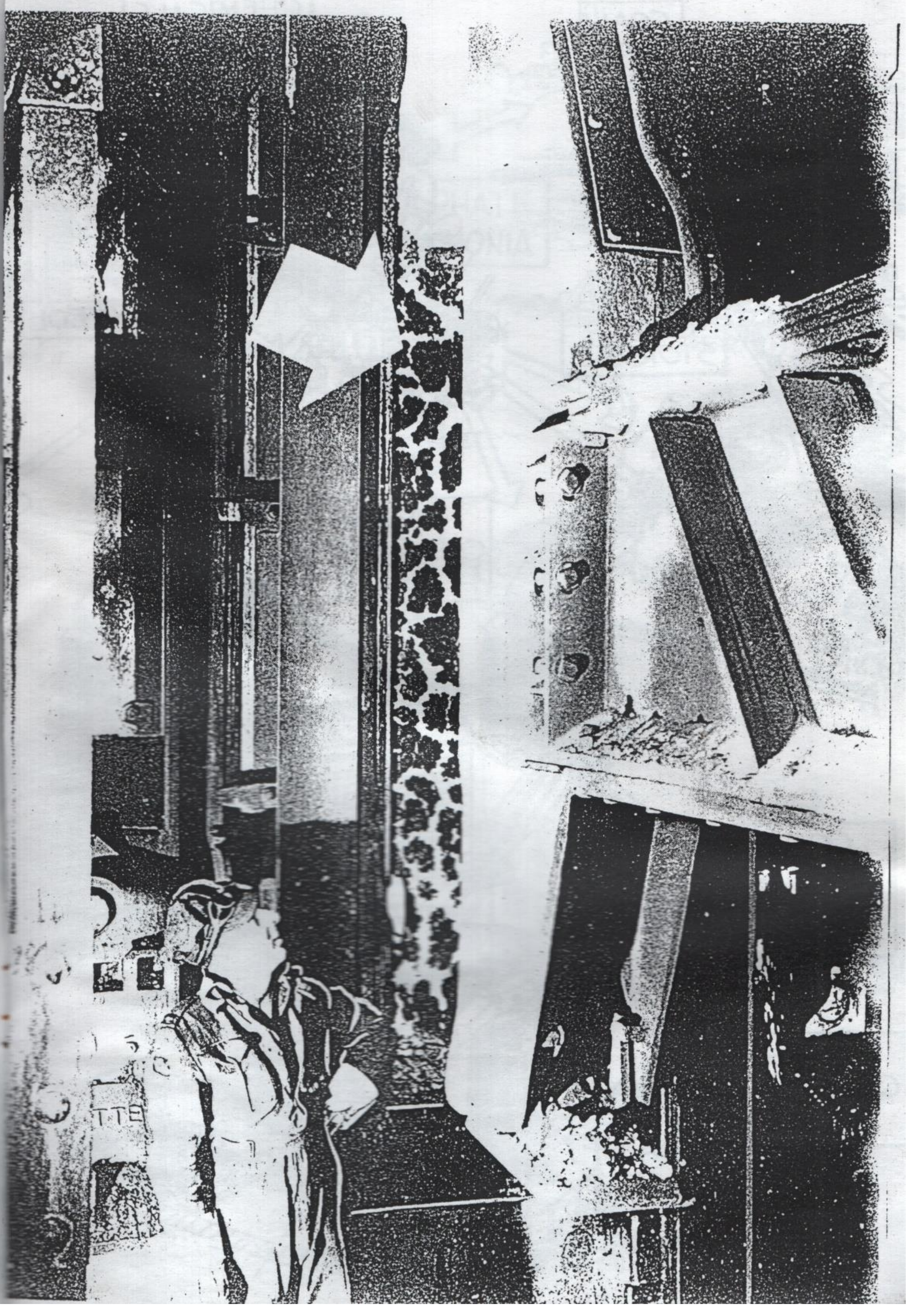
Coal blends in different coke plants vary widely, depending largely on the availability of different types of coal and the purpose for which the coke is to be used. There is no precise formula but a typical blend is 70% high-volatile coal and 30% low-volatile. Most plants use four different types of coal in their blends to get the best results.

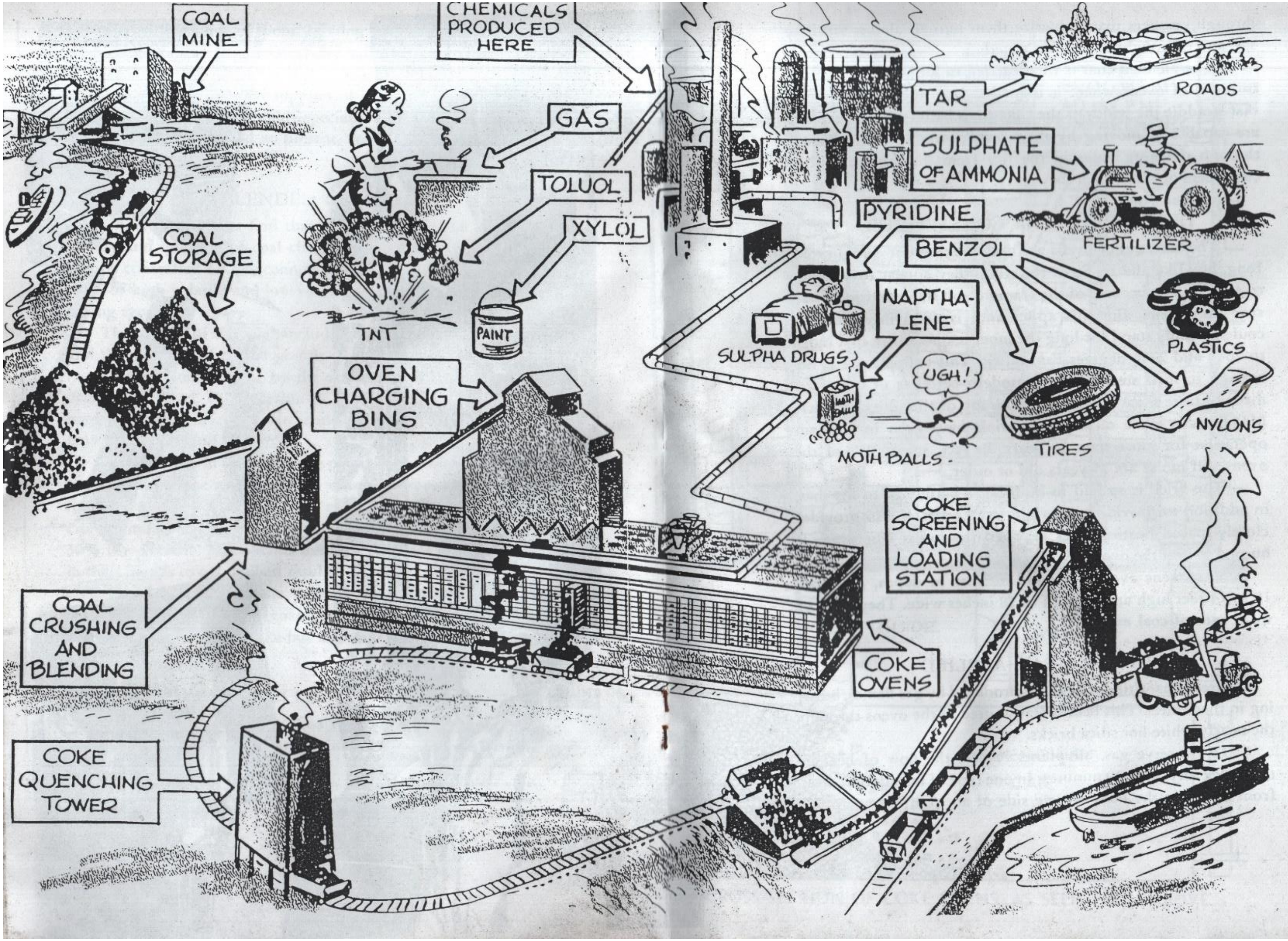
Good coke always is a primary objective but some gas companies, which operate coke plants, use types of coal that not only produce good coke but also give maximum yields of gas.

OVENS FILLED AT TOP

Coal blending is simple. Coals deposited in different bins by conveyor belts are dropped in the proper proportions

Doors of an oven are removed and "pusher" starts to shove white-hot coke (shown by white arrow) out the other side of the oven. →





COAL MINE
COAL STORAGE
CHEMICALS PRODUCED HERE
GAS
TOLUOL
XYLOL
TNT
PAINT
OVEN CHARGING BINS
COAL CRUSHING AND BLENDING
COKE QUENCHING TOWER
TAR
ROADS
SULPHATE OF AMMONIA
FERTILIZER
PYRIDINE
BENZOL
NAPTHA-LENE
SULPHA DRUGS
MOTH BALLS
UGH!
PLASTICS
TIRES
NYLONS
COKE SCREENING AND LOADING STATION
COKE OVENS

through crushers that pulverize them into an almost sandlike size and thoroughly mix them together.

The blended coal is then carried to large bins above the batteries of ovens where it is loaded into so-called larry cars that straddle the width of the coke-oven battery. The larry cars are capable of moving by their own power to fill the ovens through charging holes in the top from the big funnel-like containers of coal which they carry.

HOW OVENS ARE CONSTRUCTED

The batteries of ovens are drab-looking but complicated, long, box-like affairs. From the sides, they appear to be made of steel or iron because of the framing and the repetitious, narrow iron doors. But this appearance is deceiving. No steel could possibly stand for long the inner temperatures that range to 2600 and 2700 degrees Fahrenheit. This temperature is hot enough to melt steel. Instead, modern batteries of ovens are made of pure silica brick, faced with top quality fire clay brick. Many ovens made of these materials have been in constant operation for more than 20 years. In fact, some 40% of the ovens still in use are 25 years old or older.

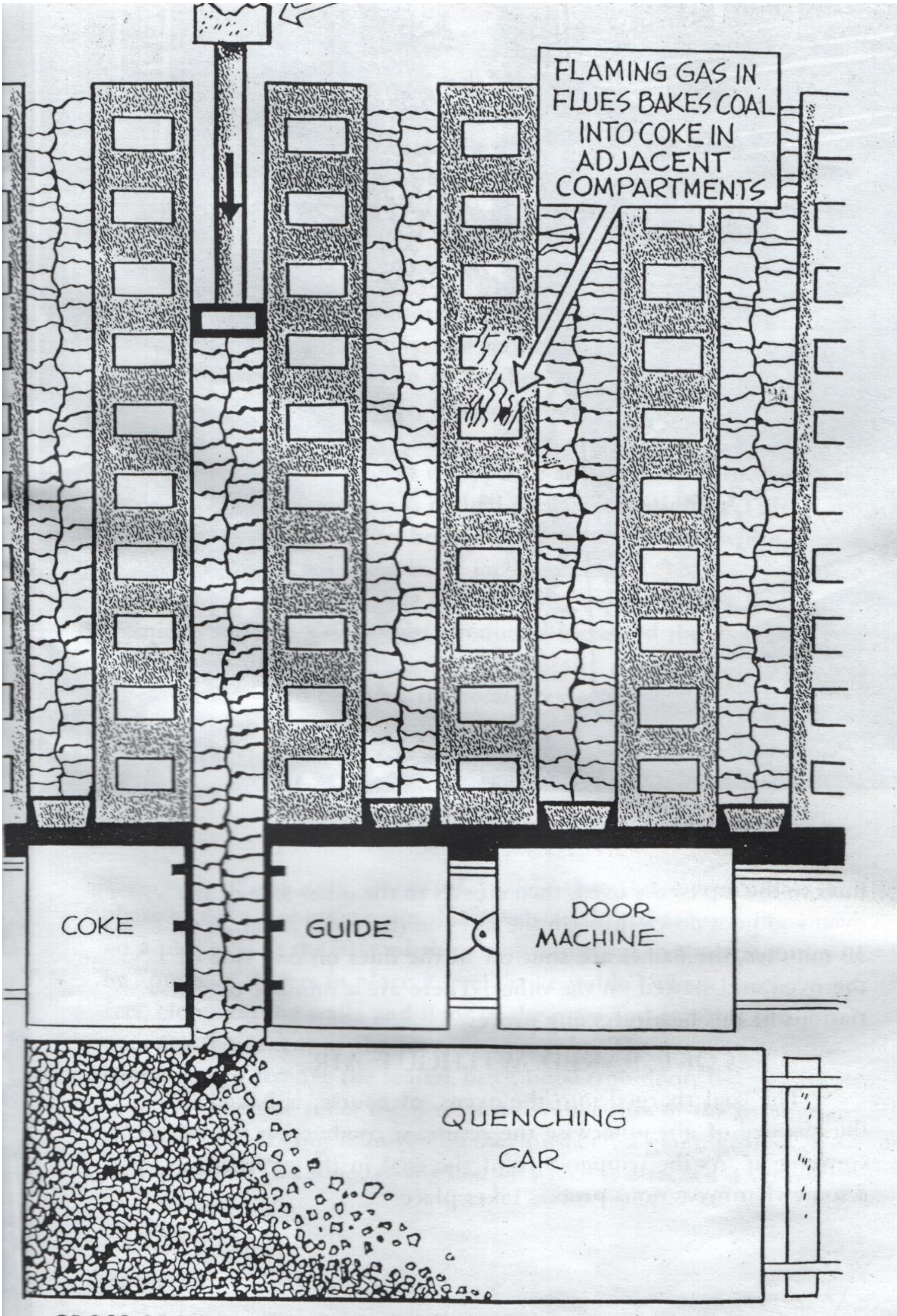
The brick is so laid in building a battery of ovens that, in addition to providing gas-tight oven walls, it also provides closely-spaced heating flues between the ovens where gas is burned to heat the ovens.

The ovens average around 40 feet in depth, are from 10 to 14 feet high and only 14 to 18 inches wide. They hold 10 to 22 tons of coal each.

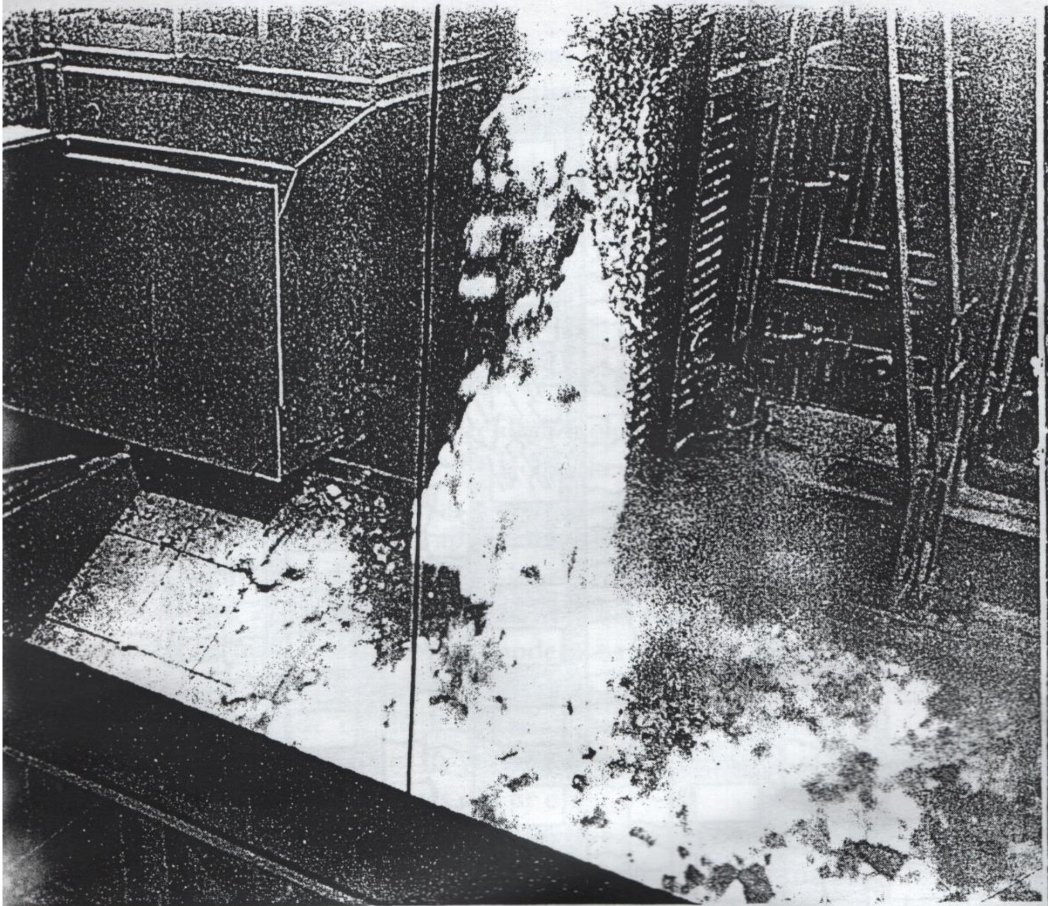
GREAT HEAT APPLIED

Great quantities of heat are produced by gas flames, burning in these flues. This heat is transmitted to the ovens through the nearly-white-hot silica bricks.

To conserve gas, all plants reverse the flow of heat in the flues every 20 or 30 minutes. In one type of installation, heat from flames in the flues on one side of an oven passes up the



CROSS SECTION OF COKE OVENS, AS SEEN FROM ABOVE.



After a 16-hour baking process, coke is pushed out of an oven.

flues to the top of the oven, then crosses to the other side of the oven and goes down through the flues on that side. After 20 or 30 minutes, the flames are shut off in the flues on one side of the oven and started on the other. There are a number of variations of this heat-reversing process.

COKE BAKED WITHOUT AIR

The coal charged into the ovens, of course, is baked in the absence of air; otherwise the resultant combustion would consume it. As the temperature of the coal in the oven rises, a somewhat mysterious process takes place.

First, the coal at the sides of the ovens—the point of highest temperature—starts to melt at the rate of about ½ inch an hour. It actually melts, reaching a consistency like thick tar. It would be capable of flowing slowly. Farther in toward the center of the oven, the coal still remains approximately intact.

COAL BUBBLES, THEN SOLIDIFIES

Tiny bubbles form in the tar-like section of coal, as it gives up its vapors and gases. It is this bubbling that causes the porosity of coke. Finally, the molten portion of the coal again solidifies and, because of further shrinkage while it is giving off its volatile matter, breaks up into the characteristic coke lumps.

This process goes on at the ½-inch-an-hour rate until the center section of the coal has melted and again solidifies. This normally requires about an hour for each inch of oven width, or about 17 hours for an oven 17 inches wide.

During the war, when demands for coke and coal and chemicals were so great, most producers increased the operating temperature of their ovens—incidentally shortening their potential life—and bettered the total previous coking time by about 10% or more. Some operators of 17-inch ovens, for instance, were able to complete a coking operation in a little more than 14 hours.

"PUSH" IS SPECTACULAR

It is at the completion of coking that the spectacular phase of coke making occurs. A cleverly-equipped car running on a platform at the base of the ovens moves up to the one to be "pushed". It sets in place a steel "coke guide" which, in effect, elongates the walls and floor of the oven and controls the outward movement of the incandescent coke. The car also has equipment to remove the sealed, brick-lined iron door.

At the same time, the door at the other side of the oven 40 feet away is being removed by the "pusher", a giant, geared ram nearly 50 feet long, to the end of which is attached a ver-

In this quenching tower, water is sprayed on the flaming coke, leaving however enough heat in the coke to dry it. Coke is carried to the tower in a specially built, sloping-bottom car. After quenching, the car is moved to a wharf where the coke is dumped to permit drying before further preparations.

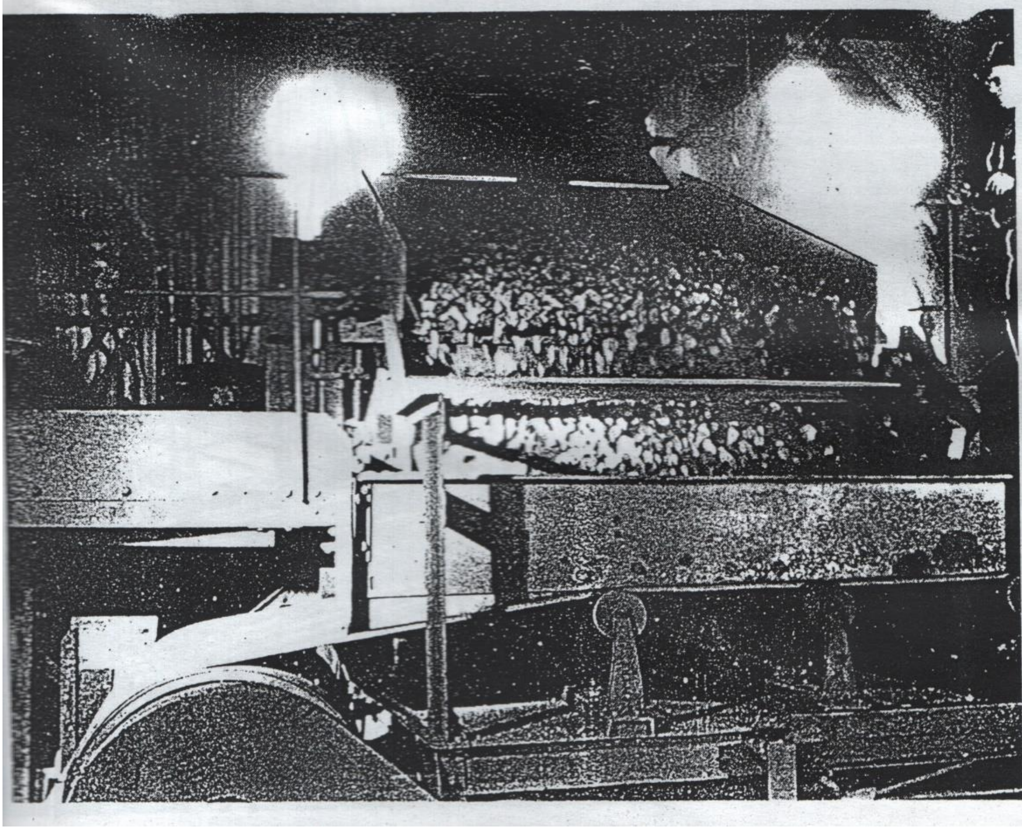
tical head just a little smaller than the inside dimensions of the oven.

The "pusher" receives a go-ahead whistle from the other side of the oven and, like an irresistible snow plow, slowly forces out the coke through the guide.

HEAT FELT FOR SOME DISTANCE

The coke slides out smoothly and retains its smooth, slab-like appearance until it has moved almost to the end of the coke guide, which extends out almost 5 feet from the oven opening. Then sections break off. Flames shoot into the air as combustion starts when the hot coke comes in contact with the

After it is crushed, the coke moves over screens. Various sizes meet the needs of home and industry.



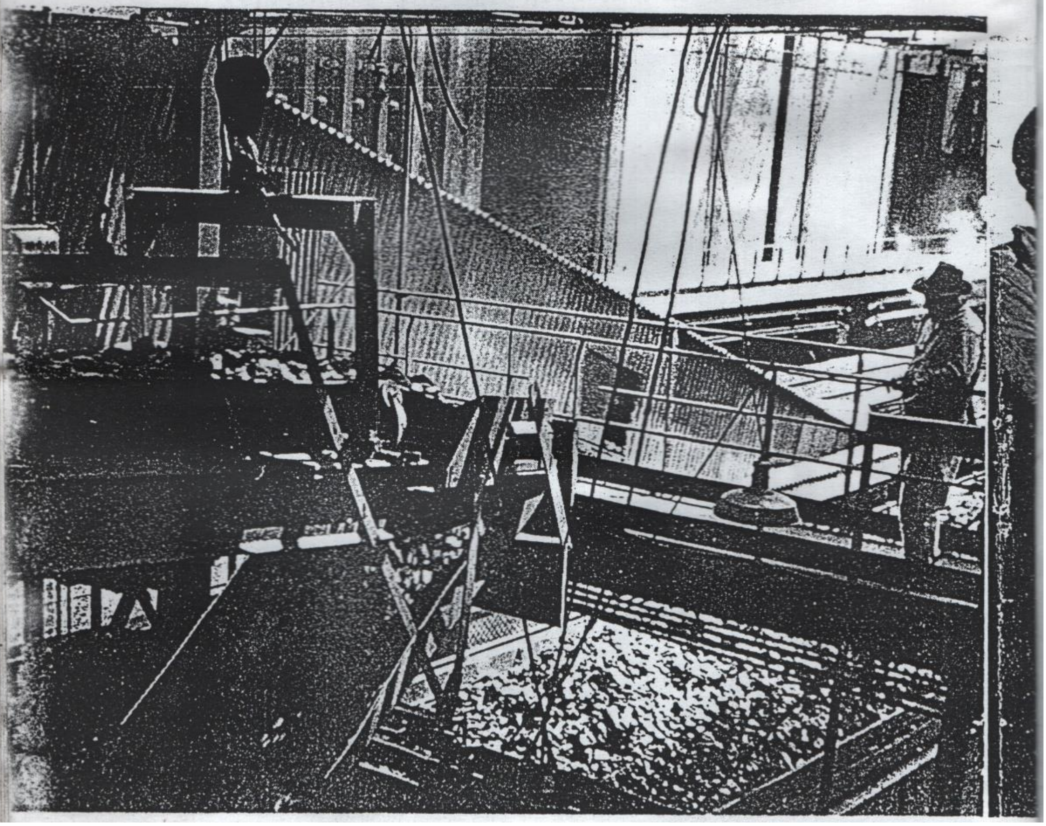
air and the fiery mass of coke drops into a specially-built, steel dump car waiting on railroad tracks below.

From a distance of about 35 feet, the heat felt by an unprotected observer is so terrific as to be frightening to those experiencing it for the first time. But it is just for a moment. Everything is handled with such an easy, almost unconcerned dispatch that one can't help be impressed by the efficiency of the relatively few workmen required for such a big operation.

WATER QUENCHES FLAMING COKE

The dump car filled with the flaming coke is rapidly pushed by an electric locomotive into a "quenching tower", where water is showered onto the mass. The water pours from the perforated sides of the dump car into a canal for further

A conveyor belt carries the screened coke to railroad cars.



New type conveyor truck for home deliveries of coke.

use. Great clouds of vapor float out of the top of the tower.

Just enough water is dumped onto the coke to cool it below the glowing stage. Enough heat is left in the coke to cause it to dry itself. It is deposited on a sloping brick or cast iron platform from which conveyor belts carry it to screens for sorting into various sizes.

HOW CHEMICALS ARE MADE

The production of coal chemicals is a process in itself. It accounts for much of the tangled spiderweb of piping in a modern coke plant and requires much expensive equipment.

At the top of each oven are one or two outlets for the hot gases and vapors that form in the coking process. Each of the pipes connecting to these outlets leads in a few feet to a large collector main that carries the gas, tar, ammonia and light oils to the processing equipment and towers.

TAR, AMMONIA, EXTRACTED FIRST

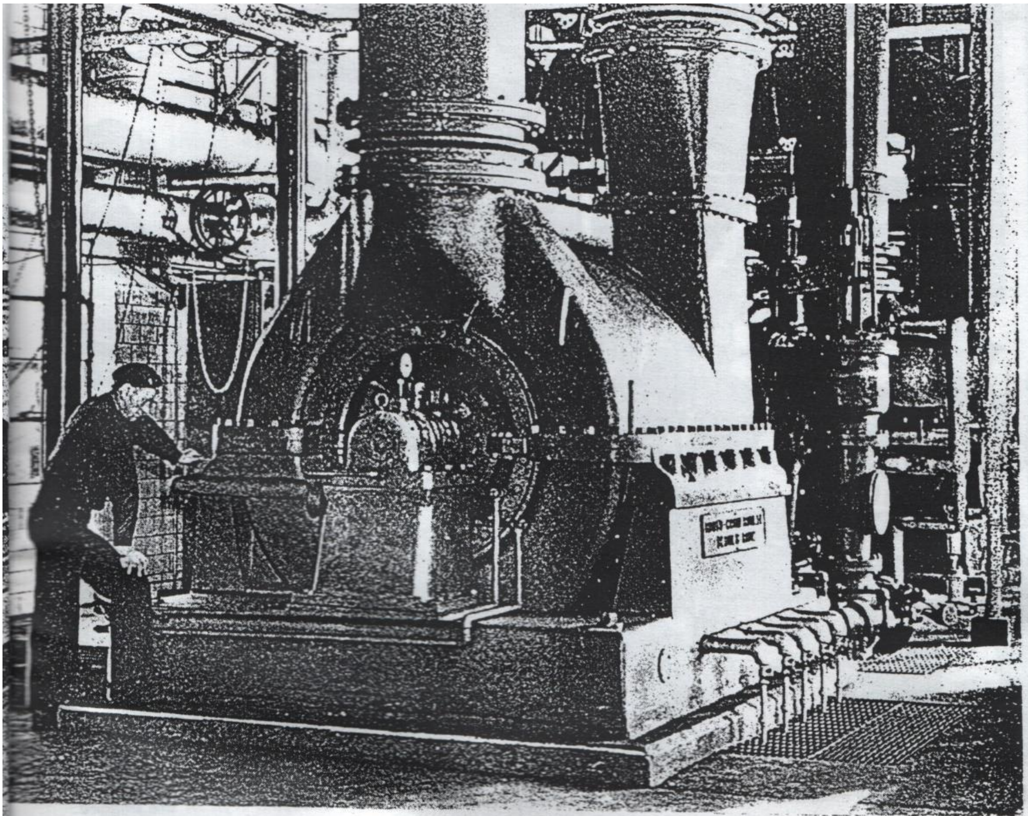
Just as it leaves the ovens, the gas is sprayed with am-

Workman checks oven heat with optical pyrometer. Pipes in background carry hot vapors from the ovens for the recovery of chemicals and gas.

monia water. This condenses some of the tar and ammonia from the gas into a liquid and this liquid moves through the main along with the gases until it reaches a settling tank, where the tar and ammonia water separate by their difference in gravity.

Some of the ammonia water is pumped back into the pipes to help condensation. The rest is pumped to storage tanks. All of the tar goes to storage tanks for shipment to tar distillers or for use as fuel.

Meanwhile, the gas passes around and between many cold-water cooling tubes in a "primary cooler", or it may be cooled directly with cool ammonia liquor. This further cool-

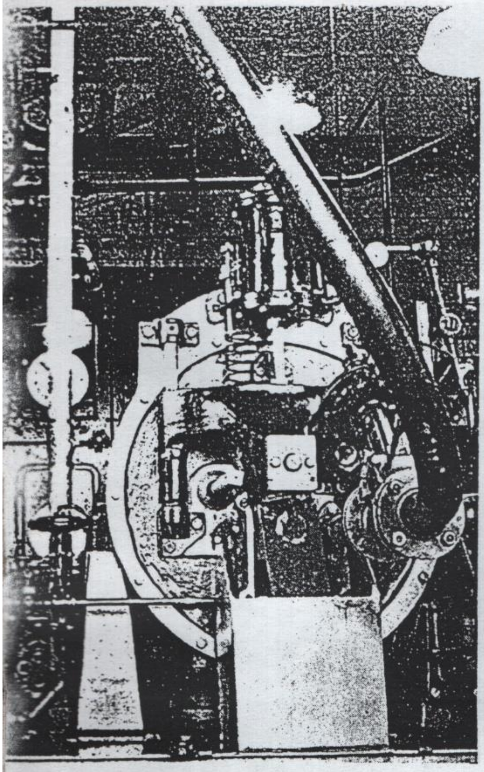


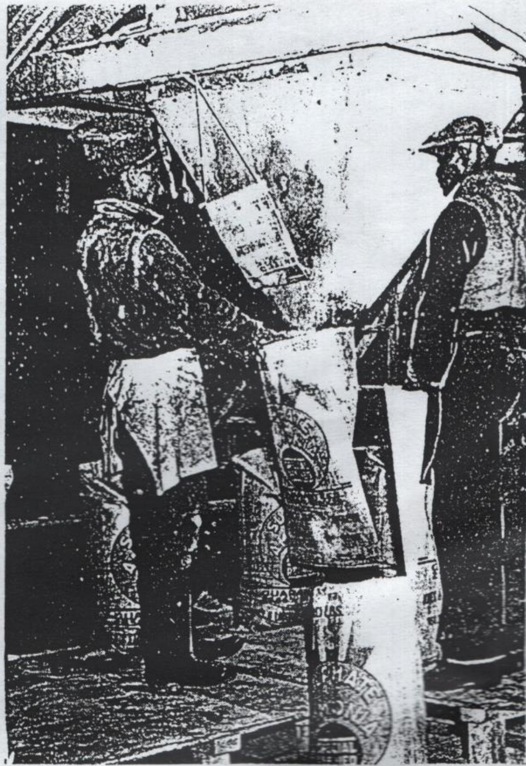
Centrifugal gas pump exhausts gas from ovens and forces it through chemical making facilities into gas holder.

ing of the gas separates out more tar and ammonia. The final traces of tar are removed by tar extractors, usually consisting of apparatus designed to pass the gas through a highly-charged electrical field.

THEN AMMONIUM SULPHATE

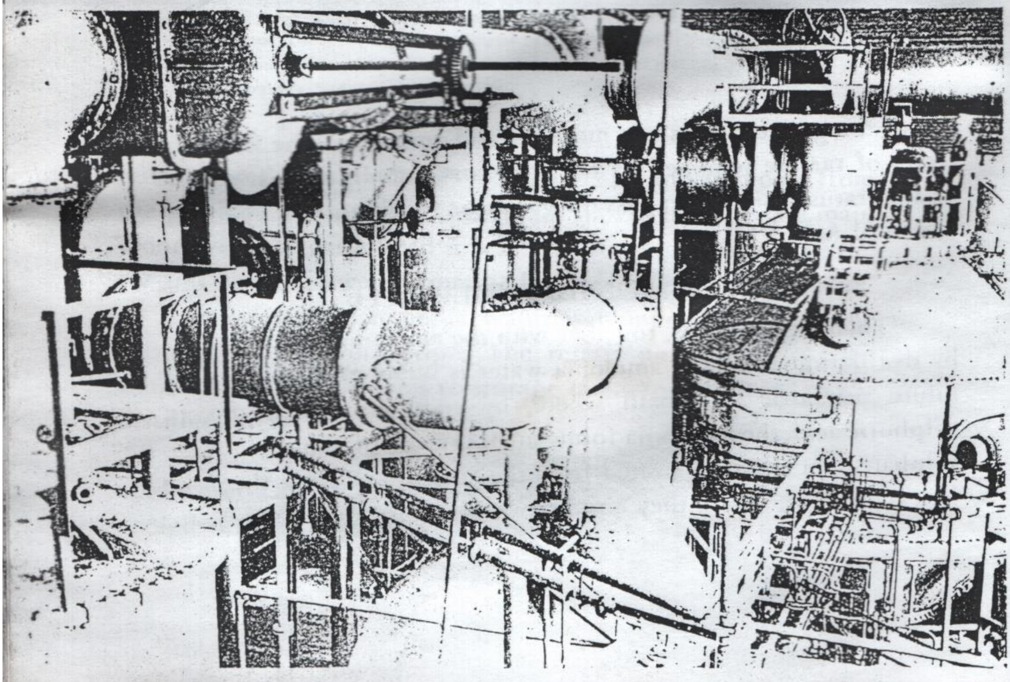
Thereafter the gas, together with the ammonia recovered by distillation from the ammonia water is bubbled through a dilute sulphuric acid bath where, by combining with the sulphuric acid, the ammonia forms small crystals of ammonium sulphate. These are separated from the acid by whirling them in a centrifuge, where they also are washed with water.





An automatic sulphate of ammonia drier.

Specially refined sulphate of ammonia crystals are bagged.



NEXT COMES NAPHTHALENE

The dilute acid used in this process is treated continuously in some plants to extract the small amounts of pyridine it has absorbed from the gas.

Now the gas, which has become heated again in the process of making the sulphate of ammonia, goes into another cooling tower where it is cooled and the naphthalene is "scrubbed out" by spraying with water. This naphthalene settles out in the form of tiny, yellow crystals. The whiteness of mothballs and mothflakes made from naphthalene is obtained by further refining.

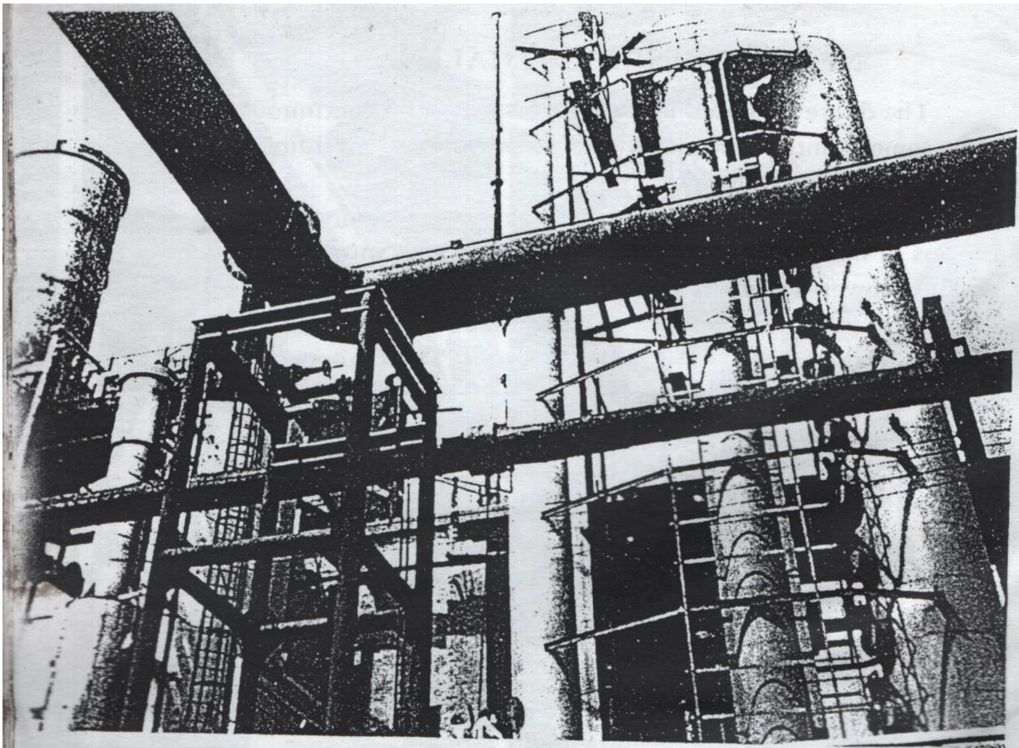
The remainder of the extractable organic material in the gas, known as "light oil", is separated by "scrubbing" it in a tower packed with one of various diffusing materials which provide a large amount of surface. This scrubbing operation is done with a petroleum oil capable of absorbing practically all of the "light oil" present in the gas. The "light oil" is recovered from the petroleum oil by distillation. The petroleum oil is used over and over again, with little loss.

BENZOL, TOLUOL AND XYLOL

Separation of the "light oil" into benzol, toluol and xylol is a rather involved operation, which includes several distillation steps and baths of sulphuric acid and caustic soda. Benzol, toluol, and xylol have different boiling points and they are separated finally by distillation.

REMAINING GAS IS TREATED

The remaining gas still contains a little sulphur and when gas is to be used for home and certain industrial uses, the sulphur is removed by passing the gas through iron ore, which absorbs the sulphur. The same result also can be achieved with newly-developed chemical processes, some of which recover the sulphur as a commercial product.



The highly important chemicals—benzol, toluol and xylol are refined in these rectifying columns.

HISTORY

The foregoing description of processes in a modern coke plant represents the methods arrived at only after centuries of effort. Several centuries ago, when charcoal was being used in the manufacture of iron, someone discovered that coke could be made by placing coal in piles containing flues formed of large-sized lumps. The piles were covered with wet straw and leaves to exclude the air.

Later this method was improved upon by the construction of brick chimneys to act as flues and still later, in the late 1700's, permanent "beehive" ovens came into general use.

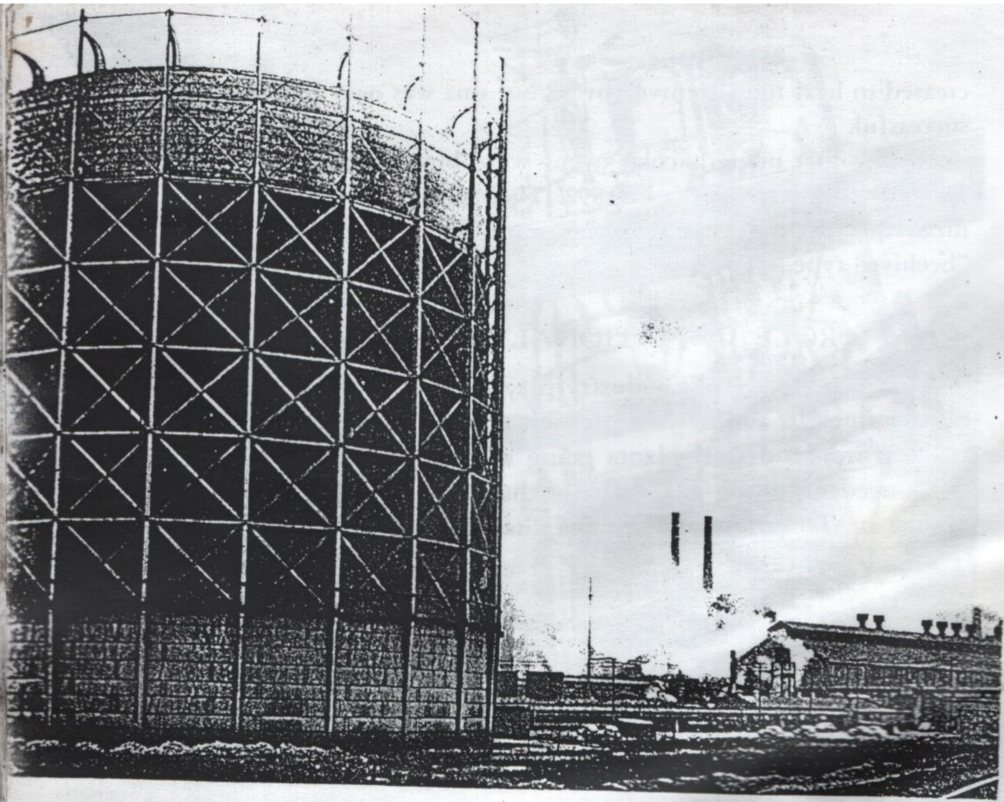
"Beehive" ovens are dome-like, brick structures in which coal is coked with reasonable efficiency. However, all the chemicals and gas are wasted. Some attempt was made to use the gas created to heat the "beehive" ovens but this was only partially successful.

The first modern coke ovens were built in the United States at Syracuse, N. Y. in 1892. Their efficiency was recognized quickly and modern ovens soon began to replace the "beehive" type.

ROLE IN NATIONAL DEFENSE

The part the coke industry played during the war was outstanding. In addition to providing the metallurgical fuel to keep iron and steel plants going at capacity, it furnished much-needed heating gas, much of the toloul for T.N.T. and all the benzol so essential to the vital synthetic rubber pro-

Liquid chemicals leave plant in tank cars.



This gas holder stores 5,000,000 cubic feet of gas. Such an amount represents only a few hours of production for the average coke plant.

gram, phenol for plastic shell detonators and for the waterproof resins that made possible such war equipment as the speedy plywood PT boats and the basic ingredients for literally hundreds of other essential war items.

THE IMPORTANCE OF COKE

It is only through the production of coke that many of the thousands of products stemming from coal can be recovered and utilized for the benefit of mankind. Bituminous coal has been described by Fortune Magazine as "the greatest and grandest resource that the North American continent possesses" and as the "substance that lies at the root of the whole U. S. industrial economy."

Much of coal's greatness comes only through its transformation into coke.

Fortune Magazine described the coal industry as "more basic than steel; upon which even steel depends; upon which the great and magnificently ingenious chemical industry in a large part relies—in turn the producer of fertilizers for the entire agricultural cycle; of drugs and dyes; of fabrics, paints and plastics."

Coal, it is true, is the parent of all this. But it is coke, the son, that is actually doing it.

COMPLIMENTS OF

KOPPERS COMPANY, INC.

ENGINEERING AND CONSTRUCTION DIVISION

KOPPERS

PITTSBURGH 19, PA.

PRINTED IN U.S.A.
THIRD PRINTING