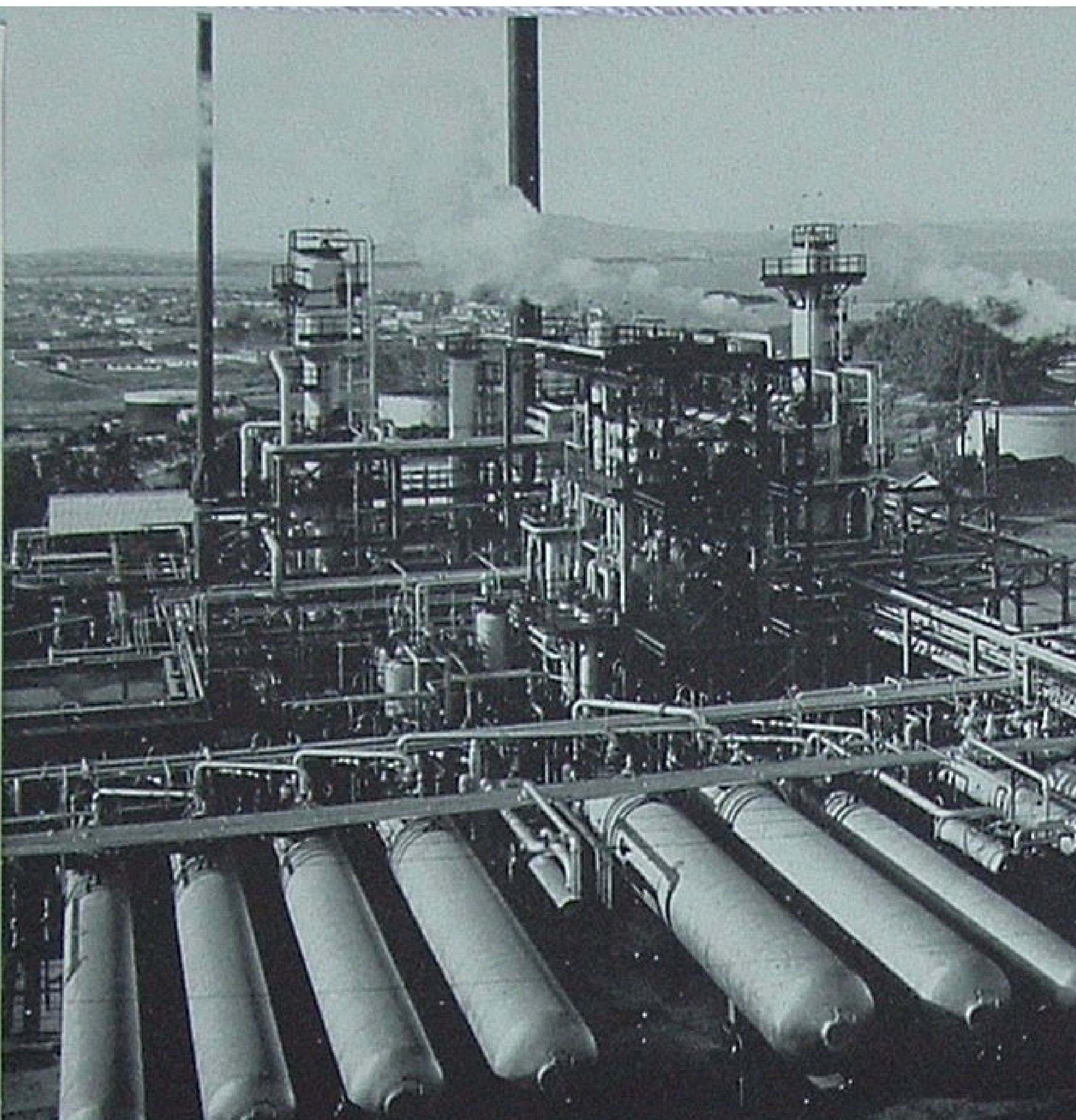
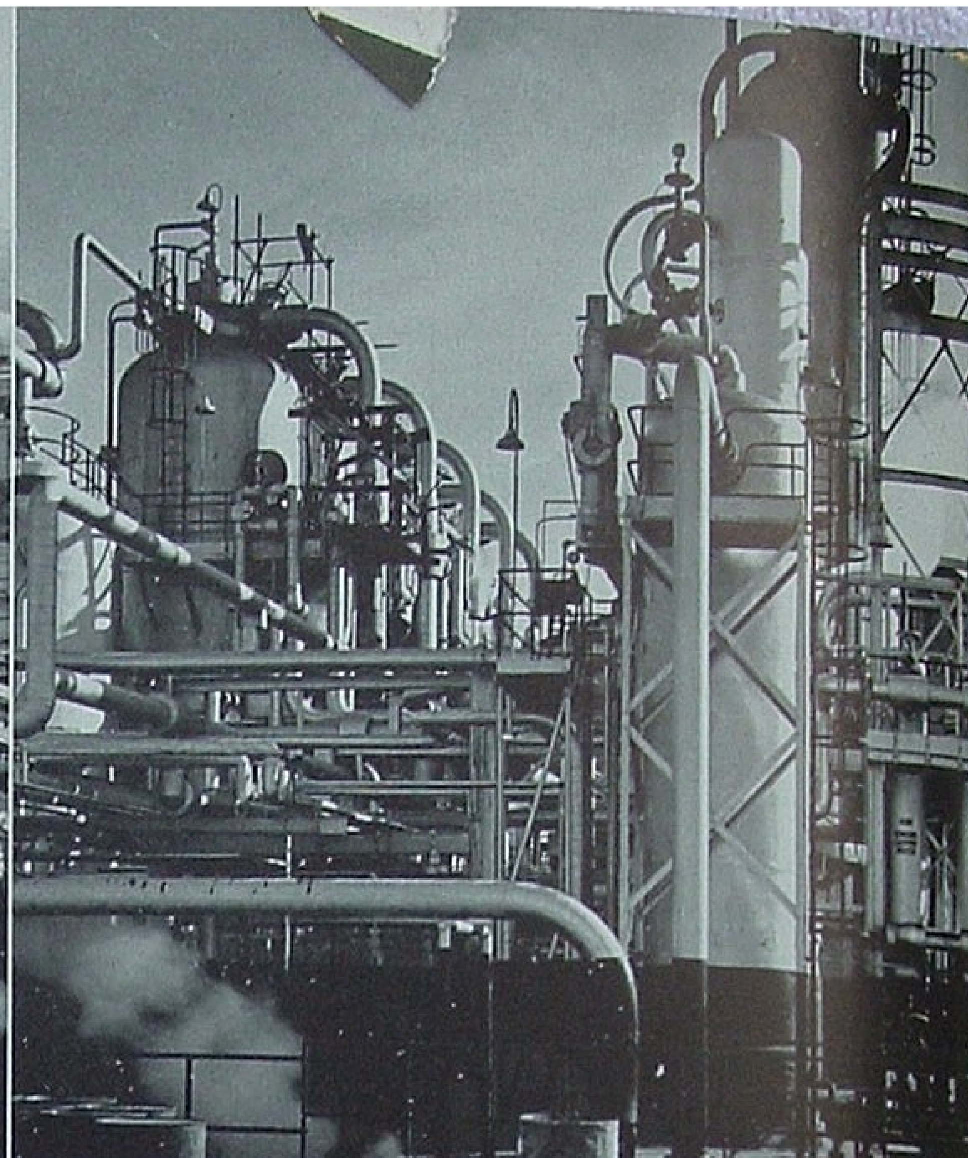
"76" VIEWS OF REFINING





Oleum Refinery

Oil and its Composition

1. Crude Oil

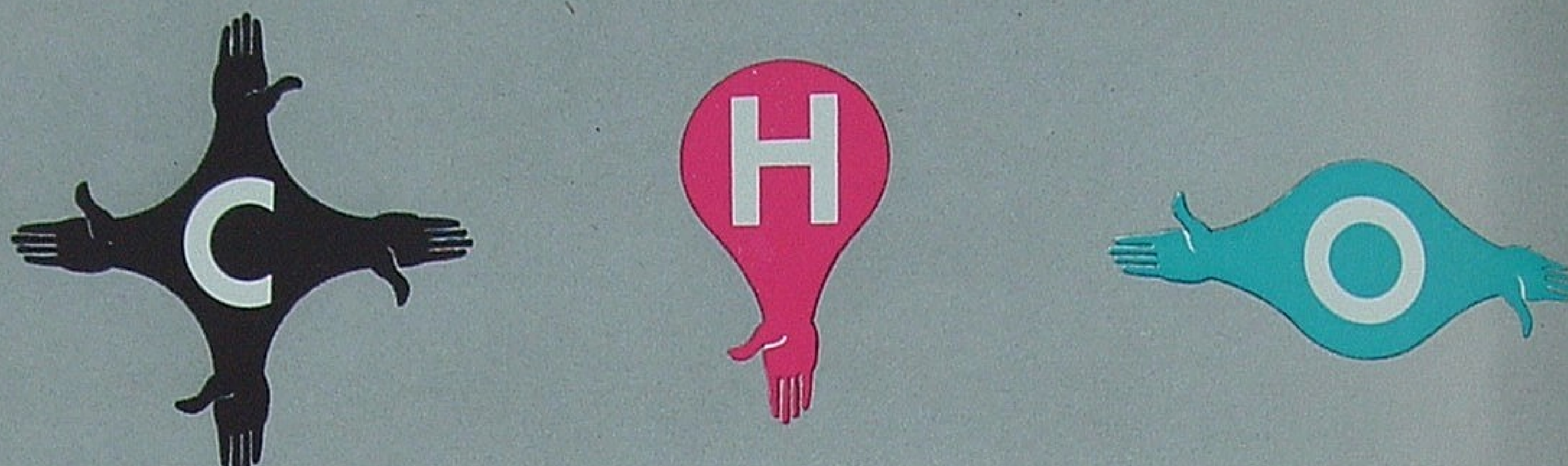
is one of the oldest servants of mankind. It was used 3000 years ago by the Sumerians for caulking boats. The early Egyptians called asphalt "mum" and used it for mummifying their dead. To make Noah's Ark seaworthy, the instructions, as recorded in Genesis, were to "pitch it within and without with pitch." This same product of the oil seeps was most probably used as a mortar for constructing the Tower of Babel. The infant Moses' floating crib of bulrushes was waterproofed "with slime and with pitch." Both the Babylonians and the ancient Incas of Peru built roadways and floors of asphalt. Hannibal in 250 B. C. routed an enemy fleet by spreading mineral oil on the water and lighting it. History records many other bits of evidence proving that oil was known to and used by nearly every generation.

However, it is only within the past hundred years that men have succeeded to any great extent in mastering petroleum sciences and techniques. Drilling of the first oil well in Pennsylvania in 1859 opened an era of abundant oil supply. Increasing supplies and demand prompted the development of better refining methods. And, as our experience with petroleum grew, it was discovered that crude oil was a far more useful and versatile substance than anyone had ever imagined.

Looking at crude oil—that black, sticky substance seen seeping to the surface or being pumped out of our earth today—it is hard to associate such raw material with mankind's welfare and happiness. Yet, crude is being transformed daily into hundreds of useful products. These include the pitch of ancient times; the heating gas, fuel oil, gasoline, kerosene, lubricating oil and grease so familiar to our present generation; and hundreds of less familiar products used extensively in the manufacture of chemicals, paints, building materials, foods, medicines, insecticides, synthetics and explosives.

The uses of petroleum are steadily expanding. Chemists have already studied over 3000 substances found in oil, each having individual characteristics that distinguish it from other compounds of the petroleum families. Scientists tell us that this work of identification and classification has only begun. It may never end because the number of possible petroleum compounds appears to be nearly as endless as infinity.

Our intention in this narrative is to present an illustrated story of oil refining in a manner that will make it interesting and informative to everyone. So do not be frightened by the following short detour through the subjects of atoms and molecules. Even a brief acquaintance will be quite helpful to a general understanding of refining processes.



CARBON HYDROGEN OXYGEN

2. Atoms are the building blocks of this earth and the entire universe. Slightly fewer than 100 varieties have been identified, and physicists do not expect to discover many more. But, just as the 26 letters of our alphabet have been arranged and combined to form more than a half-million words in our English dictionary, so have these atoms been arranged and combined to form countless millions of compounds. Our bodies, the earth at our feet, the vegetation, the water we drink, the air we breathe—all substances in all of their shapes and varieties—are composed basically of atoms.

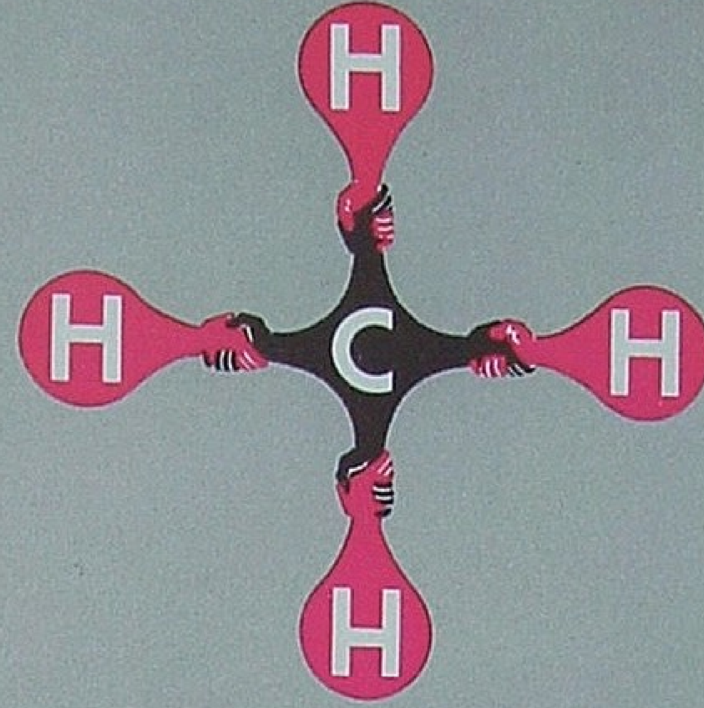
No one has ever seen one of these sub-microscopic particles. The largest is so infinitely tiny that even the powerful electron microscope has never singled one out. Nevertheless, science knows a great deal about atoms. Besides isolating and classifying each of the known varieties, scientists have determined their weights and other physical properties. They know the manner in which various atoms combine with each other. In recent years they have also succeeded remarkably in splitting the atom into its component parts, thus opening up an amazing new source of energy and knowledge.

Petroleum is composed almost entirely of only two kinds of atoms, hydrogen (H) and carbon (C). That is why chemists often refer to petroleum oils as hydrocarbons. Evidently the many different substances in oils represent carbon and hydrogen atoms joined in many ways. Some crude oils in addition contain substances in which oxygen (O), nitrogen (N) and sulfur (S) atoms are present.

We shall be more concerned with the substances in petroleum than we are with their atomic composition. But in order to understand the substances more fully we should know something about the different ways atoms can combine with each other. Each kind of atom—carbon, hydrogen, oxygen, etc.—has its own peculiar "combining habit", or *valence*, as the chemist calls it. In the accompanying drawings we have indicated the valences of several atoms by equipping them with hands. Hydrogen, with one hand, is said to have a valence of 1. Oxygen, shown with two hands, has a valence of 2; and carbon, as found in petroleum, has a valence of 4.

The thing to remember about these atoms is that they are great politicians. They insist on keeping their hands busy by taking a firm grip on each other or by grasping any other palm within reach. When two hands are joined, the coupling is called a *bond*.

WATER



METHANE

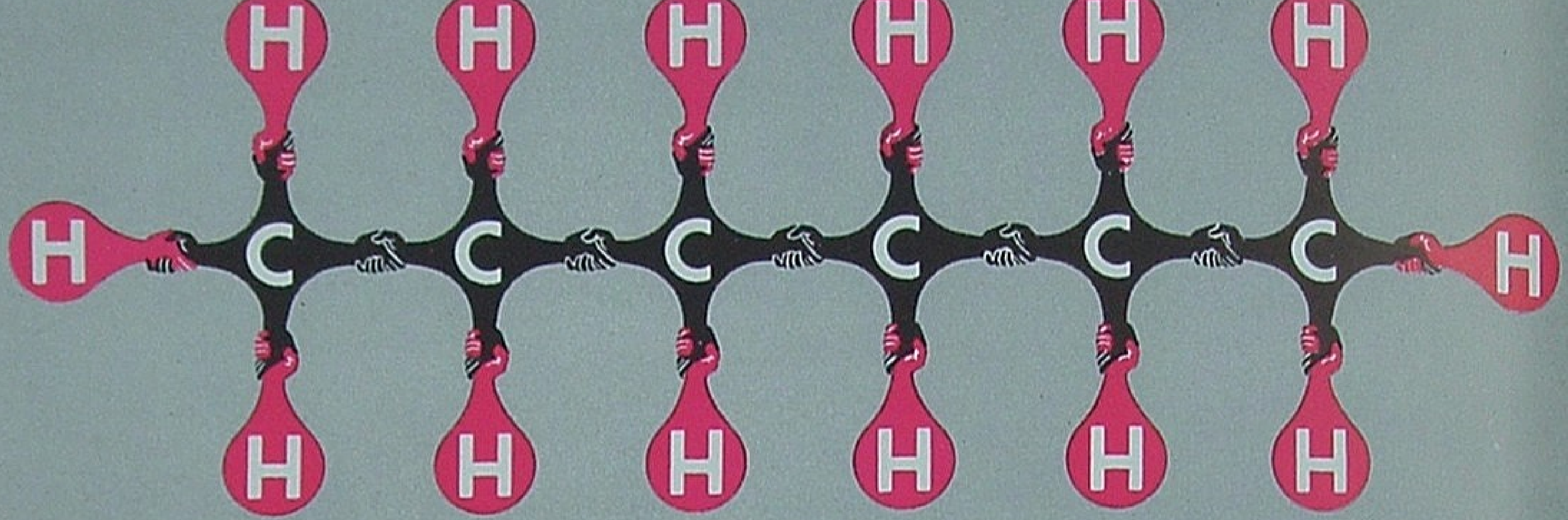
3. A Molecule is usually defined as the smallest particle or unit of a compound that has been formed by the chemical union of two or more atoms.

For example, above, when an atom of oxygen (O) grasps in each of its two hands the hand of a hydrogen (H) atom, the resulting compound is water (H_2O). The smallest possible unit into which water could be divided without destroying its identity as water would properly be called a molecule of water. Stated in another way, a molecule of water is two atoms of hydrogen chemically combined with one atom of oxygen. An interesting fact about this union is that hydrogen and oxygen normally are invisible gases when existing separately, but in combination they form a visible fluid.

Similarly, when an atom of carbon (C) clenches hands with four atoms of hydrogen (H), the resulting compound is methane (CH_4). Here too are some interesting facts: Carbon, a dense solid, boils at the extremely high temperature of 6300 degrees F. Hydrogen, one of the lightest of gases, boils at the sub-zero temperature of -423 degrees F. In combination they may produce one of the lightest of petroleum gases, which boils at -253 degrees. As commonly happens, the identity of the individual atoms is lost.

Before continuing on to a quick examination of hydrocarbon molecules belonging to several different families, it is important that we understand a less intimate way in which substances associate with each other. Once the atoms have formed into a vast number of hydrocarbon substances, these substances are not opposed to congregating in crowds. When various molecules thus mingle or "rub shoulders" without joining hands (combining chemically), the collection is known as a *mixture*.

Crude oil as it emerges from the well is definitely a mixture of compounds. Rarely does it contain any of the elements in their pure, uncompounded state. But within every barrel of crude are literally thousands of different compounds. Those composed of the smaller molecules are gaseous at atmospheric temperatures and pressures; others containing larger molecules are liquids; a third class made up of the largest molecules are solids. Some are odorless, some are foul smelling, a few qualify for use in the manufacture of perfumes and dyes. Besides the desirable hydrocarbon compounds in limitless varieties, there are quantities of undesirable salt water, nitrogen and sulfur compounds in nearly all crudes.



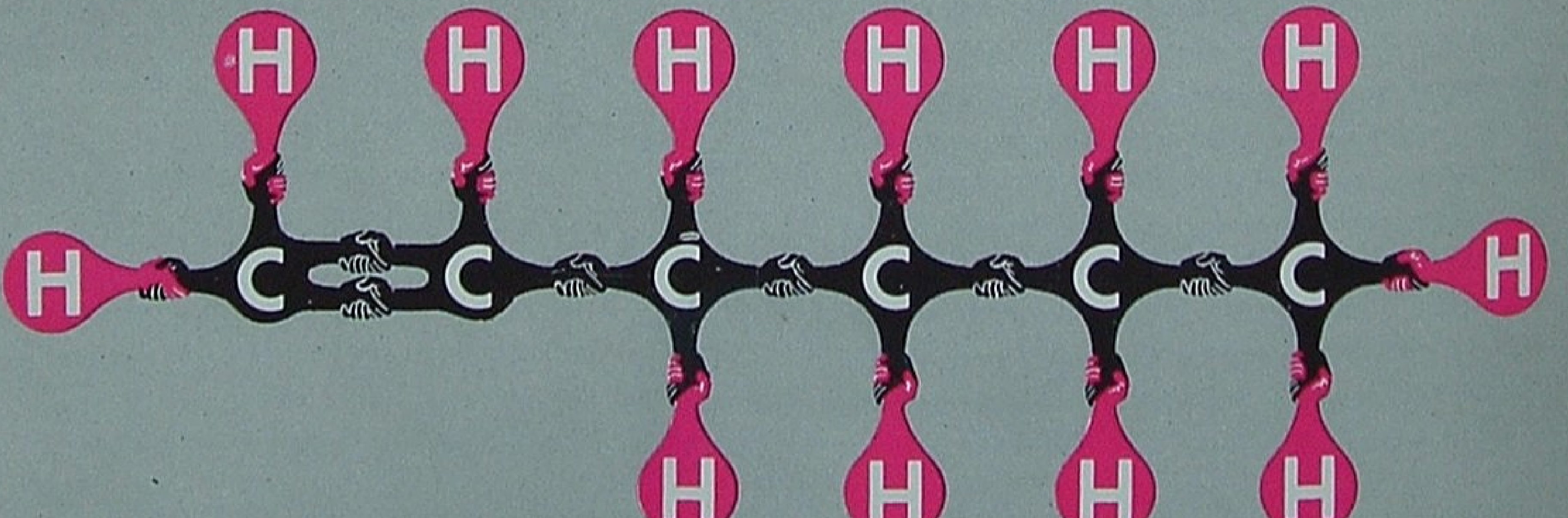
HEXANE

4. The Paraffins

are one of several hydrocarbon families that merit your acquaintance. Methane (CH_4), previously introduced, is the smallest member of this family and is found in marsh gas or natural gas. In the above illustration is another, hexane (C_6H_{14}). Hexane differs from methane only because the hexane molecule contains six carbon atoms instead of one, and fourteen hydrogen atoms instead of four; also because one hand of each hexane carbon atom grasps the hand of another carbon atom in place of holding a fourth hydrogen atom. The name paraffin, meaning "little affinity" in Latin, is appropriate for this family; their countless members have little affinity for other substances and are comparatively resistant to chemical change.

5. The Olefins,

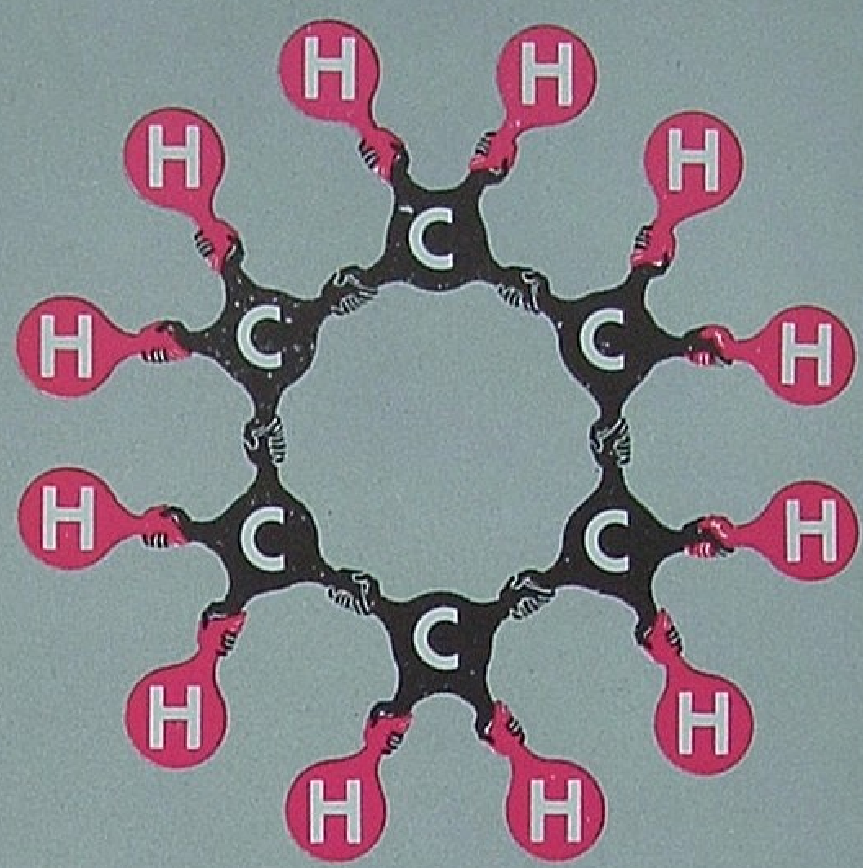
another family of hydrocarbons, are represented below by hexene-1 (C_6H_{12}). This individual's name is similar to hexane of the paraffin family because both are composed of six (*hex* is the Greek word for six) carbon atoms each. However, hexene-1 has two less hydrogen atoms than hexane, two of the former's carbon atoms having taken a double handhold on each other instead of grasping two more atoms of hydrogen. It is this characteristic that distinguishes all of the olefin family from other hydrocarbons. Each member has a double bond between two of its carbon atoms, hence two less hydrogen atoms than are contained in a paraffin molecule having the same number of carbons. Compounds that could hold more hydrogen are said to be *unsaturated*.



HEXENE-1

6. The Naphthenes

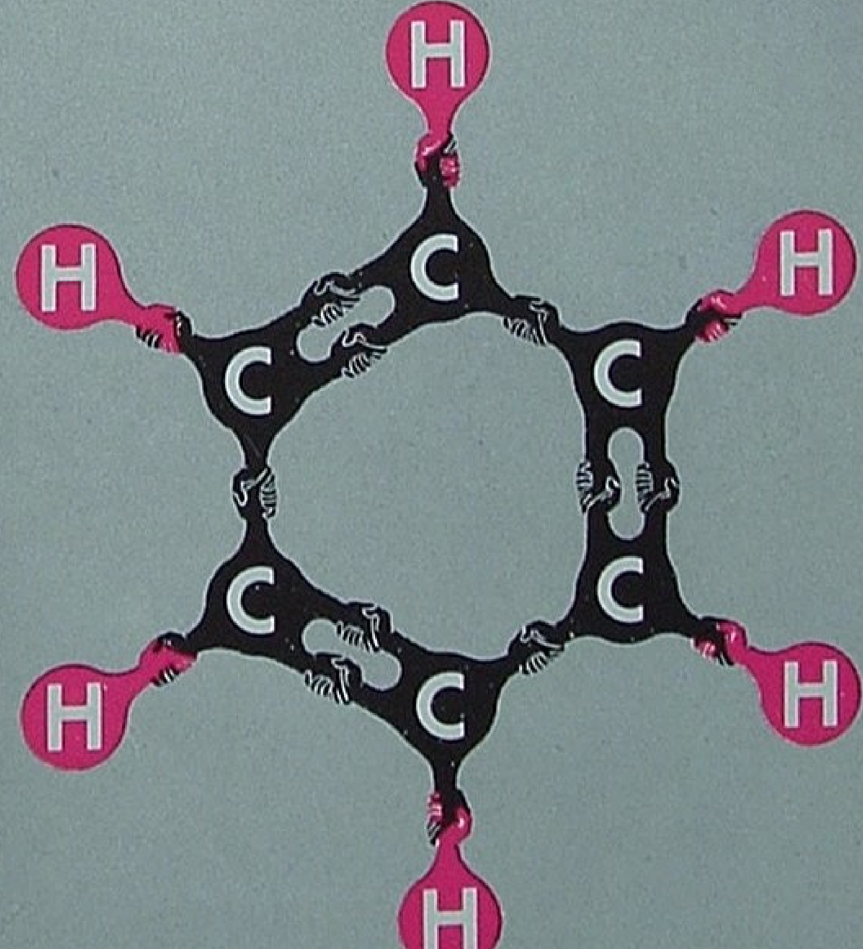
are a somewhat more complicated family of hydrocarbons whose heavy ancestors are said to have served as mortar in the Tower of Babel. Naphthenes are distinguished by the fact that their molecules are constructed in the form of rings. For example, cyclohexane (C_6H_{12}), right, of this family is formed quite as if someone had taken hexane (C_6H_{14}) of the paraffins, removed two hydrogen atoms from the ends, and connected the entire carbon chain into an unbroken ring. Cyclohexane has the same number of carbon and hydrogen atoms as hexene-1 of the olefins, but the manner of arrangement differentiates the two families.



CYCLOHEXANE

7. The Aromatics

are our final presentation of hydrocarbon families, but by no means the last ones existing. One of the better known members of this group, benzene (C_6H_6), right, establishes the family pattern, since each member must contain the "benzene ring" to qualify for membership. Note the double bonding of three carbon atoms, which makes the aromatics unique among hydrocarbons. They resemble the naphthenes in that both have a cyclic structure. Drawings of the larger members of these two families look not unlike a fence made of chicken wire. Though unsaturated, the aromatics do not tend to change readily.



BENZENE

Treating Processes

8. Field Processing

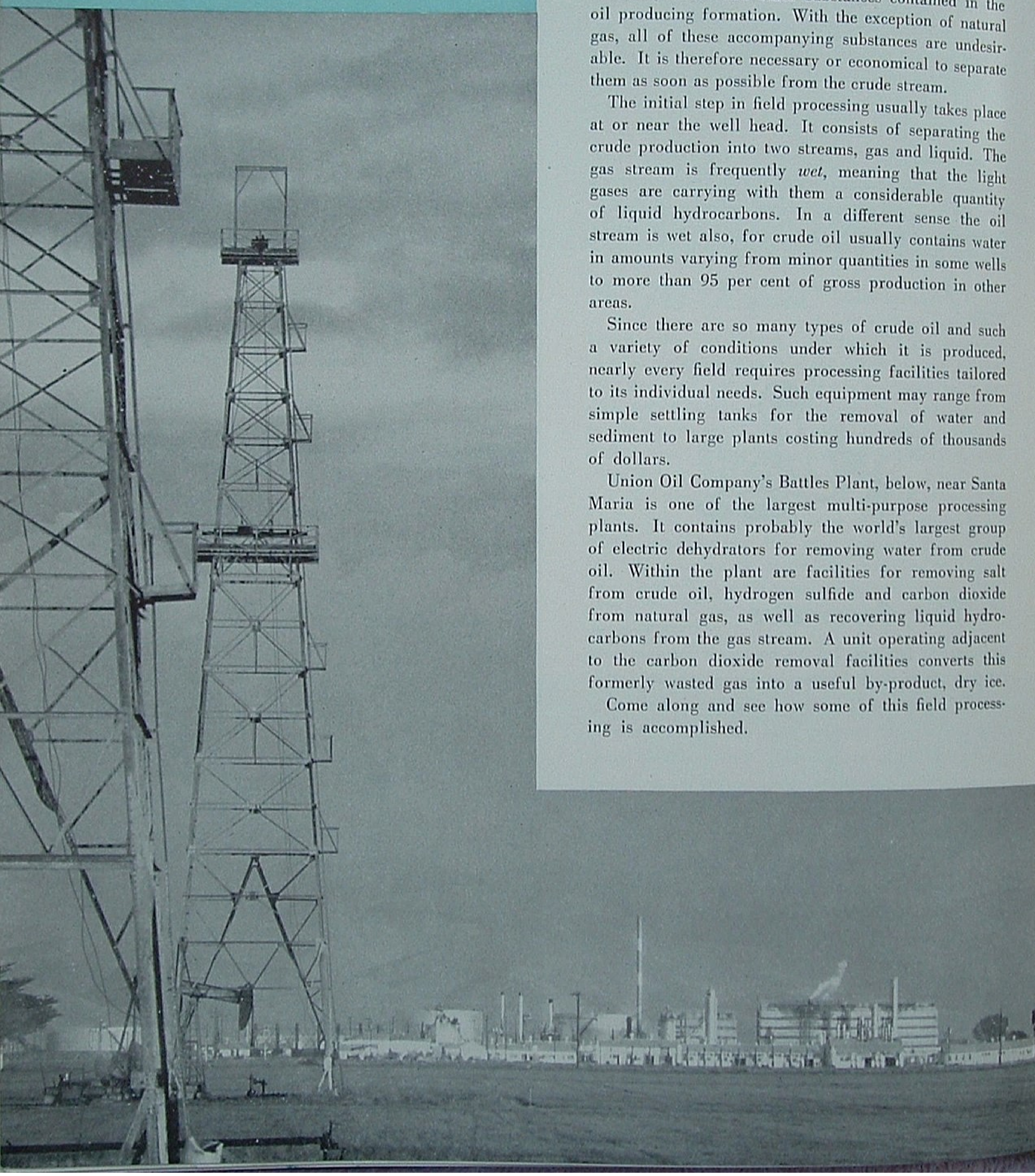
is the term applied to a number of preliminary refining operations to which oil is subjected in or near the oil fields. Crude oil as produced from the well is associated with natural gas, water, sediment, sulfur and other substances contained in the oil producing formation. With the exception of natural gas, all of these accompanying substances are undesirable. It is therefore necessary or economical to separate them as soon as possible from the crude stream.

The initial step in field processing usually takes place at or near the well head. It consists of separating the crude production into two streams, gas and liquid. The gas stream is frequently *wet*, meaning that the light gases are carrying with them a considerable quantity of liquid hydrocarbons. In a different sense the oil stream is wet also, for crude oil usually contains water in amounts varying from minor quantities in some wells to more than 95 per cent of gross production in other areas.

Since there are so many types of crude oil and such a variety of conditions under which it is produced, nearly every field requires processing facilities tailored to its individual needs. Such equipment may range from simple settling tanks for the removal of water and sediment to large plants costing hundreds of thousands of dollars.

Union Oil Company's Battles Plant, below, near Santa Maria is one of the largest multi-purpose processing plants. It contains probably the world's largest group of electric dehydrators for removing water from crude oil. Within the plant are facilities for removing salt from crude oil, hydrogen sulfide and carbon dioxide from natural gas, as well as recovering liquid hydrocarbons from the gas stream. A unit operating adjacent to the carbon dioxide removal facilities converts this formerly wasted gas into a useful by-product, dry ice.

Come along and see how some of this field processing is accomplished.

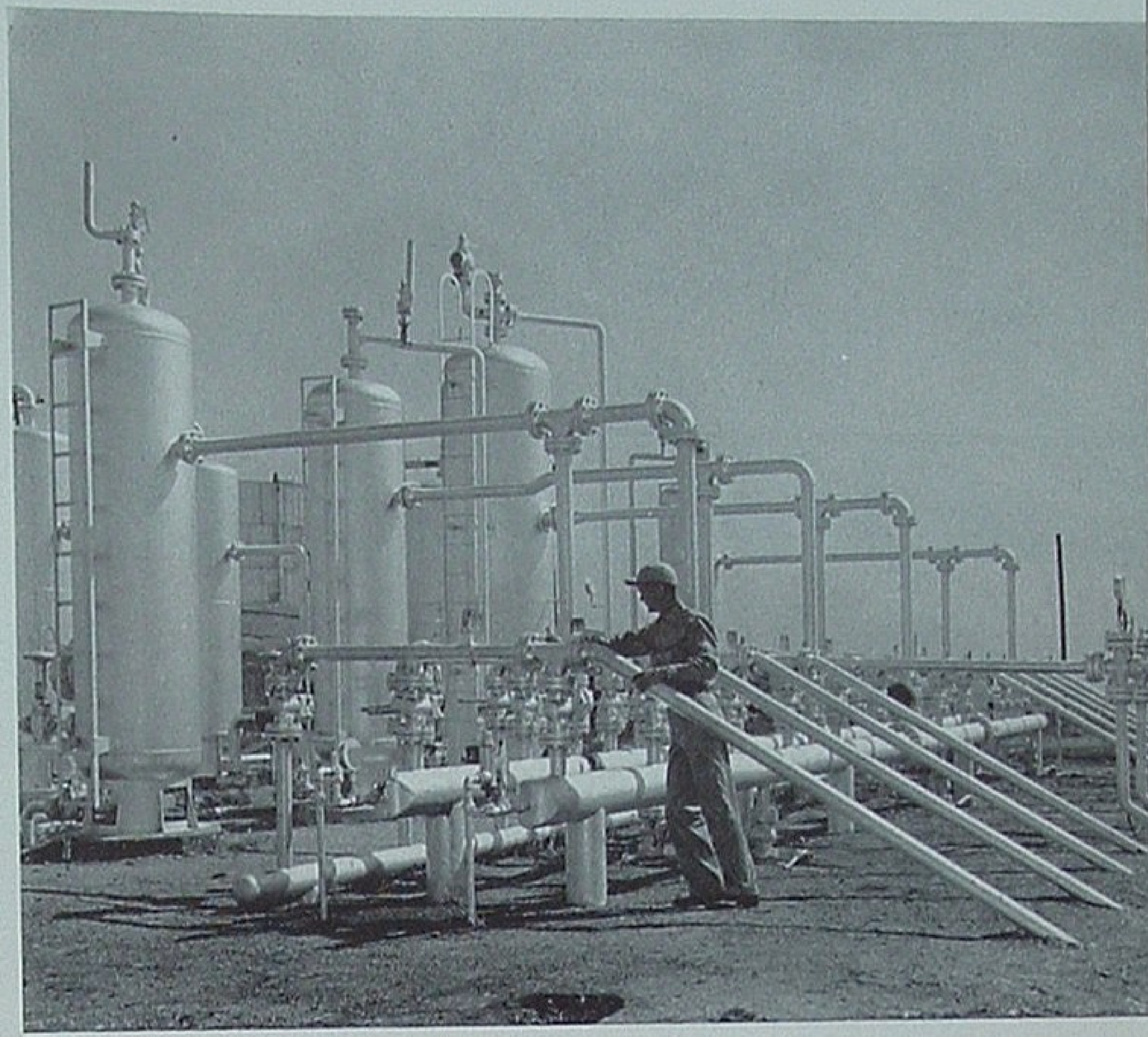


9. Gas Traps,

such as these in our Coalinga Nose Field, are used to separate natural gas from crude oil. Frequently, when crude is produced under heavy pressure, a series of gas traps is used, the oil passing from one trap to another in succession, each successive trap operating at a lower pressure. The purpose of such an arrangement is to conserve hydrocarbon vapors, most of which would be lost if the crude were delivered directly into vented storage tanks.

As the mixed stream of oil and gas enters a trap, separation takes place. The wet gas, containing valuable liquid hydrocarbons in vapor form, rises and departs through a top exit pipe line, while the oil and its content of water flow through a bottom outlet. The two streams then proceed to separate facilities for further processing.

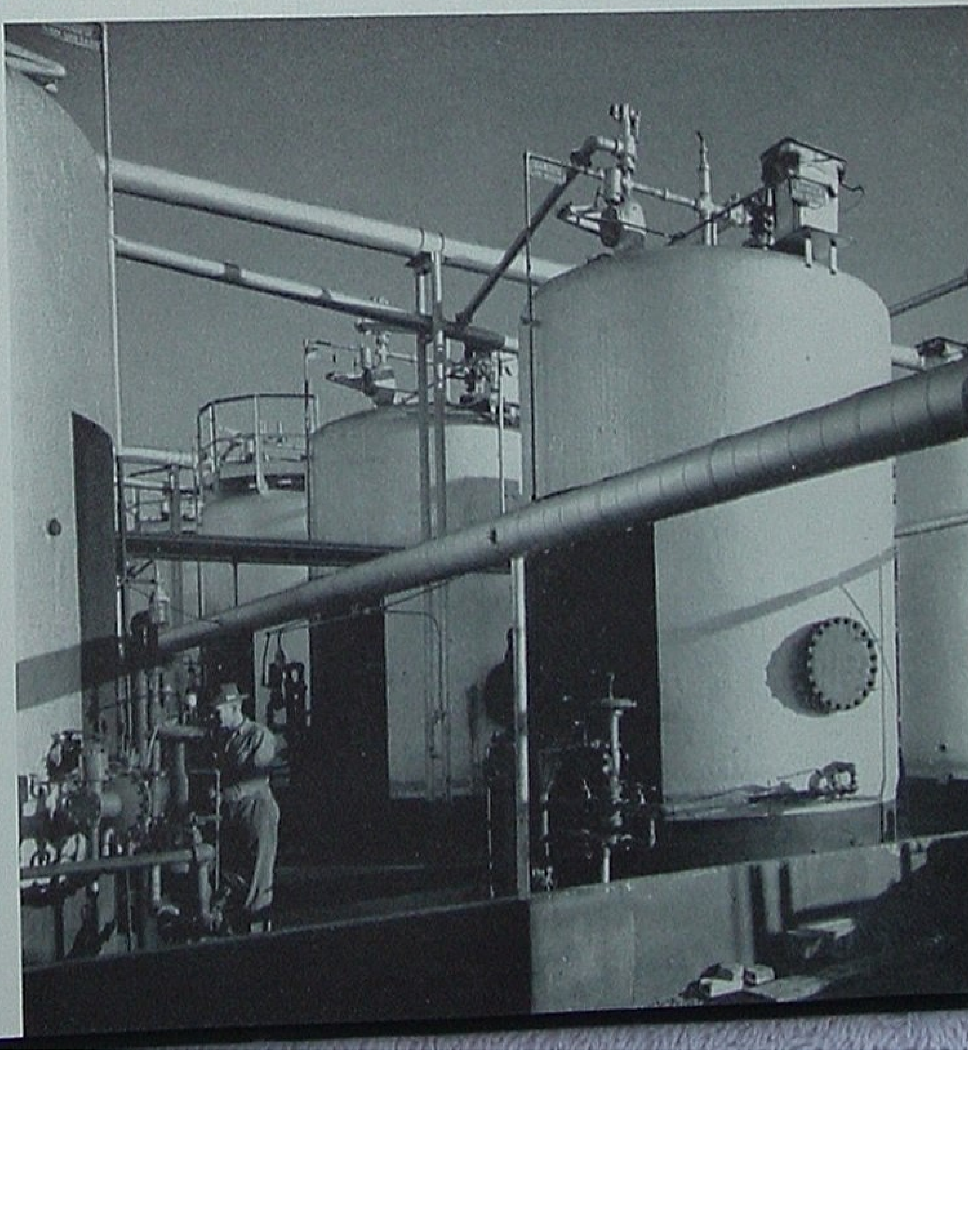
Let's follow the oil stream first and return later to see what happens to the gas.

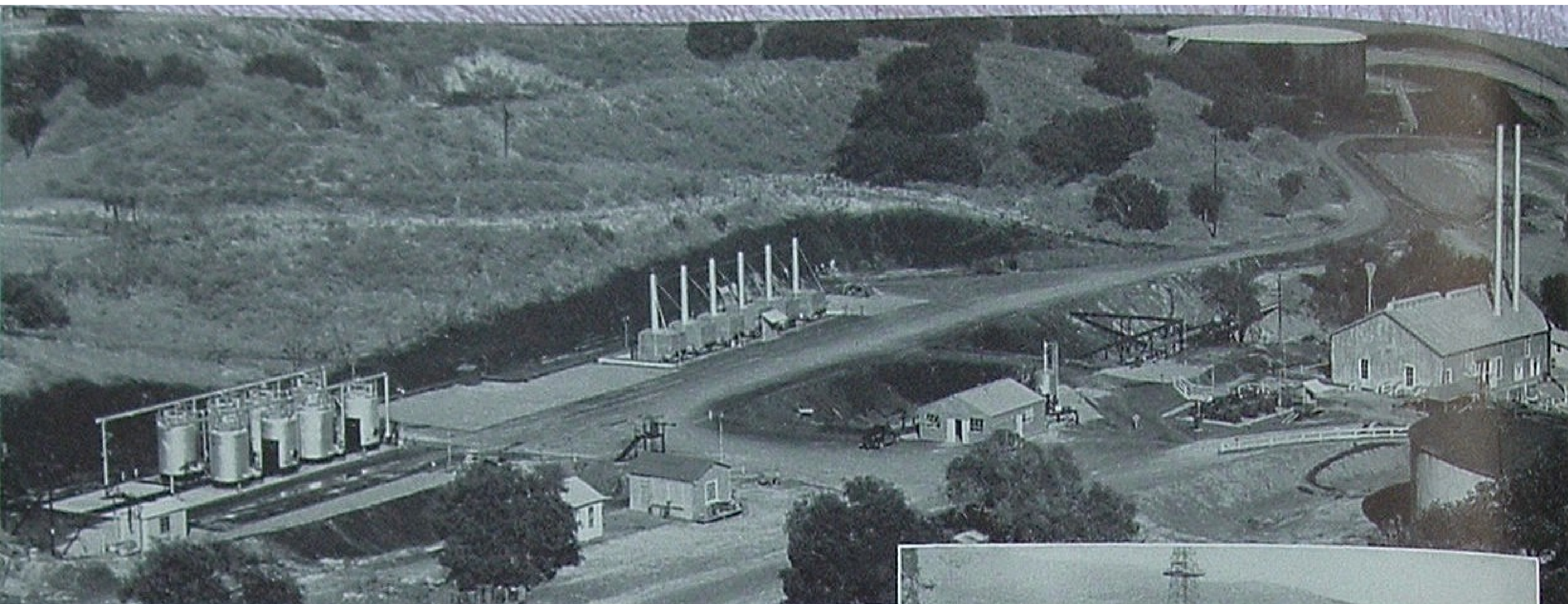


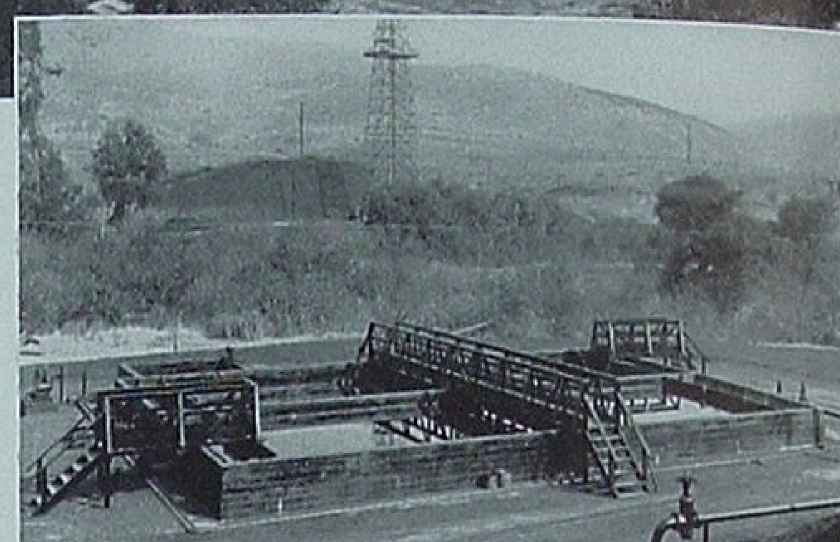
10. Electric Dehydrators

are one of several means used to remove water from oil and thereby reduce the cost of transporting oil to refineries. Of course, most of the water can be removed by letting the crude stand in a container or tank. Water and sediment settle to the bottom and can be drained off, leaving fairly *clean* oil. However, many times tiny droplets of water become competely enveloped in an oil film so tenacious that no separation takes place.

The electric dehydrators at our Battles Plant, right, are very effective in de-watering many crudes, including the Santa Maria type. After first being heated, the crude oil stream enters a lower section of these closed tanks or dehydrators. Inside each dehydrator, electrodes are spaced to set up a field of electric current with a voltage up to 16,000. As the oil stream rises through this electric field, the tough little oil envelopes are ruptured. Released water then settles to the bottom and is removed through a water disposal system. The clean oil continues upward through top exits.







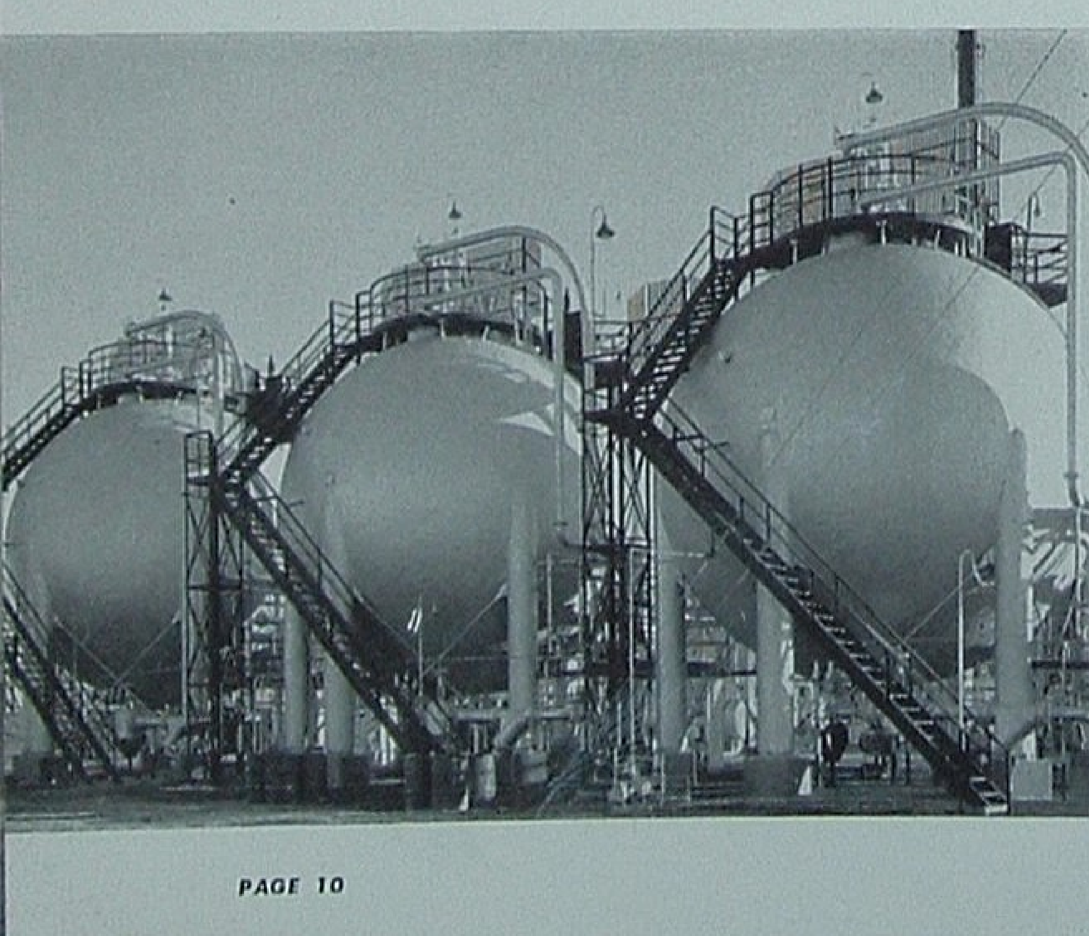
11. De-Watering Problems

sometimes demand only the use of heat, or of a special chemical that is effective in breaking certain types of emulsion. But in other cases two or three of the various means are required in combination to produce best results.

Typical of dehydration plants in use throughout several Company fields is our Cat Canyon installation, above. Here the oil and water emulsions are gathered from many wells into a large storage tank. Six heaters, shown in the center of picture, next receive the oil and heat it to about 210 degrees F. Electric dehydrators, left, similar to those in use at Battles, then complete the de-watering process. Clean oil normally collects in a shipping tank prior to starting on its journey of several hundred miles to refineries. In the building at right is housed pipe line pumping equipment, by means of which most oil is transported.

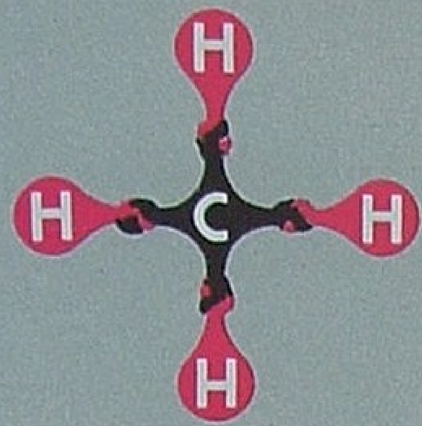
12. A Skim Pond

is useful in field processing chiefly to complete the oil-water separation. Waste water emerging from the various tanks and dehydrators carries with it small amounts of entrained oil. Most of this can be recovered by permitting the water to remain relatively still in a pond. Oil rises to the top and is skimmed off automatically while the water drains away into a disposal system. The hydrocarbons thus saved have a measure of value and are prevented from contaminating the ocean or streams into which waste water often flows.

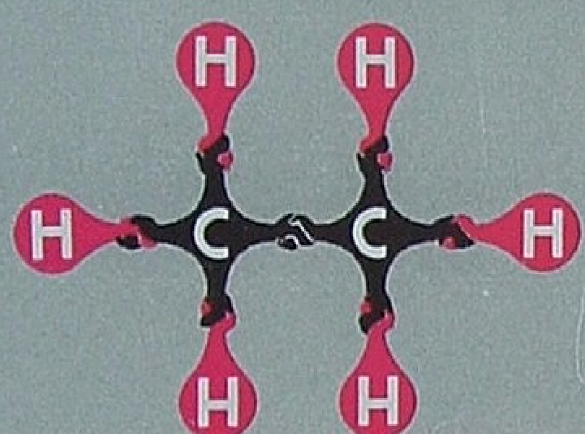


13. De-Salters

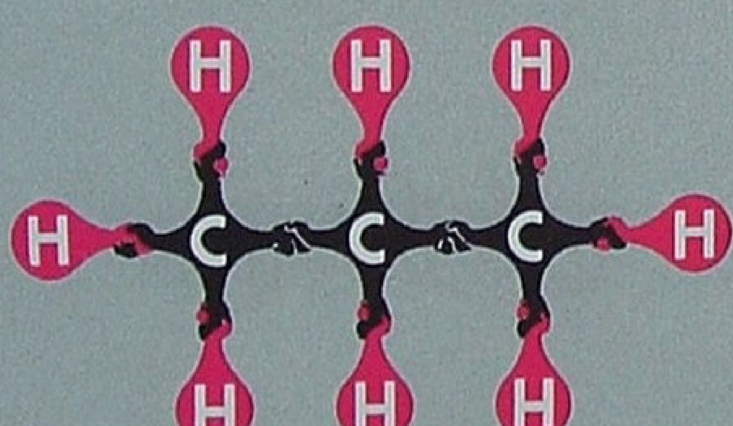
of which these three at our Battles Plant are good examples, are used only in processing crude oil having an objectionable salt content. In most cases the water produced with oil is salt water, which generally is removed in the dehydration process. However, some crudes are so extremely salty that dehydration fails to remove all of the salt crystals. This condition can cause the corrosion of refinery equipment and increase the ash residue of fuel oils made from salt-bearing crude. The de-salting process is similar to electric dehydration. First, the crude is *washed* or contacted with fresh water, which has a great affinity for salt crystals and readily dissolves them out of the oil. Then the mixture of oil and water proceeds through an electric field, where dehydration takes place in a manner similar to that previously described.



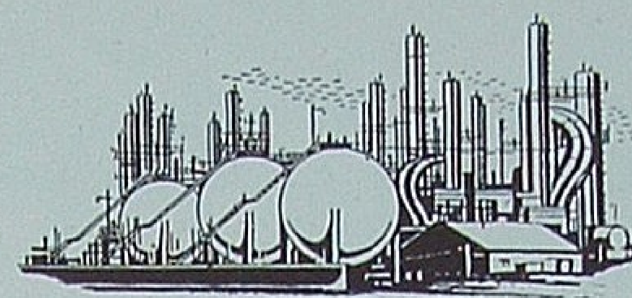
METHANE (CH_4)



ETHANE (C_2H_6)



PROPANE (C_3H_8)

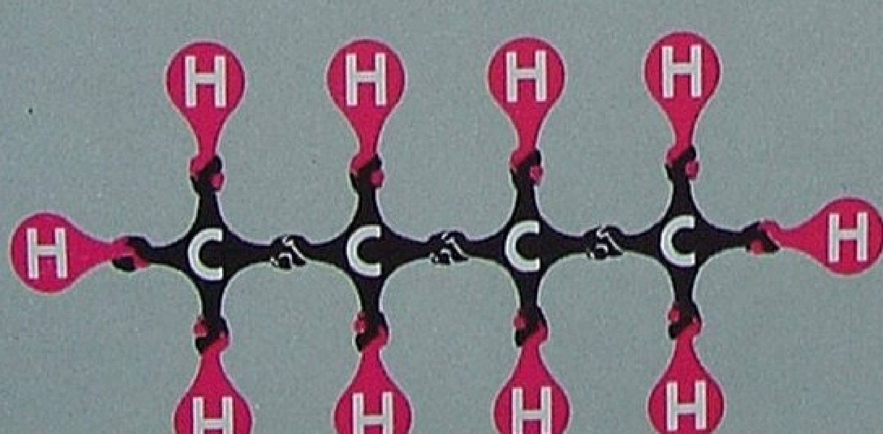


14. Natural Gas

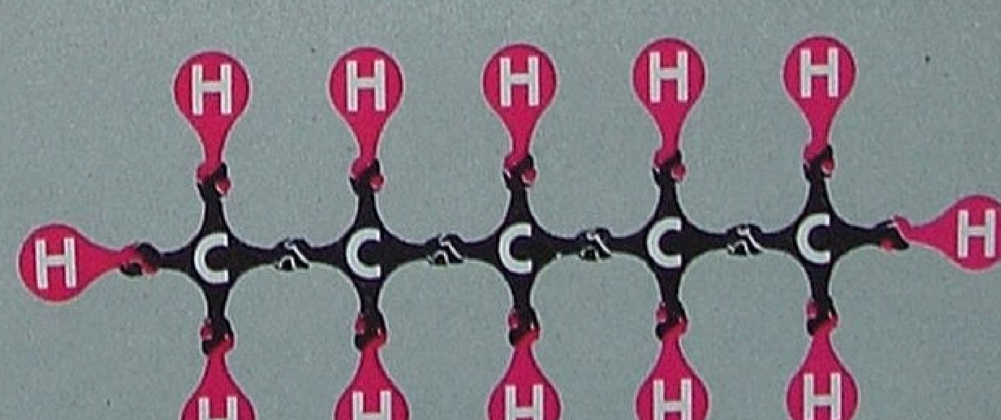
emerging in gas or vapor form from an oil well consists almost entirely of the lighter paraffins. There may be a few napthenes and possibly some aromatics present, but, if so, these other families are decidedly in the minority.

Science has devised a systematic method of naming the hydrocarbons. All of the paraffins, you will note, have names ending with "ane"; and the prefix added to this family name in individual cases is a sort of number indicating the quantity of carbon atoms contained in an individual molecule. Substituting these foreign-sounding prefixes for our own one, two, three and four, we have *meth*, *eth*, *prop* and *but*. And starting with *pent*, fifth in series, science has adopted the Greek roots, namely, *hex* for six, *hept* for seven, *oct* for eight, *non* for nine, *dec* for ten, and so on. Accordingly, such names as methane, ethane, propane, butane and pentane have a distinct meaning. Each represents a different member of the paraffin family and tells us how many carbon atoms its molecule contains.

The five paraffins shown here are the lightest members of their family and are the best known components of wet gas. Methane and ethane remain gaseous under normal atmospheric conditions and are quite generally known under the name of natural gas. Propane and butane, frequently recognized by their chemical names, are referred to oftentimes as LPG, or liquefied petroleum gases, because when held under sufficient pressure they can be handled in liquid form. Pentane and a rather lengthy series of heavier hydrocarbons are the principal constituents of stabilized natural gasoline.



BUTANE (C_4H_{10})



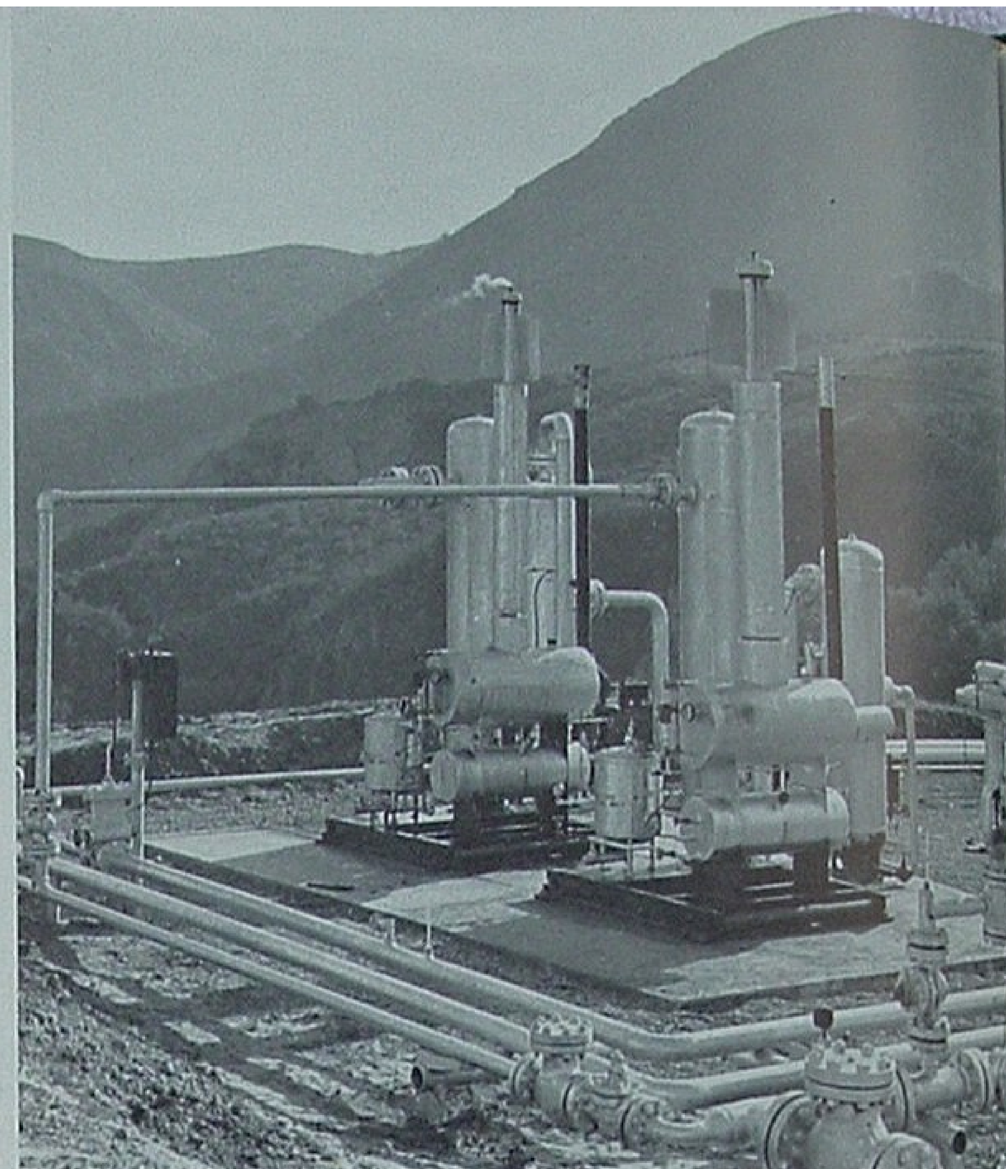
PENTANE (C_5H_{12})

15. Gas Dehydration

Returning to the gas phase of field processing, let us see what happens to this lighter petroleum stream.

Nearly all petroleum gas contains some water vapor, which, under certain conditions, may cause pipe line corrosion or may form a hydrate that freezes readily, shutting off the pipe line flow.

Modern installations, right, in our Grimes Canyon area near Santa Paula effectively prevent any such corrosion or stoppages by partially dehydrating the gas. As the stream enters one of these tanks, it contacts a glycol solution. The glycol, having a thirsty affinity for water, absorbs water vapors. Dehydrated gas then is ready for pipe line transportation. The glycol solution is prepared for re-use by being heated in a boiler section of these units. Water vapors are boiled off and released to atmosphere while the glycol solution continues its cyclic career of absorbing and freeing more water vapors. Such units operate automatically, requiring only periodic inspection and maintenance.



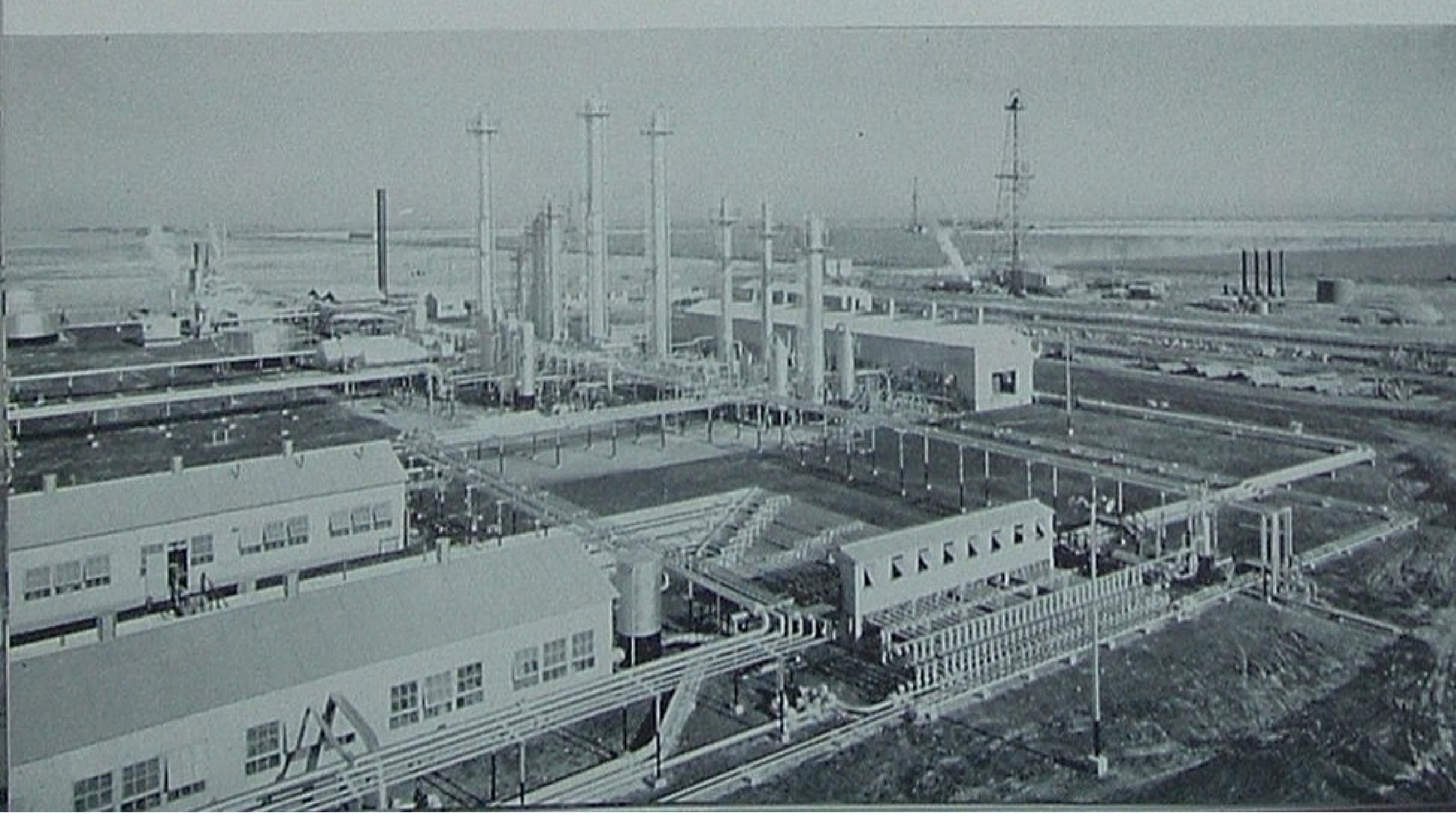
16. Gas Plant

Usually a gas stream contains large quantities of liquid hydrocarbons that can be recovered and put to many uses. This refining process also normally takes place in a plant located in or near the oil field.

Below is an exceptionally fine gas plant in San Joaquin Valley known as the Paloma Cycling Plant. Through its roadway of pipe lines, right foreground, some 125 million cubic feet of *wet* gas arrives from surrounding oil wells each day. A main function of the plant is to separate dry natural gas (methane and ethane) from accompanying liquid vapors and to further segregate the liquid into several fractions.

The 125 million cubic feet of *wet* gas thus processed daily may yield some 118 million cubic feet of dry natural gas, 3,600 barrels of propane, 2,300 barrels of butane, 2,100 barrels of pentane and other light hydrocarbons collectively known as *natural gasoline*, and 6,200 barrels of still heavier fractions called *condensate*.

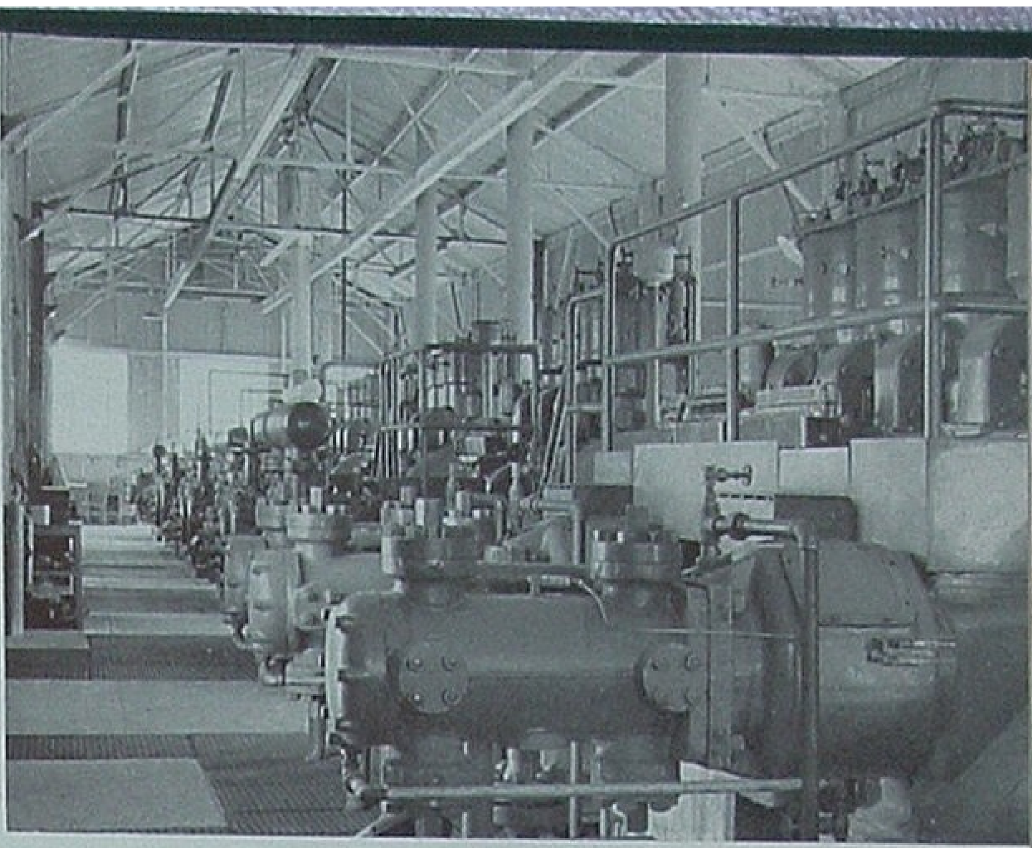
An interesting fact regarding this plant is that its production of dry natural gas is *cycled* back into the oil wells. There it helps to maintain high underground pressures; becomes saturated again with *wet* vapors; and circulates back to the plant with valuable quantities of petroleum that would otherwise remain underground.

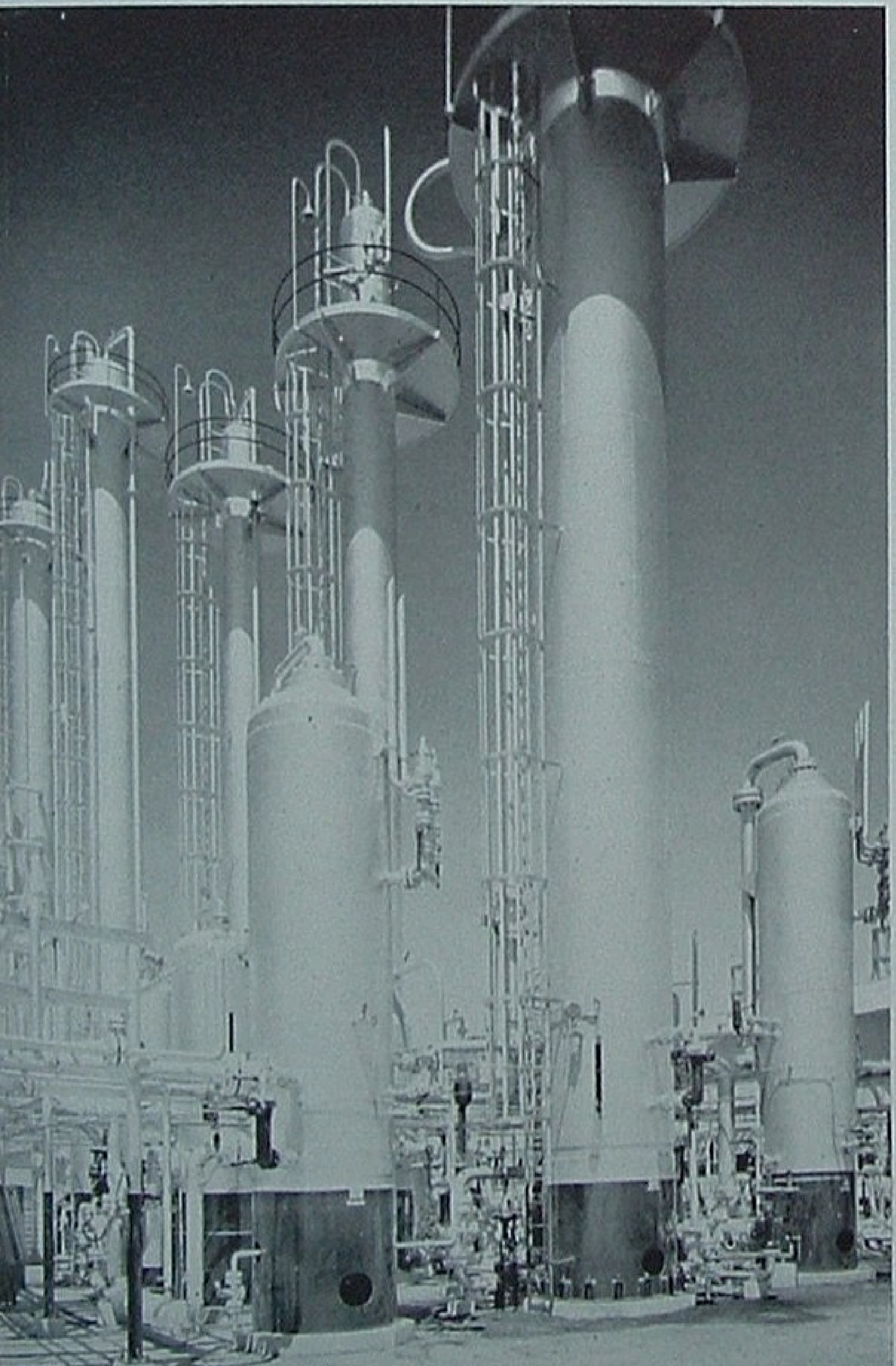


17. Compressors

play an important role in gas plant operations. Those at right in our Coalinga Nose Plant, for example, compress all incoming gas to a uniform pressure of 550 pounds. Under this pressure and when cooled to about 80 degrees F., some of the heavier hydrocarbons liquefy and are therefore easily drained out of the gas stream. Finally, compressors subject out-going dry gas to a pressure of approximately 2,000 pounds, in which condition it is pumped underground to re-pressure the oil field.

Coalinga Nose natural gas is not recycled in the manner described at Paloma. Rather, it is injected only in selected locations as a pressure means of driving crude oil through rock formations and toward the producing wells. Nearly all of the injected gas is eventually recovered and it serves to greatly increase the yield of other hydrocarbons from an oil field.





18. Columns,

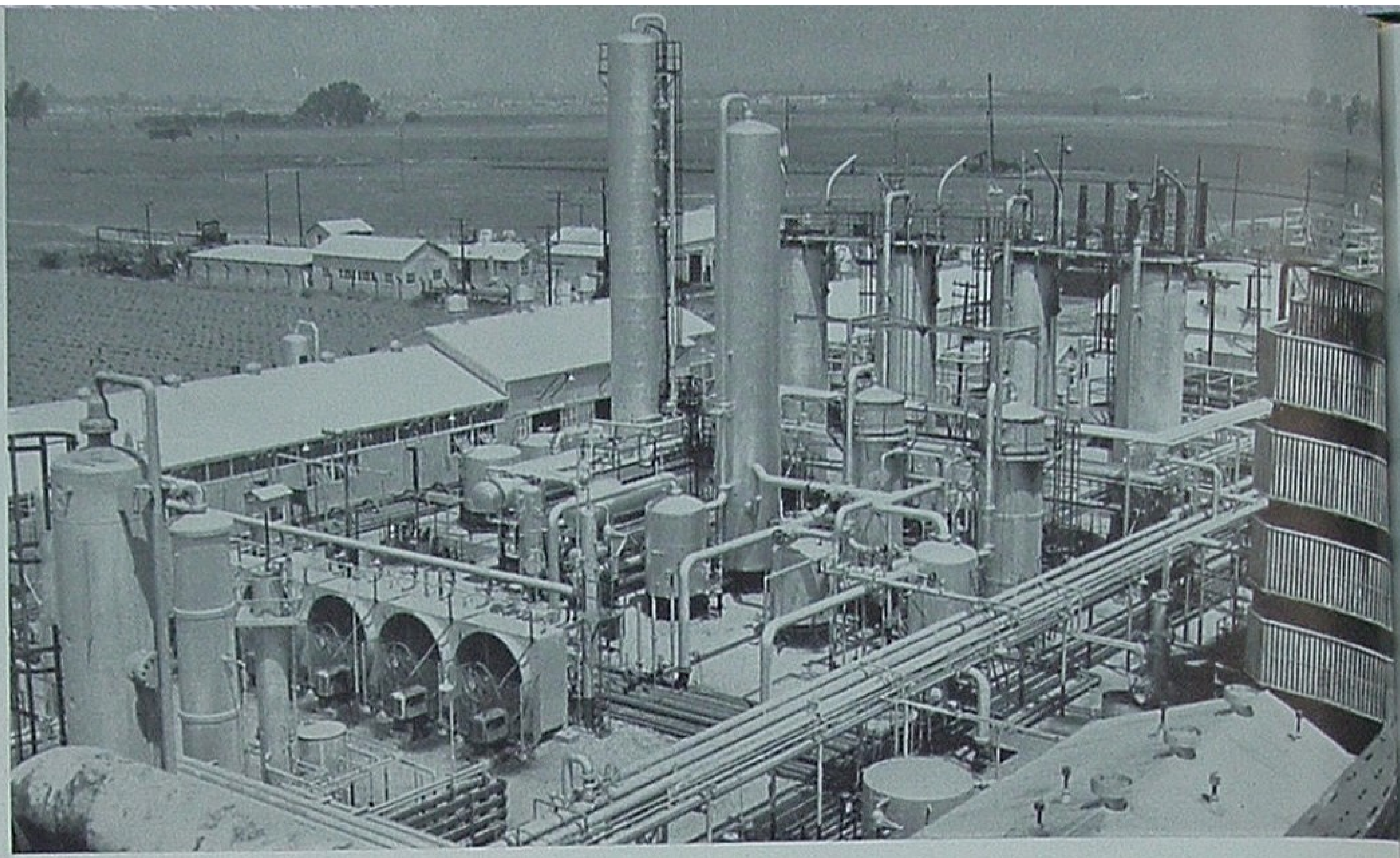
such as these graceful vessels, left, at Paloma, represent the heart of a gas plant.

The short column, left foreground, is a gas-oil separator. Although wet gas leaves the oil well in gaseous or vapor form, some of its heavier hydrocarbons soon begin to condense and form a liquid stream. The portion that freely liquefies is called *condensate* which, after flowing from the bottom of this separator, is processed separately from the upward flowing gases. Upon being heated and admitted to a *condensate debutanizer*, one of the columns in background, it loses most of its light gases held in solution and proceeds to storage under the label of *de-butanized condensate*.

The tallest column, foreground, is an absorber, used to remove liquefiable petroleum fractions from the *wet* gas stream. Inside it are layers of trays over which flow shallow streams of absorption oil. Through a series of inlets called bubble-caps, gas from the gas-oil separator is obliged to bubble upward through each stream of absorption oil. This oil, a specially refined petroleum product, has a strong affinity for the propanes, butanes, pentanes and heavier hydrocarbons.

Next step is to isolate all fractions thus absorbed. This is accomplished in another vessel by heating the *rich* absorption oil sufficiently to make the lighter fractions vaporize. On being withdrawn and cooled, these liquid portions of the distilled fractions constitute *raw gasoline*.

The further separating of *raw* gasoline into its component hydrocarbons is properly called *fractionation*. In columns where temperature and pressure are carefully controlled, propane vaporizes first out of solution, followed by butane. Pentane and other hydrocarbons in the gasoline boiling range are similarly removed and sent to separate storage as *stabilized natural gasoline*.

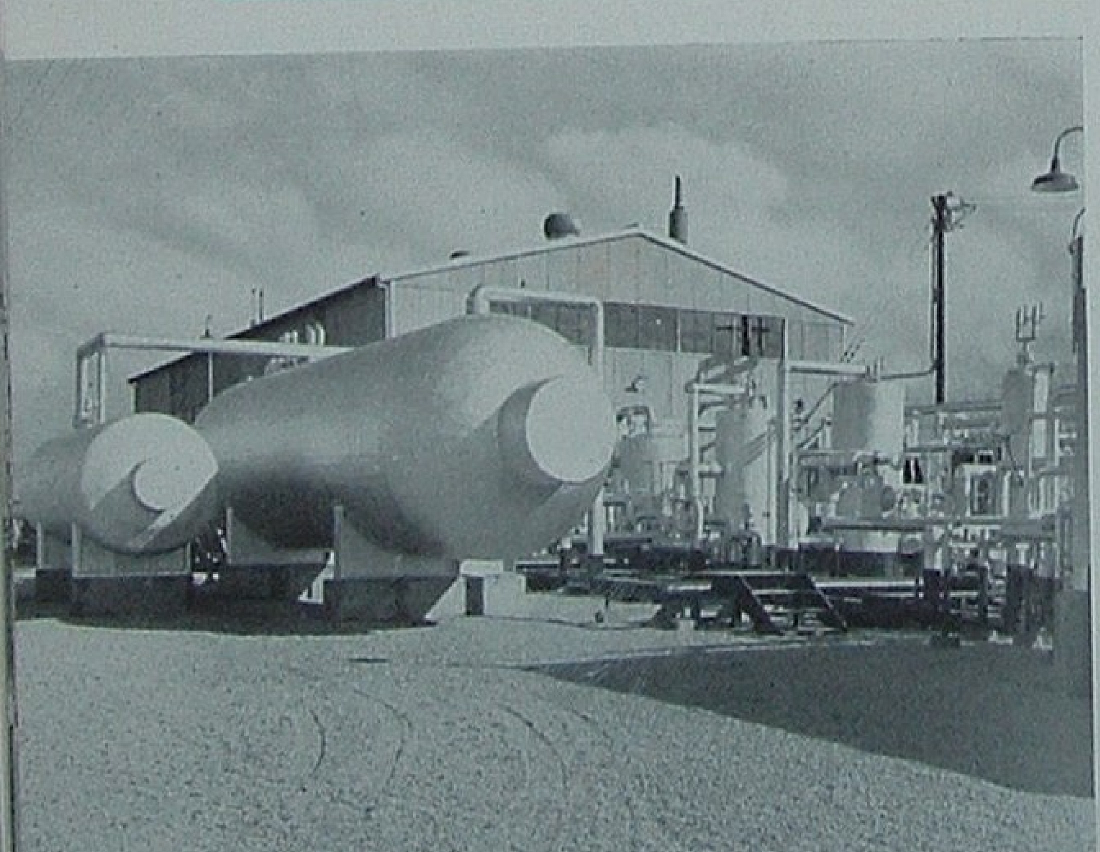


19. Impurities

that sometimes accompany a gas stream in sufficient quantity to necessitate removal include carbon dioxide and hydrogen sulfide. Part of the Battles Plant, above, consists of facilities for this type of processing.

The two tallest columns, center, are from left to right a *reactor* and an *absorber*, both designed for the carbon dioxide removal process. The *absorber*, operating somewhat like the Paloma absorber we have previously described, uses MEA (monoethanolamine) solution in place of absorption oil. Gas requiring this treating process bubbles upward through trays of MEA solution. The latter, having an affinity for carbon dioxide, becomes enriched with this non-burning substance. Heating qualities of the natural gas are thereby proportionately increased. The MEA solution then proceeds to the *reactor* column where, by application of heat, the carbon dioxide is boiled out of solution and removed in nearly pure condition.

Two shorter columns, to the right of the carbon dioxide absorber, begin the process of removing hydrogen sulfide. They contain a solution of water and soda-ash in which iron oxide is suspended. As gas passes through this solution, its content of hydrogen sulfide reacts with iron oxide and most of it leaves the gas stream. Four taller columns standing abreast, background, complete the de-sulfuring. They contain wood shavings impregnated with iron oxide. As gas passes downward through these shavings, its remaining hydrogen sulfide similarly reacts with iron oxide, forming a sulfur deposit on the wood shavings.



20. Dry Ice

became a by-product of the oil industry when the Union Oil plant, left, was added to other facilities at Battles. With large amounts of pure carbon dioxide on hand, as a result of gas purification, it was sound economy to use rather than waste this non-petroleum compound.

Dry ice is actually carbon dioxide that first has been compressed and cooled to liquid form, then released in several stages to atmospheric pressure. This release of pressure swiftly lowers the temperature of carbon dioxide, causing its formation into an extremely cold, waterless snow. The snow is then compressed into blocks of ice.

21. To Summarize

our photographic description of gas processing, let's fly over the South Coles Levee Recycling Plant near Taft.

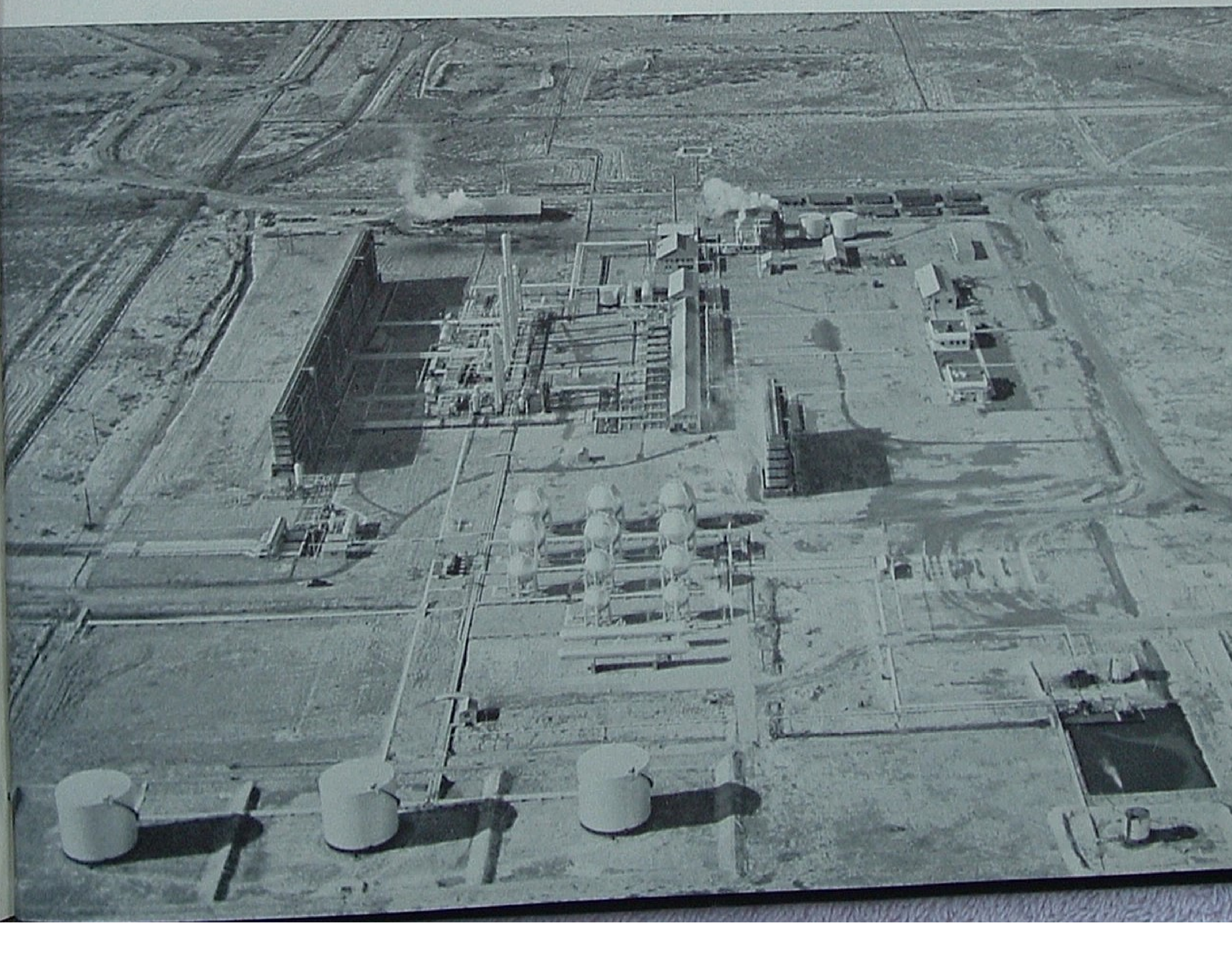
Wet gas entering the plant through a system of pipe lines, extreme left, is the lighter of two petroleum streams, the heavier oil having already departed via pipe line toward refineries.

Installations, center, are, from left to right, a cooling tower for quickly lowering the temperature of hot gases and liquids; absorber and fractionation columns where the light hydrocarbons are separated into usable products; a long row of buildings housing compressors, electric generators and pumps; in the background, heating equipment; at extreme right, office buildings and a warehouse. A smaller cooling tower, toward the right, cools water circulating to the compressors and gas engines.

The dry natural gas produced by such plants may be used in part as a plant fuel, or pumped underground to produce more oil, or delivered into gas company pipe lines as a heating fuel for homes and industry.

Propane, butane and stabilized natural gasoline are stored in the 11 spherical and two horizontal tanks, all of which keep these petroleum products under pressure and in liquid form. The road loop at right is evidence that liquified petroleum gases are generally shipped by tank truck. They go either to jobbers and large consumers as a power or heating fuel or to refineries and chemical plants for further processing into high anti-knock gasolines and synthetic compounds. Natural gasoline, although sometimes used in this form as a motor fuel, is usually a better product if blended with refinery gasolines. It is transported either by truck or by gasoline pipe line.

De-butanized condensate is stored in the three tanks, near foreground, pending shipment by pipe line to refineries.



Transportation

22. Pump Station

Enroute to refineries, we should obtain at least a bird's-eye view of how most crude oil is transported.

At right, we are looking down from a pipe line patrol airplane on Shandon Pump Station. Shandon is typical of some 15 plants that push liquid crude oil through 140 miles of pipe line connecting San Joaquin Valley fields with our Pacific Ocean terminal at Port San Luis. Such plants are equipped with two or more steam or electric driven pumps whose powerful impellers or pistons keep the oil moving at about three miles an hour. A second function of these plants it to heat some of the heavier varieties of crude, thereby causing them to remain less viscous, hence easier to pump. Storage tanks are useful at pump stations either to side-track a shipment or accumulate oil from tributary lines until a normal shipment of 50,000 barrels or more is ready for transportation through the main line.

23. Pipe Lines,

although costly to install, are among the most economical means of transporting petroleum. They recognize few insurmountable barriers and throughout America can be seen stretching across thousands of miles of deserts, mountains and fertile valleys.

The main trunk at left, taking the shortest course across foothills of Cholame Valley, actually consists of two parallel pipe lines. The pipe varies in diameter from eight to twelve inches and is buried about two feet underground, except where it lies exposed above narrow gulleys and streams. One line transports the heavier crudes. The other handles light crudes and condensate. Through similar pipe line systems, most of the stabilized natural gasoline also proceeds from gas plants to refineries.

Constant watchfulness is necessary to guard against pipe line leaks and prevent highway and other construction crews from inadvertently doing damage. Patrolling was formerly done by workmen on horses, in buggies or afoot. Today low-flying airplanes are proving more satisfactory. Pilots on these runs can spot leaks or warn trespassers in a fraction of the time formerly required. Very little oil is lost enroute.

24. Pipe Line Terminal

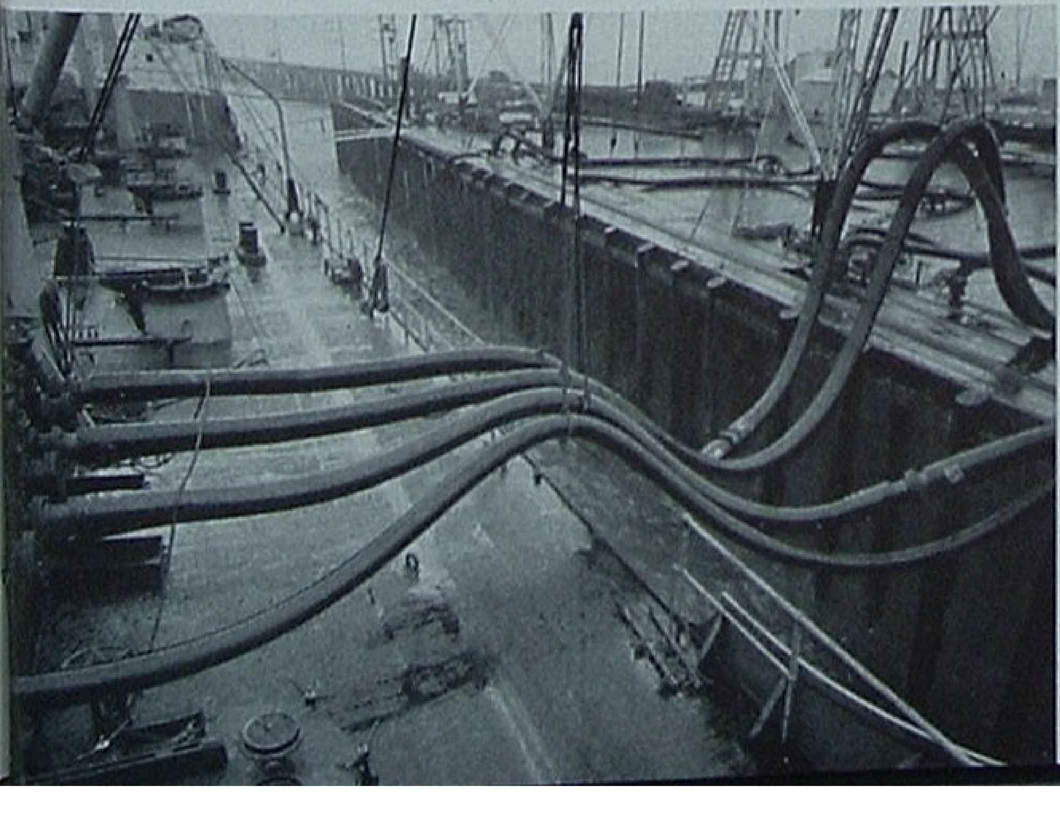
is the industry's name for Port San Luis, above, where pipe lines from the San Joaquin and Santa Maria Valleys terminate. Facilities at Avila Pump Station, here seen on the coastal bluffs, include storage tanks, oil-heating equipment and modern pumps that are capable of delivering well over 20,000 barrels per hour of crude aboard tankships. Additional reserve storage facilities, in the form of tanks and immense underground reservoirs, are located a few miles inland at San Luis Obispo.

This busy terminal often serves two large tankships at a time, operates day and night, and in a single month has accommodated nearly 50 ocean-going vessels. A ship has been loaded here with nearly 90,000 barrels of 35-gravity oil in the short interval of 4½ hours.

25. Tankships,

such as Union Oil Company's SANTA PAULA, below, take over the oil transportation job at land's end. This ship, one of eight Company vessels, has a maximum gasoline cargo capacity of 140,000 barrels, but normally carries no more than 115,000 barrels of heavier crude oils released from Port San Luis lines. A compartmentized hold permits the transportation of several commodities each voyage.

Loading at Port San Luis takes place a half-mile offshore. Large flexible hoses connect ship tanks with wharf pipe lines. Through these, water ballast is pumped ashore while oil comes aboard. The loading view, lower left, was photographed during a heavy rain squall, indicating that roughest weather seldom interferes with ship schedules and the punctual movement of crude.



26. Tank Farm

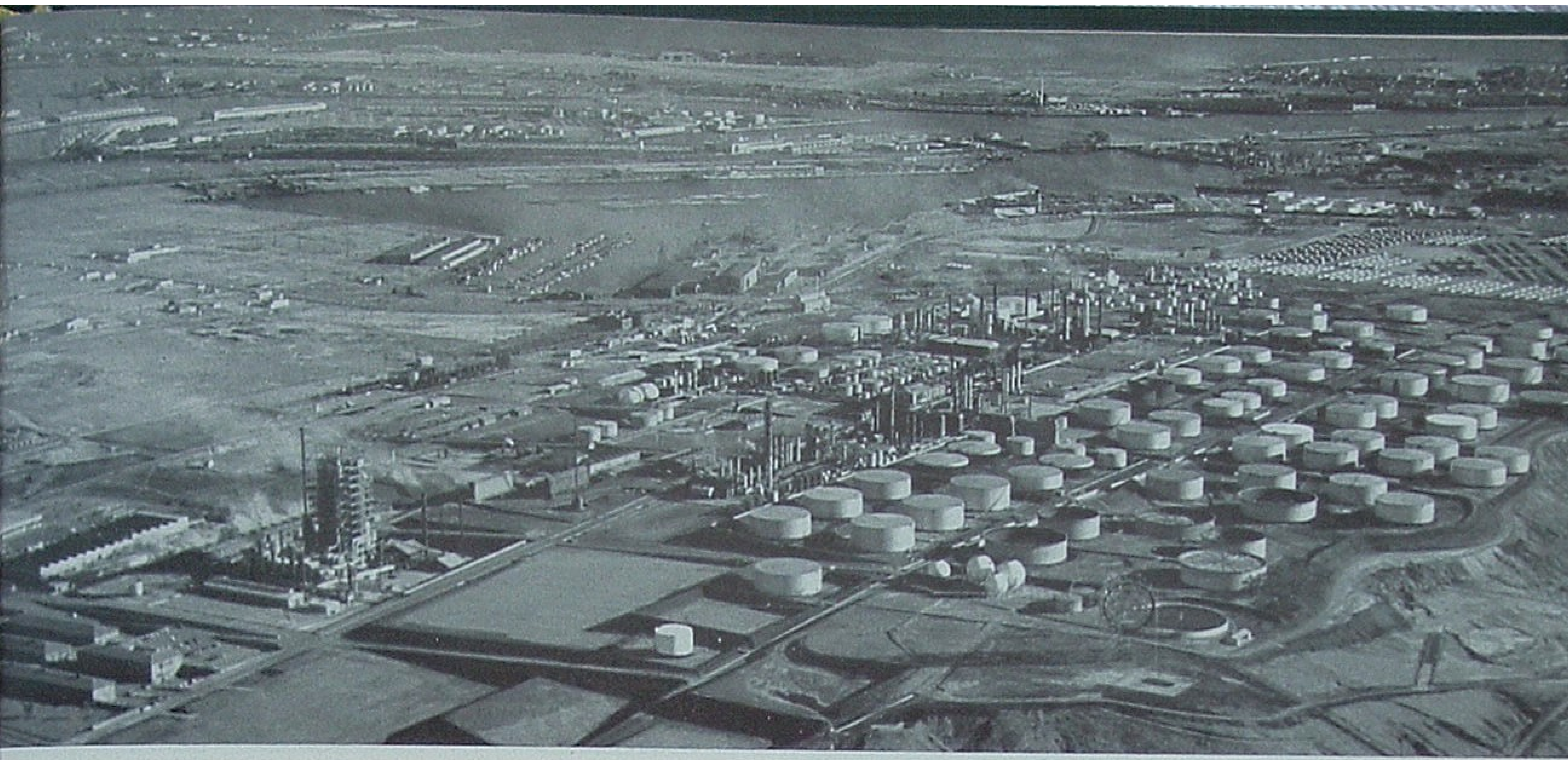
Somewhat different are the problems of transporting crude oil through cultivated areas and densely populated towns. Stewart Tank Farm, left, is the starting point of another pipe line connecting several fields directly with Los Angeles Refinery. From tank and underground reservoirs of this tank farm, oil is pumped by pipe line under orchards, farms, railways, highways, towns and cities. Fortunately laying of the pipe preceded many of these surface improvements and its existence is unknown to most people who reside near it. Nevertheless, increased vigilance is required to prevent oil leaks in such areas and to prevent pipe line damage by new construction.

Stewart Tank Farm is an important storage and relaying point for crude oils produced in the Los Angeles Basin and Orange County.

27. Marine Terminal

After a coastwise voyage of 170 miles, requiring about 12 hours, south-bound tankships arrive at the Company's Wilmington Marine Terminal, shown in right foreground of picture below. Here unloading begins at once into terminal storage tanks or on through an installation of pipe lines to Los Angeles Refinery, whose tanks stand just beyond the harbor area. This marks the end of a journey for crude oil, condensate and natural gasoline, but only the beginning of operations that will effect their conversion into hundreds of products having literally thousands of uses.

Wilmington, however, is by no means used only as a receiving terminal. Here other ships are loaded with refined products and sent to such distant markets as Alaska, South America, Hawaii and New York. Its work is geared almost to world-wide petroleum needs.



28. Refinery

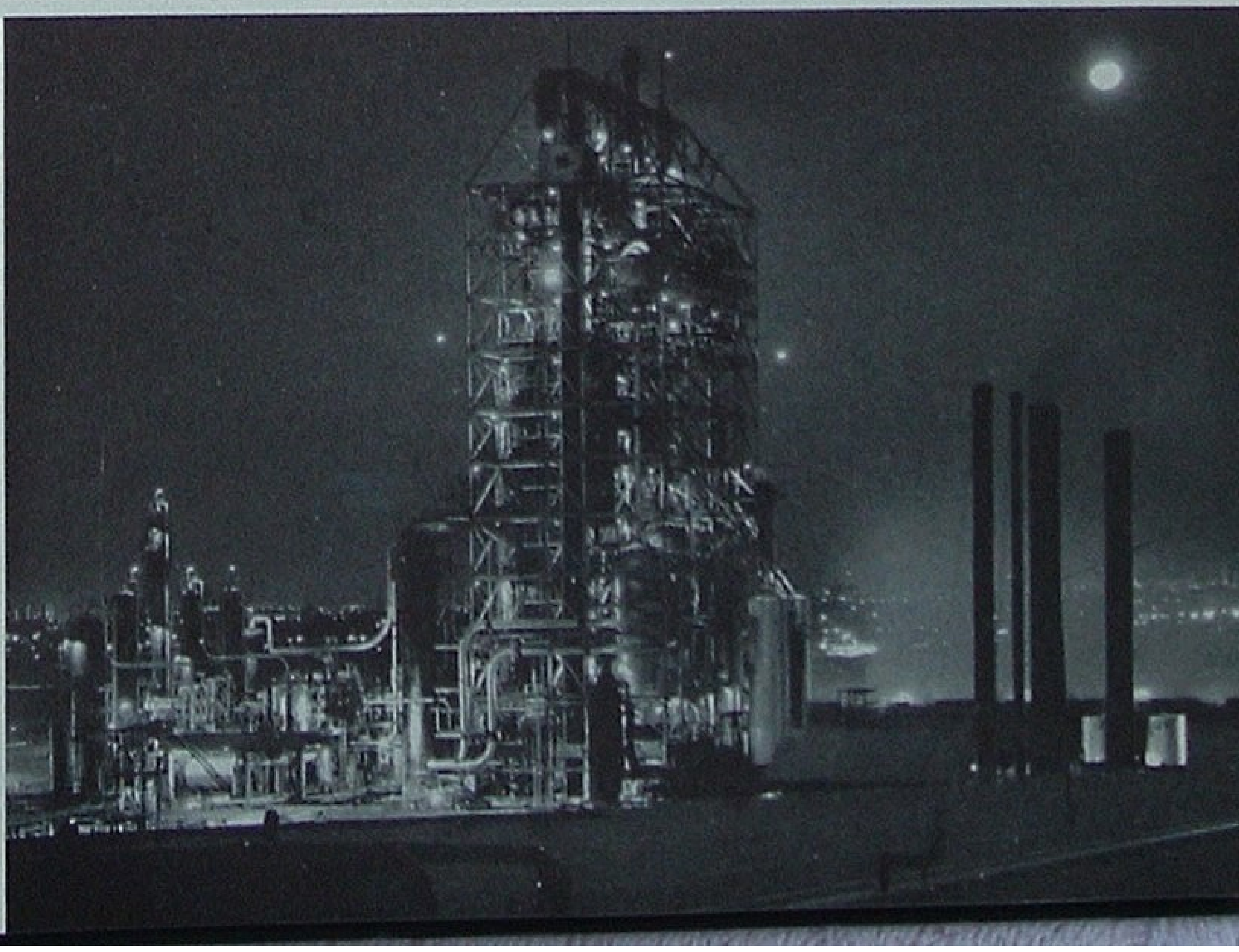
While still airborne, let's take advantage of good weather to view Los Angeles Refinery and the busy coastal area in which it is located.

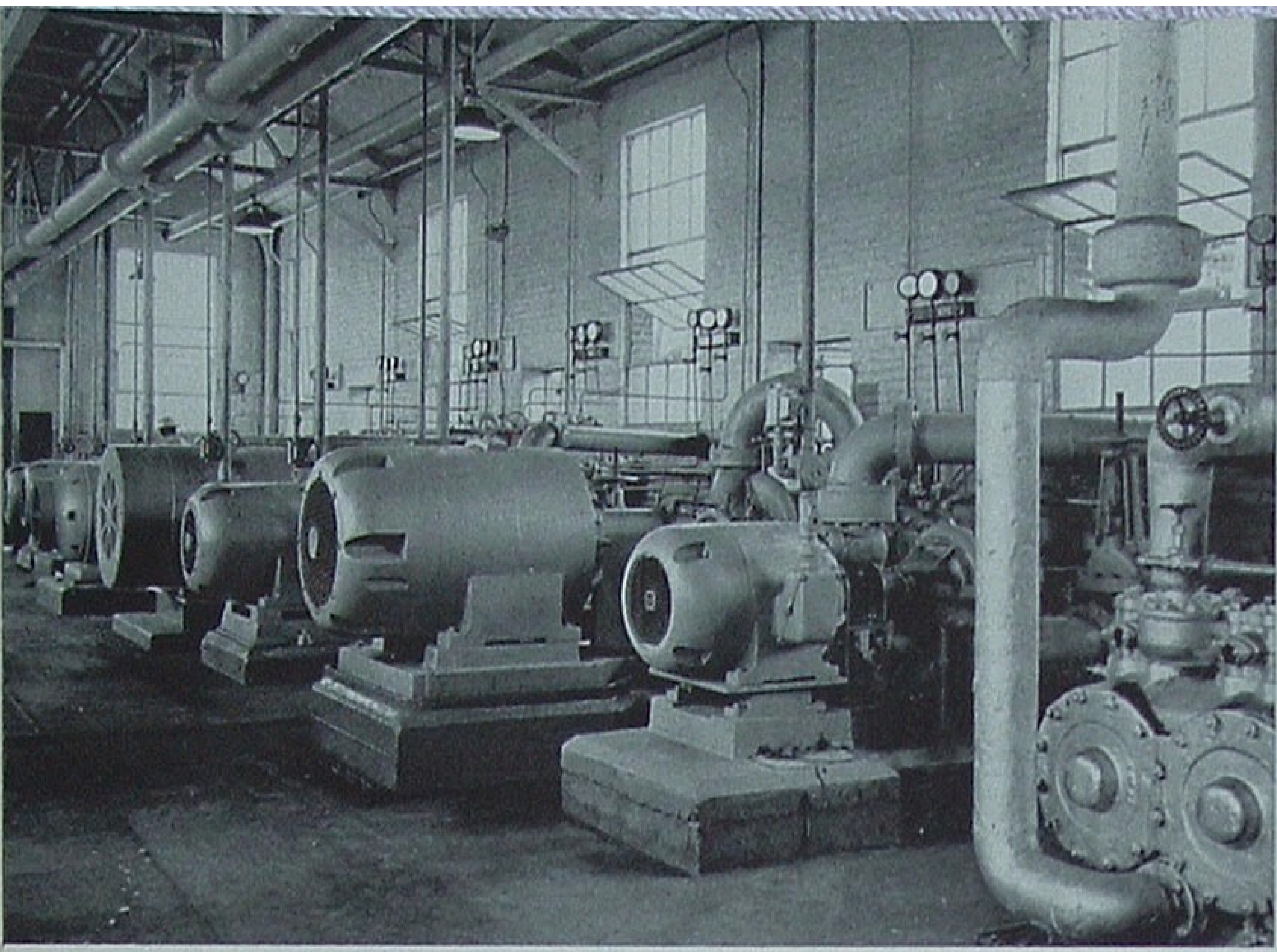
Occupying a 394-acre tract in the extreme western portion of Los Angeles County, this refinery is one of the West's largest and most modern. It contains handsome office buildings, laboratories, shops, warehouses and every modern facility for the comfort and convenience of nearly 1,000 people employed to operate it. Some of its refining units rise higher than a 20-story office building and are valued in millions of dollars. It functions day and night throughout each year with never a voluntary shut-down. Many of its installations were undreamed of 20 years ago except perhaps in the imaginations of inventive engineers; but so rapid is the growth of refining that another 20 years may witness even greater changes.

Despite size, changes and constant operation, the entire refinery presents an appearance of orderliness and exceptionally good housekeeping. It plays host to thousands of admiring visitors annually.

The products handled and manufactured in a refinery are flammable, explosive and in other ways hazardous to workers. Yet, such great care is taken in training and safeguarding personnel that a worker is less apt to be injured here than on the highway or in his own home.

Working units of a modern refinery compete even at night with the brilliance of surrounding towns and cities. At right is the Thermofor Catalytic Cracking unit on night shift. In subsequent pictures its functions will be explained.



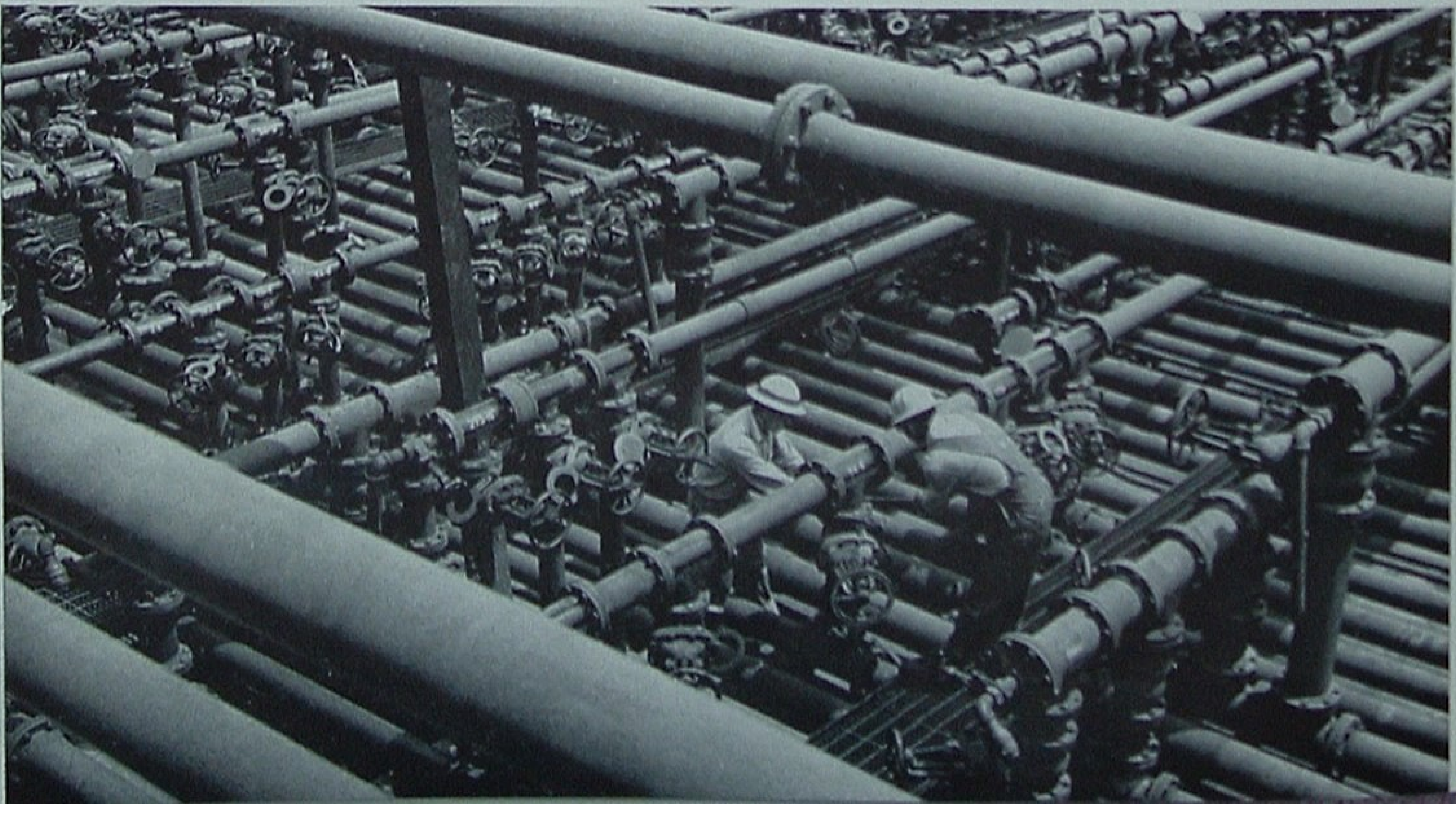


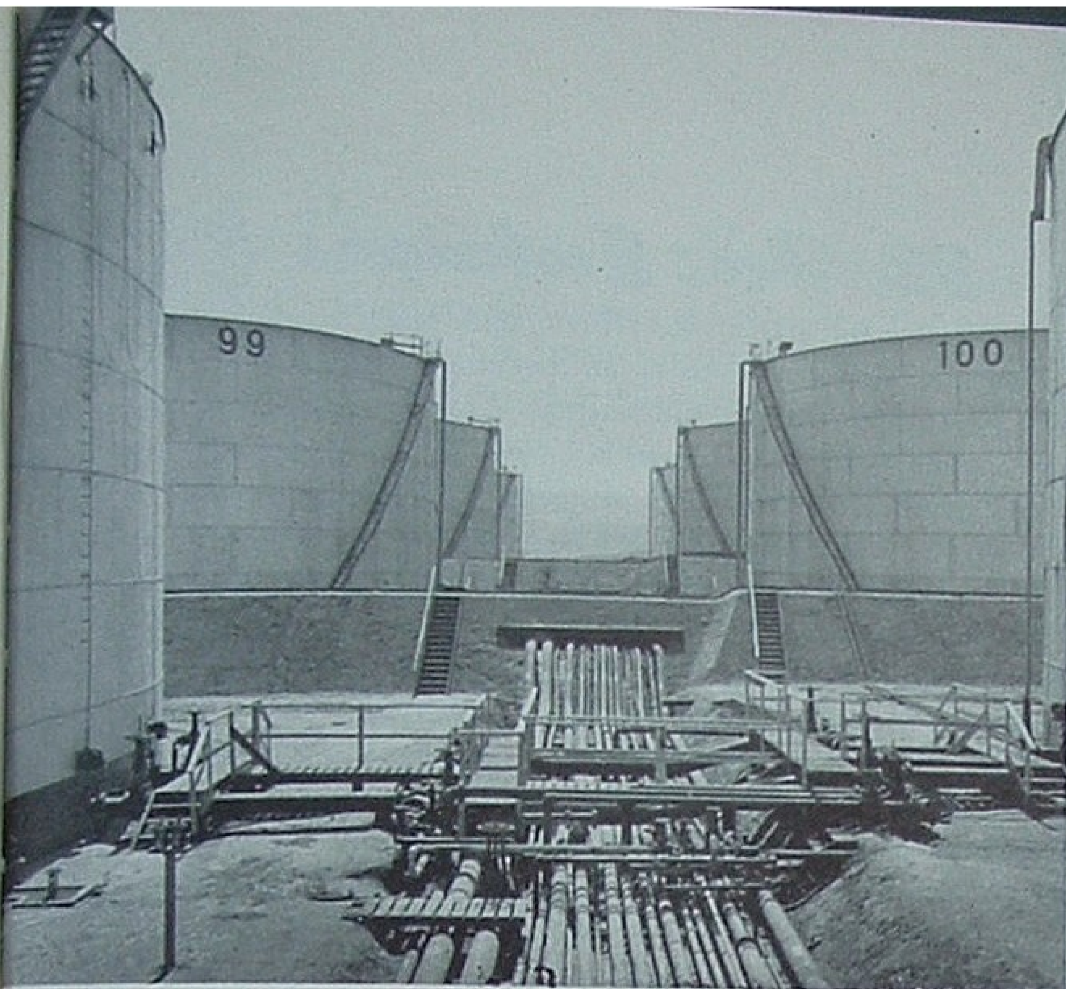
29. Pumps are the transportation heart of a refinery. They move incoming crude from fields and terminals into waiting storage tanks. They start crude through its first refining steps and pump resulting products into other storage vessels. They move streams of oil from one refining unit to another. They are equipped to handle oil of every kind—crude and refined, hot and cold—slowly and at high speed. If an electric power failure stops the electric pumps, there is steam-driven equipment on hand to take over. Through Los Angeles Refinery pumps, left, some 170,000 barrels of oil pass each day.

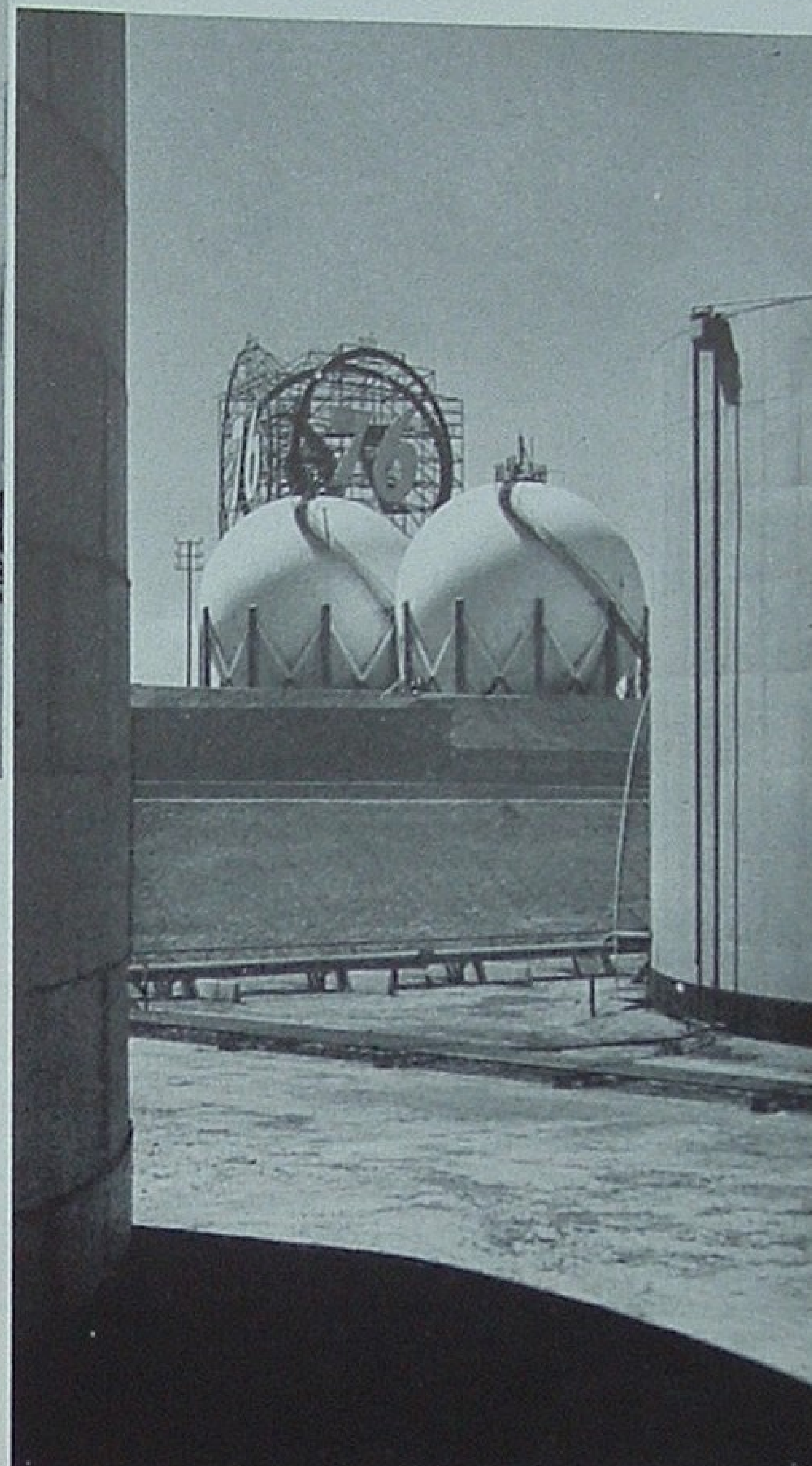
Refinery Equipment

30. Pipe Line Manifolds, shown below in the pump house area of Los Angeles Refinery, comprise a switchyard in which streams of oil can be routed through any system of lines within plant bounds. Approximately 650 miles of pipe have been installed in this one refinery to provide a complete oil transportation service. Operation of these manifolds involves the control of more than 1,800 valves. To avoid stock mixtures, spills and other costly mistakes requires that operators completely master the intricate pipe line system and use extraordinary care in directing oil traffic.

Because the best valves do not provide faultless control over oils being pumped at widely varying temperatures and pressures, every branch opening in the manifold system is provided with a metal *ring* and *blank*. When securely bolted in place between pipe flanges, the *ring* serves as an open doorway, or the installed *blank* effectively closes a passage and diverts the oil some other way.







31. Storage Tanks,

such as those above and at right, accommodate the refinery's incoming crude oil, receive partially refined products as they emerge from processing units, and hold finished products pending their shipment to market.

Each of the spherical tanks shown will hold up to 2,500 barrels of natural gasoline or other volatile products for which they are designed. But the commoner flat-topped vessels, which usually dominate a refinery storage block, have capacities ranging from 1,000 to 135,000 barrels each. There are more than 300 such tanks at Los Angeles Refinery with a total capacity of about 6,000,000 barrels.

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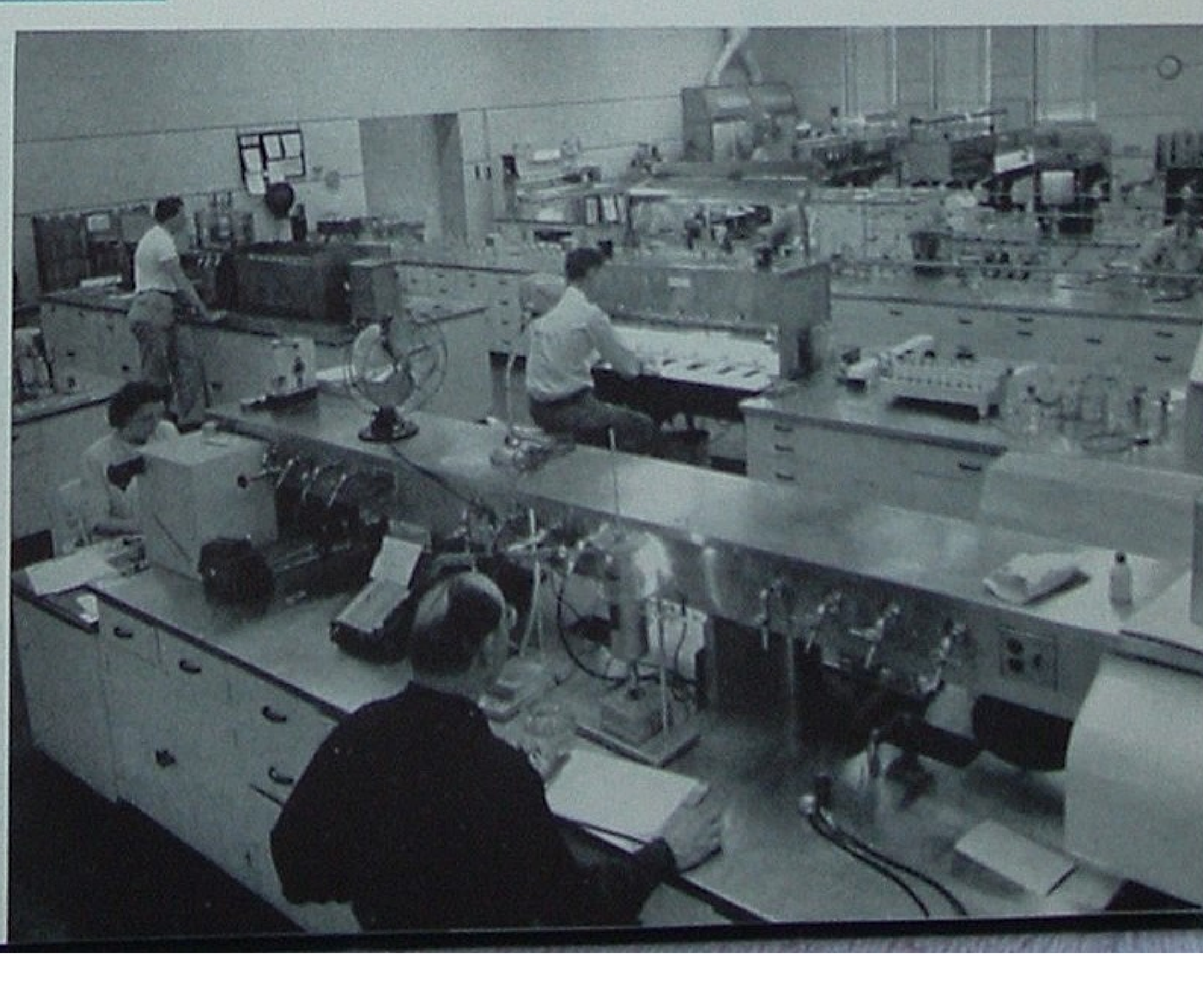
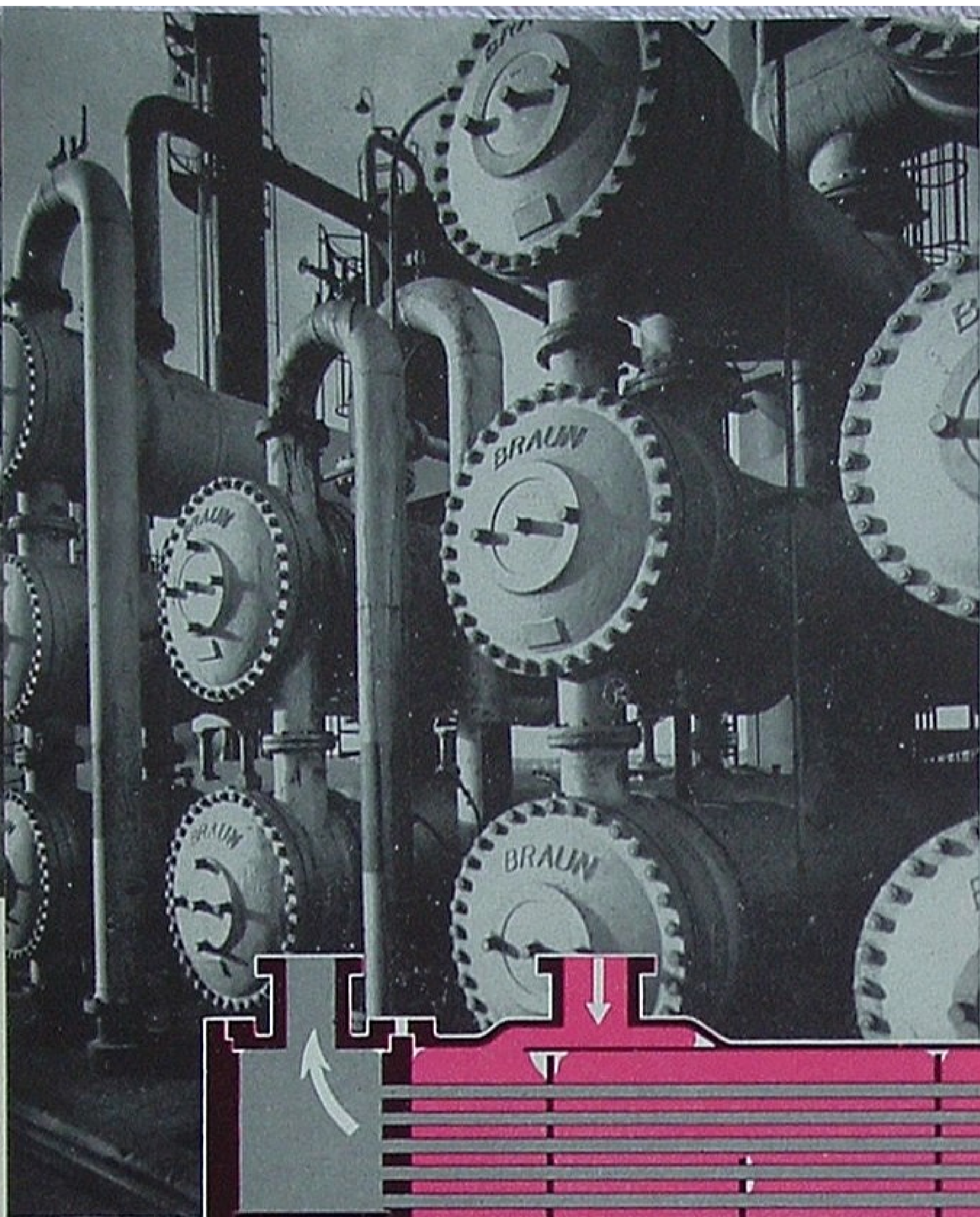
32. Analysis

is a fundamental requirement before any tank of crude is ready to be refined.

Samples taken from several levels in a tank are sent to the control laboratory, right. Here, by means of test equipment not unlike miniature refineries, the oil is carefully examined and measured. Chemists determine precisely what percentage of gasoline, gas oil and residuum it contains. They test for the presence of such foreign substances as sulfur and nitrogen bearing compounds.

In this way it is pre-determined how the crude can be refined to best advantage and what volume of finished products it will yield.



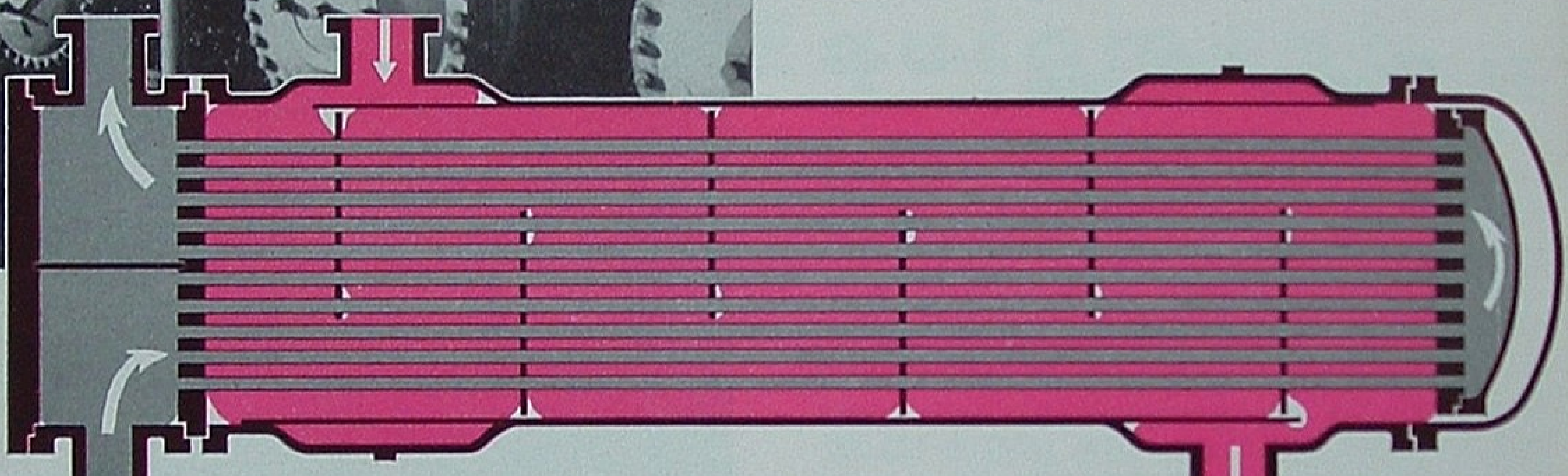


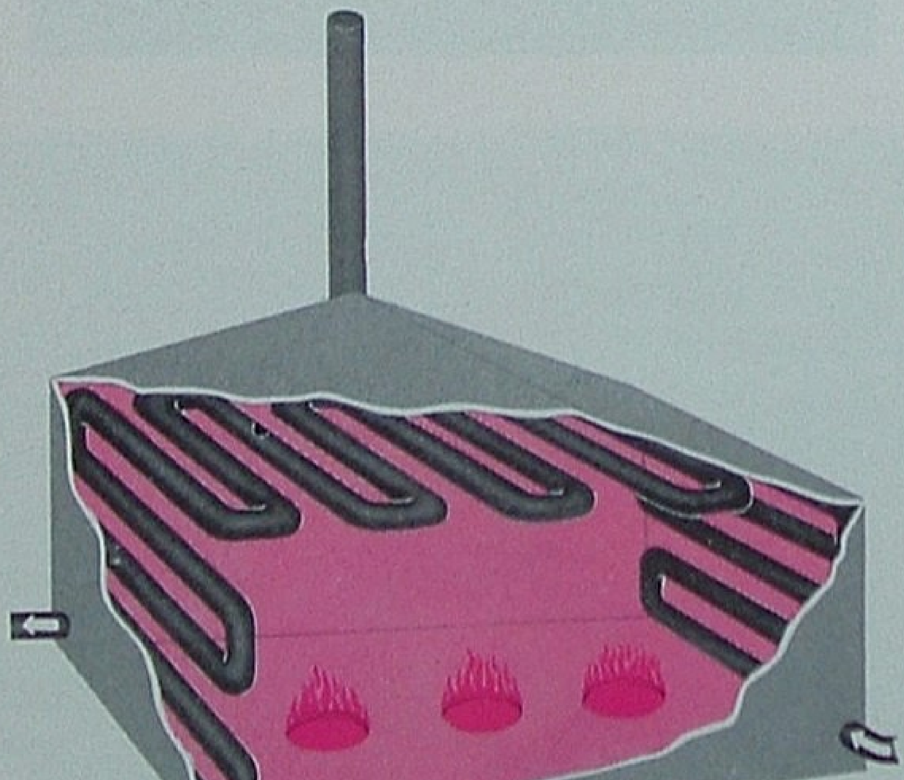
33. Heat Exchangers

Heat is the most important tool of the refiner, and, being costly to generate, it is conserved by an ingenious method.

Accompanying illustrations show a block of heat exchangers as they appear in operation and a cross-sectional drawing of how one performs. Crude oil, enroute to processing units, often passes first through a series of heat exchangers. Here it circulates inside bundles of hot piping. The piping derives its heat from a stream of hot oils and gases that circulate around the pipe bundle on their way out of a refining unit.

In this manner a two-fold economy is effected. Oil passing unit-ward through a block of heat exchangers absorbs what would otherwise be wasted heat. At the same time it helps to cool gases and oils that need to be condensed or reduced in temperature before going to storage.





34. Fired Heaters,

using petroleum gases, fuel oil or in some instances coke for fuel, are the initial source of heat used in refining processes. At left is a drawing illustrating the manner in which crude oil, after being partially heated in heat exchangers, is circulated through coils of pipe in a heater and brought up to the desired refining temperature.

Such installations operate at a wide variety of temperatures and pressures. Normally, crude oil, as it starts through the refinery, is heated only enough to drive off the lighter gases absorbed in it and cause some of the liquid hydrocarbons to vaporize. In successive steps the remaining liquids are heated to the increasingly higher temperatures needed to make them vaporize. Oil flows through such heaters in a steady stream, governed rigidly by temperature control instruments.

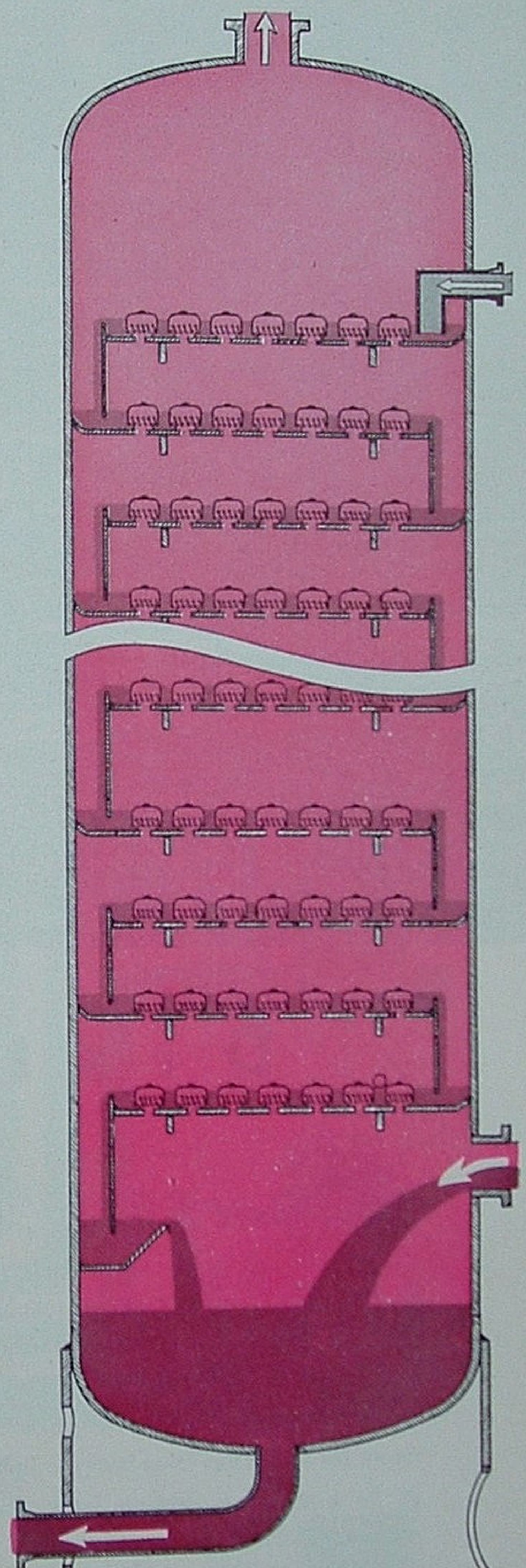
35. Distillation Columns

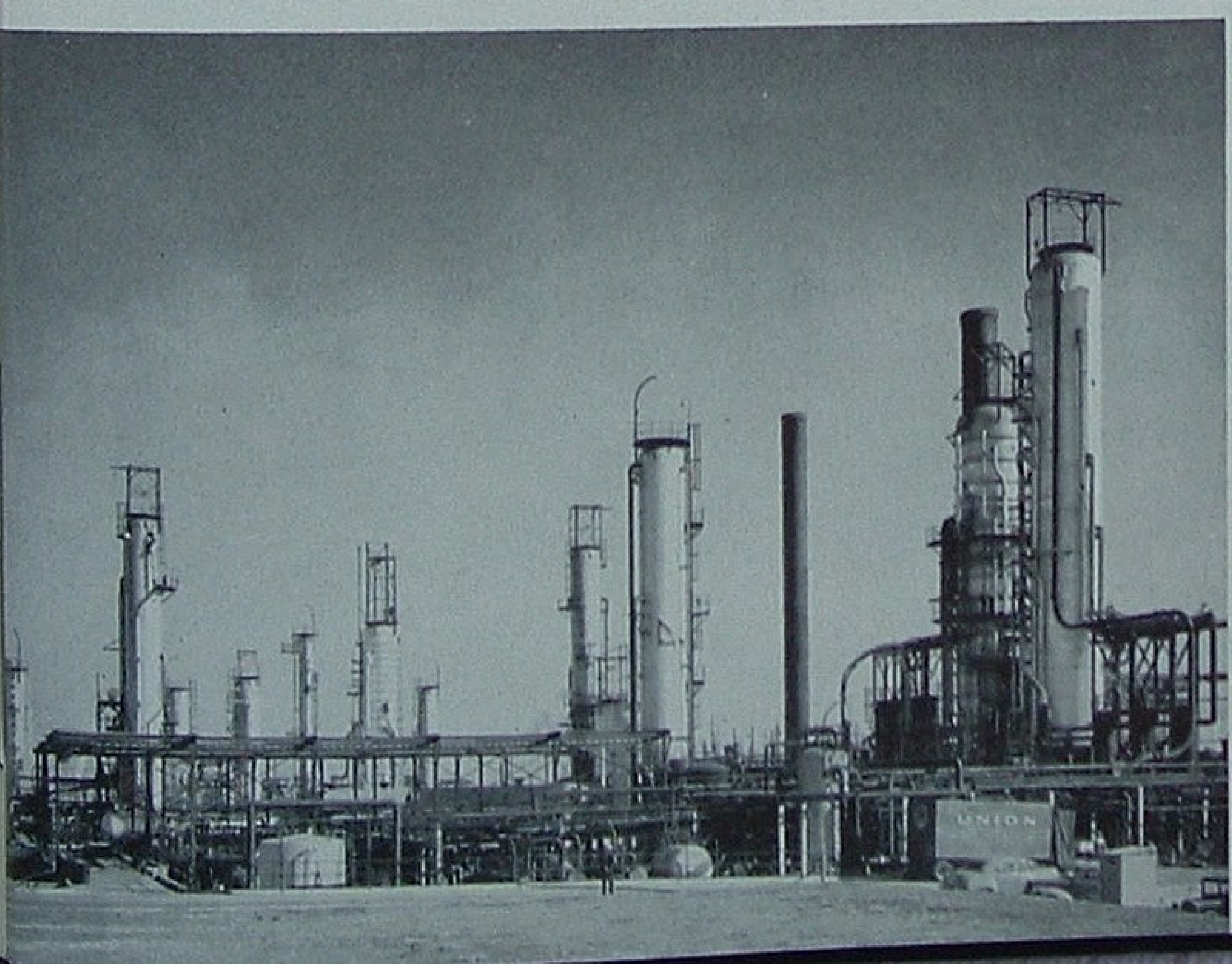
are so numerous and important in refinery operations that, as was done with heat exchangers and fired heaters, we had better pause to examine the inside of one.

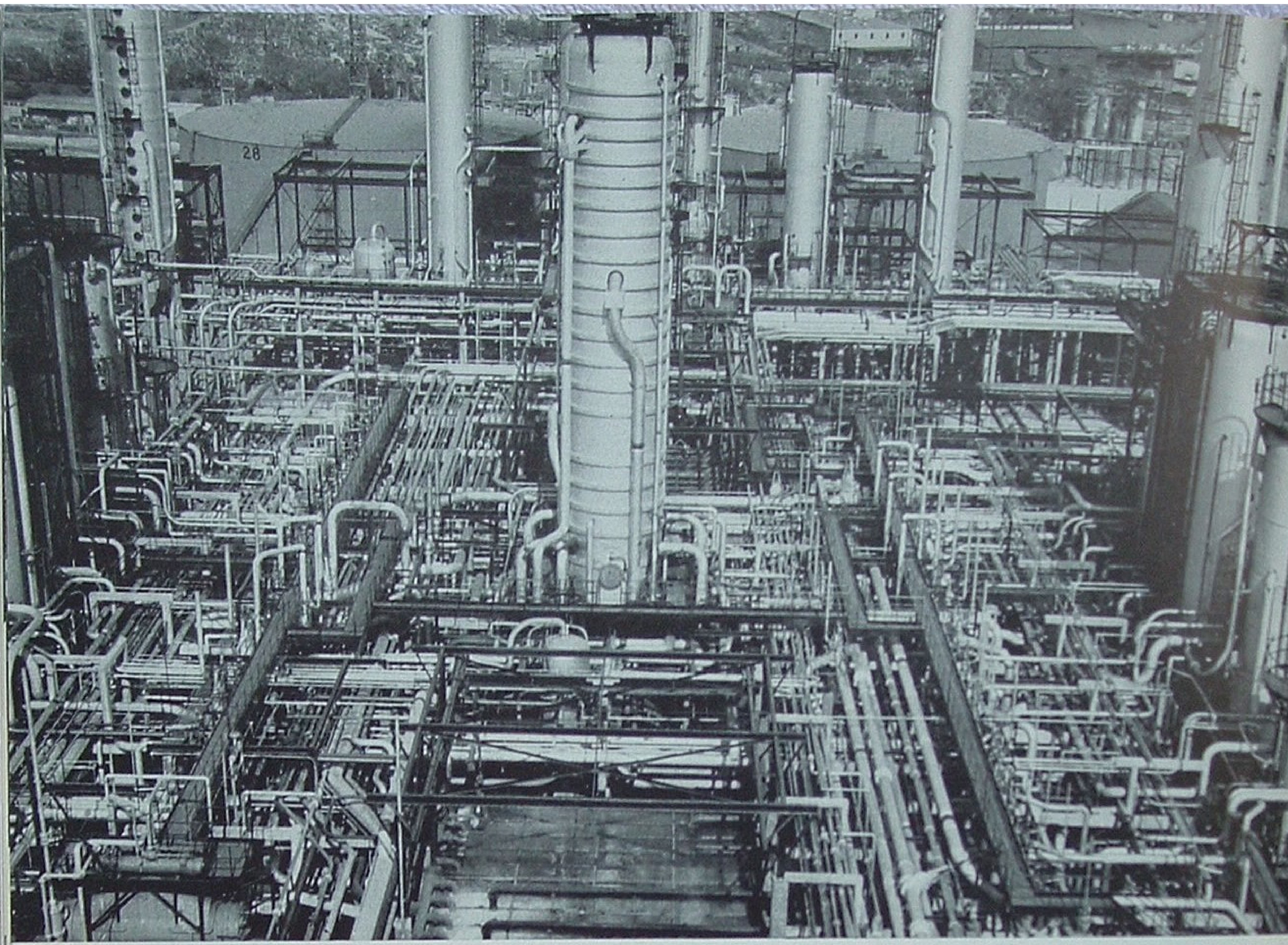
Our cross-sectional drawing shows heated oil entering a simplified distillation column through a pipe line opening, lower right. Heavy liquids flow downward into this vessel and are steadily drawn off through the bottom outlet. Other heated hydrocarbons *flash* or rise from the incoming stream in vapor form. These vapors find upward escape through the open slots of numerous *bubblecaps* mounted on overhead trays. However, in escaping, the vapors are obliged to bubble through shallow accumulations of oils that have condensed and filled the trays to overflowing. This has a cooling effect on the vapors, causing the various hydrocarbon components to condense on the trays in the order of their heaviness or boiling range. Principally, only the gaseous and lightest liquid hydrocarbons bubble upward through all trays and continue out through the column's top exits.

Liquid entering the column just above the uppermost tray is called *reflux*. It consists of gasoline vapors that have passed out the top exit, been cooled to liquid form and returned. Reflux assures a cool and adequate liquid accumulation on the top tray. Thereby any unwelcome heavy vapors that have persisted in following the lighter hydrocarbons are condensed and returned to their proper condensation levels.

Frequently, distillation columns are equipped with side exits to remove various liquids as they condense at different heights in the column. These liquids, called *side-cuts*, constitute refined or partially refined products. They range from gasolines near the top downward through solvents, kerosene and numerous fuel and lubricating oils.







Distillation

36. Unit 33, only part of whose expansive labyrinth of columns and piping can be seen in the above view, is a combination of several refining units. In its Crude Distillation Section over 60,000 barrels of crude is distilled daily. To its Thermal Cracking Section some of the partially refined products return for conversion from heavy to light oils. And in its Light Ends Section large quantities of *cracked* gasolines are segregated into several of the types and grades needed for blending into finished gasolines.

Since most other portions of the refinery depend upon Unit 33 for their crude feed supplies, this unit must be kept operating near to capacity day and night throughout the year. Some of its installations are built in duplicate to avoid a complete shutdown for maintenance work and repairs.

An idea of what is meant by "Thermal Cracking" and "Light Ends" will be given when we follow the oil *stream* back to Unit 33 from other parts of the refinery. But now is the logical time to look at its Crude Distillation Section.

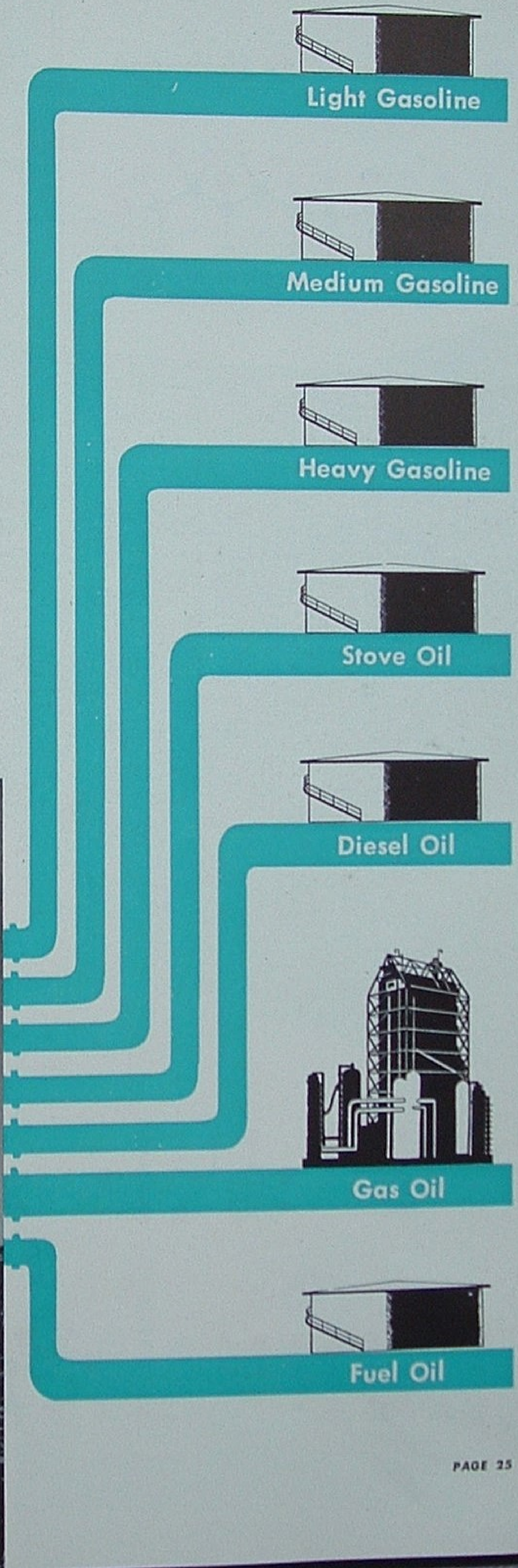
37. Crude Distillation

at Unit 33 takes place in the three columns below. Entering No. 1 column, right, at a temperature of approximately 650 degrees F., the crude is distilled into four fractions—a mixture of *light* and *medium gasoline*, *heavy gasoline*, *stove oil*, and a bottom *residuum* that did not vaporize.

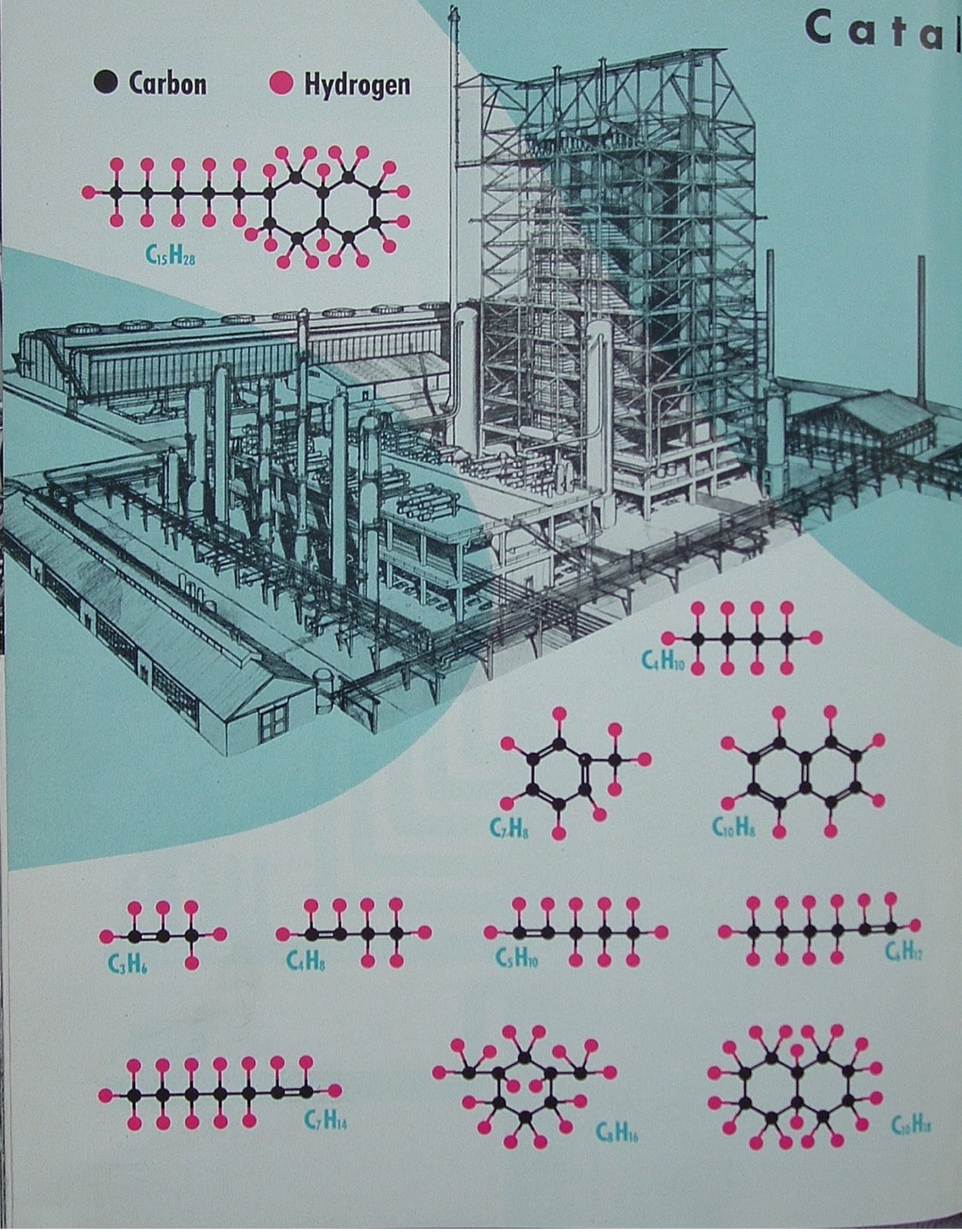
In No. 2 column, left, the mixture of *light* and *medium gasoline* is separated into these two fractions.

In contrast to No. 1 and No. 2 columns, which work at pressures of around 60 pounds per square inch, No. 3 column, center, operates at a pressure only about one-third as great as that of the outside atmosphere. This partial vacuum causes some of the oils to vaporize at a somewhat lower temperature. Thus the *bottom residuum* from No. 1 column needs to be raised to a temperature of only about 675 degrees to effect its separation in No. 3 into three fractions—*diesel oil*, *gas oil* and *fuel oil*.

So, from 60,000 barrels of crude oil entering Unit 33's Distillation Section daily, we obtain seven partially refined products. About 30 per cent of the crude goes to storage in the form of gasolines. Another 30 per cent is drawn off the bottom of distillation columns and sent to storage as residual fuel oil. The remaining 40 per cent, classified as stove oil, diesel fuel and gas oil, proceeds in part at least to the Thermofor Catalytic Cracker, where we shall presently follow its interesting adventure.



Catalyt


Carbon
Hydrogen
C15H28
C4H10
C7H8
C10H8
C3H6
C4H8
C5H10
C6H12
C7H14
C8H16
C10H18

alytic Cracking

38. Cracking of heavy oils into lighter oils is best understood by thinking of it in terms of hydrocarbon molecules.

Shown at top of the hydrocarbon stream, left, is amyl decalin ($C_{15}H_{28}$), a typical representative of many hydrocarbons known to comprise gas oil. When such molecules are heated to vapor form and exposed to a type of substance known as *catalyst,* they frequently break up or *crack* into smaller molecules.

A few of the smaller molecules that result from the *cracking* of gas oil are also symbolized here, namely, butane (C_4H_{10}) of the paraffin family; toluene (C_7H_8) and naphthalene ($C_{10}H_8$) of the aromatic family; propene (C_3H_6), butene (C_4H_8), amylene (C_5H_{10}), hexene (C_6H_{12}) and heptene (C_7H_{14}) of the olefin family; dimethyl cyclo hexane (C_8H_{16}) and decalin ($C_{10}H_{18}$) of the naphthene family.

Briefly, then, *cracking* is the oil industry's term for breaking big molecules into little ones—for converting products for which there is a limited demand into products having wide usefulness and greater demand—specifically, in this instance, for converting gas oil into high quality gasolines.

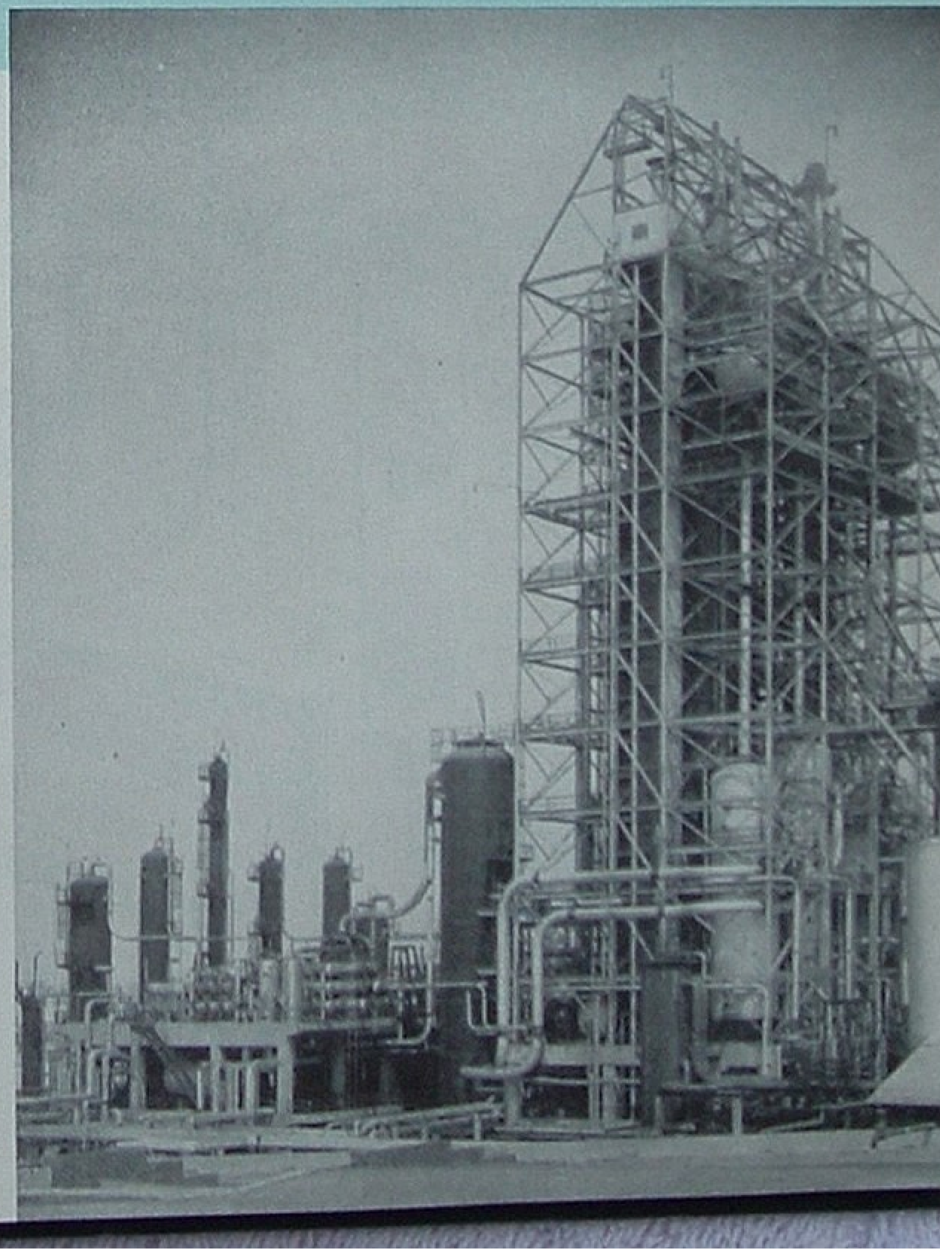
39. Catalyst is the name applied by chemists to any substance that will bring about or hasten chemical reaction among other substances without undergoing chemical change itself. As applied to the refining process under discussion, *catalyst* is a substance that will assist in causing or hastening the *cracking* of gas oil molecules into lighter products, yet will neither combine with the oils nor be changed greatly by their reaction.

The handful of pellets shown above is a sample of *catalyst* now being used at Los Angeles Refinery in the *catalytic cracking* of gas oil. It is nothing more than a white or gray clay containing small amounts of metallic oxides. Science has not offered a fully satisfactory explanation of how catalysts perform such services.

40. Unit 151, right, is often referred to at Los Angeles Refinery as the TCC unit, these initials being an abbreviation of Thermofor Catalytic Cracker. *Thermofor,* derived from the Greek word *thermo,* meaning heat, denotes a type of furnace used in the process. And *Catalytic Cracker,* as we have attempted to explain, further describes the installation's use of a catalyst to crack gas oil arriving from Unit 33.

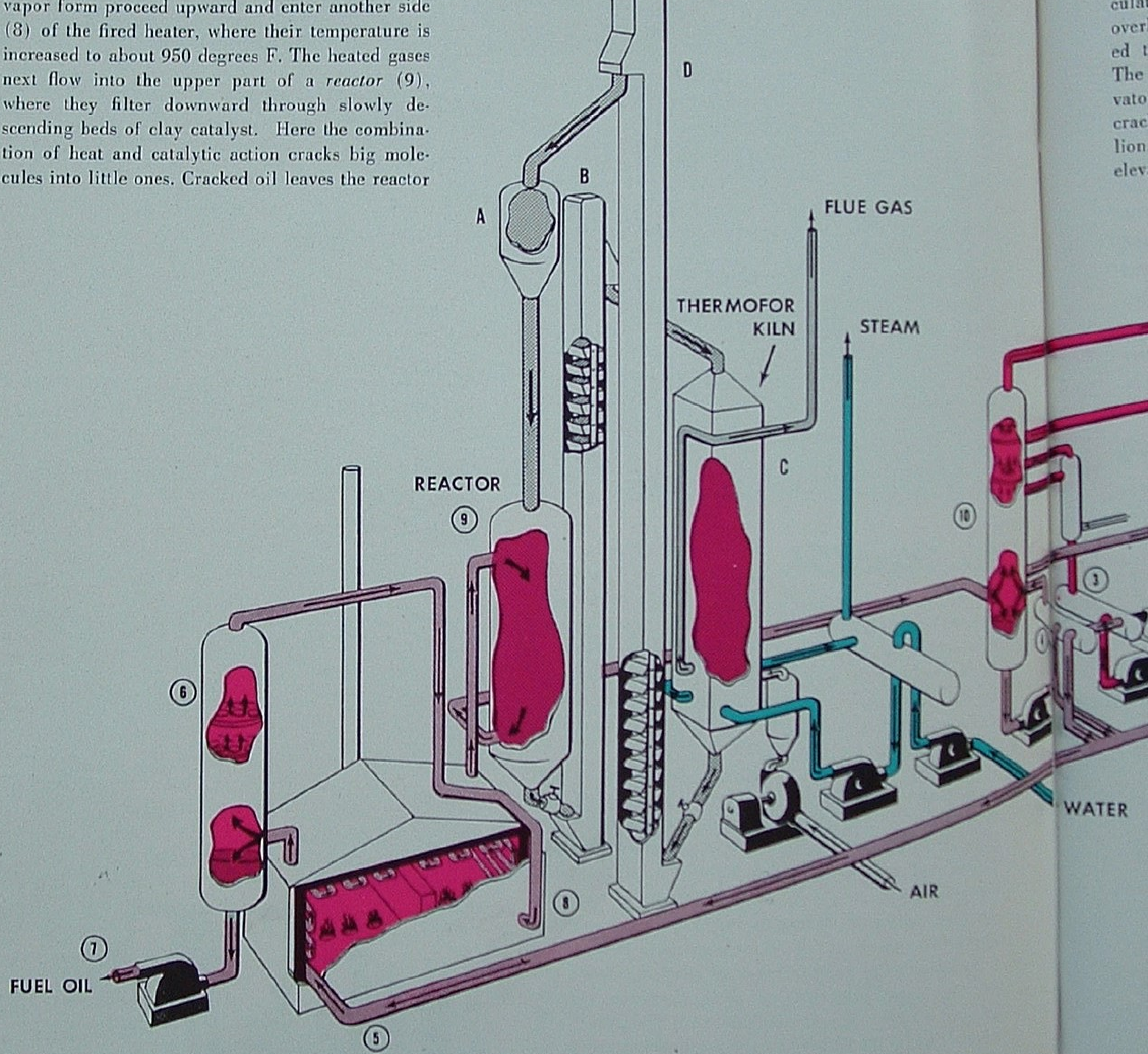
The large and costly installation is one of several throughout the United States that were built to help win World War II. In 1937, this country produced less than 20 barrels of gasoline a day of sufficiently high octane quality to power modern fighting airplanes. However, by 1944, at a cost of $50,000,000 in catalytic cracking equipment, American refineries were producing 36,000,000 barrels of 100-octane gasoline a year.

As complicated as these towering *crackers* appear and are, the basic principles of their operation can be grasped readily. For an explanation of how they work, please turn to the following cross-sectional drawing.

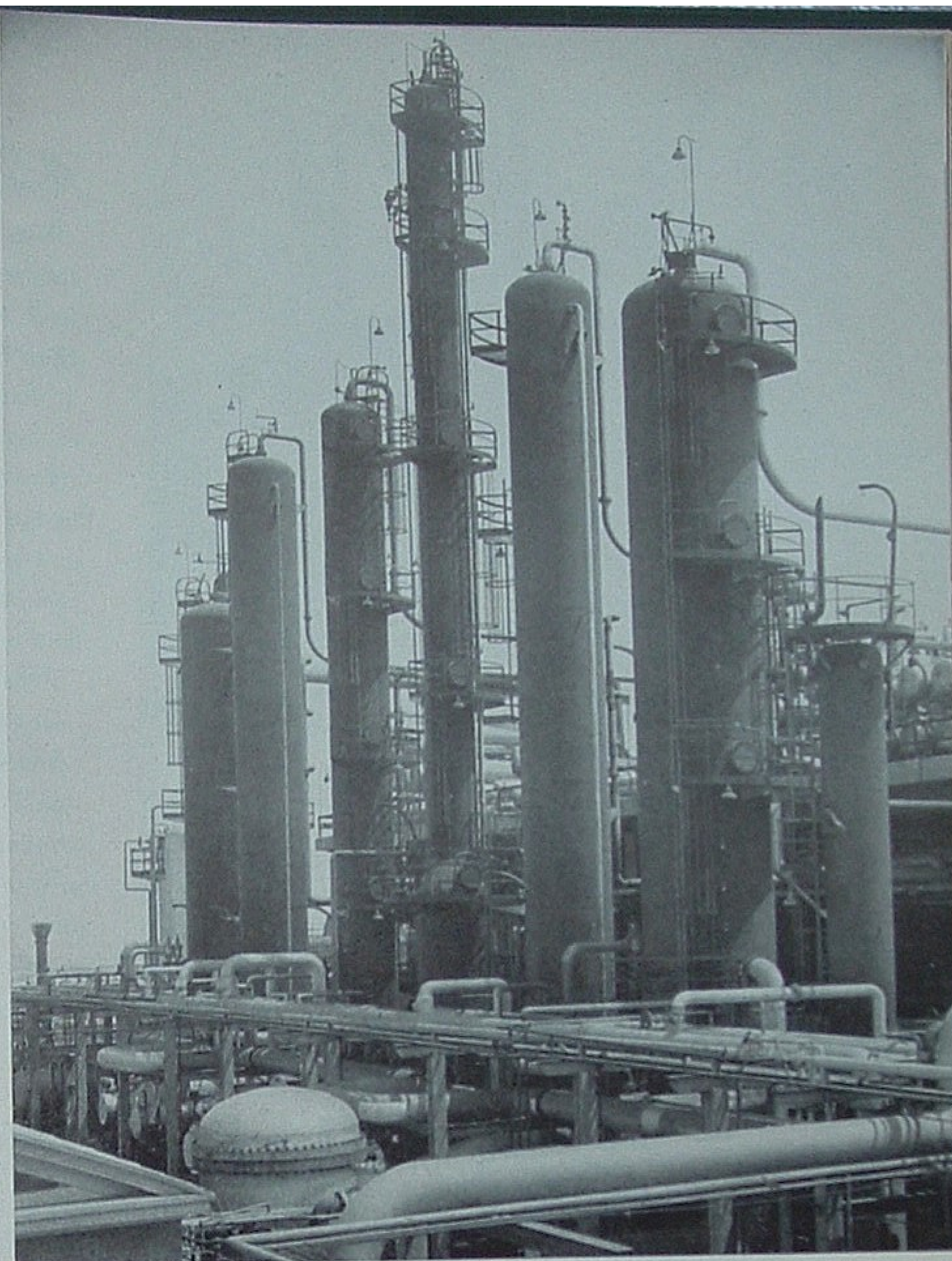


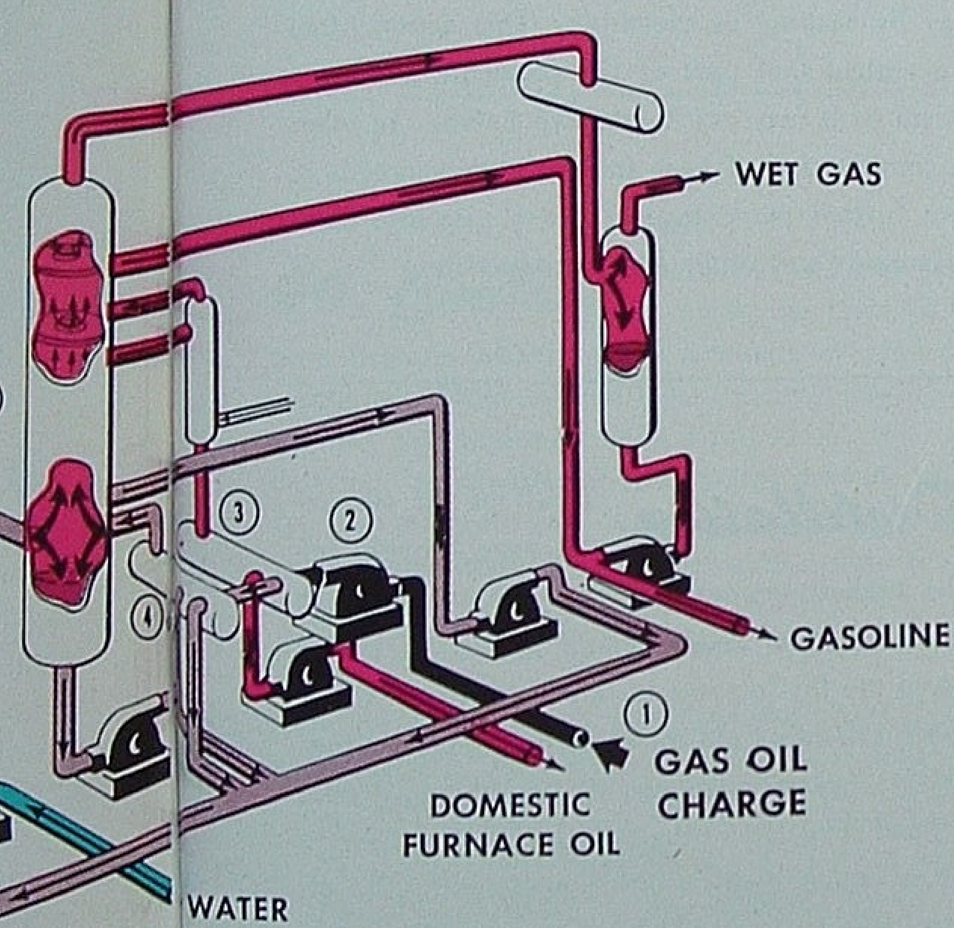
41. TCC Process

Beginning at the numeral (1), lower right of drawing, let us follow a charge of gas oil through the catalytic cracking process. The oil is forced by a pump (2) through two heat exchangers (3 and 4), then on through a pipe line to one side of the fired heater (5). On next entering a distillation column (6), a liquid fuel oil portion, not adaptable to cracking, is pumped off to storage (7). Lighter fractions in vapor form proceed upward and enter another side (8) of the fired heater, where their temperature is increased to about 950 degrees F. The heated gases next flow into the upper part of a *reactor* (9), where they filter downward through slowly descending beds of clay catalyst. Here the combination of heat and catalytic action cracks big molecules into little ones. Cracked oil leaves the reactor through a lower exit and is piped to another distillation column (10). Part of the stream there liquefies, is pumped into heat exchanger (4), and rejoins the gas oil charge stream. The cracked vapors, however, are distilled off in the forms of wet gas, gasoline and domestic furnace oil.



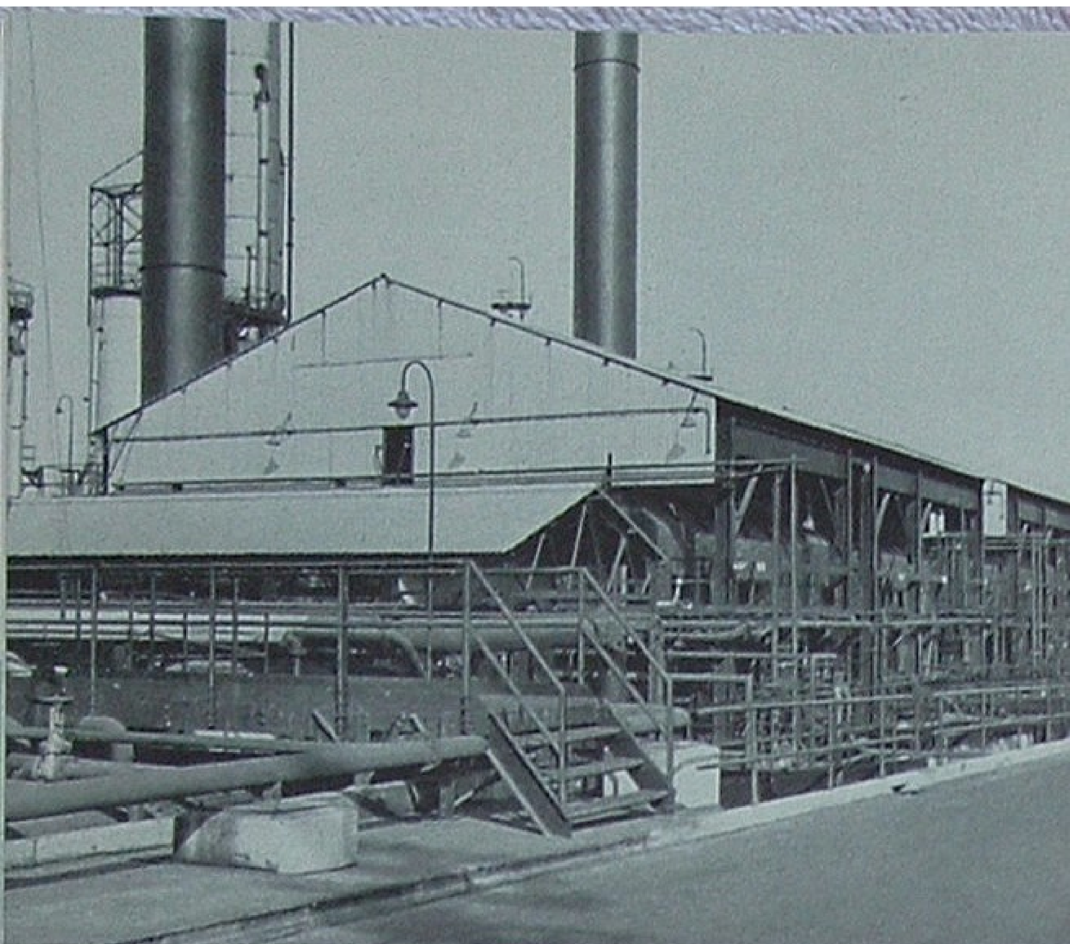
Now let's trace the catalyst. Fresh pellets of clay from the hopper (A) move down into the reactor (9). In contacting the reacting oil vapors, the catalyst pellets progressively become coated with a soot-like film. Continuing out the bottom of the reactor, they are carried upward on an elevator (B) and released into a thermofor kiln (C). Here air is admitted to burn soot from the hot catalyst while water, circulating through coils of pipe, prevents overheating of the catalyst and is converted to steam by the heat thus absorbed. The reactivated pellets are lifted by elevator (D) to hopper (A) for reuse in the cracking cycle. A load exceeding 15 million pounds per day is handled by these elevators.

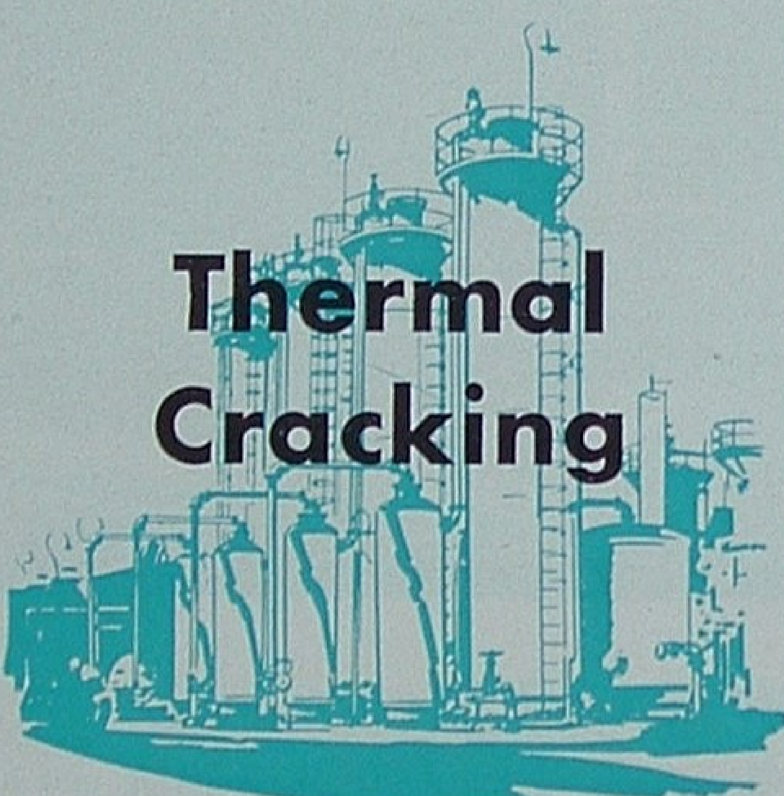




42. TCC Distillation

is accomplished in the columns shown above. The cracking unit normally processes about 25,000 barrels of gas oil in 24 hours. Lightest of the fractions distilled is fuel gas; it is an excellent fuel for use in refinery fired heaters. Some 1,600 barrels of liquefied petroleum gas (LPG), composed in large part of butane and butene molecules, is also produced here daily; it is an important fraction and will be introduced again under the subject of *alkylation*. The yield of cracked gasolines amounts to about 6,000 barrels per day; these are stored for eventual blending into finished gasolines. Of about 17,000 barrels remaining from the amount processed daily, the major portion is classified as *furnace oil;* we shall next follow it to the Cracking Section of Unit 33. Dark residuum from these columns is blended with other heavy oils and sold as fuel oil.





43. Thermal Cracking

Having resisted efforts of the TCC catalyst to break its molecules apart, the remaining gas oil, now called *furnace oil*, is sent back to Unit 33 for a more forceful type of cracking. Here in a series of furnaces, some of which are shown at left, the stubborn molecules are subjected to successively higher temperatures and pressures. Oil that refuses to crack in the first furnace proceeds on to others in the series, each furnace imposing a higher temperature and a greater pressure. In the final furnace, molecules are heated to approximately 1050 degrees F. and held under pressures up to 1200 pounds per square inch.

What actually happens during the thermal cracking process is that some of the furnace oil molecules react to extreme heat by trying to vaporize and escape from the liquid stream. However, high pressures hold them in solution and prevent their escape. While both heat and pressure steadily rise, the imprisoned molecules expend their energy by shaking or vibrating. This action often becomes so violent that part of the molecule is shaken completely off or it may crack into two halves. In other words, the combination of heat and pressure succeeds in converting a further percentage of heavy oils into more valuable gasolines and other light products.

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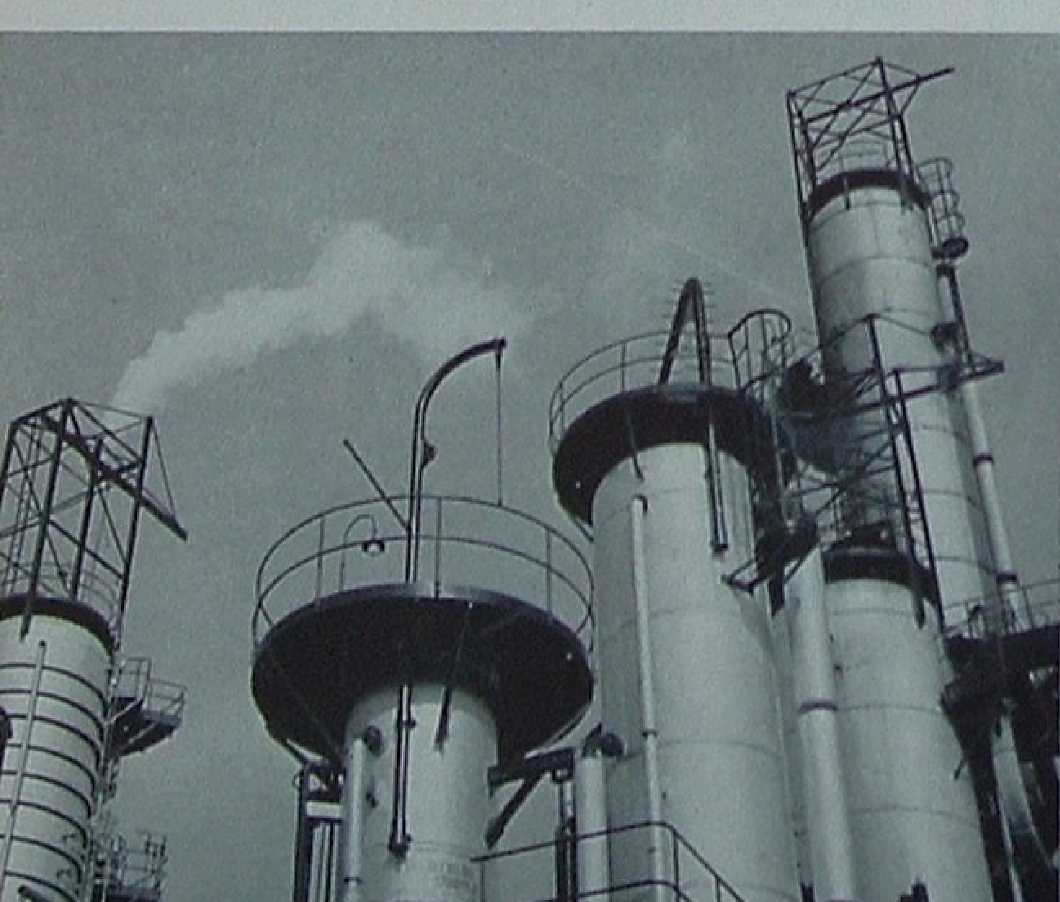
44. Distillation

If all of the furnace oil were brought initially to the highest temperature and pressure used in thermal cracking, two losses would occur. Cracking would proceed too far in some instances, converting part of the furnace oil into light gases rather than gasoline. Simultaneously, heavy portions of the charge would char into a hard coke, thus plugging the furnace tubes.

Therefore, a quick distillation is made after the oil emerges from each furnace. The columns at left accomplish this part of the thermal cracking process. They remove in vapor form the gasoline and lighter hydrocarbons, collectively known as *light ends*, immediately after each stage of cracking. Fuel oil bottoms from the columns are stripped of their vapor content and sent to storage. Only the middle fraction of furnace oil is delivered to the next higher stage of temperature and pressure for further cracking.



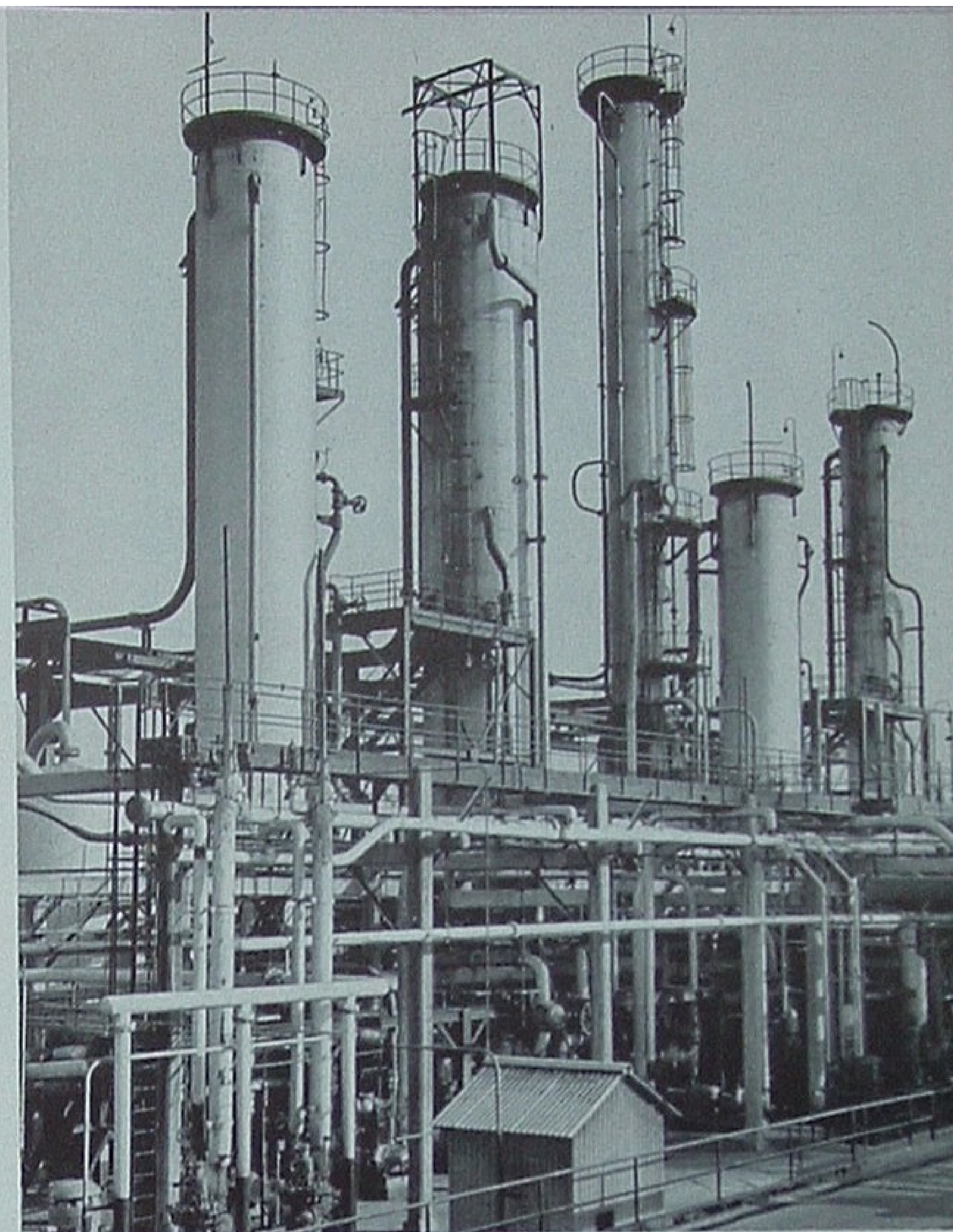
45. Light Ends

produced in the Thermal Cracking Section must be re-distilled in the columns, right, to assure a clean separation of several fractions and a high quality in the finished products.

Lightest of the fractions isolated here is *fuel gas*, which eventually finds its way back to the furnaces, but this time as a refinery fuel.

Another fraction is made up of *butane-butene* molecules similar to those produced by the catalytic cracking process. These products from both units go through an interesting transformation in the Alkylation Unit, where we shall presently follow them.

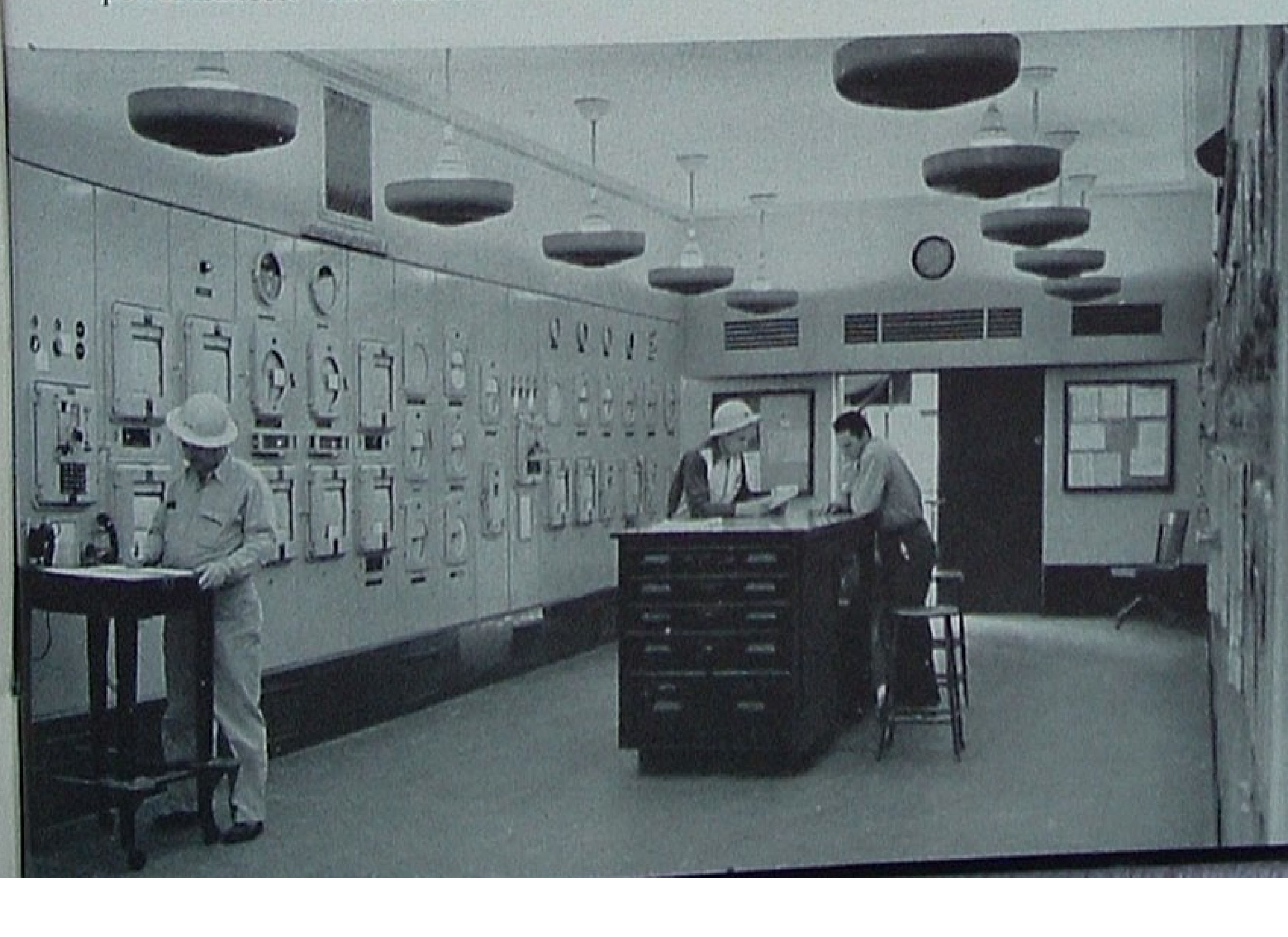
Three other products of the Light Ends Section of Unit 33 are *light pressure distillate*, *medium pressure distillate* and *heavy pressure distillate*. After being treated, to remove all harmful impurities, they are valuable as blending stocks for finished gasolines.

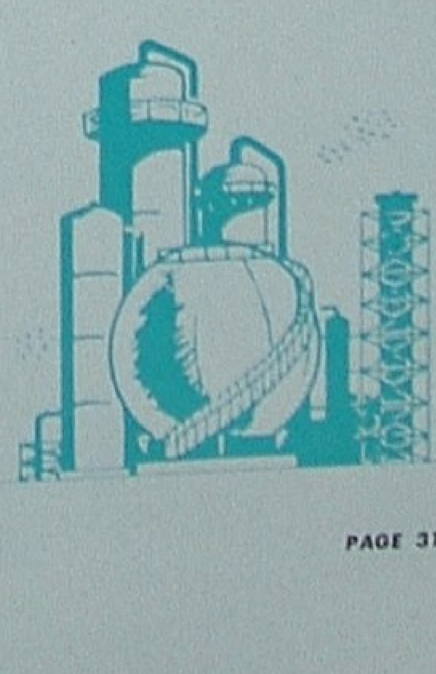


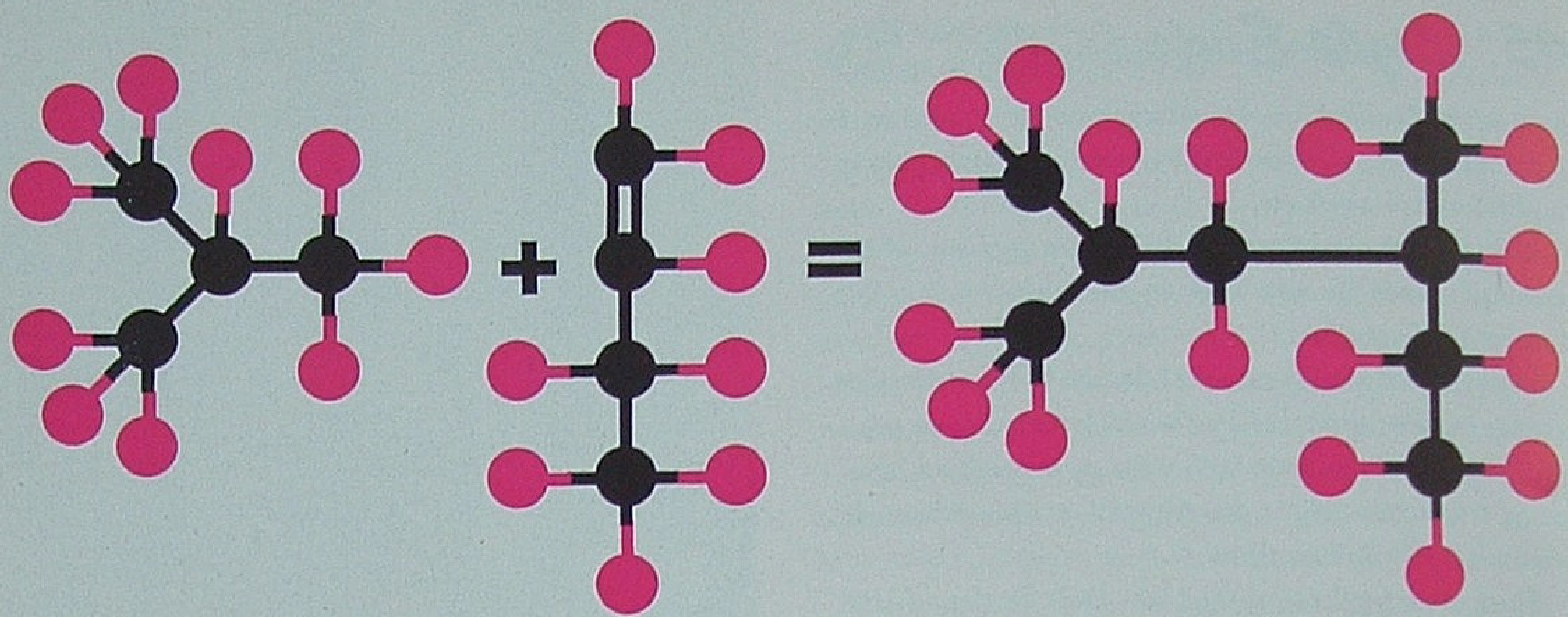
46. Control

The nearly deserted appearance of many big refining units has been brought about by the wonders of modern *instrumentation*. Many skilled men are necessary of course to operate and maintain such equipment. But control is delegated principally to mechanical devices, which regulate the columns and furnaces, open and close valves, govern temperatures and pressures, and in many instances even make an accurate written record of their performances. The human touch is necessary chiefly to *keep house*, spot trouble when it occurs, and maintain the faithful robot in working order.

Below is approximately half of Unit 33's control room. Instruments on the far wall control and record what is happening in the Cracking Section. Other panels similarly govern the Crude Distillation and Light Ends Sections. Operators, by adjusting these instruments, are able within certain limits to regulate the amount and types of products produced.







Iso-Butane (C_4H_{10}) Butene (C_4H_8) Iso-Octane (C_8H_{18})

47. Alkylation

Up to this refining point we have been concerned with either sorting petroleum into useful types of products or cracking some of the heavier oils into light oils and producing a higher percentage of gasoline. Now, since the light petroleum gases are also less in demand than gasoline, would it be possible to make some of their molecules combine and form molecules in the gasoline range? The answer is yes, and the process is known as *alkylation*.

Tipped on end in the symbolic drawing above is butene, a gaseous hydrocarbon we have introduced before in connection with cracking processes. To its left is iso-butane, another gaseous molecule, which differs from butane only because its four carbon and ten hydrogen atoms are arranged in this pattern rather than chain-like. If we can somehow join these two molecules together, we'll have iso-octane, a liquid petroleum with unusual fuel properties.

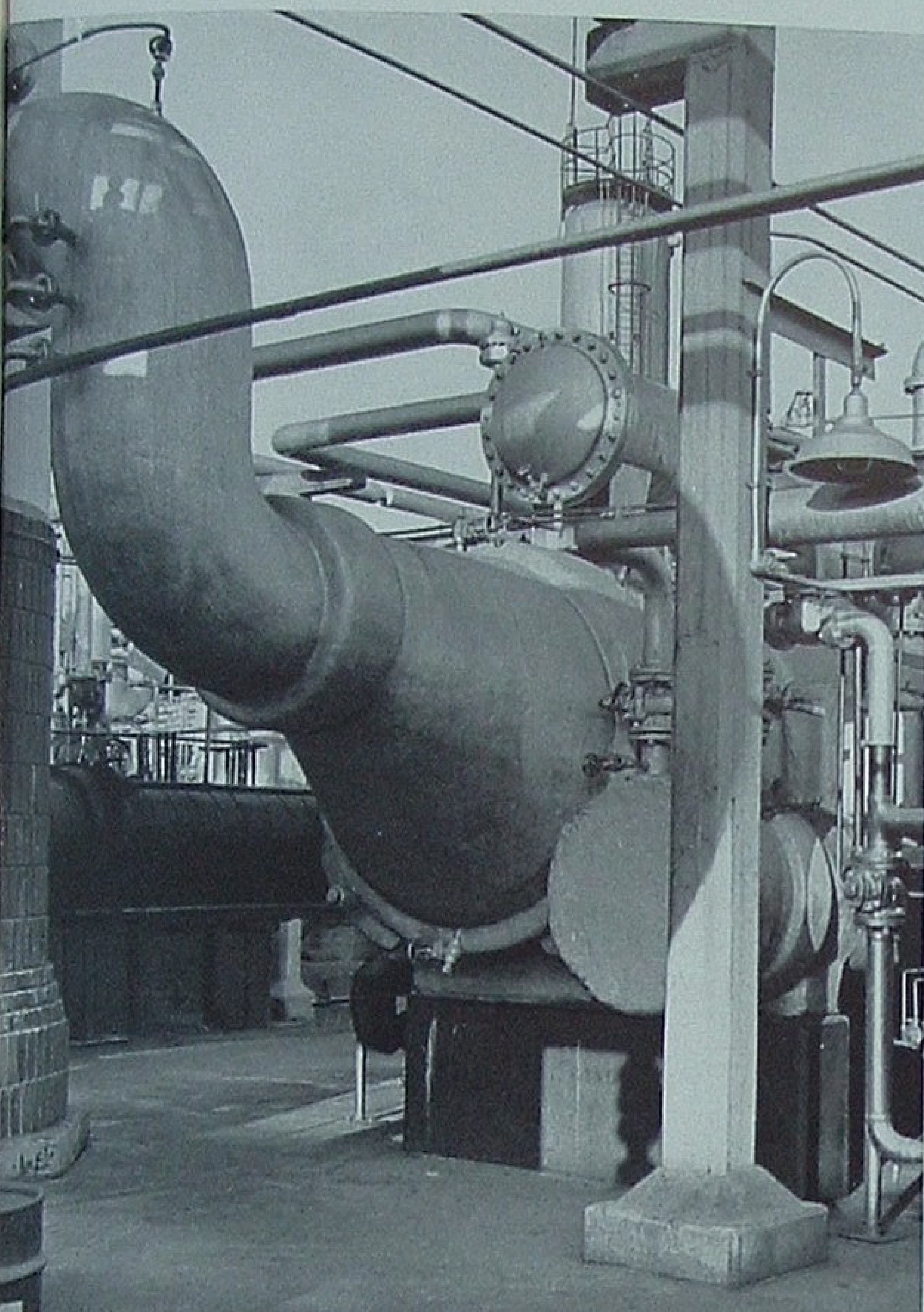
The trick performed by *alkylation* is to cause the double-bonded carbon atoms of butene to release one of their grips on each other, whereupon a hydrogen atom of iso-butane joins one of the carbon bonds and the two molecules are united through a bonding of two carbon atoms. The resulting iso-octane is not only a member of the gasoline hydrocarbons but is also an aristocrat of the group. Iso-octane is one of the highest test gasolines known. It is a principal component of the most powerful aviation gasolines, and automotive demand for it is growing with development of high-compression motors.

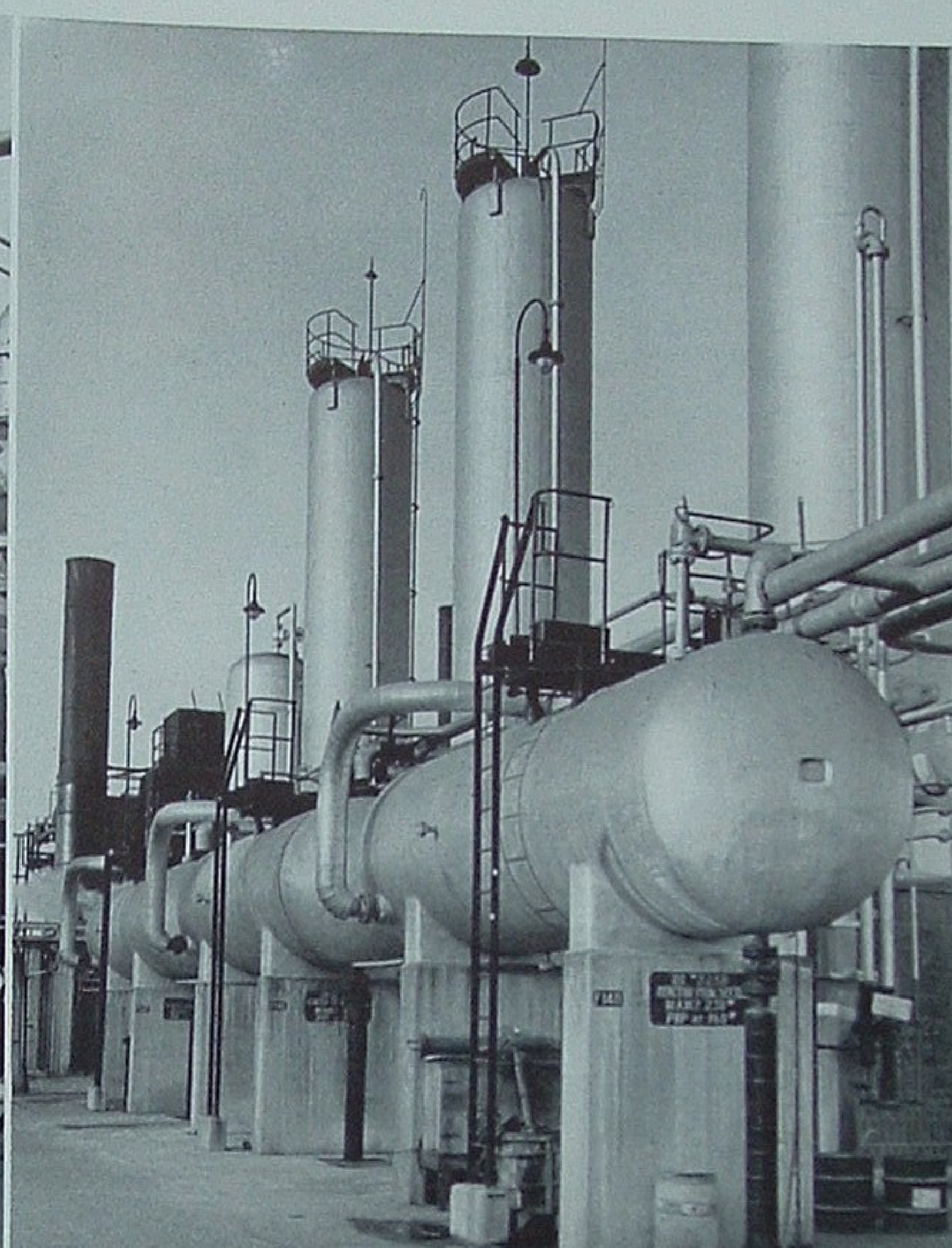
48. Acid Catalyst

To accomplish this union of iso-butane and butene, our mysterious helper, a catalyst, is introduced to the alkylation process. Only this time, clay pellets, such as those used in catalytic cracking, are not equal to the job. The material required is concentrated sulfuric acid.

At left is a refinery operator taking samples of this potent catalyst near one of the alkylation settlers. These samples are tested periodically to determine whether the acid is working effectively, or is *spent* and in need of replacement.

Note the helmet, goggles and rubber gloves worn by the acid man. Nearby also are shower baths and barrels of soda solution into which he would plunge if acid should accidentally splash on his skin or clothing. Due to vigilance and safeguards, operators are rarely harmed.





49. Reaction

of the iso-butane with butene to form iso-octane takes place in the above *reactor*, one of six such installations at Unit 110 of Los Angeles Refinery. At a temperature of 40 degrees F. and under pressure of about 90 pounds per square inch, the two normally gaseous hydrocarbons exist as liquids. In this liquid form they are brought into contact with the sulfuric acid catalyst, also a liquid. The liquids do not mix together readily but tend to separate into liquid layers; therefore, thorough mixing is required to encourage maximum reaction. After rather violent agitation by means of pumps and impellers, the liquefied gases and catalyst are circulated through pipe lines and vessels. By being kept in motion and given time to react, a greater number of the iso-butane and butene molecules are persuaded to enter into their iso-octane wedlock.

50. Catalyst Separation

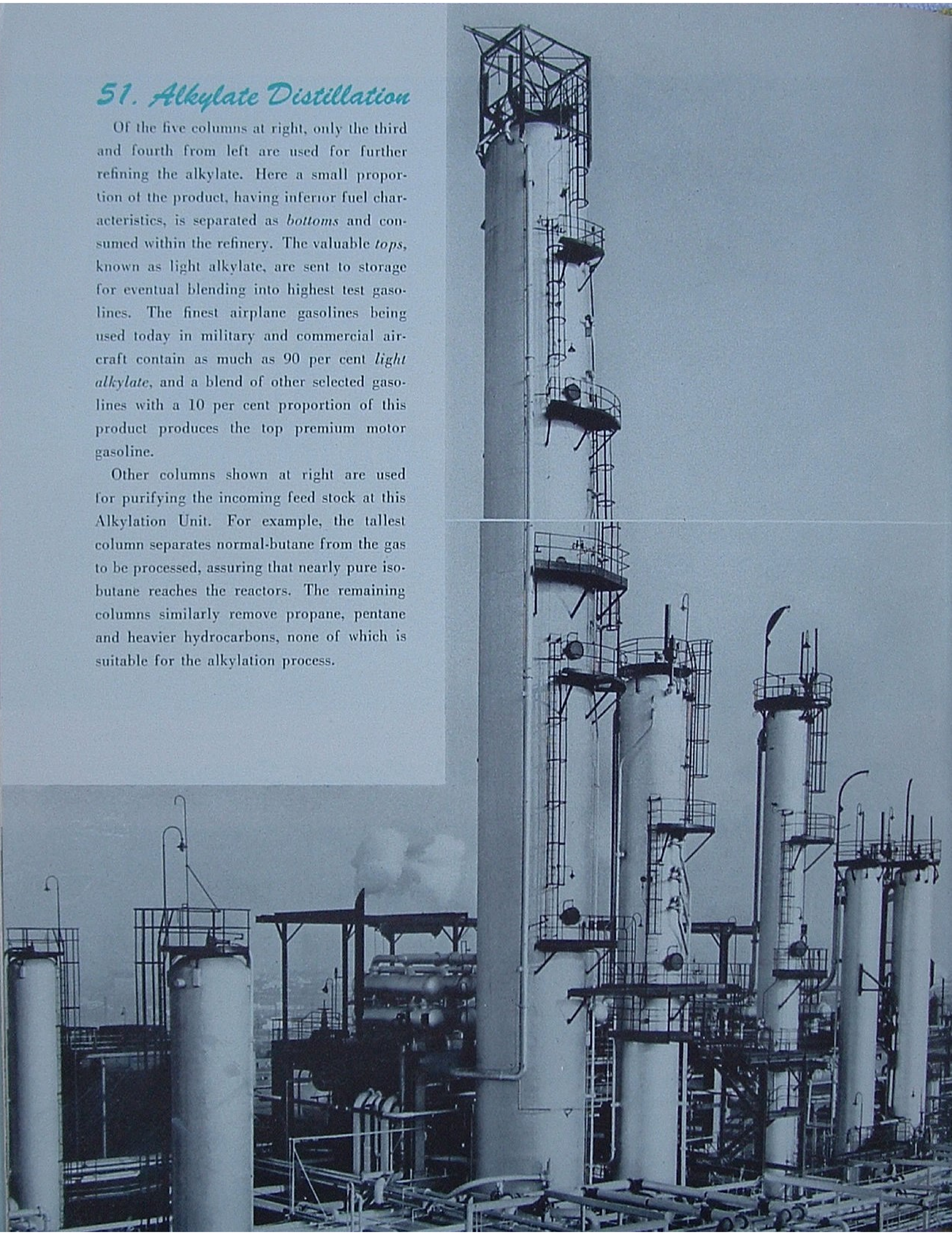
The vertical columns above are connected directly with the alkylation reactors and are called *time tanks*. As their name implies, they serve as a means of circulating the *alkylate* mixture long enough to insure the highest possible yield of iso-octane, better known to refinery men as *light alkylate*. However, not all of the mixture reacts satisfactorily and, after a later separation, some of it is recycled until reaction takes place. For this reason Unit 110 finds it necessary to circulate some 2,000,000 barrels of liquid oil products a day to obtain 3,000 barrels of end product.

The horizontal vessels above are *alkylation settlers* where the processed mixture is allowed to settle into its diverse layers. Sulfuric acid is drawn off the bottom while alkylate leaves the top of these vessels.

51. Alkylate Distillation

Of the five columns at right, only the third and fourth from left are used for further refining the alkylate. Here a small proportion of the product, having inferior fuel characteristics, is separated as *bottoms* and consumed within the refinery. The valuable *tops*, known as light alkylate, are sent to storage for eventual blending into highest test gasolines. The finest airplane gasolines being used today in military and commercial aircraft contain as much as 90 per cent *light alkylate*, and a blend of other selected gasolines with a 10 per cent proportion of this product produces the top premium motor gasoline.

Other columns shown at right are used for purifying the incoming feed stock at this Alkylation Unit. For example, the tallest column separates normal-butane from the gas to be processed, assuring that nearly pure isobutane reaches the reactors. The remaining columns similarly remove propane, pentane and heavier hydrocarbons, none of which is suitable for the alkylation process.



Asphaltic Products

52. Heavy Crude

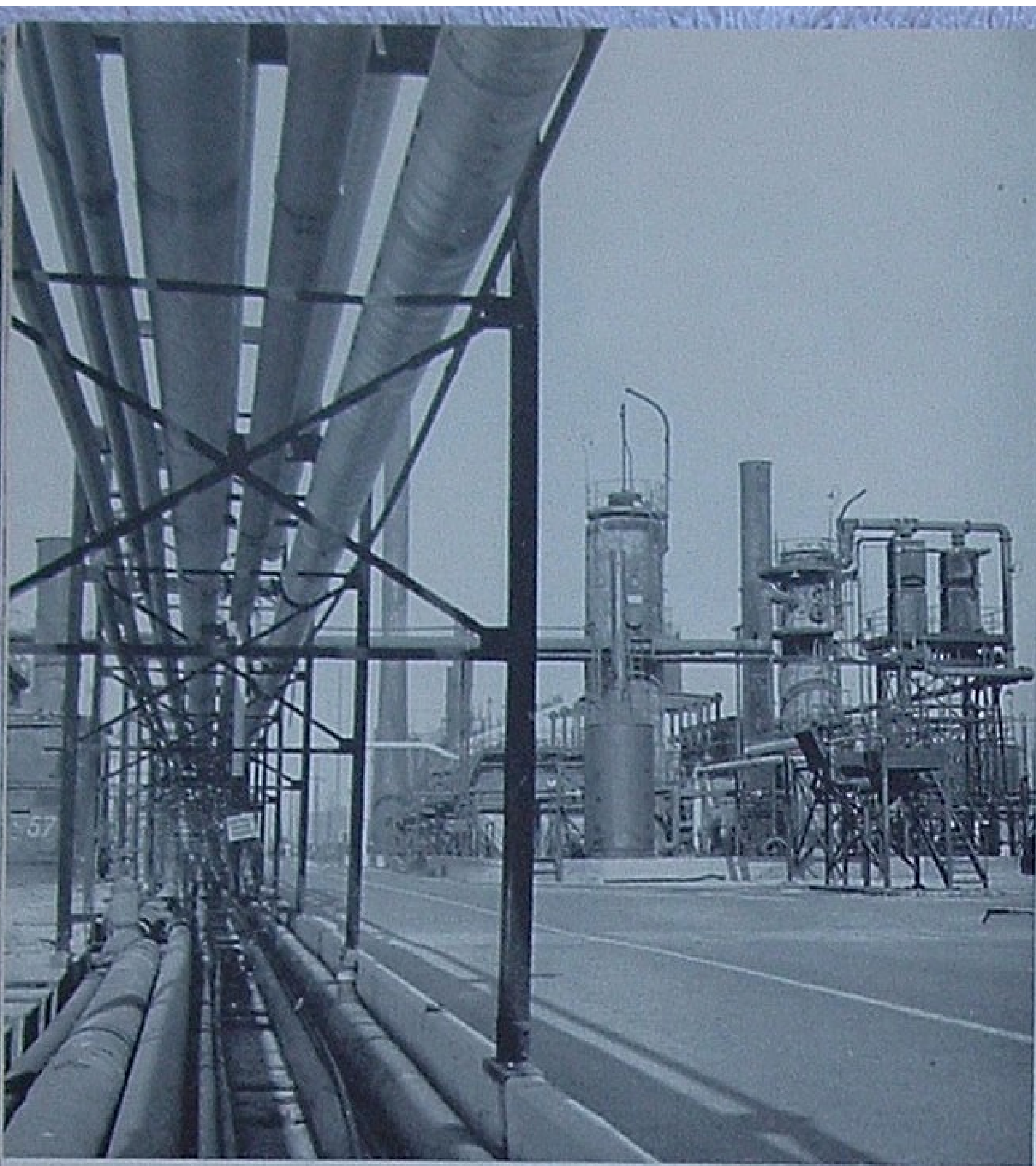
so-called because of its heavy, molasses-like viscosity, is produced in many of the world's oil fields. As found in seeps, it comprised the pitch and tar used in ancient times. Modern oil men have a natural preference for light oil, which offers a higher yield of gasoline and other light products currently enjoying brisk demand. But, as we shall presently see, heavy crude fills a number of our economic needs and is the source even of some gasoline.

Union Oil's supply of heaviest crude comes principally from Santa Maria Valley, where in a few extreme cases it is too thick to be pumped. Production men solve the problem by diluting it with heated lighter oil pumped underground from other sources. To bring it to the surface requires some of the world's largest pumping equipment, such as the unit shown at right.

53. Heavy Crude Distillation

at Los Angeles Refinery is the task of Unit 71-72, at right. Equipment consists of two fired heaters, foreground, and a single distillation column in which the heated crude is *topped* of its small percentage of gasoline and gas oil. These two products leave the distillation column together in vapor form. In a cooler the gas oil vapors are first liquefied and removed. Remaining gasoline vapors continue on to a condenser and are also cooled to liquid form.

The heavy crude thus stripped of its lighter fractions is given the refinery name of *topped residuum*. To most people it is familiarly known as asphalt or road oil, a product whose usefulness in paving highways, patching roads, coating pipe lines, and so on, stamps it as one of our most serviceable commodities.



54. Asphalt Distillation

The interval between application of road oil and the time the road or other surface is ready for use is known as "curing time."

Topped residuum is an SC-2 road oil, meaning that it is *slow curing* and produces a relatively soft surface of No. 2 hardness. By distilling out some of its *softening oils*, we can produce increasingly harder grades of *slow curing* road oil up to and including No. 6.

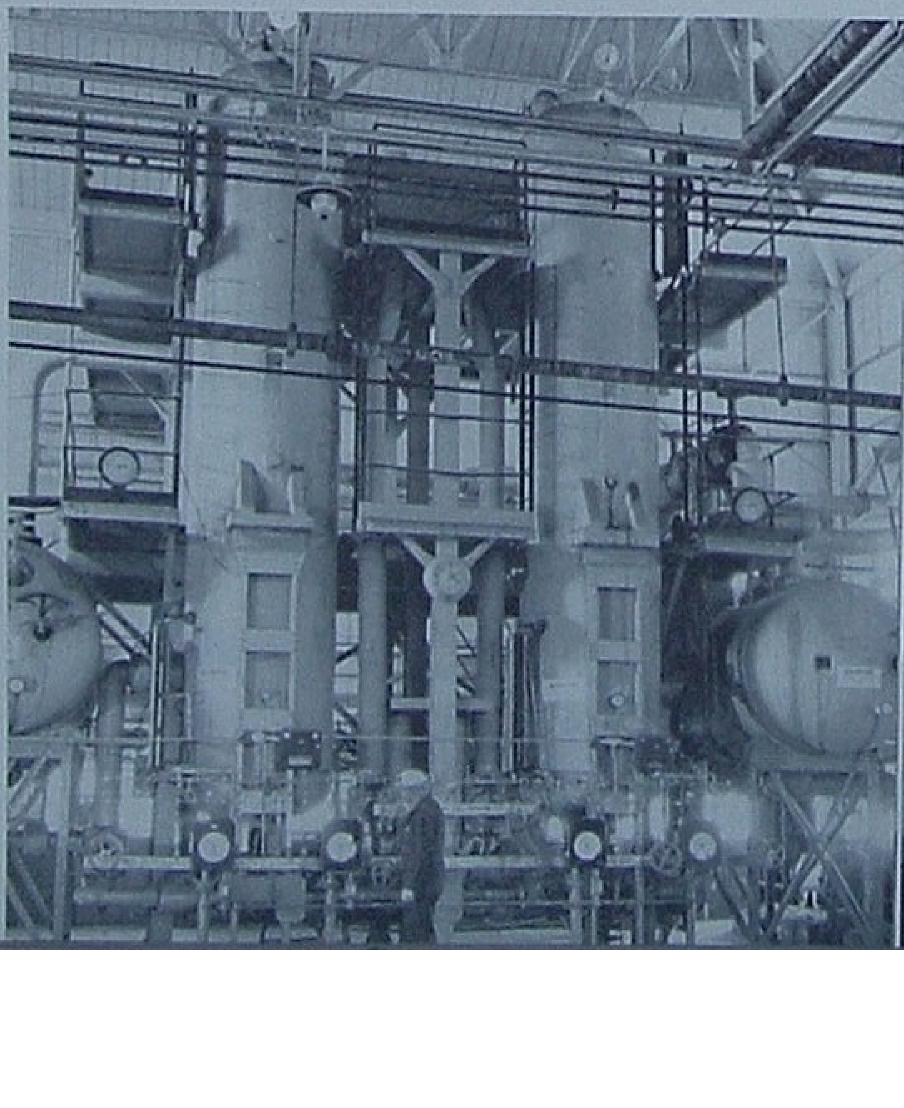
If additional amounts of the softening oil are removed, we obtain paving asphalts that are so hard they must be kept hot or diluted with a solvent to keep them from hardening in pipe lines, tanks or spray-trucks. This use of solvents to keep the asphalt fluid gives us opportunities to produce other specifications or grades. If a rapidly evaporating solvent is used, we produce an RC or *rapid curing* road oil. If a slower evaporating solvent is blended, the result is MC or *medium curing* asphalt. In all, 21 grades of SC, RC and MC road oils and asphalts are produced in the asphalt distillation unit shown in right background of picture at left.

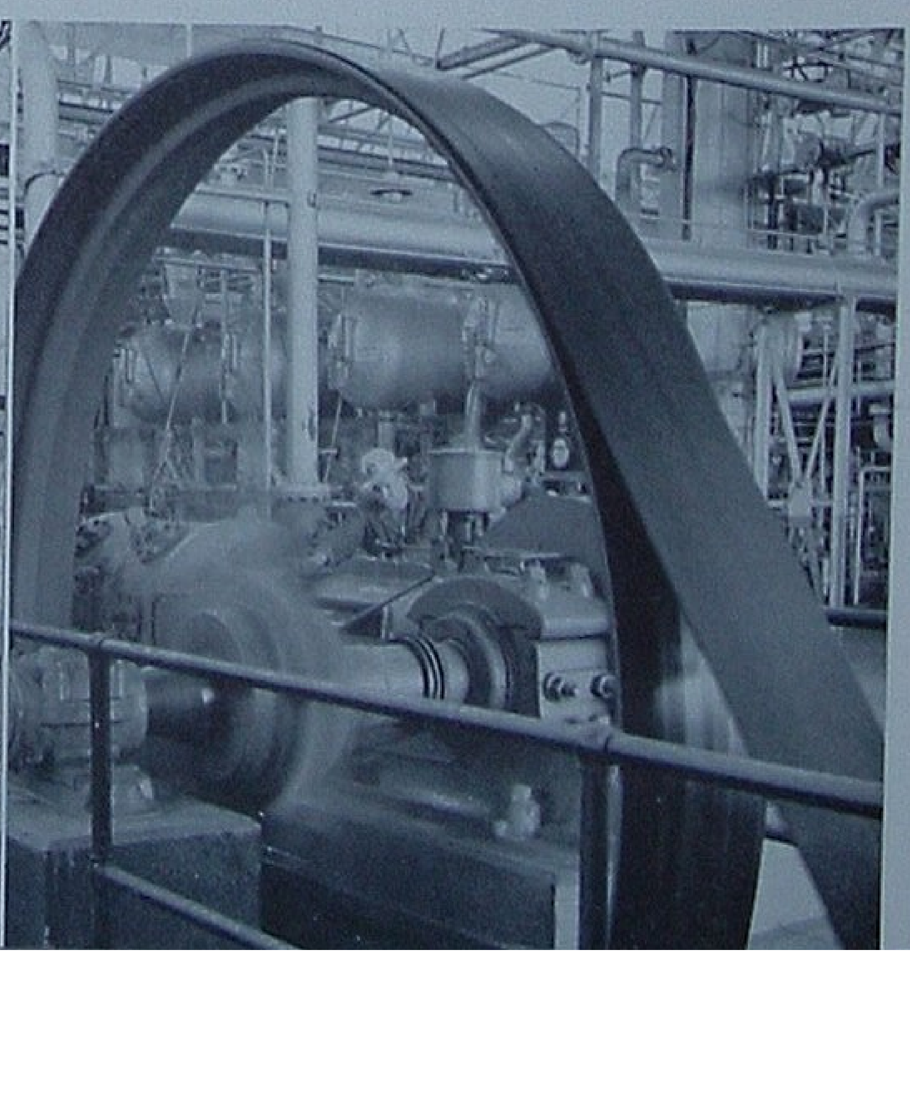
55. Edeleanu Plant

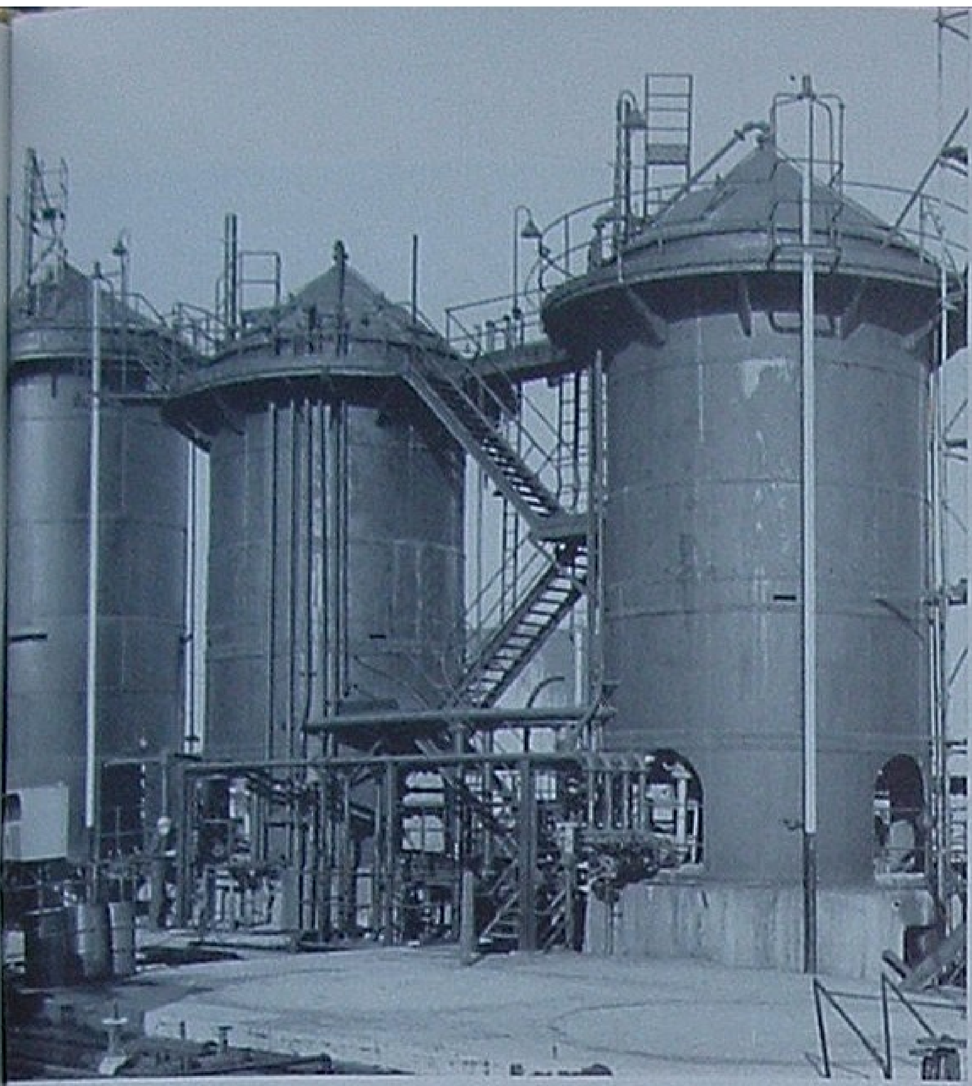
Treating is the oil man's way of applying finishing touches to his numerous products. It involves using several processes to remove the last impurities and bring oils up to exacting specifications.

The plant below bears the name of Dr. Edeleanu, a Rumanian scientist who developed an effective process for removing smoke-producing and other degrading compounds from kerosene distillate. This process is also used in similarly improving the quality of diesel fuel.

At left below are two Edeleanu mixing columns in which the kerosene distillate is thoroughly mixed with sulfur dioxide compressed to liquid form. This chemical causes the kerosene and its degrading elements to separate, one, called *raffinate*, leaving the tops of the vessels, and the other, called *extract*, leaving the bottoms. Both streams then proceed through separate batteries of evaporator tanks, some of which are visible through the whirling compressor wheel, below right, where the sulfur dioxide is recovered through evaporation and then compressed to a liquid for reuse. Coming out of the *raffinate* stream is kerosene, while from the *extract* is obtained a petroleum solvent used in the manufacture of synthetic paints and lacquers.







56. Batch Agitators

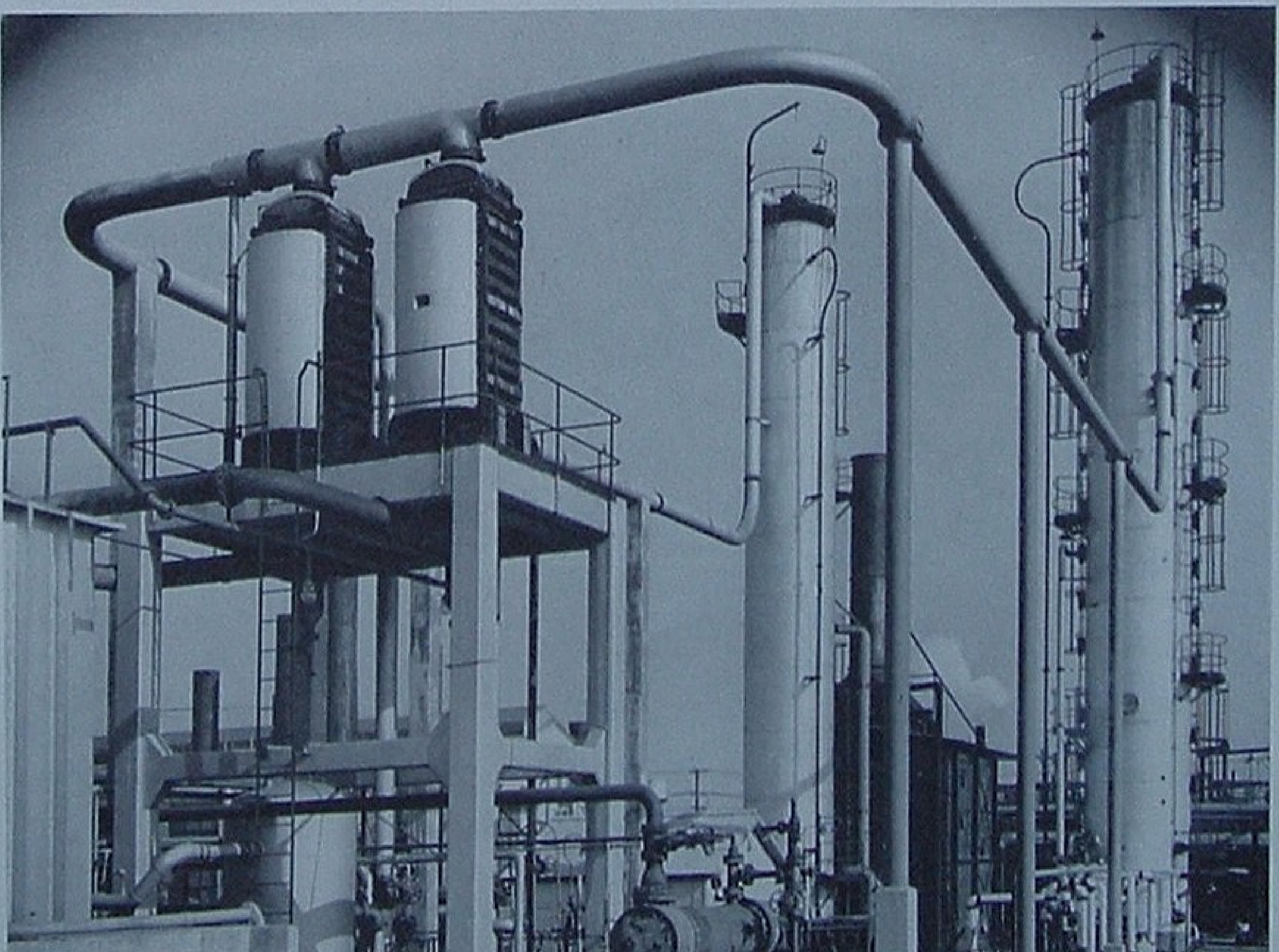
A number of refined products must be acid treated before qualifying for their "Union" labels. At left are the Batch Agitators where some of the acid treating is done. The vessels are essentially empty lead-lined tanks into which batches of petroleum products and treating chemicals are placed and agitated. Air forced through pipe openings in the tank bottoms provides the necessary agitation. Acid, having a strong affinity for nitrogen and sulfur compounds, as well as any smoke-producing hydrocarbons overlooked by the Edeleanu process, removes these undesirables from the refined oil and settles to the bottom of the tank when agitation is discontinued. After settling for about one hour, the acid sludge is drawn off. The treated product, containing traces of acid, is then washed with caustic soda to neutralize the acid, and with water to remove the caustic. Through treating of this nature, kerosene, solvents, thinners and other products are made color-stable, or smoke-free if used for fuel.

57. Redistillation

Unit 67, below, is a very versatile installation wherein several petroleum products undergo their final and most selective redistillation.

We mentioned a solvent produced as *extract* in the Edeleanu process. When distilled in Unit 67, this extract separates into two fractions, a high-boiling material that is very effective as a weed killer, and Solvent 40, the product used in making synthetic paints. The latter, after separation, is acid treated and redistilled in Unit 67 a second time before being ready for market.

Certain gasoline fractions make excellent paint thinners and cleaning solvents. However, specifications for such products call for a narrow boiling range and exceptional purity. Unit 67 accomplishes the job by making a very careful selection of fractions from the gasoline feed. Thinners No. 1 and No. 3 and Union Cleaning Solvent are obtained by this means. The quality and water-white color of all three products are further improved through acid treatment in the Agitators.

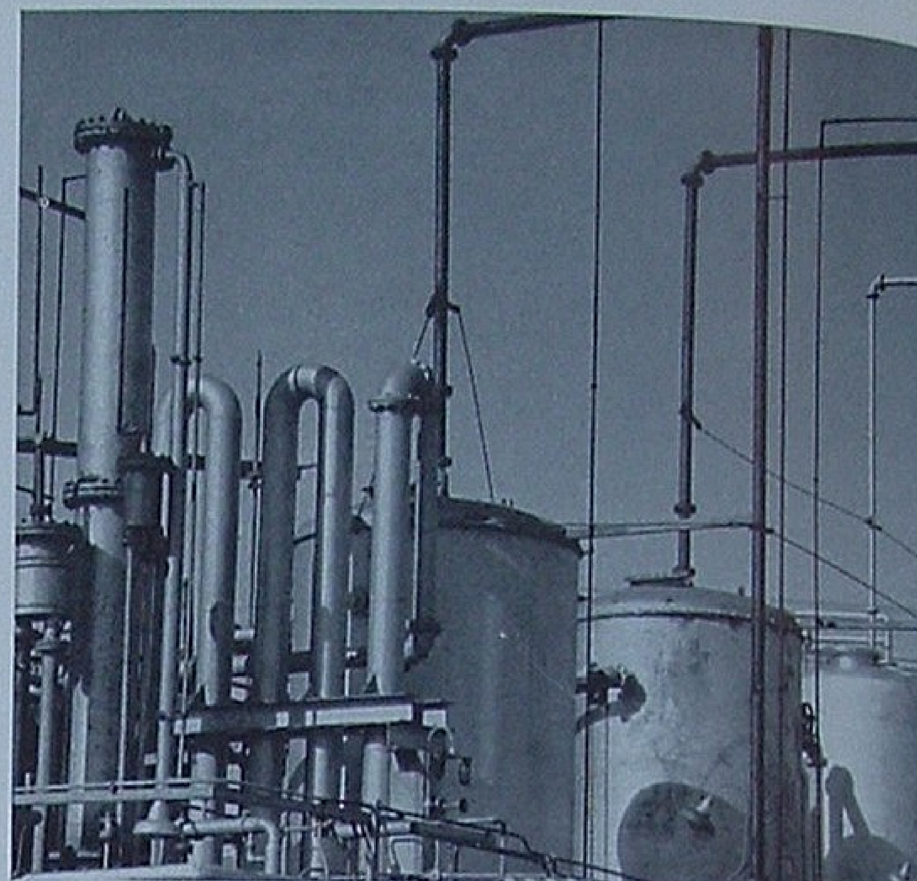


58. Continuous Acid Treaters

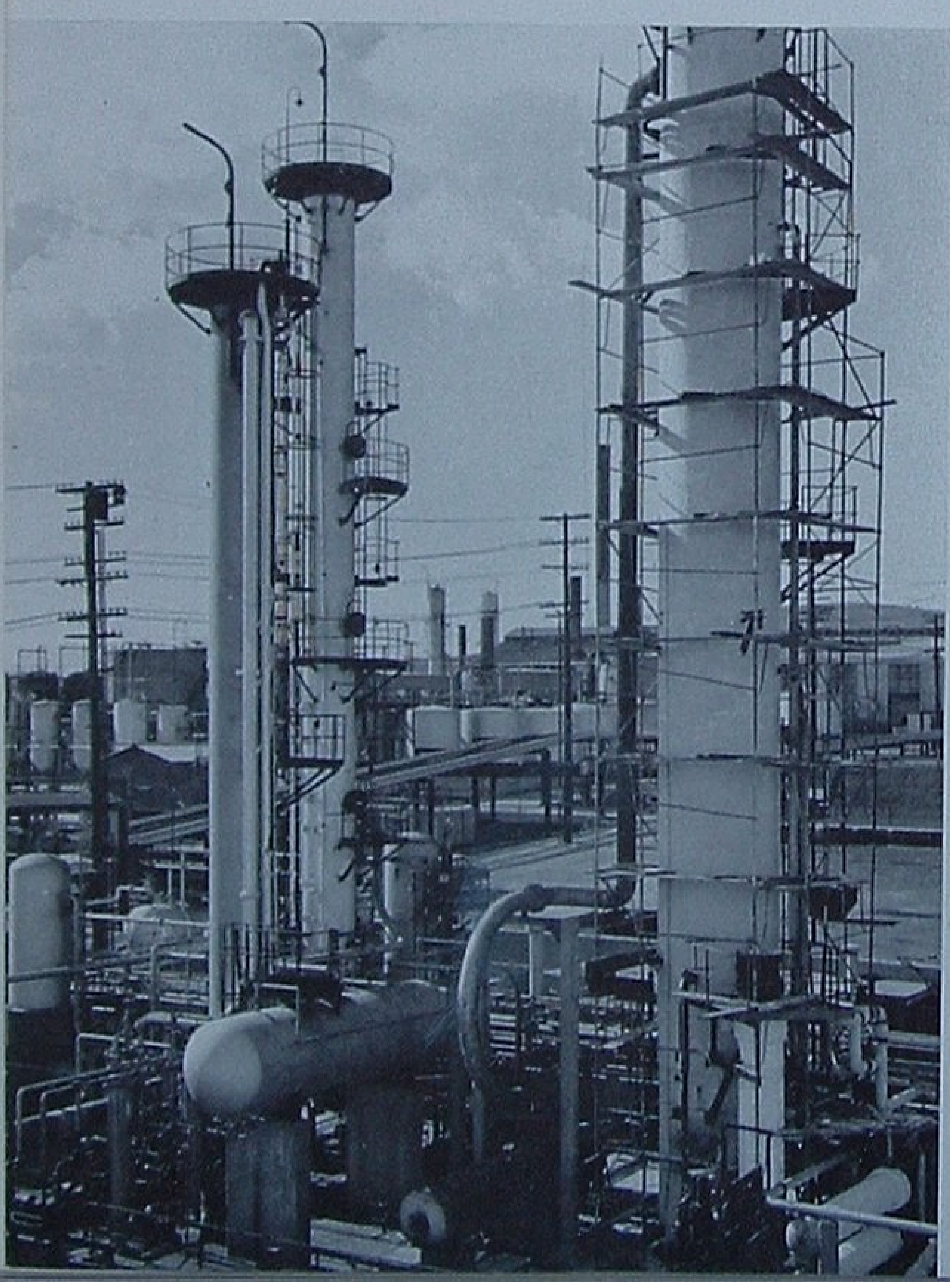
Let's leave the specialty products now and get back to our main topic of discussion—gasoline.

Up to this point we have accumulated in storage tanks a variety of different gasoline stocks. These include *natural* gasoline, *straight-run*, *once-cracked*, *severely-cracked*, *light alkylate*, and several segregations of these according to their boiling ranges and knock-ratings. Some of the stocks may have passed all laboratory tests for purity and quality, but others, particularly the cracked gasolines, are likely to show a tendency to oxidize and form gum in a gasoline motor.

Treatment to remove these gum-forming materials takes place in the Continuous Acid Treaters, right. Here strong acid is thoroughly mixed into a passing stream of gasoline. The acid combines with and removes sulfur and nitrogen compounds along with the gum-forming materials. Treated gasoline leaves the top of these vessels and is *washed* alternately with water and caustic soda to remove final traces of acid.



59. Unisol Treating Unit



Mercaptans are the sulfur bearing compounds of oil that sometimes offend our sense of smell. One reason they are not so evident around refineries as formerly is that *methyl mercaptans* are now being used in the manufacture of pharmaceutical preparations and vitamins. Also, small amounts of *ethyl mercaptans* are added to household natural gas as a safety factor—that of making gas leaks detectable. But *mercaptans* in gasoline give the product an unpleasant odor and lessen the effectiveness of any tetra-ethyl lead that might be added to improve knock rating.

Gasoline stocks containing such sulfur compounds are sent to the Unisol Treating Unit, left. Here a very interesting treatment is resorted to. Quite the opposite to acid treating, the Unisol process employs a strong caustic solution to attract and remove the *mercaptans*. However, the caustic solution and gasoline will not mix. So a third ingredient, methyl alcohol (wood alcohol), is called in to assist. Being on good terms with the caustic, the gasoline and the *mercaptans*, alcohol circulates freely through the gasoline, picks up a load of *mercaptans*, and taxis them back to the caustic. When the methyl alcohol and caustic solutions are weakened to a degree in the process, they are regenerated and can be used over again.

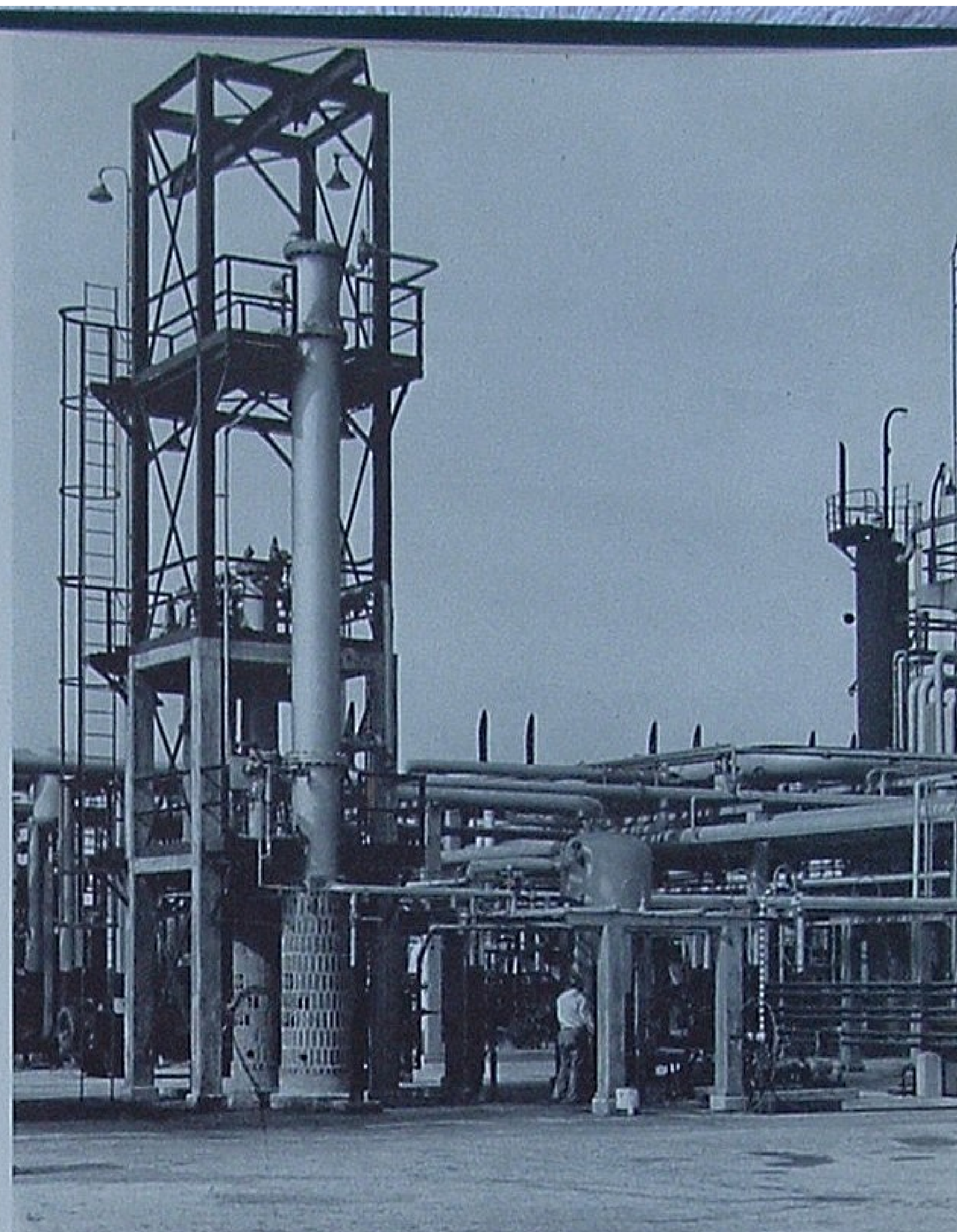
Mechanically, Unisol Treating consists of admitting gasoline near the bottom of a tall packed column. It rises against the descending mixture of caustic and alcohol and departs through an upper column exit.

Gasolines

60. Waste Disposal

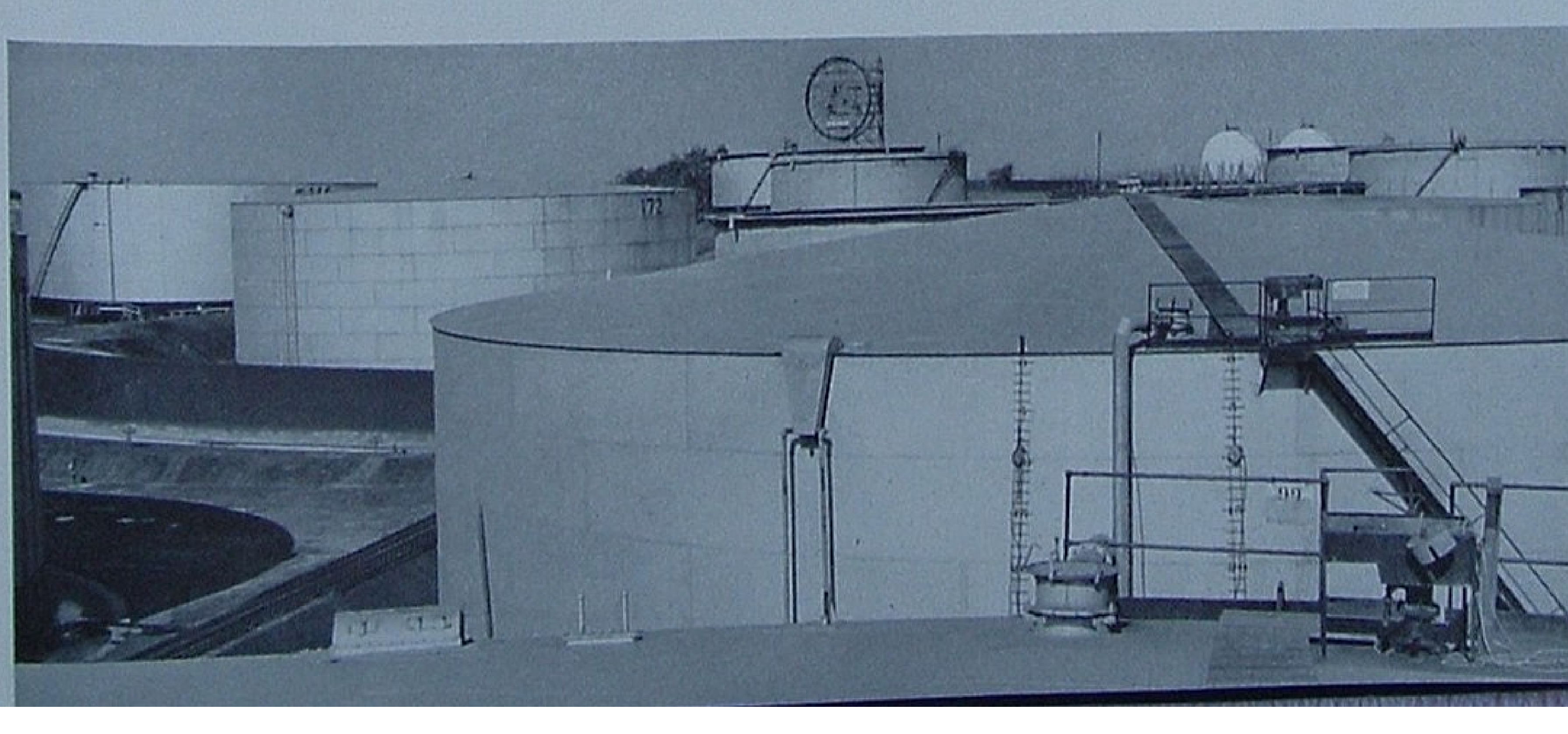
Even the troublesome impurities removed or produced during refining processes are not thrown away, but wherever feasible are preserved and put to use.

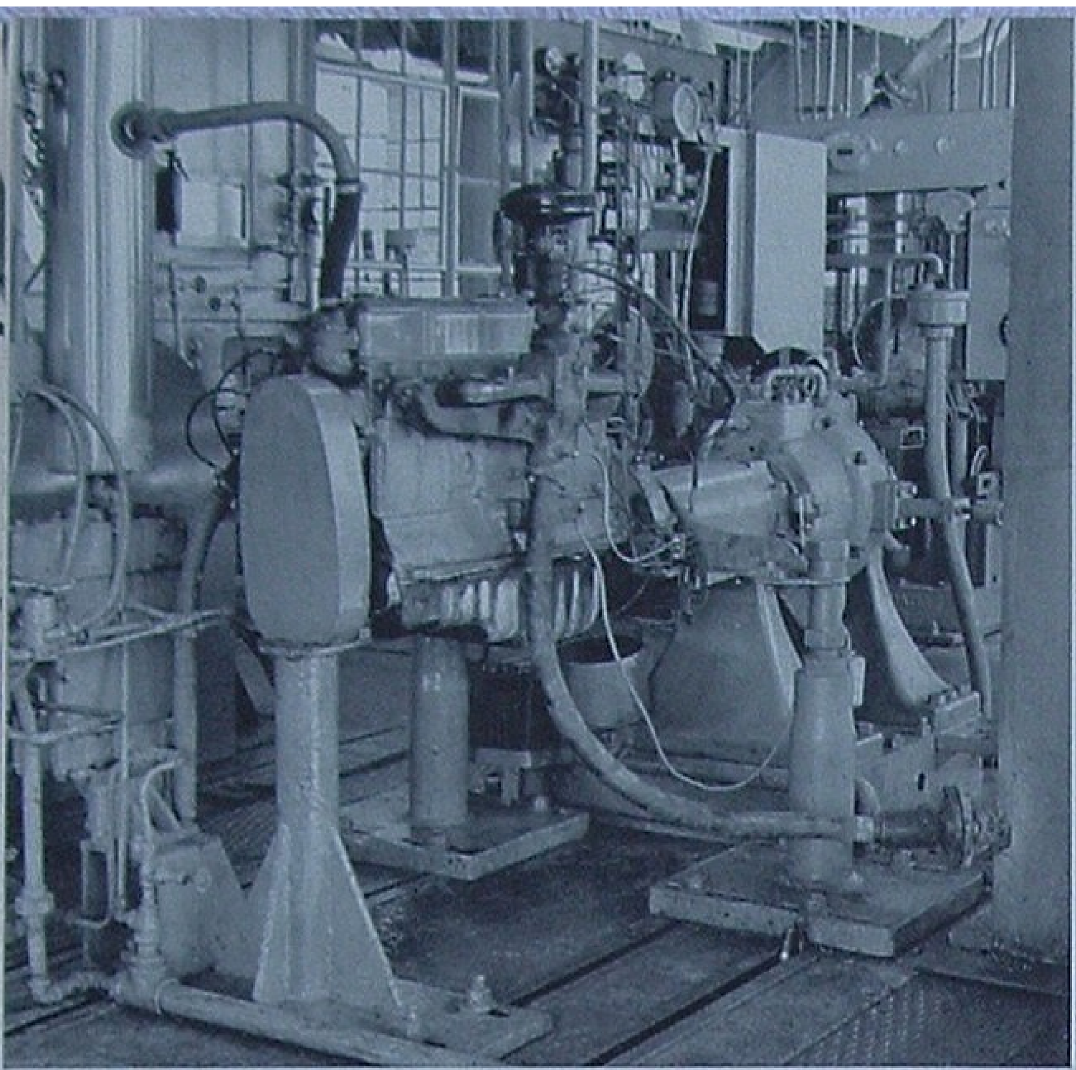
Refinery fuel gases, for example, contain quantities of hydrogen sulfide. Largely to prevent air pollution, Los Angeles Refinery sends such fuel gases through an elaborate absorption process. Hydrogen sulfide is removed from the fuel gas and, in the installation shown at right, is re-absorbed by a solution known as MEA (monoethanolamine). The *enriched* MEA solution is then trucked to a chemical plant, where its hydrogen sulfide content is used to manufacture sulfuric acid. Much of the sulfuric acid eventually returns and is used in some of the refining processes we have previously discussed.



61. Gasoline Stocks

As a result of these many processes we at last have *gasoline*—but not the two or three varieties you are accustomed to buying in service stations. Rather, they are *gasoline stocks*, ranging from relatively slow-burning to highly volatile and explosive liquids. Remember that some are *natural* gasolines; that is, very little if any refining was required to improve on the product Nature produced. Others are *straight-run* gasolines, meaning they were produced simply by heating the crude and condensing its vaporized fractions. Also we have the *cracked* gasoline from our TCC Unit, and other *cracked* varieties from Unit 33. The butane-butene fraction has given us a synthesized gasoline called *light alkylate*. Some of the stocks are further separated into *light*, *medium* and *heavy* grades. All are stripped of objectionable impurities. They are stored separately in products tanks, below, holding up to 135,000 barrels each. Hardly any *gasoline stock* alone satisfies all requirements of a good motor fuel. But, thanks to their varied qualities, several can be blended in different ways to suit numerous requirements.





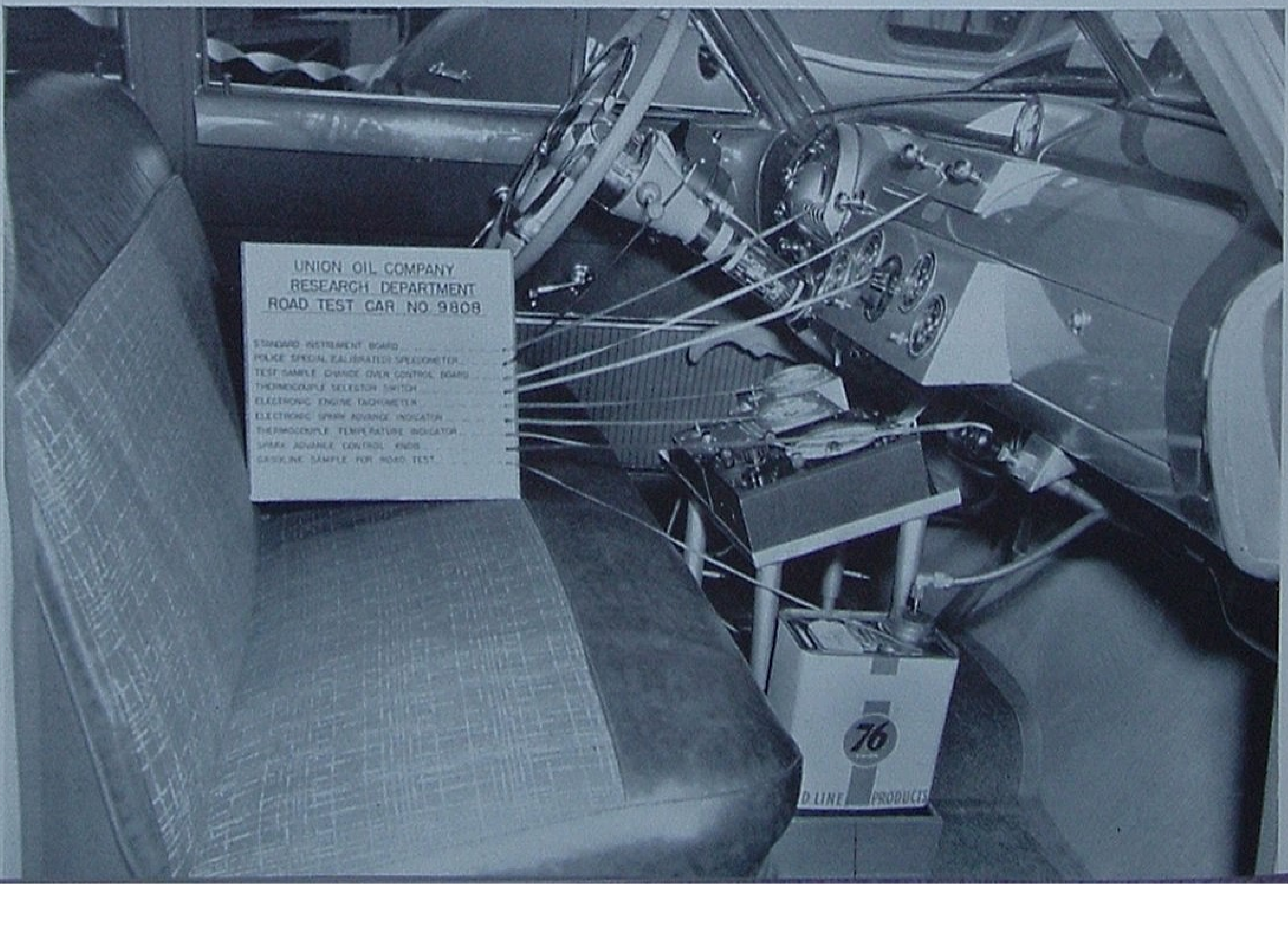
62. *Engine Testing*

is one of the means used to determine the performance qualities of gasolines. The fuels to be tested may be experimental blends of several gasoline stocks or samples of established gasolines that are being readied for market. All such tests are conducted by skilled research men.

The method usually consists of running some standard engine, such as the Chevrolet motor at left, for 100 or more hours, using the test gasoline for fuel. When the run is completed, the motor is taken apart and scientifically measured. Any deposits of gum and carbon are weighed and analyzed. Engine wear and deterioration are also scientifically measured. In this manner it can be determined whether a gasoline is efficient and generally suitable for the types of motors that will consume it.

63. *Road Testing*

is a necessary supplement to engine testing because some gasolines perform far differently on the road than in the laboratory, at high altitudes than at sea level, in summer than in winter. To overcome these variations, cars, such as the one below, are equipped with special fuel testing instruments and sent on long experimental runs. Using various blends of gasoline, they determine by actual road test the degree to which each blend will provide power, economy, quick starting and all other forms of driving satisfaction. Because of such painstaking precautions, modern Americans may drive through almost every extreme of weather, atmosphere and climate without giving thought to motor adjustments or changing their grade of gasoline. And the quality of motor fuel is steadily being improved.

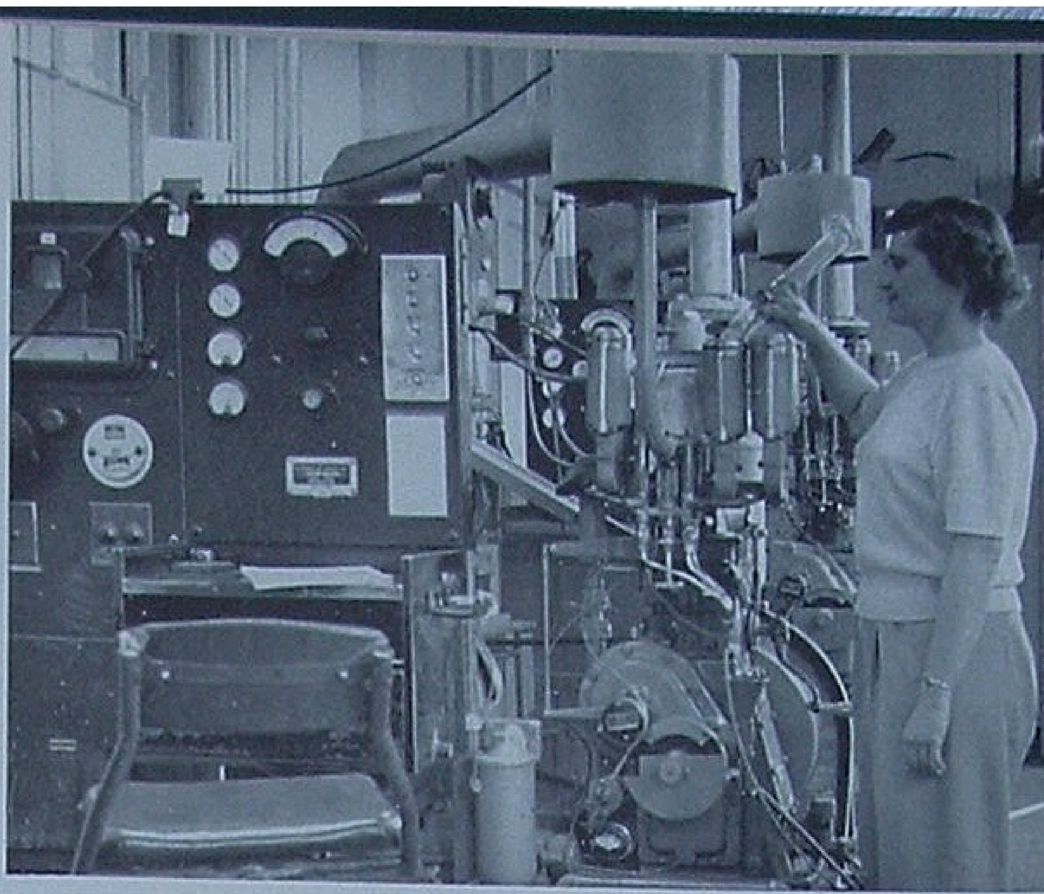


64. Knock Rating

The manner in which a gasoline burns in the cylinder head of a motor is important. If it explodes too swiftly or irregularly, some of its power is wasted and the motor protests with an audible compression *knock*. Better and quieter results are obtained if the gasoline burns with a slower and smoothly expanding flash. *Knocking* becomes an increasingly more serious problem as car manufacturers build fuel economy into motors by increasing compression ratios, or the pressure at which gasoline is ignited.

One of the poorest hydrocarbons from the standpoint of knock rating is normal-heptane, to which petroleum scientists have assigned a knock rating of O. A much smoother burning substance is iso-octane, once considered to be at the top of the hydrocarbon scale and therefore given a knock rating of 100. The petroleum industry uses these two compounds as *reference* fuels and establishes the knock rating of a gasoline by comparing its performance with a mixture of normal-heptane and iso-octane.

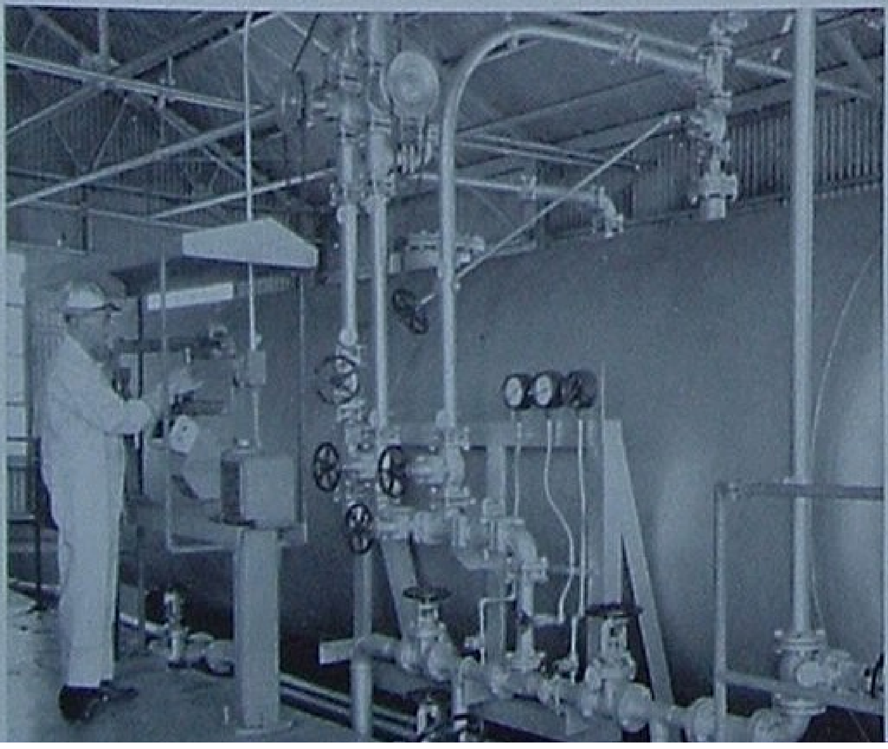
To make certain that finished gasolines will equal or exceed anti-knock specifications, gasoline stocks are tested both before and after blending by means of such equipment as the fuel research engine above. These machines are far more sensitive to knock variations in gasolines than is any automobile.



65. Tetra-Ethyl Lead

One of the oddities of petroleum science is that small amounts of lead improve the octane number of most gasolines. Of course, lead as we commonly conceive of it in its metallic form does not answer the purpose. Rather, it is combined chemically with ethylene, a hydrocarbon, to produce a liquid compound known as tetra-ethyl lead. The maximum amount of this compound that can be used is only three milliliters per gallon, but such small amounts can improve the knock rating of most gasolines from one to several octane numbers.

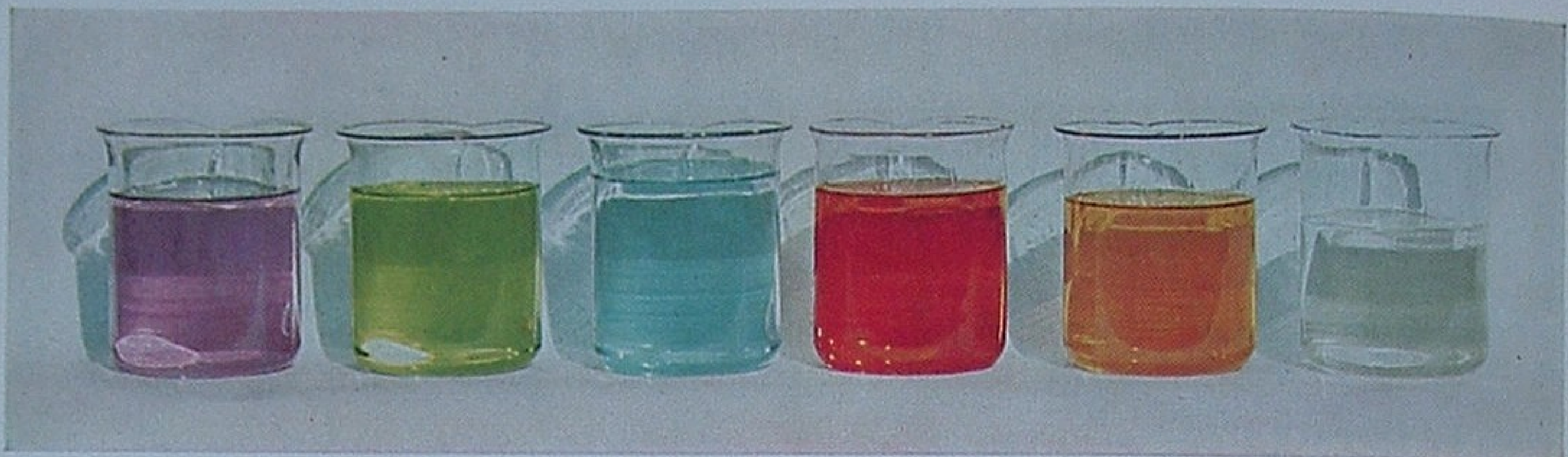
The tetra-ethyl lead storage tank below rests on a large weighing scale. When lead is ordered to bring a tank of gasoline up to refinery octane specifications, the operator responds by simply weighing out the quantity of compound required.



66. Inhibitors

Some gasolines, particularly the high-test varieties, are not as chemically stable as we'd like to have them. They are inclined to break up and combine with other substances at hand to form unwanted compounds. The most troublesome compounds thus produced are several varieties of gums which, if permitted to exist in motor fuel, might result in the fouling of carburetors, valves, piston rings, and so on. Therefore, petroleum scientists have had to devise ways of preventing any such harmful gasoline deterioration.

The shovelful of *di-tertiary butyl para cresol*, below, is one of three gum inhibitors currently being added to gasoline stocks. In minute quantities and in various combinations, these inhibitors are successful in preventing gum compounds from forming within the gasoline. The chemicals are usually added as soon as a vulnerable gasoline stock enters storage.



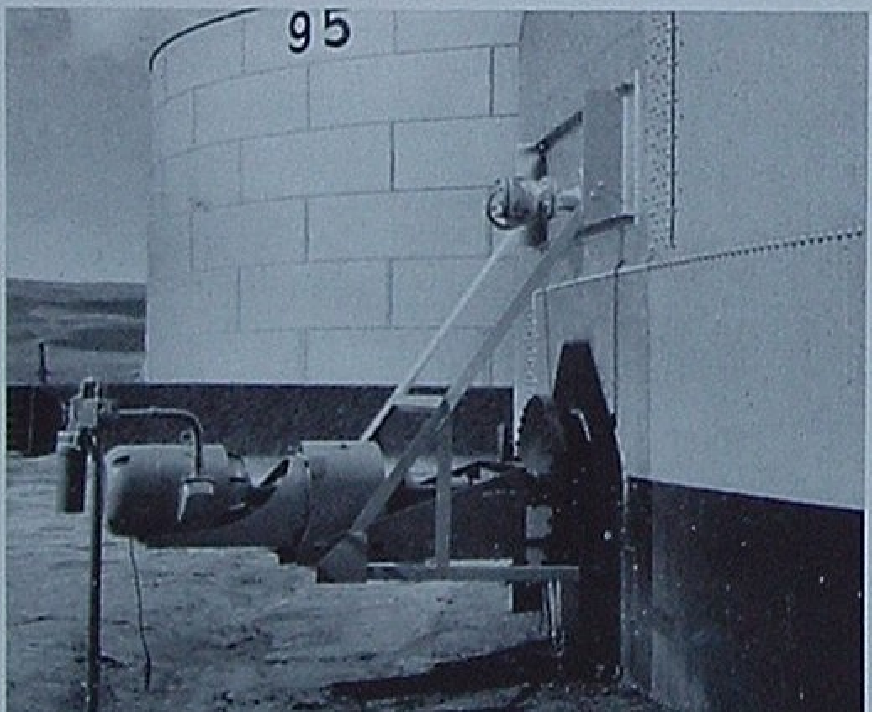
67. Gasoline Dyes

Last of the ingredients that are to comprise our finished gasolines are dyes. They are added solely for purposes of identification and safety. Employees, distributors and buyers of Union Oil products therefore would promptly identify the purple, green and blue samples above as 7600 Aviation Gasoline, Grades 115/145, 100/130 and 91/96 respectively; the red as 7600 Gasoline; the orange as 76 Gasoline. The white gasoline, containing no dye or lead, is used principally in appliances and motors that require no such additives.

68. Gasoline Blending

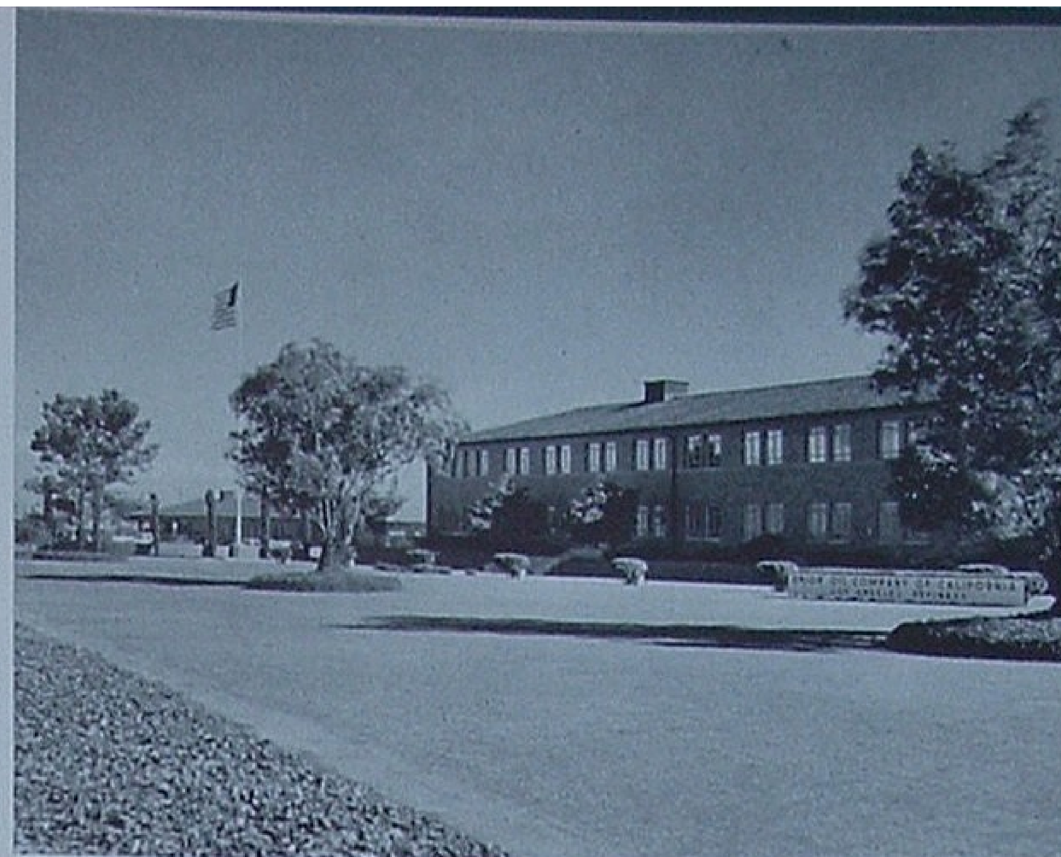
takes place in a large tank whose identifying feature is an electrically driven shaft, below. This shaft turns a large impeller, which in turn keeps the gasoline ingredients circulating until all are thoroughly and uniformly mixed.

Typical of what it takes to make an excellent finished gasoline are the refinery stocks below, shown in their approximate blending proportions. From left, they include light TCC-cracked gasoline, 20 per cent; acid-treated medium-cracked gasoline, 20 per cent; natural gasoline, 20 per cent; medium straight-run gasoline, 15 per cent; light straight-run gasoline, 10 per cent; light alkylate, 10 per cent; and butane, 5 per cent. Add to these, 3 milliliters of tetra-ethyl lead plus a few grains of inhibitors and dye and we have one gallon of 7600 Gasoline. Its exceptionally high anti-knock qualities are well ahead of the highest compression engines being developed today. It is quick-starting, powerful. It is dependable under all conditions of weather and climate. We believe it is the finest motor gasoline marketed in the world.



Other Union Oil Company gasolines are modifications of this 7600 ideal. 76 Gasoline, containing all of the foregoing stocks in slightly different proportions, exceeds the fuel requirements of most automobiles on the road and has been a leader on the Pacific Coast for many years. 7600 Aviation Gasolines are tailored to power every type of airplane from small private planes to the most modern combat aircraft.

Distribution



69. Administration

With our refining job now completed, we would be overlooking a most important factor by failing to mention the role played by skilled men and women in this great industry.

The Administration Building, right, is headquarters of Los Angeles Refinery. Here, managers and supervisors, with many years of technical education and refining experience, are given monthly quotas of refined products to meet. It becomes their responsibility to see that each commodity is produced in the quality and quantity specified, that surpluses and deficiencies are held within rather narrow bounds, and that loss and waste are kept to a minimum. Each supervisor, besides having complete technical mastery of the unit in his charge, must understand the work and problems of other departments to which his activities are geared. Besides the numerous operating units we have described previously, are others concerned with such non-operating responsibilities as new construction, maintenance, personnel, Fire and Safety, and warehousing. Greatest coordination is necessary.

70. Tankship

One of the swiftest and most economical means of transporting petroleum products from refinery to market is the tankship. Union Oil's WALLACE L. HARDISON, a wooden sailing schooner built in 1888, was the first tanker to be built and operated on the Pacific Coast. She was followed by a long list of larger and more efficient vessels that have carried petroleum products in peace and war to every quarter of the globe.

The L. P. ST. CLAIR, below, is one of eight large vessels comprising Union Oil's present tankship fleet. These ships, with cargo capacities up to 140,000 barrels each, carry refined products regularly to the Hawaiian Islands and coastwise to many ports between Alaska and Chile in South America. It is the great economy of transportation provided by these ocean-going carriers that keeps gasoline prices in remote areas fairly equal to those paid near refineries or in the oil fields.

71. Products Pipeline

Economic considerations also influence petroleum transportation men who are responsible for moving large quantities of refined products across land. An installation that has proved most successful in transporting natural gas and is proving adaptable to refined liquids is the products pipe line. Installation costs are high, but low operation and maintenance costs compensate for the investment.

At left is seen a gasoline pipe line emerging from the ground at Roscrans Terminal, at the end of a 15-mile journey from Los Angeles Refinery. Equipment in the foreground checks the gasoline for possible contamination before it continues on into terminal storage.

72. Distribution Terminal

At the end of each products pipe line or near centers of population served by water-borne transportation are located blocks of storage tanks where relatively large quantities of refined products can be accumulated. From these, gasoline and other bulk commodities, sufficient for the needs of all Company-supplied consumers in surrounding areas, are distributed. A loading rack where transportation vehicles are filled, a warehouse for packaged commodities, an office and a garage usually comprise the other installations, collectively known as a distribution terminal.

Below is an airview of Union Oil Company's distribution terminal at Whittier, Alaska, where enough refined oil must be stored to supply dependent areas until the next tankship arrives. This terminal employs tankcars in transferring bulk products to nearby Anchorage and to the busy Alaskan city of Fairbanks, many miles inland to the north. Similar terminals dot the Pacific Coast nearly to the tip of South America.

73. Tankcar

A veteran transportation servant that is successfully bidding for its share of the oil business is the railway tankcar, right. In addition to being favored for long gasoline hauls in a number of localities, tankcars serve most satisfactorily in moving hot asphalt from refineries to highway hot-mix plants or construction sites. Insulated tanks and steam coils keep the asphalt from hardening in transit. Union Oil owns over 600 tankcars and leases many more.

74. Motor Transport

is the means by which most bulk petroleum products find their way from distribution terminals, over our vast system of roads and highways, to within convenient reach of all consumers. Carrying up to 8,000 gallons per load, these vehicles move night and day, summer and winter, and across all types of terrain, delivering petroleum products as far as several hundred miles from the terminal supply point.

At left are some of the transport units assigned to our Rosecrans Distribution Terminal. They serve the Los Angeles area, wherein is located the world's largest concentration of automobiles and service stations. The Company's fleet of 50 motor transports is augmented by an even larger number of common-carrier units.

75. Marketing Station

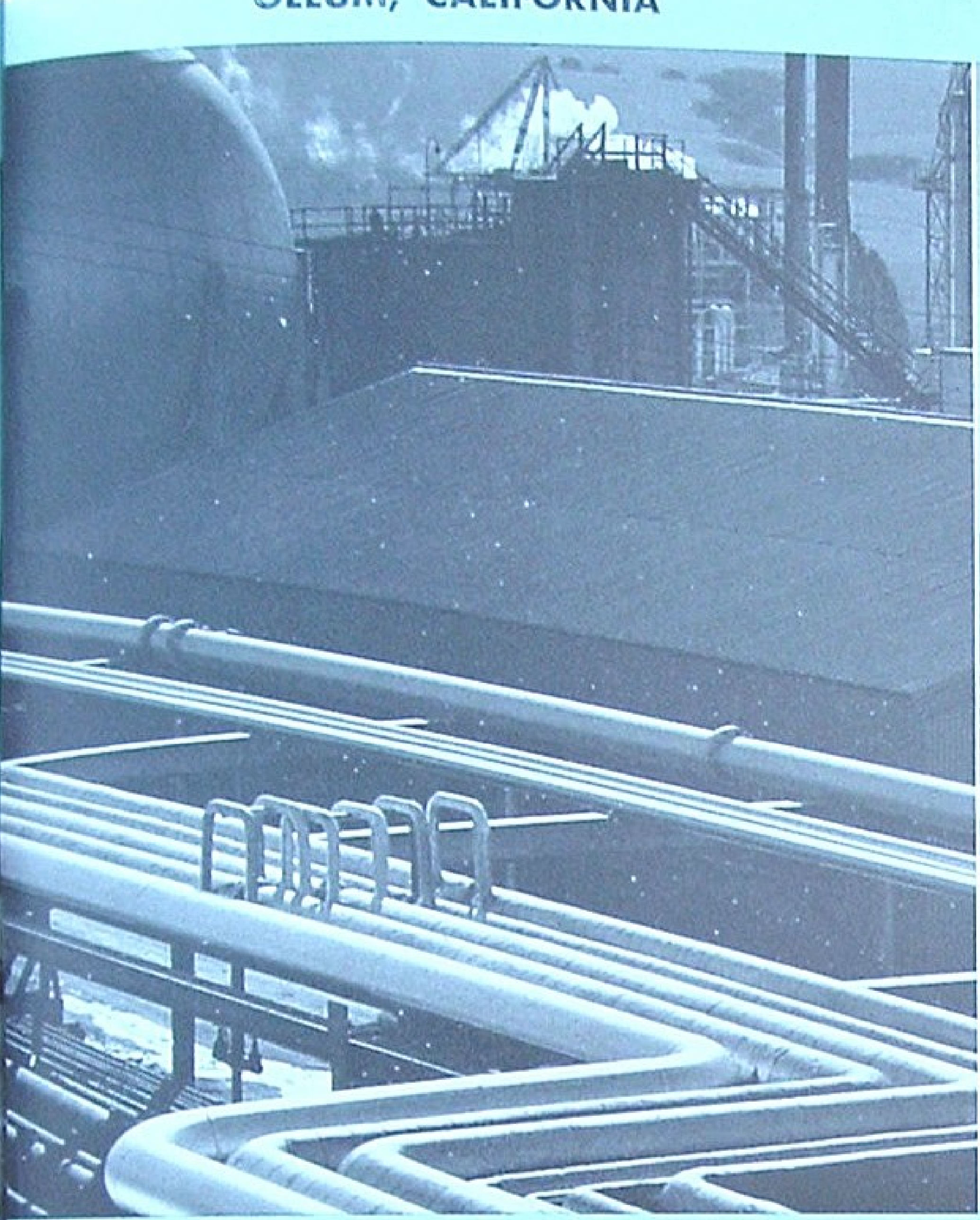
Adjacent to nearly every western town or city is a neatly fenced enclosure, normally containing several storage tanks, an office, a warehouse and garage. Located on a railway spur or highway or both, these installations, called marketing stations, receive their petroleum supplies either by rail or motor transport. The function of such plants—Riverside Marketing Station, below—is first to find markets for all types of petroleum products, and then to keep every customer adequately served and supplied.

Service Station functions of course require no elaboration on our part. Everybody is familiar with their operations, products and services. However, in concluding these "76 Views of Refining," we should like to call attention, by way of summary, to a modern industrial miracle.

This series has intimated how, after costly exploration and drilling, oil is pumped from thousands of feet underground—how it is cleaned and processed at gas plants or by means of other oil field equipment—how it is transported via pipe line and tankship hundreds of miles to refineries—how it is refined, blended and tested in scores of the largest and most expensive units men have ever designed—and how it is shipped and trans-shipped across additional hundreds of miles to market.

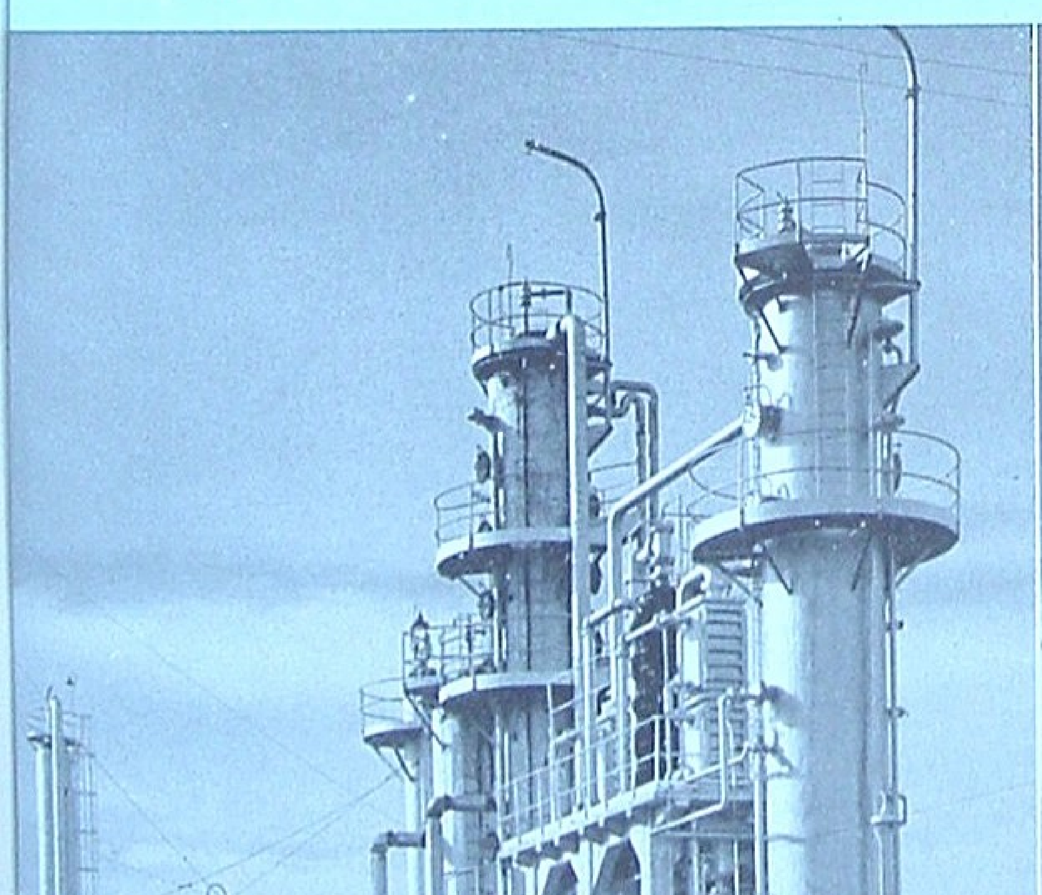
Yet, whether bought by the barrel, pound or gallon, oil products are among the least expensive we can buy, varying ex-tax from 1/4 cent a pound for fuel oil to about 3 cents a pound for gasoline. In contrast, bread costs about 20, milk about 15, lumber about 12, and an automobile about 80 cents a pound. Gasoline costs less even than bottled distilled water in many cities. But, when we ask for five gallons of gasoline at the Santa Barbara and Crenshaw service station, above, in Los Angeles or at others bearing the familiar "76," the courteous salesman is anxious to offer many other services without extra charge. Only our priceless American freedoms and competition could have made such an economic miracle possible.

OLEUM, CALIFORNIA



EDMONDS, WASHINGTON

Major Refining Facilities of Union Oil Company



MALTHA, CALIFORNIA

CUT BANK, MONTANA

Picture Quiz

1. To meet the growing needs of our civilian and military economy, the U. S. oil industry has spent over $12 billion in new facilities since World War II. This has expanded the capacity of the industry from 30% to 50% in all categories. Where did most of the $12 billion come from?

Check one:
- ☐ **BANK LOANS**
- ☐ **U. S. GOVT. SUBSIDIES**
- ☐ **REINVESTED PROFITS**

2. How much investment does it require to provide a job at Union Oil Company?

Check one:
- ☐ **$720**
- ☐ **$3,000**
- ☐ **$67,000**

3. Last year Union Oil made a total net profit of $16,257,000. $5,724,000 of this was plowed back into the business to meet the expanding needs of our customers. $10,533,000 was paid out in dividends to our common stockholders. What did these dividend payments average per stockholder?

Check one:
- ☐ **$292**
- ☐ **$5,276**
- ☐ **$10,420**

4. In 1910, Union Oil Company did an annual volume of $12 million. This represented 23% of the total oil business in the West. Today we do an annual volume of well over $200 million. What percentage of the total oil business in the West do we have today?

Check one:
- ☐ **23%**
- ☐ **12%**
- ☐ **30%**

Answers:

1. *88% of this expansion was financed from reinvested profits.* That percentage is traditional in the oil business and many others. That's why excessive taxes on corporation profits will seriously curtail the nation's economic growth and seriously affect your standard of living. For without adequate profits, expansion is impossible.

2. *$67,000. High-cost tools are typical of the oil business.* So is the large amount of capital required for raw-material supplies, transportation systems, etc. That's why it takes an investment of $67,000 in refineries, ships, tools, rigs, oil lands, etc., for each of Union Oil's 7974 employees.

3. *$292. $10,533,000 is a lot of money, but it was divided among a lot of people.* For we have over 36,000 individual stockholders in the Union Oil Company. And our largest single stockholder owns only 1½% of the total stock.

4. *12%. We do 18 or 20 times our 1910 volume.* But we have a smaller percentage of the total business—mainly because the industry is far more competitive. There are many more oil companies competing for the business today than there were in 1910.

UNION OIL COMPANY

OF CALIFORNIA

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This series, sponsored by the people of Union Oil Company, is dedicated to a discussion of how and why American business functions. We hope you'll feel free to send in any suggestions or criticisms you have to offer. Write: The President, Union Oil Company, Union Oil Building, Los Angeles 17, Calif.

Manufacturers of Royal Triton, the amazing purple motor oil