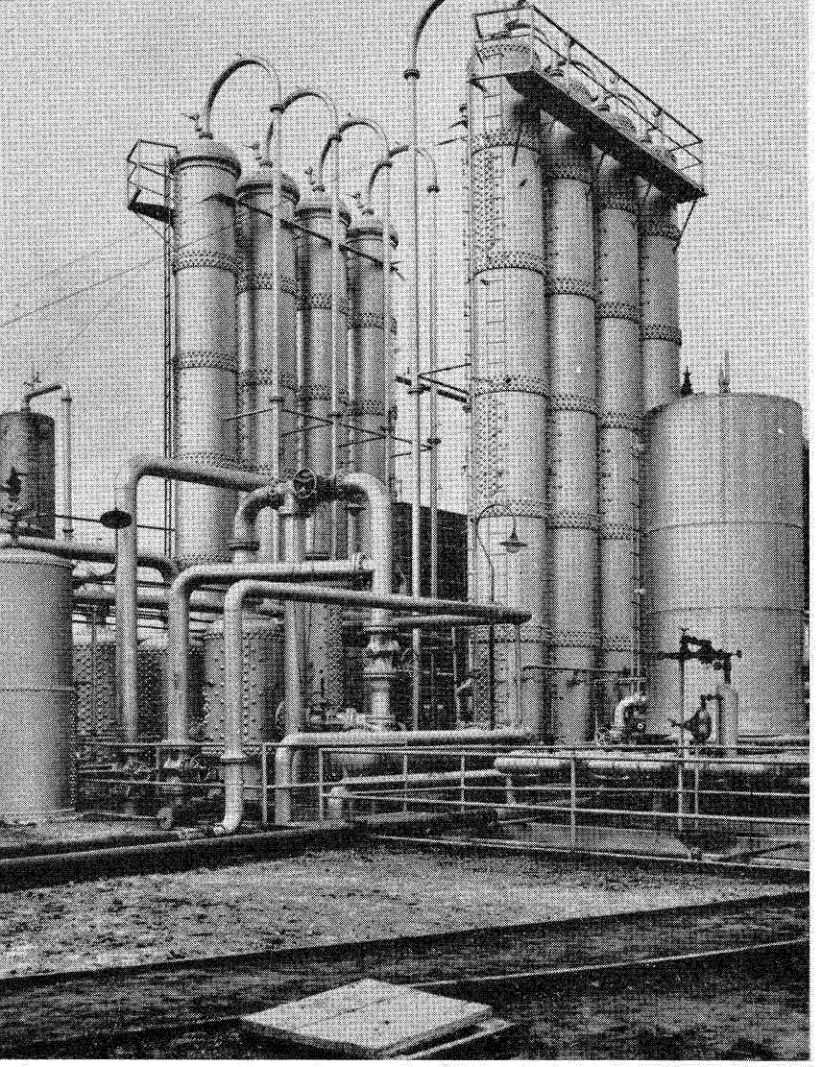


FIG. 1—Showing typical high-pressure absorber installation.

Production of NATURAL GASOLINE

By ROBERT B. BOWMAN

NATURAL gasoline is in the peculiar position of being at the same time a raw material and a finished product. It is seldom heard of in retail transactions involving petroleum products, because it is usually first blended with other fractions to produce motor and aviation fuels, in which it finds its principal outlet. In this case it may be considered a raw material. However, it is usually produced to such stringent specifications that little if any further processing is necessary after it leaves the natural gasoline plant. In this sense it may be considered a finished product.

The importance of natural gasoline is evident from the fact that in California the production of this material in recent years has amounted to about one-fifth the net production of refinery gasoline. The ratio in the United States has been smaller, but still it averaged one gallon of natural to about ten gallons of net refinery gasoline prior to the war and has now reached one gallon in six as a result of the increased demand for the volatile natural gasoline fractions in aviation fuel.

SOURCE OF NATURAL GASOLINE

Natural gasoline is extracted from "wet" gas, which is usually produced simultaneously with crude oil. Wet gas is separated from the oil by stages in field traps and tanks, whence it is collected and delivered to natural gasoline plants. The gas is called "wet" not in the sense in which the word is customarily used, but because it contains gasoline fractions in an amount sufficient to justify recovering them.

In contrast is "dry" gas, which is the natural gas distributed by public utilities for domestic and industrial fuel purposes. Either it has had the gasoline extracted from it, or it was originally produced without an appreciable amount of gasoline in it. Dry gas is often obtained from gas wells which produce no oil, such as those in the Rio Vista, Buttonwillow and other fields in California.

The predominant constituent of dry gas from wells is methane. Also present in dry gases discharged from natural gasoline plants are ethane, propane and some butane. Propane, isobutane and normal butane are intermediate between dry gas and natural gasoline and are becoming increasingly important as raw materials for various products. Originally they were disposed of principally as liquefied petroleum gases, but isobutane has become so much more valuable as a raw material in aviation gasoline that it has been virtually eliminated from this service. By direct combination with butylenes produced in refinery operations, isobutane yields a product high in isooctane content that is one of the principal base stocks for aviation fuels. Much normal butane is converted to isobutane to increase this source material. Also normal butane is dehydrogenated to butadiene, an important ingredient in synthetic rubber manufacture. Natural gasoline is composed principally of isopentane and heavier hydrocarbons, with varying amounts of normal butane depending upon specifications. A small amount of isobutane is usually present because of the difficulty of entirely eliminating this constituent. At the present time natural gasoline plants are generally operated to recover substantially all of the isobutane and heavier fractions from the inlet gas.

Table I is a compilation of compositions of typical wet gases, dry gases, liquefied petroleum gases and natural gasolines. This table serves to indicate the distribution of the various hydrocarbons in these materials. All hydrocarbons heavier than butane are grouped as pentanes (+). This is because an attempt is made always to extract all of these constituents and include them in natural gasoline. Information on the actual amounts of each one present is in general of little importance.

It will be noted that in the case of wet gases, compositions are reported both in terms of vapor per cent and "Gal./m.c.f." The latter expression is of particular significance. It represents the number of gallons of a constituent in 1000 standard cubic feet of gas. The latter quantity, abbreviated to m.c.f., is the unit customarily used in measuring gas volumes.

HISTORICAL DEVELOPMENT

Natural gas first became of economic importance in the years 1880-1890. In transporting gases in pipelines from oil fields it was noticed that a volatile liquid col-

TABLE I—TYPICAL COMPOSITIONS OF NATURAL GASES, LIQUEFIED GASES AND NATURAL GASOLINES

WET GASES FROM KETTLEMAN HILLS

Type of Gas	High Pressure Gas		Low Pressure Gas		Tank Vapors	
Component	Vapor %	Gal./m.c.f.	Vapor %	Gal./m.c.f.	Vapor %	Gal./m.c.f.
Methane	75.57		69.57		19.83	
Ethane	10.87		11.46		14.95	
Propane	7.38	2.02	8.88	2.45	26.98	7.37
Isobutane	1.09	0.35	1.58	0.51	6.26	2.03
N-Butane	2.74	0.86	4.02	1.26	17.04	5.36
Pentanes(+)	2.35	0.91	4.49	1.72	14.94	5.79
	100.00		100.00		100.00	

DRY GASES

Source	Discharge Gas from Kettleman Hills Natural Gasoline Plants		Well Gas from Buttonwillow Gas Field	Well Gas from McDonald Island Field
Component	Vapor %	Gal./m.c.f.	Vapor %	Vapor %
Carbon dioxide	0.05		0.5	0.04
Nitrogen	.....		.....	3.46
Methane	87.75		99.3	96.50
Ethane	8.33		0.2	.....
Propane	3.65	1.00	.....	.....
Isobutane	0.15	0.05	.....	.....
N-Butane	0.05	0.02	.....	.....
Pentanes(+)	0.02	0.01	.....	.....
	100.00		100.00	100.00

LIQUEFIED GASES

Name	Commercial Propane	Commercial Butane	
		(Winter Grade)	(Summer Grade)
Component			
Ethane	2.5 liq. %	2.5 liq. %	2.0 liq. %
Propane	97.0	45.0	30.0
Isobutane	0.5	1.0	1.0
N-Butane	.....	51.5	67.0
	100.00	100.00	100.00

NATURAL GASOLINES

Source	Kettleman Hills		Southern California	
Reid Vapor Press.	16 lbs.	24 lbs.	16 lbs.	24 lbs.
Component				
Isobutane	0.8 liq. %	2.0 liq. %	1.0 liq. %	2.5 liq. %
N-Butane	11.7	33.5	14.0	30.7
Pentanes(+)	87.5	64.5	85.0	66.8
	100.0	100.0	100.0	100.0

lected at low places in the lines, particularly if cooling due to low atmospheric temperatures had occurred. At that time, which was prior to the development of the automobile, light liquid hydrocarbons such as what is now called natural gasoline had no commercial value. In fact, even in refineries gasoline fractions were discarded from crude oil because kerosene was the lightest product for which there was a ready market. The volatile liquid separating from natural gas was therefore first recognized as a nuisance because it not only was valueless, but caused restrictions in the flow of gas through the lines and created a fire hazard when it was drained off.

About the beginning of the present century, gasoline began to assume value because of the birth of the automobile industry. More of this material was saved in the refineries and some attention was given to the liquid which separated from wet gases. As early as 1904, gasoline became of sufficient importance to justify considering means for extracting from natural gas more of the volatile liquid fractions than were separating from natural causes in gas lines.

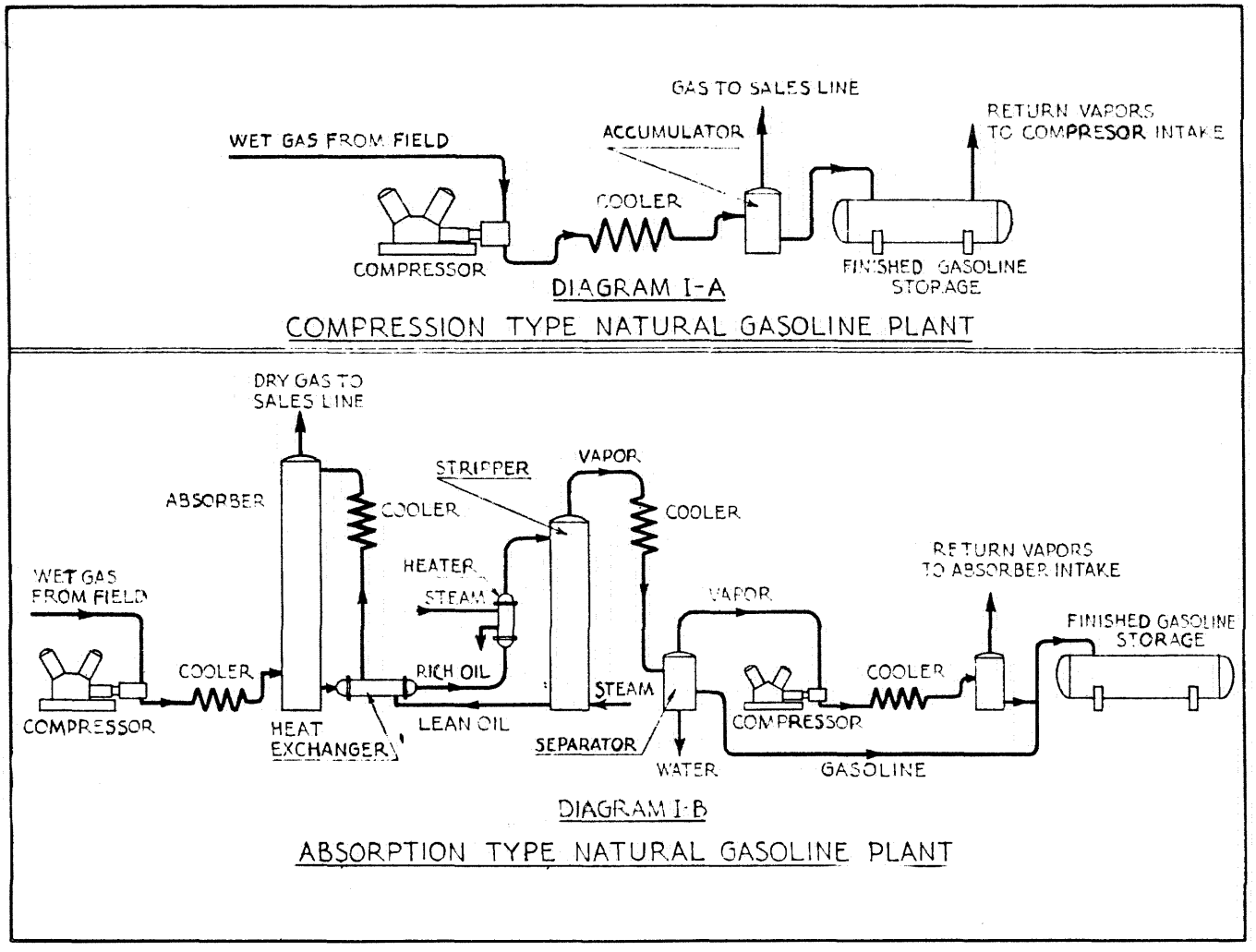


DIAGRAM I-A (Above)—Flow chart of a typical compression type natural gasoline plant. DIAGRAM I-B (Below)—Flow chart of absorption-type natural gasoline plant.

A. COMPRESSION METHOD OF EXTRACTION

It is a fundamental principle that condensation is induced either by a decrease in temperature or by an increase in pressure below the range where the retrograde phenomena occur. Therefore, the first method tried in attempting to obtain more gasoline fractions was to compress the gas and cool it, then separate the condensed liquid in an accumulator. *Diagram I-A* is a simplified flow sheet for a natural gasoline plant of the so-called compression type. The liquid from the accumulator was drawn off into tanks and the uncondensed portion of the gas was delivered to fuel lines. When high pressures were used, a large quantity of ethane and propane was retained in the liquid and an exceedingly volatile or "wild" gasoline was obtained. It was partially stabilized by withdrawing vapors from the tanks and returning them to the intake to the compressor. In passing again through the process of compression and cooling, some of the lightest components of the vapors failed to condense and were rejected into the fuel lines.

The principal weakness of the compression process was its inefficiency. Excessively high pressures or very low temperatures were required to recover substantially all of the pentanes and heavier fractions which could be included in finished gasoline. Also, the quality of the product was poor because it contained a large amount of the hydrocarbons such as methane, ethane and propane, which are not properly designated as natural gasoline. In spite of these weaknesses, however, and in the absence of a well-developed better process, the number of compression-type natural gasoline plants rapidly grew, until in 1912 there were 250, in 1916 there were 550, and in 1921 there were 865. Nevertheless, since 1921 the number has declined and the compression process has given way almost completely to the oil absorption process.

B. OIL ABSORPTION PROCESS

The oil absorption process consists basically of bringing wet gas in contact with an oil, whereupon the oil absorbs the gasoline from the gas. The action of the oil may be pictured as that of a sponge drawing into itself the gasoline fractions. After contacting the gas, the oil is heated and contacted with steam to drive off the absorbed fractions, which are then condensed as natural gasoline.

Diagram I-B is a simplified flow sheet of a natural gasoline plant of the oil absorption type. The individual items of equipment are discussed more fully later. The principal features of the process are as follows:

Wet gas from the field is first compressed and then cooled before it is introduced into the absorber. It then passes upwards counter-currently to a descending stream of oil, and out at the top into fuel lines.

The oil possesses the important property of preferentially absorbing the heaviest hydrocarbons from the gas. This so-called "selective" feature is an advantage of the oil absorption method over the compression method of extracting natural gasoline. The separation between heavy and light fractions in an absorber is, however, by no means a sharp one. When enough oil is circulated to absorb all the hydrocarbons which are desired in finished gasoline, some of the lighter ones are also extracted, but the separation is much sharper than when compression and cooling alone are employed.

The contacted sponge, or "rich" oil as it is called, leaves the absorber at the bottom and is heated before it passes into a stripper. Here steam is introduced to act as a carrier to remove the gasoline fractions from the oil. The "lean" or stripped sponge leaves the bottom of the stripper and is cooled before being circulated again into the absorber.

The steam and gasoline fractions are carried overhead from the stripper and are then cooled. The steam condenses and is drawn off as water from the bottom of the separator. The heaviest gasoline fractions also condense and form a liquid layer on top of the water in the separator, whence they are drawn off to the storage tank. The uncondensed vapors are then subjected to a step similar to the compression type of natural gasoline plant. They are first compressed and cooled, then the condensed portion is conducted to the storage tank, and the portion still in the vapor form is recycled to the absorber to recover any residual gasoline fractions.

A comparison of *Diagrams I-A and I-B* will indicate that compression still plays an important role in the oil absorption process. However, the use of oil makes possible the recovery of substantially all the gasoline from wet gas at ordinary temperatures and reasonable operating pressures. The efficiency and economy of the oil absorption process have made it the predominant method of operation now employed in the natural gasoline industry.

C. OTHER METHODS OF EXTRACTION

In addition to the compression and oil absorption processes, two other methods of extracting natural gasoline have received consideration; namely, (1) charcoal absorption and (2) refrigeration. Neither method has been extensively employed in the past, but future developments could bring either or both of them into prominence.

TYPICAL PRESENT-DAY PLANT

Diagram II is a flow sheet of a modern gasoline plant such as is operated at Kettleman Hills. Basically, this flow sheet is similar to *Diagram I-B*. Among the principal elements are the absorber, the stripper, the separator, and the vapor compressor, all of which appear in *Diagram I-B*. The only additional major feature is the rectifier or stabilizer in which specifications of the final product are controlled. However, the stabilizer is a single unit only when all the recovered hydrocarbons

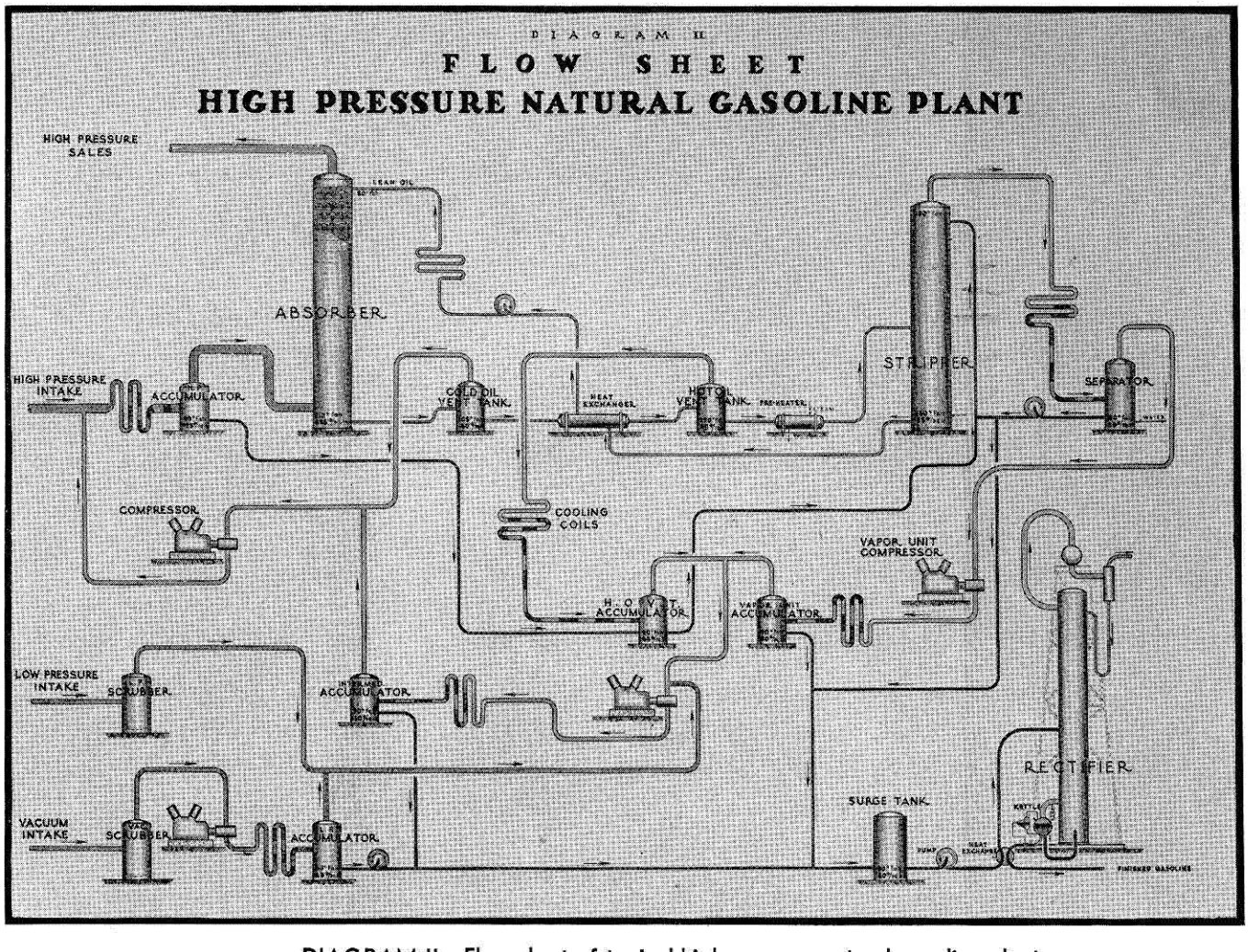
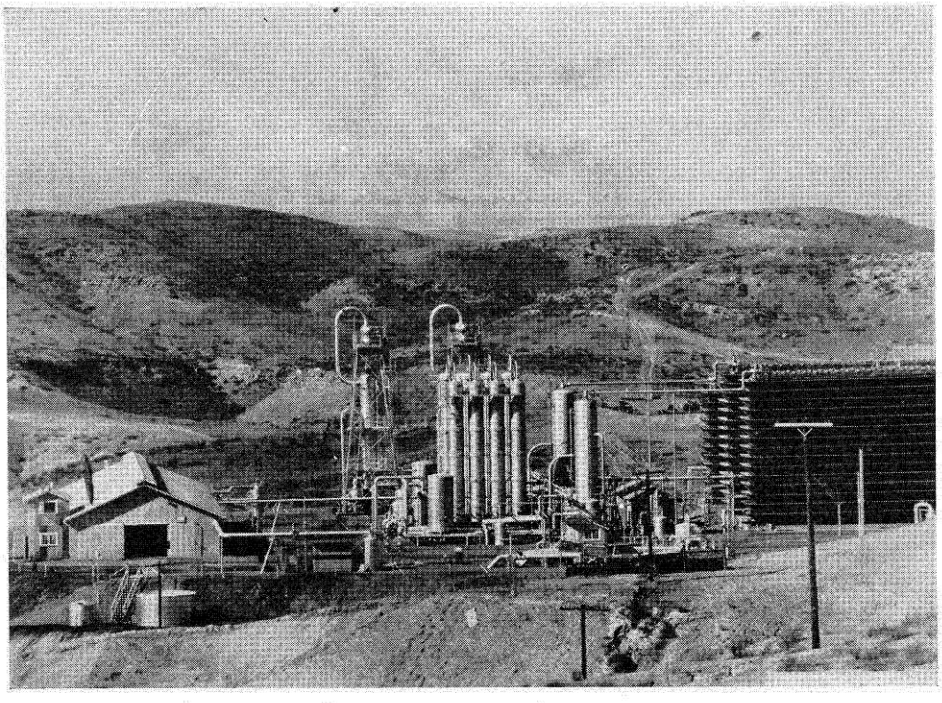


DIAGRAM II—Flow chart of typical high-pressure natural gasoline plant.



AT LEFT:
FIG. 2—Typical high-pressure natural gasoline plant located at Kettleman Hills, Calif.

are delivered from the plant as a mixture to be further separated at a refinery. In many cases batteries of rectifiers are located in the field, and propane, isobutane, normal butane, and natural gasoline are produced separately. The miscellaneous accumulators, coolers, vent tanks, etc., are all essential, but they play relatively minor roles in the process and are shown only for the purpose of completeness.

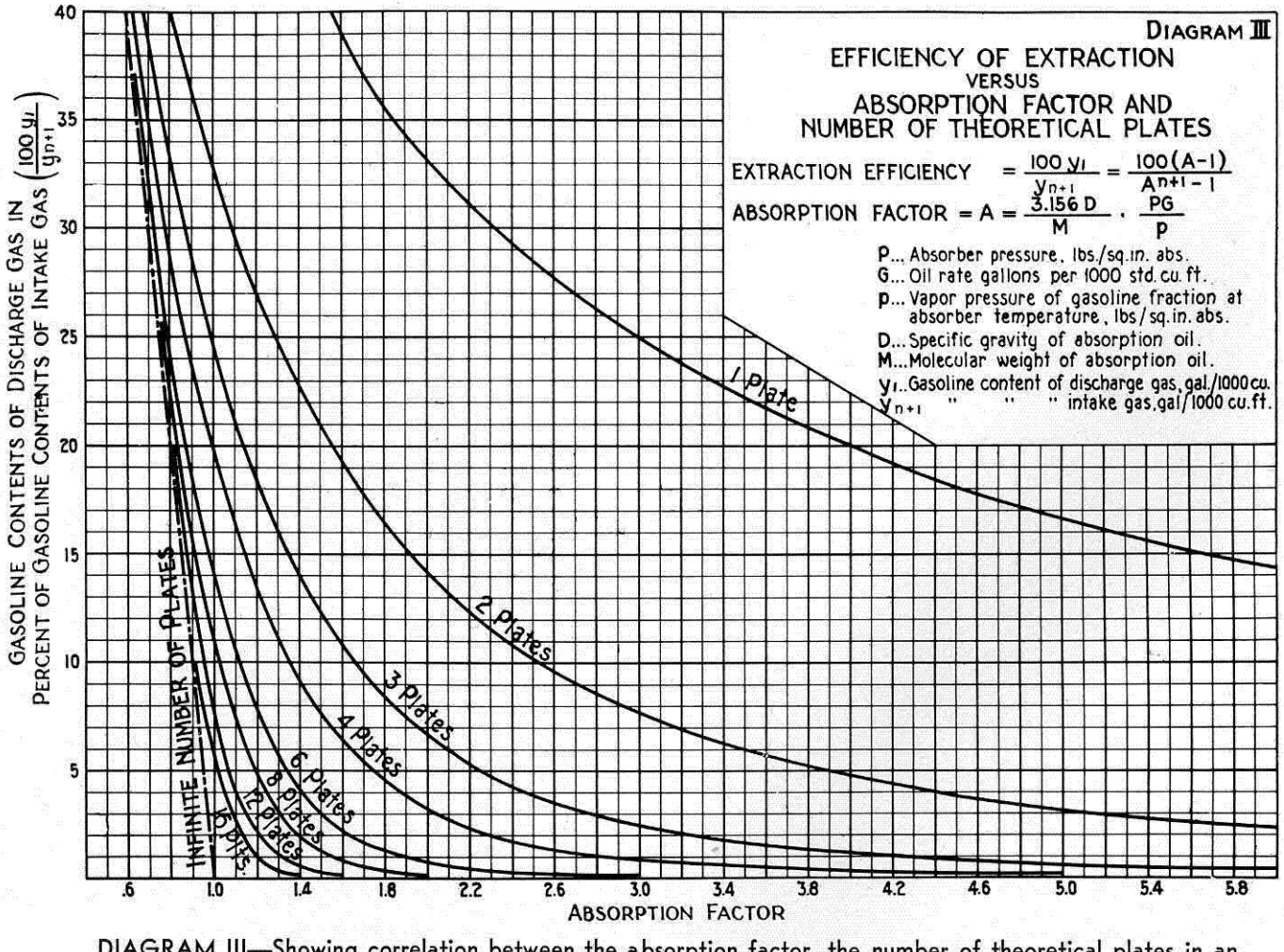


DIAGRAM III—Showing correlation between the absorption factor, the number of theoretical plates in an absorber, and the efficiency of extraction.

A. THE ABSORBER

High pressures and low temperatures are favorable to absorption because they make possible the complete extraction of the desirable gasoline fraction at relatively low rates of oil circulation. The operating pressure employed depends upon the pressure at which gas is available from the wells and the pressure at which it must be delivered to fuel lines after gasoline has been extracted from it. A pressure of 35 pounds per square inch ahead is approximately the minimum at which an absorption plant can be economically installed and operated. If wet gas is produced at a lower pressure in the field, general practice is to compress it to at least 35 pounds per square inch ahead of the absorption step. If gas is available in the field at a pressure above 35 pounds per square inch, or if delivery to fuel lines at higher pressures is required, the absorption step is conducted at the greater of these two pressures. At Kettleman Hills, conditions are such that absorber operating pressure is maintained at about 425 pounds per square inch. Some gas is available in the field at this pressure, but most of the field gas, all crude oil tank vapors and vapors originating within the plant require compression ahead of the absorption step.

TABLE II—PRODUCTION OF NATURAL AND REFINERY GASOLINE
(All Figures in Gallons per Day)

YEAR	NATURAL GASOLINE		REFINERY GASOLINE*	
	UNITED STATES	TOTAL CALIFORNIA	UNITED STATES	TOTAL CALIFORNIA
1911	20,345	**	**	**
1912	33,008	2,844	**	**
1913	65,921	9,482	**	**
1914	116,858	20,770	**	**
1915	179,082	35,164	**	**
1916	282,767	46,883	5,625,354	845,628
1917	596,943	78,953	7,809,690	1,059,786
1918	774,070	88,408	9,781,632	1,190,154
1919	963,110	110,647	10,843,476	1,144,710
1920	1,051,213	131,716	13,340,292	1,356,390
1921	1,232,697	159,507	14,119,350	1,411,662
1922	1,385,481	183,890	16,992,402	1,899,996
1923	2,236,236	474,874	20,701,170	3,515,568
1924	2,551,533	635,462	24,480,036	3,665,928
1925	3,088,959	830,630	29,871,912	4,885,020
1926	3,734,493	1,042,099	34,489,938	5,760,426
1927	4,496,284	1,364,438	38,012,310	6,917,358
1928	4,956,377	1,595,932	43,255,968	7,651,350
1929	6,119,693	2,302,260	50,063,790	10,668,672
1930	6,056,148	2,273,186	49,737,324	9,671,634
1931	5,018,953	1,863,943	49,653,198	8,084,790
1932	4,163,388	1,507,915	45,055,122	7,545,048
1933	3,890,041	1,355,992	46,210,458	7,256,466
1934	4,206,465	1,387,047	47,975,760	7,088,088
1935	4,525,989	1,464,723	52,683,204	7,976,682
1936	4,908,033	1,621,355	57,919,176	8,853,600
1937	5,659,000	1,709,299	64,339,506	9,275,616
1938	5,908,422	1,810,658	63,960,834	8,977,584
1939	5,943,000	1,663,663	68,572,182	9,216,564
1940	6,340,000	1,601,079	68,540,220	8,945,412
1941	9,304,000	1,588,000	77,224,000	9,941,000
1942	9,588,000	1,494,000	67,542,000	9,951,000
1943	10,423,000	1,598,000	68,169,000	10,638,000

* Includes straight run gasoline, cracked gasoline and natural gasoline blended.
** Information incomplete.

An absorber is a vertical cylindrical column such as those illustrated in *Figure 1*. This picture shows a group of eight units arranged in two rows of four each. In the early days of the absorption process, the columns were filled with wooden grids, wire coils or sometimes even baling wire to promote intimate contact between oil and gas. At the present time, bubble plates or trays are used almost exclusively for this purpose.

The use of bubble plates makes possible the absorption of gasoline fractions at low oil rates. At the same time the selectivity of the process is improved; that is, less of the undesirable fractions is absorbed by the oil while the desirable fractions are being recovered. Absorbers generally contain from 16 to 24 bubble plates.

B. THE STRIPPER

Stripping is the reverse of absorption. High pressure and low temperature are favorable to absorption, but low pressure and high temperature are favorable to stripping. Also, steam is admitted into the bottom of the stripper to act as a carrier in removing absorbed fractions from the oil. Thus in an absorber, gasoline fractions are removed from a wet gas by contacting the gas with a "lean" sponge under conditions of high pressure and low temperature, while in a stripper, gasoline fractions are removed from a "rich" sponge by contacting it with a dry gas (steam) under conditions of low pressure and high temperature.

The rich sponge leaving the absorber, after first being vented by reducing its pressure to remove a portion of the undesirable fractions which are unavoidably picked up in the absorber, is heated before it is introduced into the stripper. The first step in the heating is by transfer from hot lean oil returning to the absorber from the bottom of the stripper. The rich oil is again vented, then heated by indirect contact with steam in a preheater.

Rich oil is introduced about midway between top and bottom of the stripper. Steam and stripped vapors pass upwards through the column, and the oil passes downwards over bubble trays. The steam and vapors pass overhead from the column, then through cooling coils into a separator. Here, as was shown previously, the steam is removed as water, and a portion of the gasoline fractions is condensed. Some of these gasoline fractions are returned as reflux to the top of the stripper to wash back any of the light fractions of the oil itself which might tend to be carried overhead by the steam. The remaining gasoline fractions from the separator are conducted to the rectifier, which is described later.

In *Diagram II*, some of the stripper reflux is shown to be supplied by condensed material originating elsewhere in the plant. Any liquid is suitable which is similar in composition to the separator gasoline. Use of material already condensed elsewhere in the plant reduces the load on the stripper vapor condensing system.

The most favorable stripper operating pressure is of the order of 25 pounds per square inch gauge. At this pressure it is usually impossible to condense all the absorbed fractions that have been removed from the oil. The uncondensed portion is therefore subjected to compression and cooling in the plant vapor system.

C. PLANT VAPOR SYSTEM

The uncondensed vapors from the separator are first compressed to a pressure of about 80 pounds per square inch gauge and are then cooled to remove additional gasoline fractions, which are in turn delivered to the rectifier. Even at this pressure some of the gasoline fractions fail to condense. The remaining vapors are therefore subjected to additional compression and cooling and are finally conducted into the absorber. In some cases a separate absorption step operated at low pressure is employed for processing uncondensed separator vapors. This procedure is called reabsorption.

D. THE RECTIFIER

It has been mentioned that the absorption process, while representing an improvement over the compression process for extracting natural gasoline, is still unable to pick up all of the desirable hydrocarbons without at the same time recovering a portion of those not desirable in finished gasoline. It is the function of a rectifier to make the required separation. The nature of the rectifier installation depends upon a number of factors, such as the type of facilities available for transporting finished products, the demand for liquefied petroleum gases in the vicinity of the plant, etc. Where a pipeline outlet to a refinery is available, often the composite final product is shipped as a whole and separation into individual products such as propane, isobutane, normal butane, and natural gasoline is made in the refinery that receives the mixture. In this case the rectifier installation at the natural gasoline plant comprises only one fractionating unit with the simple function of removing methane, ethane, and excess propane from the mixture. When, for example, liquefied gases are produced locally or flexibility in the disposal of finished products is desired, a series of fractionating columns is employed to make the separation.

The operation of the individual fractionating or rectifying units is similar and will be illustrated by a description of a single-unit system. In this case the condensed hydrocarbons from the separator and various accumulators are collected in a so-called mixing or surge tank, from which they are pumped through a heat exchanger into the rectifier. The mixture is designated as "raw" product. The rectifier consists essentially of three units, comprising a column, a reflux system, and a kettle or reboiler. The raw product is introduced into the column about midway between top and bottom. When it enters the column, it separates into two parts: a vapor portion which rises towards the top, and a liquid portion which travels downwards. As in the case of absorbers and strippers, there are a number of bubble-cap trays or plates in the column, usually between 24 and 30. These trays are so designed that the liquid and vapor may travel countercurrently to each other and will be brought into intimate contact on each tray. The kettle or reboiler is the source of ascending vapor from the bottom of the column and the reflux system is the source of descending liquid from the top of the column. The contact between vapor and liquid on each tray results in an interchange of the various constituents, the lighter hydrocarbons tending to find their way upwards in the vapor stream and the heavier ones tending to find their way downwards in the liquid stream. The final result is that the product removed from the kettle contains essentially only those fractions which are desired to be retained. At the same time, the undesirable fractions are rejected overhead without carrying any desirable fractions with them.

In the case of a multiple-unit installation a common practice is to make the first unit a depropanizer in which propane and lighter fractions are removed overhead and isobutane and heavier fractions are retained in the bottom product. The second unit is a debutanizer, the feed to which is the bottom product from the first unit. In the second unit all isobutane and as much of the normal butane as is not desired in the finished gasoline are removed overhead and the bottom product is natural gasoline. A third unit processes the overhead material from the first unit and produces commercial propane as a bottom product. A fourth unit processes the butanes mixture from the second unit, separating it into isobutane and normal butane. The principal differences in the units are operating pressures and temperatures and the number of bubble trays in each one. The number of bubble trays is a function of the ease of separation (difference in boiling points) and the efficiency of separation desired. The column making the separation between isobutane and normal butane generally contains about twice as many trays as the others.

E. MODIFICATIONS

The flow sheet represented by *Diagram II* is shown principally as an illustration: many modifications of it are employed. For example, instead of having absorbers operated at only one pressure, two or three pressures may be utilized. If a substantial quantity of gas at low pressure were required locally for fuel purposes, an absorber might be operated at a pressure of the order of 10 pounds per square inch, in which case hot oil vent tank, vapor unit accumulator and low pressure field gases might be processed in it. Again, it might be found expedient to conduct a portion of the absorption step at a pressure of 150 pounds per square inch, in which case the intake gas would comprise cold oil vent tank and intermediate accumulator vapors. A still further modification is to conduct the compression of low pressure and vacuum field gases ahead of the gasoline plant, and deliver all gas to the plant in a single high pressure line.

The hot oil vent tank might be eliminated and a so-called rich oil rectifier be used in its place. In this case, gasoline content of the rejected vapors could be kept low enough to omit further processing. At the same time, light fractions might be eliminated to the extent that the entire remaining gasoline fractions could be condensed and delivered directly to the rectifier without setting up a vapor recycle.

The stripping step may be conducted in two stages instead of one as indicated on *Diagram II*. In many plants the lightest fractions are first removed from the oil in a primary stripper and this step is followed by removal of the heavier fractions in a secondary stripper which is operated at a lower pressure. Variations in the rectifying step have already been discussed.

Figure 2 is a general view of the absorption, stripping and rectification systems at a high pressure natural gaso-

line plant. It shows the compact arrangement of equipment.

F. COMPRESSORS

As was noted previously, compressors play an important role in the operation of an absorption-type natural gasoline plant. They are employed to boost field gas and vapors to absorber operating pressure and to process plant vapors. At Kettleman Hills, where dry gas must be delivered to sales lines at a pressure of about 425 pounds per square inch, this pressure, as was stated previously, becomes the most favorable absorption pressure. Compressors are required to boost much of the field gas to this final pressure. They are also employed to raise the pressure of gas utilized in producing wells by the gas-lift method. At the present time the total investment in compression facilities at Kettleman Hills far outweighs the value of the actual gasoline extraction equipment represented by the oil circulating and processing systems and the rectifiers.

Compressors have undergone an interesting development. Originally they were steam-driven because the internal combustion engine had not been developed to a sufficient degree of dependability to justify its adoption. Steam-driven units were subject to two major disadvantages. First, they were inefficient and required as fuel a very large quantity of salable gas. In the second place, water with a sufficient degree of purity for boiler operation was frequently not available at places where natural gasoline plants were located. Expensive treating equipment was then required. With the rapid development of the gasoline-driven automobile engines, a parallel improvement in gas-engine driven compression equipment occurred. By 1920, practically all of the steam-driven equipment had been displaced.

The first method of transmitting the power of the engine to the compressor was by means of a belt. Most of the early natural gasoline plants consisted of a row of engines on one side of a wide room and a row of compressors on the other side. The engines were placed well away from the compressors as a safeguard against explosions in the engine rooms. In some cases the engines and compressors were even put in separate rooms, and the belts were run through separate holes in the sidewalls or partitions.

Belted units were bulky and were expensive to maintain. Rapid improvements in gas engines soon greatly reduced the fire hazard, and direct-connected gas-engine driven units were soon recognized as practical and safe. The direct drive is much more efficient than the belted drive and has many less moving parts to keep in repair. Also, it is economical from the standpoint of space requirements, which are often an important consideration in natural gasoline plant design and construction.

The first direct-driven units were horizontal, with the power cylinders in alignment with the compressor cylinders. They were comparatively slow-speed, operating usually at 220 r.p.m. or less, and had high power outputs per cylinder. The result was that immense concrete foundations were required to absorb the large horizontal thrust which was developed.

Early in the 1930's, so-called angle-type units were introduced. These are constructed with vertical power cylinders and horizontal compressor cylinders. The power output per cylinder has been reduced, and the speed and number of cylinders has been increased to provide a high total power output in a compact and efficient unit. A typical unit has a *V*-type arrangement of eight power cylinders. Four compressor cylinders are arranged horizontally and operate from the same crankshaft as the power cylinders. The power output is 300-horsepower per unit. Angle-type equipment can be installed for about two-thirds of the cost of the horizontal units, and is proportionately more economical in maintenance costs and space requirements.

Gas-engine driven compressors are available in units having well over 1,000 horsepower each. However, these are practicable only in service on large dry-gas transmission lines where comparatively steady volumes are handled. For natural gasoline plant service, smaller units possess greater flexibility and can be readily installed or removed to meet changing field conditions.

PLANT CONTROL

The most important basis for control over plant operation is what is known as the Absorption Factor, which was originally developed by Kremser and presented in a paper before the California Natural Gasoline Association in 1930. The original form of the absorption factor equation was as follows:

$$A = 3.156 \frac{D}{M} \frac{PG}{p} \qquad \textit{(Equation 1)}$$

wherein A = absorption factor,
D = specific gravity of sponge,
M = molecular weight of sponge,
P = absorber pressure, pounds per square inch absolute,
G = gallons of sponge per m.c.f. of gas, and
p = vapor pressure in pounds per square inch absolute of constituent for which the factor is computed.

TABLE III—NUMBER OF NATURAL GASOLINE PLANTS IN OPERATION

YEAR	UNITED STATES	TOTAL CALIFORNIA
1911	176	*
1912	250	7
1913	341	14
1914	386	19
1915	414	20
1916	596	26
1917	886	49
1918	1,004	56
1919	1,191	60
1920	1,154	70
1921	1,056	73
1922	917	77
1923	1,067	119
1924	1,096	140
1925	1,081	145
1926	1,102	172
1927	1,119	152
1928	1,078	147
1929	1,087	153
1930	1,035	148
1931	937	136
1932	830	109
1933	779	97
1934	741	92
1935	715	88
1936	700	87
1937	679	90
1938	696	96
1939	652	91
1940	651	88
1941	609	86
1942	606	83
1943	610	83

* Information incomplete.

Quality Controlled

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This equation quantitatively relates the variables in absorber operation. A change which increases the numerical value of the factor increases the efficiency of extraction. The ratio D/M in the equation takes into consideration the nature of the absorbent or sponge stock. Thus an oil which has a high density but low molecular weight is the preferred type of sponge. Other conditions remaining the same, the absorption factor is directly proportionate to the absolute operating pressure or to the oil rate. The influence of temperature is introduced in the term p. The importance of operating at low temperatures is evident when it is realized how rapidly the vapor pressure of a substance increases with a rise in temperature.

At the present time most natural gasoline plants are operated to recover substantially all the isobutane from intake gas. Thus an isobutane absorption factor is usually the basis for operating control.

Since plant capacity is a function primarily of the ability to circulate sponge stock once the operating pressure has been established, the absorption factor presents a simple means for comparing the sizes of plants that will effect different extents of recovery of light fractions. Before butanes were in demand, natural gasoline plants were operated for substantially complete isopentane recovery. In the normal range of operating temperatures (70°-100° F.) the isopentane absorption factor is about three and one-half times the isobutane factor for a given set of conditions. Thus to extract a given proportion of the available isobutane requires the circulation of about three and one-half times as much oil as to extract the same proportion of the isopentane.

Diagram III, taken from the Kremser paper, is a correlation between the absorption factor, the number of theoretical plates in an absorber and the efficiency of extraction. The importance of having an adequate number of trays is obvious when it is noted how rapidly at a given absorption factor the efficiency of extraction increases as the number of trays is increased. Likewise, it will be noted that a given efficiency of extraction can be maintained with a materially lower absorption factor and attendant plant investment and operating cost if adequate trays are used. It must be emphasized that the number of trays is based on theoretically perfect performance. For actual conditions the efficiency may be much lower. In this case the performance would be based on the line corresponding to the number of theoretical trays times the plate efficiency. Thus the performance of a 24-tray absorber having a plate efficiency of 50 per cent would be represented by the line of *Diagram III* corresponding to 12 theoretical plates. As a matter of interest, it will be noted that 100 per cent extraction would be obtained at a factor of 1.0 in an absorber having an infinite number of trays.

In terms of equilibrium constants, the absorption factor equation becomes:

$$A = \frac{L}{KV} = 3.156 \frac{D}{M} \frac{G}{K} \quad \textit{(Equation 2)}$$

wherein L = mols of liquid sponge,
V = mols of vapor, and
K = equilibrium constant, at absorber pressure and temperature, of the hydrocarbon for which the factor is computed.

The general concept of the absorption factor is extremely helpful in other phases of plant operation. Inverted, the absorp-

(Continued on Page 20)

Picking up overseas mail "...on the fly"

Nothing is quite so precious to a fighting man as a letter from a loved one back home—nothing more miserable than "sweating out" mail call—for the letter that doesn't come.

Picking up mail "on the fly" at small stations, as shown here, is one way Southern Pacific and other railroads see to it that your letters are handled quickly.

Another example of fast, efficient mail service was Southern Pacific's handling of Christmas mail to the men overseas.

All mail to the Pacific fighting fronts is first routed to Army and Fleet Post Offices in San Francisco. During the last Christmas season, 2,931 carloads of overseas mail rolled into Oakland and San Francisco rail terminals! If the mail bags in these cars were placed end to end they would have formed a continuous column from San Francisco to Seattle.

To get this unprecedented volume of mail through on time—loading, transporting, switching, handling, and trucking problems were worked out well in advance. Many solid trains of mail were run across the country—thousands of freight cars were "drafted" for mail service.

Everything possible was done to assure your fighting man a letter or package from home on Christmas.

We want you to know that mail for fighting men comes first with us. It is never put aside for other traffic. You know how letters help the morale of men and women at the front. So, won't you write more letters? Whether it's V-mail or regular mail, write often.

S·P The friendly Southern Pacific

Natural Gasoline

(Continued from Page 12)

tion factor becomes a stripping factor applicable to controlling the operation in which the absorbed fractions are removed from the rich sponge stock. By an appropriate change in units, the equation becomes:

$$S = \frac{1}{A} = \frac{KV}{L} = \frac{KW}{150}\frac{M}{D} \quad \textit{(Equation 3)}$$

wherein S = stripping factor, and
W = pounds of steam per gallon of oil.

A similar approach could be made to the performance of a rectifier or fractionating column. The section of the column above the feed could be considered as an absorber and that below the feed as a stripper. Reflux in the upper section serves as sponge stock, and vapors from the reboiler serve as the stripping medium in the lower section.

STATISTICS

Table II is a summary of the average daily production of natural gasoline and refinery gasoline in California and the United States for the years 1911 to 1943. The figures for refinery gasoline include the natural gasoline which has been blended into the product.

Production of natural gasoline in the United States is now slightly more than 15 per cent of the entire output of refinery gasoline. In California, the ratio is almost the same. Prior to the present war, the ratio in California was appreciably higher than in the United States as a whole. However, in the concerted effort to increase the production of light fractions for use in aviation gasoline it was possible to expand production at a much faster rate elsewhere than in California. California is now the source of about 15 per cent of the total natural gasoline produced in the United States, but in a number of prewar years the percentage was about double that.

Table III represents the number of natural gasoline plants operated in the United States and in California in the years from 1911 to 1943. The total number in the United States is shown to have increased rapidly from 176 in 1911 to a peak of 1,191 in 1919. From that time until 1930, with the exception of one year, the number stayed in excess of 1,000 but subsequently there has been a decline.

The relatively static position of the number of plants in the 1920's was due to the fact that as fast as new ones were built, there was an elimination of small units which became unprofitable to operate. Also, with the inception of the oil absorption process, there were many cases where a single new plant of this type took the place of several small compression plants. The decline since 1930 has been in a large measure due to construction of jointly-owned plants in new fields which are co-operatively developed by the various oil operators. The result has been a trend towards a smaller number of plants with larger individual capacities. In recent years, approximately one-seventh of the entire number of plants in the United States has been operating in California.

The above statistics are believed to indicate, in turn, the importance of natural gasoline in relation to the entire output of motor and aviation gasoline and the importance of California in the natural gasoline industry of the United States.