Testing and Metering in Natural Gasoline Operations

By ROBERT B. BOWMAN

THE article on "Production of Natural Gasoline" that appeared in the June, 1945, issue of *Engineering and Science* covered in detail the process of recovering light liquefiable hydrocarbons from natural gas. From a review of the article it will be obvious that the process must be carefully controlled in order to obtain the maximum yield of products of satisfactory quality as economically as possible. This control is exercised through testing and metering the various liquid and vapor streams encountered in the process. The following discussion of the procedures involved is intended to supplement the original article.

TESTING

Both periodic and incidental tests are required to supply a basis for controlling the quality of finished products and the efficiency of extraction. Periodic tests are made principally on wet and dry gases and on finished products. Incidental tests are made also on absorption oil, engine lubricating oil, and water used in the various cooling systems. The present discussion will be limited to those tests which are made periodically.

WET GAS

Wet gases are tested principally for their gasoline content and specific gravity.

1. GASOLINE CONTENT

When a new oil field is discovered, gasoline content tests are made to determine whether the anticipated yield of gasoline from the available quantity of wet gas is sufficiently large to justify an investment in extraction equipment. After a plant is installed, tests on wet gas serve primarily as a means of allocating finished gasoline to the various properties from which gas is delivered to the plant.

The field testing procedure adopted as standard in California is called the charcoal adsorption test. A small stream of gas is passed through a tube of charcoal (usually a three-quarter-inch pipe about 30 inches long) under controlled conditions. The charcoal is then taken to the laboratory, where it is distilled and the adsorbed fractions are recovered. The distillation is conducted with the receiver held at a pressure of 30 pounds per square inch gauge and a temperature of 32°-34° F. The amount of condensate obtained under these conditions is proportionate to the isobutane and heavier fractions in the gas. This condensate is then weathered under controlled conditions to give a product of approximately 20 pounds Reid vapor pressure, which represents an average natural gasoline. The volumes of condensate obtained and the volume of gas passed through the charcoal are then related to obtain yields in terms of gallons per 1,000 standard cubic feet or "G/M," as this quantity is usually abbreviated. By the application of appropriate factors, these results are converted into corresponding yields of isobutane, normal butane, and "pentanes and heavier."

For more exact results, fractional analysis is employed. This method is of sufficient importance to be discussed in more detail later. Other methods for determining enrichments of wet gases are the freezing test, the oil absorption test, and the compression test. These, however, have in general yielded to the charcoal adsorption method, principally as the result of its greater selectivity. This feature would make the charcoal method an attractive plant process if the disadvantage of discontinuity could be overcome.
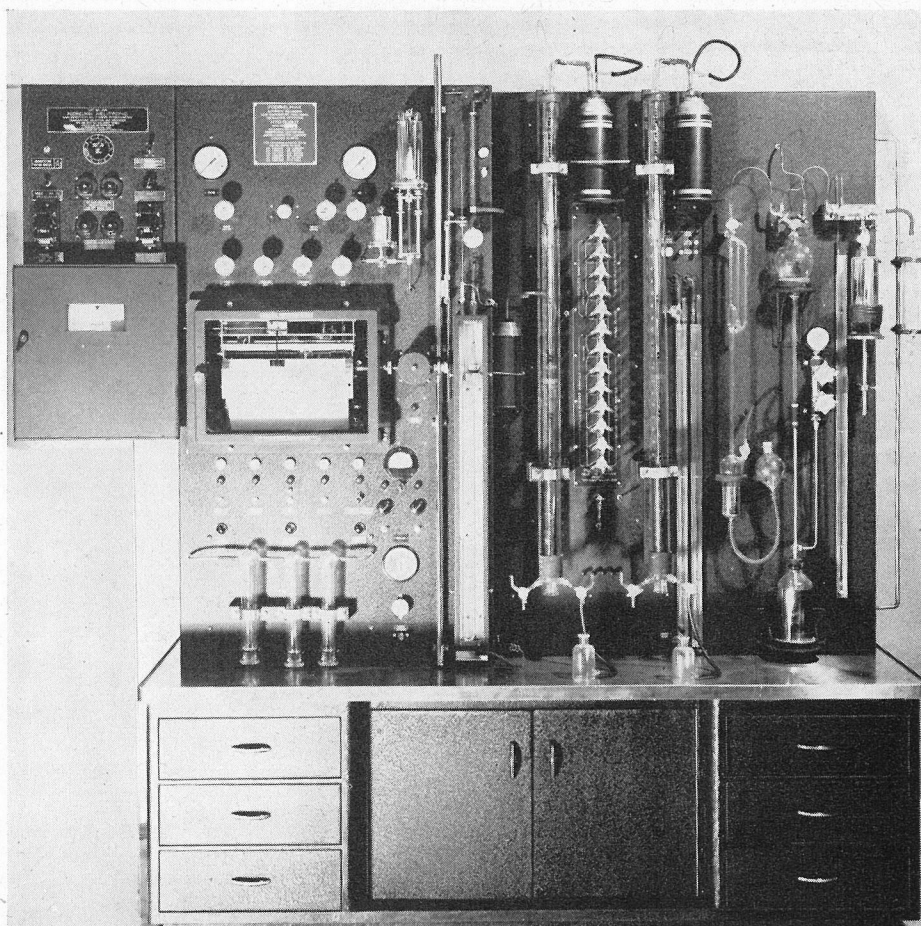

FIG. 1. Hyd-Robot Automatic Recording Low-Temperature Fractional Analysis Apparatus.
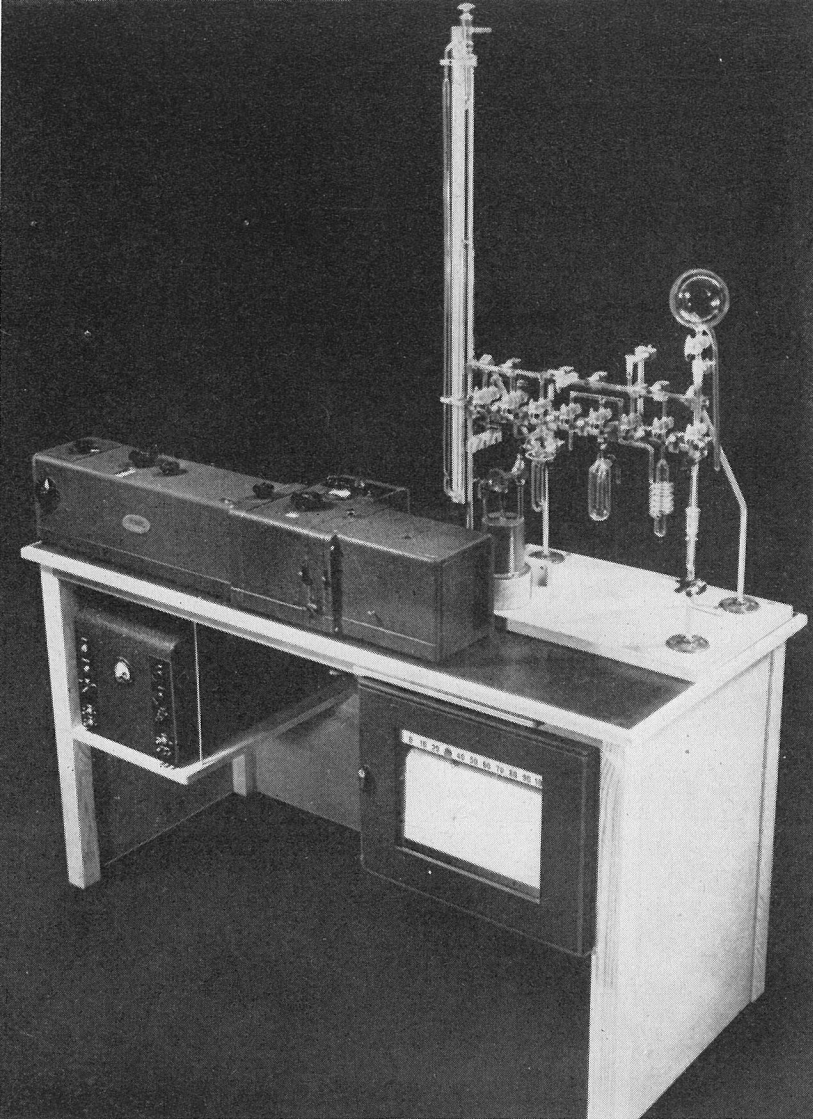
FIG. 2. Beckman infrared spectrophotometer.

2. SPECIFIC GRAVITY

As is discussed later, volume of natural gas is generally measured by orifice meter. The specific gravity of the gas must be known in order to compute the volume recorded by this type of meter. Two methods are commonly employed for determining specific gravity. These are the use of a so-called Schilling's bottle and of an Edwards gas balance.

A Schilling's bottle is a means for discharging a small quantity of gas through a small circular orifice under fixed conditions. A gas having a low specific gravity will pass through at a faster rate than one having a higher specific gravity. The time taken by air to pass through the opening is first measured. Then an equal volume of gas is passed through and the time required is noted. The specific gravity of the gas is the square of the ratio of the "gas time" to the "air time."

The Edwards balance depends upon the principle that the buoyancy or lifting power of a fluid (i.e., either a vapor or a liquid) is directly proportionate to the density of the fluid. A gas with a high density will float a light body more readily than will a gas with a low density. The density of a gas is proportionate to its absolute pressure. It is therefore possible by controlling the pressure on a gas to control its specific gravity.

An Edwards balance is a small evacuated metal bulb mounted on a small metal beam. The beam is pivoted near the center on a knife-edge support. The end opposite the bulb is a pointer which serves to indicate the position of the bulb. This assembly is mounted in a metal container having a glass window opposite the pointer. Gas is introduced into the outer shell and the pressure is increased until the bulb is floated by the gas. A gas having a low specific gravity will require a higher pressure to float the bulb than will a gas of higher specific gravity. The ratio of the pressure of air required to float the bulb to the pressure of gas required to support it in the same position is the specific gravity of the gas.

DRY GAS

The most important tests made on plant discharge gases are likewise those of specific gravity and gasoline content. Specific gravity determinations are made for application in metering the volumes of gas disposed of to sales lines, plant and lease fuel systems, etc. The test procedure is identical with that for wet gases. Gasoline content tests are made to determine the efficiency of gasoline extraction. The low gasoline contents of plant discharge gases make necessary the application of a different procedure from that used in testing wet gases which have much higher gasoline contents.

A procedure now employed quite extensively is known as the "B-W Test." This is an abbreviation of "butane absorption and weathering test." A measured quantity of the gas to be tested is bubbled through a liquefied petroleum gas mixture in a special apparatus maintained at a low temperature (usually about $-44°$ F.) by being immersed in a bath of boiling propane. The liquefied gas mixture is principally butane. At the low temperature used in the test, the butane acts as an absorbent for any pentanes (+) fractions that may be present in the gas. After a few cubic feet of gas have been bubbled through the absorbent, the gas flow is stopped, and the temperature of the absorbent is allowed to rise slowly to $+35°$ F. During the course of the rise in temperature most of the absorbent weathers or evaporates. The temperature at which 90 per cent has evaporated is noted, as is the volume of liquid remaining at 35° F. Each different combination of these two readings corresponds to a particular quantity of pentanes (+) material in the mixture at the end of the absorption step. The concentration of pentanes (+) fractions in the original gas sample can then be computed.

More recently, following the trend towards complete recovery of butanes, the principle of the weathering test has been extended to the determination of isobutane (+) contents by absorption in a propane solvent.

FINISHED PRODUCTS

Vapor pressure and composition are the most important characteristics of finished products from natural gasoline plants. Vapor pressures are determined by standardized procedures in which equilibrium is established between a liquid and its own vapor under fixed conditions, and the pressure is simply read from a gauge connected to the vapor space of the container. Correlations can be made in many cases between vapor pressure and composition, with the result that a vapor pressure determination alone is adequate for some purposes.

Compositions are determined by fractional analysis, spectrometry, or weathering tests. The first two procedures are discussed in detail below. Weathering tests are applied principally in the case of propane, isobutane, normal butane, or mixtures of them. A small sample of the stock to be tested is allowed to evaporate under controlled conditions, and composition is estimated from correlations between volumes and temperatures observed during the evaporation. Tests of this

type are decidedly attractive in many ways. They are simple and inexpensive and can be run directly at the processing equipment by a non-technical operator. Their low cost is conducive to frequent testing, and the ability to obtain results promptly without the delay of transporting samples to a laboratory facilitates maintaining close control over plant processes that influence quality of products.

FRACTIONAL ANALYSIS

This method is so called because it is employed in analyzing liquid or gaseous hydrocarbon mixtures in terms of the individual constituents or fractions, such as methane, ethane, propane, etc., which are present. It is the only procedure capable of accomplishing this objective by physically separating the individual components. As is explained below, spectrometry gives results in terms of the individual components, but no actual separation is made. The expense involved in conducting a fractional analysis (usually $5 to $25, depending upon the nature of the sample) prohibits routine use of the method. It is applied principally in (1) standardizing and interpreting results of the empirical test methods which have been briefly reviewed above, and (2) special investigations requiring a higher degree of accuracy or a wider range of results than could be supplied by empirical methods.

Basically, the procedure is similar to the rectification step in the plant process. A small glass apparatus is used, comprising a kettle, a column, and a reflux condenser. However, operation is at atmospheric pressure or under a vacuum, in contrast to the high pressures employed in plant equipment. The sample is first introduced into the kettle, where it is completely liquefied. This is accomplished by having the kettle immersed in a suitable cooling bath. If methane is present in an appreciable quantity in the sample, liquid nitrogen which boils at $-320°$ F. is used in the bath. For more stable materials, a bath of liquefied propane that boils at $-44°$ F. is often adequate.

Boiling is next allowed to commence in the kettle, and refluxing starts when the top of the column is cooled. In a short time the material at the top of the column is the lightest hydrocarbon, in a high degree of purity, which was originally present in the sample. The temperature in the top of the column will then be the boiling point of the lightest hydrocarbon present. Some of this fraction is next withdrawn as vapor into an evacuated flask. Withdrawal is slowly continued until there is a tendency for the temperature in the top of the column to rise, which indicates that the amount of the lightest hydrocarbon has been nearly depleted and the next heavier hydrocarbon is starting to arrive at the top of the column.

The withdrawal is then reduced to a very slow rate, and when there is an abrupt rise in temperature, it is discontinued. The amount of material withdrawn up to this point represents the amount of the lightest fraction originally present in the sample. Withdrawal is then commenced at the higher temperature until another rise in temperature begins, after which the process described above is repeated.

If natural gas (either wet or dry) or liquefied petroleum gas samples are involved, the usual procedure is to remove each fraction overhead as vapor. If the sample is natural gasoline, the normal butane and lighter fractions, and sometimes the isopentane and normal pentane, are taken overhead as vapor, but the composite heavier fractions are retained in the kettle and measured as liquid. Factors are available for converting vapor volumes of the individual fractions to equivalent liquid volumes, and vice versa. When the volumes of the individual fractions have been determined, they are converted to a uniform basis. The sum is the amount of sample originally present. The percentage of each fraction can then readily be computed.

In a modern laboratory fractionation apparatus, a large portion of the operation is automatic and one operator is able to conduct a number of analyses simultaneously. *Fig. 1* is a picture of a widely used type of equipment known as the Podbielniak Hyd-Robot Automatic Recording Low-Temperature Fractional Analysis Apparatus. It is a two-column unit, and preparations can be made for running a second sample while the analysis of one sample is in progress. Not visible in the picture are the measuring flasks into which the individual vapor fractions are withdrawn from the top of the column for measurement. It is interesting to note that the columns themselves, which were the principal features of the original manually operated type of equipment, represent only a comparatively minor portion of the assembly of potentiometers, relays, and other controls that are required to make the operation substantially automatic.
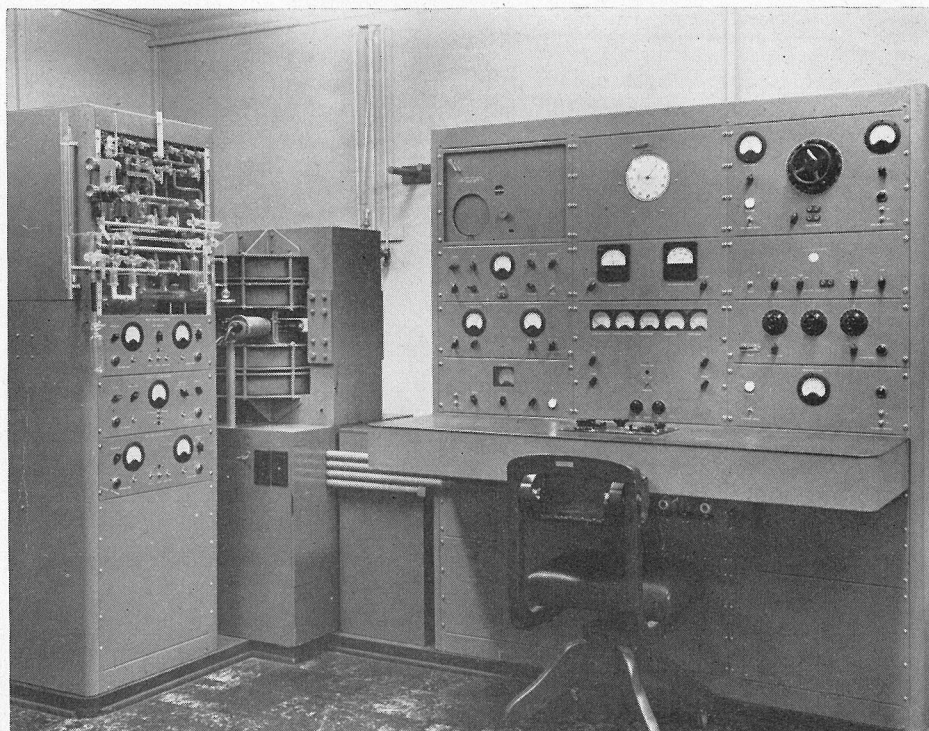

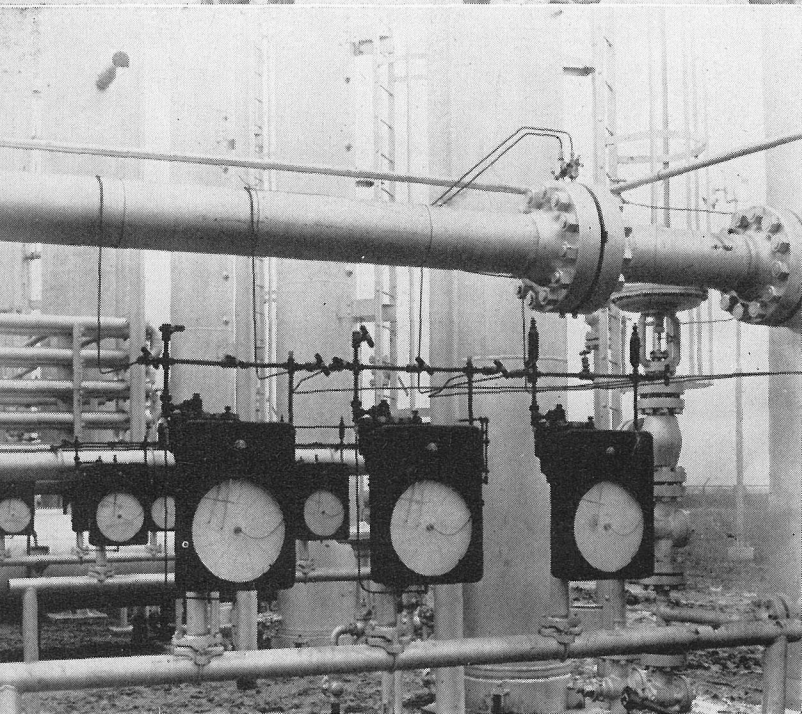FIG. 3. Typical Consolidated Mass Spectrometer Installation.

FIG. 4 (at top). Multiple orifice meter installation on gas lines from gas-oil separators for individual wells. FIG. 5 (at bottom). Orifice meters in a natural gasoline plant.

SPECTROMETRY

The most modern developments in equipment for analyzing gases and liquids of the types encountered in natural gasoline operations occurred during the war. These are infrared spectrometry and mass spectrometry.

Infrared spectrometry is based upon the principle that changes in vibrational energy that are constantly occurring within molecules give rise to absorption of radiation in the infrared range. A small sample of the hydrocarbon mixture to be analyzed is subjected to infrared radiation of a fixed series of wave-lengths and fixed intensity. Part of the energy is absorbed by the sample and the residual energy is measured. In this manner an energy absorption spectrum is obtained. The amount of absorption is specific for each atomic pattern and from the spectrum of a mixture the components can be identified and their concentrations computed.

Fig. 2 is a photograph of a Beckman infrared spectrophotometer of the type employed for analyzing hydrocarbon mixtures. The spectrometer itself is in the case. Below it are the amplifier and recorder for indicating the absorption pattern. To the rear is the system for handling the sample preparatory to introducing it into the infrared light path.

At the present time infrared spectrometry is employed principally in analyzing comparatively narrow ranges of fractions, such as mixtures of isobutane and normal butane or of butanes and butylenes encountered in refinery operations. Undoubtedly its use will be extended to cover other mixtures, but mass spectrometry appears to offer greater promise in analyzing all of the types of mixtures encountered in natural gasoline operations.

In mass spectrometry* the sample to be analyzed is bombarded by a stream of electrons which break down the molecules into electrically charged fragments. These charged fragments or ions are then drawn through a combination of electrical and magnetic fields in such manner that the ones of different weights can be segregated and their relative abundance can be determined. A definite pattern, called a mass spectrum, exists for each type of molecule when it is bombarded by a stream of electrons of specific energy. From the mass spectrum of a mixture the presence of the individual components can be identified and their amounts determined. At the present time it is possible to analyze a mixture containing all the paraffin hydrocarbons from methane through pentane, and rapid progress is being made in extending this range. However, despite the ability of a mass spectrometer to analyze in a single operation for a wider range of constituents than an infrared spectrometer, the latter instrument possesses the advantage of being able to distinguish between stereoisomers of the *cis* and *trans* type. Thus both types of instruments will probably find their most suitable ranges of applicability and will supplement rather than compete with each other in the general field of hydrocarbon analysis.

Fig. 3 is a view of a Consolidated Mass Spectrometer of the type employed in making routine hydrocarbon analyses. At the left is the assembly for conditioning the sample and introducing it into the ionizing chamber. The ionizing chamber and the electrostatic and electromagnetic fields are shown at the left center. At the right is the control panel for obtaining and recording the so-called mass spectrum.

The principal advantage of spectrometry as compared with fractional distillation lies in the speed with which the spectrum can be obtained and results computed. One hour or less is required to determine the composition of a sample that would require several hours for analysis by fractional distillation. On the other hand, spectrometric equipment is much more expensive to install, and in order to take full advantage of the time-saving feature a high load-factor with respect to number of tests must be maintained. Accordingly it is unlikely that spectrometry will supersede fractional distillation, except in comparatively large central laboratories where a large number of analyses are made.

METERING NATURAL GAS

The measurement of gas volumes occupies an important place in the natural gasoline industry. Both the volume and gasoline content of wet gas delivered from each individual lease must be known in order that the proper allocation of finished gasoline may be made. Also, a similar allocation of dry gas must be made, for which purpose it is necessary to measure the volumes of gas delivered to the various outlets, such as sales lines, field fuel lines, etc.

*See *Engineering and Science*, October, 1945.

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but they were all high-priced cars, ranging from $2,500 for the four-cylinder car of 1905 to $6,500 for certain later models. A seven-passenger, six-cylinder model appears in *Fig. 12*.

By 1915, it had become clear to me that mass production methods would eventually spell the doom of the high-priced car. I was in ill health at the time, and, having received an excellent offer from the Westinghouse Company for our plants in Chicopee Falls and Springfield, I accepted the offer and retired. This move I have never regretted.

Testing and Metering in Natural Gasoline Operations

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The equipment now almost universally employed for measuring gas volumes is the orifice meter. Its operation is based upon the principle that the rate of flow of fluid is a function of the pressure drop caused by the presence of a suddenly restricted opening or orifice of known size inserted in the line.

For every combination of pipe size, orifice size, flowing pressure, and temperature and specific gravity of gas, a given differential pressure across the orifice corresponds to a definite rate of flow of gas through the line. Tables are available for relating these quantities.

Of the factors named above, pipe size of course remains constant. The size of orifice may be varied at will simply by removing one orifice plate and inserting another. The specific gravity of the gas from a particular source is usually so nearly uniform or changes at such slow rate that periodic determinations of this property are adequate. Temperature is either taken daily at a time representing average conditions, or, where large volumes of gas are involved, it may be recorded continuously. Continuous records of both line pressure and differential pressure are usually made on clock-operated charts attached to the orifice meter. These charts are usually changed daily.

The charts are sent in to a field office, where the pressures indicated on them are averaged. From carefully kept records of the other conditions existing at each meter, the corresponding volumes of gas are computed with the aid of the tables mentioned above.

Fig. 4 is a photograph of a number of orifice meters installed on gas lines from gas-oil separators in which fluid from individual wells is separated into wet gas and crude oil streams ahead of the natural gasoline plant. *Fig. 5* is a picture of a number of orifice meters located inside a natural gasoline plant to measure streams entering or leaving processing equipment.

METERING LIQUIDS

Orifice meters are applicable to the measurement of liquid flow as well as gas flow and are widely employed for this purpose in natural gasoline operations. Typical locations are on lean oil streams to absorbers, feed and reflux streams to fractionating columns, etc.

On the other hand, orifice meters are less reliable in determining rates of flow of volatile liquids than in measuring the flow of gases and vapors. Accordingly, while they have been widely used for operating control purposes, they have been considered unsuitable for measuring volumes of finished stocks produced at natural gasoline plants. For this service, positive displacement meters of the general type used in domestic water and gas service are often employed. The use of meters

on finished product streams makes possible the observation of rate of production without the necessity of accumulating large quantities of highly flammable liquids in gauging and shipping tanks in the plant area where boilers and gas engines might present an ignition hazard.

As has been the case with most industries, there has been tremendous technological progress in the last 25 years in the natural gasoline industry and the related liquefied petroleum gas industry, which actually developed from infancy to maturity during that period. Improvements in metering and testing methods have contributed effectively to that progress.

The Month in Focus

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government. This report can be obtained from the Government Printing Office for 30 cents.

November 13, 1945

To the Members of the
Senate Committee on Commerce
and the
Senate Committee on Military Affairs
Gentlemen:

We have a feeling of deep concern regarding the pending legislation on federal aid to science. We share the belief of the sponsors of this legislation that expansion of our scientific work can yield returns of great benefit to the nation.

The manner in which this aid is administered is vital to the success of any program undertaken. We have studied this matter, and we transmit to you our considered opinion on the two administrative plans which you now have under discussion.

It is our belief that the top authority in the proposed National Research Foundation should rest in a board or commission of scientists and laymen chosen by the President on the basis of interest in and capacity to promote the purposes of the Foundation, and not in a director who would be aided by a board with only advisory duties. The responsibilities of the top authority will be so great and the fields to be covered are so extensive that only a broad and representative board of most able men could effectively assume this responsibility and authority.

We believe that the Foundation can achieve its objectives better by grants to institutions for the support of broad fields of scientific research and scientific education than by contracts for research on specified and closely limited problems.

We believe that the Foundation should not supervise or direct research activities of other government agencies, and should not have the duty of surveying these activities, but should arrange for suitable interchange of information between government agencies and research men carrying on work with the support of the Foundation; and that officers of other government agencies should serve *ex officio* on certain advisory panels of the Foundation, such as Advisory Panel to the Division of National Defense, but that no such *ex officio* members should serve on any board or commission of this Foundation to which authority is delegated.

Recognizing the great need of study of human relationships, we believe that the Foundation should provide suitable support for the social sciences and humanities as well as for the medical and natural sciences, that the social sciences and humanities should be suitably represented in the membership of the board or commission, and that provision should be made for scholarships