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THE SEPARATION OF GASES.

By Dr. Martin Ruhemann.

Scope of Gas Separation.

The properties of most gases, whether natural or artificial, have had a profound influence not only on the history of technology, with consequent repercussions on human society, but on the evolution of plant and animal life, including man himself. Clearly a different composition of the earth's atmosphere would have led to very different organic forms and might have given rise to something very different from the human race. The atmosphere, with its unvarying composition, is now the basis of vast technological processes of which blast furnaces are but one, though perhaps the most outstanding example. The radical differences between the British and the American gas industries is due to the fact that the gas industry in America is based primarily on natural gas, consisting mainly of methane, while that in Britain is based on retort gas with a very different and far more complex composition.

Nature has her own way of separating gaseous mixtures. Thus, when producer gas is burned, the molecules of oxygen in the air select the hydrogen and carbon monoxide in the gas and enter into the well-known reactions, leaving the uncombustible nitrogen. In many cases we have so perfectly adapted our technique to this state of affairs that we are inclined to look down the wrong end of the telescope and insist that the chance composition of some of our natural and technological gases has been ordained by Providence to suit human needs. On the other hand, in an increasing number of cases we have been forced to admit the pernicious influence of certain constituents in gaseous mixtures and to take the necessary steps to remove them. The presence of sulphur compounds in town's gas is an example and, in more recent times, the removal of carbon monoxide from the initial reagents of the synthetic ammonia process has become a necessity, owing to its ruinous effect on the catalysts. Nowadays there is a marked tendency to get away from the chance composition of gaseous mixtures, to produce from them pure or almost pure gases or to make up mixtures of a definite composition particularly suitable for technological processes. A gas-separating industry has developed, as a result of which the presence of certain constituents together in a gaseous mixture is no longer a valid reason for their joint utilisation.

The significance of this statement is best realized by considering the quantities and compositions of the gases surrounding us. Take as a first example atmospheric air. It is present in virtually unlimited quantities. Apart from its main constituents, it contains relatively small, but still enormous amounts of the so-called rare gases. Every one of its components is useful and most are in constant use—oxygen for cutting and welding, nitrogen for fertilizers and explosives, argon for incandescent bulbs and neon for discharge tubes. Shortly before the war krypton and xenon, present in a concentration of one in a million, were being used for lamps, and the only reason why helium was not being separated from air was that it could be obtained more cheaply from other sources. It is important to realize that all these developments have taken place in the present century, mainly as the result of Linde's invention of a machine for producing liquid air on a commercial scale.

Most of the other common gases contain combustible components and are connected in some way with the transformations of organic matter. Some are associated with coal and its treatment; others are associated with mineral oils. The utilization of most of these gases is to-day still at a primitive stage, in that most of them are either burned or wasted, in spite of the fact that they contain a great variety of constituents, some of which are valuable and admirably suited for important chemical processes. Though the science of gas separation is highly developed, its industrial application is still new and has many technical, psychological, and economic difficulties to overcome. At the same time, marked progress has already been made in the economic utilization of some of these mixtures, especially coke-oven gas and the gases evolved in the processes of cracking and pyrolysis.

TABLE I.

Gases Associated with Coal.

	Compositions in % by volume.					
	CH_4.	C_nH_m.	H_2.	CO.	CO_2.	N_2.
Town's gas	33	3	56	8	—	—
Coke-oven gas	30	3	50	7	2	8
Low-temperature gas	48	13	27	7	3	2
Firedamp	97	—	—	—	2	1
Produced gas	3	—	12	28	3	54
Mond gas	4	—	25	12	16	43
Water gas	1	—	49	42	5	3

TABLE II.

Gases Associated with Oil.

	Compositions in % by volume.								
	H_2.	CH_4.	C_2H_6.	C_3H_8.	C_4H_{10}.	C_2H_4.	C_3H_8.	C_4H_8.	N_2.
Natural gas	—	99·8	—	—	—	—	—	—	—
	—	95	—	—	—	—	—	—	2
	—	81	11	6	2	—	—	—	—
	—	41	—	—	—	—	—	—	59
(contains 2% He)	—	15	—	—	—	—	—	—	83
Cracker gas	6	31	15	5	1	22	14	6	—
Pyrolysis gas	19	43	8	6	1	18	4	1	—

In the Tables I and II some typical figures are given for the compositions of the best known of these gases. The compositions vary considerably and the figures shown are to be regarded only as examples. They show the basic characteristics of the several types: the presence of hydrogen in all the "artificial" gases, the varying concentrations of carbon monoxide in gases produced from coal, the predominance of methane in fire-damp and natural gas, and the olefine content of the products of cracking and pyrolysis.

Another gas should be added to this list, as it is becoming increasingly available for industrial purposes, and that is the mixture of 70 per cent. methane and 30 per cent. carbon dioxide obtained in the decomposition of sewage. In the modern sewage works of Birmingham and West Middlesex, gas from sewage sludge is being utilized as engine fuel, and the modernization of the whole sewage-disposal system in this and other countries will furnish large quantities of this valuable mixture.

It is difficult to obtain accurate data on the quantities of these gases which are annually produced or emerge from the earth's surface. About 3×10^{12} cu. ft. of natural gas are utilized every year, over 90 per cent. in the United States. Much larger quantities are wasted. The annual production of coke-oven gas for the whole world is about the same. Town's gas is produced in smaller quantities, and only in our own country is more gas made as towns' gas in retorts than as coke-oven gas in ovens. The amount of cracker gas produced is about one-tenth of this figure.

Until recently only very small portions of these gases were separated; but the gas-separating industry has been growing rapidly, and it seems reasonable to suppose that, within a few years, the amounts of some of the gases separated will be a considerable proportion of the quantities produced. One installation built some years ago in the Soviet Union separated rather more than 10^{10} cu. ft. of coke-oven gas per annum, probably not far short of 1 per cent. of the total amount of coke-oven gas produced in the world. If all the major countries were to erect plant of this size, separation of coke-oven gas would soon catch up with production.

The time is not far distant when the economic utilization of the world's gas resources will become an urgent problem. The quantities of hydrogen, carbon monoxide, and olefines required for chemical processes will be so great that we shall no longer be in a position to squander these gases by firing them together with any other constituents that may occur in mixtures. Then the separation of gases will become the rule instead of the exception.

Methods of Gas Separation.

Since all gases are completely miscible, the separation of gaseous mixtures necessitates the introduction of other phases that are not gaseous. This can be achieved either by introducing liquid or solid absorbents or by a partial liquefaction of the initial mixture. In general the latter method is the more economical.

The critical temperatures of most gases in natural and industrial mixtures are below the temperature of the environment. Separation by partial liquefaction therefore requires low temperatures, which necessitates a specialized technique and the employment of refrigerating machinery. Even if the ultimate products are to be withdrawn at atmospheric temperature, refrigeration is still required to cool down the mixture initially and to maintain the low temperature in the plant during the separating process, by absorbing heat inflow from without and heat exchanged within the units. If, as in the case of the liquid oxygen industry, one or more products must be withdrawn as cold liquids, a much greater refrigerating performance is needed, so that, especially in large plants, power becomes the principal item in the production costs. Hitherto refrigeration at the very low temperatures involved in gas separation has always been achieved with compression plant in which the power consumption is considerable.

Cooling can be effected in either of two ways: by introducing foreign refrigerants or by utilizing the gaseous mixtures themselves or some of their fractions as refrigerating agents. Both methods are used extensively in industrial practice, frequently in the same plant. Thus in the classical Linde plant for separating air and producing liquid or gaseous oxygen the compressed air is the main refrigerant, but is supplemented by an auxiliary closed system containing ammonia. Most Russian plants for separating cracker gas use two auxiliary cycles, one with ammonia and one with ethylene, whereas a number of American plants for the same purpose make use of the refrigerating capacity of the components of the cracker gas.

When a gas that is to be separated serves as its own refrigerant, the customary distinction between the refrigerant and the substance to be cooled becomes somewhat obscure. In the course of its passage through the plant, the mixture divides into one portion which is cooled and separated and another which merely acts as a refrigerant. This is a feature of most plants for separating air.

The use of the so-called permanent gases as refrigerants is necessary, but, in current practice, not very efficient. This is because the gases are merely compressed and expanded in valves without previous liquefaction. The refrigerating capacity of a compressed gas is very much smaller than that of an evaporating liquid and the process is more irreversible. Thus a given refrigerating performance requires more power than when the refrigerant is liquefied before expansion.

There are two ways of overcoming this difficulty. One is to allow the compressed gas to do work during expansion, thus increasing the refrigerating performance by the thermal equivalent of the power generated. This may be achieved with a reciprocating expansion engine or a turbine. Until recently only expansion engines were used for this purpose, as introduced by Claude at the beginning of the century and later developed by Heylandt. These expansion engines, which operate between 1 and 200 atm., are only moderately efficient and not easy to handle. Lubrication at low temperatures is a serious difficulty, and care must be taken to avoid liquefaction in the expansion cylinder. In the Heylandt plant, which was until recently the most efficient machine for producing liquid oxygen, the compressed air is separated into two almost equal streams; one is expanded in the engine from room temperature to about − 130° C., while the other is pre-cooled in a heat exchanger and subsequently expanded in a valve as in the Linde system. The air passed through the expansion engine thus serves as a refrigerant for the rest of the air, which also acts as its own refrigerant. This combination was found to be the most efficient, as it avoids expansion in the cylinder at very low temperatures. On the other hand, it requires higher pressures than the original Claude plant.

In the "rich air" industry, which produces impure oxygen for blast furnaces, the Linde–Fränkl system has for some time employed expansion turbines at temperatures close to atmospheric and pressures of about 3 atm. abs. as an auxiliary source of cooling. The use of turbines as primary sources of refrigeration for air at low temperatures has been delayed through technical difficulties. This problem was solved quite

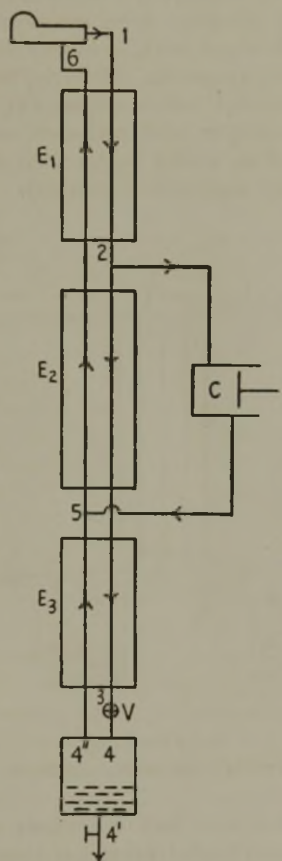


FIG. 1.*
CLAUDE LIQUEFIER.

recently by Kapitza in Moscow, who designed an expansion turbine working from 7 atm. at very low temperatures, taking into account the fact that, under these conditions, air is about midway between a gas and a liquid in the usual sense. It appears that Kapitza's machine can produce cheaper " rich air " than the Linde–Fränkl plant. It was intended mainly to supply impure oxygen for the underground gasification of coal and will, incidentally, yield large quantities of krypton and xenon for filling incandescent bulbs. The change-over from argon to a krypton–xenon

* Blocks kindly lent by the Institution of Chemical Engineers.

mixture in bulbs has been calculated to save several million kilowatt-hours per annum.

The other method of improving the refrigerating performance of gas-separating plant is based on the so-called cascade principle. It is possible to secure liquefaction of compressed gases before expansion, and a consequent rise in efficiency, by employing a series of refrigerants with different critical temperatures and allowing each compressed gas to condense in the evaporating liquid of a gas with a higher critical point. Thus, by using four cycles containing ammonia, ethylene, methane, and air respectively, each gas being liquefied before expansion, the liquefaction of air and its separation into oxygen and nitrogen can be effected and the separated oxygen removed as a cold liquid with a smaller expenditure of mechanical work than by any other method. The cascade principle,

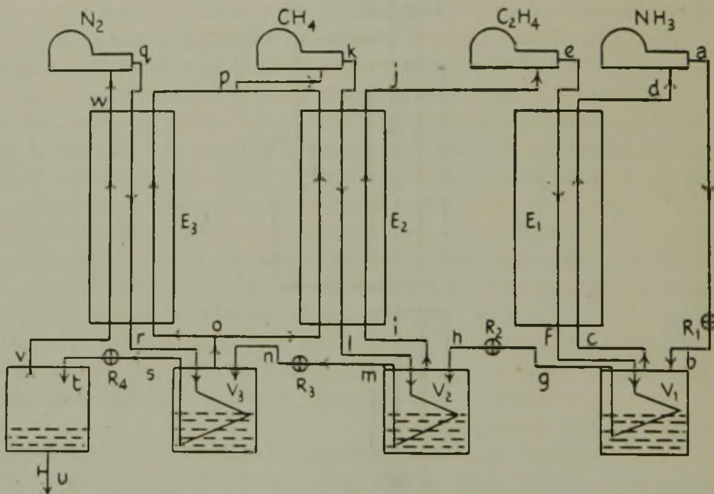


FIG. 2.

KEESOM'S NITROGEN CASCADE.

though conceived by Pictet over half a century ago and utilised in the Leyden laboratory by Kamerlingh-Onnes, has never yet been employed in large-scale industrial practice. However, with the present tendency towards larger plant and liquid products and the consequent importance of power economy, this method will probably soon find its place in industry.

A further probable development in power economy will be the increased use of absorption methods. Hitherto absorption units with ammonia–water mixtures have been used mainly at relatively high temperatures. By using heat, especially waste steam, instead of power, they can be made very economical. The work of Altenkirch in Germany and of the late Dr. Maiuri in England has shown theoretically and practically the value of the absorption method. Dr. Maiuri devoted much time in the later years of his life to developing the method for lower temperatures, and it is to be hoped that this work will bear fruit in the near future.

The separation of a gaseous mixture into two phases by partial liquefaction is in general a first step towards the separation of the components in concentrating one of the constituents in the liquid or the gaseous phase. In some cases this is sufficient to effect practically complete separation, such as in removing benzole from coke-oven gas by refrigeration with liquid ammonia and in the separation of helium from natural gas by liquefying all the components except helium. But in most cases liquefaction leads only to a partial separation of the mixture.

Partial liquefaction yields liquid and gaseous phases in thermodynamic equilibrium with one another. Such a system has the same temperature and pressure throughout, but different concentrations in the two phases. Its practical significance lies in the formation of a definite and permanent phase boundary across which a finite concentration head is set up and maintained indefinitely. Generally one such phase boundary is insufficient and there must be several boundaries each with its own concentration head. A device which enables a series of phase boundaries to be maintained, across each of which the composition of the mixture changes by a finite amount, is a fractionating column, more especially a plate column with its finite number of rectifying plates each leading to a definite change in the composition of the mixture passing through it. A packed column may be considered as containing an infinite number of plates, each providing an infinitely small change in composition. The significance of the plate column lies in the fact that the concentration heads are maintained in accordance with the laws of phase equilibrium. The physical phase boundary is that between the liquid on the plate and the bubbles of gas passing through it. The metal plate is merely a frame allowing the physical phase boundary to be set up and maintained. For all finer processes of gas separation, *i.e.*, when components are to be separated whose thermal properties are not too far apart, a fractionating column is an essential part of the equipment.

It is thus evident that the principal tools of gas separation are: (1) refrigerating plant, such as compressors, condensers, evaporators, expansion engines, and turbines, and (2) fractionating plant, such as columns and dephlegmators. To these must be added (3) machinery for the exchange of heat, *i.e.*, heat interchangers and cold accumulators, and finally (4) in most cases some preliminary absorption device for removing impurities such as water and CO_2, which must be removed because they solidify at relatively high temperatures. Lagging plays an important part in the efficiency of all gas-separating plants, more especially in the smaller units, and this should properly be included in the items of refrigerating equipment.

Problems and their Solution.

(1) *Air separation in the double column.*—It is well known that the production of oxygen and nitrogen from atmospheric air is normally carried out in two fractionating columns, one placed on the top of the other, the lower column working at a pressure of 4–5 atm. abs. and the upper column working at atmospheric pressure. It is of interest to ascertain why this arrangement was found necessary and why it has been maintained in industrial practice without notable changes for 35 years.

In the rectification of spirit and in the separation of most binary systems above room temperature, a single column has been found sufficient. The liquid mixture is introduced in the middle, is partially rectified in the exhauster, evaporated in the sump, and finally rectified in the concentrating column above with the help of the reflux from the condenser. Why is this simple device inadequate in the case of air?

The reason is to be found in the particular circumstances of the low temperatures involved and the consequent refrigerating requirements. In separation above room temperature, where no refrigerating machinery is needed, there is no necessary relation between the heat supplied to the boiler and that withdrawn in the condenser. Steam and cooling water are generally available in any required quantities and are quite independent of one another. In the separation of air at low temperatures, where no

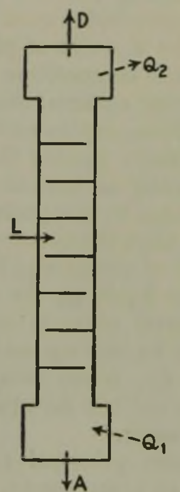


FIG. 3.

DEVELOPMENT OF DOUBLE COLUMN.

foreign refrigerants are available, the cold must be supplied by the air itself. The only way in which heat can be withdrawn from the condenser is by evaporating liquid air or one of its constituents. The only cold liquid available is that formed in the evaporator, and this, in the case of a single column, is pure oxygen. But the liquid reflux from the condenser must be colder than the liquid in the evaporator, and so the refrigerant in the condenser must be colder still—colder than pure liquid nitrogen and much colder than liquid oxygen, whose boiling point is 13° C. above that of nitrogen. Since it is impracticable to work at pressures far below atmospheric, the only way out of the difficulty is to raise the pressure in the column to such an extent that the boiling point of nitrogen at this pressure becomes higher than that of oxygen at 1 atmosphere. It is then possible to take liquid oxygen from the evaporator, expand it to atmospheric pressure, thereby lowering its temperature, and to use the latent heat of vaporization of this oxygen to condense nitrogen at the elevated pressure, thus obtaining the necessary reflux. This explains why the separation of air has to take place partially at a pressure of about 4 atm.

This is only one step, however, towards solving the problem. Air contains about 79% nitrogen and 21% oxygen, neglecting the argon at this stage of the argument. If pure liquid oxygen were collected in the evaporator, that liquid would be insufficient to produce the necessary reflux in the condenser. There would not be enough refrigerant available. To overcome this difficulty, the liquid oxygen in the evaporator has to be heavily diluted with nitrogen. It can be shown theoretically that the

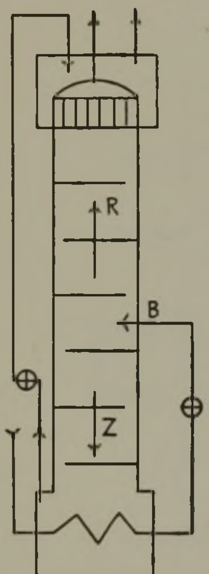


FIG. 4.

DEVELOPMENT OF DOUBLE COLUMN. SECOND STEP.

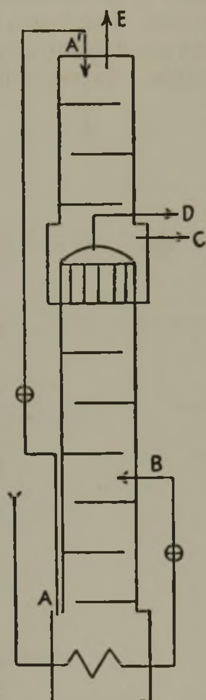


FIG. 5.

DEVELOPMENT OF DOUBLE COLUMN. THIRD STEP.

highest oxygen concentration permissible in the sump is 60%. In practice the liquid contains about 45% oxygen. This secures the correct balance in the condenser for producing the reflux and enables pure nitrogen to be obtained at the top of the column. There is then the problem of purifying the 45% oxygen mixture. This is achieved by taking another step forward in the direction of the double column : a number of plates are inserted between the inlet of the expanded liquid oxygen and the condenser. However, though this procedure can and does lead to pure oxygen in the intratubular space of the condenser, the vapour passing upwards from the oxygen inlet cannot contain more nitrogen than is in equilibrium with the liquid oxygen entering the upper column. This vapour will contain about

15% oxygen, which will be lost unless the rectification is continued above the inlet. To produce a reflux in the upper part of the low-pressure column, a refrigerant is available in the form of the liquid nitrogen formed in the condenser. The final step is achieved, therefore, by withdrawing some liquid nitrogen from a trough below the condenser, expanding it to atmospheric pressure, and introducing it at the top of the upper column,

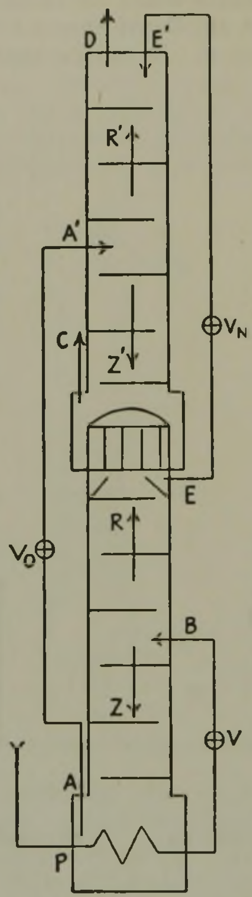


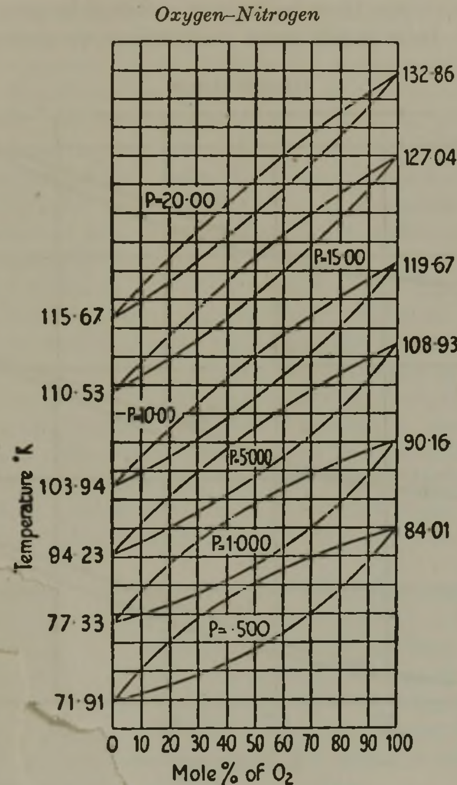
FIG. 6.

LINDE DOUBLE AIR COLUMN.

where it completes the rectification by replacing the oxygen in the vapour rising from the liquid inlet.

It will be seen from this analysis that the double air column is not just one of many possible chance solutions which has been retained in the industry by conservatism or lack of enterprise, but a logical development of applying the well-known principles of rectification to a mixture of gases with very low boiling points, where the only refrigerants available are the mixture treated and its liquefied components.

The double air column, as originally patented by Linde in 1908 and subsequently used, with certain unessential modifications, in most industrial plant, enables pure oxygen and pure nitrogen to be produced simultaneously. In practice this is not usually attempted. Most industrial plants are designed either for pure oxygen (99·6 per cent.) or pure nitrogen, the other component being somewhat impure. The large Linde plant for delivering nitrogen for the ammonia synthesis yields 99·5 per cent. nitrogen



(*T*, *x*) CURVES AT 0·5, 1, 5, 10, 15, AND 20 ATM. DODGE AND DUNBAR, "CIRCULATION METHOD."

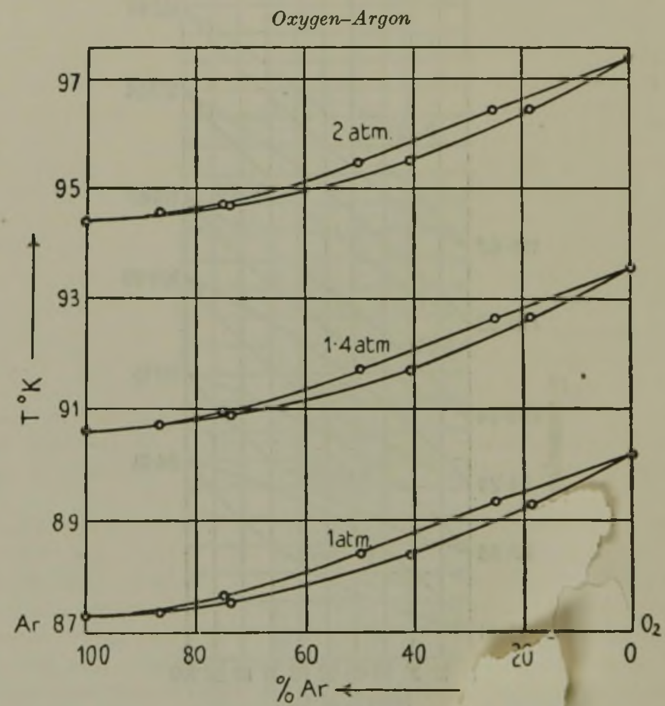
and 94 per cent. oxygen. Some German and Russian plant can be adjusted to yield either component pure, as desired.

One of the reasons why the simultaneous production of pure oxygen and pure nitrogen is not practicable is that it would require more plates than are economically justified. The other reason is more profound and is worth more detailed consideration.

(2) *The Separation of Argon from Air.*—Atmospheric air contains 0·94 per cent. argon. Though the concentration is low, the presence of argon is important for two reasons. Firstly, argon is a valuable element, especially for filling incandescent bulbs. Secondly, the presence of argon

makes it virtually impossible to obtain pure oxygen and pure nitrogen at the same time.

The boiling point of argon lies between the boiling points of oxygen and nitrogen, and is only 3° C. below that of oxygen. During the rectification of air in the double column, argon accumulates, more especially in the lower part of the upper column, where its concentration can be 12 per cent. or even higher. As a result, it is possible to withdraw an " argon fraction " from this part of the double column, containing between 7 and 10 per cent. of argon, which can then be further rectified to give technical argon for filling lamps. It is much more economical to obtain argon from a



(*T*, *x*) CURVES AT 1, 1·4, AND 2 ATM. BOURBO AND ISCHKIN. " BOILING-POINT METHOD."

FIG. 7.

10 per cent. concentrate than from a mixture containing only 1 per cent. On the other hand, if the argon fraction is not withdrawn, the lower part of the upper air column is wholly concerned with separating the argon from the oxygen. The nitrogen content of this part of the column is negligible.

It is very much more difficult to separate argon and oxygen than nitrogen and oxygen, owing to the proximity of the boiling points. A correct estimation of the function of such a column, more especially of the number of plates required, is impossible without a knowledge of the liquid-vapour equilibrium of oxygen-argon mixtures, just as the design of air-separating plant presupposes a knowledge of the oxygen–nitrogen equilibrium, which was furnished by the classical papers of Baly [1] and of Dodge and Dunbar.[2] A study of these mixtures was undertaken by Bourbo and Ischkin,[3] in the research laboratory of the Russian State organization known as VAT., which is principally concerned with building air separating plant. The results are shown side by side with those for oxygen and nitrogen, where the curves for dew-point and boiling point are very much farther apart. Clearly the separation of oxygen and argon requires more plates than that of oxygen and nitrogen.

The theory of argon concentration in an air column was developed by Hausen [4] of the German Linde Company on the basis of a theoretical diagram for the liquid-vapour equilibrium of the ternary system. The result of this work has been to show that, in all large-scale plant, it is advisable to combine oxygen and argon production. Not only does the removal of the argon fraction from the correct point in the lower column allow the production of technical argon in one auxiliary argon column, but the withdrawal of this fraction materially assists in obtaining pure oxygen in the primary air column.

(3) *Problems of Coke-oven Gas Separation.*—The Linde–Bronn process for the separation of coke-oven gas is one of the most highly developed and complicated processes of gas separation, the object being to obtain a 3 : 1 mixture of hydrogen and nitrogen for ammonia synthesis. It is in some ways superior to the Claude process in that it yields purer products. Initiated in Germany shortly after the last war, it was introduced into the Soviet Union in 1932, where it has since been considerably developed and diligently studied, especially at the Low Temperature Research Station at Kharkov, where most of the scientific data required for calculations have been obtained during the five years before the German invasion.

The process consists in cooling the coke-oven gas, compressed to about 12 atm., to a very low temperature, condensing out a series of fractions and leaving finally hydrogen and nitrogen as the product. The refrigerant is liquid nitrogen obtained from a separate air-separating unit. Apart from its rôle as a refrigerant, the nitrogen has two other tasks to perform; it is used to scrub carbon monoxide out of the product, the presence of which poisons the ammonia catalyst, and it is added in sufficient quantities to bring the product to the correct concentration.

Apart from the usual questions of heat-transfer coefficients, viscosities, and latent and specific heats of cold liquids and their mixtures, the design of large-scale plant of this nature presents a number of problems owing to the complex composition of coke-oven gas. As shown in Table I, coke-oven gas includes six components in concentrations over 1 per cent. and numerous impurities in smaller concentration whose presence interferes with the separation process. In addition to moisture and carbon dioxide, there are a benzole fraction containing benzene, toluene, and some metaxylene, which is only partly removed at source, a certain amount of naphthalene and traces of sulphur compounds.

The main fractions of coke-oven gas are the ethylene, methane, and carbon monoxide fractions, each of which contains two or more components. It is essential to know the compositions of these fractions, as they depend on temperature, pressure, and the composition of the original mixture. This involves a detailed study of liquid-vapour equilibrium of binary and ternary mixtures at various pressure and temperatures. Some of these mixtures have been studied in England, notably by Verschoyle [5] and, more recently, by a group of scientists in the Imperial College.[6] However, most of the work was done at the Kharkov Research Station and in some other Russian laboratories.[7] There are now available all the requisite data on the liquid vapour equilibria of ethylene and ethane, ethylene and methane, ethane and methane, and their ternary mixture,

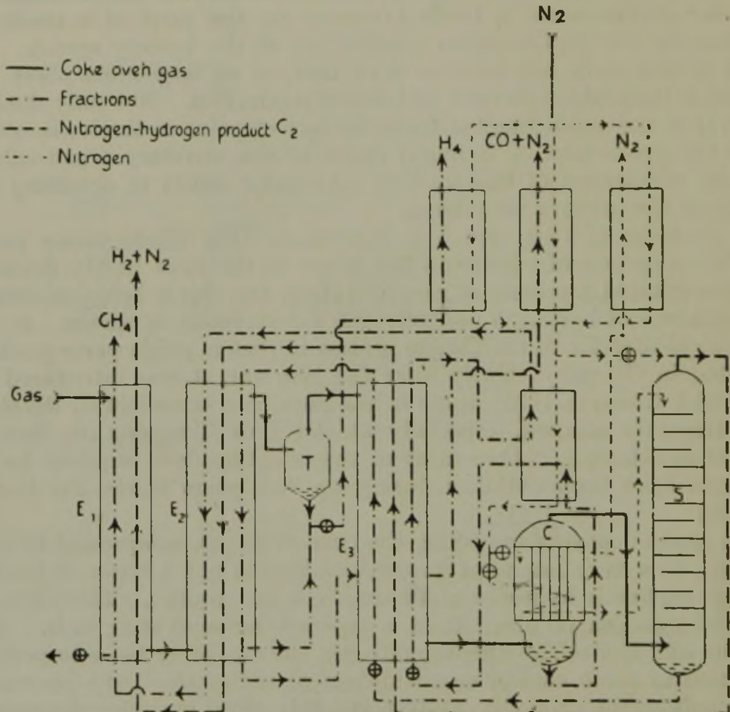


FIG. 8.

THE LINDE-BRONN PROCESS FOR SEPARATING COKE-OVEN GAS.

covering the requirements of the ethylene fraction. There is also all the information required on the following mixtures which occur in the methane fraction: methane–nitrogen, methane–hydrogen, hydrogen-methane–nitrogen, and, finally, for the carbon-monoxide fraction, hydrogen-nitrogen, hydrogen–carbon monoxide, and hydrogen–nitrogen–carbon monoxide. A detailed study has been made of the scrubbing column and the process of replacing carbon monoxide with nitrogen by scrubbing the mixture with liquid nitrogen,[8] and a new thermodynamic diagram of nitrogen has been constructed,[9] replacing the faulty Dutch diagram and extending to higher pressures the diagram issued by the American Bureau of Mines. Finally the Kharkov scientists have determined the viscosity in the liquid phase of all the components of coke-oven gas at all temperatures between the triple points and the critical points and have investigated a large number of binary mixtures.[10]

Experiments on semi-scale plant, also made at Kharkov [11] have established the possibility of obtaining technical hydrogen from coke-oven gas on a commercial scale with a purity of over 96 per cent., and work has been commenced with a view to obtaining pure ethylene from the same source for chemical synthesis, more especially for the synthetic rubber industry.[12]

The benzole fraction in coke-oven gas has long been a source of trouble to chemical engineers. Its removal by absorption is expensive and not

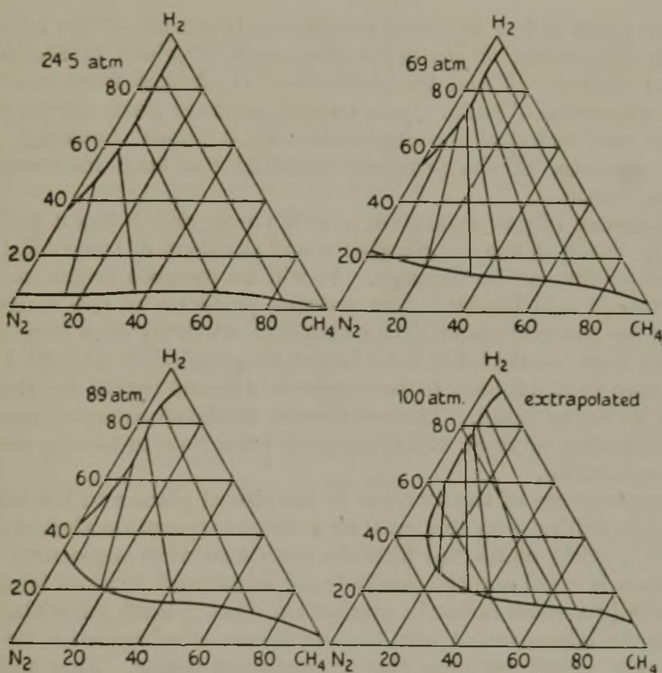


FIG. 9.

METHANE–NITROGEN–HYDROGEN.

always efficient and attempts to dispose of it by condensation at low temperatures have frequently led to solidification and consequent blockages of pipes. In order to remove the last traces of benzole vapours, it is necessary to cool the mixture to about − 45° C. with liquid ammonia, and to do this successfully we must know what concentrations of benzene, toluene, and xylene are still liquid at these temperatures. This problem was attacked with considerable success by B. M. Kravchenko [13] at Kharkov, who determined the solidification curves of the ternary mixtures benzene–toluene–metaxylene and benzene–metaxylene–naphthalene and constructed a solid model showing the course of the eutectic curves. He has since devoted himself to the still more complex and arduous problem of the quaternary mixtures, and the first results were published in the last Russian journal to reach these shores.

It can now be said that the scientific data required for the full development of coke-oven gas separation are available. The path is free for an extension of the process to the production of other fractions and components apart from a mixture of hydrogen and nitrogen and for the separation of other gases of somewhat different composition but containing essentially the same components in different proportions. Also, from a scientific point of view, valuable data have been obtained for the elaboration of a theory of the liquid state and for the thermodynamics of mixtures and solutions.

In this paper it has not been possible to touch on all the existing processes and problems of gas separation, each of which possesses its own points of interest. Thus, the production of olefines from cracker gases and the separation of helium from natural gas have given rise to important scientific and technical developments. It is hoped, however, that the general character of the problems involved has been indicated by the examples chosen.

The industry of gas separation is still young and it has a great future before it. Even in the complicated world situation of to-day the trend of its development can be foreseen. It will be towards larger units and a greater use of cold liquids. The pressing problems of fuel economy and the need for the raw materials for chemical synthesis on a large scale will force this issue, so that it will no longer be permissible to burn away any gas mixture that happens to be available without regard for the relative value of its components. The advantages in the storage and transport of liquids over that of gases will drive us to learn how to handle cold liquids in large quantities.

The consequence of the increase in the size of plant and the removal of cold liquids will raise as the main issue in gas separation that of economy in power, a point which has hitherto been somewhat neglected. As long as the plant is small and the products are withdrawn at room temperature, power is only a small factor in production costs. With large plant, which cheapens the labour factor, and the added cost of refrigeration for yielding cold liquids, power becomes the predominant factor. This will lead to new methods in refrigeration, of which a further development of the absorption method and the general use of mixed refrigerants will in all probability be a prominent feature.

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DISCUSSION.

A JOINT Meeting of the Institution of Chemical Engineers, the Institute of Petroleum, and the Chemical Engineering Group (Society of Chemical Industry) was held at the Institution of Mechanical Engineers, London, on Tuesday 14th July. Mr. C. S. Garland (President, Institution of Chemical Engineers) was in the Chair, and a paper on "The Separation of Gases" was presented by Dr. Martin Ruhemann. (See page 215.)

DR. P. M. SCHUFTAN raised one or two points of a practical nature. He suggested that it was perhaps not quite true when the author said that the cascade process was not employed to any great extent industrially. The Americans used it for air separation, and in some form or another it was being used quite a lot for the separation of complicated hydrocarbon mixtures.

The author had rightly stressed the importance of producing cold at the lowest possible cost and referred to the use of expansion engines. It was perhaps not generally known that the expansion engine, especially of the Heylandt type, was very efficient and even expansion turbines, which had been used in the past and were now being proposed again, would hardly be able to compete.

There was a very large field to work in connection with coke oven gas separation, but it should be realized that a great deal had been done apart from the Russian plant mentioned, although that was one of the largest plants in the world. There were scores of coke-oven gas separation plants all over the world, mostly producing the hydrogen–nitrogen mixture required for ammonia synthesis, but also some producing hydrogen up to 98 per cent. as required for hydrogenation, while others were producing by-products such as methane and ethylene.

MR. PHILIP BORCHARDT said this paper gave him an opportunity of making some remarks about gas separation, partly of historical and partly of technical interest.

The development of the double-column air separator had a predecessor in Mr. G. Claude's "liquefaction sous pression avec retour en arrière." The column of Mr. Claude was therefore the first to adopt rectification of air in two steps, then a great achievement fully appreciated by the late Prof. von Linde. It was, however, possible to produce "pure" nitrogen before Mr. Claude introduced double rectification and, in fact, Linde had supplied as early as 1904 several plants producing nitrogen with about 0·1 per cent. oxygen using a nitrogen circuit and a single-column rectification. The double rectification, however, gave the great advantage of dispensing with this circuit. Linde considered the Claude principle of using a reflux condenser as first step in rectification was not entirely satisfactory, and he replaced this condenser by a normal rectification column working, as Dr. Ruhemann had pointed out, at 4 to 5 atmospheres, and he remembered the first separator unit of this kind he had the honour to construct in 1910. Yield and purity of the products of these separators were, of course, not satisfactory, compared with the results of a modern separator.

A single rectification column gives theoretically, when producing pure oxygen, a waste nitrogen of about 7·5 per cent. oxygen content—practically 8–9 per cent. The first double-column separators brought this figure down to about 3 per cent. Since then the improvement, due mainly to the increasingly better effects of the rectification trays of modern design, had resulted in the following state of air separation: When liquid oxygen is the product to be obtained, the yield of a modern Heylandt plant, using Linde rectification columns, was nearly 20 per cent. of the air to be separated. In the case of gaseous oxygen and/or nitrogen to be produced, the air might be separated in oxygen of 99–99·5 per cent., and in absolutely pure nitrogen produced simultaneously a small portion of not more than 8 per cent. of the air to be withdrawn from an suitable point of the upper column in the form of a waste oxygen with 40–50 per cent. oxygen content. This withdrawing of a small amount from somewhere between the top and the bottom of the upper column was necessary not only, as mentioned by the author, for the elimination of the argon, which otherwise would be trapped in the lower part of the column, but also to stabilize the operation of the separator, because any change of the working conditions inside the unit would result in an impurity of one of the products, if not, the third or waste fraction would be withdrawn.

The reason why some of the Linde plants for the production of pure nitrogen were not designed for a simultaneous production of pure oxygen, but only for about 93 per cent. of waste oxygen, was the fact that the nitrogen to be used for ammonia synthesis had to be as far as possible free of argon, and the simplest way to obtain that was to produce the oxygen with not more than about 93 per cent. The simultaneous production of both oxygen and nitrogen of highest purity had been adopted everywhere where the buyer of the plant was interested in both products.

With regard to the purity of the products obtained by a modern Linde plant, nitrogen with no more than 20 parts per million of oxygen was nowadays a standard product, such nitrogen no longer giving any mists when brought in contact with phosphorus. Further, the argon content of such nitrogen, as proved by the operation of modern ammonia synthesis, was negligible.

The power consumption of a modern air separator was mainly dependent on the size and purpose of the plant. All bigger plants were still based on the use of the Joule–Thomson expansion using, however, high- and low-pressure air. It was remarkable what an enormous influence the very simple experiments carried out by Joule and Lord Kelvin had on modern life through the application of their results on gas separation by the late Professor Linde. Not enough emphasis could be laid on the fact that the whole of the work done on gas separation with most of the applications was originated in this country through the work of British scientists, whilst the technical and industrial application of this work was carried out by scientists in other countries.

Mr. George Claude, the eminent French scientist, had achieved many improvements in gas separation, and it would be unfair not to mention his merits. The introduction of liquefaction under pressure had already been mentioned. His other inventions were characterized by the use of an expansion engine for a part of the air instead of the Joule–Thomson throttle valve, and later he developed the production of rare gases in pure form from air. In this same connection should be mentioned the work of British scientists such as Sir William Ramsay and Travers which had been of enormous technical value.

With reference to the Claude liquefaction principle, it was remarkable that Linde had applied the same process during the last decade before the war in smaller units for oxygen production, the expansion engine giving special advantages in simplicity, and lower power consumption than the Joule–Thomson expansion, if the units are so small that the Linde process for high and low pressure could not yet have been usefully applied. Bigger units were now mostly applying this principle of high and low pressure and gave even lower power consumption than the Claude process, with many other advantages. The biggest units of this kind were for about 9000 cu. metres of air giving 6800 cu. metres of pure nitrogen and 1600 cu. metres of pure oxygen per hour. The argon production was not a very important matter, nor were neon and helium, for they were in the air in such minute quantities that their production was a speciality of only a few makers.

As the author had said, krypton was an interesting gas, but there were many conflicting opinions about it, and he warned people against putting too much hope on this gas. Linde had constructed a big krypton plant in Hungary, where the krypton was promoted violently. Some 50,000 cu. metres per hour of air were separated in this plant but, of course, not liquefied entirely, because the boiling point of krypton was so high that it could be separated from the bulk of the air in a kind of reflux condenser. There was still a certain difficulty to be faced in condensing only the highest boiling constituents of the very large quantities of air because of the very small content of acetylene which was present in the air everywhere, and which accumulated in the condensate together with the krypton. Special precautions had to be taken to cope with this danger, which in the past had done so much harm to the separation of air, but in all normal plants this problem had been solved satisfactorily nowadays.

With regard to coke-gas separation, it was of importance that this process became of interest when and where there was an excess of coke gas available without any possibility of using it.

The extraction of hydrogen from gas mixtures like water gas was an old and well-known process. For instance, there was in this country at Selby before the first world war such a plant under construction. It was Bronn who pointed out that the combination of gas-coke separation and ammonia synthesis would be an interesting process. The Bronn patent was famous in the twenties and thirties of the present century, although it gave but little advice as to how the coke-gas separation could be carried out. Moreover, so little was known apparently about the most valuable and important invention of Mr. Maxted, now used in every coke gas separation for ammonia synthesis, that Dr. Ruhemann did not even mention Dr. Maxted in his book "Gas Separation." The Maxted invention dealt with the scrubbing of gas mixtures like coke gas by liquid nitrogen in order to remove the CO content and replace it by nitrogen. Linde obtained the licence for the use of this invention, without the use of which it would not be possible to produce the CO free hydrogen–nitrogen mixture now produced all over the world in numerous partly very important works. The importance of the Maxted process was made clear when it was pointed out that this purely mechanical procedure in the form Linde had given to the process resulted in at least the same purity of CO as the best chemical absorption methods—for instance, scrubbing with cupreous ammonia formiate. It was possible nowadays, however, by using the Linde–Maxted process to dispose of a pre-catalyst in the ammonia synthesis, which catalyst had been necessary in the earlier years when the process had been developed in order to remove the last traces of CO. Without the great success of the Linde coke-gas separation process it would scarcely have been possible that the other constituents of the coke gas could have found so much interest as had been the case in recent years.

Ethylene produced in the normal Linde plant as a fraction already rich in olefines can be purified to any wanted purity. Methane is a by-product which so far had been neglected by the chemical industry, but the electric-arc process developed in the U.S.A., for transforming methane into a mixture rich in acetylene, had changed the situation, and this process was now used in a Buna plant for the production of artificial rubber where the by-product methane of another important Linde coke-gas separation was available. Therefore, many modern Linde coke-gas separation plants were now producing, besides the hydrogen–nitrogen mixture or pure hydrogen, pure ethylene and pure methane, whilst the coke-ovens were burning cheap producer gas instead of the valuable coke-gas or the constituents thereof. All this progress was partly due to the Maxted invention and partly, of course, to other contributions of Linde and their engineers.

It would also be unfair not to mention that a great part of this work had been done by Dr. Schuftan, now also in this country. The analytical work, the investigation of the equilibria of the coke-gas constituents, the research work connected with the many tricky matters in the operation, and many other scientific and practical achievements in this field stood to his credit, and this work had been carried out long before the Russian engineers commenced their research work.

The author mentioned the production of nearly pure hydrogen from coke gas. The actual purity of such hydrogen in a modern Linde plant was 98–99 per cent., the purity depending mostly on the size of the vacuum pump for nitrogen by which the lowest temperatures in the process were obtained. As these temperatures were below the dew-point of air, special care had to be taken in the design of those parts of the unit subject to these temperatures, in order to avoid the air condensations on the surfaces of the cold parts. The latest model of hydrogen units of this kind operated in a plant for hydrogenation purposes, including the production of pure ethylene, was separating 12,000 cu. metres of coke gas per hour.

Although very large quantities of ethylene were produced by all these plants, it seemed that the hunger for still more ethylene had to be satisfied. As early as 1936 he himself had suggested the possibility of producing ethylene from coke gas by using the regenerator principle which so far had been applied only on the Linde–Fraenkl plants for air separation. Such a plant had been constructed by Linde in

1938 as a pioneer plant, the idea being that no other constituents of the coke gas besides ethylene should be recovered.

Summing up, Mr. Borchardt expressed the hope that after the war a powerful and independent industry would be developed in this country for gas separation, which would supply plants of any description and for any gas, for instance, oxygen or nitrogen, hydrogen or ethylene, to everyone who had so far been depending on foreign makers. The paper demonstrated that there were experts in this country available for this.

Mr. T. P. Dee said this paper was of particular interest to his Company, as they were operating both a Linde double-air column and a Lindre–Bonn plant for the separation of hydrogen from coke-oven gas, the hydrogen being used for the synthesis of ammonia. They intended to study the recent work in Russia to which the author had referred. He gathered from the paper that the production of argon in an auxiliary column assisted in obtaining both nitrogen and oxygen in a high degree of purity from the double air column. It would be interesting, however, if the author could say what future there was for argon, in view of his statement that a krypton–xenon mixture was much better for incandescent bulbs.

Mention was made in the paper of three purposes for which nitrogen was used in separating coke-oven gas—viz., for scrubbing out carbon monoxide, for refrigeration, and to mix with the hydrogen to give a 3 : 1 mixture. In their plant they used normally 14 cu. ft. of nitrogen per 100 cu. ft. of hydrogen for scrubbing purposes, and 9 cu. ft. for evaporation in the nitrogen vessel, where it brought about the final cooling of the gas. It would interest him to know how these figures compared with modern practice in Russia. Could the author also say what was the pressure at which the nitrogen was usually maintained in the evaporator in Russian practice?

Mr. R. J. Low said that when, some years ago, he investigated the question of hydrogen production, several points came out. A great deal was heard about the power required, but nobody had mentioned how little power was theoretically required. He believed that one American inventor had claimed to get down to 3 kw. per 1000 cu. ft. of oxygen, and it would be interesting to know how much power was required, first, if an infinite number of heat exchangers were used on a theoretic basis, and secondly, if a definite number of heat exchangers were used—say one, two, three, or four. It was rather like stage feed-heating with turbine plants.

The question of working up the gases was a very interesting one, and a really definite effort had been made to extract everything possible out of coke-oven gas before using the hydrogen. A great point had been made of collecting ethylene and working it up into products worth about £110 per ton instead of merely burning it under the coke-ovens.

On the question of power, he said that on the average plant the power was comparatively easily obtained, but many chemical works did not consider degrading their heat stage by stage. The first portion could go under the boiler-producing steam, then taking the steam to the turbine or engine, and then using the waste heat from the engine in an evaporator, perhaps for the boiler plant, or in some other way. The same might apply to the flue gases, and it would be interesting to hear what could be done in that way on plant for the production of oxygen partly worked by steam to produce power and partly by the waste heat from the steam to produce the refrigeration effect. Where oxygen was produced for the purpose of making nitrogen, if steam plant was used the possibilities might be considered of putting oxygen into the combustion air for the boilers. If anybody was afraid of burning the boiler out, consideration might be given to the fact that it was always possible to use the re-circulation of gases to get mass flow and maintain the heat transfer without getting over-temperature in the furnace.

With regard to large plants, no mention had been made of a point which was brought out a few weeks back in *The Engineer* or *Engineering*. In America large quantities of natural gas were liquefied with a view to storage. Large quantities of natural gas were available, but the demand fluctuated due to climatic conditions in the city where it was used. Those concerned went into the question of pipe-lines and also using ordinary atmospheric pressure hydration, but they found the best way in the end was to use three-stage refrigeration and actually liquefy the whole of the peak load of the gas and keep it stored in liquid form until it was required—say, when there was a cold snap. There seemed to be a very great future for that.

As to the Selby plant that had been mentioned, he remembered finding out about that in the Patent Office, but he would like to know more about it. Hydrogen on a small scale seemed to have been produced economically. It started off with water gas to get hydrogen, and used the CO in particular to run a gas engine to produce the power. In this connection he thought the old-fashioned gas engine might be considered when using coke-oven gas.

With regard to hydrogen production, some time back he investigated the possibilities of producing hydrogen directly from coke in an electrolytic plant, and also of taking cheap coke breeze and using that in a gas engine to produce the power for electrolytic production. One interesting thing arising from this was that, rather to his surprise, the gas engine was roughly as efficient as steam plant. He did not go into the question of the gas engine from the point of view of producers. If one wanted to work up the mixed gases, one way would be to take the gases, separate them, use the hydrogen for the purpose for which it was required, and use the waste gases to drive a gas engine, and use the waste heat from the gas engine, which was usually 30 per cent. of the original heat, in the form of power, and have a waste-heat boiler for working an absorption machine for producing cold. Speaking of the absorption machine, he said that some time ago the problem arose of getting a temperature between what was usually associated with an ammonia machine and liquid air, and he was assured by a manufacturer that the absorption machine could easily get down to $-100°$ C.

Mr. J. A. Oriel remarking that, although the meeting had been arranged as a joint conference, he felt that the petroleum industry seemed to have had a rather poor show so far. He felt scarcely qualified to speak on the subject or the technical aspects of the separation of petroleum gases. He might say something which would inspire those present who did know a good deal about them to give some technical data. To get a sense of proportion in this matter he directed the attention of the meeting to the fact that a considerable amount of work in gas separation had been carried out in the petroleum industry during the past 15 or 20 years. The author had given analyses of cracked gas and natural gas, and these gases had been the foundation of what might be called a complete new industry in the United States—*i.e.*, the industry of chemicals and solvents built up entirely on cracked and natural gases. This had only been made possible by the work carried out on the separation of gases in order to obtain them in the pure state. It was true he was not speaking of the same order of refrigeration as had up to then been considered during the discussion; nevertheless, the order of purity with which these gases had been obtained had enabled a whole new industry to grow up; which industry was responsible for a considerable number of materials necessary for the Allied Nations. The industry which most readily leapt to mind was the synthetic rubber industry, which was now growing to very large proportions in the United States based on the separation of gases from the cracked gas industry. There was also the production of acetone, glycerine, and several other pure chemicals that could only be obtained in their pure state due to the very fine fractionation that had been developed for gases in the petroleum industry.

Mr. R. P. Donnelly said that a few years ago he was seeking information on the separation of oxygen, and it was difficult to find any references. The only one he could find was one in the *Journal of the American Chemical Society* in 1928 in connection with some work by Dodge. What was definitely needed in industry, and particularly those industries which would be using oxygen in the post-war period, was precise figures of power costs as compared with the size of the plants and oxygen producing units. The nearest figure he could get was for the Linde process, and it was 20 h.p.-hours per 1000 cu. ft. of oxygen. With the Linde–Fraenkl process using the regenerative system instead of the recuperative system the figure was about 15 h.p.-hours per 1000 cu. ft. of oxygen, the lower figure being for a more impure oxygen. Did that represent the limit, or how much could it be improved by increasing the size of the plant? It was on such matters as these that the non-specialist at present was at a loss.

THE AUTHOR, replying to the discussion, said that he could not answer all the questions that had been put, even if he were in a position to do so, in the short time available, but that he would like to make a few comments. All the contributions had been extremely helpful, and had supplemented what he himself had said.

He would have liked to deal more fully with the separation of coke-oven gas, especially with the methods of obtaining other products besides a nitrogen–hydrogen mixture, such as pure hydrogen, methane and ethylene, and he was glad that these points had featured in the discussion. He regretted not having mentioned Dr. Maxted as the inventor of the process for scrubbing out carbon monoxide with liquid nitrogen.

In reply to Mr. Dee's question as to the nitrogen pressure used in Russian plant for separating coke-oven gas, he believed that the nitrogen was compressed to 180 atm. and evaporated in the methane condenser at just over 1 atm. pressure when a nitrogen–hydrogen mixture was to be produced. However, much lower pressures were necessary when the product was to be almost pure hydrogen. To obtain 96 per cent. hydrogen, about 0·35 atm. were needed and, to judge from Mr. Borchardt's remark, he supposed that about 0·2 atm. were used in Germany, as otherwise he did not think it would be possible to obtain hydrogen of a purity of 98 or 99 per cent. In the Russian plant for producing the mixture for ammonia synthesis about 170 cu. ft. of nitrogen were used for 1000 cu. ft. of coke-oven gas.

It was clear that, as Dr. Schuftan and Mr. Borchardt had said, much valuable research work had been done on the components of coke-oven gas and their mixtures before the investigations made in Russia. Without this it would have been impossible for the Linde Company to design their plant. However, not very much of this work was available in the literature.

He was very glad that reference had been made in the discussion to gas separation in the petroleum industry, because he felt that insufficient consideration had been given to the very valuable work done in America on the separation of light paraffins, especially the investigations of Kay, Sage, and Lacey on the liquid–vapour equilibrium of mixtures of methane, propane, butane, etc.

With regard to power consumption in the production of gaseous oxygen, the figures given by Mr. Donelly were, in the main, correct, and he himself could give some figures which also indicated the influence of the size of the plant. In the following figures the size of the plant was given in cu. metres of oxygen produced per hour and the power consumption in kw.-hours per 1000 cu. ft. of oxygen.

Power Consumption in Oxygen Production.

Cu. m./hr.	Kw.-hr./1000 cu. ft.
10	48
30	29
80	23
200	21
500	19
8000	12·7

The last figure referred to 98 per cent. oxygen and corresponded to the 15 h.p.-hours mentioned by Mr. Donelly. Personally he did not think it was possible, with present technique, to get very much lower than this figure, because the Linde–Fraenkl system was extremely efficient.

He agreed with Mr. Low that absorption refrigeration had a very great part to play in the future. He believed that it would be quite possible to achieve a temperature of − 100° C. with the extensive use of absorption methods. In this connection he would direct attention to the work of Dr. Altenkirch in Germany on reversibly absorption machines and to the work carried out in this country by the late Dr. Maiuri on obtaining low temperatures with absorption methods. It was particularly important that the absorption machine enabled the extensive use of waste steam, which would be a great step in the direction of power and fuel economy.

He also had been greatly interested in the work quoted by Mr. Low on the storage of liquefied natural gas in America, as showing the possibilities of large-scale gas liquefaction. He regretted that the authors of this paper had made little mention of the difficulties which must have been encountered.

In a written reply to Mr. Dee's question regarding the future of argon, the author expressed the opinion that this could not be foreseen, just as it was impossible to foresee the future of incandescent bulb lighting. He thought it probable that incandescent bulb lighting would be largely replaced by discharge lighting before the argon–krypton question had been answered, and thereupon the same problem would reappear on a new level. The importance of argon lay in the fact that it was a necessary by-product, which krypton was not, and that there was 10,000 times more argon in that air than krypton.

Finally the author agreed with Mr. Bagley's written suggestion that the subject here dealt with should take its place in the University. If, as Mr. Borchardt hoped, a powerful and independent gas-separating industry was to be developed in this country, research on a scale compatible with that carried on in the U.S.A. and the U.S.S.R. was a necessity, and facilities for such research would have to be provided.

Mr. S. J. Tungay (Chairman, Chemical Engineering Group), proposing a vote of thanks to the author said they had listened to a fascinating paper which reminded them of how Nature, that great and incomprehensible alchemist, appeared easily to separate gases and apply the various fractions for her own purposes and then showed how difficult it was when science and industry endeavoured to accomplish the same thing and apply the fractions to industrial purposes. The study was a fascinating one but, as the author had said, the industry was still a young one, and a deep debt of gratitude was owing to him for bringing this subject forward so effectively. The author had so simplified details of this complicated and complex system that "he who runs may read," and they had had a most enjoyable evening.

Mr. Ashley Carter (Institute of Petroleum) seconded the proposal and included in the vote of thanks those who had taken part in the discussion. He expressed regret that so few members of the Institute of Petroleum were present, but on behalf of the President and members of the Institute he expressed appreciation of the opportunity afforded by the Institution of Chemical Engineers and the Chemical Engineering Group to attend this joint meeting. He imagined that the paper and discussion would be published in the Institute's *Journal* so that all the members would have an opportunity of reading what had taken place and what had made the evening such an interesting one.

The vote of thanks was cordially given.

Mr. D. Bagley writes: the three Institutes who have sponsored this contribution to science are to be congratulated. Dr. Ruhemann's paper is of value to industry, as he is one of a very limited number conversant with large-scale research and practice in the development of gas separation.

As Dr. Linde's Chief Engineer was present at the meeting, I may recall that the late Mr. Murray, Chairman of the British Oxygen Company for many years, introduced my firm to Linde's at a time both were pursuing the oxygenated blast, which terminated with practical application at Gutehoffnungshutte, and not, as we originally determined, in Cumberland. The Iron and Steel Federation thoroughly investigated this development following the computations of the late Mr. Saniter and myself, and rightly concluded that the returns were inadequate, although I believe they were in agreement as to the economy to be secured in reducing the coke consumption with a furnace running on ferro-manganese.

Of particular interest to-day is the separation and liquefaction of the methane fraction in coke-oven gas, as also the liquefaction of marsh gas ex the Collieries, and sewage gas. Dr. Borchardt informed me before I entered the hall that not much further progress had been made in Germany. I may cite *Automobiltechnische Zeitschrift* (10th Sept., 1938), which indicates six gases suitable for motor use, and in particular "Motoren Methan," probably consisting of 70 per cent. CH_4, with varying percentages of propane and butane, an interim stage between the compressed gas and the liquefied gases. The number of cars propelled by these gases in Germany is well known. If we consider the low boiling point of methane, we perceive the difficulty of practical application, for a standard automobile tank at room temperatures, capacity 15 gallons, would probably lose nearly a quarter of the charge whilst filling.

Dr. Ruhemann refers to the use of cold accumulators, a positive means of power economy. Linde has suggested the use for coke-oven gas separation; we have, I think, improved a device known in other branches of industry for generations by introducing a rapid scavenging between reversals, to avoid gas contamination. By this means, rich coke-oven gas in process of cooling is not deprived of some of its valuable constituents; the lean return gas under low pressure is expanded into the accumulator previously evacuated by pressure release and pump. In the prior stage of benzol recovery the use of the accumulator is permissible by the employment of another refrigerant in place of ammonia, recoverable at a further place in the cooling system. The Kapitza turbine is a considerable improvement on German practice, and precedes any modification of which I am aware.

The octane value of methane transcends 140, which means that a liquid gallon of methane equals in power output a standard gallon of petrol if the compression ratio be raised to 10, possible with most standardized engines. Our resources are vast. Dr. Ivon Graham has reviewed this phase in relation to Colliery Methane. From my own knowledge coke-oven gas is a potential source. It will be obvious that 25 gallons additional of motor spirit per ton of coal is far more profitable than any grid sales for domestic heating. Besides, a mobile liquid gas avoids costly boosters and pipe-lines and enables distribution over a very wide range, without the intervention of the gas distributor.

Liquid oxygen was employed by Linde for explosives in 1900. Mewes had suggested the use of oxygen at a much earlier date. When we investigated liquid oxygen with cotton-filled cartridges in the Cleveland Ironstone Mines twenty years ago as an economical means of displacing gunpowder, the conclusion reached was that evaporation rendered this practice doubtful. The maximum power depends on detonation at a given instant, the sensitivity is high, and the conveyance of dipping flasks from point to point means a continuing loss.

I have directed attention to two phases only which coincide with the activities of ourselves and our collaborators, and now mention our dependence on scientific control at each and every stage in the design and manufacture of plant and equipment for efficient gas separation. The separation of gases, if rightly pursued, infers new industries at a time when we shall be confronted with great difficulty in purchasing our overseas-derived sustenance.

With my collaborators' sanction, we recommend a University Chair for Gases, preferably Cambridge. Our major industries are dependent on more exact knowledge of gases. The Petroleum Institute is, I know, continuously directing research to the utilization of gas from the oil-wells, and Dr. Dunstan of the Anglo-Iranian Company directed attention to this aspect some years ago. I recommend the suggestion to the three Institutes. Cambridge possesses liquefaction plant probably not in use to-day, and within the precincts of the laboratory we find all the gases we require. If this equipment is not available, it is possible that friends owning similar plant will permit its use for research. We are to-day confronted with a fuel shortage. As Mr. Hughes, late Prime Minister of Australia, reminds us, our Air Force is completely dependent on sea-borne supplies of aviation spirit, whilst a huge fuel reservoir wastes under our feet. Stripped to the K ring as we "pass through the valley of adversity," let us "use it as a well," and avoid the just censure of a future generation if we fail to employ in times of need the gases Providence has placed at our disposal.

Mr. G. Baars writes: I have followed with great interest the lecture of Dr. Ruhemann on Tuesday last about the separation of gases and make use of the opportunity given to ask one question regarding the statement that: "A detailed study has been made of the scrubbing column and the process of replacing carbon monoxide with nitrogen by scrubbing the mixture with liquid nitrogen, and a new thermodynamic diagram of nitrogen has been constructed, replacing the faulty Dutch diagram and extending to higher pressures the diagram issued by the American Bureau of Mines."

I should very much appreciate it if Dr. Ruhemann could tell me where I can find the Dutch diagram mentioned and what was wrong in it.

Dr. Ruhemann, in a private reply to Mr. Baars, furnished him with a copy of the paper by I. M. Guask,[9] containing a reference to the Dutch diagram, comparing it with the diagram published by the U.S. Bureau of Mines. He thought that Mr. Baars would be interested to know that Keesom and Houthoff's diagram of ethylene, published in the Leyden Communications in 1931, had also proved to be incorrect.

Mr. Baars, acknowledging the loan of the paper by Gusak, referred to the work by Keesom, which, he felt, had not been sufficiently appreciated by the author.

Dr. Ruhemann replied that he had the greatest respect for the work in this and other fields of Prof. Keesom, with whom he had been in close touch. He had felt bound, however, to point out the errors in these diagrams because of their use by engineers for practical calculations. While he believed that the nitrogen diagram was based on the best available data at the time, in the diagram for ethylene there was an unfortunate slip at low pressures which seriously impaired its value for practical and theoretical purposes. He felt that Mr. Baars would agree that even the greatest scientists occasionally made mistakes, but that this did not detract from their greatness.

Mr. B. C. Oldham wrote directing attention to the last paragraph on page 220, in which reference was made to absorption methods. It occurred to the writer that the term " absorption " might be ambiguous; it did not refer, as some readers might conclude, to absorption of a gas for the purpose of separation, but to the absorption method of refrigeration.

THE EXAMINATION OF ETHYL ALCOHOL AND ALCOHOL BLENDS FOR USE AS MOTOR FUEL.[1]

By S. J. W. Pleeth, B.Sc.[2]

Introduction.

The post-war world will see an increase in the use of home-produced substitute fuels such as alcohol and benzole, in all countries not possessing natural petroleum resources. For this reason it is considered expedient at this intermediate stage to discuss tentative methods for the testing of such materials and their blends with petrol, in so far as these tests differ from the standard methods laid down by the Institute of Petroleum, (I.P.), British Standards Institution (B.S.I.), or the American Society for the Testing of Materials (A.S.T.M.). The present paper deals with the examination of ethyl alcohol and its blends with benzole and petrol as practised in the Central Laboratory of the Cleveland Petroleum Co., an organization with many years experience in marketing a successful and popular alcohol blend. The author wishes to thank the directors of this Company for permission to publish this paper and to acknowledge their aid and encouragement in the early years of testing and development.

PART I.—ETHYL ALCOHOL.

The examination of ethyl alcohol is complicated by the attitude of H.M. Customs and Excise, which lays down certain regulations covering the use of alcohol for motor spirit. These state that ethyl alcohol may be used as a motor fuel only when denatured with 5 per cent. wood spirit, 0·5 per cent. pyridine, and a minimum of 30 per cent. petroleum spirit or benzole, and coloured with an approved red dye-stuff. Where it is blended under bond with amounts of petroleum spirit or benzole exceeding this minimum of 30 per cent. (which is the normal commercial practice) it may be supplied containing only 5 per cent. petroleum spirit or benzole, or even, in exceptional circumstances, with no such admixture, other than the first-mentioned denaturants, wood-spirit and pyridine. This section will deal with ethyl alcohol containing no petroleum spirit or benzole, but reference will be made to the pure material, and that after the addition of the legal denaturants, in which case the Customs nomenclature will be adopted—namely, Power Methylated Spirits Stage 1 (P.M.S.1). It will be apparent that all the standard tests for pure alcohol will be modified by the admixed denaturants.

A. Pure Ethyl Alcohol.

It is suggested that the procedure laid down in the B.S.I. Specification 507–1933 be used, modified as shown.

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[1] Received 7th August, 1942.

[2] Chief Chemist, Cleveland Petroleum Company.

1. British Standard ethyl alcohol shall be clear, colourless, and free from matter in suspension and shall contain no adulterants of any kind.
2. Strength. Omit this paragraph.
3. Miscibility with water. Omit this paragraph.
4. Residue on Evaporation. The material shall not leave more than 0·01 per cent. by weight of non-volatile residue, when tested in the manner described.
5. Acidity. The acidity of the material, other than that due to dissolved carbon dioxide, shall not exceed 0·005 per cent. by weight calculated as sulphuric acid and determined in the manner described.
6. Aldehyde Content. The material shall contain not more than 0·1 per cent. by weight of aldehyde, calculated as acetaldehyde, when tested as described.

B. Power Methylated Spirit Stage 1 (P.M.S.1).

1. *Specific Gravity.*

This determination is usually made with an accurate hydrometer, range 0·790–0·810, length of stem 20 cm., and subdivided so that each small

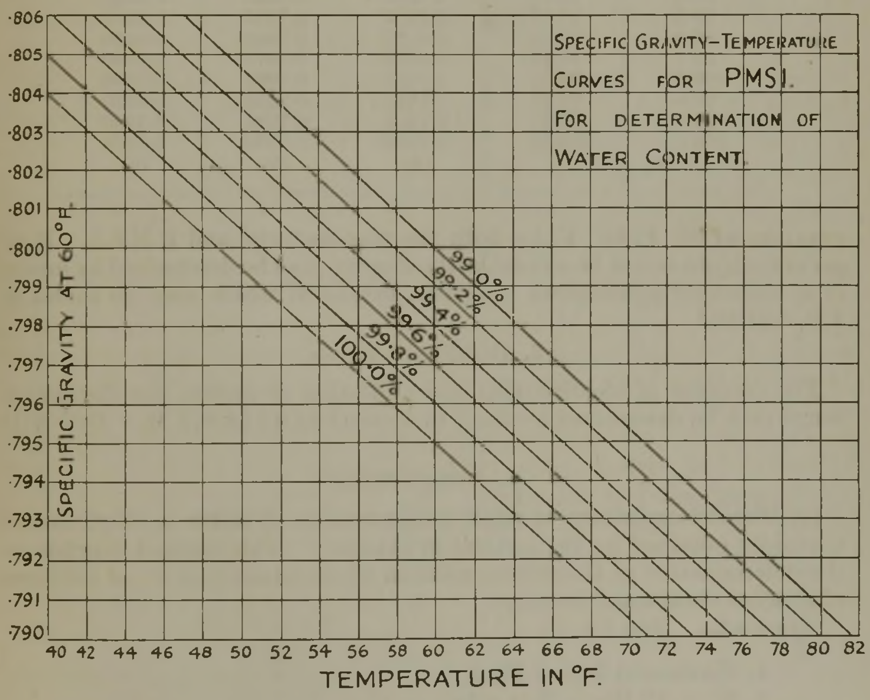

Fig. 1.

division of 0·001 is 10 mm. apart, permitting estimation to 0·0001. The temperature of the alcohol is then determined to 0·5° F., and by calculation, or by the use of a chart similar to that shown in Fig. 1, the specific gravity at 60° F./60° F. may be obtained. This chart may also be used to determine the water content; it must be remembered that the presence of denaturants slightly alters the standard tables for ethyl alcohol.

Specific Gravity Temperature Correction :

	Pure Ethyl Alcohol.	P.M.S.I.
Per 1° C. . .	0·00086	0·00082
1° F. . .	0·00048	0·00046

Table I gives details of alcohol strengths by volume and weight, together with the corresponding densities of the pure ethyl alcohol, and the specific

TABLE I.

Alcohol, % by vol.	Alcohol. % by wt.	Pure Ethyl Alcohol.		P.M.S.1. S.G. at 60/60° F.
		Density at 20° C.	S.G. at 60/60° F.	
98·0	96·90	0·7988	0·8033	0·8050
98·2	97·15	0·7980	0·8024	0·8040
98·4	97·44	0·7971	0·8014	0·8030
98·6	97·75	0·7962	0·8005	0·8020
98·8	98·07	0·7953	0·7995	0·8010
99·0	98·38	0·7943	0·7985	0·8000
99·2	98·70	0·7933	0·7976	0·7990
99·4	99·02	0·7923	0·7966	0·7980
99·6	99·34	0·7913	0·7956	0·7970
99·8	99·67	0·7903	0·7946	0·7960
100·0	100·00	0·78934	0·7936	0·7950
		(4)	(5)	(6)

gravities at 60° F./60° F. for both the pure material and P.M.S.1. If no accurate hydrometer be available, the density may be determined by means of a calibrated pyknometer or bottle, details of which may be found in I.P.—59/42.[1]

2. *Distillation Range.*

For purposes of identification and indication of purity, the distillation range may be determined by the I.P. Method 28/42 [A.S.T.M. : D86–30].[2]

3. *Water Content.*

(*a*) The determination of small concentrations of water in ethyl alcohol is rapidly obtained by the method of Crismer.[7] This method depends on the determination of the critical solution temperature (C.S.T.) of mixtures of aqueous alcohol and kerosine.

Apparatus. (See Fig. 2).

1. Unsilvered Dewar Flask.
2. 6″ × 1″ Pyrex Test-tube.
3. Thermometer calibrated from 0° to 20° C. in 0·1°.

Method.—Pure anhydrous ethyl alcohol is prepared by refluxing A.R. ethyl alcohol in contact with calcium wire for 2 hours. An approximate C.S.T. is then determined with the kerosine available by mixing 10 ml. of

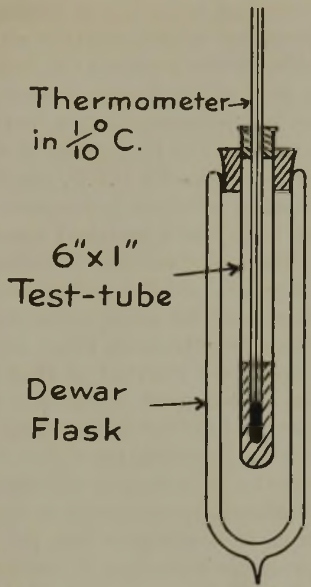
Thermometer in 1/10 °C.
6"x1" Test-tube
Dewar Flask

FIG. 2.

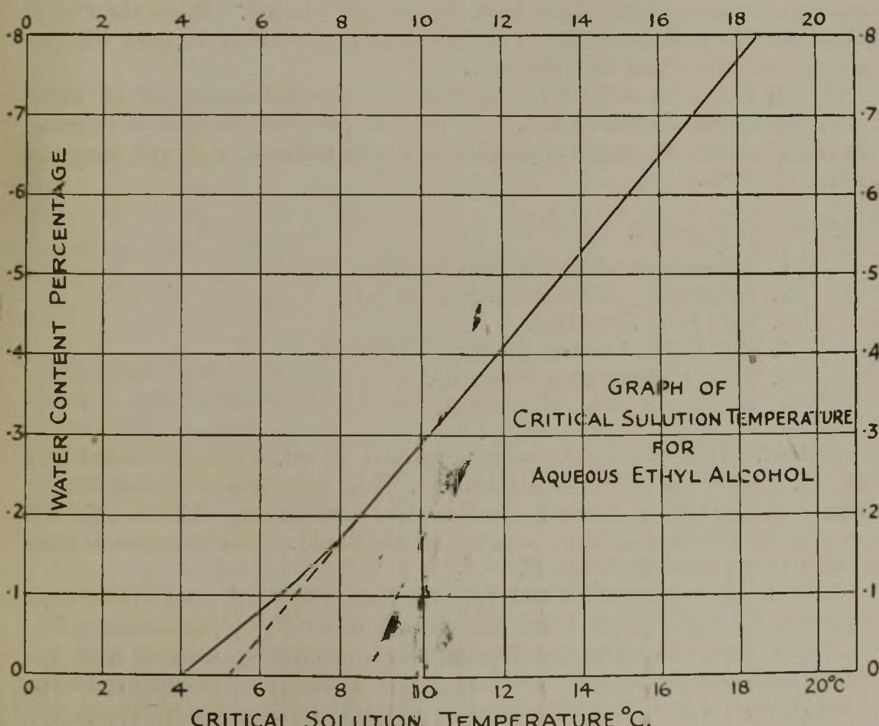
0 2 4 6 8 10 12 14 16 18 20
·8 ·7 ·6 ·5 ·4 ·3 ·2 ·1 0
WATER CONTENT PERCENTAGE
GRAPH OF
CRITICAL SULUTION TEMPERATURE
FOR
AQUEOUS ETHYL ALCOHOL
0 2 4 6 8 10 12 14 16 18 20°C
CRITICAL SOLUTION TEMPERATURE °C.

FIG. 3.

each liquid in the test-tube and warming or cooling until a clear solution is obtained; and by adjustment of temperature until a cloudiness is seen. This C.S.T. is then adjusted to come within the lower range of the thermometer scale by replacing part of the kerosine with petroleum ether. The suitable blend of kerosine and petroleum ether, carefully dried over $CaCl_2$, is prepared in bulk sufficient for the remainder of the determination.

The next stage is the preparation of a C.S.T. graph, similar to that shown (Fig. 3). An aqueous alcohol solution is prepared by adding a weighed quantity of water (about 5 gr.) to a weighed quantity of the anhydrous alcohol (about 95 gr.). Then, by suitable blending of weighed amounts of the anhydrous and aqueous alcohol, solutions containing accurately known quantities of water may be easily obtained. 10 ml. of aqueous alcohol and anhydrous kerosine-petroleum ether are each pipetted into the pyrex test-tube, the thermometer inserted so that the bulb is covered by the liquids and the whole chilled until separation is observed. The tube is carefully wiped and inserted into the Dewar flask. The rise in temperature should be sufficiently slow to enable the C.S.T. to be determined within 0·02° C. (This corresponds to an accuracy of 0·001 per cent. in the water content.) Sufficient determinations are made to enable a reasonable curve to be plotted. The graph is a straight line for water contents above 0·2 per cent., but an appreciable deviation is observed below this figure.

The final stage is the actual determination of the water content of the sample in question. This proceeds as in the preparation of the C.S.T. curve, care being taken that both liquids are filtered. From the C.S.T. obtained, the water content of the aqueous alcohol may be read with an accuracy approaching 0·01 per cent.

(*b*) An excellent alternative method for the determination of water contents is that due to Botset.[8] It may be preferred to that of Crismer, as it requires no elaborate apparatus and is suitable for a greater range of water contents.

Materials Required.

1. Absolute alcohol of known strength.
2. Anhydrous carbon tetrachloride A.R.
3. Two 10-ml. pipettes.
4. One 10-ml. burette, graduated 0·05 ml.
5. 6″ × 1″ hard glass test-tube.
6. Thermometer in °F. (or °C.).

Method. Into the test-tube are pipetted 10 ml. absolute alcohol and 10 ml. anhydrous carbon tetrachloride. The test-tube is closed with a tightly-fitting cork in which is inserted the thermometer, which is adjusted so that the bulb is entirely immersed in the liquid. The test-tube is then cooled to approximately 60° F.

From the burette distilled water is added, drop by drop, until a cloudiness appears, the temperature being maintained at 60° F. by immersion in ice-water at intervals. The test-tube is then warmed by contact with the hand, until the solution becomes clear, when another drop of water is added. This procedure is continued until two burette readings are obtained, one giving a cloud point below 68° F., and one above, so that by interpolation an exact titration figure for the cloud-point may be obtained. A result accurate to 0·02 ml. of water is possible by this means.

This method is then repeated with ethyl alcohol containing known amounts of water, until a calibration curve is obtained, similar to Fig. 4. In general, absolute ethyl alcohol requires a titration figure of 2·0 ml. at 68° F. (25° C.), although denaturants slightly affect this figure. Furthermore, each 1° F. is equivalent to 0·01 ml. of water in causing separation.

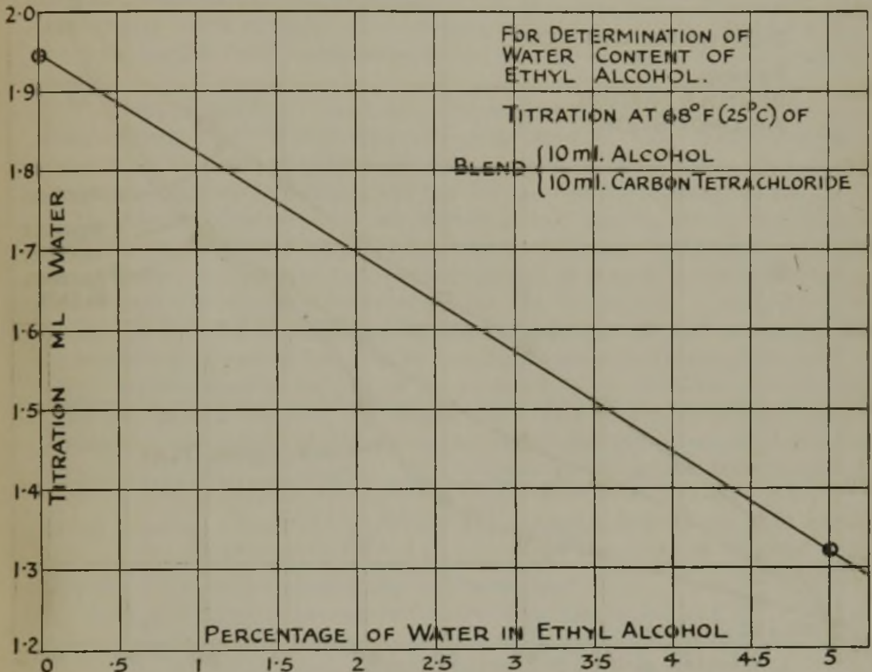

Fig. 4.

When we come to examine an unknown alcohol sample, it is titrated in the same way as indicated above and the water content read off directly. For instance, a titration of 1·75 at 68° F. would correspond to a water content of 1·53 per cent.

The accuracy of the method is within ±2 per cent. of the stated water content.

PART 2.—ALCOHOL BLENDS.

The examination of motor fuels containing alcohol differs but little from that of other motor fuels, and in the following section only the special tests will be given in full. It is understood that the complete details of the normal tests may be found in the standard tests issued by the Institute of Petroleum, American Society for Testing Materials (A.S.T.M.), etc.

1. *Specific Gravity.*

This property is usually determined by hydrometer and recorded at 60° F./60° F., in accordance with the I.P. Method 59/42. The correction to be applied to the value at a temperature other than 60° F., to reduce to that standard temperature, is usually taken as 0·00048 per 1° F. This value is approximate and applies to blends containing up to 20 per cent. alcohol and 20 per cent. benzole. If the fuel contains higher percentages

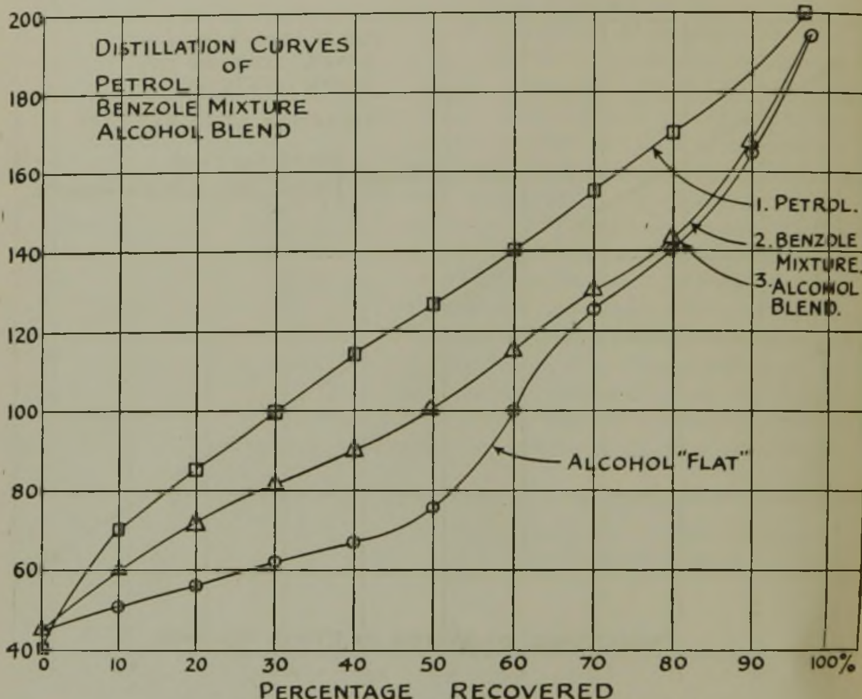

FIG. 5.

of these substances, the appropriate correction must be calculated from the values for the constituents, which are as follows :—

Petrol,* Sp. Gr. below 0·740 . . .	0·00048 per °F.
,, ,, ,, above 0·740 . . .	0·00044 ,, °F.
Alcohol	0·00046 ,, °F.
Benzole	0·00056 ,, °F.

* For fuller details see I.P. Standard Methods, p. 267.

2. *Distillation.*

The standard method is I.P.—28/42 or A.S.T.M. D86–30. Owing to the formation of azeotropes during the distillation, a typical feature of the distillation curve is the " alcohol flat " (see Fig. 5, Curve 9). This affects the rate of distillation, for when the temperature reaches about 80° C., the rate falls, while the temperature rises rapidly to about 110° C., and then both the rise in temperature and the distillation rate proceed normally. It is generally accepted that the flame height should not be adjusted during this period, to maintain the standard rate of distillation.

3. *Vapour Pressure.*

In the standard method for the determination of the Vapour Pressure of Motor Spirits by the Reid method (I.P.—69/42, A.S.T.M. : D323–32T) certain precautions and modifications are necessary when examining blends containing ethyl alcohol. The present note may be found useful to new workers in this field, in consequence of the growing importance of alcohol blends.

The first precaution is obvious : the sample cannot be obtained by water displacement, and the gasoline chamber may be filled either by direct immersion into the sample to be tested, or by pouring, if the temperature be low enough, or by siphon, the normal method for laboratory use.

The second precaution is less obvious, and may easily be overlooked. The standard method states that the air-chamber shall be rinsed with water before use and the temperature of the air within the chamber taken. When now the spirit is introduced, the bomb assembled, and the whole immersed in a bath at the standard temperature of 100° F., the rise in pressure is due to the increase in vapour pressure of the gasoline and the water (considered as saturated by providing excess) and by the normal pressure increase of air. To obtain the required vapour pressure of the gasoline, a correction is applied to the gauge reading corresponding to the two other factors introduced. This is given by the standard correction

$$\frac{(P_a - P_t)(t - 100)}{460 + t} - (P_{100} - P_t)$$

where t = initial air-chamber temperature, ° F.
P_t = vapour pressure of water in lb. per sq. in. at t° F.
P_{100} = vapour pressure of water in lb. per sq. in. at 100° F.
P_a = normal barometric pressure in lb. per sq. in.

In the author's laboratory it has been observed that the amount of water left in the bomb after rinsing is usually sufficient to cause separation of the alcohol blend into the two phases : aqueous alcohol and petroleum spirit.

The standard correction no longer applies, for there is no free water in the bomb. In any case, the recorded vapour pressure is erroneous, for, by Raoult's Law, the total vapour pressure of immiscible liquids is the sum of their partial pressures, and would lie between the values for aqueous alcohol and petroleum spirit; whereas it is well known that alcohol and petroleum hydrocarbons give azeotropes of higher vapour pressure than either of their constituents.

We have therefore taken the liberty of modifying the standard method when testing alcohol blends by using a dry bomb, by rinsing with alcohol or acetone and blowing with air; an initial air temperature is obtained, the gasoline chamber filled by siphoning, and the method proceeds as before.

The correction factor to be applied in this case ignores the water-vapour factor, as we assume that the pressure of the water vapour in the air at the commencement of the test increases with temperature to the same extent as does the air. The factor now becomes

$$\frac{P_a(t - 100)}{460 + t}$$

or to a close approximation

$$0{\cdot}03(t - 100) \text{ lb.}$$

Using this method, the true vapour pressure of alcohol blends is obtained, and the phenomenon of the enhanced vapour pressure of azeotropes of ethyl alcohol, benzole, and petroleum spirit readily observed.

One final point: it has often been stated, especially in the American journals, that alcohol motor-spirit blends cause greater vapour locking in an automobile than normal petroleum-spirit fuels of the same Reid Vapour Pressure. We have never found this difficulty to arise in practice on English roads, and this may be due to the less severe temperature conditions that apply here. An alternative explanation might be obtained in the light of the present paper.

Failure to observe the precautions outlined above would result in a depreciation of vapour pressure of alcohol motor spirits of several lb. per sq. in. Thus an alcohol motor spirit of true Reid Vapour Pressure of 10 lb. might be recorded as only 8 lb. This fuel would then be tested in an automobile against a petroleum motor spirit of only 8 lb. vapour pressure, and would, of course, reveal an enhanced tendency to vapour lock. Had it been tested against its equivalent—a petroleum motor spirit of 10 lb. vapour pressure—the opposite result would have been recorded, as our own road tests have shown, a result that confirms theoretical considerations.

4. *Water Tolerance.*

There are a number of methods by which this property of alcohol blends may be determined and recorded. That adopted by this laboratory is the amount of water that just causes separation at 60° F., recorded as ml. per gallon (that peculiarly Anglo-Saxon hybrid) or as a percentage.

Apparatus Required.

1. 1-ml. micro-burette (in 0·01 ml.).
2. 50-ml. pipette.
3. 6″ × 1″ hard glass test-tube.
4. Internal scale thermometer 32° F.–100° F.

Method.—30 ml. of the alcohol blend are pipetted into the dry test-tube and closed with a tight-fitting cork, in which is inserted the thermometer, the bottom of which should be about 1 inch from the bottom of the test-tube. (The purpose of the internal scale will be appreciated when one observes the rapidity with which the colour of the normal thermometer scale is removed by the blend; a burnt-in scale will also prevent this occurrence.)

The test-tube is then inserted into an ice-water bath and the temperature of the contents reduced to about 40° F. Water is then added from the micro-burette until the contents become cloudy. It is clarified by warming with the hand, and another 0·01 ml. added, again causing clouding, which in turn is removed by warming slightly. This is continued until sufficient water is added to cause the contents of the tube to remain cloudy at 60° F. It is always advisable to continue to warm the tube slightly and obtain the exact temperature of clarification. This guards against an accidental admission of excess water, for it is known that 0·01 per cent. water is equivalent to 2° F. (or 0·01 ml. = 4° F.).

The titration is doubled, to record percentage. To convert to ml. per gallon, the percentage is multiplied by the factor 45·5.

Remarks.

Fig. 6 records the results of determinations in the author's laboratory by the above method. The materials used were P.M.S.1, a high-grade acid-washed motor benzole, and a cracked Venezuelan petrol.

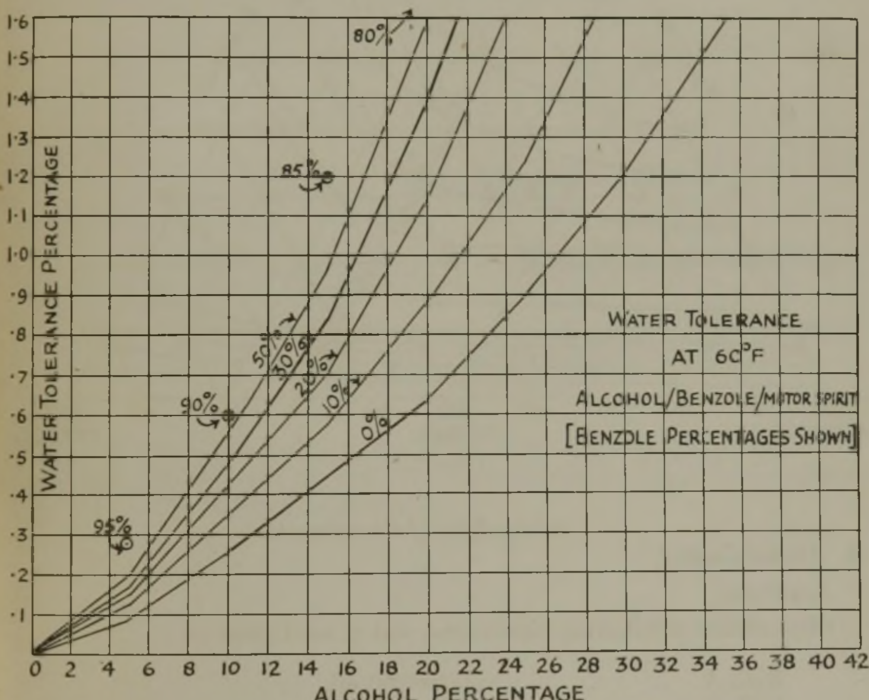

Fig. 6.

Fig. 7 represents these results in a more comprehensive form by means of a triangular graph.

Fig. 8 represents these results in a form complementary to that shown in Fig. 6. It illustrates an empirical formula for the calculation of the water tolerance of petrol blends containing not more than 20 per cent. alcohol and 20 per cent. benzole—that is, within the normal commercial limits.

$$\text{Water Tolerance at } 60° \text{ F.} = \frac{(1{\cdot}2A - 3)(B + 30)}{1000} \text{ per cent.}$$

The full lines record actual results, the dotted calculated by this formula. Within the limits stated the accuracy is experimental (5 per cent. or less).

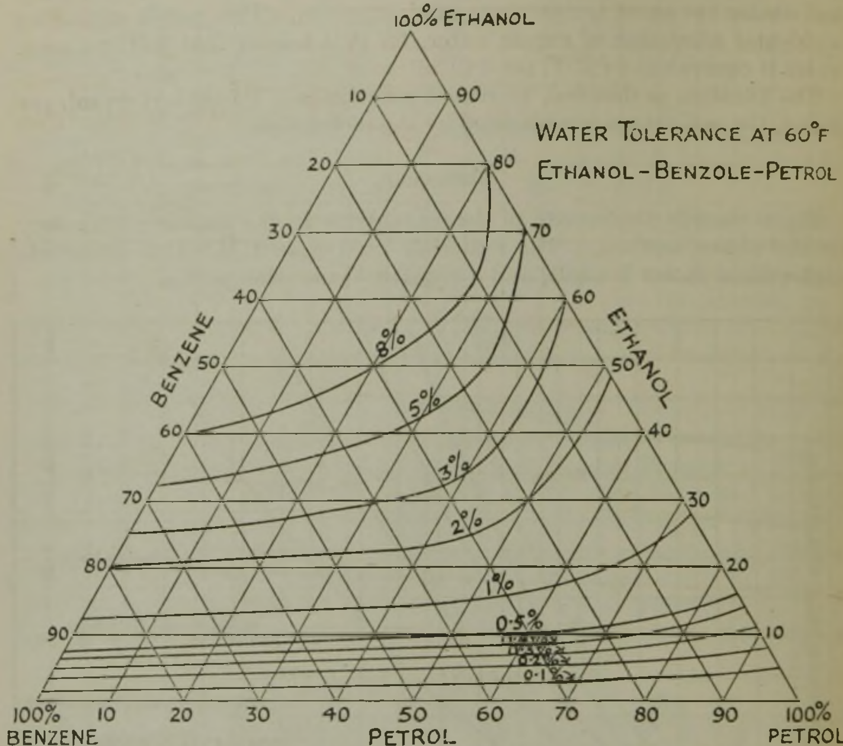

FIG. 7.

5. *Analysis of Constituents.*

1. *Alcohol Content.*

Apparatus.

Glass shaker of following dimensions, and of hard glass :—

Bulb A . . .	volume 250 ml.
Bulb B . . .	,, 80 ml.
Stem CD . . .	,, 20 ml., graduated to 0·1 ml.
Total volume C to E .	,, 100 ml.
Graduations to commence from 0 at C.	
Bulbs A and B . .	pear-shaped.
Bulb A . . .	with neck for cork.
Bulb B . . .	with tap.

Method.—A small volume of brine is sucked through the tap to reach lowest graduation E. 100 ml. of the alcohol blend are pipetted into the vessel, so that it reaches C. 100 ml. of saturated brine are added, the cork tightly fitted, the vessel inverted and shaken for 5 minutes and allowed to stand vertically. When separation is complete, the brine is run out until

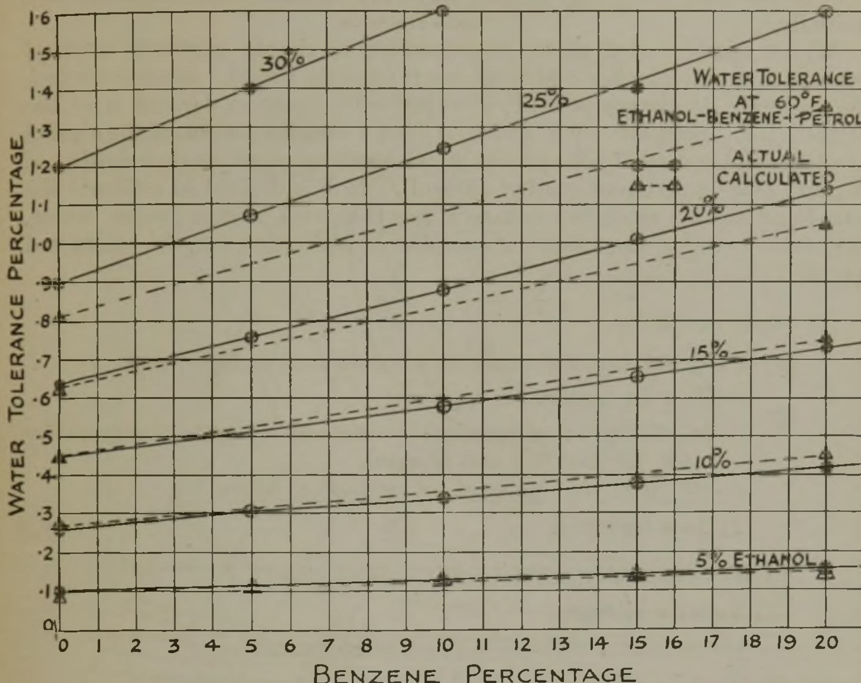

FIG. 8.

the lower level of the petrol reaches graduation E. The vessel is allowed to stand for a few minutes, and the level again adjusted, and this is continued until no further drainage is observed.

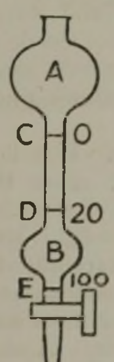

FIG. 9.

The reading of the upper petrol level records directly the percentage of alcohol in the original blend. If the alcohol content is over 20 per cent., an alternative vessel is used, similar to that shown, but omitting bulb B, and with the graduated portion extending along the entire stem from C to E, the volume now being only 50 ml., and that volume of alcohol blend used initially.

Whilst most alcohol motor fuels consist of simple mixtures of ethyl alcohol and petrol, other additions are frequently found. Methyl alcohol, for example, is always present, together with pyridine derived from the denaturant. Sometimes it is added to form a definite portion of the alcohol content (cf. German alcohol blends, in which the alcohol portion consists of 2 parts ethyl and 1 part methyl alcohol). If it is desired to estimate the ethyl and methyl alcohols separately, together with acetone, ether, water, and other possible ingredients, a complete examination may be conducted on the following plan :—

(1) *Shake with brine.*

- (*a*) *Water Soluble* (*containing the alcohols, acetone, ether, water, etc.*).
  - (1) Test for acetone.
    - (*a*) Positive : determine by method (i) or (ii), remove by method (iii) and proceed.
    - (*b*) Negative : proceed by method (*a*) below.
  - (2) Test for ether.
- (*b*) *Water insoluble* (*petrol, benzole, aniline, etc.*).
  - (i) Test for nitrogen.
    - (*a*) positive : estimate aniline, nitro-benzene.
  - (ii) Test for thiophene (added benzole).
  - (iii) Extract with 100 per cent. H_2SO_4 and determine aromatics, unsaturateds, and other hydrocarbons.

The most complex blends are to be found in racing fuels, which may contain ethyl and methyl alcohols, acetone, ether, nitro-benzene, aniline, petrol, motor benzole, tetraethyl lead, and water, in addition to many other ingredients, subject to the whims of the driver, mechanic, or designer of the engine. Each blend presents its own analytical problems, which cannot be dealt with fully here. The following notes cover the broad analysis of the main types of alcohol blends.

(*a*) *Ethyl and Methyl Alcohols.* If it is suspected that the motor fuel contains water-soluble materials other than ethyl alcohol, a complete analysis may be made on the brine extract. First, the petrol layer is shaken with a further 50 ml. of brine, and this second extract added to the first. The entire brine extract is then carefully distilled, using a splash-trap and vertical coil condenser (so that no condensate is trapped), until the distillate has a total volume of 95 ml. It is then cooled to 60° F., and water added until it reaches the 100-ml. mark. (A standard 100 ml. graduated flask should be used to collect the distillate.)

The specific gravity of this distillate is accurately determined by means of a 50-g. bottle; from the appropriate tables [9] the methyl and ethyl alcohol strengths are obtained.

The refractive index of this distillate is then measured by means of a Zeiss Immersion Refractometer, an instrument peculiarly adapted to this specific purpose, or by means of a prism refractometer of equal accuracy.

TABLE II.[10]

Immersion Refractometer Readings at 20° C.

Alcohol, % wt.	Methyl Alcohol.	Ethyl Alcohol.	Alcohol, % wt.	Methyl Alcohol.	Ethyl Alcohol.	Alcohol, % wt.	Methyl Alcohol.	Ethyl Alcohol.	Alcohol, % wt.	Methyl Alcohol.	Ethyl Alcohol.
0	14·5	14·5	26	30·3	61·9	52	39·6	91·8	78	27·6	100·9
1	14·8	16·0	27	30·9	63·7	53	39·6	92·4	79	26·8	100·8
2	15·4	17·6	28	31·6	65·5	54	39·5	93·0	80	26·0	100·7
3	16·0	19·1	29	32·2	67·2	55	39·4	93·6	81	25·1	100·6
4	16·6	20·7	30	32·8	69·0	56	39·2	94·1	82	24·3	100·5
5	17·2	22·3	31	33·5	70·4	57	39·0	94·7	83	23·6	100·4
6	17·8	24·1	32	34·1	71·7	58	38·6	95·2	84	22·8	100·3
7	18·4	25·9	33	34·7	73·1	59	38·3	95·7	85	21·8	100·1
8	19·0	27·8	34	35·2	74·4	60	37·9	96·2	86	20·8	99·8
9	19·6	29·6	35	35·8	75·8	61	37·5	96·7	87	19·7	99·5
10	20·2	31·4	36	36·3	76·9	62	37·0	97·1	88	18·6	99·2
11	20·8	33·2	37	36·8	78·0	63	36·5	97·5	89	17·3	98·9
12	21·4	35·0	38	37·3	79·1	64	36·0	98·0	90	16·1	98·6
13	22·0	36·9	39	37·7	80·2	65	35·5	98·3	91	14·9	98·3
14	22·6	38·7	40	38·1	81·3	66	35·0	98·7	92	13·7	97·8
15	23·2	40·5	41	38·4	82·3	67	34·5	99·1	93	12·4	97·2
16	23·9	42·5	42	38·8	83·3	68	34·0	99·4	94	11·0	96·4
17	24·5	44·5	43	39·2	84·2	69	33·5	99·7	95	9·6	95·7
18	25·2	46·5	44	39·3	85·2	70	33·0	100·0	96	8·2	94·9
19	25·8	48·5	45	39·4	86·2	71	32·3	100·2	97	6·7	94·0
20	26·5	50·5	46	39·5	87·0	72	31·7	100·4	98	5·1	93·0
21	27·1	52·4	47	39·6	87·8	73	31·1	100·6	99	3·5	92·0
22	27·8	54·3	48	39·7	88·7	74	30·4	100·8	100	2·0	91·0
23	28·4	56·3	49	39·8	89·5	75	29·7	101·0			
24	29·1	58·2	50	39·8	90·3	76	29·0	101·0			
25	29·7	60·1	51	39·7	91·1	77	28·3	100·9			

TABLE III.[11]

Conversion from Zeiss Refractometer Readings to Refractive Indices.

Scale Divisions.	Refractive Index.	Scale Divisions.	Refractive Index.	Scale Divisions.	Refractive Index.	Scale Divisions.	Refractive Index.
− 5	1·32539	25	1·33704	55	1·34836	85	1·35931
0	1·32736	30	1·33895	60	1·35021	90	1·36110
+ 5	1·32931	35	1·34085	65	1·35205	95	1·36287
+10	1·33126	40	1·34274	70	1·35388	100	1·36464
+15	1·33320	45	1·34463	75	1·35570	105	1·36640
+20	1·33513	50	1·34650	80	1·35751		

The Zeiss Refractometer has a limited range of refractive index readings (with Prism I) ranging from 1·325 to 1·366, recorded on an arbitrary scale ranging from 0 to 100. This scale corresponds to the complete range of values found in aqueous ethyl and methyl alcohols, and permits a rapid determination of their relative proportion to be obtained. In the absence of such an instrument, the normal refractive index must be converted to Zeiss Refractometer readings by means of Table III.

The method is best explained by means of an actual example.[10] Let us suppose that the specific gravity of the unknown solution is 0·97917 at 60°/60° F. From the standard tables, this corresponds to 13·70 per cent. ethyl or 12·83 per cent. methyl alcohol.

From Table II we observe that the Refractometer reading for 13·70 per cent. ethyl alcohol is 38·16 and for 13·70 per cent. methyl alcohol 22·42. The actual refractometer reading of the unknown solution is (say) 30·0. Then by applying the simple Rule of Three, we have

$$\frac{38{\cdot}16 - 30{\cdot}0}{38{\cdot}16 - 22{\cdot}42} \times 100 = 51{\cdot}8 \text{ per cent.},$$

i.e., 51·8 per cent. of the alcohol in the solution is methyl alcohol.

Now the total weight of mixed alcohols in the solution is given by $(12{\cdot}83 \times 0{\cdot}518) + 13{\cdot}70\ (1 - 0{\cdot}518) = 13{\cdot}25$ per cent., of which $13{\cdot}25 \times 0{\cdot}518 = 6{\cdot}86$ per cent. is methyl alcohol, and $13{\cdot}25 \times (1 - 0{\cdot}518) = 6{\cdot}39$ per cent. is ethyl alcohol.

It must be understood that this method is applicable only in the absence of appreciable amounts of other water-soluble materials that may affect both the gravity and refractive index of the distillate, and therefore invalidate the deductions made. In case of doubt detailed tests must be made for other constituents, and the method is briefly as follows.

(*b*) *Acetone*. The presence of acetone in addition to the alcohols may be confirmed by the following test : to the aqueous solution ammonia is added until it is just alkaline and avoiding excess. A solution of iodine in potassium iodide is then added, drop by drop, until a small amount of black precipitate (NI_3) is formed. The solution is then gently warmed until the precipitate disappears. The presence of acetone is shown by the formation of iodoform (crystals or odour). Under these conditions of test ethyl alcohol does not produce iodoform.

If acetone is found present, its determination may be obtained by one of two methods, depending on the presence or absence of methyl alcohol.

(i) If methyl alcohol is absent, proceed by the method of Rakshit and Messenger [12] or Marasco.[13]

(ii) If methyl alcohol is present, proceed by method of Sunwalla and Katti.[14]

(iii) If acetone is present, it must be removed from the brine solution before proceeding with the determination of the alcohols. This is accomplished by adding to 50 ml. brine washings 3 ml. benzaldehyde to each 1 ml. acetone, and 1 g. KOH per 10 ml. liquid. Water is added and the whole refluxed for 30 minutes. It is then distilled, using a splash-trap until all alcohol has been removed. The distillate is saturated with salt and extracted twice with benzole and twice with petroleum ether. The brine washings are then distilled and the method proceeds as in (*a*).

For more complete details of the tests for, and determination of, other possible water-soluble ingredients, such as ether, pyridine, etc., refer to Simmonds' " Alcohol " or other standard work on quantitative analysis.

(*c*) *Water*. Water is best determined by difference, after the determination of other constituents, with a final check by its Water Tolerance.

2. *Petrol*.

That portion of the alcohol blend insoluble in brine may be more fully examined to determine the nature of the petrol used and whether benzole has been added. The procedure follows the customary lines : specific gravity, distillation range, and bromine value (for unsaturated hydrocarbons) will establish the general type of the petrol and give some indication of the presence of benzene. Although there is no specific test for benzene, most motor benzole contains thiophene (C_4H_4S), and this may be detected by the following test.

(*a*) *Test for Thiophene.* In a white porcelain dish pour a few c.c. of concentrated H_2SO_4. Gently run petrol upon the surface by means of a pipette, taking care not to disturb the interface. Sprinkle a few specks of isatin upon the surface. A blue colour indicates thiophene; normally, yellows and browns develop. This test is not very satisfactory, and does not always reveal the presence of thiophene. It may be assumed that if the test is positive, the petrol contains added motor benzole.

If the thiophene test is negative, or if it be deemed of insufficient value as an indication of added benzole, the petrol may be examined more fully by extraction with concentrated H_2SO_4, on the lines laid down in the I.P. tentative method, and the total aromatics determined by the aniline point. As far as the composition of the fuel is concerned, it matters little whether the aromatics are derived from the petrol itself or from added motor benzole; the results are indistinguishable.

Crank-case Dilution.

In the standard method for the determination of crank-case dilution (A.S.T.M. D322–35 and I.P.—23/42 (T.)), only the petrol portion is caught and measured. The alcohol, if any, remains in solution in the water used, and escapes detection.

It is preferable, therefore, in this case to revert to the original method of direct steam distillation of the crank-case oil, capturing the petrol diluent in the usual siphon trap and collecting all the condensed water. When the steam distillation is completed, the entire distillate is saturated with salt, the petrol part extracted by two or three washings with petroleum ether, and the aqueous portion distilled to 95 ml. in a standard 100-ml. flask. Water is added to the mark and the specific gravity determined. Reference to the standard alcohol tables (see Simmonds' "Alcohol"[9]) enables the alcohol content to be calculated, and from that the alcohol content of the diluent.

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Geology and Development.

815.* Science Beats Guesswork Finding Oil. Anon. *Petrol. Eng.*, July 1942, **13** (11), 56.—Geology, geophysics, geochemistry, or some combination of these scientific methods was used to locate 2399 of the wildcats drilled in 1941, and 471 of the wells found oil. Only thirty of the 801 wildcats located non-technically were successful. The reasons for drilling sixty-four wells, two of which were successful, are unknown.

Normally about one-tenth of all wells drilled each year are wildcats or wells sunk in the hope of finding new fields. This year, because of the shortage of steel, the total wells will probably number only half that for 1941. G. D. H.

816.* Wyoming Awaits More Favourable Conditions for Full Development. T. R. Ingram. *Oil Gas J.*, 16.7.42, **41** (10), 70.—Three new discoveries were made in Wyoming in the first half of 1942. Only two new discoveries were made in 1941 and four in 1940. The smallness of the number of discoveries is a consequence of the restricted wildcatting. Wildcatting activity is a reflection of political and economic conditions.

The first oil-well in Wyoming was completed in 1884 near a seep on the Dallas dome. The Shannon pool was discovered in 1889, and in 1906 the first well to the first Wall Creek sand at Salt Creek proved the presence of an important field.

To-day Wyoming has ample refining facilities, and pipeline connections with Colorado, Montana, Utah, Kansas City, Chicago, and other places.

Over 250 structures have been mapped in Wyoming, and eighty-five have been found to contain oil and/or gas in commercial quantities, although not all of them have been drilled, and many have not been tested through all the possible oil horizons. Seventy-seven structures have been developed commercially, forty-five being primarily oilfields. The cumulative production of oil up to the end of 1941 was 529,521,300 brl. The proven reserves are estimated at 248,480,000 brl.

Most of the fields are on anticlinal folds around the edges of large structural basins. Only three of the seventy-seven structures have been drilled to the basement. Many hidden highs may occur within the basins, and they may be capable of location by modern methods. In Western and South-western Wyoming there are many structures in the Tertiary. Tertiary production has been found at La Barge, Hiawatha, and Powder Wash.

In 1931 a flowing well was completed at Badger Basin in the Big Horn Basin at a depth of 8723 ft. in the Frontier. Deeper production has been found in a number of fields a considerable time after the development of the shallower horizons. Some structures which are barren in the shallower horizons are productive in the deeper horizons. The oil and gas possibilities below the Tensleep are practically unknown.

This year oil has been found in the Tensleep on the Pilot Butte dome at a depth of 6446 ft. Previously the area had given oil at 1255 ft., and gas from the Muddy at 3362 ft. Tensleep production was found at 4640 ft. in the Cody field, and a gas discovery was made at 2950 ft. in the Dakota on the Sherrard dome.

Tables show the deepest zones tested in the seventy-three producing structures up to the end of 1939, and the producing zones, discovery date, number of wells, average daily production, cumulative production, type of structure, depth range, average zone thickness, and oil gravity in the various oilfields in Wyoming. G. D. H.

817.* Gradual Drilling Decline Continued through June. Anon. *Oil Gas J.*, 23.7.42, **41** (11), 54.—During June 1309 wells were completed in the U.S.A., 119 fewer than in May. The decline in activity was mainly in field development. In June seven more gas-wells were completed than in May. Drilling was less than one-half of what it was in June 1941.

A table gives by States and districts the numbers and types of completions in June, together with the total footage drilled, the number of wells drilling, and the numbers of wells in different depth ranges. G. D. H.

818.* Record Number of New Fields Being Discovered. Anon. *Oil Wkly*, 20.7.42, **106** (7), 27).—At present none of the 173 new oil- and gas-fields discovered during the first half of 1942 seems likely to be exceptionally large or prolific. 106 new horizons have been opened up in established fields.

Two prolific Ellenburger discoveries were made in Ward and Andrews Counties, West Texas. Known highs between these two discoveries are to be tested in the near future. The Fullerton find in Andrews County is in the Clear Fork. Cambrian production has been found at Wentz, and some small Delaware discoveries have been made in Ward and Pecos counties.

In North Texas the Forrestburg prospect yields oil from the Marble Falls at 7176–7323 ft. North-west of Clingingsmith a prolific Bend producer has been drilled. In Jack County the Worsham-Steed Smithwick discovery has proved to possess a gas-cap.

In South-west Texas eight discoveries have been made this year in the Carrizo-Wilcox series of the Wilcox trend. The up-dip Wilcox trend now seems to be established as a source of production. The Yegua production at 7767 ft. at Alice, Jim Wells County, directs attention to the Vicksburg trend as a potential deep producer. The Black Oak prospect of East Texas had a good Paluxy well at 6262–6350 ft., and several nearby wells have passed good possible oil production in the sub-Clarksville at 4000–4100 ft.

Camp Eleven and Mercy are probably the most important of the eleven discoveries on the Texas Gulf Coast. The major find in South Louisiana was Bay DeChene. Two new Wilcox fields were found in North Louisiana, and in one case gas-distillate was proved below the Wilcox, probably in the Paluxy.

Twenty-seven new fields were opened in Illinois, the shallow Boulder field, which gives oil from the Bethel, probably being one of the most important. A Trenton pool has been found in Madison County on the extreme west side of the basin. The Osage lime has proved productive in the old Hazleton area of Indiana.

The Midway Smackover field of South Arkansas has been defined to the north and south, and appears to be a narrow structure. At New London Cotton Valley production has been obtained at a depth of 5757 ft. Sweet gas has been discovered in the Cotton Valley at McKamie, Dorcheat, and Macedonia, fields which previously gave only sour gas from the Smackover.

None of the new Kansas strikes seems to be outstanding, and the same appears to be true of the Oklahoma discoveries. A shallow heavy-oil field was found on the west side of the San Joaquin Valley 3½ ml. west of North Belridge. Production is from the Miocene. Eight oil discoveries and two new horizon discoveries were made in Michigan. At Adams Monroe production was found at a depth of 4229 ft. Extensions have been made to the Reed City and Kawkawlin pools adding 600–1000 acres to each. G. D. H.

819.* Wells Deeper and Footage Off Less than Completions. Anon. *Oil Wkly*, 20.7.42, **106** (7), 19.—Although the number of completions in the first half of 1942 was 23·2% below that for the corresponding period of 1941, the footage was down by only 19·9% as the average depth per well increased from 2987 to 3118 ft. The 11,090 tests represented 34,586,883 ft. of drilling.

The bulk of the footage was in Texas, where it amounted to 37·7% of the U.S. total. Due to the 40-acre spacing rule, drilling at East Texas came practically to a standstill. West Texas, with 3,819,890 ft., led the State in both completions and footage.

Louisiana was the second most active State as regards footage, and its wells averaged 6584 ft. and totalled 3,391,135 ft. In South Louisiana the average depth was 8748 ft. Pennsylvania was third in terms of total footage with the wells averaging 1657 ft.

Alabama, Arkansas, Colorado, Georgia, Michigan, New Mexico, New York, and West Virginia showed increases in footage, and all these States except Colorado and Michigan had a larger number of completions.

Tables show the number of wells, total footage, and average depth each year since 1925, and the completions, footage, and average depth in the first halves of 1941 and 1942 for the various States and districts. G. D. H.

820.* Wildcatting Decline Smaller than Total Completion Slump. Anon. *Oil Wkly*, 20.7.42, **106** (7), 20.—During the first half of 1942 the U.S. wildcat drilling was only 9·2% less than in the first half of 1941. 12·8% of the completions were wildcats. Of the 1942 wildcats 193 were oil-wells and forty gas-wells, practically the same percentage success as in 1941. The successful wells opened 172 new oil- and gas-fields.

It is unlikely that the 4000 wildcats hoped for in 1942 will be attained. Kansas completed 56·4% more wildcats than in the first half of 1941, and 17·5% of the 183 wildcats found oil or gas. In Oklahoma 23·5% of the wildcats were successful. West Texas had seventy-eight wildcats, more than twice the number drilled during the first half of 1941. 36·6% of South Louisiana's wildcats found oil or gas, but North Louisiana had only 5·3% of successes. 39·9% of the U.S. wildcats were in Texas, 13·6% of them being successful.

A table gives the wildcat completions and results in the first half of 1942 for the various States and districts, and the numbers of wildcats drilled in the first half of 1941. G. D. H.

821.* Year's Well Completions Likely to Exceed Predictions. Anon. *Oil Wkly*, 20.7.42, **106** (7), 17.—The results of the first six months of 1942 show that the year's drilling activity may be greater than was generally expected. 11,090 tests have already been drilled. The weekly number of completions fell from January to April, but has risen since then. It seems likely that future reductions in drilling are more likely to be due to shortage of materials than to spacing regulations.

The total completions in the first half of 1942 are 23·2% below the 1941 figures. A smaller percentage (53%) of the completions were oil-wells, as compared with 1941 (60·1%). 25·1% of the wells were dry. There has been an enlarged percentage of deepened and input wells this year.

Among the six major producing and drilling States, Illinois suffered the greatest decline, a 43·7% decrease in completions in six months. Texas has a 32% decrease, California 30·9%, Oklahoma 25·4%, Kansas 24·6%, and Louisiana a 23·1% decrease.

Tables show by States and districts the cumulative completions for the first half of 1942; details of completions in June 1942; the weekly average completions in the first six months of 1940, 1941, and 1942; details of the activity at the beginning of July 1942. G. D. H.

822.* Sharp Increase Advocated in California Heavy-Oil Fields. L. P. Stockman. *Oil Gas J.*, 23.7.42, **41** (11), 18.—An increase of 80% in the development of the Californian fields producing oil of 23·9 gravity and under has been recommended for 1943. However, the present prices do not favour such increased development. The rehabilitation of heavy-crude wells is suggested as the quickest way of obtaining the increase.

13,311 wells are potentially capable of giving heavy crude, and of these 11,651 are producing, 861 shut down, and 799 idle. Increased prices would encourage owners to clean out and work over those producing and shut-down wells needing such treatment, if ample equipment were available.

On a five-acre spacing there is room for 600 new wells at Wilmington, and it is recommended that these new wells must be completed in the tar zone, upper and lower Ranger and upper Terminal zones, multiple completions being allowed.

A table gives the heavy-oil fields with the undeveloped acreage, average well depth, proposed spacing and number of new wells, ultimate well production, and recovery per acre. G. D. H.

823.* Alberta Tar-Sands Tapped to Meet Canadian War Needs. J. Montagnes. *Oil Wkly*, 27.7.42, **106** (8), 96.—The Athabaska tar sands are variously estimated to have 100,000,000,000 to 250,000,000,000 brl. of oil. They are saturated for thicknesses up to 225 ft., and may contain as much as 25% of oil by weight. The tar-sands cover an area estimated to be 10,000–50,000 sq. ml., although much of the sand is buried at depths which may be as much as 1800 ft. It is not considered feasible to mine the sand where buried. A good asphalt can be extracted from the sands.

An extraction plant started operations last year, and it produces crude oil which is refined to produce gasoline, fuel oils, asphalt, and coke. G. D. H.

824.* Argentina Extends Old Fields and Discovers New Areas. M. L. Villa. *Oil Wkly*, 27.7.42, **106** (8), 58.—In 1941 Argentina produced 22,013,472 brl. of oil, 6·8% more than in 1940. The Comodoro Rivadavia field was extended by the opening of the El Tordillo zone. Three dry holes were drilled in Santa Cruz territory. A fourth well found a large gas-flow consisting mainly of carbon dioxide.

15 ml. east–south-east of Plaza Huincul oil-sands were found 3200 ft. deep. In the Portezuelo zone 19 ml. west–south-west of Plaza Huincul oil and gas were found at a depth of 2730 ft., and three gas-sands deeper.

Oil-shows were met in a well 10 ml. north–north-west of Zapala. In the Senillosa zone good oil indications were found in the Lower Cretaceous. Shows were observed in a deep well on the Carrizal structure, 7 ml. south–south-east of the Barrancas discovery well. Oil-sands were found in a well 2 ml. north-west of Tupungato. In Southern Mendoza province dry gas was encountered in the Upper and Lower Cretaceous, and heavy oil in the Upper Jurassic.

7,768,776 brl. of oil were produced in Argentina during the first four months of 1942. Non-commercial shows of oil and gas were found in the La Heras zone of Comodoro Rivadavia. The importance of the Challaco zone has been established at Plaza Huincul.

Tables give production and drilling data. G. D. H.

825.* Exploration Progresses in Scenic West Indies. Anon. *Oil Wkly*, 27.7.42, **106** (8), 88.—So far the oil production is confined to the Motembo field of Cuba, where

7,000,000 gal. of naphtha are estimated to have been produced during 1941. Several tests were drilled in Cuba during 1941 without finding commercial production. Geological studies were carried out there and in Haiti. Tests are to be drilled in the Dominican Republic, one being on the Comendador anticline 75 ml. west of San Juan. Shallow tests are also planned for the Maleno anticline 6 ml. north-west of Azua near old wells which have produced. Drilling is expected to be undertaken east of the highly faulted Maleno structure, which has eight abandoned wells. G. D. H.

826.* **Large Decline Indicated in World Crude Output.** J. Logan. *Oil Wkly*, 27.7.42, **106** (8), 45.—The 1942 world oil output is expected to fall substantially below the record output of 1941. This is due to the destruction of much productive capacity in the Far East, to the probable inability of the Russians to maintain normal production, to the shutting off of part of Venezuela's normal market by submarine warfare, and to a probable decline in the U.S.A. output. The U.S.A. output may fall by 30,000,000 brl.

The world production in 1941 is estimated to have been 2,226,836,000 brl., 4% more than in 1940.

The production data of the various countries are given for 1941, and the outputs of the leading countries are compared for 1931, 1939, 1940, and 1941. The production in 1939, 1940, and 1941 is tabulated for the countries of the Far and Near East, and for Russia, Venezuela, and the U.S.A.

Tables on pages 114, 116, and 118 give the annual production of the different countries since 1857. G. D. H.

827.* **Most Canadian Provinces Being Prospected.** Anon. *Oil Wkly*, 27.7.42, **106** (8), 94.—In Ontario the recent exploratory work has been mainly in search of gas. No new fields were found, but drilling was maintained in the Malahide field. Ontario's oil output fell. At Stony Creek, in New Brunswick, oil and gas are obtained from the Albert series (Middle and Lower Mississippian) in lenticular sandstones on the north limb of the Hillsborough syncline. In 1941 653,430,000 cu. ft. of gas and 22,334 brl. of oil were produced. A test is being drilled on the south limb of the Hillsborough syncline. Geological reconnaissance has been carried out in the Havelock–Cornhill and the Sussex–Portage Vale areas of New Brunswick.

Four deep tests are planned in Saskatchewan. G. D. H.

828.* **Rumanian Oil Situation Deteriorates.** E. A. Bell. *Oil Wkly*, 27.7.42, **106** (8), 72.—The 760,960 ft. estimated to have been drilled in Rumania during 1941 was less than the 1940 figure. The Dambovitsa and Prahova regions probably produced 35,700,000 brl. of oil in 1941, and the Buzau and Bacau areas may have given 525,000 brl.

The refining during 1941 is expected to have amounted to 33,600,000 brl., less than half of the estimated capacity.

The 1941 exports are estimated at 21,700,000 brl., a further decline. Exports by overland routes during 1941 may have been 9,217,000 brl., more than double the 1940 figure.

Tables give data on the production, refinery runs, exports, and the quantities exported by various routes in different years. G. D. H.

829.* **Shell Opens Badly Needed New Field for Colombia.** J. V. Hightower. *Oil Wkly*, 27.7.42, **106** (8), 80.—During 1941 oil was found in Casabe 1 on the Yondo concession, which now has four producers. Elsewhere in the Magdalena Valley the wildcats were disappointing. Two producers were completed in the Tres Bocas and Socuavo areas north of Petrolea.

In 1941 the Colombian oil output fell by 4% to 24,423,551 brl. 84% of the total was from the De Mares concession, and 82% of the De Mares oil was from La Cira. 3,945,654 brl. came from the Barco concession and mainly from Petrolea.

Gas was found in Cimitarra 1, and a show of heavy oil. Tres Bocas 1 found oil at a depth of over 3000 ft., and Socuavo 1 found it at about 9100 ft. South Sardinata 1 gave a little oil before being abandoned.

The rate of exploration has been maintained during 1942.

Drilling and production data are tabulated and the concession bids and changes during 1941 are listed. G. D. H.

830.* Shrinking Exports Bring Drop in Mexico's Output. Anon. *Oil Wkly*, 27.7.42, **106** (8), 76.—Fourteen oil-wells, one gas-well, and fourteen failures were completed in Mexico in 1941. The oil production was 42,885,000 brl., as compared with 43,920,000 brl. in 1940. The 1941 domestic consumption was 28,075,000 brl. 5,920,000 brl. of oil were produced on the Isthmus. Three of the 1941 producers were completed in the Tampico-Panuco area, four in the Poza Rica–Mecatepec field, and seven on the Isthmus.

15,810,000 brl. of oil were exported to U.S.A. in 1941. Gasoline consumption in Mexico increased by 14·5% last year.

Production and drilling statistics are given for 1940 and 1941. G. D. H.

831.* Venezuela Sets Crude Production Record Before War Crisis Checks Exports. J. V. Hightower. *Oil Wkly*, 27.7.42, **106** (8), 52.—226,000,000 brl. of oil were produced in Venezuela last year, 10% more than in the record year of 1939. There were production increases in both the eastern and western areas, with 73% of the oil obtained from the west. Oficina had a rise of 59% to 24,500,000 brl. There was a big increase at Jusepin, and El Roble and San Joaquin had increases of 172% and 162%, respectively. In the west all the fields except Bachaquero showed rises, Tia Juana, Concepcion, and Cumarebo being outstanding.

The Santa Rosa field commenced production in 1941. Prolific production was found in the Periquito sand in Rincon Largo 1 at 8775–8790 ft. The Leona-Tigre field was developed during 1941. In Monagas the Santa Barbara field gives oil from depths of about 4200 ft. Mulata 1 gave gas from a depth of 4100 ft., and in January 1942 a producer, Mulata 2, was completed with oil at 4590–4751 ft. Quiamare 1 obtained oil at 7300 ft. on a well-defined east–west anticline. In Central Guarico production has been found in Mercedes 2, which has upper gas-sands and a lower oil-sand. Two further wells are being drilled in this area. In Eastern Guarico oil was found at Las Ollas, 30 ml. west of Santa Ana. Anaco 1 found oil at a depth of over 8550 ft. on a dome midway between El Roble and Santa Ana.

Development has continued in the same areas during 1942. The Mulata field now has seven oil-wells and two gas-wells.

Tables give production and drilling data, and the exports in 1941. G. D. H.

832.* War Pressure Stimulates Alberta Operations. F. K. Beach. *Oil Wkly*, 27.7.42, **106** (8), 99.—In 1941 Alberta gave 98% of Canada's oil output, and the bulk of this came from Turner Valley, where the drilling amounted to 376,676 ft., compared with 296,832 ft. in 1940.

In 1941 six wells were producing from the continental Lower Cretaceous beds at a depth of 2200 ft. at Wainwright. The terrace structure of Red Coulee gives oil from the Blairmore at a depth of 2500 ft. The Lower Cretaceous is also productive at Vermilion at depths of 1850 ft., but the field is patchy. At Princess the oil is in the Palæozoic limestone at 3200 ft. 20 ml. south of Princess oil was found at Tilley, but neither area is yet of much importance.

Turner Valley has been extended to the north by large producers, and it has also been extended to the south. Water at depths of 4300–4500 ft. below sea-level limits the field to the west. Forty-one producers were completed at Turner Valley during 1941, and they had average initial productions of 722 brl./day. All the wells are acid treated. In the first ten years of the development, vapour-phase oil was the principal objective, and 11,750,000 barrels of naphtha had been obtained up to the end of 1941.

Viking and Kinsella supply gas. During 1941 about 20,000 brl. of oil were obtained from the Athabaska tar-sands.

Drilling and production data are tabulated. G. D. H.

833. Fuel Power and the Soviet State. M. Edelman. *New Statesman and Nation*, 29.8.42.—A short account is given of the Russian plan, announced in 1938 by Molotov, for the establishment of a second Baku between the Volga and the Urals, which by 1943 is to produce 6,000,000 tons of oil—about 20% of the average production of the Caucasian oilfields. Workings have been started at Syzran, on the Volga, where a refinery has been established and connected by pipe-line to the cracking plant at Ufa, which now provides the Soviet's current reserve of aviation fuel; this being in addition to storage tanks in the Volga and Ural regions, unofficially estimated at over 6,000,000 tons.

The Ishimbayevo wells were yielding in 1938 more than six times the output of the Syzran fields, and lower-grade fuel is being produced in Kazakhstan.

This Volga–Ural–Kazakhstan region should produce over 5,000,000 tons of oil in 1942 if the Third Five-Year Plan has been fulfilled. M. G.

834.* Appalachian: Search for New Oriskany Gas Yields Few Results. Anon. *Oil Gas J.*, 30.7.42, **41** (12), 136.—In South-west Pennsylvania the Lower Devonian was tested on several structures without success, although there were oil- and gas-showings. On the Chestnut Ridge additional wells have been completed in the Onondaga and Oriskany, one of the Onondaga wells being gauged at 12,000,000 cu. ft. of gas/day. A well which entered the Helderberg found a large but rapidly declining flow of gas, probably from a fissure. Four gas-wells have been completed in the Injun and Fifty Foot sands of Fayette County, and east of Monongahela Township a good show of oil was found in the Big Dunkard, but it was cased off because of its remoteness from other oil production.

The Oriskany pool in Kanawha and Jackson Counties, West Virginia, seems practically to have been defined. Few of the wells have gauged less than 1,000,000 cu ft., and many are over 5,000,000 cu. ft.

A small oil-pool in the Big lime has been developed in the heart of the Oriskany field. A large gas-well has been drilled in the Buffalo district.

In western Lee County, Virginia, a small high-gravity producer was completed in the Trenton, and opens up for prospecting a narrow belt along the Appalachian Mountain front.

A summary is given of the completions during the first half of 1942. G. D. H.

835.* California: Discovery Rate Maintained but Added Reserves Small. L. P. Stockman. *Oil Gas J.*, 30.7.42, **41** (12), 94.—During the first half of 1942 California's crude-oil reserves were reduced by 53,000,000 brl., following on the 116,000,000 brl. reduction in 1941 in spite of the discovery of nine new fields. Although the rate of discovery has been favourable during the past eighteen months, with few exceptions the discoveries have been small. Little attention is being given now to Cretaceous possibilities which seemed to show promise several months ago.

A test in the Wheatville district of Fresno County flowed 186 brl. of 61·8 gravity distillate and 3,958,000 cu. ft. of gas/day from 8020 ft. A well is to be drilled at Yorba Linda, where oil and gas were indicated at a comparatively shallow depth in 1937.

It is estimated that about 2700 additional wells could be drilled in fields producing heavy oil.

230,700,000 brl. of oil were produced in the first six months of 1942—a greater quantity than has been produced in any six-month period since 1938.

The Bowerbank gas-field was discovered in 1942. It produces from the Pliocene Mya zone. Deeper drilling and extension work in the Elk Hills and Newhall Potrero fields have increased crude reserves in both areas. Miocene Stevens production has been proved at Elk Hills, and the Pliocene zone producing area has been extended. At Newhall Potrero, a well south of a cross-fault has proved an additional 400 acres in the Modelo.

Production statistics for the fields are given for six-month periods commencing 1939, and the completions in the first half of 1942 are tabulated. G. D. H.

836.* Canada: Exploration Blankets Wide Area in Western Provinces. V. Lauriston, *Oil Gas J.*, 30.7.42, **41** (12), 126.—Since 1920 three producing wells have been completed in the Fort Creek shales at Fort Norman. 53 ml. below Fort Norman seepages are known both on the upper Mackenzie River and near the Great Slave Lake.

In the Peace River block of northern British Columbia oil prospects are believed to be favourable, and two Alberta areas related to this block are potentially oil-bearing. To the east the Pouce Coupe structure is being tested. A large gasser was obtained, and several oil- and gas-shows have been found in later wells. The oil in the slightly tilted monocline of the Peace River field still farther east was drowned by big water-flows.

Plant capable of giving 540 brl. of oil/day is again in operation near McMurray, where the Athabaska tar-sand is the raw material.

The Priddis and Jenner structures are being tested in southern Alberta. Operations have been discontinued in the Steveville–Princess field.

A new field has been opened near Tilley. Strong oil-shows have been found in the Devonian on the Ram River structure. Cretaceous heavy oil is being pumped at Vermilion.

Turner Valley continues to be the dominant producing area, and drilling activity is the greatest in the field's history.

The well completions are tabulated. G. D. H.

837.* Clayton Pool Only Active Area in Ohio. Anon. *Oil Gas J.*, 30.7.42, **41** (12), 130.—101 oil-wells and 209 gas-wells were obtained out of a total of 469 completions in the first half of 1942, when activity was 38% below that in the same period of 1941.

A 40-acre spacing is being permitted for gas-wells in all horizons except the Onondaga, Oriskany sandstone, or Devonian shale horizons.

The proven area of the Clayton pool is now 4500 acres. A test 3 ml. south of the present pool has shown a little gas in the Clinton.

Only fair results have been obtained from Berea and shallower tests in proved fields. Tests are being made in search of stratigraphic traps on the western side of the Parkersburg syncline. The east flank of the Cambridge anticline is also being tested.

The Hinckley pool seems likely to be a major Clinton gas-pool, and one oil-well has been drilled. A 9,000,000 cu.-ft. gas discovery has been made in a Clinton sand-lens in Holmes County. In the prolific Brush Creek pool the gas completions have been below average. A gas-strike has been made in the Clinton in west central Vinton County at a depth of 2400 ft.

The well completions in the first half of 1942 are summarized. G. D. H.

838.* Drilling in the United States Falls Below Recent Levels. W. V. Howard. *Oil Gas J.*, 30.7.42, **41** (12), 76.—There were 3846 fewer completions in the first half of 1942 than in the corresponding period of 1941, and 2995 fewer oil-wells. The decline in drilling has affected nearly all areas except the eastern fields, Indiana and New Mexico. Gas development has declined notably. Much of the development drilling can be attributed to a few widely scattered new fields. Imposition of the 40-acre spacing rule has not affected normal practices in all areas. The tendency towards deeper drilling has been accelerated in the past half-year, resulting in a 10% increase in average depth.

Drilling has fallen off by 40% in Illinois as compared with the first half of 1941. The main activity in Arkansas–North Louisiana–Mississippi has been at Midway, the Pettit zone at Haynesville, and in the eastern part of the Wilcox trend surrounding La Salle parish. The results of recent drilling in Nebraska and the adjacent parts of the Forest City basin have not been encouraging. The small discoveries except in the southern part of the State are largely responsible for the 33% decline in completions in Oklahoma. A new small Woodbine fault-line field and a Paluxy discovery in the basin south of the fault have revived interest in the East Texas area. Recent discoveries in North Central Texas have been mainly small.

Lack of markets has restricted activity in South-west Texas and on the Gulf Coast, and while there are marketing difficulties in the Rocky Mountain area also, production has actually increased. Deep drilling has declined considerably in California, but the demand for heavy oil may cause many shut-down wells to be reconditioned.

A table compares by States the completions in the first half of 1941 and in the first half of 1942. G. D. H.

839.* Forest City Basin. Anon. *Oil Gas J.*, 30.7.42, **41** (12), 139.—Seventeen wells were completed in Nebraska in the first half of 1942, compared with forty-seven in the same period last year. Most of the wells were in the Dawson pool, which produces from the Hunton. A Viola test is reported to have swabbed some oil from a depth of 2922 ft., but water intruded after acid treatment. Another test in the Dawson pool showed stained Wilcox at 3230 ft., but, on testing, gave water only. The Viola and Simpson both had showings of oil.

A table gives well-completion data. G. D. H.

840.* Illinois : Intense Prospecting Uncovers Many Small Pools. Anon. *Oil Gas J.*, 30.7.42, **41** (12), 119.—The discovery rate of new fields in the first half of 1942 reached a higher peak than in the same period of any previous year. Total completions were nearly 50% below those for the first half of 1941. The number of oil-wells declined by 637 to 480. Oil production fell from 11,585,000 brl. in January to 8,429,500 brl. in June.

With the exception of Boulder, all the new pools are considered small. The first Boulder well was completed as a Devonian gas-well in 1941. Saturation was reported in the Benoist and Cypress, which were not tested. In April 1942 a large Benoist oil-producer was completed south of the discovery well. The new wells have not tested the Devonian.

Many new discoveries have been made in Wayne County, most of them being in a line with Dundas, Clay City, and Johnsonville. However, most of these fields are relatively unimportant, in spite of comparatively large discovery wells.

Few discoveries have been made, and there has been relatively little development this year in the Wabash River area, which yielded most of the new fields in 1941, although it has very good possibilities.

A summary is given of the well completions in the first half of 1942, and the half-yearly production is tabulated for the period commencing 1939. G. D. H.

841.* Indiana : Small Fields Found in Posey and Other Southern Counties. Anon. *Oil Gas J.*, 30.7.42, **41** (12), 130.—Not a single new field of major importance was discovered in the first half of 1942, in spite of widespread wildcatting. Out of a total of 207 wells only eighty were oil-producers, a considerably lower percentage of success than last year. 60% of the State's oil is obtained from the Griffin pool, which has had practically no development this year. This would have caused a marked drop in Indiana's production but for the output of Mount Vernon, discovered late in 1941.

Osage lime production has been found in the Hazleton area. New pools in Posey County were heralded by large discovery wells, but later tests either failed or gave small outputs.

Well-completion data are tabulated for the first half of 1942. G. D. H.

842.* Kansas : Interest Directed Mainly to South Flank of Barton Arch. C. Hoot. *Oil Gas J.*, 30.7.42, **41** (12), 91.—724 wells, including 148 wildcats, were completed in Kansas during the first half of 1942. Eighteen of the wildcats had an initial potential of 7046 brl. Cambrian production was obtained on a south-eastern extension of the Alberta–Otis structure in the Lamotte sand at a depth of 3551 ft. A few Arbuckle and Lansing–Kansas City wells were drilled in this area, but found little production.

In Reno County the new Peace Creek Viola lime trend was extended north-east and south-west, and the five pools along the trend were joined by producing wells into a single field. There has been rapid development of the Smyres pool on the eastern flank of the Central Kansas uplift. This yields oil from the Mississippian at about 3330 ft.

The Ray pool has extended Lamotte sand production into Norton County.

The production of the various fields is tabulated for half-yearly periods from the beginning of 1939, and summaries are given of the well and wildcat completions during the first half of 1942. G. D. H.

843.* Louisiana Gulf Coast : Spacing Rules Cause of Drop in Drilling and Discoveries. F. L. Singleton. *Oil Gas J.*, 30.7.42, **41** (12), 115.—Well completions fell markedly in the first half of 1942, due mainly to the 40-acre spacing rule, which has curtailed work around salt-domes. Activity has shifted to blanket sand fields which are generally assumed to be deep-seated salt-dome structures. Only four new fields were opened. At Ferriday gas-distillate was found in the Tuscaloosa at 8935 ft., but the well was plugged back and completed in the Wilcox at 4567 ft. Gas-distillate was found at Hayes at depths of 11,646 and 11,660 ft., and several other sands were logged. Salt at 10,005 ft. has been proved at West Bay field, which was discovered in 1940. This field yields oil mainly from Miocene sands at 6800–7400 ft. The Bay De Chene gas-field has been shown to be a salt-dome. Prolific Miocene production was found at 7470 ft. in an outpost test in the La Fourche Basin Levee district.

It seems likely that the Bayou Sale field will be joined to the Bateman Lake field.

Gas-distillate production in a new sand at 10,703 ft. was found in the extreme south of the former field. New sands were found at Delta Duck Club and Delacroix Island. New production was found on the flank of the old Leeville dome.

A summary is given of the completions in the first half of 1942, and the production of individual fields is tabulated for half-year periods from 1939 onwards. G. D. H.

844.* North Louisiana, Arkansas, Mississippi : Midway and Haynesville Keep Area in Spotlight. Anon. *Oil Gas J.*, 30.7.42, **41** (12), 140.—The discovery of Pettit production at 5500 ft. revived the declining Haynesville field, thus accounting for 75% of the North Louisiana activity.

The Midway field was opened by a 12,000–15,000-brl. well in the Smackover at −6032 ft., and a narrow north-west–south-east structure has been developed. The northern edge has been partly defined.

The east end of the Wilcox trend in La Salle and neighbouring parishes had considerable development in the first half of 1942, leading to the discovery of new fields at South Jena, Summerville, Trout Creek, and Willow Lake. The Ferriday test showed oil in the Tuscaloosa, although it was completed as a Wilcox producer.

Well-completion data for the first half of 1942 are summarized, and the production of individual fields is given for half-year periods commencing 1939. G. D. H.

845.* Michigan : Northern Sector Development Raises Production. O. C. Pressprich. *Oil Gas J.*, 30.7.42, **41** (12), 129.—Production during the first half of 1942 was 10,296,000 brl., compared with 6,849,000 brl. for the same period last year. The increase is due mainly to the development of Reed City and Headquarters, which gave over half the total oil.

The Reed City pool has been extended by nearly 1000 acres this year. Production has been found in the Monroe at Adams, and this has encouraged deeper exploration throughout the entire north-central basin area. Although no discoveries have yet been made, shows have been found. Evart seems to be the best discovery of 1942 so far. The Riverside play was short-lived.

Gas-well completions are at about the same level as in the first half of 1941.

The half-yearly production of individual fields is given from 1939, and well completions in the first half of 1942 are summarized. G. D. H.

846.* Oklahoma : Paul's Valley Find Opens Large Prospective Area. C. Hoot. *Oil Gas J.*, 30.7.42, **41** (12), 122.—The completions in Oklahoma during the first half of 1942 were almost 50% below the figures for the first half of 1941, and, due to the 40-acre spacing rule affecting the ratio of wildcats to exploitation wells, the proportion of oil-wells to total wells also fell in the first half of 1942.

On the northern flank of the Arbuckle Mountains, Wilcox production was found at a depth of 3900 ft., north-west of Paul's Valley. Favourable indications have been found east of the discovery well.

The most active areas were Hotulke and West Hotulke, which have now been united. Production is from the Viola, Hunton, and Second Wilcox. The Brooksville find has oil in the Hunton, Centerpoint oil in the Simpson, and McComb oil in the Hunton.

The Navina pool obtained oil in the Layton on the Nemaha granite ridge after finding the Wilcox dry.

The production of individual pools is given for half-year periods commencing 1939, and the completions in the first half of 1942 are summarized. G. D. H.

847.* Permian Basin, Panhandle : Major Pool Development Under Way in Andrews County. R. Ingram. *Oil Gas J.*, 30.7.42, **41** (12), 99.—A group of new pools in the south-western part of Andrews County seems likely eventually to coalesce into a single producing area. The fields involved are Embar, Mascho, and West Fuhrman, the first two being 1942 discoveries. Embar has both Permian and Ordovician oil. At Fullerton 640 acres have been proved in the Clear Fork below 7000 ft. Marketing difficulties have seriously curtailed drilling on proven acreage at Slaughter and Wasson.

Cambrian production has been found below the Ellenburger at Wentz in north-central Pecos County. Ordovician production has been found below 10,000 ft. in Eard County. A major deep field has been proved by four more 9000-ft. wells at

Barnhart. Ten other new areas or new sands were discovered in the first half of 1942, during which period the West Texas production fell by 15% because of transport difficulties.

No new producing areas were found in the Panhandle, where there are many undrilled but proven locations, and where 98% of the wells drilled gave oil or gas.

A production decline of 25% has taken place in South-east New Mexico due to reduced demand for oil there. A new producing area has been opened 7 ml. west of Tatum. About one-third of the total completions were in the Maljamar and Square Lake areas.

Well completions are summarized for northern and southern West Texas, the Panhandle and South-east New Mexico, and production data are given for each field for six-month periods since 1st January, 1939. G. D. H.

848.* Production for First Half of Year Approaches 1940 Peak. W. V. Howard. *Oil Gas J.*, 30.7.42, **41** (12), 74.—678,934,000 brl. of oil were produced in the first half of 1942, 17,491,000 brl. more than for the same period of 1941, but only 5,781,000 brl. less than in the first half of 1940. The Texas output declined by 2% in the first half of 1942, that of Oklahoma by 5%. There was a small rise in California, and also a rise in Louisiana and Kansas. Remoteness and consequent severe proration caused a 20% decline in New Mexico, whereas Mississippi attained an average daily output of 80,000 brl.

55·1% of the total oil is derived from the seventy-five largest fields. The major fields are listed, with the output in the first halves of 1940, 1941, and 1942, and cumulative production to the end of June 1942.

A table shows the trends of the major fields, and another table shows the output by States for the years 1936–41 inclusive, and for the first half of 1942. G. D. H.

849.* Reserves Added by Discoveries Do Not Balance Withdrawals. W. V. Howard. *Oil Gas J.*, 30.7.42, **41** (12), 54.—During the first half of 1942 reserves estimated at 367,870,000 brl. have been added by discoveries and extensions, and while this is 311,064,000 brl. less than the production in the same period, the deficiency is made good by the upward revision of proven reserves in older fields by 314,070,000 brl. The estimated reserves discovered are 257,836,000 brl. less than for the same period of 1941. The 1942 discoveries are less than those for 1941 in California, Texas, and the northern Mid-Continent, whereas the reverse is true in the Rocky Mountain area, New Mexico, Arkansas, and Louisiana. However, the Texas discoveries hold out promise of much greater additions in the near future.

The smallness of the amount of oil discovered is a reflection of the exceptionally small amount of development drilling, so that although numerically the discoveries and extensions are similar to those of previous years, lack of development has caused less to be added to reserves.

The first half of 1942 has opened up more new areas and new zones than any other recent half-year period. In Michigan new fields have been found on the north-west side of a belt trending north-east–south-west across the State, and in old fields there has been extensive deepening of wells to the Monroe. The Viola trend has been extended in Kansas, and oil and gas have been found in Pennsylvanian and Ordovician pays in Barber County well down the flank of the Barton Arch. Sweet oil has been found in the Smackover at Midway, opening up a large area which extends into Texas. There have been further developments in Wilcox production, and the Ellenburger production has been extended in West Texas, raising the hope that many Permian fields will also have oil in older beds.

A table gives by States the reserves on 1st January, 1942, reserves added by discoveries and extensions in the first half of 1942, and the production during the same period. G. D. H.

850.* Rocky Mountain Area: Drilling Operations Decrease; Two Deep Sands Found. T. R. Ingram. *Oil Gas J.*, 30.7.42, **41** (12), 134.—Colorado, Wyoming, and Montana had substantial decreases in completions during the first half of 1942 as compared with the same period of 1941, but North-west New Mexico showed an increase.

Four discoveries were made in Wyoming, those at Pilot Butte and Cody being deeper oil horizons, and those at South Elk Basin and Sherrard being gas-wells. At West

Kevin and Midway, Montana, small extensions were made to 1941 discoveries, but Colorado had no success with either of its two major wildcats.

Improved demands for heavy crudes led to increased production in all areas.

Development of the Hospah field in New Mexico increased drilling during the first half of 1942 as compared with the same period of 1941.

Most of the prospecting in the Rocky Mountain area, in spite of the existence of many untested structures, has been the drilling of deep tests on producing structures, many of which remain to be tested in the Tensleep and Embar, with the possibilities of the Madison and other pre-Pennsylvanian horizons in Wyoming and Colorado still practically unknown.

Well completions in the first half of 1942 are given, and tables show the production for half-year periods starting 1939, for all the areas except New Mexico. G. D. H.

851.* Eastern Texas : Black Oak May Start Paluxy Play in Middle of Basin. R. Ingram. *Oil Gas J.*, 30.7.42, **41** (12), 124.—The Concord discovery north-east of Montalba has had two dry holes, one 1500 ft. south-west of the producer, and the other 1 ml. north-west. Club Lake, a Woodbine discovery, has two further producing wells. Two dry holes drilled at Club Lake may be due to faulting. The Black Oak Paluxy production is the first in the Tyler–Woodbine basin south of the fault system.

When Smackover production was found north of the fault system at Midway in southern Arkansas, there was much leasing along a line a little north and west of the Balcones fault system.

A summary is given of the completions during the first half of 1942, and a table sets out the production of individual fields during half-year periods commencing 1939. G. D. H.

852.* North Central Texas : Ordovician and Mississippian Pays Found Over Wide Area. R. Ingram. *Oil Gas J.*, 30.7.42, **41** (12), 131.—During the first half of 1942 several Mississippian lime discoveries were made, in addition to finds in the Ellenburger and Simpson. In the Simpson oil was found east of Bowie at a depth of 7200 ft. Ellenburger production in the south-western part of K.M.A. continued to dominate development. Near Post Oak, in Jack County, Ellenburger production was found. Marble Falls production at a depth of 7173 ft. was obtained east of Forrestburg after a well had failed to find oil in the Ellenburger.

Among the wildcats there were eighty-seven dry holes and thirteen discoveries.

Production and well-completion data are tabulated, the former being for half-year periods beginning 1939 and the latter for the first half of 1942. G. D. H.

853.* South-west Texas : Discoveries Increase Despite Drop in Exploratory Drilling. F. L. Singleton. *Oil Gas J.*, 30.7.42, **41** (12), 103.—Fifteen fields were opened in South-west Texas during the past six months, when 631 wells were completed. Probably the most outstanding feature was the expansion of Wilcox development along the old Jackson shore-line trend. The first Carrizo production was opened at South Caesar at a depth of 6552 ft., with a second sand at 6611 ft. A gas-distillate producer was completed at Yorktown in the Wilcox at 7192 ft., with a second distillate producer in the Wilcox 11 ml. to the south-west and at 8300 ft. There has also been up-dip development of the Wilcox, the play having extended into part of the old Balcones fault-line district. Activity has been curtailed around the Agua Dulce–Stratton field due to the 40-acre ruling and sand irregularity. The Seeligson field has been extended to the south-west, adding several million barrels of oil to the reserves. In the east a new sand has been found. The Frio may be the producing sand in two new fields in Jim Wells County.

In the Laredo district development was largely concentrated along the Frio-Vicksburg trend. Five new pools were found, two being gas-distillate producers.

Well completions in the first half of 1942 and production data for six-month periods starting 1939 are tabulated by fields. G. D. H.

854.* Texas Gulf Coast : Greater Penetration of Wilcox Finds Important Fields. F. L. Singleton. *Oil Gas J.*, 30.7.42, **41** (12), 111.—The Mercy structure on which Wilcox production has been found at 8273 ft. appears to be of considerable size. On the east side of the Lake Creek field a gas-distillate producer has been completed at 11,700 ft. This is the fourth Wilcox sand to be found productive, the others being at 9200, 9700, and 10,300 ft. The top of the Wilcox is at about 8500–8600 ft.

There are now few Cockfield sand-pools along the trend in which Wilcox production has not been found.

Production from the Frio at 5300–5400 ft. has been found in three new fields—Mayo, Harmon, and West Mauritz—in Jackson County. A second sand has been opened at 5600 ft. at North La Ward. This sand appears to be a blanket sand.

None of the Wilcox areas opened recently has been fully developed, because the market cannot handle the added oil.

The production is tabulated by fields for six-month periods commencing 1939, and the well completions in the first half of 1942 are summarized. G. D. H.

855. Neutron Logs Find Porous Zones in Western Kansas Limestones. W. L. Russell and R. B. Downing. *Oil Gas J.*, 6.8.42, **41** (13), 66.—In western and central Kansas electric logs do not indicate the porous producing horizons of the limestones and dolomites with sufficient accuracy.

Neutron well-logging consists of subjecting the rocks around the well to a penetrating bombardment with artificially produced neutrons, and measuring the effect by means of an ionization chamber some distance above the neutron source. The response of the ionization chamber depends primarily on the amount of hydrogen-containing substances in the rocks—*i.e.*, on the amount of oil or water—and since these generally occupy pores, the response is often a measure of the rock porosity. However, chemically combined water in limestone or shale will also affect the ionization, thus giving misleading indications regarding porosity.

Neutron logs can be made in cased holes. If neutron logs are used in conjunction with radioactivity logs, it is possible to pick out shale horizons which give misleading porosity indications. While neutron logs at present do not show the nature of the fluid content of the pores, they do yield data about the depths, thicknesses, and continuity of the various porous rocks, which may be helpful in deciding whether oil, gas, or water is likely to be present.

The neutron and radioactivity logs of two wells are appended, and their indications are discussed. G. D. H.

856. Permian Basin Productive Area Shows Continuous Expansion. R. Ingram. *Oil Gas J.*, 6.8.42, **41** (13), 67.—The Permian Basin of West Texas and South-east New Mexico is 800 ml. long and 300 ml. wide. In the northern West Texas sector the two main geological features are the Central Basin platform, and the Midland basin which extends to the Bend Arch. Important production has been developed on the platform and in the eastern part of the basin, but during the last few years activity has been centred on the fields on the east and west edges of the platform.

The first West Texas production was found at Westbrook in the Midland basin in 1920. Not until 1925 and 1926 did development spread throughout the district, and except for the Snyder pool discovered in 1937, this accounted for most of the major development to date in the Midland basin. The Lubbock pool found in 1941 may be in the basin, or possibly on the eastern rim of the platform, if the platform turns north-east at Slaughter.

During the first half of 1942 there has been drilling at Sharon Ridge, at Welch, and in the Iatan-Denman district in addition to the Central Basin platform, where 440 wells were drilled. 313 were at Slaughter and fifty-one at Wasson. The Deep Rock–Fuhrman–West Fuhrman area has been developed into a big field. Midway between North Cowden and West Andrews production has been found in the Permian and Ellenburger at Embar, foreshadowing a link with West Andrews. In the northern district the Ordovician has been tested without success in three fields, but the Embar Ellenburger discovery is likely to increase Ordovician exploration in that district. Some believe that the Ordovician highs are much smaller than the Permian highs, and that two, three, or more Ellenburger structures may underlie the big Permian fields.

A map shows the fields of northern West Texas, and the 1942 discoveries are tabulated together with the producing fields, with information on discovery date, number of wells, production, depths, pay thickness, etc. G. D. H.

857. Trenton Strike Gives Western Illinois Area New Life. E. Sterrett. *Oil Wkly*, 3.8.42, **106** (9), 17.—Another Kimmswick lime (Trenton) pool has been opened on the edge of the Eastern Interior Basin. The discovery well, which is near St. Jacob, is 2353 ft. deep, and in an area where there have been many dry Trenton tests. Previously the Trenton had produced commercially on the western edge of the basin only along the crest of the Waterloo–Dupo anticline.

The first Trenton production in Illinois was discovered in 1910 at Westfield, on a dome on the axis of the La Salle anticline. In 1920 the first western edge production from the Trenton was found at Waterloo. Dupo, the third Trenton producer outside the Illinois basin, is also along the crest of the Waterloo anticline. Both Waterloo and Dupo had over 100 ft. of closure and 50 ft. or more of saturated reservoir rock near the top of the Kimmswick. The closure at St. Jacob is not yet known.

The St. Jacob discovery makes it desirable to re-examine the well logs and to make new tests in Monroe, St Clair, and Washington Counties east and south-east of the Waterloo–Dupo pools ; in Bond, Clinton, and Fayette Counties slightly north of east from St. Jacob ; and in the south-east quarter of Macoupin County.

Cores from the Dupo field show the Kimmswick to have an average porosity of 14%, and an average permeability of 7·7 millidarcys. The St. Jacob crude has a gravity of 40·9° A.P.I.

A contour map on the base of the Kinderhook–New Albany, and electrical logs of the St. Jacob well are included. G. D. H.

858. Typical Oilfield Structures : Salt-Dome ; Esperson and Barbers Hill, Coastal Texas. Anon. *Oil Gas J.*, 6.8.42, **41** (13), 42.—Salt-domes occur in the coastal plain from the Mississippi to Jackson County, Texas. The formations of the plain outcrop in bands roughly parallel to the coast, and range from the Lower Cretaceous to the Pleistocene. Some beds change from continential to marine towards the coast. Although there are many sands, unconsolidated clays form the bulk of the section. The regional dip is gently coastward, with some reversals which may be due to deep-seated salt-domes. In addition there are piercement and non-piercement salt-domes. The salt may be steep-sided or overhanging. The anhydrite caps are believed to be residual, and a Jurassic age is assumed for the salt.

Oil may occur in supra-cap sands, in the cap-rock or in flank sands, the age of the producing beds ranging Pliocene to Wilcox. The producing sands are often lenticular, and the oil in the supra-cap and flanking sands may be indigenous to the pay-horizons.

Salt-domes occur also in the interior of Texas and Louisiana, and in Germany and Roumania.

The early salt-domes were found by surface features, but later the torsion balance and refraction seismograph were the chief means of discovery. Now the latter have been superseded by the gravimeter and the reflection seismograph. G. D. H.

Drilling.

859.* Procedure for Use of Drilling Lines. R. B. Southworth and H. J. Kelly, Jr. *Petrol. World*, April 1942, **39** (4), 28–31.—Determination of the length of line to be purchased depends on the height of the derrick, number of lines up, type of standby or tiedown unit, and the capacity of the draw-works drum. The total length of line in the system having been calculated, the authors suggest that a length between two and three times the length of line in the system be purchased. This may be determined by plotting the total length of line against the coat/unit wear, assuming there is one unit wear for every foot of rope moved through the system, and comparing the decrease in the cost/unit wear as the total length increases, against tho probability of damage occurring to the line. As there is no way to positively determine this probability, it will have to be left to the judgement of the purchaser.

A procedure is laid down for the determination of the rate at which the line is to be moved through the system. This determination is made from a careful calculation of the work done by the rotary drilling line on similar wells already completed, coupled with a careful consideration of the total amount of work it is possible to put on a wire line of given length in this type of service.

The possibilities of this procedure are quite broad. It will give definite information on how lines, moved in accordance with the procedure, performed, and will enable an operator to increase his rate of movement to any definite objective. Eleven curves are given. The first three deal with the determination of the most efficient length of line to purchase; the other eight are ton-mile depth-curves with points at which round trips were made spotted on them. These are average curves from various California fields. The size of drill-pipe generally used in drilling in these fields and the value of the $M + c/2$ factor used in calculating the work done by the wire line are shown on the curves. An example is worked out. A. H. N.

860.* World's Largest Power Rig in California. E. Timbs. *Petrol. World.* April 1942, **39** (4), 32.—The drilling rig described is the world's largest "power rig," or "spark-plug rig," and is being operated in California by the Superior Oil Co. It was designed and built for deep drilling, and incorporates hydraulic couplings to engage flexibly the power from each of the engines to the drive-shafts to supply the total power available for the draw-works and mud-pumps.

The rig consists of a National Type 125 Consolidated Rig, with four Waukesha engines and a National Type C–350, $7\frac{1}{2} \times 18$, and one C–250, $7\frac{1}{4} \times 15$ power-pump hooked up to two Waukesha engines, each with drive equipment mounted on the engine skids. Portable steel mud-tanks with Overstrom mud-shakers are included in this arrangement. The mud-lines to and from tanks and pumps are assembled so that the pumps may be operated either with straight discharge to drill-pipe, or compounded through the second C–350 pump when higher fluid pressures are required. Also, when greater volume of mud is required, both C–350 pumps can be operated in parallel, so that the combined fluid capacity can be discharged to the drill-pipe.

The draw-works unit is a National Type 125 which has a hoisting capacity of 680,000 lb. when using 8-line reeving and line-speeds from 270 to 3150 ft./min., plus an extra line speed of 3900 ft./min. for handling empty blocks. The Type 125, consolidated rig is rated for 12,000–13,000-ft. drilling with safety. The draw-works is described in some detail. The controls are placed for convenience.

The American Blower type of hydraulic coupling used on this rig is one in which the output speed and power are controlled by means of a scoop-tube, which by manipulation from an outside lever can be set in any position, from full dip to fully retracted. The hydraulic coupling consists fundamentally of three main elements: the impeller, the runner, and the enclosing cover, plus an outer rotating oil reservoir, a fixed manifold, and the adjustable scoop-tube. With the control of the scoop-tube from the outside, the amount of oil required to pass through the working chamber to give a determined amount of power and speed is picked up by the scoop from the outer rotating reservoir. The impeller which is formed in the cover is attached to the engine-shalf and the runner to the driven shaft. The impeller and runner are radial-vaned, but not in actual face contact with each other, and are so arranged that the impeller delivers its kinetic energy to the runner at a constant torque. The scoop, when set in any of the various positions, changes accordingly the amount of power to be delivered to the driven shaft. The control of the coupling power and speed output is particularly important when fishing, and very essential when compounding the slush-pumps.

The slush-pump unit is described in some detail. A. H. N.

861.* Casing Unloaded More Efficiently and Safely with Portable Crane. G. M. Wilson. *Oil Wkly*, 18.5.42, **105** (11), 14.—Unloading and stacking of a carload of casing in only 2 hrs., a job which formerly required at least 5 hrs., is typical of the savings being realized by a major company through use of a portable cantilever boom-crane. Unloading, and if necessary shifting of cars on the track, is accomplished by remote control from a centrally located double-drum hoist, the cable being run through a unique and efficient unloading head located beside the track to permit unloading on either side of the hoist. The crane is described and illustrated photographically. The boom is of all-welded cantilever construction, the arm or rigid section being 30 ft. long and set at an angle of approximately 45°. It was designed so that, with the crane snubbed up against one side of the railroad car, the top sheave would be slightly beyond a point directly above the opposite side of the car. Over-all clearance between the ground and the top of the sheave is $25\frac{1}{2}$ ft.

The principal members of the boom are of 3-in. tubing, and the cross-bracing sections of 2-in. Distance between the anchor or base and the boom support is 9 ft., and from there to the top sheave is 21 ft.

Of particular interest in connection with the smooth operation and control of the combined units is the specially designed unloading head. Inasmuch as the direction of travel of the cable must be turned through 90° for the cable to approach the crane parallel to the track, some type of head, preferably removable, had to be devised which would permit the cable to pass under the tracks. The unloading head is described in detail.

Numerous advantages, from the standpoint of both safety and economics, have resulted from the use of this unloading crane. Unlike a gin-pole, this crane does not require that the pipe be swung up and carried over the heads of some of the ground men, with the resulting hazards accompanying such an operation. At no point does the unloading operation require any of the men to expose himself to hazardous positions. Portability constitutes another advantage. A. H. N.

862.* Convenience and Safety Feature Portable Tool-Box Trailer. G. M. Wilson. *Oil Wkly*, 25.5.42, **105** (12), 15–16.—Considerable time and effort are being saved by the well-connection gangs and field crews of one company through use of tool-box trailers which can be towed to the job, parked in a location handy to the crew, and picked up in the evening by the truck, thus leaving the truck free to move to other parts of the field during the day.

Measuring approximately 43 × 72 in., the body of the box is of all-welded, $\frac{1}{8}$-in. steel construction. It is mounted on a pair of automobile wheels, complete with leaf-type springs. The tow-bar is a length of 3-in. pipe, amply reinforced with angle iron braces. To provide easy access to the interior of the box, the top was designed with a peaked-roof construction, with each of the two sides or covers, being hinged at the ridge-pole. Over-all height of the box itself at the peak is approximately 32 ins. and the sides are 14 ins. high. Full details are given. A. H. N.

863.* Special Arrangement of Mud Systems Necessary on Drilling Barges. G. B. Nicholson. *Oil Wkly*, 1.6.42, **105** (13), 19.—In a long paper a detailed account of the mud system used in drilling from barges is given. Principal mud-handling equipment is centralized on the middle deck. In typical barge installations, mud returns leave the casing by one flow-line, although in many cases a double line is used; and returns are transported to one side of the barge through 4-in. or 6-in. flow-line pipes and carried to the shale-shaker. Many rigs are equipped with two shale-shakers, while degassers are often used.

Fluid mud leaving the shaker drops into a settling chamber placed immediately below, while cuttings are segregated for disposal. Settling chambers are deep-bottom steel boxes about 8 ft. long, erected to remove sand and other solid particles from the mud before it is turned into the slush-pits. Mud enters the boxes at one end and flows over baffles to reach adjacent compartments. The chambers have two or three such compartments, separated by baffles, and flow through them is restricted to overflow, with the result that there is little disturbance and the period of quiescence allows sand to settle. Mud leaves the box by overflowing into the mud-ditch, which is attached to the upper section of the last compartment and receives only surface fluid from the top of the chamber.

Settling chambers are usually manipulated according to particular requirements, with baffles removable or adjusted to desired height and spacing. Trap-doors opening to the outside are provided for cleaning, with water-tight fittings to prevent leakage of mud. Accumulated sand and solids are removed through the doors. Mud-circulating systems are similarly detailed. Disposal of cuttings and transportation of mud are discussed, and special problems are analysed. A. H. N.

864.* Portable Basket Improves Moving of Derrick Parts. Anon. *Oil Wkly*, 1.6.42, **105** (13), 17.—As finally constructed, the equipment for moving a derrick consisted of three units or baskets built of reclaimed tubing and sucker rod, and collectively capable of carrying the entire structural parts of a derrick, with the exception of the (usually) unitized substructure beams and the heavy water-table, these being handled as before by means of winching to place on the truck-bed.

The basket, welded throughout, is provided with one side rigidly fixed at 90° to the base, the side being braced with diagonal crossed strips to prevent sagging under load. The opposite side, also braced for structural rigidity, is affixed to the side of the base by means of loops formed in the vertical braces, so as to allow this side to hinge about the rail and lie flat to facilitate stacking or removing of the derrick members from the basket.

This drop-side eliminates the need of lifting heavy derrick parts over the side, and possible damage through their being dropped on to material already stacked. Both sides are equipped with lifting bails, hinged to permit closure above the lead, and into which a winch-line or crane-hook may be inserted to provide a straight lift. A. H. N.

865.* Fluorescence Analysis Reaches Practical Development Stage. F. B. Taylor. *Oil Wkly*, 22.6.42, **106** (3), 27.—Analysis of drilling muds by fluorescence is described. When ultra-violet rays strike an ordinary atom and the energy of the rays are absorbed, an electron assumes a new orbit about the nucleus ; the new orbit due to the additional energy being of greater diameter than the original orbit. In such circumstances an unnatural condition obtains and the atom is unstable. In regaining its stability, the excited electron leaves the orbit into which it was forced and returns to its normal orbit. This transition releases energy in the form of light. The entire process is fluorescence.

Types of lamps used are described, together with the apparatus for viewing samples. Roughly, crude oils fluoresce in accordance with their gravities. A distillate may show practically no glow, or possibly a thin blue. From here the emitted colour under the lamp grades down through blue and opalescent blues in the medium-light gravities to yellow in the medium-heavy gravities and to yellowish-brown, brown, and to a brown tinged with green in the very heavy-gravity group. In an Arkansas well a heavy-gravity dead crude was recovered that exhibited no fluorescence until cut with a solvent, when it showed a brick brown. Refinements of analytical technique are discussed. The difficulties of differentiating between crudes in the mud and oils or greases from the rig are indicated. A. H. N.

866.* Auxiliary Hydraulic Hoist Facilitates Handling of Casing and Drill-Pipe. Anon. *Oil Wkly*, 29.6.42, **106** (4), 14–16. An efficient hydraulically operated catline hoist for handling drill-pipe and casing around the derrick is used by a major company operating in West Texas. The hoist can be quickly and easily installed above the V-door in almost any type of drilling derrick with but a small amount of additional reinforcing of the girts. The simple hoist-control valve is conveniently located on the floor beside the V-door.

Outstanding advantages of this hoist include : elimination of certain hazards on the derrick floor that exist when the cathead is used for hoisting and towing services ; reduction of fatigue of floor-men and drillers ; increase in speed of handling drill-pipe and running casing ; decrease in catline wear ; and facilitation of handling of miscellaneous pieces of heavy equipment, since inactivity of the draw-works permits normal conversation between men above and beneath the floor. The patented device is described in detail. The maximum possible lift of the hoist is calculated to be about 3000 lb.

Desirable features, largely pertaining to the design and construction of the hydraulic unit, include : (1) elimination of freezing difficulties, since the cylinder is self-draining ; (2) retraction of the piston is automatic, eliminating the need of external aid ; (3) packing-glands are completely eliminated ; (4) the hoist unit is integral with the derrick, making unnecessary extensive alterations when the derrick is skidded, and a minimum of dismantling if the derrick is torn down ; (5) convenience and size of control unit are such that it may be placed at any suitable out-of-the-way point on the derrick floor, although it is advisable to place it as near as possible to the V-door ; and (6) with the exception of the wire line and rope, all forces are under compression. A. H. N.

867.* Power Take-off from Truck Speeds Field Threading of Large Pipe. G. M. Wilson. *Oil Wkly*, 29.6.42, **106** (4), 34.—A saving of two-thirds in the time usually required for field threading of larger sizes of pipe is regularly being realized by the field-construction departments of a large company. Instead of having the men cut such threads by hand, a mechanical method is used that employs a power take-off from the rear axle of the service truck. The apparatus is described.

A typical instance of the time being saved is shown in the cutting of a 4-in. pipe-thread. A 4-in. pipe-thread that formerly required up to 15 mins. time, and at least two men, is cut now in only 5 mins., and except for the handling of the heavy pipe, seldom requires more than one man to attend the machine. Not only in time saved on the actual cutting process, but some of the men usually required on the cutting jobs are now free to work on other phases of the field job. A. H. N.

868.* Portable Drilling and Servicing Units and Steel Conservation. J. Moon. *Petrol. Engr*, May 1942, **13** (8), 42.—It is estimated that approximately 90,000 tons of new steel derricks were used in 1942 and left standing over the holes of nearly 10,000 wells. The basis of the estimate is given.

Permanent derricks are used only a few times a year, the average being less than 1% of the time. The rest of the time they stand idle, and thus " tie up " thousands of dollars in steel and capital. On the basis of this idea, a portable 84-ft. telescoping derrick was designed in 1938, and was so successful in use that it was soon followed by other designs in different heights and capacities. Now, after several years, there is a wide variety of portable derricks, both for drilling and servicing. They are mounted on truck, trailer, or skids. Their adoption has led to the reduction or elimination of the permanent derrick, thus effecting a large economic saving for the oil industry. These remarks are elucidated.

Of several types of portable derricks now on the market, one of the popular types is designed for servicing wells to 11,000 ft., and has a 90-ft. two-piece telescoping derrick, mounted either on truck or trailer, which is usually built especially for the hoist and derrick installation to make a complete well-servicing or drilling machine. This complete machine includes draw-works, hoist, transportation, derrick, engine, crown block, raising mechanism, electrical equipment, and line, and in some cases a rotary-drive attachment. The machines travel with blocks strung and carrying their own guy-lines. Moving the equipment into position, raising, locking, and guying the derrick required from 30 mins. to 1 hr., a figure comparable to that required to move into a regular permanent derrick with a portable hoist and tie on to the pulling line or string the sand-line. Raising the portable derrick is done by the power supplied and built into the equipment, and requires no help from outside sources. The blocks are left permanently strung and the guy-wires remain attached.

Further to increase the usefulness of this type of equipment, it is available with a rotary-drive attachment, making it suitable for exploratory drilling, for shallow-production drilling, for medium-depth " slim-hole " drilling, for deepening, clean-out, and for following up big rotaries. These units are also used for all servicing operations in connection with the repair and maintenance of oil-wells. The rods are hung and the tubing is stacked in a manner similar to that in regular derricks. A typical example of the usefulness of these units is the experience of a drilling contractor in Texas, who in one year with one of these rigs, worked on fifty-eight wells, including sixteen clean-outs, eleven deepenings, ten rotary follow-ups, and twenty-one jobs of running tubing. Moves in excess of 100 miles and rig-up the same day were not unusual.

Other examples are given. A. H. N.

869.* Automatic Instrument Aids Mud and Well Control. J. B. Warren, Jr. *Petrol. Engr*, Annual Number, 1942, **13** (10), 76.—The importance of mud control is emphasized. Mud records are briefly described, in particular density records. Many wells get out of control while coming out of the hole. This is due either to " swabbing " or failure to keep the hole full as the pipe is withdrawn. The safest practicable method of detecting whether " swabbing " is taking place, and keeping the hole full at the same time, is to run the " fill-up " pump slowly until the hole overflows, shut the pump down, and after a short interval repeat the procedure. An experienced man on a drilling rig can then tell whether the hole is " taking " mud as it should. If the amount of mud that the hole is taking is in correct relationship to the speed with which the drill-pipe is being withdrawn, then the hole is not being swabbed and the danger of a blow-out is minimized. Simple as this operation appears, a little observation on various rigs will prove that this accepted method is not always followed. The reasons are simple : either the crews purposely let the mud-level in the hole go down so that a "dry" string of pipe can be pulled, or the man operating the fill-up pump intends to avoid the trouble of starting and stopping the pump so often. Consequently, the pump is set to run at a speed at which it can be left to run continuously; hence it is not possible to tell with any degree of accuracy where the mud-level is, whether the mud is running over, or what proportion of the fluid is going into the hole. The importance of this should be stressed to the men, and in addition some method or check provided to assure carrying out of the proper procedure.

There is a need for more advanced practices in mud handling and greater education of the man on the rig regarding the importance of accuracy and thoroughness. From observation and study of the methods now used, the writer believes that a third of the weighting material used is wasted, that three-fourths of the blow-outs could be prevented, and that half of the various troubles could be eliminated by employing the caution and thoroughness any other business would employ when similar expenditures are involved. A. H. N.

870.* Drilling in Swamp Area of Louisiana Gulf Coast Simplified by Use of Barges. C. C. Pryor. *Petrol. Engr*, Annual Number, 1942, **13** (10), 122.—The barge described has been employed in drilling both in open water in the bays along the Gulf of Mexico and in swamp-lands. This barge is typical of the wide improvement that has been attendant on deeper drilling where heavy equipment operating under the severest of conditions is utilized. Unusual features of the barge are its large size and the compactness and accessible arrangement of equipment.

The main unit of the rig or drilling barge consists of two barges, 10 ft. deep, 145 ft. in length, and 32 ft. in width. When over the location for a well, the two barges are situated one on each side of two rows of six pilings, marking the location of the well. The barges are then joined by two transverse trusses. After being joined, the two barges are sunk to the bottom, forming a level platform of more than 10,000 sq. ft. The structural steel framework on the barges is covered with $\frac{1}{2}$-in. welded-steel plate on the sides, and $\frac{3}{8}$-in. plates on the bottom. The deck is of $\frac{5}{16}$-in. plate. Each barge is divided into six compartments, which are flooded to sink the barge on location. This compartment-type construction is typical of marine vessels, guarding against the entire barge being sunk when the plates of one compartment are ruptured. It is not generally necessary to prepare a level setting for the barge. Most locations in dredged canals, lakes, and bays are suitably near level. The weight of the barge usually displaces the silt in settling on the bottom, preparing its own level setting; however, should listing occur, lightening the proper number of compartments will level the barge-deck. Further details of the barges and of the equipment used are given. A. H. N.

871.* Mud-Analysis Logging in California Fields. W. A. Sawdon. *Petrol. Engr*, Annual Number, 1942, **13** (10), 48.—The equipment is housed in a trailer. Briefly it consists of a depth-meter that indicates the total depth of the hole and the location of the bit in relation to bottom; a pump-cycle counter and meter showing the rate at which the pump is operating in cycles/min.; a gas detector, and an ultra-violet light apparatus for oil detection. A sclerograph, operating in connection with the depth-meter, records the drilling rate, instrumental gas readings, pump-cycle counter readings, and power applied to the rotary table. Also included in the trailer is complete core-analysis equipment for determination of permeability, porosity, and residual fluids of any cores that may be taken. Electrical equipment employed is operated by 110-volt, 60-cycle alternating current, and when direct current is being used on the rig it is converted to alternating current by a motor-generator set mounted in the trailer.

During drilling the bit drills-up and disintegrates a circular core of the formation, and the gas, oil, or salt water contained in the pore spaces of this core are picked-up by the drilling fluid. By analysing continuously the fluid on its return to the surface and correlating for depth, the gas, oil, or salt content of the formation at the point drilled can be determined. Due to the salinity of the mud fluid generally used in California, accurate determinations of salt-water content of the formation are difficult to make, and it has been the practice in California to confine the logging to gas and oil determinations.

Logging and typical logs are described and analysed. Detection of oil and gas in the mud is particularly studied. It appears from results obtained that mud-analysis logging provides reliable qualitative data on oil and gas saturation of formations drilled. As with other subsurface information, the results should be evaluated in connection with all other data obtained. A. H. N.

872.* **Rate-of-Penetration Record Facilitates Drilling.** W. A. Sawdon. *Petrol. Engr*, Annual Number, 1942, **13** (10), 71.—A combination record of factors in well drilling is described. The device providing the combined chart consists mainly of a weight indicator, tachometer, mud-pressure and torque gauges, and a kelly altmeter. The kelly altmeter shows the feet up on the kelly, and is connected to the recorder to give the rate-of-penetration graph. The recordings of each of the factors are made on an electrically-operated strip chart on which the five records are traced continuously while drilling. The recorder is mounted in a steel box with the indicating gauges, the recorder being placed to the right of the gauges so that it can be observed most conveniently by the driller. The assembly is installed at the driller's position.

The co-ordination of drilling operations provided by the chart for greater overall efficiency begins with the driller. The record is passed from driller to driller, the data are available for inspection of the tool-pusher and superintendent at any time, and the chart can be used by the engineer and geologist either during the drilling of the well or at a later date. Relative hardness of formations is indicated by the graphs, aiding in correlation work.

A specific example is described in detail. The applications of the combined chart are discussed. In slim-hole drilling when close control is more essential than in conventional drilling operations, the data provided by the five graphs should be valuable. When drilling wildcat wells, the records can help greatly in subsequent wells. The data can guide in selection of the bit and in determining when it should be changed. If it is known that the bit is about to enter a soft formation, a round trip may be saved. Whether in a wildcat well or not, a careful opinion of the condition of the bit when changed should be noted on the chart together with other bit data.

As the rate-of-penetration curve when evaluated with the other drilling factors indicates a change in formation, it should aid materially in correlation work. In addition to breaks and markers, it should also pick up faults. In one well where it was used a break was indicated when other records showed no indication of such a change. Action was taken on the basis of this information and, although details were not released, it is known that further data were obtained that verified the presence of the break. A. H. N.

873.* **Rotary Pressure-Drilling Practice.** E. V. Foran. *Petrol. Engr*, Annual Number, 1942, **13** (10), 44.—The primary object of pressure drilling is to control the circulating pressure on the bottom of the hole for the purpose of either suppressing or increasing the tendency of the well to flow. The control of such operations may often extend through a range sufficient to cope effectively with a potential high-pressure blow-out or to " drill-in alive " when making a completion in a producing horizon of subnormal pressure. It is apparent that to attain such objectives, equipment other than that conventionally used in rotary drilling will be required. A method of application suitable to local conditions must also be applied in conjunction with the particular drilling equipment used. Pressure drilling is not limited to depth, the records revealing that it has been carried out under prevailing conditions at depths from 3000 to 12,000 ft. Equipment and methods of pressure drilling are described.

Certain applications to which pressure-drilling equipment is most favourable are limited to consolidated formations. " Live-well " completions must be restricted to formations of the consolidated character, due to the fact that at times the pressure maintained on the bottom of the hole is less than the prevailing pressure within the productive formation. Any attempt to drill-in with a bottom-hole circulating pressure less than that existing in the formation in the case of an unconsolidated sand is certain to end in failure and difficulties the risks of which do not justify the attempt. In consolidated formation there should be no difficulty encountered in drilling ahead " alive " after the casing has been set and cemented. Any effort to drill-in " alive " before setting the casing would be extremely hazardous, and most likely would result in failure. While drilling " alive " through high-pressure formations, the amount of circulating water may be greatly reduced, probably in the amount of 75 brls./hr., in which case any section of the producing zone having good permeability will produce freely and may require some back-pressure restriction at the surface. The water-and-oil or water-and-gas condensate may be readily separated on the surface through a high-pressure separator with a minimum of cut oil resulting.

Pressure drilling in wildcat wells is described. A. H. N.

874.* Application of Magnetic Method of Deflecting-Tool Orientation. B. Weiss, Jr. *Oil Gas J.*, 25.6.42, **41** (7), 92.—Earlier methods of bit control in directional drilling are briefly mentioned. An illustration gives the present method of magnetic orientation of tools in bore-holes. The inclination unit of a small-size single-shot instrument is temporarily replaced by a second compass unit. The single shot is then lowered through the drill-pipe until it rests in its proper position in a non-magnetic sub near the bottom of the drill-string. The second compass unit in the single shot comes to rest opposite two small bar magnets fixed in the walls of the non-magnetic sub. The photographic record which is made superimposes the position of the second compass unit upon the record of the regular compass card of the single-shot unit. This record establishes the true directional position of the two bar magnets in the non-magnetic sub, and the orientation can then be completed by considering the relative azimuthal position between the face of the deflecting tool and the North attracting magnet in the non-magnetic sub. This latter relationship is measured on the surface before the assembly is lowered into the hole. An example is worked out in full to illustrate the use of the tool. Details of the development of the tool are given.

It is noted that on completion of the orienting procedure it is possible to take a second or check single-shot survey to confirm the orientation of the whipstock. These check surveys were actually made for the specific purpose of determining whether or not the rotating procedure would disturb the accuracy of orientation. In every case it was found that the whipstock orientation was actually correct—in fact, the setting in every case checked as closely as it is possible to read the single-shot record. The practice of taking check surveys has been discontinued because results have shown this step to be unnecessary.

The design of this whipstock is such that the taper is on the outside or back of the whipstock, and the curved channel which guides the bit is very deep. One of the advantages claimed for this design is the prevention of any roll-off of the bit while drilling down the face of the whipstock. In order to test this feature, all the settings made by Sun have been made with zero allowance for roll-off. Results obtained have been uniformly satisfactory, and in a number of cases where drilling conditions have been ideal the results have checked exactly with the results predicted by the vector diagram calculations. A. H. N.

875.* Application of Mud-Analysis Logging in Gulf Coast Area. R. W. Wilson. *Oil Gas J.*, 25.6.42, **41** (7), 86.—Conventional methods of mud analysis in the Gulf Coast are described. In this area, determinations of the presence of salt water in formations by mud analysis have been successful where either of two conditions exist: First, where the sand is drilled at a very high rate, as is relatively shallow holes; and second, where the salt-water-bearing sand has sufficient rock pressure to cause inflow of the formation fluid into the mud-stream. In both these cases relatively large increases in the salt concentration in the mud occurs, allowing a distinct contrast to the usual small variations in the electrical resistivity of the mud which are due to the small amounts of soluble electrolytes picked up from shales and other non-reservoir rocks.

Many improvements have been made in the apparatus and methods of mud-analysis logging in recent months. In the latest equipment, mud is pumped from the well discharge through the portable laboratory where the gas-trap and sampling device for obtaining mud samples for oil determinations are located. This feature has lessened considerably the labours of the operating engineer and has contributed to more closely regulated and standardized operation of the various elements of this equipment. The automatic drilling-rate meter has been greatly improved along with the recording mechanism. The weight on the bit is now accurately recorded, and is used to aid in the interpretation of the drilling-rate log. An experimental drilling-rate meter now being tested has an automatic compensation for the weight on bit which renders the drilling-rate log more nearly proportional to the work done by the bit and a more reliable index to the formation hardness.

The benefits of continuous and accurate mud analysis are illustrated by cases from fields. Two incipient washouts in a string of drill-pipe were detected in one day in a well at West Columbia, Texas. These incipient washouts were detected by a gradual continuous increase in the rate of action of the mud-circulating pump; the pump rate being one of the functions continuously indicated and recorded by the well-logging equipment. By indicating the gradual increase in pump rate, which is not noticeable to the driller, the washout is noted before it develops to the extent of losing a portion of the drill-pipe and tools in the hole.

Detection of gas and/or oil in the mud is explained together with the advantage of carrying out such tests. A. H. N.

876.* Completion of Two-Zone Wells is Greatly Simplified. J. O. Farmer. *Oil Gas J.*, 25.6.42, **41** (7), 89.—Development of two-zone completion practice is briefly described. Use of side-door chokes is the main item of the paper. The removable type, already proved practical by the many hundred successful installations in New Mexico and California fields, has been largely adopted for this purpose. For the Texas and Louisiana completions, the device provides a simple but positive means to open or close circulating ports in the tubing string a short distance above the packer, after the packer has been set and the surface connections permanently installed. This makes it possible to establish circulation and to unload completely both areas without the hazards previously encountered. After the tubing and casing are unloaded and both zones cleaned out, the circulating ports are closed. This completely separates the two zones, and permits them to be produced independently of each other.

The circulating ports, which are in the special " landing " nipple, are closed when desired simply by running a blank side-door choke into the tubing under pressure and setting it in the landing nipple. This blanks off the circulating ports, allowing only flow from the lower zone through the tubing. The construction of the choke is such that it will seat and lock only in its landing nipple. The running and pulling of the choke are accomplished under pressure on an ordinary steel measuring-line, in much the same manner as a bottom-hole pressure-gauge is run.

During the five years that the side-door choke has been in use, more than sixty-two installations have been made. The tool, while originally designed and used for providing a means for utilizing gas from an upper zone to assist in flowing oil from a lower zone, has been used for several other purposes, including the separating of sweet and sour gas-zones, oil-zones producing different gravities of oil, and zones producing condensate from zones producing oil. Its latest application is to the bringing-in of two-zone wells, for its use permits permanently setting the packer and installing the christmas tree before starting circulation to unload the well. Its use also permits the taking of bottom-hole pressures of either of the two zones, and, in addition, provides means for kicking either zone should loading up occur. A. H. N.

877.* Greater Precautions Needed in Tests for Water Shut-off. H. W. Bell. *Oil Gas J.*, 25.6.42, **41** (7), 130.—A positive test of shut-off lends assurance that any water above the shoe will not have access to the formation below, that the casing will be able to withstand gas pressure without blowing out between the casing and the walls of the hole, and that pressure between strings may be obviated. There is always the possibility that the bit may have entered a water-sand below the shoe, in which case the shut-off may be erroneously considered defective. It is advisable to secure samples of the formation below the shoe, and not drill more than 5 ft. below.

The test for water shut-off is: After the casing-pressure test, the plug is drilled and formation is again entered with the bit. The hole is then bailed dry or to a point where the collapse safety factor is not reduced below two (2·0). The hole is then left undisturbed for about 12 hrs., and if any increase in fluid-level does not exceed the probable collection due to drainage-off of the pipe, the cementing is cleared for further drilling. If faulty conditions are disclosed, drilling should not be resumed until the deficiency is remedied. A. H. N.

878.* Mud Acid is Widely Used in Gulf Coast Wells. S. C. Morian. *Oil Gas J.*, 25.6.42, **41** (7), 111.—More than 1000 chemical treatments have been made on various types of wells on the Gulf Coast. Nearly all of these have been made on wells completed in sands that either produced oil and gas or were used as input wells, in recycling, pressure-maintenance, and water-disposal projects.

The principal treating chemical used in Gulf Coast treating is mud acid. This material not only dissolves a large percentage of nearly all types of rotary-drilling muds, but also dissolves and disperses the clay-like, fine materials commonly found in almost all Gulf Coast producing zones. The removal of these finely divided compounds plus infiltered mud and water, and sometimes certain types of scale deposits, results in large increases in permeability, and consequent increase in production from oil-wells and higher input rates or lower compressor pressures on injection wells.

The units used to inject mud acids are described. In one such unit the pump is operated from a power take-off and has a capacity of approximately 240 g.p.m. at 500 lb./sq. in., providing fluid can be supplied to the truck-pumps in those quantities by the facilities on the operator's lease. The unit will handle about 25 g.p.m. at 5000 lb./sq. in., which is an ample induction rate for tight formation requiring high pressure. The unit will handle all types of fluid, such as acid, water, oil, mud, and cement if necessary. The truck is of the six-wheel type, equipped with an extra large motor to give plenty of reserve power for pumping and difficult field conditions. The chemical tank is of the two-compartment type with bottom suction connections for the pump, which are duplicated in parallel to assure ample fluid capacity and safety for the large triplex pumps. The piping is so arranged, and complete, that only a minimum of connections are necessary in hooking up to treat a well. The unit is equipped with fire-extinguisher, first-aid kit, and fire-blanket as a measure for personal safety of the crews.

Mud acid contains acids that will react with any carbonates that may be present either in the sand or in scale deposits that may have formed on the face of the producing sand, screen openings, and perforations in casing, liners, and tubing. Mud acid will also dissolve an appreciable amount of a typical bentonitic mud. For example, 1 gal. will put ½ lb. of bentonite mud in solution. Ordinary 15%-by-weight hydrochloric acid, which is commonly used in treating wells producing oil and gas from limestones, will dissolve practically none of the bentonitic mud.

Mud acid contains inhibitors to minimize acid corrosion on iron and steel well equipment at the high temperature common to the Gulf Coast wells. Surface-tension-lowering agents are also present in the mud-acid solution, and the compounds permit easier and more uniform penetration of the producing sands by the acid and its more complete and rapid removal following the completion of the treatment. Emulsion preventers and wetting agents are always used to minimize emulsions of spent acid in oil, thus aiding in returning the well to production earlier and avoiding oil-treating operations. A. H. N.

879.* New Methods in Completion and Drilling on Gulf Coast. P. D. Torrey. *Oil Gas J.*, 25.6.42, **41** (7), 82.—The use of hydraulic transmission permits a power-driven rig to approach the smooth and generally better performance of the steam-engine-driven rig. It is, of course, well known that a steam-engine develops its greatest torque at low speed, whereas the internal-combustion engine develops maximum torque at or near its rated speed. As the revolutions/minute of the gas engine are reduced, the torque declines to almost zero at the stalling point. For this reason the draw-works of conventional power-driven rigs have had to be equipped with a multiplicity of gears, and the clutches have had to be designed to withstand heavy shock loads when the gears were engaged.

Similar to the fluid drives on automobiles, hydraulic drives for the transmission of power on drilling rigs permit the utilization of the more economical gas or diesel engine with the same desirable torque performance obtained from the use of steam-engines or electric motors. One type of hydraulic drive consists of a centrifugal pump connected to the engine, which corresponds to the generator on an electrical rig, and a turbine connected to the draw-works, which corresponds to the electric motor. The flow of fluid from the pump rotates the turbines, which, in turn, supplies the power for drilling and pulling the drill-pipe. Thus, with this type of equipment, the gas or diesel engine may run at a speed which will conform to the power output desired. With the maintenance of a constant speed of the prime mover, the speed of the turbine will depend on the load, and with a decline in turbine speed there is a greater development of torque.

In addition to advantages in power transmission, hydraulic drives on drilling rigs will eliminate the effects of shock loads and high stress from the drill-pipe to the engine, the fluid in the unit acting as a cushion. In like manner, the strain on drive-chains is dampened, resulting in smooth operation and reduction in wear of moving parts.

Advantages of automatic and other time loggings are discussed. Centrifugal desanding and reclamation of weighting materials in muds are explained. The use of desanding and concentrating equipment will help to keep the drilling fluid constantly in proper condition, thus reducing the hazards on stuck drill-pipe. At the same time, the elimination of the sand will reduce the abrasion of the pumping equipment and drill-pipe. The reclamation of weighting material, either while a well is being drilled or after it is completed, is an important item of cost reduction, particularly at remote locations where transportation costs for new mud-making materials are high.

Open-hole diameter surveys and their significance are amply detailed. The effects of slim-hole drilling on design of casing strings are discussed and the problems encountered studied. Cementing and squeezing in the area are described, as well as the requirements of good cements.

Three different methods of gravel packing are now used in Gulf Coast fields. The first, which is similar to the method used for the completion of water wells, consists of placing the gravel around the screen in open hole below the casing. The second method is to place gravel both inside and outside of a perforated liner, with screen set in the liner on the tubing before the placement of the gravel. The third method, which is the one most recently developed, is a pre-packed gravel liner which can be run in on the casing or set through the casing after it has been cemented and the plug drilled. The methods are explained in some detail.

Multiple-zone well completion and pressure method of drilling and completion are also discussed in this exhaustive paper. A. H. N.

880.* Power-Driven Rig is Specially Designed for Coastal Drilling. N. Williams. *Oil Gas J.*, 25.6.42, **41** (7), 84.—Development of power-driven rigs having greater flexibility in transmission and capable of absorbing the heavy shock loads of deep drilling is leading to more general use of such equipment in wildcat operations on the Gulf Coast. Steam power, which still cannot be equalled in smoothness and performance, continues to be favoured in fields and areas where fuel and boiler-water are readily available at relatively low cost, but many wildcat tests on the coast, particularly those in South Louisiana, are located in remote, isolated swamp or marsh regions. Here fuel and water must be hauled long distances. Because of the excessive costs which are often associated with transportation of fuel and water for boilers, the use of power-rigs, requiring relatively little fuel and negligible water, is considered desirable in the circumstances. The use of power-rigs is especially to be desired at this time, as they usually require only one barge, eliminating the need of one for boilers. To counteract the disadvantages of the torque characteristics of the internal-combustion engines, electric generators and motors are incorporated in the power system of the rigs.

Indicative of the development and use of direct-powered mechanical rigs on the Gulf Coast is the large, new direct-diesel power assembly which one company now has in South Louisiana. This rig, which has just completed its first hole, drilled to below 11,000 ft., embodies some of the latest improvements in direct-power and deep-drilling equipment. Some of the features had not previously been employed on the Gulf Coast and only very recently elsewhere.

The rig, specially designed for operations where drilling conditions require the use of 4½-in. drill-pipe to a depth of 12,500 ft., is powered by three 6-cylinder (8½-in. bore × 10½-in. stroke), full diesel engines, each developing 300 h.p. at 900 r.p.m. They operate through a chain-drive compounding unit in which the power of any one or two engines or their combined power may be used for hoisting, or for driving the rotary and slush-pump at their required speed while drilling. The rig is described in detail. A. H. N.

881.* Salt-Water Evaporator System Reduces Boiler Operation Cost. W. A. Shellshear. *Oil Gas J.*, 25.6.42, **41** (7), 118.—A method of converting the salt water around the rig into pure water will eliminate barging costs, as well as give all the advantages of having the best steaming conditions in the boilers. With these things in mind an evaporator system for distilling sea-water has been designed and installed by Gulf Refining Co., on one of its boiler barges in South Louisiana.

The evaporator system which was designed for the first installation consists of the following equipment: (1) Two submerged-coil vertical evaporators, each with 294 sq. ft. of heating surface. (2) One two-pass surface condenser with 262 sq. ft. of cooling surface. (3) One 1000-g.p.m. centrifugal pump driven by a steam turbine for condenser cooling water. (4) One flash-tank. (5) One $10 \times 4\frac{1}{2} \times 10$-in. reciprocating feed-pump. (6) Two steam-traps. (7) Regulator valves, pump-governor, and inter-connecting pipe and fittings. These are described in detail.

The system is arranged so that the evaporators may be opened in series or singly when one of them is shut down for cleaning. Steam is taken from the line to the rig, and its pressure reduced to 130 lb./sq. in. and run through the coils of the first evaporator. It gives up its heat of vaporization in the coils, and causes the salt water surrounding the coils to boil. The quantity of steam passing through the coils is regulated by a trap connected to the lower header, which will only allow water formed by the steam condensing in the coils to pass through to the flash-tank. The boiling salt water surrounding the coil forms steam, which passes into the coils of the second evaporator, where the same process occurs, the steam condensing in the coils giving up its heat to salt water surrounding them, which produces more steam. The steam from the second evaporator then goes to the condenser, where it gives up its heat to the circulating water and is itself condensed to distilled water. A system of this type is known as a double-effect evaporating system, and will yield approximately 17 lb. of distilled water/lb. of steam furnished to the coils of the first evaporator.

Costs are given. A. H. N.

882.* Triplex Pump Marked Advance in Gulf Coast Drilling. H. F. Simons. *Oil Gas J.*, 25.6.42, **41** (7), 88. The principal obstacle to the successful and economical drilling to depths of 12,000 ft. and beyond on the Gulf Coast, has been the lack of sufficient fluid capacity on the pumps used on the rotary rigs. A step in the solution of this problem has been the recent introduction of triplex steam-pumps for pumping the mud-laden fluid in and out of Gulf Coast wells. One practical effect of supplying more fluid capacity is a reduction in the amount of mud treatment required on many wells. As the burden which the fluid can carry is dependent on the velocity, the specific gravity, and viscosity, it was formerly the practice to increase the latter two values as the drilling progressed. Part of the effect of increasing the viscosity was lost, due to the fact that the pressure required to move the fluid through the pipe was also raised. With sufficient fluid capacity available, the engineers can concentrate on the water loss and filter characteristics and maintain much lower viscosity in the mud. The specific gravity will need to be maintained in cases where there is any danger of blowouts, and the viscosity will need to be kept as low as possible in such cases. There have been wells which failed to reach the projected depth because of the impossibility of obtaining all of the above factors—volume, viscosity, and weight.

Other, and possibly more important effects of using a triplex pump, are the increase in the rate of penetration and the increase in the footage/bit which will result from a greater fluid capacity and lowered viscosity and specific gravity. The jetting action effect is briefly explained.

As developed for oil-field service, the triplex steam slush-pump is not merely a conventional duplex mud-pump with an additional set of cylinders. By using cast steel for the fluid end and semi-steel for the steam end, and by designing for overall compactness with due allowance for convenience, ample strength has been obtained without excessive weight. The steam-valve mechanism developed for this application by the pump manufacturer makes it possible to operate with a shorter cushion in the steam cylinders than is required for duplex pumps having conventional valve-gear. This not only reduces steam consumption in relation to output, but also results in minimum overall length. The new triplex steam slush-pump (size $18 \times 7 \times 20$ ins.) weighs 31,500 lb., and can be moved on the highways without any dismantling and without the necessity of obtaining a special permit. Overall length, including skids, is 12 ft. 7 ins.; width is 7 ft. $10\frac{1}{2}$ ins., and height, including air-chamber, is 8 ft. $8\frac{3}{4}$ ins.

Typical pump data are given. A. H. N.

883.* Torque Converters Applied to Drilling and Servicing Rigs. T. P. Sanders. *Oil Gas J.*, 2.7.42, **41** (8), 25.—In the first applications of the torque converter to drilling rigs, the draw-works drives were designed so that the torque converter was to serve as an hydraulic transmission. Save for a high and low speed on the hoist-drum, all speed adjustment was accomplished at the converter. While these applications were successful according to all standards, a fault existed in the fact that the torque converter, acting over such wide speed and load ranges, was called on much of the time to operate at unfavourable points on its efficiency curve. By providing four speeds forward, the new rig makes it possible for the converter to act under speed and load conditions falling within the flat portion of its efficiency curve where average efficiency ranges from 75 to 85%. An example of hoisting by converters and by ordinary gearing is discussed.

In pulling a heavy string of drill-pipe the driller is ordinarily called on to be an expert judge of loads, so that he can shift draw-works speeds at the proper times. If he shifts too soon he may have to return to the lower speed, thereby consuming additional time. The torque converter serves to adjust when a higher speed is used too soon, making it unnecessary to return to the lower speed, while at the same time guarding the engines against the overload.

In addition to the feature of using torque converters with a four-speed transmission, the new rig introduces another innovation in torque-converter application. Ordinarily, when two or more internal-combustion engines are compounded it is extremely difficult to synchronize the machines so that each will carry its share of the load at all times. Small differences in the timing, the extent of wear, the condition of the intake and exhaust passages, or small cyclic variations will cause two engines to oppose one another to some degree. The use of a torque converter on each engine of the new rig serves to give the same general performance that would be obtained by compounding two electric motors. The converters are mounted on what would normally be the clutch housings of the two engines, and the output shafts of the converters are compounded, each shaft being provided with a friction clutch. In the past it has been generally supposed that it would be impractical to drive the slush-pump through torque converters. Analysis of the factors involved led to a new appraisal of this possibility. A. H. N.

884.* Automatic Recording of Mud Weight Prevents Many Drilling Difficulties. Anon. *Oil Gas J.*, 9.7.42, **41** (9), 37.—Density is one of the most important properties of drilling mud, and should be carefully controlled. If it is too great in upper formations, a serious loss of circulation may result, or excessive wall-cake may be formed, which may cause drill-collars to stick and interfere with the running of casing. At great depth, in many wells, it appears to be necessary to use mud of relatively high density to prevent small but serious incursions of gas, light petroleum, or salt water each time the bit is pulled up from the bottom. Control of mud density requires very close attention, because of the irregularities introduced by scraping walls when making trips, by adding water without measurement, by adding weighting material at a varying rate, and many other causes.

Disadvantages of the ordinary method of checking mud weight at regular intervals are discussed, and the use of automatic and continuous recording instruments is advocated. One instrument of this type receives a uniform sample from the flow line every 2 mins., and records the weight on a 24-hr. circular chart. The principle of operation is the registration of the gas or air pressure required to overcome the hydrostatic head of a given column of mud, on a chart calibrated directly in lb./gal. This machine is simple in principle, and does not depend on any delicate balance for its operation. It is entirely automatic, and differences in weights of 0·1 lb./gal. or less can easily be read on the chart record.

One typical record is presented, and, to illustrate the many things that can be recorded and observed, the following study is given: Leading up to this chart, the record for the preceding day had shown a variety of mud conditions. The testing of the casing with water pressure had been completed and the bit had been run to the top of the plug. Drilling of cement was begun with water circulation, and the dirty returns varied from 8·9 to 8·4 lb./gal. When all but 5 ft. of the cement was drilled, circulation was changed from water to 10·6 lb./gal. mud. This came back at 3 : 05 p.m. The last of the plug was then drilled out and the bit was run several joints below the casing into the open hole, bringing back cement mud and also some gassy mud from the old hole. Adding baryte was begun at 6.30 p.m., and the gain in density showed in the returns at 8 p.m., and increased continually until a streak came back at 10.20 p.m. showing the mixing in of light mud that was gunned up in the adjoining pit some time after starting the addition of baryte. The density finally showed higher than the desired 13 lb./gal., whereupon some mud was pumped out to the reserve pit, where it sunk to the bottom, and some of the light mud from the reserve pit was allowed to flow off the top into the circulation pits. This procedure was repeated several times.

Then on the chart presented is shown the gradual equalization of heavier mud with lighter mud, until orders were received to cut the density back to 12·0 lb./gal., to permit the nitroglycerin shot to sink in the hole. Only the mud in the small suction pit and in the well was then diluted with water; which was started at 2.45 p.m. After all the mud in the system was equalized at 13·0 lb./gal., the crew started out of the hole with the drill-pipe at 9.20 p.m. At 1.45 a.m. the drill-pipe had been pulled from the hole. Notations on the chart show the other operations performed, until the chart was again changed at noon. A. H. N.

885.* Drill-Pipe Inspection as Basis for Improving Drilling Technique. T. P. Sanders. *Oil Gas J.*, 11.6.42, **41** (5), 33.—As originally conceived, the internal inspection of drill-pipe provided a systematic method for eliminating defective drill-pipe joints before they could cause fishing jobs or loss of the hole through failure in service. Careful study of a great number of strings, however, made it possible to recognize all types of abnormal drill-pipe deterioration. Correlation of this accumulated information with certain direct field observations of drilling conditions and technique led to the ability to define quite accurately the cause or causes of any disruptive condition found in the pipe.

The ingenious form of periscope used for internal inspection of drill-pipe and other tubular goods makes use of a series of lenses. Carried at the end of the instrument is a 250-watt, 150-volt mercury-vapour lamp for lighting the pipe interior. The observer can view two distinctly different types of image, depending on his manipulation of the instrument. The " annular " image, used for locating defects, takes in 6 or 7 in. of the pipe interior, and this is viewed under a magnification of 1·5. For studying individual defects in order to determine their magnitude or their cause, an angle mirror is brought into use. This makes it possible to obtain a 90° view directly into the pit or other defect under a nagnification of 2.

Thorough cleansing of the pipe interior is, of course, necessary before a successful visual analysis can be undertaken. Power-driven steel brushes provide a rapid and thorough means of accomplishing this cleaning. All equipment needed for cleaning, inspecting, and spraying the pipe interiors is carried in a service truck. Generating equipment that furnishes electricity for lighting the mercury-vapour lamp also supplies power for driving the cleaning brushes. The compressor that supplies compressed air to blow away the scale and rust as it is removed by the steel brushes is also utilized to operate the spray-gun. Drill-pipe can be cleaned and inspected at the rate of 1000–1500 ft./day. A. H. N.

886.* B. of M. Reports on Particle-Size Distribution in Drilling Fluids. Anon. *Oil Gas J.*, 23.7.42, **41** (11), 42.—An abstract of the Bureau of Mines Report, R.I. 3645, is presented together with three graphs and the main conclusions. A. H. N.

887.* Gamma-Ray Well-Logging in Trinidad. G. M. Conklin. *J. Inst. Petrol.*, July 1942, **28** (223), 141–145.—A general report on gamma-ray well-logging as practised in Trinidad is given. A. H. N.

888. Patents on Drilling. F. J. Hinderliter. U.S.P. 2,284,869, 2.6.42. Appl. 27.2.40. Blow-out preventer.

J. H. Adkison. U.S.P. 2,284,969, 2.6.42. Appl. 17.4.40. Method of completing wells drilled into a stratum to be tested for production.

B. S. Minor. U.S.P. 2,284,983, 2.6.42. Appl. 9.6.39. Casing-head construction for wells.

J. B. Ferguson. U.S.P. 2,285,024, 2.6.42. Appl. 11.8.39. Sample-taking-apparatus for side-wall sampling in a well-bore.

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L. G. Howell. U.S.P. 2,288,278, 30.6.42. Appl. 23.6.41. Gamma-ray well-logging using a Geiger–Muller counter. A. H. N.

Production.

889.* Cleaning Liner Slots by Means of Explosives. J. H. Collins. *World Petrol*, May 1942, **39** (5), 29–30.—The paper describes a new explosive charge, used in the shape of a rope, which is lowered into slotted casing and fired to clean the slots. It creates high-pressure wave, sufficient to clear the slots, but with energy content to low to injure the casing. It is compared to high-voltage, low-amperage shock circuit. The inventer is Ford Alexander, who is now using it extensively.

The rope is shipped by ordinary express, with no restrictions, and is no more dangerous than dynamite fuse. In the past year the inventor's organization has used 200,000 ft.—nearly 40 miles—of it with no mishap, nor any damage to anybody's oil-well. A 15,000-ft. well could be shot from top to bottom. Neither the weight of the column of material in such a hole, nor the temperature, would affect the rope at the bottom, and no damage could possibly be done, although the velocity of the explosive is over 23,000 ft./sec. A. H. N.

890.* Chemical Reconditioning of Old Wells. J. H. Adkison. *Petrol. Engr*, May 1942, **13** (8), 156.—Field use of the acid jet-gun has proved it to be of even greater value as an auxiliary tool for increasing the efficiency of chemical treatments of oil-wells than laboratory tests initially indicated. Although it was designed primarily as an acidizing tool, its application has been broadened, so that it is now used as a means of selective re-acidizing, removing cement and mud-sheaths, removing acid-soluble cement retainers and cement plugs, cleaning out limestone cavings, and for minor deepening jobs. It has also been used in the removal of gyp and paraffin formations when ordinary circulation of acid has proved ineffective.

Application of the jet-gun in operations in which acid is not the fluid medium includes certain types of formation-cleaner treatments where paraffin solvent, butane, gasoline, kerosine or low-surface-tension water may be used as a fluid agent.

After various studies the following conclusions are recorded: (1) Various types of jet-guns may be used advantageously in the chemical treatment of oil, gas or input wells for: (i) Aiding in the selective acidizing of a formation. (ii) Cement or mud-sheath removal. (iii) Magnesium-alloy retainer removal. (iv) Drilling-out cement plug. (v) Deepening jobs of small magnitude in limestone. (vi) Removal of gyp deposits. (vii) Removal of paraffin deposits.

(2) The action of the jet stream will be affected by: (i) Design of the jetting nozzle. (ii) Acid concentration for cement or limestone. (iii) Chemical solubility of material being removed. (iv) Physical characteristics of material being removed. (v) Differential pressure maintained. (vi) The distance of the jets from material being removed. (vii) The length of time jetted up to the critical point, when distance from the jet prevents further removal. (viii) Size of the jets being used.

(3) Having the required differential pressure across the jets, the action is not affected by the hydrostatic column of fluid in the casing, as acid may be considered as incompressible, and therefore the viscosity of the fluid is unchanged.

(4) The jet-gun has definite limitations in regard to its maximum action and its effect on the permeability of a formation and the production increases that may reasonably be expected.

(5) The jet-gun will thoroughly prepare the formation of a well for a subsequent

squeeze acidizing treatment, thereby increasing the efficiency in most acid treatments. To the well-informed operator, this auxiliary treating tool is well worth the additional preparatory work necessary for its successful application. A. H. N.

891.* Engineering Study Determines Advisability of Pressure-Maintenance Installation. J. D. Collett, Jr. *Petrol. Engr*, May 1942, **13** (8), 62.—Studies of the North Novice field, Texas, are given. The producing sand in North Novice is relatively tight, of low permeability, and irregular, and most of the wells have been shot in order to obtain potentials high enough to satisfy normal operating requirements. Immediately south-west of the field is the elder Novice field, which produces from the same sand and under pressure maintenance. The success of this operation indicated that North Novice field might also benefit from return of gas to the reservoir. Novice production, which had been declining rapidly, has remained quite constant since operations were placed on a gas-return basis.

Well tests are described in some detail. It was determined that with a uniform drainage pattern it should be possible to control the gas returned to the reservoir by careful studies of bottom-hole pressures and gas–oil ratios. All wells were therefore tested for gas–oil ratios and producing rates. While this testing was in progress, bottom-hole pressures were again run on each of the wells during the potential test, to establish the productivity index of most of the wells in the field.

These data were desirable for two purposes: First, it was necessary to know that the wells were capable of producing sufficient oil to meet allowables assigned and yet have bottom-hole pressures that were high enough to prevent too much gas from coming out of solution. It was also necessary to know what effect increased allowables would have on those wells that would be affected by reallocation of allowables from wells used for injection. The second factor was the need of index data, in order to determine the pressures that would be required to inject the gas being produced by all the wells under normal producing rates. The well index-data were then used to calculate, for the wells chosen for injection, the pressure required to inject all the gas produced in the area affected by the well. This can be done either graphically with straight-line curves or by direct calculation.

The principles governing the selection of injection wells are detailed, and the plant is described.

No trouble developed during testing, and injection was begun immediately. At first very small volumes of gas were introduced into the well tubing of the injection wells, and the calculations of injection pressures checked extremely well. Rates of injection were slowly increased over a 90-day period approximately until full load was reached, at which time all calculations for pressures and capacities were checked, and found to be closer than had been expected.

Only a few minor troubles have developed to date. Regulation of the conventional separator vent-valves had to be made, and they caused some trouble. The tendency of separators to overload and force oil into the gathering line and fill the field scrubbers, thus shutting down the plant, had to be corrected. Regulating field production to allowables and constant plant-load had been the greatest problem. No trouble has occurred with the key wells. A. H. N.

892.* Locating Cased-Off Productive Zones. W. A. Sawdon. *Petrol. Engr*, May 1942, **13** (8), 55.—Radioactivity logging provides a means of logging through casing by running a highly sensitive detector into the well on a conductor cable to measure the gamma rays that enter the hole from the contiguous formation. These rays, originating in the formation, pass through the casing and cement or other material occupying the annulus between the casing and the wall of the hole, and thus identify, by means of their relative measurements, the character of the formations behind the casing. The intensity of the rays is naturally decreased by the steel of the casing and by surrounding cement or other matter. It has been found that this dampening effect of the steel is approximately four times that of the mass usually found between the casing and the wall of the hole. This resistance, however, remains a fixed constant in each particular well during logging operations, and does not affect the number of rays emanating from the formation. Radioactivity measurements have been taken through as many as five strings of cemented casing, and there are clear indications on the record when the instrument passes from or into the shoe of a string, depending on whether the run is being made down or up. A certain amount of explanation about the theory of radio-activity logging is given.

As is the case with similar subsurface records, the interpretation of the radioactivity log is of vital importance. In fields where electrical logs have been taken in nearby wells that have been drilled recently, the general stratigraphical data supplied by the electrical log will facilitate the interpretation of the radioactivity log of an old well. When the radioactive log is taken in a well for which an electrical log is available, a comparison of the two logs assists in making a close determination of the limits of the prospective zone. In most of the fields of California the shales are decidedly more highly radioactive than the sands, and the decrease in radioactivity, shown by the trace on the chart, clearly indicates the sand-bed. In a few areas in the San Joaquin Valley the radioactivity of certain formations does not appear to conform to the conventional, and logs taken in those areas are more difficult to interpret.

Application of such logging is studied. In the Long Beach field there are two cased-off zones known to be productive in certain areas and wet in others. A portion of another zone that is cased-off in some wells is also known to carry clean oil. In other areas portions of still another zone can be profitably produced if located accurately. Most of the wells in which these zones are cased-off are old holes that were drilled with undue speed in order to reach the main producing zone. No attention was paid to maintaining vertical hole at the time the wells were drilled, and very few surveys have been made to determine their actual course below the surface. Sharp dips and numerous faults add to the difficulty of locating the prospective zones lying behind one or more strings of casing.

The radioactivity log has been used to advantage in this field to locate zones behind as many as four strings of casing. The log has sometimes been taken to determine the limits of a specific zone and at other times to provide a complete correlation of the entire well. In fields of this kind where numerous radioactivity logs have been taken and many electrical logs are available from adjacent wells recently drilled, the interpretation of radioactivity logs run in cased holes is comparatively simple. A. H. N.

893.* Packer Tester Reduces Workover Time and Labour. Anon. *Petrol. Engr*, May 1942, **13** (8), 60.—A packer tester is described and illustrated. A swage and nipple were welded to one end of a piece of 5-in. O.D. casing long enough to cover the packer rubber. Below the packer rubber a connection was welded to the section of casing. To test a packer, the equipment is inserted in the casing section, heavy clamps tightened on the swage nipple, and a second nipple on the upper end of the packer. Tightening the clamp applies sufficient pressure to set the packer. After the packer has been set, pressure from a pump may be applied through the connection welded below the packer rubber. Pressures as high as 3000 lb. have been used in testing packers.

As a result of testing packers before running in the well, savings in workover time and labour have been effected. A. H. N.

894.* Petroleum Engineering. Part 5. L. C. Uren. *Petrol. Engr*, May 1942, **13** (8), 31–34.—Further studies of American facilities for training petroleum engineers are given in this part of the paper. A. H. N.

895.* Production and Disposal of Salt Water in the East Texas Oilfield. B. W. Payne. *Oil Wkly*, 18.5.42, **105** (11), 21. *Paper Presented before American Petroleum Institute.*—In a comprehensive paper various aspects of the problem of water production and disposal in East Texas are treated from historical, technical, and economical viewpoints. This field is a water-drive field. It was inevitable, therefore, that in East Texas, as in other fields of this type, large volumes of salt water would be produced together with the oil long before final depletion of the reservoir. Until recently it had been less well appreciated, except by engineers and technologists, that since salt water under pressure constitutes the driving-force that moves the oil from the sand to the well-bore, it is of paramount importance that the water pressure in the reservoir be conserved and utilized in such a way as to yield the greatest ultimate recovery of oil. The problem of pressure and production relationship is analysed. Methods of plugging back water failed and other methods had to be found. It was first thought that the water could be evaporated in open pits in the field, but the idea was soon discarded when it was learnt that the rate of evaporation in East Texas was practically equivalent to the rate of rainfall. Various methods of disposing of salt water were considered, including : (1) Evaporation in open pits. (2) Evaporation by aid of artificial heat. (3) Continuous of discharge of salt water into streams. (4) Storage of salt water and controlled discharge during periods of heavy rainfall. (5) Transportation of salt water to the Gulf by pipe-line. (6) Injection of salt water to subsurface formations.

Each of the above possibilities was explored. Early in 1936 the feasibility of returning salt water to the Woodbine sand was demonstrated in a test well about 2½ miles west of the field in the south end. At that time less than 50,000 brls. of salt water/day were being produced, but it was realized that the problem was one of increasing importance. Through experimentation, the return of salt water to the Woodbine sand was determined to be the most practical.

Not only has the return of salt water to the Woodbine sand been demonstrated to be the most practical method of disposal, but it also contributes materially to the maintenance of the reservoir pressure. This pressure maintenance arises from the fact that when a barrel of produced water is returned to the sand it offsets the withdrawal of a barrel of water and cancels its effect on the pressure decline. Thus, if all the produced water were injected, the effect would be about the same as if there had been no water production. It has been estimated that the reservoir pressure would now be in the neighbourhood of 1200 lb./sq. in. instead of 1000 lb../sq. in. if there had been no water production or if all the produced water had been returned to the Woodbine sand.

It is now widely accepted by engineers and technologists that water-drive is the most efficient mechanism for the production of oil, whereas production by gas-drive resulting from release of gas from solution at low pressure is the most inefficient mechanism. The relative differences in recovery between these two possible methods of production may vary in excess of 100%. It becomes apparent, therefore, that in order to obtain the maximum possible amount of oil from the East Texas field it is extremely important that the operations of the water-drive be maintained until the field is exhausted.

The growth of the practice and the engineering and economical aspects of water injection are then analysed. A. H. N.

896.* Gas-Drive Prolongs Producing Field Fifteen Years. G. B. Nicholson. *Oil Wkly*, 25.5.42, **105** (12), 17.—The system employs thirty injection wells, located at strategic sites in the field. The key wells are changed as conditions in the reservoir vary, with the purpose of receiving the highest recovery/cu. ft. of gas injected, in addition to flooding new areas previously untouched. Input pressures vary from 15 to 250 lb., with wells located near the edges of the structure requiring more pressure, due to proximity with the water-level. At each key well is placed a regulator to adjust pressures applied, with three types used, as follows : (1) manual controller, (2) differential controller, (3) volumetric controller, each type offering specific advantages to cope with conditions met in wells.

Gas with pressure reduced to the desired amount is turned directly into the casing of the key well served by the regulator. Input wells use no tubing, being equipped with 6-in. casing and having light fittings at the casing-head and swages to facilitate connecting gas-line. A gate-valve is also provided on the line to allow shutting off gas supply when desired. In the lower section of the hole is set a 4¾-in. slotted line, allowing injected gas to escape from the casing and penetrate the formation.

Producing wells are provided with the usual type pumping equipment, consisting mostly of older-type 25-horse-power units, although two central powers operate several wells. The majority of pumps are placed close to bottom, but local conditions in many wells require variation in subsurface installations, to overcome the tendency of wells to gas lock, or to avoid troubles from soft sand, which is sometimes prevalent. As a rule, sand troubles are slight, excepting after injection pressures and procedures are altered, or when location of input wells is changed. Other details of the system are given.

The company operating the system, by carefully manipulating position of key wells and by skilful application of conservation methods, economically and profitably operates the field, having established the gas-drive unitization at the opportune time to save the life of the producing area. Based on estimates from present rate of production decline, engineers figure that parts of the field will produce economically for another five years, with probability of producing 2,000,000–3,000,000 brls. during that period. A. H. N.

897.* Unsteady Flow of Vaporizing Hydrocarbons Through Unconsolidated Sand. Part 2. T. Y. Ju and R. L. Huntington. *Oil Wkly*, 25.5.42, **105** (12), 28.—Experimental data are presented in tabulated and graphical forms and are discussed in this, the second part of the paper. Correlation of experimental with calculated values of cumulative production *versus* time check well. The equation is

$$Q = \beta T^{\gamma}$$

where Q = cumulative production in time T; β and γ = constants.

Rate of vaporization of propane in the pipe and the rate of production from the pipe are not the same. Calculations are presented. For butane runs, the vapour pressure is so low that the rate of production and the rate of vaporization are practically the same. A. H. N.

898.* Systematic Removal Essential to Paraffin Control. G. M. Wilson. *Oil Wkly*, 1.6.42, **105** (13), 27.—Through efficient use of tubing scraping, steaming, and combinations of such controls that have been developed by service companies, together with some developments of control instigated by certain larger operators, the paraffin problem has been reduced mainly to a matter of properly scheduling the working-over of affected wells.

Scraping devices have probably become most widely used. One service company, operating out of several bases located in both West Texas and New Mexico, has a fleet of small truck units specially equipped for scraping and cleaning out the string of tubing in a flowing well—for example, in as little as 2 hrs. total elapsed time from setting up the equipment to tearing down and leaving the location. Longer periods are required, of course, in wells in which particularly large amounts of paraffin have been permitted to accumulate and which have not been cleaned out for some time.

The 3-ft. scraping tool or knife is lowered into the tubing on a piano-wire line. A combination sinker bar and short-stroke jar are used in conjunction with the knife, similar to the way in which the drill-stem and jars are used in a cable-tool outfit. Scraping is discussed in some detail. Reversed circulation and steam may be used to help in scraping. A. H. N.

899.* Unsteady Flow of Vaporizing Hydrocarbons Through Unconsolidated Sand. Part 3. T. Y. Ju and R. L. Huntington. *Oil Wkly*, 1.6.42, **105** (13), 32.—Further experimental data are presented. From the results of the investigation presented here, the following conclusions may be reached for a butane or propane reservoir: (1) The vaporization of butane or propane in unconsolidated sand is more or less isothermal, due to the large heat capacity of the sand body. (2) Due to the presence of sand, the pressure change in liquid phase cannot keep pace with the removal of the liquid by vaporization. Consequently there exists a pressure gradient between different heights in the liquid section of the reservoir, over and above the hydrostatic head. (3) The curve for production-rate decline of reservoirs of this type is similar to that for reservoir depletion of the usual type. The only difference is the absence of the sharp initial drop in the case of the reservoir used in this investigation. (4) The cumulative production quantity is complicated with many variables, such as rate of production temperature of reservoir, nature of hydrocarbons, etc., yet it may be expressed as a simple relation by

$$Q_p = \beta T^{\gamma}$$

(5) The rate of vaporization of the liquid declines in the same manner as the rate of production. (6) The rate of production can be expressed by a modification of Pierce and Rawlins' formula for gas-wells:

$$\frac{\Delta Q_v}{\Delta T} = C\left[\frac{P^2 - P_s^2)}{(Q_0 + Q_v)}\right]^n$$

Q_0 is zero if the reservoir has no gas-cap, and Q_v is practically the same as Q_p, especially for butane. Therefore, from the pressure-decline data it is quite possible to estimate the future production rate by means of this equation within the accuracy generally required for practical application. A. H. N.

900.* Development, Operation, and Valuation of Oil and Gas Properties. Part 2. P. J. Jones. *Oil Gas J.*, 4.6.42, **41** (4), 53–54.—This part of the paper deals with the flow of homogeneous fluid through linear porous media. The flow of liquids and gases is treated mathematically and illustrated with examples. Cases of constant and variable permeabilities are studied. A. H. N.

901.* Application of Back-Pressure Tests to Gathering Systems. J. W. Ferguson and M. F. Shaffer. *Oil Gas J.*, 4.6.42, **41** (4), 39–42.—The Authors develop a graphical method of solving the problems of well deliveries in a gas system against a given range of pressures. A layout of a gathering system, with a considerable spread in rock pressures, is assumed, and the problem is solved as an illustration of the method. A composite curve with irregular kinks is the result. If the rock pressures were all within a narrow range, any kinks in the composite curve would fall close together, at pipe-line pressures close to the rock pressures of the wells. In this event it is not necessary, or even particularly desirable, to calculate a great many points for plotting the final curves. Only enough points should be calculated to define the final composite curve.

It is noted that if it is desired to limit the amount of gas produced from each well to a percentage of its open flow, or by any other arbitrary procedure, the process for obtaining the composite curve would be identical, except that the quantities from a given well would increase with decreasing line pressures until the allowable is reached; from there on, the allowable would be used instead of the actual producing ability of the well. This condition would, of course, pre-suppose the necessity for manual or other control of each well to limit its production to the allowable quantity. A. H. N.

902.* Record System Aids Repressuring Efficiency. G. M. Wilson. *Oil Wkly*, 15.6.42, **106** (2), 16–19.—A system of recording the activities of one property is described in detail. The property is divided into three general, roughly defined areas—the north-west, north-east, and the south-east. For production-record purposes, each of these areas is further broken down into subdivisions, making thirty subdivisions for the repressured area. Distances and certain royalty matters are factors governing the formation of the smaller subdivisions. Each of these subdivisions is made up of from five to fifteen wells which produce into an individual trap, header, and tank battery, where gas and oil produced are accurately gauged and recorded.

A card-filing system is kept in which a complete " case record " is noted for each individual well. Each well has a card on which is tabulated the depth, casing, and tubing data, and a chronological record of all changes of pump locations, or significant changes in the well's performance. Special note is made of instances where a well is changed from producing over to an input well, or vice versa. Each month, following tabulation in columnar form of all the production and injection data, the figures are transferred to the curve-sheets. The values in each curve in most cases are plotted against time, the latter being in monthly units.

The following items are recorded: (1) Average daily oil production at each battery. (2) Average daily oil production for each of the three general areas. (3) Average daily production for entire repressured area. (4) Gas produced daily on each subdivision. (5) Average gas–oil ratios for the month for each subdivision. (6) Average gas–oil ratios for the month for each of three general areas. (7) Average gas–oil ratios for the month for entire repressured area. (8) Daily oil rate *versus* cumulative production of entire repressured area. (9) Rock pressure of each injection well. (10) Multi-curve sheet containing five quick-reference curves. (11) Multi-curve sheet containing five quick-reference curves. This is similar to (10), but is compiled as an average for the entire repressured area. (12) Gas returned to each of the injection wells. (13) Gas returned to each of the three general areas. (14). Total gas returned to entire repressured area. (15) Extraneous gas injected. (16) Gas volume treated at gasoline plant. (17) Gasoline produced at plant for entire field. (18) Gallons of gasoline/1000 ft. of gas. (19) Decline curve of repressured area. (20) Decline curve for each of the three general areas.

Each of these items is briefly described. A. H. N.

903.* Controlled Water Injection Sustains Reservoir Energy. G. B. Nicholson. *Oil Wkly*, 22.6.42, **106** (3), 17–19.—Plymouth Oil Company, by controlled injection of water into one of several producing sands in the Plymouth field of San Patricio County, South Texas, maintains constant bottom-hole pressure and calculates sustaining a driving-force which will be of economical benefit in receiving greatest ultimate recovery from the reservoir. Volumetric withdrawals are replaced systematically by forcing salt water into the bottom of the sand section, with an additional amount injected to assure minimum pressure fluctuation.

Injection water is obtained from wells in the field producing from other formations; and careful chemical and mechanical treatment is given it to remove undesirable elements which seal the face of receiving sand or add to the corrosion of equipment, assuring highest operating efficiency. Salt water produced from sand at 5800 ft. is used for injection, being obtained from gun-barrels of three tank batteries serving wells producing from that formation. With injection of all water produced by these wells, flooding provides a dual purpose, as salt-water disposal is also effected, with construction of evaporating pits or other disposal facilities unnecessary. By staggering delivery of water from batteries to the injection system, loads on delivery lines are kept low, permitting use of the simplest, most effective, and least expensive gathering system.

Water, after being drained from the tank batteries, is stored temporarily in an open pit. When each battery feeds its water into the injection system, a centrifugal pump located near the pit at the battery is placed in operation, lifting water from the pit and forcing it into the delivery system to reach the injection plant. Automatic controls, regulated by hard rubber floats on each pump, stop pump action when fluid level is lowered near bottom.

Details of the pumping of water are given. No wells on the lease produce water, and all flow naturally. Gas is still being injected into one well located high on the structure, an average of 350,000 cu. ft. daily being forced into the single key well. Gas injection was started in October 1938, and has been continued without cessation in attempting to maintain constant bottom-hole pressure. A. H. N.

904.* Efficient Equipment Lowers Gas-Lift Costs. Anon. *Oil Wkly*, 22.6.42, **106** (3), 38.—By making certain changes in the equipment employed in the operation of a gas-lift project to obtain oil from wells ranging around 6000 ft. in depth, a major producer has been able to reduce the quantity of gas 76½% of the amount formerly used to lift even a smaller number of barrels of fluid. The type of gas-lift installed at the start of the programme was the conventional type, which required an ascertained depth of submergence and at various times a high gas-pressure to kick them off.

One well in particular, while producing on the old-style gas-lift, required an average of 1,067,000 cu. ft. daily to lift 128 brls. of fluid, but when changed to the newer type required only 250,000 cu. ft. to raise 136 brls., the sum total of which, when multiplied by several wells of this character, amounts to a substantial saving of operating horsepower, lower lifting costs, and a reduction on depreciation of equipment.

Details of the improvements are given. A. H. N.

905.* Development, Operation, and Valuation of Oil and Gas Properties. Part 5. P. J. Jones. *Oil Gas J.*, 25.6.42, **41** (7), 197–198.—In this part of the paper formulæ and graphs are given for the flow of oil-water mixtures through media of uniform permeability. From the discussion it is deduced that, aside from surface and gravitational forces, the ultimate recovery from oil reservoirs available to natural and artificial water-drives is limited by (*a*) non-uniform distribution of specific permeability, (*b*) a physical upper limit of available or induced pressures, and (*c*) an economic upper limit of water–oil ratios. Specific permeability ratios can be controlled, within limits, by selective completion methods. On the other hand, pressure may be controlled, within limits, by selective location of wells for primary production purposes and by spacing wells for artificial water-drive purposes. A. H. N.

906.* Hydraulic Pumping is Applied to Deep Wells on Gulf Coast. C. E. Buchner, Jr. *Oil Gas J.*, 25.6.42, **41** (7), 136.—Development of hydraulic pumping in deep wells both in California and Gulf Coast is briefly reviewed. The principal factors to be considered in the Gulf Coast area are: (1) depth; (2) free gas; (3) sand; (4) paraffin. The hydraulic pumping system has certain innate characteristics that are easily adapted to any or all of these conditions.

Due to the high efficiency obtained from hydraulic transmission of power, depth is no factor in adapting this means of pumping to Gulf Coast wells. Besides this advantage the hydraulic system offers in wells of all depth the maximum amount of horse-power available to the subsurface unit with a minimum amount of weight. This is especially economical in deeper wells where the ratio of horse-power to weight becomes quite great with the older mechanical methods of pumping. A 12-h.p. hydraulic-power unit punmping a 7700-ft. well is illustrated. The hydraulic system further ensures greater safety in tubing setting depths, as any movement of the tubing due to pumping pulsation is eliminated. Furthermore, the elimination of any moving mechanical parts within the tubing prevents wear on the tubing, which is especially important in crooked holes as sometimes encountered in the deeper wells. Free gas, sand, and paraffin effects are discussed.

Multiple well pumping with the hydraulic system offers several savings in critical materials so vital to the Government as this time. Due to the low ratio of horse-power to weight, savings of from 30% to 85% in steel may be effected over the conventional method of pumping an oil-well. The largest savings are, of course, on multiple-well installations, frequently making it possible to pump seven wells with the same amount of steel previously required to pump one well. Centralizing of controls at the tank battery also affords a saving in rubber. The pumper has to visit the tank battery to gauge the tanks periodically, and there he can check the operation of each well without visiting the individual well-heads. Any adjustments necessary to specific wells can be made at the manifold. Bottom-hole pressures, pumping-fluid levels, and other important factors can be quickly determined, providing a constant knowledge of down-hole pumping conditions.

In conclusion it is stated that the hydraulic pumping system has been considered for pumping 15,000-ft. and deeper wells. Equipment has been designed to lift as much as 500 brls./day from such depths. It is within the realm of this method of pumping to lift larger quantities from this depth or deeper, if the occasion demands. Sizes are now available in capacities up to 4500 brls./day and depths to 15,000 ft.

A. H. N.

907.* Operation of Gulf Coast Field is Aided by Gas-Cycling Programme. F. L. Singleton. *Oil Gas J.*, 25.6.42, **41** (7), 113.—As a result of a pressure-maintenance and re-cycling programme, three main objectives are being achieved in one field : (1) The installation has made possible operation of wells that were shut in because they could not be produced without wasting some of the reservoir gas essential to the maximum ultimate recovery of the oil. (2) Reservoir pressure is being maintained while oil is being produced, thus making possible efficient recovery of the oil existing in the reservoir through widely spaced producing wells. (3) Production is being made available by the use of far less quantity of steel and other materials than would be required to develop an equal production by drilling of addition wells. The field is described together with the plant used.

The pressure-maintenance and recycling programme was designed to serve the entire productive area, and was made possible by a unitization plan agreed to by most of the operators and lease-owners in the field. The unitized block consists of about 2000 acres, and the pooling agreement is of special interest in view of the fact that it not only covers gas and condensate, but also crude-oil production. Such an agreement has not been made, so far as is known, in any other pooling agreements on areas serving pressure-maintenance or recycling plants.

The plant was designed to process and return to the formation approximately 25,000,000 cu. ft. of gas daily. The installation is one in which oil and condensate are recovered separately by dual installation of the separators and tank batteries. The dry gases from both separator batteries go into a common header through a final separator scrubber to the inlet of the compressors, where it is boosted to the required pressure to return to distillate formation. A. H. N.

908.* Production Curtailment Makes Paraffin Problem More Difficult. P. D. Torrey. *Oil Gas J.*, 25.6.42, **41** (7), 143.—In a long paper paraffin scraping and removal by other means are discussed in some detail. The paraffin, when it first comes out of solution, is in the form of minute wax crystals. These fine particles tend to coalesce into larger fragments, and are carried along in suspension until they find a favourable point for accumulation, which is generally at places where some physical change affects the carrying power of the oil. These places may be at points of slight irregularity in the tubing and at the tubing cellars, at gas-lift valves where the expansion of gas has a cooling effect, and at points where the fluid level varies from time to time by intermittent production, resulting in a periodic recoating of the pipe-wall with a film of oil. In high gas–oil ratio wells, where the oil comes from the well as a mist or froth, the recurrent coating of the tubing wall with oil, at a point where the temperature is sufficiently low to precipitate the paraffin from solution, will almost invariably result in the formation of a deposit. The reduction of high gas–oil ratios by some form of remedial work is one preventive measure for the elimination of paraffin accumulations. Although all these various factors affect the deposition of paraffin to varying degrees, probably the chief source of the increased trouble in flowing wells that has been experienced in recent years in Gulf Coast fields is due to restricted production. When the wells are shut in or are produced at a very slow rate, there is a greater loss in heat to the surrounding formations, resulting in a lowering of the temperature of the oil, to the point where paraffin will come out of the solution. Also, since the velocity of flow is greatly reduced, the carrying capacity of the oil is diminished, so that the fragments of paraffin tend to accumulate rather than to be flushed out.

Several types of scrapers are described. Heat and chemical treatments are also discussed. Probably the best method for preventing the formation of paraffin deposits over the sand-face or perforated liner is to maintain always the oil-fluid level above the top of the sand. Exposure of the sand-face permits the evaporation of the lighter liquid fractions, which results in the precipitation of the paraffin, and is accompanied by a reduction in oil production. Removal of paraffin accumulations from the sand-face and from liners may be accomplished by the use of hot water, steam, high-test gasoline, heat-generating chemicals, or chemical solvents and softeners. The use of various chemicals combined with vigorous swabbing has produced satisfactory results in some of the older Gulf Coast fields. A. H. N.

909.* Radioactivity Logging Proves Help in Reworking Old Wells. Anon. *Oil Gas J.*, 25.6.42, **41** (7), 140–142.—It is emphasized that radioactive logging does not provide information regarding the content of porous formations, nor does the amplitude of radioactive intensity of various formations enable the operator to reach any reliable conclusion concerning the porosity and permeability of the formations, such as may be gained from a study of the self potential curve of electrical logs, other than the general fact that sandstones are usually more porous and permeable than shales. Therefore, the development of new production, by the use of radioacitve surveys, from older wells must be based either on a knowledge of the productive possibilities of a particular horizon obtained from the record of other wells, or on a series of tests designed to provide this information. In the latter case, a radioactive log will show the position of the more promising horizons, and thus prevent shooting of bullets into and testing of shale sections.

Radioactive surveys may be made in open hole or through casing. They have been made in larger number in cased holes, where it is impossible to make electrical surveys. As shown in a table, the relative radioactivity of various sedimentary rocks varies to the extent that a measurement of the amount of radioactivity provides an excellent criterion of the formation. Thus, by measuring progressively the radioactivity of the formations encountered in a well, it is possible to predict their lithology.

The amount of radioactive material in a particular bed or formation may remain fairly constant over a wide area, so it is possible to distinguish various horizons from the radioactive logs by the amplitude of the intensity curve, and thus use the logs for the purpose of correlation where other records are not available. The difference in radioactive content of different beds gives a fairly definite change in amplitude of the recorded curve at contacts, and therefore permits these points to be established with a degree of accuracy comparable to that obtained from the use of electrical logs.

Characteristics of the three types of radiation and the mechanism by which they are detected and amplified are briefly discussed. A study is made of typical radioactive logs before and after squeeze-cementing a well. A. H. N.

910.* Tubing Perforators to Solve Special Gas-Lift Problems. G. G. Kingelia. *Oil Gas J.*, 25.6.42, **41** (7), 120.—The purpose of the tubing perforator is to provide a simple and a positive means to perforate tubing mechanically under pressure with the use of an ordinary steel measuring line, jars, and stem. This perforator is a wedge-and-knife tool that is easily lubricated into the hole under pressure, set at any depth, and any number of holes can be made with one trip of the tools. It consists of an adjustable stop, a wedge, a knife, and knife-base. A hole is punched through the tubing simply by driving a tapered wedge against the back of the knife. The angle of the face of the wedge is small enough to enable the conventional tubing jars and stem to impart a blow sufficient to drive the cutter through the tubing.

When the perforator is suspended, the weight of the knife and knife-base holds the cutter in a retracted position and facilitates the running and pulling of the tool. In order to expand the cutter, a stop is first set in the tubing to act as a rest for the perforating tube, to permit the wedge to be driven against the knife. The rigging up necessary in order to run the tubing perforator is approximately the same as that required for running and pulling any other subsurface tool that is run through a lubricator. Three applications of the tool are described in some detail to illustrate the benefits of perforating in the well for gas-lift purposes and thus obviate the necessity of pulling out the tubings. A. H. N.

911.* Reservoir Pressure Maintained by Regulated Gas Injection. G. B. Nicholson. *Oil Wkly*, 29.6.42, **106** (4), 24.—Regulated gas injection into the Heep sand, one of several producing formations in the Plymouth oilfield, has terminated a previous steady drop in reservoir pressure, kept rate of production decline level, and maintained satisfactory flowing conditions in virtually all wells producing from that horizon. Of a total of eighty-four Heep-sand wells on the large Welder lease, all flow with the exception of two which are on gas-lift, these being located in a sand-lens not directly related to the main body, and accordingly not completely affected by repressuring. As result of gas injection, the affected formation now has the same capacity for producing as it had when discovered.

By maintenance of constant reservoir pressure, the bulk of dissolved gas has been held in solution, keeping underground oil less viscous, and hence easier to move through the sand-pores, as well as maintaining driving energy within the fluid. By proper rate of flow combined with gas injection, energy has been utilized as a driving and lifting force rather than dissipated in either the reservoir or tubing.

Controlled and scientifically engineered injection into the Heep sand has maintained the existing gas-cap in its original state, and holds the pressure of the water drive constant. Water influx admitted in proper volume exerts the force necessary for obtaining greatest recovery, and full efficiency of the water-drive is being obtained. Company engineers estimate that recovery from this formation will be increased up to 60% over expected recovery without repressuring. Among other benefits from repressuring are: (1) utilization of maximum natural reservoir energy and gas in solution; (2) water encroachment from edges has been controlled, and coning in producing wells rectified, with less volume of water produced to-day than when injection started; (3) net cost of production is less than if wells were worked over; (4) additional oil is now recoverable without expenditure of steel and vital war materials. A. H. N.

912.* Arkansas Oil and Gas Industry Managed on Engineering Basis. A. M. Crowell. *Petrol. Engr*, Annual Number, 1942, **13** (10), 55.—The State's conservation statute is described and the benefits derived from its application are explained. The work is praised. A. H. N.

913.* Determining Productivity Index of Pumping Well by Copper-Tubing Method. Anon. *Petrol. Engr*, Annual Number, 1942, **13** (10), 115.—Productivity index is defined and the formula for obtaining it from pressure build-up is derived. The determination of the productivity index of a pumping well by the copper-tubing method consists of the following steps: (1) determination of build-up characteristics of well by measuring rate of fluid-level rise in the casing after pump is stopped; (2) fluid-gradient determination by copper-tubing method. (This requires that the fluid level remain constant while two separate measurements at different depths are made); (3) substitution of values for h_1 and h_2 in the integral formula for corresponding values of t_1 and t_2. Values for the four variables are scaled from the *h versus t* build-up curve.

In many instances in production engineering work it is convenient to determine productivity indices when wells will not flow—that is, when the bottom-hole static pressure is not sufficient to raise fluid to the surface. This is particularly important in newly completed wells in areas of semi-wildcat character. Many times such wells test as potential producers, but will not flow with continued swabbing.

There then arise the questions whether (1) the well is merely slow in attaining a flowing state due to a low permeability of the sand, (2) the drilling fluid has penetrated the formation clogging the pores, or (3) the productivity index is very low and the well must be placed on the pump immediately. As the well cannot be made to flow naturally, a productivity index is not attainable by the ordinary methods. In such a case the method of determining productivity index by means of measuring rate of rise of fluid in the well over a period of time may be used. A. H. N.

914.* Gravel-Packing Wells to Increase Production Efficiency. L. C. Uren. *Petrol. Engr*, Annual Number, 1942, **13** (10), 81.—A comprehensive review of gravel-packing is appended by a good bibliography on the subject. Many advantages are visualized for the well equipped with a gravel-packed liner, all of which tend to increase its production efficiency. When properly placed in the annular space between the wall of the well and the perforated liner, gravel supports the walls of the well, preventing caving of formations against the liner, and serves to restrain sand from unconsolidated and disintegrating strata, so that it may not enter the well. More effective screening of sand, possible by this means, diminishes the destructive influence of sand-scouring on well equipment, tending to reduce maintenance costs. Equipment repairs and well clean-out operations are less frequent and the well is able to produce for a greater part of the time than would otherwise be the case. The well so protected is therefore capable of maintaining a larger monthly production rate.

Using gravel to sustain the walls of the well, it is possible to form and maintain a well of larger diameter through the producing formations, without elsewhere increasing the normal diameter of the well or that of the well-casing. This larger-diameter hole through the producing zone results in increased current rate of production and ultimate production of the well. Ability thus to increase the production efficiency of wells results in increase in the percentage recovery of drainable oil; or, for a given percentage recovery, may permit wider spacing of wells and result in reducing development and operating costs on oil-producing properties.

The development of gravel-packing is given. The principles of gravel-screening, size of gravel, bridging, thickness of the envelopes, and their porosities and permeabilities are each discussed separately. The three types of gravel-packs are described in some detail and are compared with each other. Economics of gravel-packing are further discussed. There are cost data and oil-recovery records obtained from operations in several California fields that demonstrate important economic advantages for wells packed with gravel, by the reversed-circulation method. Additional costs of gravel-packing, in comparison with the cost of conventional completion methods, range from \$1050 to \$3250/well, varying with the depth and thickness of the producing formation to be gravelled and the diameter of the well and liner. The higher figure is for wells in the Wilmington field, California, where the average thickness of the zone gravelled is 400 ft., 5⅝-in. liners are used and wells are wall-scraped to about 16 in. A large part of the cost is represented by the cost of rig time, which is included in the figures quoted at the rate of \$350/day. In the case of the Wilmington field, the cost of five days' rig time, or \$1750, is included. The material and equipment cost does not exceed \$1500 in any case. Gravel can be purchased in this locality for \$6/ton. Savings are discussed. A. H. N.

915.* Gravel Pre-Packed Liners. F. A. Graser. *Petrol. Engr*, Annual Number, 1942, **13** (10), 36.—A review of the development of gravel-packing is presented. Eighteen years ago the relationship of the size of sand-grains that could be screened by a slot was established, whereby it was determined that sand-grains would not pass through a slot if the diameter of the grain was greater than one-half the width of the slot. At the same time it was found that if there was a mixture of different sand-grains with one-seventh of a larger size, then this larger-size sand would form a bridge over the slot-opening and screen out the finer sand. Later work along this line in a separate investigation developed the fact that this percentage could be as small as one-tenth of the volume in order to screen effectively the balance of the sand. Later development resulted in pre-packed gravel liners.

Pre-packed liners have the following advantages over conventional pack: (1) very short and very long liners cn be landed in proper position; (2) the pre-packed liner is adaptable to multi-zone production and to the use of combination strings; (3) the gravel is held in position by a retaining sheath, so that all portions of the pack are of uniform thickness; (4) the cost of under-reaming in stages and subsequent water loss are diminished; (5) bottom water can be more easily plugged-off, due to the fact that well-shooting is practicable and that the casing is nearer the size of the under-reamed hole.

There have been two principal objections raised against the pre-packed liner: (1) that the retaining sheath acts as an outer casing and that a casing inside of a casing tends to seal-off and prevent the maximum amount of oil from entering the well; (2) that lignitic materials and waxes will be left in the gravel and gradually seal-off the oil. The first of these objections has been obviated by using large gravel.

Methods of cleaning these packs are described. Not all the mud is removed from the well with the present methods, as was shown by the fact that very little water is lost to the formation after the filter-cake is removed. Further work may be done in this direction, and it is probable that an acid or a de-flocculating agent may be spotted back of the liner as a final operation before closing the ports of the hanger.

There are no records of liners becoming frozen off bottom because of the removal of the filter-cake. In fact, the opposite is generally the case, and the liners are picked up more freely after washing. Operators space their well-cleaning guides 20–30 ft. apart as a rule, and then remove the liner that distance to pass " scratchers."

In the past it has been necessary to use opposing swab rubbers and a washing tool for wells in which a part of the liner was cemented-off or in which a combination string was used. Some of the operators are so confident of the advantages of the abrasive action in use with washing liners that considerable effort is being made to devise means of washing and " scratching " wells under these increasingly difficult conditions. If a method is in sufficient demand, the oil operator or engineer will devise the means, and the prediction can be made that this is a step to be expected in the near future.

A. H. N.

916.* Oil Reservoir Drainage Increased by Intermittent Air-Injection. F. R. Cozzens. *Petrol. Engr*, Annual Number, 1942, **13** (10), 120.—When a large volume of air is forced into porous sections of sand for a number of hours, and the pressure released for a like period of time, the air gradually filters or " bleeds " back into the more permeable channels, bringing with it oil and water containing considerable residue. This residue, commonly known as " floating sand," soon settles out, and on examination is found to be made up of cement-like material that forms the natural binder of the sand itself. When the air pressure is again applied, this fluid, minus most of its residue, is forced back into the so-called dormant pockets of the sand, returning again during the " off " interval with more residue. The action is similar to that in the violent jetting of water against a surface rock, which eventually becomes honeycombed and porous by the force and intermittent action. In a sand such honeycombing continues in several directions, and when the binder in the sand in the immediate area of an oil pocket or reservoir is removed by erosion, the accumulation of oil is released into more permeable channels, and thus recovered. In practically every locality where intermittent air-drive is practised, this action manifests itself by sudden increases in oil production in certain wells that may amount to several times the normal output. The volume of production increase and its duration depend on the size of the reservoir that has been drained. In this manner, oil pockets and reservoirs in various parts of any producing formation may be tapped.

Details are given for Eastern U.S. fields. A. H. N.

917.* The Stripper-Well Problem. J. F. Weiler. *Petrol. Engr*, Annual Number, 1942, **13** (10), 162.—A discussion of stripper wells in the U.S.A. is presented. Of the producing wells of the country, 75% are stripper wells that comprise 18% of the reserves. Of the total abandonments, practically all are stripper or marginal wells, and a decreased price and overproduction in 1931 accentuated an excess abandonment of 62% over drilling, but abandonments because of depressed prices are greatly overstated. Many stripper wells are profitable. The marginal-business argument is not applicable, because a natural resource is being depleted. The marginal-well cost, however, could be eliminated under an optimum-rate limitation for production. These wells could be shut-in for the duration of the low-price period, and most could be produced again unless water problems were present, and by more efficient secondary recovery methods the total recovery would be considerably greater and more economic.

In Texas the marginal-well law should be revised, taking into consideration all economic factors, not just depth, so that the wells can be pro-rated on an optimum-limitation schedule. In the future the importance of the stripper-well argument will decline under optimum-rate control of flush fields, for the properly produced oil-pool will leave a less persistent legacy of stripper wells, thus rendering the unrecovered reserve in the stripper stage of less relative importance than it is to-day. Therein lies the key to the stripper-well problem.

The present Government policy is indicated in a publication in *The Petroleum Engineer*, March 1942, in which a sub-committee of the Petroleum War Council appointed by Petroleum Co-ordinator Ickes studied ways and means of increasing oil reserves and preventing abandonments of marginal wells. The sub-committee found that a depletion allowance enabled the industry to continue exploration activities, and thus find new reserves, and enabled operators of marginal wells to keep on producing, and thereby maintain the continuity of their output for war purposes. References are given at the end of the paper. A. H. N.

918.* Submersible Magnetic Strain-Gauge. E. H. Lamberger and B. F. Langer. *Petrol. Engr*, Annual Number, 1942, **13** (10), 64.—As the magnetic strain-gauge is the basic element of the submersible gauge, a brief description of its construction, principle of operation, and characteristics will be of interest. The magnetic strain-gauge may be defined as a device that transforms small displacements into readings on an electrical instrument. It has a wide variety of applications, and many quantities, such as stress, force, torque, and acceleration, can be measured by means of the displacements that they produce. In the submersible gauge an axial displacement is measured. The gauge is illustrated and described.

Under the most favourable conditions one of the gauges illustrated can give full-scale deflection on an indicating instrument, or 4-in. deflection on the film of a magnetic oscillograph for about 0·0003-in. gauge motion. The maximum sensitivity when used with a graphic meter is full scale for 0·001-in. motion. These valves are based on a gauge with a maximum motion of 0·010 in. and a power supply of 115 volts, 800 cycles. Under these conditions the gauge requires about 15 volt-amp. at a low power factor. The sensitivity is directly proportional to the impressed voltage and inversely proportional to the total air-gap. The air-gap mechanically limits the maximum motion. A lower power-supply frequency necessitiates a lower voltage in order to keep the gauge from overheating. The calibration can be adjusted to the desired value by varying the voltage or adjusting the calibration resistor.

The complete gauges were thoroughly tested under pressure in the laboratory during development. During one test a gauge was under pressure for more than 2 weeks, with maximum pressures of 2500 lb./sq. in. They were tested in tension at loads as great as 20,000 lb. The calibration was practically linear over the entire range of load. The combined characteristics of the gauge, its control, and the recording oscillograph were such that load variations with a frequency up to 18,000 cycles/min. could be measured with a maximum error of 10%.

One of the gauges used in actual service in oil-well pumping tests was placed in the sucker-rodstring just above the pump plunger at a depth of 3500 ft. The second gauge was placed in the string approximately 1750 ft. down the hole. These gauges were in the field for 6 months, were lowered into the well three times, and were in operation in the well for a total period of more than 4 weeks. They had been sealed before leaving the factory, and were returned to the factory at the end of the tests with original seals unbroken. Calibrations at the end of the pumping tests checked original calibrations. A. H. N.

919.* Multiple-Zone Completions of Oil- and Gas-Wells. E. O. Bennett. *Petrol. Engr*, July 1942, **13** (11), 19–20.—A brief discussion of multiple-zone completion problems is presented. The following are stated to be advantages of multiple-zone completion practices: (1) Steel requirements are reduced by half when the zones are closely spaced. (2) Drilling costs are cut in half, as one well is used to produce the allowable normally produced by two. (3) The method provides the maximum number of injection locations in pressure-maintenance operations. (4) Approximately 50% reduction in the cost of pumping equipment when contemporaneous pumping is carried out for two zones. (5) Saving of time in drilling a new field when conditions suitable for multiple-zone completions exist. (6) Provides increased availability of steel for exploratory development now that a shortage of steel exists. (7) Reduction in the cost of well-head equipment/zone. A. H. N.

920.* New Removable-type Circulating Valve. J. O. Farmer. *Petrol. Engr*, July 1942, **13** (11), 35–36.—The purpose of this new tool is to provide a means to open circulation ports above a packer by pumping into the tubing, to close these ports when the pumps are shut down, positively to prevent interzone communication at all times, and to alleviate the task of moving the tubing or pulling the side-door choke to produce the same result. The valve is described together with its mode of installation and its action. Although this tool is quite new, results from its use have been most satisfactory and encouraging. All installations have been made at approximately 10,000 ft. and under the most adverse conditions of temperature, pressure, and mud. The advantages realized from the new tool are summarized as follows : (1) Under no condition are the two zones of a dual completion produced simultaneously. (2) Accumulated head in either or both tubing and casing may be unloaded simply by connecting high-pressure gas into the tubing. (3) The need of pulling the side-door choke to permit circulating is eliminated. (4) Both zones may be circulated-in after the packer has been set and tubing connections permanently installed. (5) It provides simple but positive means to circulate mud from above a packer in a single-zone well. A. H. N.

921.* Overcoming Tendency of Packer to Stick in Casing. F. H. Love. *Petrol. Engr*, July 1942, **13** (11), 13–24.—A troublesome problem connected with the use of packers in oil- and gas-wells is the tendency of packing element or sleeve to vulcanize to the casing, caused by high temperatures existing in wells of certain areas. To remove the packer thus stuck frequently develops into a difficult operating problem, and almost invariably results in a torn and worthless packing element.

To overcome this difficulty, and at the same time provide a packer with an effective seal, one manufacturer began experimenting 2½ years ago. The result is a lubricant-impregnated packing element. The element is made of neoprene, and the lubricant is milled and moulded into the construction in such a manner that under heat and load the sleeve " sweats " its own lubrication and prevents vulcanizing to casing even at temperatures as high as 300° F. The packing element has internal metallic reinforcing which imparts added strength and ensures multiple ring expansion for effective packing. The packer is described in some detail, with illustrations, and its use is discussed. A. H. N.

922.* Petroleum Engineering. Part 7. L. C. Uren. *Petrol. Engr*, July 1942, **13** (11) 25.—Professor Uren concludes his paper on the education of petroleum engineers in the U.S.A. by surveying the possibilities of and requirements for getting a job in the industry immediately after graduation. A. H. N.

923.* Reworking California Oil-Wells. W. A. Sawdon. *Petrol. Engr*, July 1942, **13** (11), 21–22.—The effect of war demands on Californian oil-fields is briefly discussed. According to the O.P.C. report, it appears that the present rate of productive capacity of heavy oil should be maintained at more than 300,000 brls./day, but that the normal annual drilling programme in the heavy-oil fields will not provide a sufficient number of wells to maintain this capacity. The development rate in these fields should therefore be increased, and the report recommends that : (1) Wildcat drilling be encouraged in every possible way, and top primary assistance be given for the drilling of exploratory wells. (2) All economically producible wells be rehabilitated and equipped where necessary. (3) The development of undrilled acreage, in fields capable of producing heavy oil, be stimulated to meet the demand made on this most important source of fuel oil.

As the immediate demand for more heavy oil is caused by the war, such oil that cannot be produced within the next few years will be of little value to the present war effort. California heavy-oil fields require close spacing to produce a high percentage of recoverable oil in the desired period of time, and the report made by the district office of the O.P.C. suggests that old pools with undrilled areas and pools in the primary development stage be drilled with one well to 10 acres, but that the well-spacing pattern provide for secondary development of one well to 5 acres; that undrilled single locations in old pools be drilled according to the uniform spacing already prevailing; and in drilled areas of old pools, where closer spacing is justified by the remaining reserves and the steel factor, the spacing for additional drilling be variable to allow for subsurface conditions. Work in California is described in particular in connection with the reworking of wells. A. H. N.

924.* Reservoirs under Hydraulic and Volumetric Controls. A. H. Nissan. *J. Inst. Petrol.*, July 1942, **28** (223), 146–157.—An anomaly appeared to exist in deriving the velocity-pressure relationship, for reservoirs under volumetric or hydraulic controls, by two methods. The two equations were $Ve = KP^{\frac{1}{2}}$ and $Ve = KP$. A study of the two methods reveals the fact that the assumption made in applying only orifice equations to the problem are not justifiable, and that if a truly representative model be constructed, the anomaly disappears and a single equation is the result:

$$Ve = K_1P_1 + K_2P_2^{\frac{1}{2}}.$$

It is further shown that P_2 is negligible in oil reservoirs under volumetric or hydraulic controls, and therefore the equation becomes $Ve = KP$. A. H. N.

925.* The Value and Accuracy of Field Measurements. C. J. May and R. Pike. *J. Inst. Petrol.*, July 1942, **28** (223), 133–140.—A discussion of the desirable order of accuracy and of types and sources of errors in field volume and pressure measurements on producing wells is presented. A. H. N.

926.* Calculation of Load and Stroke in Oil-Well Pump-Rods. Part 1. B. F. Langer and E. H. Lamberger. *Oil Gas J.*. 2.7.42, **41** (8), 27.—*Paper Presented before Society of Mechanical Engineers.* Sucker-rods used in oil-wells can have a prolonged lift if they are operated in a manner which will prevent shocks and over-loading. This article deals with formulæ recently developed for the determination of these factors. The sucker-rod pump as used in oil-wells is treated as a problem in longitudinal vibration of bars. Solutions are obtained for the forces and motions at both ends of the rod-string, thus giving formulæ for the calculation of polished-rod load and plunger travel. The results of the calculations are compared with test results.

When making calculations in the field, it is not convenient to use the formulæ given. It is possible to simplify those formulæ for use over a limited range of conditions by assuming no damping in the rod-string. The authors did this, and at the same time modified the constants to make the calculated results agree more closely with the test results. The field formulæ thus derived are given. They agree with test results more closely than the complete formulæ in the range which the tests cover but must be used with caution for abnormal conditions.

$$PPRL = W_R - W_{Rb} + W_{OD} + 45SN\,[17A_R \tan (0{\cdot}002LN)^0 + A_0].$$

$$EPS = \frac{S}{\cos (0{\cdot}002LN)^0} - \frac{W_{OD}L}{24(10^6)}\left[\frac{1}{A_R} + \frac{1}{A_T}\right].$$

where $PPRL$ = peak force at polished rod; W_R = weight of rod-string; W_{Rb} = buoyant force on rods; W_{OD} = differential fluid load = load due to net fluid-head on full area of plunger; S = polished-rod stroke; N = strokes/sec.; A_R = area of rod cross-section; L = total length of rod-string; A_0 = area of fluid cross-section = net area of plunger; EPS = effective plunger stroke; and A_T = area of cross-section of tubing wall. All dimensions are in inches, pounds, and seconds. A. H. N.

927.* Development, Operation, and Valuation of Oil and Gas Properties. Part 6. P. J. Jones. *Oil Gas J.*, 2.7.42, **41** (8), 34–35.—This section deals with the flow of gas-oil mixtures through media of uniform permeability. Equations and graphs are reproduced and examples are worked out. A. H. N.

928.* Marine Christmas Trees Require Special Protection. G. B. Nicholson. *Oil Wkly*, 6.7.42, **106** (5), 21.—In the event of damage occurring to a christmas tree, and a well blows out, either by external damage or defective equipment, oil companies use every possible safeguard against catastrophic effects of waste and pollution, protecting not only their own interests, but also the welfare of many families whose livelihood depends on fish and oysters living in the waters. To care for possible unavoidable damage of this nature, general practice in marine fields includes use of safety valves, usually placed in the tubing near the bottom of the hole, and designed to reduce or cut off flow automatically before harm is done. Casings are packed off.

The use of pilings and boards and other precautions against the elements are described, and are illustrated by several photographs of typical well-heads. A. H. N.

929.* Calculation of Load and Stroke in Oil-Well Pump-Rods. Part 2. B. F. Langer and E. H. Lamberger. *Oil Gas J.*, 9.7.42, **41** (9), 26.—Test data on a well are summarized, and the results are compared with those calculated by formulæ developed in the previous part. The well was specially selected. It was an abandoned, " dead " well, quite straight, quite constant as to casing fluid-level, with fluid being chiefly salt water (specific gravity 1·04) with only a trace of oil. The tests were conducted in such a way as not to disturb the fluid-level to any appreciable degree.

The formulæ developed are compared with A.P.I. and with the Mills formulæ.

In conclusion, it is stated that peak polished-rod loads and effective plunger strokes in an oil-well can be calculated by using the following formulæ : (1) Complete formula for peak polished-rod load :

$$PPRL = W_R\left(1 + \frac{ESK_1}{288L^2\delta_0}\right) + W_0\left(\frac{E_0\,\omega\,S_P}{144\mu_0 L_0}\right) + 2W_{0D} - W_{Rb}.$$

(2) Field formula for peak polished-rod load :

$$PPRL = W_R - W_{Rb} + W_{0D} + 0{\cdot}75SN\,\{17A_R \tan\,(0{\cdot}0004LN)^0 + A_0\}.$$

(3) Complete formula for effective plunger stroke :

$$EPS = \frac{S}{R} - \frac{24LW_{0D}}{E}\left[\frac{1}{A_R} + \frac{1}{A_T}\right].$$

(4) Field formula for effective plunger stroke :

$$EPS = \frac{S}{\cos\,(0{\cdot}0004LN)^0} - \frac{W_0L_D}{2(10^6)}\left(\frac{1}{A_R} + \frac{1}{A_T}\right).$$

The strokes and areas are expressed in inches, forces and weights in pounds, the well depth L in feet, and the pumping speed N in strokes/min. These dimensions are commonly used in the oilfields. Values of K_1 and of $1/R$ are given in figures. The results calculated by the foregoing formulæ agree closely with test values obtained from a comprehensive test programme, carefully carried out on a single well. It is believed that data determined by tests made with similar care on wells at other depths, or under other operating conditions, will also closely agree with calculated values. Such comparisons are invited.

Appendices give formulæ for the acceleration of fluid columns and for the natural frequency of stepped rods.

[*N.B.*—See Abstract No. 926 for Part 1 of the Paper.] A. H. N.

930.* Development, Operation, and Valuation of Oil and Gas Properties. Part 7. P. J. Jones. *Oil Gas J.*, 9.7.42, **41** (9), 25.—This part of the paper deals with the flow of gas–oil–water mixtures through media of uniform permeability. The work of Leverett and Lewis on 2-phase and 3-phase flow is summarized. A. H. N.

931.* Development, Operation, and Valuation of Oil and Gas Properties. Part 3. P. J. Jones. *Oil Gas J.*, 11.6.42, **41** (5), 35.—Formulæ are developed and graphs presented for the flow of homogeneous fluids through porous radial systems of uniform permeability. Pressure recovery in closed wells is studied. A. H. N.

932.* Factors Affecting the Volumetric Efficiency of Sucker-Rod Pumps. G. M. Stearns. *Oil Gas J.*, 11.6.42, **41** (5), 41–42.—Based on field experience, reported investigations and deductions, the factors listed below have been chosen as the conditions that may possibly influence the volumetric efficiency of a sucker-rod pump :

(1) Inherent well conditions : (*a*) amount of gas in solution in the fluid being pumped that may be reduced from solution between the valves of the pump ; (*b*) viscosity of the pumped fluid ; (*c*) temperature of the fluid being pumped ; (*d*) foam accumulation in the well-bore ; (*e*) well depth ; (*f*) suspended solids in the fluids ; (*g*) density of the pumped fluid. (2) Pump design : (*a*) size and shape of valve openings ; (*b*) minimum clearance volume between valves ; (*c*) plunger fit ; (*d*) type of check (ball, drop, plumb bob, etc.) ; (*e*) size, length, and design of gas-anchor ; (*f*) plunger length ; (*g*) plunger surface—*i.e.*, (i) metal *versus* leather or composition, or (ii) grooved metal *versus* plain metal. (3) Pump operation : (*a*) length of stroke ; (*b*) valve spacing ; (*c*) pumping speed ; (*d*) submergence.

These factors are discussed in brief. A. H. N.

933.* Review of Ultimate Recovery Factors and Methods of Estimating. S. F. Shaw. *Oil Wkly*, 13.7.42, **106** (6), 16.—An historical review is presented at the beginning of this long paper. There are five methods employed for estimating ultimate recovery : (1) Arbitrary estimates of barrels/acre, or barrels/acre-foot, based on recovery from fields with supposedly similar conditions. (2) Estimates based on volumetric, or saturation, contents of the reservoir. (3) Estimates based on decline curves constructed by plotting production against elapsed time. (4) Estimates based on the initial production of the well produced at maximum capacity for one day, or on the average daily production of the first year multiplied by a factor. (5) Estimates based on plotting the decline of reservoir pressure against the accumulated production.

Each of the methods is critically reviewed, with references to original papers on the subject. The conclusions reached from this review are as follows : (1) Factors for determining the ultimate recovery of oil are many and varied, and are as yet far from being thoroughly understood. (2) Methods of estimating ultimate recovery of oil are far from being perfect, but are gradually being improved as a better understanding of the various factors is obtained. (3) The most satisfactory method of estimating oil reserves yet devised is that obtained from elapsed-time-production decline curve on logarithmic cross-section paper, but this method may be affected by changes in methods of production. This method of estimation cannot be used satisfactorily when production is at a restricted rate. (4) The tendency of the elapsed-time-production graph for estimating reserves seems to be on the conservative side, while that of estimation by volumetric or saturation method seems to result in an exaggerated estimate. (5) Percentages of 10–20% recovery, as stated in early days, was only an opinion, and applied only to shallow reservoirs with tight formation rock and only to primary methods of production. It was the best expression of opinion obtainable in early days, based on the scanty evidence available at that time. Such a figure never has had, nor does not now have any application to recoveries obtained in the average producing fields of the U.S.A., and should never be used as a basis of comparison for different methods of production. A. H. N.

934.* Water-Heater System Prevents Freezing of Regulator Valves. G. B. Nicholson. *Oil Wkly*, 13.7.42, **106** (6), 14.—To prevent freezing of valves, orifice, or other units of a regulator on a gas-well, one company uses a special heater in which parts of the regulator prone to freeze are kept submerged in a vat filled with hot water, with heating element consisting of an inexpensively constructed underground pipe fed by a flame regulated by a pilot light and using gas from the separator.

Important element of the heater consists of a vat, 13 ins. deep and 24 × 36 ins. in lateral dimensions, set in a shallow pit. Constructed of firebrick and lined with mortar, the vat is water-tight and filled with water at all times. Regulator sets in the hot water, with the orifice and parts of the regulator body under the surface, and freezing on downstream side of the orifice is prevented.

Water in vat is maintained at proper level by an overflow consisting of a ½-in. pipe extending through the wall of the vat 1 in. below top, opening into a concrete drain set at a slight angle in the ground. On end of the ½-in. nipple, fittings are connected for attaching another nipple about 1 in. long, arranged in swing-fashion to stand vertically, or to be adjusted to any desired level not exceeding top of the vat. Height of this pipe determines level of the fluid inside the vat, with excessive water overflowing automatically through the drain, and following the ditch to a shallow excavation or gathering pit, where it is later picked up and returned to a storage drum.

Water requirements are low as little waste occurs, temperature of the water seldom attaining point where evaporation is acute. The rest of the equipment is described.
A. H. N.

935.* Development, Operation, and Valuation of Oil and Gas Properties. Part 8. P. J. Jones. *Oil Gas J.*, 16.7.42, **41** (10), 44.—The paper deals with recovery from gas reservoirs, detailing some of the gas laws and compressibility data. Pseudo-criticals are discussed, together with the mechanism of recovery by gas expansion. Data are presented graphically and formulæ are given in full. A. H. N.

936.* Review of Secondary Recovery in the United States. Part 2. P. D. Torrey. *Oil Gas J.*, 16.7.42, **41** (10), 39.—Secondary-recovery methods in Oklahoma (water-flooding), Texas (air and gas repressuring), and the Rocky Mountain States are reviewed. It is concluded that successful secondary-recovery operations in the U.S.A. are restricted largely to fields where primary recovery has been obtained by the action of internal gas-drive. Fields in which active natural-water drives are in operation are generally not adapted to secondary-recovery operations on account of low residual oil content. It should be pointed out also that better reservoir efficiency in more recently discovered internal-gas-drive fields should eliminate in some part the necessity for future application of secondary-recovery methods. If oil had been produced efficiently in many of the older fields, it is doubtful whether there would be such a high present activity in secondary-recovery operations. Therefore, secondary recovery, in a certain sense, is the correction of past mistakes, and with the knowledge that mistakes have been made, it should be possible better to avoid them in the future development and operation of oilfields. In this, studies of primary pressure control will undoubtedly play a very important part.

A study of oil reserves available from secondary recovery in the U.S.A. is presented.
A. H. N.

937.* Development, Operation, and Valuation of Oil and Gas Properties. Part 9. P. J. Jones. *Oil Gas J.*, 23.7.42, **41** (11), 35.—This part forms a continuation of the discussion on recovery from gas reservoirs begun in Part 8. Problems of recovery under water encroachment, and under partial water-drive with no by-passing are discussed. Economic limits for abandonment pressures and productions are studied.
A. H. N.

938.* Electrolytic Chlorinators Used on East Texas Disposal Projects. T. P. Sanders. *Oil Gas J.*, 23.7.42, **41** (11), 31–32.—Chlorine and chlorine compounds, widely used to eliminate sulphate-reducing bacteria and algæ at water-disposal projects in the East Texas field, have recently become practically unobtainable. As a result, East Texas operators are adopting an electrolytic process for liberating chlorine directly from the salt of the oilfield brine. Five disposal plants, operated by three different major companies, have already installed electrolysis equipment, and all other west-side operators having water-disposal wells are now planning similar installations.

Electrolytic chlorination consists of placing a series of carbon electrodes in a trough where the salt water will flow at a fairly uniform rate. With direct current of high amperage and low voltage, the reaction is made to take place, breaking down a small portion of the salt (sodium chloride) in the water. Chlorine is liberated as a gas at the positive pole, while sodium is liberated at the negative pole. However, the sodium combines with water instantaneously during the reaction to form sodium hydroxide. This reaction liberates hydrogen from the water, so a gas can be seen bubbling up from both positive and negative poles.

Because of the constant flow of water around the poles, the chlorine is quickly absorbed, and the portion escaping as gas is considered insignificant. Proper treatment calls for generating a slight excess of chlorine. Trouble was expected from the formation of sodium hydroxide in the water, but there has been none. It is believed that this alkali reacts with the magnesium and calcium carbonates present to form sodium carbonate and water, thereby being neutralized immediately.

The working of typical plants is described. A. H. N.

939.* Recovery of Gasoline Stored in Laboratory Crude Reservoirs. H. Vance and P. Martin. *Oil Gas J.*, 23.7.42, **41** (11), 33–34.—This paper deals with the recovery of gasoline injected into artificial crude-oil reservoirs on a laboratory scale. Attempts were made to duplicate as near as possible within the laboratory actual field conditions which would exist around one well in a field under gravity drainage alone. The equipment is described.

The crude oil used throughout these experiments was from the East Texas field and had a gravity of 35·8° A.P.I. The gasoline used was commercial third grade, having an A.P.I. gravity of 50·2°. The sand was from an outcrop of the Yegua sandstone; it had a sand-grain analysis similar to the productive Woodbine sand in the Cayuga field in Anderson County, Texas, but slightly coarser.

In each case the sand was first dried and then dampened with water having the same chemical composition as the Woodbine water produced from the East Texas field. The water-wet sand was sifted into the reservoir, and after the sand had stopped setting, the excess crude oil was drained off, leaving the pore spaces saturated with crude oil and water. During the depletion of the sand, natural gas saturated with gasoline filled the top of the reservoir above the sand-face, allowing natural gas to enter the pore-space as it was depleted of its oil. This gas was then displaced as the pore-space was resaturated at a uniform rate with gasoline or a mixture of gasoline and crude oil.

Recovery data are presented graphically. About 30% more crude oil was recovered after injecting gasoline than was recovered by normal production methods. Neither the crude-oil saturation at the time of injecting gasoline nor the point of gasoline injection has much effect on the percentage of crude-oil recovery. The most favourable results from the standpoint of recovery injected gasoline were obtained by injecting the gasoline in the bottom one-third of a sand having low crude-oil saturation. Under these conditions there was an increase in crude-oil recovery of 25%, and 29·3% of the injected gasoline was not recovered. A. H. N.

940.* Development, Operation, and Valuation of Oil and Gas Properties. Part 10. P. J. Jones. *Oil Gas J.*, 30.7.42, **41** (12), 163–164.—The paper illustrates how the volume factors determined by Sage and Lacey, in their work on oil-gas mixtures under Research Project 37 of the American Petroleum Institute, can be used to make accurate estimates of oil recovery by either gas-expansion or water-drive. Equations are formulated and graphs are plotted based on the use of these factors. A. H. N.

941.* War Conditions Change Trend of Production Practice. H. F. Simons. *Oil Gas J.*, 30.7.42, **41** (12), 154–155.—Some of the outstanding things brought to the fore during the past six months include such equipment and ideas as : (1) Calipers which can be run in a bore-hole to determine its diameter from top to bottom. (2) The storing of butane in depleted horizons. (3) The use of an electrolytic chlorinator to remove sulphate-reducing bacteria from salt water which is to be disposed in a sub-surface formation. (4) The application of gravel-packing as a means of eliminating troubles and increasing production in fields which are almost depleted. (5) Accurate instruments for measuring the weight and viscosity of drilling fluid and more complete instrumentation generally of drilling rigs. (6) More efficient equipment for the desulphurization of gas in sour-gas fields. (7) A new method of multi-zone completion which calls for running a succession of liners beginning at the bottom of the hole. (8) A triplex mud-pump which increases the fluid volume moving through the drill-pipe and well-bore approximately 50%. (9) An evaporator which permits a steam rig mounted on a barge to use sea-water for the boiler-feed. (10) An automatic spider and slip arrangement for handling rotary drill-pipe. (11) Studies on pump operation to increase the efficiency and reduce the number of breaks in sucker-rods. (12) A better understanding of the causes of drill-pipe and tool-joint failure. (13) Wider use of double-box and double-pin subs for connecting joints of drill-pipe. (14) More efficient use of all types of logging, including electrical, mud analysis, and time. (15) Redesign of reverse circulating rotary rigs which allows them to be used for clean-out and completion work. (16) A new type slim-hole rig, wheel-mounted and propelled while moving by the drilling engines. (17) Greater centralization of lease equipment. (18) Electrical and steam heating of tubing to remove paraffin or prevent its deposition. (19) Further experimentation with fibre-pipe in a shallow well using this type of tubular equipment for casing and a greater application being made of this material for salt-water gathering lines. (20) Use of carbon monoxide as a tracer in repressure projects. (21) Use of reabsorber gases from gasoline plants for field fuel. (22) Automatic tank batteries which do not require the constant attention of a pumper or switcher. (23) Use of citrous-fruit pulp as a viscosity-reducing agent in drilling mud. (24) A wider use of torque convertors for increasing the life of internal-combustion engines. A. H. N.

942. Patents on Production. J. R. Betts. U.S.P. 2,284,632, 2.6.42. Appl. 31.5.39. Centrifugal pump with a well casing and having water-lubricated bearings.

A. Boynton. U.S.P. 2,284,634, 2.6.42. Appl. 31.1.39. Pneumatic piston-pump of the differential type for oil-wells.

R. T. Knapp. U.S.P. 2,284,908, 2.6.42. Appl. 10.1.39. Deep-well pumping mechanism utilizing liquid pumped under pressure.

A. S. Parks. U.S.P. 2,285,049, 2.6.42. Appl. 27.1.39. Means for purging flowing wells.

M. P. Burke. U.S.P. 2,285,109, 2.6.42. Appl. 8.6.39. Displacement-valve gas-lift system and apparatus.

H. C. Pyle. U.S.P. 2,285,169, 2.6.42. Appl. 27.1.38. Well-pump with a special type of gas separator attached to the inlet side.

L. Davis. U.S.P. 2,285,256, 2.6.42. Appl. 4.6.41. Pressure pump for oil-wells.

D. H. Larsen. U.S.P. 2,285,291, 2.6.42. Appl. 15.1.40. Gravel-packing of wells using an emulsion at least one of whose phases is soluble in petroleum.

C. C. Carlisle. U.S.P. 2,287,779, 30.6.42. Appl. 18.9.40. Deep-well pumping mechanism with a reversing valve.

H. J. Pankratz. U.S.P. 2,288,142, 30.6.42. Appl. 27.3.41. Well-pump with a special fluid-accumulation chamber.

R. C. Boughton. U.S.P. 2,288,225. 30.6.42. Appl. 24.2.41. Pipe-coupling.

E. C. Kopp. U.S.P. 2,288,245, 30.6.42. Appl. 9.1.40. Oil and gas separator with special type of baffles.

L. W. Vollmer. U.S.P. 2,288,556, 30.6.42. Appl. 28.6.39. Method of and composition for producing permeable packs in wells.

L. W. Vollmer. U.S.P. 2,288,557, 30.6.42. Appl. 20.6.40. Method of and composition for producing permeable cement packs in wells. A. H. N.

Transport and Storage.

943. Evaporation from Gasoline Storage Tanks. C. L. Marner. *Refiner*, May 1942, **21** (5), 147–149.—Evaporation losses from gasoline tanks result in: (1) decrease in vapour pressure (affects starting); (2) increase of 10–50% boiling point (affects acceleration and performance); (3) decrease in octane number.

Practically all data covering evaporation have been based on the theory that the loss occurring is directly proportional to the vapour pressure of the product and the surface area of the tank in which the product is stored. However, later information indicates that evaporation loss is directly proportional to the vapour pressure of the gasoline and the capacity of the tank. The loss being correspondingly greater from smaller tanks than from the larger ones. One of the major oil companies recently completed tests which proved that with 10 ft. or more of outage from a tank, the evaporation loss remained the same regardless of the amount taken out. This is undoubtedly true because the most important factor in breathing is the increase in the vapour pressure of the gasoline as its temperature increases. This effect is in addition to the expansion of the vapour caused by increase in temperature. The closer the gasoline-level to the top of the tank, the higher the surface and vapour-space temperatures, as well as a correspondingly greater fluctuation in temperature range, and any vapours expelled during breathing would be considerably richer due to the higher surface temperature and the smaller space to be saturated.

Tabulated data show typical losses obtained in tests by fourteen large oil companies. Losses by windage, breathing, filling, and boiling are discussed. Filling losses may be eliminated by using floating roofs or by having the vapour spaces of all tanks manifolded together, and then to a gas reservoir or to a comparatively limited number of tanks equipped with expansion or variable-space roofs having sufficient capacity to equal difference in volume of gasoline produced and shipped/day plus the proper allowance for breathing. One major oil company using this method for the past several years reports that tanks containing sweet and sour products have been manifolded without any evidence of contamination of either product.

Breathing may also be eliminated by storing motor gasoline in 3-lb. pressure vessels. When pressure tanks are used the total cost for complete protection is considerably higher than when manifolding cone-roof tanks to roof of the variable-space type, because each unit must be of the pressure type.

Inhibitors are used in gasoline to prevent oxidation of unsaturated hydrocarbons, and thus eliminate formation of gum. Some of these inhibitors are soluble in water. Thus, when water comes in contact with gasoline, the inhibitor losses its effectiveness, and as a result, objectionable quantities of gum are formed. A. H. N.

944. Practical Methods for Storing Volatile Liquids. D. E. Larson. *Refiner*, July 1942, **21** (7), 217–225. *Paper Presented before American Institute of Chemical Engineers.* —The requirements of storage for these liquids are : (1) Retaining each product for the required period of time without deterioration or loss of quality. Some liquids may become contaminated or go " off specification " unless properly protected from contact with air, water, dust, or other foreign substances. (2) Retaining the product without loss of volume. Evaporation and leakage are the primary sources of loss from storage containers. Losses from both sources can be eliminated by selecting the type of container best adapted to the service for which it is to be used. (3) Storing the product at the lowest possible cost/gal. commensurate with safety. As a rule, the type of container most nearly fulfilling the requirements listed above will provide the most economical storage even though its first cost is higher than that of other types. (4) Storing the product with the least possible danger from fire. Where defence materials are concerned, the ever-present threat of sabotage makes the problem of protection doubly important. Fires must be prevented from starting and spreading.

Five basic types of tanks are : (1) atmospheric tanks with fixed roof ; (2) tanks with variable-volume vapour spaces ; (3) floating-roof tanks ; (4) pressure tanks ; (5) underground storage tanks.

After a detailed examination of various types of losses, it is concluded that the classes of service to which each of the five basic types of storage containers are best adapted may be summarized as follows : (1) Atmospheric tanks with fixed roofs equipped with conservation vent-valves are suitable for products of low volatility such as fuel oil, kerosine, and heavy crude oil. (2) Tanks with roofs which provide a variable-volume vapour space are used most advantageously in these ways : (*a*) breather roofs provide economical storage for light products such as motor gasoline or light crude oil in tanks which normally remain full or nearly full ; (*b*) balloon roofs, which have a relatively large volume, afford the lowest-cost storage for motor gasolines and similar products in slow-working tanks which are filled and then emptied gradually over a period of several months. (3) Floating roofs provide the most economical means for storing motor gasolines, light crude oils, and other products of similar volatility in active tanks which are worked either continuously or intermittently. Floating roofs are also recommended for installation in which reduction in fire hazard is one of the prime considerations in selecting the type of tank. (4) Pressure tanks such as spheres and spheroids afford the only practical method for storing natural gasoline, *iso*pentane, butane, and other light products which would suffer enormous losses from boiling in ordinary storage tanks. (5) Underground storage is much more costly than above-ground storage, and is used primarily for installations in which concealment is necessary for defence purposes or where tanks must be placed below the surface to comply with city ordinances.

A discussion of the paper is appended. A. H. N.

Gas.

945. Butane Requirements Demand Efficient Extraction. R. W. Machin. *Refiner*, May 1942, **21** (5), 143–146.—Manufacture of natural gasoline by the absorption method is accomplished by three distinct steps. In the absorption plant the rich gas is contacted with oil in absorbers to remove the constituents desired in the finished products. After the oil has absorbed these constituents, the rich oil is passed successively through vent tanks, heat exchangers, and preheaters to the distillation unit, where, by a process of distillation, the absorbed constituents are driven off by heat under pressure. The absorption oil is cooled by heat exchange and coolers to be recycled through the absorbers, while the light constituents absorbed from the gas are liquefied by cooling and accumulated in tanks.

From there the condensate is pumped to stabilizers, where the constituents are broken up into as many various products as the plant is equipped to segregate. The three units that make up the absorption plant are : (1) the absorption unit ; (2) the distillation unit ; and (3) the stabilization unit. In conjunction with these three units will be found such auxiliary units as the cooling-tower and boiler-house.

Each of the three units is discussed in some detail, together with the mechanism of absorption. The importance of temperature and pressure effects is explained. Other factors directly affecting obsorption are the characteristics of the absorption medium, gas–oil ratio, velocity of gas through the column, kind of gas, and design of the equipment. Perhaps as important a factor as temperature and pressure is the regulation of the gas volume and the oil rate, so that both will be as nearly consistent as is possible. It has also been found by many operators that when the oil–gas ratio is higher or lower than a certain definite point, maximum efficiency is not obtainable, and at that point of " maximum effect " is acquired the peak of plant production. A. H. N.

946. Importance of Butane in This War. R. L. Huntington. *Refiner*, May 1942, **21** (5), 127–130.—The production of butane from gas and crude-oil fields, from distillate fields and from secondary recovery operations is discussed briefly. Operations with vacuum on the casing-head are studied. The maintenance of present equipment free of trouble is analysed under three headings : (1) Scale prevention and removal ; (2) importance of clean absorption oil ; and (3) water supply. Under the third item it is pointed out that prevention of scale can be had in three ways : (1) By water treatment calling for the precipitation and removal of scale-forming chemicals before water enters the plant system. (2) By adding a colloid which will keep the scale-forming compound in suspension until the concentration becomes great enough to warrant a renewal of raw water within the system. (3) By use of zeolite treatment, in which hard salts are converted into non-scale-forming salts of sodium.

A brief study of oil absorption is then given, discussing pressures, temperatures, number of theoretical plates, and type of absorption oil. Certain general rules for the type of oil to be selected are given. (1) The oil should have an initial boiling point well above the end-point of the raw natural gasoline, so that the oil will not distill over with the gasoline. (2) The oil should be free of heavy ends which may cause too high a pour test thereby resulting in solidification of the oil in the cooling coils. (3) Waxy hydrocarbons should be absent (or present in very small amounts). Heavy asphaltic fractions may promote the formation of emulsions which are highly undesirable. (4) The number of mols./unit of liquid volume should be a maximum. This result usually can be accomplished by selecting a low-molecular-weight oil. An example is worked out. (5) The absorption oil should be one from which the gasoline constituents can be readily denuded or stripped out in the still. (6) In high-pressure absorbers operating at 600 lb. or more, higher molecular-weight oils are recommended since there is a tendency for vaporization to take place in the retrograde region, especially for the lighter oils. A. H. N.

947. A Suggested Standard Method for Calculation of High-Pressure-Gas Measurement. D. L. Katz. *Refiner*, June 1942, **21** (6), 170–176.—A standard procedure for converting orifice-meter readings on high-pressure gases into quantities of gas flowing is desirable for the natural-gas and natural-gasoline industries. Such standards have been used for low-pressure gases for many years, and cover most of the procedures for high-pressure gases. The chief item on which complete agreement has not been reached is the correction for deviation of the gas from ideal gas laws. The compressibility-factor method is generally accepted, and the lack of agreement lies in the method of choosing this compressibility factor for specific cases. The prime purpose of this paper is to suggest standard procedures for selecting water-correction factors to account for the compressibility of the gas flowing. A brief discussion of measuring the flow of two phases is included. The following procedures for establishing standard meter factors including the deviation from ideal gases are as follows, depending on the accuracy desired : (1) For the highest degree of accuracy, a gas analysis should be obtained to eliminate any doubt as to pseudo-criticals. The errors in metering due to gas density alone should not exceed 1% on the average. (2) For average metering of high-pressure gases of varying gravity, representative analyses should be obtained to be used to establish a curve of gas gravity *v.* pseudo-critical temperature and pressure. From this curve a chart or series of tables should be prepared, giving the meter factors at even gas gravities. The errors in metering due to gas density alone should not exceed 2% on the average. (3) For cases in which analyses are not available, the meter-correction factors are recommended. These are illustrated. The error in metering due to gas density should not exceed 3% for the average gas, but an unusual gas at conditions to give low-compressibility factors might be in error by as much as 10%. (4) Further study of gasoline contents may indicate their usefulness for certain groups of gases in establishing the correct pseudo-critical conditions *v.* gas gravity. (5) Metering of gases above 1000 lb. known to contain less than 10% of liquid by volume should be computed as if the entire stream were a gas phase, provided the meter operation is indicative of uniform dispersion of the liquid in the gas passing through the meter run. (6) The compressibility-factor plot should be used for natural gases containing less than 7·5 N_2 and 2% carbon dioxide. For appreciably higher concentrations the measurement of the compressibility factors is recommended for reliable results. (7) The double importance of temperature because of its effect on compressibility factors as well as on the ideal volumetric expansion should be recognized in high-pressure measurement.

The paper is well illustrated by graphical compressibility data. A. H. N.

948. The Density of Natural Gases. T. A. Matthews, C. H. Roland, and D. L. Katz. *Refiner*, June 1942, **21** (6), 164–169.—Although one page is missing from the paper, enough of graphical and tabular data are included in the remainder to render it of value. Extensive graphs and tabulated data are presented for single and two-phase natural gases under conditions of pressure and temperature. A. H. N.

Synthetic Processes.

949.* Substitute Fuels as a War Economy. G. Egloff and P. M. Van Arsdell. *J. Inst. Petrol.*, July 1942, **28** (223), 115–132.—A systematic study of substitute fuels used by the belligerent countries is presented, based on statistics, official and Press statements. In conclusion it is stated that many types of motor fuels and substitutes are being used by the Axis Powers. There is a decided stringency in the allowable use of even substitute fuels, due to lack of raw materials, manufacturing facilities, and man-power for their preparation. The relatively poor quality of the Axis fuels has curtailed the manœuvrability of their automotive transportation, including aeroplanes.

A. H. N.

Refining and Refinery Plant.

950. Condensation Combined With Water Treating. Anon. *Refiner*, May 1942, **21** (5), 131.—The system includes condensation of steam from turbines, reboilers, and heaters in a special fan-cooled radiator unit. Water thus recovered is combined with raw feed, all of which is treated with chemicals.

Exhaust from the steam-powered and steam heating units is collected in an 8-in. line running through the main pump-room and connected to a horizontal 8-in. header across the top of the tube-and-fin condensing sections. The other end of the exhaust-steam line is connected to a pressure-operated hot well, from which an excess exhaust-steam line leads to a remote part of the plant. An automatic pressure controller on this line, set to operate at 15-lb. gauge, serves as a relief valve for the condensing system.

The system is maintained with an operating pressure of 10-lb. gauge, on the hot-well end of the exhaust line, and 5-lb. on the collection drum at the base of the tube-and-fin sections. Because of the pressure differential, a turbine-driven pump removes the condensate from the collecting drum by instrument control. The system has capacity of 14,000 lb. of exhaust steam/hr. under normal atmospheric conditions.

A. H. N.

951. Heat Transfer, Pressure Drop, and Fouling Rates of Liquids for Continuous and Non-continuous Longitudinal Fins. A. Y. Gunter and W. A. Shaw. *Refiner*, May 1942, **21** (5), 150–158. *Paper Presented before American Society of Mechanical Engineers.*—The data herein reported refer to pipe-within-pipe type units, and are not strictly applicable to other types of fin-tube units. The present paper has three objectives, as follows: (1) To furnish test data on liquids in laminar flow for long-continuous fins, correlated with published data and theoretical curves for air. (2) To indicate the advantage of non-continuous longitudinal fins over long-continuous fins for liquids. (3) To present analysis of the theoretical aspects of fouling on fin tubes, as compared with bare tubes, together with a presentation of actual fouling rates encountered in intermittent semi-plant-scale operations.

Full experimental data are presented and discussed, and are correlated especially with the works of Norris and Streid (*Trans. A.S.M.E.* (1940), **62**, 525–533) and of Norris and Spofford (*A.S.M.E.* Annual Meeting, New York, December 2, 1941). The general conclusions reached are, for heat transfer: (1) The use of non-continuous fin sections instead of long-continuous fins increases h_f in the ratio of 2 to 1, where $L = 1{\cdot}2$–10 ft. (2) Correlation to test data for liquids in this paper, where L/D_h is controlling, indicates the curve shown in Norris and Streid's Figure 4, are conservative above $R_h = 200$, because present test results show the transition range beginning at about this point. (3) The dimensionless function (μ/μ_w) 0·14 should be included in the J_A value when correlating viscous liquids.

For pressure drop: (1) The pressure-drop efficiency factor for non-continuous fins is comparable to that on long-continuous fins where $L =$ 1–10 ft. (2) Correlation of test data on pressure drop in this paper with Norris and Spofford gives fair agreement in the range of $R_p =$ 700–2000 for one sample.

For fouling rates: (1) From a theoretical viewpoint, fouling has less effect on fin tubes than on bare tubes, for as fouling increases, the fin effectiveness increases, tending to offset the fouling effect. (2) A fouling factor of 200 for longitudinal fin tubes in heavy-fuel service, with steam temperatures not above 350° F., will normally assure at least 1 year of service without cleaning. Intermittent operations or operations at less than design throughputs may shorten this period.

The test equipment and procedure are presented in full in an appendix.

A. H. N.

952. Protecting Plants in War-time. Anon. *Refiner*, May 1942, **21** (5), 139–142.—Deception through camouflage painting and complete blackout are the hindrance to bombing. Special lighting, adequate fencing, and alertness of the operating personnel are the counteracting measures used in anticipation of wilful damage. Together with these are emergency methods of shutting-down operations, diverting gas into the air or into other plant-lines, and protecting plant-forces.

Protection against bombing may be obtained to a degree with camouflage painting and colours containing pigments which cause the painted objects to blend into the colour of the soil and adjacent scenery. Many storage tanks, processing columns, and vessels which recently glistened with bright colours, are now toned down to the olive-drab of the Army. Paints are now being compounded containing special ingredients that prevent photographing with infra-red film, so that pictures taken from reconnaissance planes will not show the location of important installations.

In localities which have organized systems of raid information and adequate warnings, the sequence of the three principal alarms will provide sufficient time to extinguish all lights and blackout the plant. Lights of some sort are almost essential for operating the machinery, and in some plants the lighting circuits are being rearranged so that the master switches will cut off all but three or four outlets. These in turn are fitted with special blackout hoods which prevent illumination from being detected outside the building and concentrate the beams to a very narrow circle on the floor.

All these various items are detailed and certain of them are illustrated. A. H. N.

953. Design and Installation of Steel Tank-Bottoms by Arc-Welding. E. G. Woolman. *Refiner*, June 1942, **21** (6), 189–190.—In reconditioning tanks, safety must be given first consideration, in order to protect both men and materials. Tanks which have contained lighter petroleum fractions are more dangerous, but are more easily cleaned. Those containing heavier oils must be thoroughly cleaned. Steaming is the accepted method of removing the bulk of the oils, followed by application and removal of fuller's earth applied to the bottom. These two steps result in a dry, gas-free tank.

A special method of installing steel tank-bottoms is described and illustrated by diagrams. A. H. N.

954. Heat Exchange Allows Increase in Cracking-Unit Charge. Anon. *Refiner*, June 1942, **21** (6), 191.—One of the latest additions to cracking facilities consists of two sets of heat exchangers. One is mounted on the vapour-condenser box and employed as a vapour-to-charge exchanger, which has resulted in recovering waste heat, and reducing the quantity of water for cooling and condensing the pressure distillate vapours.

In the crude charge flow the second set of exchangers is mounted on low concrete piers beside the residuum coolers, and is connected to the flow-piping with a manifold which provides for by-passing the exchanger or routing the crude charge from the vapour exchanger to the exchanger handling the residuum to recover waste heat at this point.

Advantages are briefly outlined. A. H. N.

955. Increasing Recovery of Liquefied Petroleum Gases in Natural-Gasoline Plants. J. W. Wilson. *Refiner*, June 1942, **21** (6), 176–181. *Paper Presented before Natural Gasoline Association of America.*—Statistical data about liquefied petroleum gases are presented. Theoretical considerations of oil-absorption plants are reviewed. Certain definite conclusions may be reached from this work : (1) For economical operation and maximum extraction efficiencies an absorber should have a minimum of twelve theoretical plates. (2) A sixteen-plate absorber of moderate plate efficiency will in general give better performance than an absorber of more elaborate design; but having a smaller number of plates. (3) Absorption factor is directly proportional to absorber pressure and oil rate, and inversely proportional to the molecular weight of the absorption oil, and to the vapour pressure of the individual component to be extracted taken at the temperature of the oil leaving the absorber. (4) For 99% extraction of normal butane with an absorber having twelve theoretical plates, a normal butane absorption factor of about 1·3 will be required. The *iso*-butane absorption factor in that case would be about 0·85, which means that only about 85% of the available *iso*butane would be absorbed from the gas. For complete extraction of *iso*butane the normal butane absorption factor will have to be increased to slightly less than 2·0.

Desirable qualities of absorption oil are listed as : (1) The molecular weight should be low, as absorption efficiencies increase with decrease in molecular weight of the absorption oil. (2) The oil should have a low average boiling point. (3) The boiling range should be short—*i.e.*, around 100° F. (4) The initial boiling point should be as low as practicable with the type of distillation equipment employed, but probably should not be below 400° F. in most cases. (5) The gravity should be between 38° and 40° A.P.I. (6) The oil should contain a low percentage of unsaturated hydrocarbons, due to their poor stability to heat and air. On the other hand, a high percentage of naphthene and paraffin hydrocarbons are desirable, as they are the best absorbents, and resist oxidation, or deterioration from heat. (7) The oil should be free from organic acids and refining agents. (8) The oil should have low pour and cloud tests. The pour point should be considerably below the lowest operating temperature. (9) The oil should be sulphur-free. (10) The colour should be 16–21 Saybolt as an indication of refinement.

Pressure, temperature, and economic factors in absorption are discussed.

A. H. N.

956. Mercaptan Reduction and Doctor Treating Combined. Anon. *Refiner*, June 1942, **21** (6), 185–188.—In the refinery at Santa Fe Springs, the raw-pressure distillate is stabilized to a Reid vapour pressure between 10 and 11 lb., where most of the hydrogen sulphide is removed in the stabilizer overhead discard. The first part of the pressure-distillate-treating plant is in two sections operating in series and continuously, beginning with the first contact between gasoline and the treating agent for the removal of hydrogen sulphide. This section is followed immediately by the second, where the mercaptans are reduced an average of 65% with a constant circulation of continuously regenerated caustic solution.

When treating a pressure distillate produced by cracking gas-oil and kerosine distillate, the caustic solution in the mercaptan section of the treating plant is held at a Be. gravity of 18°. When this solution loses its efficiency, it is dumped from the system, and part of the liquid pumped into the hydrogen sulphide stripping section. This section is a horizontal drum with connections and piping arranged with an eductor type tee which withdraws the solution from the lowest side of the drum by the velocity of the gasoline passing through the instrument. Both gasoline and caustic enter the drum at the top through an extension of the piping, which delivers the mixture to the low side where gasoline spreads through the bulk of the caustic as it separates and rises to the top, passing from the drum at the end opposite the connection where solution and gasoline enter.

The mercaptan reduction section contains seven vertical vessels, four of which are employed in the contact circuit and three as separators, removing caustic solution from the gasoline as it flows from the section to storage. The four vessels in the contact circuit are divided in pairs, the two pairs in series in the gasoline flow, and each pair working in parallel. Beyond the contact and scrubbing vessels is the caustic-regeneration system, where the mercaptans are released from the solution. Regenerated caustic is pumped from the regenerator cooling side to the second pair of contact vessels, working through a set of turbulence-forming tees and passing with the pressure distillate to the vessels, from which it is withdrawn by a pump and passed backwards to the first set of contact vessels. Meeting the hydrogen-free pressure distillate, the partly spent caustic breaks the edge of the mercaptans in the gasoline, and is removed through a single-level controller from both vessels. This is accomplished because both vessels are connected at their bases by a large pipe, to afford an unrestricted flow of solution from one vessel to that which is equipped with the liquid-level-control instrument. Gasoline from which the maximum of mercaptans have been removed flows through the separators to storage.

Regeneration of the caustic and doctor solution is described in detail. A. H. N.

957. Rôle of Chromium in Steels for Cracking-Still Tubes. C. L. Clark. *Refiner*, June 1942, **21** (6), 159–161.—While rigid restrictions are being imposed on the use of chromium in alloy steels, the addition of this element to steels for cracking-still-tube service is essential, mainly because the corrosion resistance to hot petroleum products is proportional to the amount of chromium present. Likewise, molybdenum must be added, for the straight-chromium steels are susceptible to temper embrittlement after service at elevated temperatures.

The severity of corrosion in different cracking units varies greatly, depending on the particular crude used and to some extent on the operation conditions. The grade of chromium steel required thus also varies, a higher chromium content being required the more corrosive the hot petroleum products. In order to meet these varying requirements, steels are available containing up to 9·0% chromium, as well as 18–8 and its several modifications for the most severe conditions. The resistance to corrosion is further discussed, as well as oxidation resistance. Chromium also has an influence on the high-temperature strength, but it is not true that the strength is proportional to the chromium content. From this it follows that a decrease in the chromium content does not necessarily decrease the strength, and in fact it may result in an improvement in this property.

There is not as yet general agreement as to the high-temperature-strength characteristics most suitable for design. Some use the creep resistance, while others resort to the rupture strength. Insofar as cracking-still tubes are concerned, the stress-rupture characteristics are believed the most suitable, for they not only afford a basis for design, but also show the behaviour of the steel under overheating conditions, and give an indication of the degree of bulging or deformation to be expected prior to the rupture of the tube.

NOTE.—*Refiner* numbers sent to Britain have page 16 cut by the Censor ; but enough of the paper is left to be of value, as graphs are included. A. H. N.

958. N.P.S.H. and the Centrifugal Pump. L. H. Garnar. *Refiner*, July 1942, **21** (7), 196–200.—In centrifugal pumps an important point is to keep the pressure at the entrance to the impeller vanes above the vapour preesure of the liquid at all times. The energy available at the pump-suction flange to do this and to overcome pump suction losses is called " net positive suction head over the vapour pressure." This term is commonly abbreviated in use to N.P.S.H., and was originally used in conjunction with pumps handling boiling liquids where all the available energy came from the static elevation of the liquid above the pump.

The pump manufacturer usually has the suction limitations of a given pump plotted in the form of a curve showing minimum N.P.S.H. requirements for all capacities in the operating range. As long as the available energy equals or exceeds these figures there will be no undue vaporization causing limited capacity, cavitation, and accompanying troubles. This means that for all practical purposes all values stated by the pump manufacturer for minimum N.P.S.H. requirements are based on: (1) The pressure drop from the suction flange to the impeller vane. Since the size of suction opening is usually unknown to the purchaser at the time of negotiation, this pressure drop includes the velocity head at the pump-suction flange. (2) All values quoted for N.P.S.H. required have been corrected to refer to the pump centre line. Since pumps may have top suction, side suction, end suction or bottom suction, such practice is of assistance for pre-engineering and comparison purposes. For preliminary use the pump-shaft centre-line can be assumed to be 3 ft. above the pump-house floor.

To make the best possible pump selection, all the information regarding operating conditions should be given to the pump-builder. Assuming that all other pertinent data have been furnished, the suction information should include: (1) pressure at the pump suction at the design capacity; (2) N.P.S.H. available at the pump suction at the design capacity; (3) if there is a static lift its value should be stated; (4) the value of the vapour pressure is desirable, but it is not essential if the above data are given.

The determination of N.P.S.H. is discussed and five examples are worked out as illustrations. A. H. N.

Metering.

959.* Oil-Well Meters. G. L. Paulus. *World Petrol.*, May 1942, **39** (5), 33.—In a long paper the principles of oil-well meters, their special problems as met in oilfields with wax, gas, sand, salt water, and scale, their installations are all studied in some detail. Positive displacement, current, and weigh-meters are discussed. The calibration and checking of meters are also studied.

In comparing the cost of gauging well production by means of oil-meters or gauge-tanks, the policy of individual companies must be considered. This policy may often be influenced by lease requirements. To arrive at the relative investment required for tank-gauging facilities and oil-meters, it can be assumed that two 250-brl. gauge-tanks will be required for each well and one meter installation/well. Comparing the installed cost of the tank with the installed cost of the oil-meter, there is a marked saving possible in the oil-meter. Oil-meters vary in price from about $25 to $500. Most wells can be handled by a meter costing in the neighbourhood of $150—at least, this is a good average cost for the purposes of comparison. Detailed cost comparisons are given for typical cases which show results in favour of the meter.

On a lease where positive displacement meters have been used for a number of years, the monthly net production arrived at by means of daily-production records based on meter readings has checked actual net produced within less than 1%, month after month. The lease has about seventy active meters, and no other well-gauging facilities are available. A. H. N.

Chemistry and Physics of Hydrocarbons.

960. Vapour–Liquid Equilibria for Hydrocarbons. C. D. Shiah. *Refiner*, May 1942, **21** (5), 134.—A review of previous work is given. Cox's and Lewis's work on vapour pressure and fugacity is made the basis of the theoretical considerations of the paper. Based on these considerations, a chart is prepared to represent vapour–liquid equilibrium constants for all hydrocarbons at all temperatures and pressures. For compactness and ease of application, this single chart excels all other forms of presentation. Of course this chart can be no more accurate than the experimental data and calculated results from which it is derived, but as more accurate and complete data becomes available, this chart can be easily adjusted accordingly.

The reason that n-pentane is chosen as the reference compound is simply because its vapour–liquid equilibrium constants, which have been determined by Katz and Cummings, cover a wider range and distribute more evenly on the chart. The use of this chart is self-explanatory. To find the value of K for a certain compound at a certain temperature, one has only to find the corresponding temperature for n-pentane to have the same value of K from right-hand half of the chart. The K of n-pentane at the specified pressure at this temperature, which is equal to the K of the compound at the temperature and pressure in question is read from the left-hand half of the chart.

Data from the chart are compared with that from other sources and found acceptable.
A. H. N.

961. An X-Ray Study of Carbon-Black. J. Biscoe and B. E. Warren. *J. appl. Phys.*, June 1942, **13** (6), 364–371.—X-Ray studies have been made of a number of carbon-blacks, prepared under different conditions, and subject to various heat treatments. The patterns were made in evacuated cameras, using CuKα radiation monochromated by reflection from rocksalt. The patterns consist of crystalline reflections (*ool*), and two-dimensional lattice reflections (*hk*). The structure is one of true graphite layers arranged roughly parallel and equidistant, but otherwise completely random. The dimensions within a layer are the same as in graphite; the layer separation is somewhat larger than in graphite. The effect of heat treatment is to increase the size of the parallel layer groups. At graphitization the material changes discontinuously to the crystalline graphite structure. The usual carbon-black is not finely divided graphite. Small-angle-scattering studies indicate the existence of clusters of a few hundred angstroms in size. It is these clusters which are measured by microscope counts, by the electron microscope, and by surface areas, rather than the much smaller parallel layer groups.
A. H. N.

962. Multicomponent Distillation. Graphical Method for the Estimation of Number of Theoretical Plates as a Function of the Reflux Ratio, Minimum Number of Plates, and Minimum Reflux Ratio. C. D. Shiah. *Refiner*, June 1942, **21** (6), 182–184.—A new graphical method is presented by which the curve of O/D *v.* the number of theoretical plates, sufficiently accurate for cost estimations, can be obtained when one set of rigid or approximate stepwise calculation data is available. This method makes use of the fact that the function of a multicomponent distillation is the separation of a complex mixture into two fractions. Thus any complex mixture can be considered as a binary mixture of the two fractions to be separated. An equilibrium curve can thus be drawn from the stepwise concentrate gradient data. McCabe and Theile's method can then be applied to determine the minimum reflux ratio, minimum number of plates, and number of plates at any reflux ratio.

An illustrative example is worked out.
A. H. N.

963. Photochemistry in Petroleum Technology. J. De Ment. *Refiner*, July 1942, **21** (7), 206–216.—The systematic classification of photochemical reactions is acknowledged to be difficult. Often one and the same reaction passes from one class to another, according to the experimental conditions, with vague boundaries of transition. However, photochemical reactions can be recognized as being of two kinds. In one, light usually accelerates a transformation which takes place to a lesser extent in the dark, with a diminution of free energy in the system. These are technically called exoenergetic reactions. In the other, the reaction cannot proceed alone unless light supplies the necessary energy. This second kind is the endoenergetic reaction.

With exoenergetic reactions the colour stability of gasoline, oils, and many lighter compounds can be interpreted. Also, gumming and formation of objectionable compounds in refined oil products may frequently be explained by the exoenergetic mechanism. On the other hand, the endoenergetic reaction can be considered to be of greater importance when it is remembered that many reactions take place on a much larger scale when energy is introduced into the system externally through the agency of light. The paper deals mainly with endoenergetic reactions.

The ideal source of light is extremely intense, and concentrated with efficiency and convenience. A concave mirror behind the source increases intensity. Best sources of light are the sun, which costs nothing, but which has several patent disadvantages; large carbon arcs; mercury-vapour lamps; metallic-vapour lamps other than mercury; and incandescent filament lamps. High-current-density high-potential sparks between metal electrodes are very good light-sources, since they emit short wave-lengths in abundance and at high intensity. The explosion of metal foils produces powerfully intense radiations. A very brilliant light, up to 14,000,000 candle-power, of extremely short duration is produced by the explosion in argon of a liquid explosive, such as tetranitromethane, the spectrum extending far into the ultraviolet. The use of X-ray tubes, the cyclotron and radioactive substances as sources of energy is discussed. The principles of photochemistry and the law connecting photochemical effects linearly with the quantity of light absorbed are outlined. Generally, photochemical activity increases with a decrease in wave-length. This means that rays of greatest activity will be on the violet end of the spectrum, hence the assumption that X-rays and radium rays may soon be of importance in industrial photochemical processing. Conversely, rays on the red end of the spectrum usually have little photochemical action. Certain peaks are observed in the absorption bands.

The most effective approach in an attempt to process oil and petroleum products by light, therefore, is : first, a laboratory determination of the main absorption bands in the substances being worked for all wave-lengths, especially those in the ultra-violet region ; second, to choose a light-source whose maximal emission occurs at the same region in the spectrum as the absorption bands in the oil ; third, to apply the fundamental photochemical laws which describe the intensity of radiation, duration of exposure, thickness, and concentration of the reactants ; fourth, to develop the process by actual experimentation with as much control as possible ; fifth, to prepare a flow-sheet and processing diagram ; sixth, to prove the process by small-scale operation, before any attempt at large-scale production is even considered feasible.

Fluorescence, catalysis, bleachings, cracking, stabilization, photo-polymerization, and photo-halogenation are each discussed in some detail. The long paper ends with special applications such as deodorization of refinery rooms by ultra-violet, treating moving belts with irradiation to discharge accumulated static electricity with safety, mist stabilization, etc. Seventy-three references are included in the bibliography.

A. H. N.

Lubricants and Lubrication.

964. Frictional Phenomena. Part X. Lubrication. A. Gemant. *J. appl. Phys.*, June 1942, **13** (6), 355–360.—The application of the viscosity concept to this technically important field is presented. Discussed first is film lubrication, which occurs when the film thickness is greater than 10 cm. This mechanism is chiefly controlled by the viscosity of the liquid. The basic mathematical theory is developed, and it is shown how this adequately describes the experimental facts. Next, boundary lubrication is discussed, a type occurring with stable layers less than 10^{-5} cm. thick. This mechanism is essentially a plastic flow within the boundary layer. The chief experimental data are described together with their technical implications.

The technological aspects of film lubrication are treated briefly and these remarks are made : (1) The equations developed indicate that low viscosity of the lubricant is desired. However, too low values are undesirable because such films might easily break down. (2) A further important requirement is chemical stability against oxidation, particularly at elevated temperatures prevalent in the bearings. The requirements under (1) and (2) have led to the preferential use of medium viscosity mineral oils as lubricants. (3) More specifically, the viscosity *v.* temperature curve should not be too steep in order not to obtain too low viscosities when the temperature rises. Spiers showed that temperatures in bearings increase rapidly with decreasing clearance, and that oil cooling has little value in reducing these temperatures. (4) Also the pressure variation of viscosity should be within certain limits. Muskat recently investigated this question as well, showing that the exponent in the exponential viscosity-pressure relation should not exceed the value 2. The limiting load, therefore, can be made higher, by selecting lubricants of relatively flat viscosity-pressure curves. Testing of oils for lubricants is very briefly indicated.

A mathematical theory of boundary lubrication does not yet exist, the whole field being still in the experimental stage. Bowden in a recent paper tried to show that the behaviour of such films is essentially controlled by their ability to withstand breakdown during sliding. It is important from a practical standpoint that small additions, say 1–2%, of fatty acids to mineral oil improve the lubricating property of the latter appreciably. In these cases the oil acts not only as a viscous film lubricant, but independently by way of adsorption to form stable boundary layers of the fatty acids. The result is that at higher pressures when the oil film becomes too thin to remain stable, the acid layer still remains intact and the viscous action of the oil is then simply replaced by a plastic flow of the acid. The technical aspects of boundary lubrication are discussed in a recent paper by Fogg (*J. Inst. Petrol.* (1940), (1), 1). Inorganic materials for boundary lubrication are discussed. A. H. N.

INSTITUTE NOTES.

October, 1942.

PROFESSOR F. H. GARNER.

The Institute wish to congratulate Professor Garner on his appointment to the Chair of Oil Engineering and Refining at the University of Birmingham. The Chair was founded by the late Lord Cadman, and was held by Professor Nash until his death in March.

Professor Garner was in charge of the lubricating oil laboratory at the Royal Aircraft Establishment in 1917, and since then he has been continuously engaged in work connected with the petroleum industry. He was an 1851 Scholar of the University of Birmingham in 1919, and became a Fellow of the Mellon Institute of Industrial Research at Pittsburgh in the Petroleum Fellowship in 1920. In 1921 he took the Ph.D. of the University of Pittsburgh, with which the Mellon Institute is associated. He returned from the United States in the same year and became Chief Chemist of the Agwi Petroleum Corporation, whose refinery at Fawley was then being constructed, and in 1928 became Chief Chemist of the Anglo-American Oil Co., Ltd. In 1935 he took charge of the Esso European Laboratories, comprising both Engine and Chemical Sections, and he has now relinquished this post to take up the Chair at Birmingham.

Professor Garner has been associated with the Institute of Petroleum since 1921, when he joined as an Associate Member, transferring to Membership in 1925. In 1936 he was elected Vice-President and in the following year he became Honorary Associate Editor of the *Journal*. He was elected a Fellow in 1939. He has published a number of papers on petroleum subjects, including papers on the knock-rating of pure hydrocarbons and on viscosity, and is the editor of the *Annual Reviews of Petroleum Technology* which are published by the Institute. He is also Chairman of the Standardization Committee which will shortly publish the 4th Edition of "Standard Methods of Testing Petroleum and its Products."

Professor Garner is also Vice-Chairman of the Road and Building Materials Group of the Society of Chemical Industry, and editor of a book on "Modern Road Emulsions" whose 2nd Edition was published in 1939.

CANDIDATES FOR ADMISSION.

The following has applied for admission to the Institute, and in accordance with the By-laws the proposal will not be considered until the lapse of at least one month subsequent to the issue of this *Journal*, during which time any Fellow, Member or Associate Member may communicate by letter to the Secretary, for the confidential information of the Council, any particulars he may possess respecting the qualifications or suitability of the candidate.

The object of this information is to assist the Council in grading the candidate according to the class of membership.

The names of the candidate's proposer and seconder are given in parenthesis.

HARKESS, John Mackay, Chemist, Lobitos Oilfields, Ltd. (*J. S. Parker; V. Biske.*)

STUDENTS' SECTION, BIRMINGHAM UNIVERSITY.

At a general meeting of the Students' Section of the Institute on 29th September, the following officers were elected :—

Chairman	A. W. Pearce.
Vice-Chairman	P. A. Garrett.
Secretary	G. F. Dod.
Hon. Sec. and Treas.	Dr. A. H. Nissan.
Committee Members	M. L. Fellowes.
	G. K. Ashforth.

NEWS OF MEMBERS.

The Institute has received information that Mr. T. H. G. Brayfield (Fellow), and Mr. A. W. Black (Fellow) are in an internment camp in Hong Kong and are both in good health.

Mr. W. M. Wright (Member) is reported to be missing, believed killed in action.

MEMBERS SERVING WITH HIS MAJESTY'S FORCES.

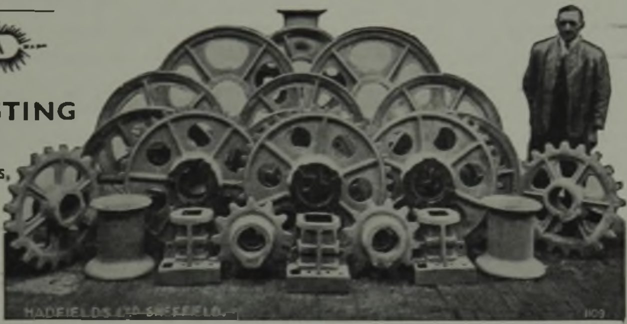
The Council invites members serving with any branch of H.M. Forces to send a note of their rank and unit to the Secretary.

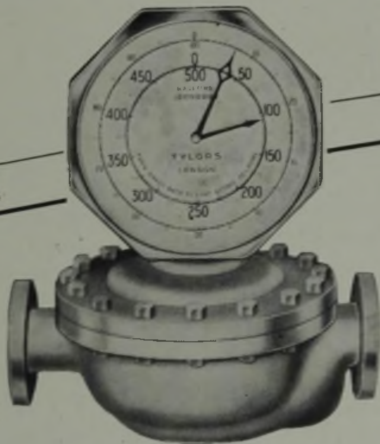
The following additions to lists already published have been received :—

DIXON, J. F., Pilot Officer, R.A.F.V.R. (Technical Branch).
WYGARD, E. J., Private, Polish Corps of Signals.
WISEMAN, K. W., 2nd Lieut., R.A.O.C. (Radio Location Maintenance).

ADDRESSES OF MEMBERS.

Since the outbreak of war the postal addresses of many members have changed. A considerable number of such changes has been notified to the Secretary, and every effort has been made to give effect to these in the despatch of the *Journal*. Members whose *Journals* are still being forwarded to a wrong address are asked to advise the Secretary of their correct address.





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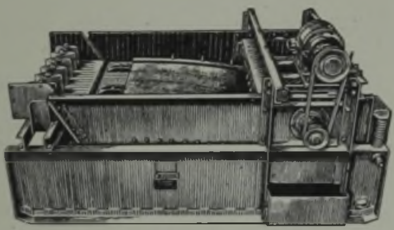

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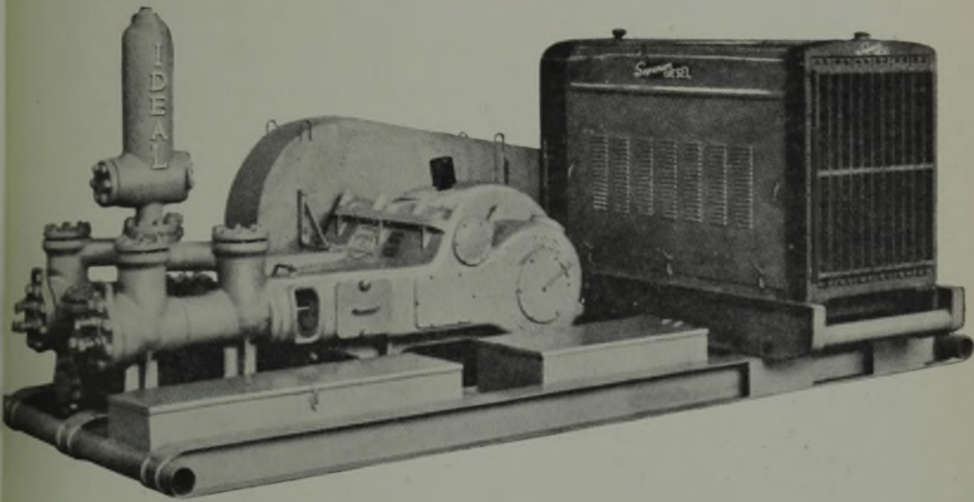

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