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GEOPHYSICAL METHODS APPLIED TO OIL PROSPECTING.

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Editorial Note.—*With the greatly broadened scope of membership and the change in character of the Institute of Petroleum, the Council has felt the time ripe to undertake the preparation of a work under the title of "Modern Petroleum Technology" which shall present to its readers a composite picture of the present state of petroleum technology.*

The aim of this series of articles is that they will be primarily of general interest to all classes of members of the Institute and, although not popular in the generally accepted sense of the word, that they shall convey the knowledge of the specialist in an intelligent and educative manner to his less specialized confreres in the industry.

While the proposal is to publish the series in the form of a manual of petroleum technology, it is hoped that the articles will first be published, as received, in the Journal.

During the last thirty years a new tool has been placed in the hands of prospectors for mineral deposits, in the form of the recently developed methods in which physics has been applied to geological problems. These methods make use of a difference in some physical property of the mineral sought and the surrounding rocks, with the provision that the physical property must be capable of influencing a physical observation which can be made at the surface. This last condition limits the number of properties which can be usefully employed in this work, and the four which have been exploited most are the rock densities, their elastic properties combined with their densities, their magnetic properties, and finally their electrical conductivities. These four properties lead to the four well-established groups of prospecting, the gravitational methods, the seismic methods, the magnetic methods, and the electrical methods.

In some cases the deposit itself provides the contrast in the physical properties, but in many cases the search is indirect, since the mineral has no outstanding physical characteristics. Oil is a case in point, since an oil-bearing formation, as a rule, differs little from the neighbouring rocks. The search here is for structures with which oil accumulations may be associated. Thus the gravitational method has been used to locate salt-domes, anticlines, and fault-traps, and the magnetic method to locate uplifts in an igneous basement rock, or for the location of faults by magnetic rocks which may be associated with them. The seismic method has been found useful in obtaining detail of small structures or features the gentle slopes of which render them unsuitable for gravitational work and also as a reconnaissance survey for saltdomes. In common with all geophysical surveys, it must be emphasized that the presence and nature of the deposit cannot be inferred explicitly from the observations. The methods can be used only to guide the placing of drill-sites in the most promising positions.

The Seismic Methods.

Mechanical disturbances in the ground, produced, for example, by an explosion or an impact, travel through different rocks with different velocities. In the seismic methods of prospecting use is made of this, together with the reflection and refraction of the disturbances by boundaries between adjacent rocks, to obtain information concerning the position and form of the interface. The method was originated in 1920 by Mintrop, who suggested that the principles, which had been applied so successfully to the interpretation of earthquake phenomena, might be applied to small-scale geological problems, the natural earthquake being simulated by the detonation of a buried explosive charge.

Waves in Solid Bodies.

The explosion of a buried charge produces, in general, a complex deformation of the rocks in its vicinity, and the deformations of the rocks travel outwards from the explosion in exactly the same way as a sound-wave from an explosion in air. In a solid body at least two types of waves are produced, each travelling with its own characteristic velocity. The two types are called the P wave and the S wave, respectively. The former is a compressional wave, of a similar nature to a sound-wave, with the vibration of the rock particles backwards and forwards in the direction of propagation, while the latter is a transverse wave with the rock movement across the direction of travel of the wave. The velocities with which these elastic waves travel through the rocks depend on the elastic properties and the densities. Since different elastic properties are called into play in the two types, they travel with different velocities, and in all cases the P wave is the faster, and usually its velocity V_P is about $1{\cdot}7\,V_S$, where V_S is the velocity of the S wave. The magnitude of the velocities of the P waves for a number of rocks is given in Table I.

TABLE I.

Sandy clay	1200 metres/sec.	Granite	7000 metres/sec.
Limestone	4500 ,,	Sandstone	3000 ,,
Rocksalt	5000 ,,		

In addition to these, when the explosion takes place near the free surface, a surface wave—the Rayleigh Wave—is also set up. This carries away a large fraction of the energy of the explosion, and, since it is propagated over the surface only, its intensity dies away far more slowly than that of either the P wave or the S wave, for these travel in all directions throughout the body of the rock. Thus the displacements of the ground when the Rayleigh Wave passes over it are, in general, greater than those produced by the other waves. This wave can also be recognized by its much slower velocity, which is only about nine-tenths of the velocity of the S wave.

Behaviour of Elastic Waves at Boundaries.

When an elastic wave is incident on a boundary between two rock media transmitting the disturbances with different velocities, it behaves in much the same way as an incident light beam on a glass surface. Part of the energy is reflected, the incident and reflected beams obeying the normal laws of reflection, and part of the energy is transmitted into the second medium with a change of direction (Fig. 1). A simple relation exists between the angle of incidence θ, the angle of refraction r, and the two velocities—*i.e.*:

$$\frac{\operatorname{Sin} \theta}{\operatorname{Sin} r} = \frac{V_1}{V_2}.$$

If V_2 is the greater, r will be greater than 0, and there will be a certain critical angle of incidence θ_c for which r is 90°—*i.e.*, the refracted wave travels along the boundary with the velocity V_2. For any incidence

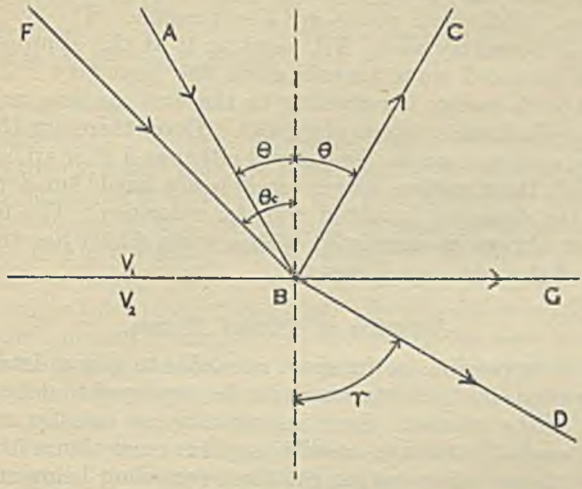

Fig. 1.

REFLECTION AND REFRACTION OF ELASTIC WAVES.

AB is the incident wave giving the reflected wave *BC* and the refracted wave *BD*. For critical incidence *FB*, the refracted wave travels along the boundary *BG*.

greater than θ_c all the incident energy is reflected, none being transmitted into the second medium. This is a simplified version of the actual events which occur, for, in general, change of type also takes place, an incident

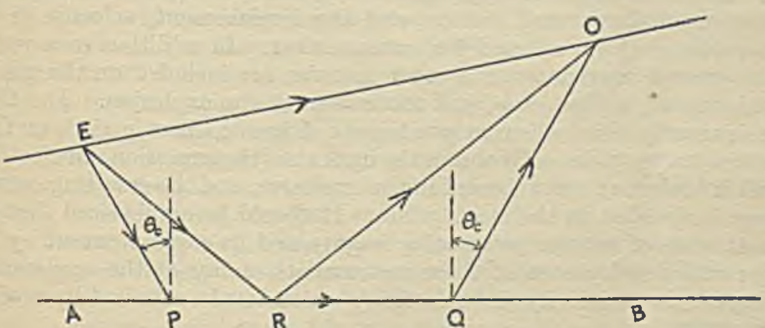

Fig. 2.

POSSIBLE PATHS FROM AN EXPLOSION AT *E* TO INSTRUMENT *O* ON THE GROUND SURFACE.

P or *S* wave giving rise to a reflected *P* wave, a reflected *S* wave, a refracted *P* wave, and a refracted *S* wave.

The motion of the ground surface can, accordingly, be extremely complicated in the presence of a boundary. First there are the three direct waves (Fig. 2), the *P* wave, the *S* wave, and the surface Rayleigh Wave travelling from the explosion to the observation point along *EO*, and arriving at different times. To these must be added a number of reflected waves following paths such as *ERO*, since the energy can travel to the reflecting boundary as one type and be reflected as the same type or as a changed type. Refracted waves are also possible. The incident energy travels to the boundary along *EP*, meeting it at the appropriate critical angle. The refracted wave travels along the boundary *PQ*, and at all parts of its path energy is returning to the first medium and some will travel to the observation point along *QO*. Here, there are three parts of the path and each section can be covered either as a *P* or an *S* wave. The order in which these various waves arrive is not fixed, but depends on the relation of the distances involved and the velocities. The first arrivals, however, can always be associated with a wave which has travelled over all sections of its path as a *P* wave.

Detection of Ground Motion.

It would be impossible in the space available to give a detailed description of the various instruments which can be employed to detect and record the motion of the ground. Such instruments are usually called seismographs, although this term is usually used in connection with mechanical instruments, those incorporating electrical recording being referred to as geophones. They are essentially pendulums of various designs in which the inertia mass tends to remain stationary while the frame of the instrument follows the ground motion. The relative movement between mass and frame is thus a measure of the ground motion, and this relative motion suitably magnified is recorded on a moving film. In mechanical seismographs the magnification is obtained by mechanical and optical levers, while in geophones the amplification is achieved by stages of valve magnification. Instruments can be designed to record either the vertical or horizontal component of the ground motion, and the displacement, velocity or the acceleration may be selected for measurement. In addition to a record of the ground movement, two other features are included on the photographic record, a time scale, and the instant of the explosion. The time-scale is usually obtained from pendulums of known short period, or from standard tuning-forks. To obtain the instant of the explosion, an electrical circuit is broken at a wire buried in the explosive, and the resulting current change is recorded on the moving film. It should be emphasized that the present state of seismic prospecting is governed to a great extent by the design and development of these instruments, many of the applications relying on the sensitivity and selectivity which can be attained by modern instruments.

Methods of Utilizing Elastic Waves.

There are two main methods by which the elastic waves can be made to furnish information concerning the underground structure : the refraction method and the reflection method. The refraction method can be employed as a reconnaissance method for locating regions transmitting the waves with a high velocity—*i.e.*, saltdomes, to determine depths and dips of persistent horizons, or to obtain depth variations of a particular boundary. Accordingly, it is convenient to subdivide the refraction method into (*a*) fan shooting, (*b*) traverse shooting, and (*c*) arc shooting, respectively, depending on the object of the survey. In reflection prospecting there are two main methods, the method adopted being governed by the nature of the geology examined. The first method is depth shooting, in which the depth determination is the important consideration, and the second is dip shooting, the structure of the area being revealed mainly by the variations in the dip of the reflecting horizons.

Refraction Prospecting.

(*a*) *Fan Shooting.*—If a series of seismographs are placed on an arc of a circle with the explosion point as centre, and if the ground is everywhere uniform, all instruments will receive the first arrival at the same time. When, however, one of the lines joining an instrument to the explosion point passes over a saltdome, which transmits the wave with a greater velocity, this particular instrument will be excited before the others. This is the simple theory of fan shooting. In general, it is not convenient to place all instruments at the same distance from the shot, and a modified procedure is necessary. A number of detectors are laid out on a straight line passing over normal ground, free from any velocity peculiarities, and through the explosion point. This gives a normal time-distance curve for the region. For the fan shooting, the time is plotted against distance on the same diagram, those points falling on the curve corresponding to a line passing over normal ground, and for a line passing over a saltdome or other high-velocity region the point will fall below the curve.

The saltdome at Vermilion Bay [1] was located by this method, the lay-out and time–distance curves being shown in Fig. 3. The position of the detectors for some of the shots are given in Fig. 3(*a*). In all, sixty-one shots were fired in sixteen days. The distance from the shot to the receiver was measured by the time taken for the sound-wave to travel to the instrument through air. In this method corrections have to be applied for temperature, humidity, wind velocity, etc., but it is claimed that over water errors are less than 200 ft. in a distance of five miles. In Fig. 3(*b*) the smooth curve gives the normal time–distance curve for the area, and it will be seen that the majority of the observation points for the various fan lines fall about this curve. A few points, however, fall well below the curve, and the discrepancy is too great to be accounted for by experimental error. They actually correspond to lines passing over a saltdome, and a number of overlapping fans gave its exact location.

(*b*) *Traverse Shooting.*—The main object of traverse shooting is the measurement of depths and dips of boundaries between the different rocks. In it, a series of seismographs, S_1, S_2, S_3, etc. (Fig. 4), are laid out on a straight line passing through the explosion point O, and the travel time of the first arrival at each instrument is recorded and plotted as a time–distance curve. The method is best illustrated by the simple case of a surface layer of uniform thickness H resting on a rock transmitting the shocks with a *greater* velocity. The method cannot be applied unless this condition is satisfied. The first arrival can reach the seismograph by two paths, the direct path OS_1, or by an indirect refracted path $OPQS_1$. In this the impulse from the explosion travels down to the interface, which it meets at the critical angle θ_c, and is then refracted along the

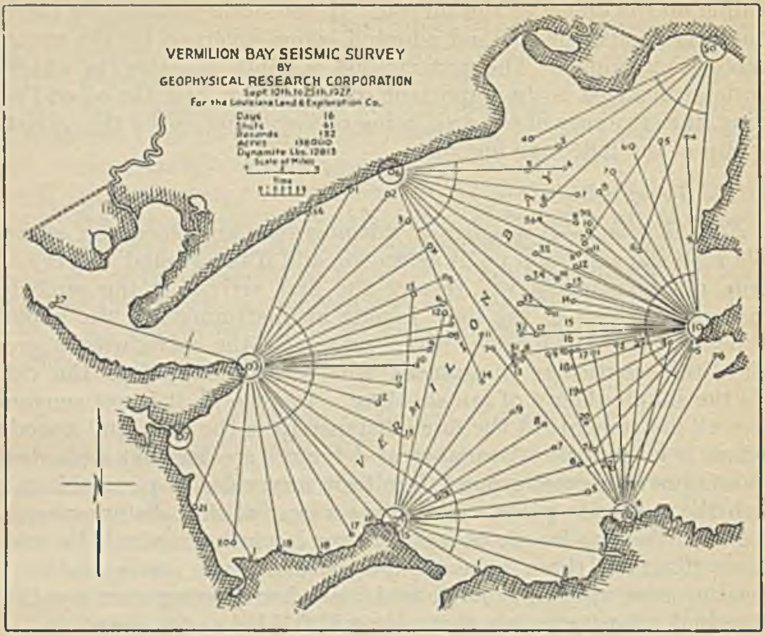

Fig. 3 (*a*).

LAY-OUT OF THE FANS AT VERMILION BAY.

Fig. 3 (*b*).

RESULTS PLOTTED ON THE NORMAL TIME-DISTANCE CURVE.

boundary with the greater velocity V_2. At all points along the boundary, energy will re-enter the upper layer and travel along the paths QS_1, RS_2, TS_3, etc., to the various detectors. For the direct wave, travelling with the velocity V_1 of the upper layer, the time–distance curve will be a straight line OA, the slope of which allows the velocity V_1 to be measured. For the refracted wave there is a time delay corresponding to the time taken to travel to and from the boundary. At short distances the direct wave is the first arrival, but at greater distances the delay is more than compensated by the length of the path covered with the greater velocity, and the refracted wave arrives first, corresponding to the section BC of

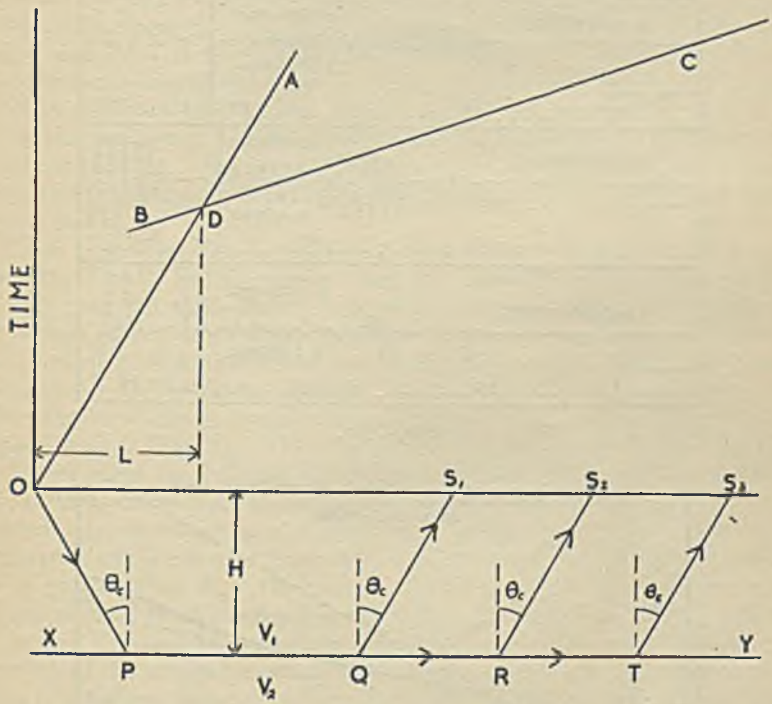

Fig. 4.

THE PRINCIPLES OF TRAVERSE SHOOTING.

the time–distance curve. This portion again is a straight line the slope of which gives the velocity V_2. This is easily appreciated, since of the paths $OPRS_2$ and $OPTS_3$, OPR is common, RS_2 and TS_3 are equal, and the time difference between S_2 and S_3 is due to the path RT along which the wave travels with the velocity V_2. The two straight lines intersect at a point where the direct and refracted waves arrive simultaneously; the delay in the refracted path is just compensated by the length of the path in the high-velocity layer. If the depth of H is small, this lag is small and only a short length of high-velocity path will be necessary to compensate for it—*i.e.*, the intersection will be close to O. On the other hand, a large delay, corresponding to a great depth, will require a long

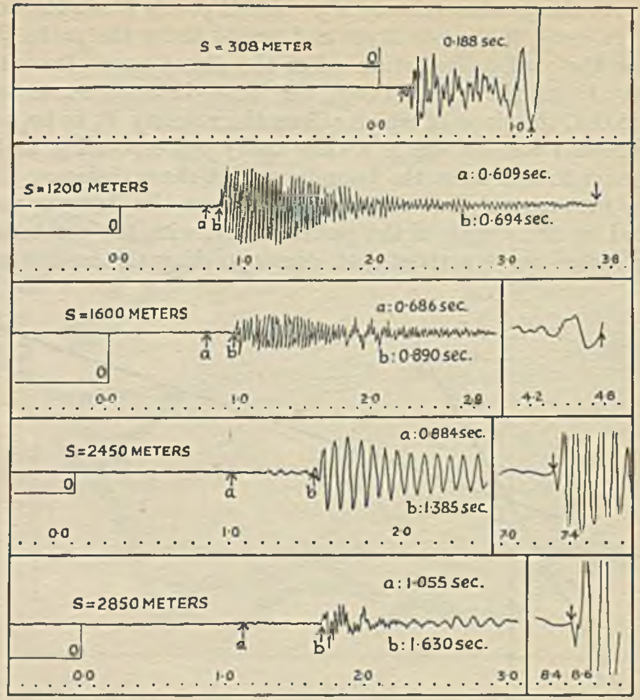

Fig. 5 (*a*).

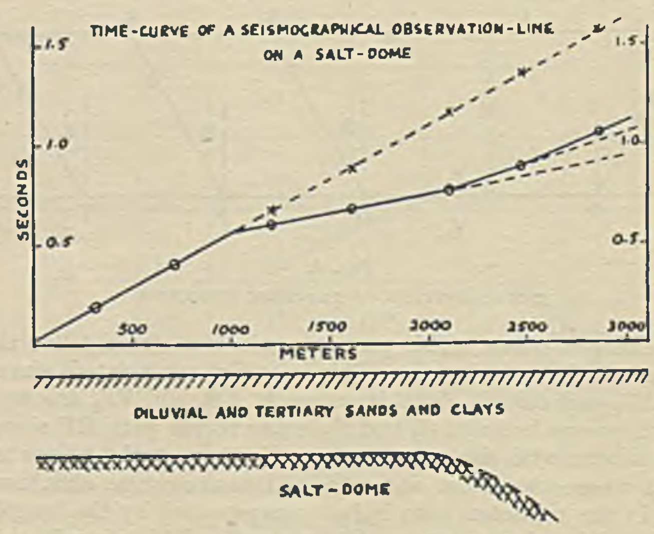

Fig. 5 (*b*).

Fig. 5 (*a* and *b*).

RECORDS AND TIME-DISTANCE CURVES OBTAINED BY SHOOTING OVER A SALT-DOME.

length of high-velocity path. Accordingly, the distance of the intersection D from the explosion is related to the depth, and it can be shown that in the above simple case

$$H = \frac{L}{2}\sqrt{\frac{V_2 - V_1}{V_2 + V_1}}$$

when L is the distance of the intersection from O.

These principles are well illustrated by Fig. 5, which shows the seismograph records and the time–distance curve for a survey over a saltdome covered by sands and clays.[2] Examination of the records (Fig. 5(a)) reveals that in all cases a strong arrival is present, corresponding to the direct surface wave. At short distances this is the only event, but at larger distances it is preceded by a weaker pulse, the refracted wave. The time–distance curve consists of two straight lines which give a surface velocity of about 1850 m./sec. and an underlying velocity of 4900 m./sec. From the position of the intersection, the depth of the top of the saltdome is about 350 m. At large distances the time–distance curve departs from the two straight lines, since the structure does not conform to that shown in Fig. 4.

These principles can be extended to a series of layers, as long as the velocity of each bed is greater than the velocities of the beds above it. In this case the time–distance curve becomes a number of straight lines the slopes of which give the velocities in the various beds, and from the positions of their intersections the depths of the refracting surfaces can be calculated. In addition, sloping boundaries can be examined. Once again the time–distance curve consists of two straight lines OA, BC for an explosion at O (Fig. 6). The slope of the refracted portion (BC), however, no longer gives the velocity V_2, for an inspection of the two paths $OPQS_1$ and $OPRS_2$ shows that the latter has a much shorter emergent path RS_2. Accordingly, shooting up the slope leads to the shorter times than for the corresponding horizontal boundary, and the apparent velocity of the line BC is greater than V_2. On shooting down the slope the opposite is true, the apparent velocity being less than V_2. This obviously gives a method of testing the case of a dipping boundary. Another test is to move the position of the explosion, when the distance of the intersection of the two parts of the time–distance curve will change, its distance from the explosion point increasing as the explosion is moved down the slope. Of these two methods, the former is preferable, since the additional information allows the true value of the velocity V_2, and the dip, to be calculated from the apparent velocities up and down the slope. Knowing these, the depth of the boundary below either shot points can be computed. When sloping boundaries are involved, other conditions have to be satisfied in addition to $V_2 > V_1$. The dip, added to the critical angle, must be less than 90° for the critical path to be possible. When shooting up the slope, it is possible to have conditions where the apparent velocity for the refracted wave is infinite or negative. Such features immediately point to a sloping boundary.

(c) *Arc Shooting.*—In arc shooting,[3] the variations in depth below the surface of some particular boundary are investigated, as distinct from the measurement of the total depth. The surface arrangement is similar to that used in fan shooting, the explosion point being the centre of a circular arc on which the seismographs are placed. The distance from the shot-point to the various detectors is so chosen that the refracted wave is the first arrival. As in traverse shooting, the path from shot to receiver (Fig. 7(*a*)) is divided into three parts : (1) from the shot point down to the refracting boundary, (2) the path in the high-velocity medium, and (3) the emergent path from the refracting boundary to the detector. If the surface relief of the boundary is mild, the first part of this path will be approximately the same for all the receivers. Again, under the same

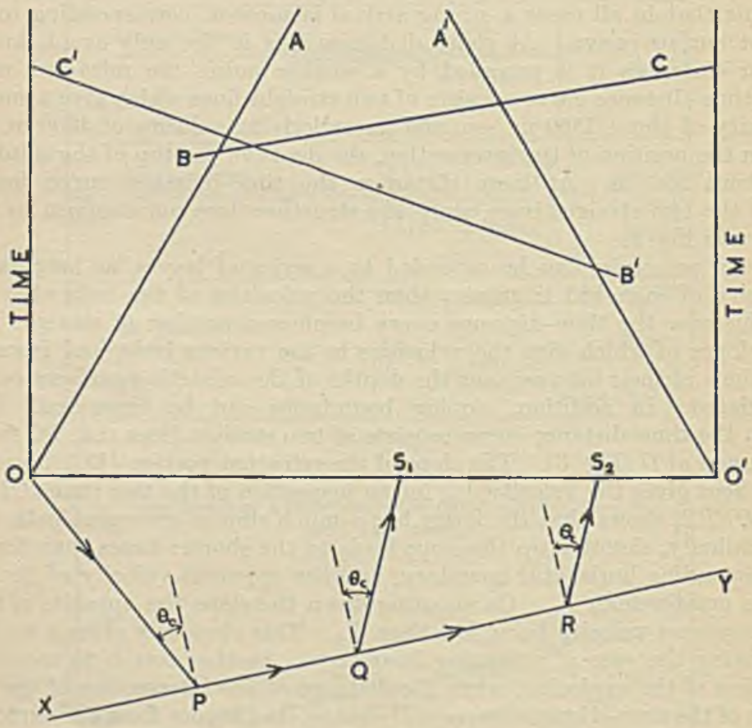

FIG. 6.
SHOOTING OVER A SLOPING BOUNDARY.

conditions, the lengths of path in the lower medium will also be roughly equal. Accordingly, the elastic pulses leave the refracting boundary on their way to the different seismographs at the same time. Thus, any time difference in their arrival can be associated with differences in the length of the emergent path. In fact, it can be shown that, for small angles of dip, the time t taken by the wave is

$$t = K + \frac{R}{V_2} + kH$$

when K is a constant depending on the depth below the shot point, R the distance from shot to detector, H the depth below the receiver and k a constant depending on the velocities V_1 and V_2. Thus, variations in t arise only from variations in H, equal changes in the former correspond to equal changes in depth. If the various velocities are known, the value of k can be calculated and the time variations converted into feet if necessary. Alternatively, if the arrival times are plotted on a suitable scale with increasing time vertically downward, against position, the curve so obtained should reveal the section of the boundary. Fig. 7(*b*) is a diagram

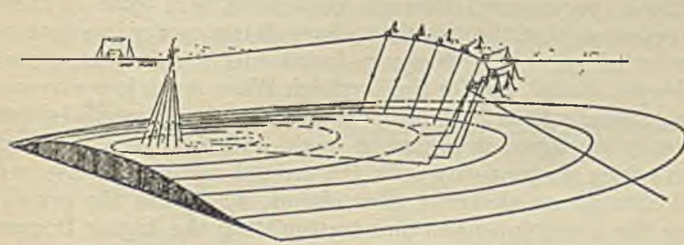

Fig. 7 (*a*).

THE PRINCIPLE OF ARC SHOOTING.

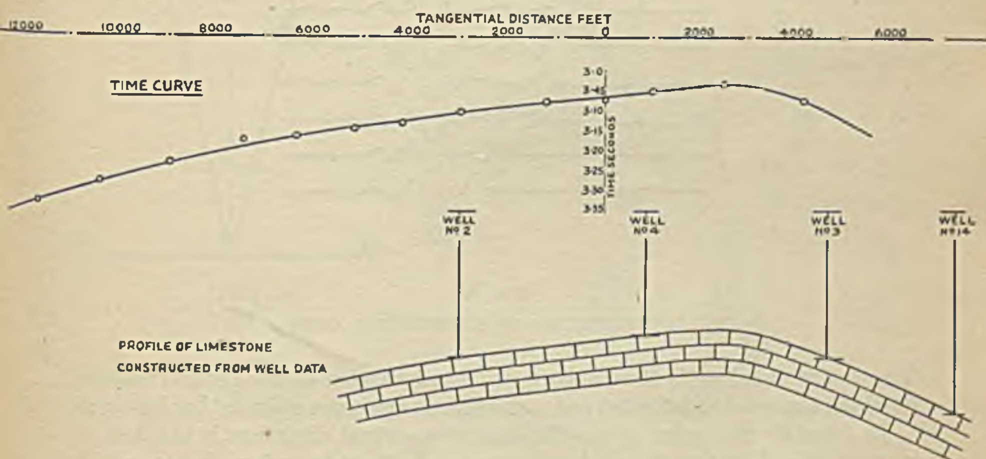

Fig. 7 (*b*).

COMPARISON OF ARC SHOOTING RESULTS AND THE KNOWN STRUCTURE.

of this nature in which the shape, revealed by the arrival times, is compared with the actual section of the refracting limestone boundary known from borings.

Reflection Shooting.

If the sequence of arrivals at an observation station are considered, it is obvious that a reflected arrival can never be a first arrival, and when the reflection arises from a deep-seated boundary, it will excite the seismograph after all the surface waves. Now, the intensity of a P wave falls off inversely as the square of the distance travelled, and only a small fraction of the incident energy is reflected. The reflected pulse is feeble in comparison with the Rayleigh Wave, which carries a large fraction of the explosive energy, travels a short distance along the surface to the detector, and the intensity of which falls away only as the inverse of the distance. The problems to be solved are how to detect the weak pulse against the large background, and how to identify the arrival as a reflected pulse.

It is found by experience that the frequency of the reflected pulse differs from the frequency of the Rayleigh Wave, or ground roll. Any pulse can be split into a spectrum of different frequencies, and some of these frequencies are transmitted through the rocks with less energy loss than others. For the reflected pulse, the energy is found within a frequency range of 40–60 cycles per second, but for the Rayleigh Wave much lower frequencies predominate, usually from 20 to 30 cycles per second. Electrical geophones are universally employed in reflection work, and their output consists of a current varying in sympathy with the ground motion. These currents are passed through an electrical filter circuit, which has the property of suppressing the low frequencies and transmitting the higher frequencies.

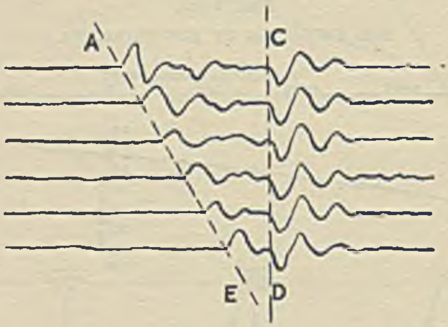

Fig. 8.

THE IDENTIFICATION OF A REFLECTED ARRIVAL.

The record obtained is thus a very distorted version of the ground motion, in which the wanted reflected pulse stands out against a reduced background.

To identify the pulse as a reflection, the arrival direction is utilized, in general this direction for a deep-seated reflecting boundary being nearly perpendicular to the ground surface. A series of geophones are laid out at equal intervals on a straight line passing through the explosion point, the distances involved being from 300 to 1000 ft. The instruments are joined up to a central recording station, where all records are made side by side on the same film (Fig. 8), the various traces across the film corresponding to increasing geophone distance. For a direct wave, or refracted wave, the geophones will be excited in succession at equal time intervals, and a line AE joining the arrivals on the record will be a straight line crossing the film at an angle. The reflected pulse, however, arriving vertically from below, will excite all instruments at the same instant, and if the geophones are matched, identical records will be obtained on all traces. In this case the line CD joining the onsets cuts the film at right angles. If, as is usual, the arrival direction is not vertical, the onsets are not simultaneous, but in very rapid succession. The time difference between the first and last onset of the same event at the geophones is known as the " step-out " of the reflection. The record therefore yields the time taken for the reflected pulse to travel down to the boundary and back, and the " step-out ".

Before these time measurements can be used for depth determinations, the velocity along the path must be obtained. So far, the velocity in any medium has been considered constant, but in general it is found to increase with depth. When this is the case, the time–distance curve obtained from traverse shooting is a smooth curve, concave to the distance axis, instead of a straight line (see Fig. 3(*b*)), and from it the velocity at various depths

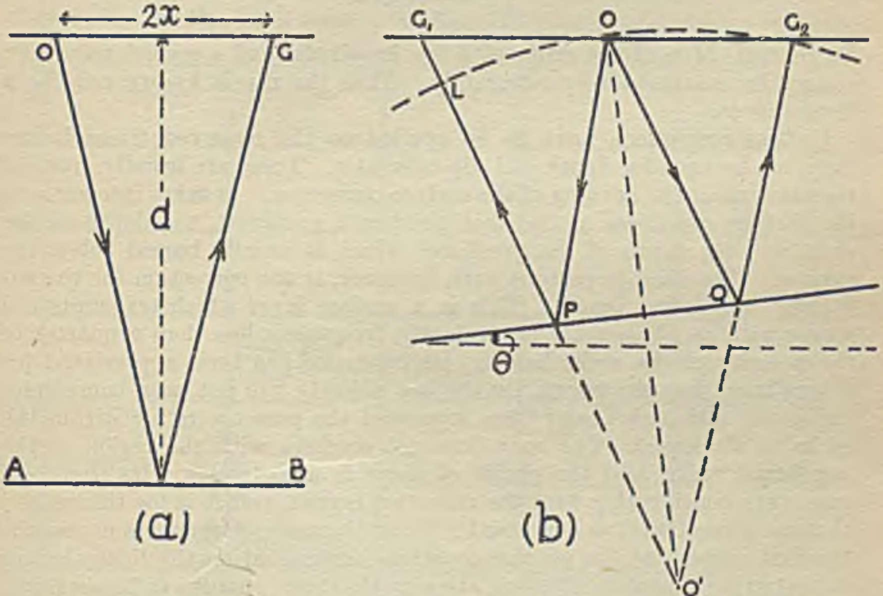

Fig. 9.

(*a*) ILLUSTRATING THE DEPTH CALCULATION. (*b*) THE PRINCIPLE OF DIP MEASUREMENTS.

can be calculated. Sometimes it is possible to make direct velocity determinations by well-shooting. In this, a geophone is lowered to various depths down a well, and the time observed for a pulse to travel from a surface explosion to the geophone. By these, and other methods, the velocity along the path of the reflected wave can be computed and the depth of the reflecting horizon obtained. For a uniform velocity V and an arrival time t, the depth of the reflecting surface AB (Fig. 9(*a*)) is given by

$$d^2 = \frac{V^2t^2}{4} - x^2$$

where $2x$ is the distance between explosion and geophone. Since x is usually small in comparison with d, this may be replaced by $d = \frac{Vt}{2}$. Many records show an abnormal " step-out " (Δt) for the depth obtained, and this has been rightly attributed to a dipping boundary, large step-outs corresponding to shooting down dip, and small values to up dip shooting. The step-out can be used to estimate the dip, and the principle is illustrated in Fig. 9(*b*), in which the geophones G_1, G_2 are placed symmetrically on each side of the explosion point O. For a surface layout of this nature, and a horizontal reflecting boundary, both geophones would be excited at the same instant. With the sloping boundary, G_1 is excited after G_2 by an amount corresponding to the path length G_1L, which is obviously related to the dip. In this case the angle of dip θ is given by

$$\theta = \frac{d}{x} \cdot \frac{\Delta t}{t}.$$

In general, Δt is of the order of a few hundredths of a second only, and cannot be measured very accurately. Thus the dip is known only to a degree or so.

Certain corrections have to be applied to the observed times before they can be used for depth and dip estimates. These are usually grouped together under the heading of the surface correction. It takes into account the surface elevations at the shot point and geophone, the depth of the shot, and the depth of the geophone, which is usually buried below the surface. The most important part, however, is the correction for the so-called "weathered zone". This is a surface layer which transmits the waves with an abnormally low velocity, frequently less than a quarter of the velocity of the rocks below. Its existence has been appreciated for a long time, but the reason for the low velocity has not been completely explained, although Lester [4] has suggested the presence of air within the rocks as the cause. The zone does not conform with the region of the weathered rocks, and the choice of name is unfortunate. Its thickness may vary considerably over the reflection layout, and it is for this reason that the correction is so important. No additional experiment is necessary, the first arrivals at the geophones, when interpreted on the lines already indicated for refraction shooting, allowing the depth changes to be obtained.

(*a*) *Depth Shooting.*—The necessary conditions for satisfactory depth shooting are: (i) that there should exist in the region a contact between two media which acts as a good reflector, (ii) the contact should conform to the structure to be investigated, and finally (iii) the contact should persist throughout the whole area to be examined. In these circumstances there is on each record a strong arrival which corresponds to a reflection at the boundary in question, and the arrival can be correlated with similar arrivals on all other records. Depth and dip determinations are made at each station, and the results plotted on a section. By joining the depth points so obtained, a profile of the structure is developed and, if necessary, contours of the contact can be constructed. This procedure has been found satisfactory, for instance, in Oklahoma, where shales overlie Mississippi and Ordovician limestones, the contact between them serving as a good reflecting horizon.

As an example of this type of survey, one described by McDermott [5] may be considered. It was carried out in the Eastern Navarro and Western Henderson Counties of Texas, in a region where sands and shales rest on Pecan Gap chalk, which in turn lies on Austin chalk. The work consisted of measuring the depth of the top of the Pecan Gap chalk and of a basal member of the Austin chalk. The upper sections of the Austin chalk did not give consistent reflections. Two shots were used at each station, a small one yielding a reflection from the upper reflecting horizon, but giving insufficient energy to allow the pulse from the lower horizon to be detected. The latter was observed by the detonation of the second and larger charge. Part of the results are shown as a section in Fig. 10. At station Nos. 55, 56, 57, and 59 normal records for the district were obtained, but at station Nos. 58 and 210 peculiarities were observed which confirmed the presence of the faults. At station No. 58 no reflection from the Pecan Gap chalk was obtained, but the strongest reflection from the Austin chalk was observed. On the other hand, at station No. 210, no matter how large the

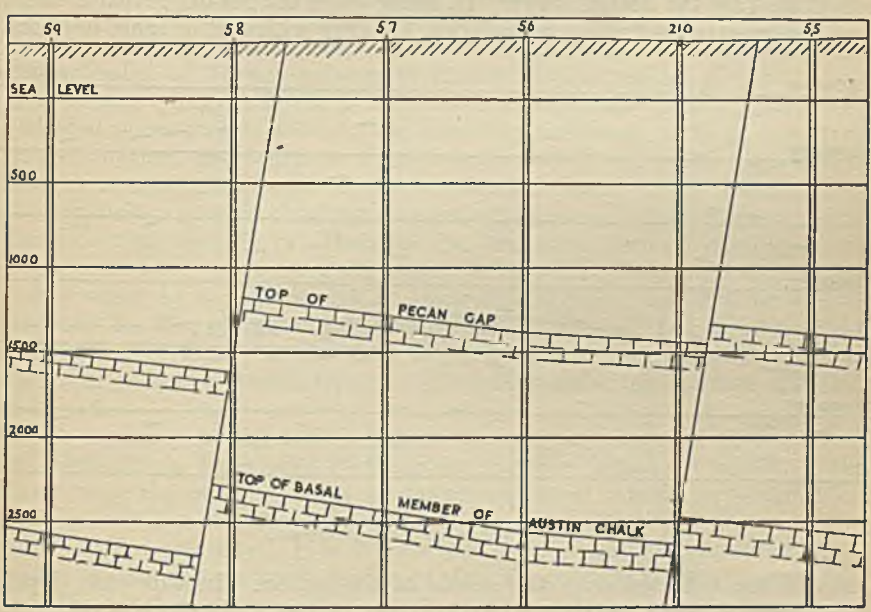

FIG. 10.

AN EXAMPLE OF DEPTH SHOOTING.

charge employed, no response could be obtained from the lower boundary, and the small charge gave a normal reflection from the Pecan Gap chalk. In all, seventy-five depths were measured in a period of two weeks, the cost working out at less than 10 cents per acre.

(*b*) *Dip Shooting.*—A more difficult problem presents itself in the Texas-Louisiana Gulf coast of America, where structures occur without persistent reflecting horizons. These conditions exist in certain sedimentary structures where a series of beds provides a number of surfaces giving similar reflected energies. Accordingly, the records are characterized by a sequence of reflected pulses of roughly the same intensity, rendering it impossible to select from each record the pulse from the same horizon. In addition, the individual beds themselves are often of small horizontal extent, thinning out laterally and being replaced by other beds of somewhat different character. This feature tends further to confuse any attempt at correlating arrivals. Consequently, if a series of depth measurements are plotted, as in the case of depth shooting, the resulting picture reveals a number of points apparently distributed at random, from which no conclusions can be reached concerning the general structure. If, however, the dip at each reflecting surface is determined, and through each plotted point a short line is drawn with the appropriate angle of dip, the shape of the structure immediately becomes apparent. An example of this type of survey is shown in Fig. 11, which gives a typical profile in the Texas–Louisiana Gulf Coast area.[6] The dip at each depth determination is shown by the short lines, and the general structure derived from the measurements is indicated by the dotted curve. In many cases the results reveal a series of disconnected reflecting boundaries, together with one or more horizons

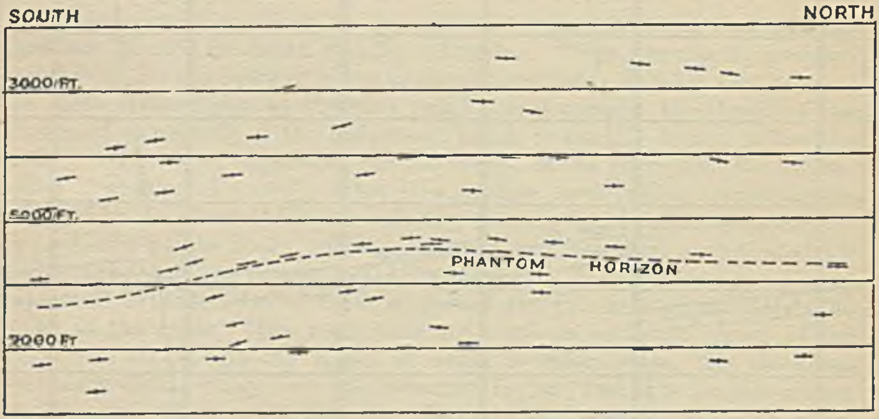

Fig. 11.

THE RESULTS OF DIP SHOOTING.

which are detected over the whole of the region. In this case depth shooting might be used, but the dips assist materially in the identification and correlation of the reflecting boundaries.

Limitations of Seismic Methods.

In general, the limitations of a geophysical method can be divided into two parts : those due to the instruments, and those arising from geological considerations. In refraction prospecting there is a definite limit to the depths which can be investigated, since the great distances involved means that ultimately the arriving signal will be too weak to be detected. In addition to this, the changing conditions over long traverses may render the interpretation obscure. The signal from the explosion must always be greater than the general ground unrest (microseisms) which form a background against which it must be picked out. To improve the ratio of signal to background, a greater charge of explosive must be employed. A similar problem arises in reflection prospecting, since the reflected arrival must be detected against the background of other arrivals also arising from the explosion. Here, to improve conditions, the instrument selectivity must be improved.

The refraction method of prospecting has a number of disadvantages; in particular, since the distance between explosion and seismograph may be many miles, only an average section of the structure is obtained. In addition, the horizontal extent of the structure must be large, small features being unsuitable for the method. A severe restriction is also imposed by the velocity relation which has to be satisfied. Further, there are possible combinations of velocities and boundary depths in the multilayer case for which certain of the refracting boundaries will not be revealed by the use of first arrivals only. In the case of dipping strata, the angle of dip must be less than a certain value, fixed by the appropriate critical angle, before any refracted ray can emerge to the surface. Accordingly, the method is unsuitable for steep dips.

Many of these objections are overcome by the reflection technique, for, theoretically, all abrupt velocity or density discontinuities give rise to a reflection of energy. If the detector and explosion are close together, the reflected pulse travels down to the boundary and back, so that, to a first approximation, the depth at a point is measured, thus allowing smaller structures to be examined. Against these advantages there is the objection that no information is obtained concerning the nature of the rocks beyond the reflecting boundary. There is also the possibility of missing a reflecting horizon, for if the path distances between pulses from two boundaries differ by a wave-length of the reflected pulse, one will be superimposed on the other, and the lower boundary will not be detected. On the other hand, if the path difference is half a wave-length, the two will interfere destructively, and neither reflecting horizon will be detected.

The accuracy of the interpretation depends on a number of features; in particular, a knowledge of the wave velocity, which, in general, will vary along the path. The exact determination of this factor is difficult, and calculations are usually based on the assumption that the velocity varies with depth only. It is obvious that in the vicinity of anticlines, etc., where the results are most important, this assumption is not justified, for it is the depth variation of any one bed which is under examination. An important feature limiting the accuracy of dip shooting is the weathered layer, small errors in the estimation of its varying thickness leading to large errors in dip. As Rosaire and Adler point out, a difference of 3·5 ft. in the thickness of the low-velocity zone between the ends of the geophone spread may easily produce an error of about 1° in the computed angle of dip, if not properly corrected. One great advantage of the method is that the ruggedness of the surface offers no difficulty, as correctness can be applied for level differences. As with most methods, there are areas where the records show a complex character and are difficult to interpret, and it appears that the method is unsuitable for regions of large dips.

Achievements of the Seismic Methods.

Sawtelle's data show that the seismic refraction method, alone or supported by the torsion balance, played a part in the discovery of some forty saltdomes in the Gulf Coast region of the U.S.A. during the period 1924–1930. The particular mode of application, which proved so effective for a time in this area, was fan shooting, and this served as a relatively simple method for the purpose.

In its more conventional form, the refraction method is suitable for regional studies, by its ability to determine the depth of the basement in areas with a thick cover of comparatively unconsolidated sediments, while the arc method has proved valuable, and was, indeed, designed, for locating structures in the competent Asmari Limestone beneath the highly contorted and incompetent cover of the Fars series in Iran. It has also been employed extensively in England.

The start of the second major peak in the saltdome discovery rate for the Gulf Coast of U.S.A. coincides with the introduction of the reflection seismograph. Its effectiveness in this direction may be judged from the fact that in the period 1931–1936, it played a part, alone or in conjunction with the torsion balance or the refraction method, in the discovery of nearly all the saltdomes located. It has also been responsible for the location of some deep-seated domes by detecting the arching produced by them in the overlying beds.

Correlation shooting (depth shooting) has proved most satisfactory in Oklahoma, West Texas, and Kansas, when the strata dip gently and good reflecting horizons are persistent. In Central Oklahoma, and parts of West Texas, the Oswego, Mississippi, and Viola limestones give reflections which can be used in depth mapping. Coupled with core-drilling, the reflection methods have proved an important factor in the location of oil-fields associated with the Central Kansas Uplift.

In much of California and the Gulf Coast area, lateral variations and the lenticular character of the formations preclude the use of depth shooting, and dip shooting is employed. The reflection method is satisfactory for the detailing of structures, provided that the dips are not too steep and the structure not too complexly faulted. It also offers possibilities in the location of stratigraphic traps by its indication of the convergence of reflecting horizons or dips.

Gravitational Methods.

The Gravitational Field.

The gravitational method is based fundamentally on the universal attraction which exists between all bodies, a force which is proportional to the masses of the attracting bodies and inversely proportional to the square of the distance between them. For terrestrial bodies, the forces operating are extremely small, and in the case of two equal lead spheres, each 1 metre in diameter and of mass $5\frac{1}{2}$ million grams, it is only $\frac{1}{4}$ gram weight if the spheres are just touching. When one body attains the size and mass of the earth, the attraction becomes appreciable and it is recognized as the weight of the attracted body. To specify the attractive force due to the earth, the force per unit mass is given, and this is defined as the force of gravity (g). To a first approximation this force is directed towards the centre of the earth, its direction being given by the plumb line, and its magnitude changes with latitude from 978 dynes per gram at the equator to 983 dynes per gram at the poles.*

Surfaces which always cut the direction of the plumb line at right angles are called equipotential surfaces or level surfaces, since any mass moving along such a surface does not change its potential energy—*i.e.*, there is no component of the gravitational force operating along the surface. In the case of the earth the level surfaces have the shape of an ellipse rotated about its minor axis, this axis coinciding with the polar axis.

Returning to Newton's Law, the attraction between a fixed mass and a small volume will depend on the density of the material filling the volume; the greater the density, the greater the mass and force of attraction. It

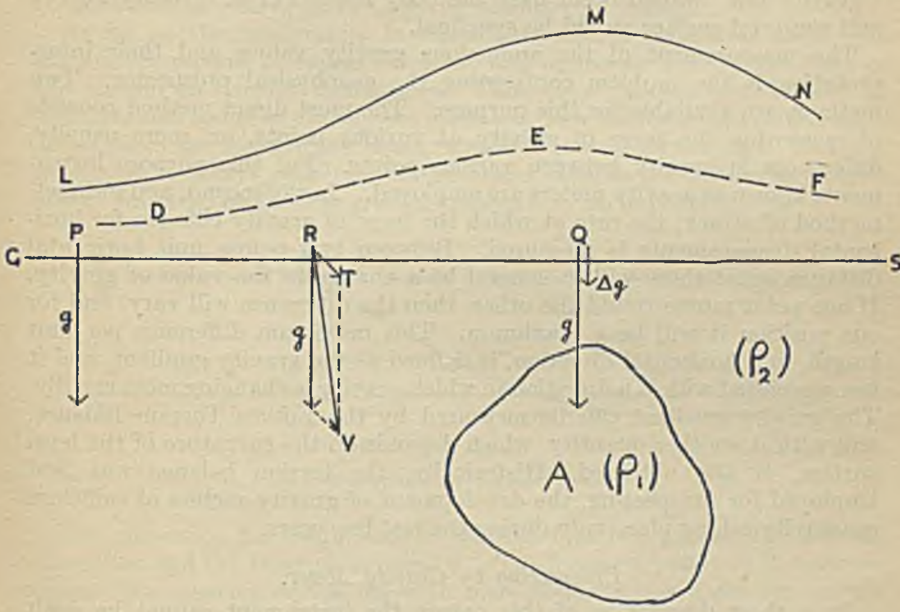

FIG. 12.

DISTORTION OF THE GRAVITATIONAL FIELD BY A BURIED DENSER BODY.

follows that local density variations in the ground will modify the force of gravity. Consider the effects of a buried body *A*, having a density ρ_1 greater than ρ_2 of the surrounding rocks. This distribution consists of: (*a*) a uniform density ρ_2 everywhere, together with (*b*) an excess density $(\rho_1 - \rho_2)$ in the zone *A*. The force acting on a unit mass at the surface consists of two parts, from these two density distributions. The former gives rise to the normal value of gravity, acting downwards through the earth's centre, this force being constant. The latter gives a force which will be directed towards the zone *A* (Fig. 12), and its magnitude

* The force per unit mass gives the acceleration produced, and hence the force of gravity is identical with the acceleration due to gravity, and can be measured in centimetres per second per second. In geophysics a unit of the gal. is employed where 1 gal. = 1 cm./sec.^{2}.

will decrease as the distance from the body increases. At P, some distance from the body, it will be negligible, and the normal force of gravity will operate. At Q, immediately above the body, the additional force will be appreciable, and will act in the same direction as g, giving a local high value of gravity. Thus gravity will increase to a maximum over the body, and then fall to its normal value on the other side, as indicated by the curve LMN. In addition, the plumb line is deflected, for the resultant of the two forces at R, given by the diagonal of the parallelogram, does not coincide with the direction of g. Since the level surface is perpendicular to the plumb line, it will be distorted into an anticlinal shape shown by the broken curve DEF. Had the zone A been of smaller density, a " gravity low " would occur over the body instead of a " gravity high ", and the level surface would be synclinal.

The measurement of the anomalous gravity values and their interpretation is the problem confronting the geophysical prospector. Two methods are available for this purpose. The most direct method consists of measuring the force of gravity at various points, or, more usually, differences in gravity between various points. For this purpose instruments known as gravity meters are employed. In the second, and indirect, method of attack, the rate at which the force of gravity changes for horizontal displacements is measured. Between two points unit horizontal distance apart there will in general be a change in the value of gravity. If one point moves round the other, then the difference will vary, and for one position it will be a maximum. This maximum difference per unit length, in a horizontal direction, is defined as the gravity gradient, and it has associated with it a direction in which gravity is changing most rapidly. The gravity gradient can be measured by the Eötvös Torsion Balance, and with it another quantity, which depends on the curvature of the level surface, is also obtained. Historically, the torsion balance was first employed for prospecting, the development of gravity meters of sufficient sensitivity taking place only during the last few years.

Prospecting by Gravity Meter.

In a short description of this nature the instrument cannot be dealt with adequately, but it is worth while considering the sensitivity required for prospecting purposes. The general calculation of the gravity anomaly due to an irregular body is cumbersome, but some idea of the size of the anomaly associated with a given feature can be obtained by considering a buried sphere. A sphere 1000 ft. in diameter, with its centre 1000 ft. deep, will produce a gravity anomaly of 0·001 gal. (1 milligal.) immediately above its centre, if it differs in density by 1 gm./cm.^{3} from the surrounding rocks. This will be superimposed on a normal background of 980 gal., and so the effect of the structure is to change gravity by 1 in 1,000,000 only. Gravity meters must be sensitive to changes of this order, and they represent the finest work of instrument designers, all precautions being taken to eliminate unwanted effects due to temperature changes, etc. Many instruments claim to detect changes of 1 part in 10,000,000 or better.

In practice some station in the area is selected as a datum station, and by a series of observations with gravity meters the difference in gravity between the various field stations and the datum station is obtained. The total measured difference, however, is not all attributable to the subterranean geology, many other effects contributing to the observed values. These must be estimated and subtracted from the observations, and there are three corrections to be applied. They are usually called : (*a*) the normal correction, (*b*) the topographical correction, and (*c*) the correction due to level differences.

It has already been pointed out that gravity varies continuously from the equator to the poles and, if the field station is to be north or south of the datum station, part of the measured difference is due to this cause. Formulæ are available which allow the gravity change to be calculated. It varies most rapidly in latitude 45°, and here a displacement of 4000 ft. to the north (or south) gives a gravity change of 1 milligal.

As far as the topography is concerned, surface elevations above the station correspond to excess densities, and depressions below the level of the station to density deficiencies. Thus they make a contribution to the measured value in exactly the same way as a hidden density difference. In all cases the topography tends to reduce the measured value, and this correction is always positive. Irregularities close to the station have little effect, but large features at great distances may be important.

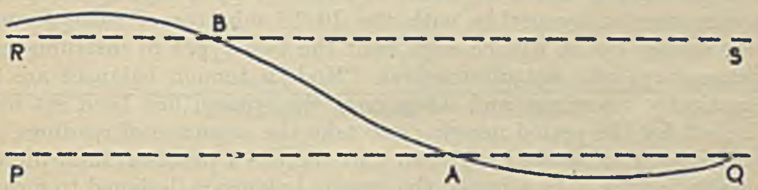

Fig. 13.

THE BOUGUER CORRECTION.

The correction for height can be divided into two parts : the free air correction and the Bouguer correction. The former depends on the inverse square law, gravity decreasing with increasing distance from the earth's centre. Over the range of levels on the earth's surface, the decrease with height is constant, and equal to 0·094 milligal per foot. The accuracy, with which levelling must be carried out, will thus depend on the accuracy of the gravity meter employed in the survey. If *B*, Fig. 13, is the field station and *A* the datum station, when the observations are corrected for topography the values at *A* are reduced to the value which would have been observed if the earth's surface had been *PQ*. Similarly, the value at *B* is reduced to the surface *RS*. Thus, the attracting earth for *B* is greater than the attracting earth for *A*, the difference being due to the layer of rock between the two horizontal planes. This layer increases the attraction at *B*, but is not considered at *A*. The value at *B* must be reduced by the effect of this layer, a correction which depends only on the density of the rock and its thickness. This correction is known as Bouguer's correction.

The space change in the residual values, remaining when these corrections have been applied, arise entirely from the effect of the local geology, and there are two main methods of representing the results. On maps, gravity values are known at a number of points, the value at the datum station being taken as an arbitrary zero. From these values, lines of equal gravity are drawn in the same way that contours are constructed from a series of spot levels. Such lines are known as isogams, and they form closed curves surrounding regions of gravity high or gravity low. When the observations are made along a traverse, a gravity profile can be constructed. Here the gravity values are plotted against position, and a smooth curve, showing the variation of gravity along the traverse, drawn through the observations.

Torsion-Balancing Prospecting.

The use of the Eötvös Torsion Balance is for the indirect investigation of gravity anomalies, and it measures the gravity gradient and a quantity, the horizontal directing tendency, which depends on the curvatures of the level surface. In this simple description of the principles of prospecting, the latter quantity will not be considered. The unit of gravity gradient is the gal. per centimetre. This unit is extremely large, and a smaller one, the Eötvös Unit (E.U.), is employed, 10^9 E.U. making 1 gal. per centimetre. The torsion balance is somewhat slow in operation, modern instruments taking about $1\frac{1}{2}$ hours to measure up a station completely. This compares unfavourably with the 10–15 minutes of some forms of gravity meter, but it will be seen later the two types of instrument are supplementary, and not alternatives. Modern torsion balances are now automatically recording, and when once the station has been set up, it can be left for the period necessary to take the sequence of readings. As to sensitivity, experience has shown that there is a practical limit dictated by outside factors. As a result, the torsion balance is designed to measure gradients to about the nearest Eötvös Unit.

As in the case of gravity meters, the torsion balance responds to extraneous effects in addition to those arising from buried density differences, and again a number of corrections have to be applied to obtain the residual values. The corrections are : (*a*) the normal correction and (*b*) the correction for topography. As before, the former takes into account the normal increase of gravity from the equator to the poles, and in the northern hemisphere the gradient is equal to $8{\cdot}2 \sin 2\lambda$ E.U. directed towards the north, where λ is the latitude. In the southern hemisphere the same formula applies, but the direction is towards the south.

The correction for topography is usually the most important correction, since surface irregularities near to the balance have a pronounced effect. The effect depends on two factors : the surface geometry, which can be obtained by levelling, and the density of the surface rocks. Since the near features have the greatest influence at the balance, within a circle of about 200 ft. radius about the station, levels are taken to the nearest 0·01 ft. At increasing distance the necessary levelling becomes rougher, and between 200 ft. and 1000 ft. from the station contours at 5 ft. intervals are used in the calculations, while outside the 1000-ft. circle contours at 50-ft. intervals are sufficient. These three regions are usually known as the terrain region (0–200 ft.), the topographical region (200–1000 ft.), and the cartographical region (greater than 2000 ft.). From the levels, or the contours, the gravity gradient produced by the surface features at the observation station can be obtained using well-established formulæ, either by direct calculation or by graphical methods. The importance of the correction can be appreciated from the fact that a slope of 1 degree, with a surface density of 1·8 gm./cm.^{3}, will produce a gradient acting up the slope of 13 E.U. Of these, 9 E.U. arise from the ground within the first 10 ft. of the balance. For this reason, the ground in the immediate vicinity of the instrument is levelled and the sites must be selected with care. Large gradient corrections arise if the stations are placed on a hill-side, but for stations on a ridge, or at the bottom of a valley, the corrections are small, since the effects of deficiencies (or excesses) of mass on each side tend to balance out. In addition to these two main corrections, special features near the balance, such as trees, buildings, cuttings, embankments, etc., are also considered. In general, it is more convenient to consider the

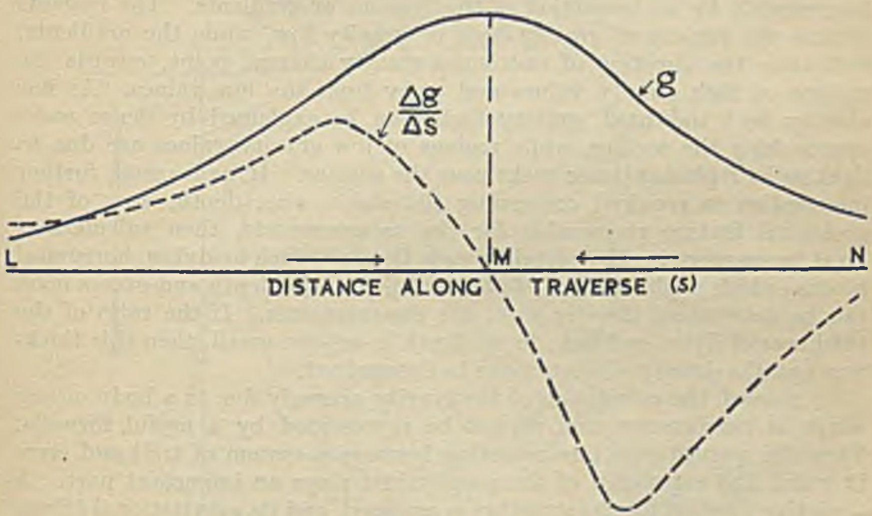

Fig. 14.

RELATION BETWEEN GRAVITY AND GRAVITY GRADIENTS.

two last named features independently instead of including them in the correction for topography.

To represent the gravity gradients on maps, an arrow is drawn of length equal to the magnitude of the gradient on some suitable scale. The direction of the arrow gives the direction in which gravity is increasing most rapidly. The gradient is a vector quantity, and can be resolved into components, or compounded with other gradients acting at the same point, by the same laws that are used to resolve and compound forces. Obviously at right angles to the direction of the gradient there can be no component of the gradient—*i.e.*, gravity does not change in a direction perpendicular to the arrow. This must be the direction of an isogam and, in general, isogams can be drawn from the gradients using this property.

Gravity gradient profiles can also be constructed if a series of observations are made along a traverse. In this case the total gradient is not plotted, but the component of the gradient along the traverse is employed—*i.e.*, the values plotted show the rate at which gravity is changing along the traverse. In this it is conventional to represent a reversal of direction as a change of sign. Thus in Fig. 14 the positive gradients between L and M represent gradients pointing to the right, and the negative values in the interval MN gradients pointing to the left. There is a simple relation between the gravity anomaly and the gradient, the latter giving the slope of the former (Fig. 14). Further, by integrating the area under the gradient curve, the gravity anomaly can be obtained. Thus, theoretically, the same information can be obtained from both the gravity meter and the torsion balance.

Interpretation of Results.

A qualitative interpretation of a gravitational survey can be obtained immediately by an inspection of the isogams or gradients. The isogams enclose the regions of gravity high or gravity low, while the gradients, indicating the direction of maximum gravity change, point towards the regions of high gravity values and away from the low values. As has already been indicated, gravity highs can be explained by dense rocks approaching the surface, while regions of low gravity values are due to light rocks replacing dense rocks near the surface. If, as is usual, further information is required concerning the shape, size, depth, etc., of the geological feature responsible for the measurements, then calculations must be employed. For certain simple features, such as dykes, horizontal blocks (which might be formed at a fault), etc., the depth and excess mass can be determined directly from the measurements. If the ratio of the thickness of dyke, or block, to its depth is not too small, then this thickness and the density difference can be determined.

In general, the calculation of the gravity anomaly due to a body of any shape is cumbersome and cannot be represented by a useful formula. Thus the quantitative interpretation becomes a system of trial and error in which the experience of the geophysicist plays an important part. A tentative solution for the structure is assumed, and its gravitational effects are calculated and compared with the measurements. Depending on the difference between the two, the assumed structure is modified and its effect recalculated, and this process is repeated until satisfactory agreement is obtained between calculated and measured values. To reduce the time occupied in this process, graphical methods have been developed for the calculation of the effects of irregular bodies and, in some cases, the effects can be measured by using suitable models. Certain principles are used which assist materially in the process. The shape of the anomaly is controlled only by the shape of the structure, the horizontal scale of the anomaly—*i.e.*, its surface extent is controlled by the depth of the feature, while the magnitude of the gradients or gravity values depends on the density difference. Thus a certain feature at a given depth will produce a definite gravity anomaly at the surface. If the depth and dimensions of the feature are doubled, then the anomaly will be spread out over twice the distance on the surface. The magnitude of the gravity gradients remain unchanged by this scale modification, but the gravity values are doubled. Again, changing the density difference by a given factor alters both gradient values and gravity values by the same factor.

These effects are well illustrated by a buried sphere, of radius r, with its centre at a depth equal to its diameter. For unit excess density, the maximum gravity anomaly is given by $\Delta g = 1/3\pi rG$, where G is a constant ($20/3 \times 10^{-8}$ c.g.s. units). Thus, as the sphere increases both in size and depth, the anomaly increases in magnitude, and it becomes more readily detected by a gravity meter. At shallow depths its effects are small and negligible, and this conforms with the statement that surface irregularities near the meter have a small effect. The maximum gradient produced by the sphere is 30 E.U., no matter what its depth, and this maximum always occurs at a distance from the point on the surface immediately above the centre equal to half the depth of the centre. In this case the sphere

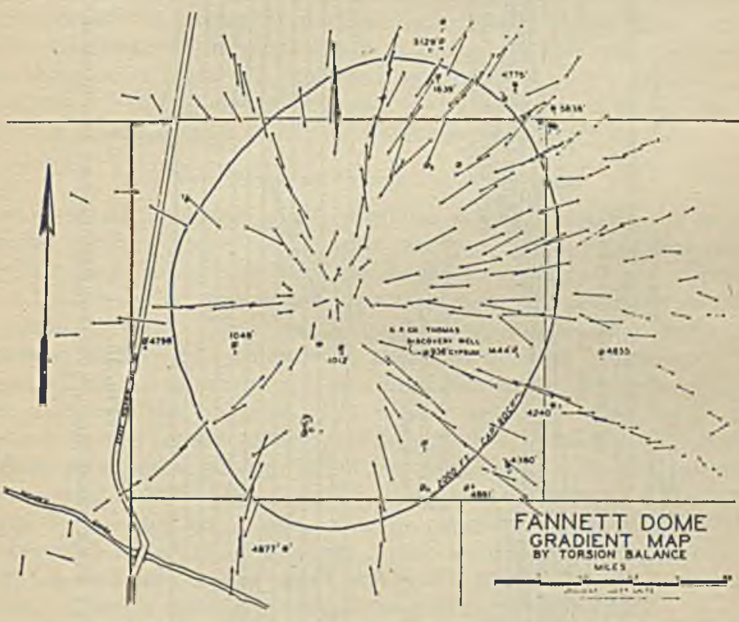

FIG. 15.

GRAVITY GRADIENTS OVER THE FANNET SALT DOME.

is equally detectable at all depths. Thus surface irregularities near the balance have a pronounced effect. For small, shallow features the gravity meter is useless, but the torsion balance can be employed successfully.

An excellent example of a torsion balance survey is the one over the Fannet Dome [7] in Jefferson County, Texas (Fig. 15), the dome being a vertical-sided narrow stock. This dome was originally discovered by seismic methods in 1925, and the torsion balance survey carried out subsequently. It will be seen that all the gradients point to the dome over which there is a gravity high. The cause of this high is the dense cap-rock, for, in general, the salt has a smaller density than the surrounding rocks. As a result, in shallow domes the effect of the cap-rock outweighs the effect of the salt; in deep-seated domes the effect of the salt predominates and a gravity low is usually obtained.

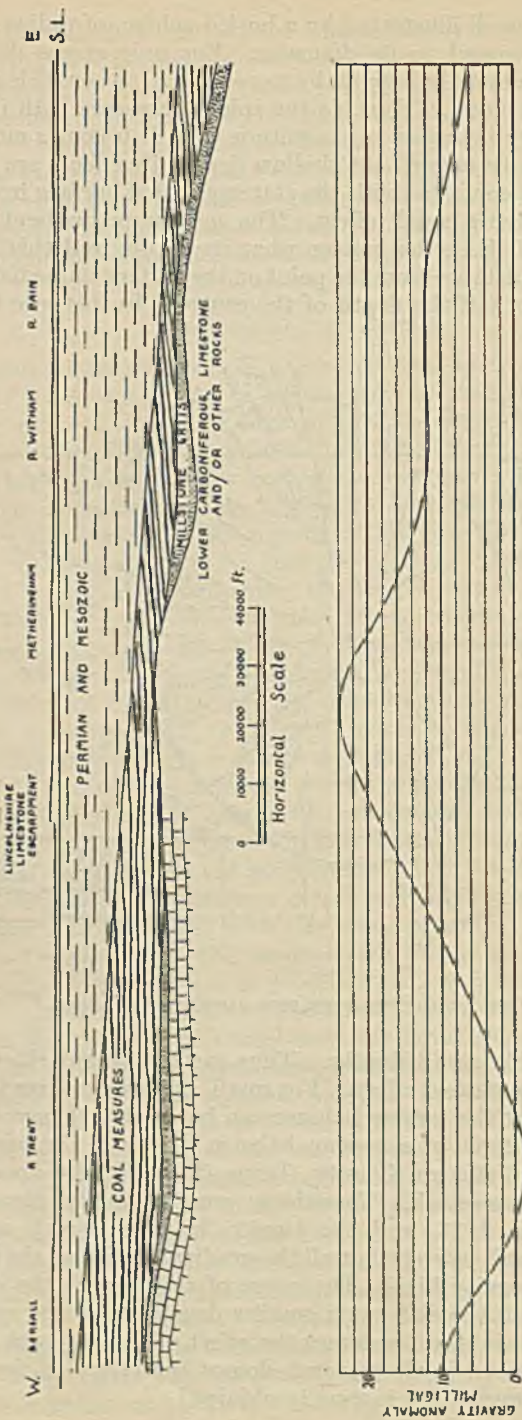

Fig. 16.

GRAVITY SURVEY OVER DERBYSHIRE, NOTTINGHAMSHIRE AND LINCOLNSHIRE.

In the search for oil in England by the D'Arcy Exploration Co., Ltd., a subsidiary of the Anglo-Iranian Oil Co., Ltd., geophysical methods have been employed to detect structures beneath unconformities or alluvial covers. The results of some of their work are shown in Fig. 16, which represents a gravity profile along a traverse of about 40 miles across Nottinghamshire and Lincolnshire.[9] These results have not been obtained directly from gravity meter observations, but have been deduced from a set of torsion-balance stations. The results of some of the torsion-balance work were subsequently confirmed by observations with an Ising gravity meter, and also by pendulum observations at a small number of stations. Over the traverse there is a variation of 26 milligals, with a major maximum near the centre and a smaller ill-defined one farther to the east. These maxima imply an excess of matter immediately below them, and one possible qualitative interpretation is indicated in the geological section, where the gravity highs are explained by anticlines in the Lower Carboniferous rocks. It is possible, however, that they are due to the rise of an older rock massif against which the Carboniferous beds thin out.

Limitations of Gravitational Methods.

One essential condition which must be satisfied is that the structure examined must possess considerable vertical relief, since flat-lying or gently dipping boundaries produce negligible gravitational effects. It should be noted that this latter type of structure is most favourable for the seismic method. With the gravity meter, one limiting factor is the instrument sensitivity, which with the best modern instruments is 0·1 milligal. Thus an anomaly of 2–3 milligal can be examined in reasonable detail, although the presence of a smaller anomaly could be detected. Reference to the buried sphere, which produces 1 milligal, demonstrates that quite pronounced geological features must be available for examination by the method. In short, the gravity meter is suitable for the investigation of large deep-seated structures. On the other hand, the Eötvös Torsion Balance, with which the sensitivity is not a limiting factor, may be employed for shallower bodies which will give a pronounced and measurable gradient, although the magnitude of the gravity value is small.

The smallest gradient of 1 E.U. which can be measured is fixed by the correction for topography. The latter cannot be obtained with very great accuracy, and in rugged country a condition is ultimately reached in which the correction uncertainty masks the effects of the buried geology. The limiting surface conditions obviously depend on the magnitude of the gravity anomaly anticipated for the feature; the larger the gravitational effects, the more rugged the surface may be before the limiting condition is reached. The topography is of minor importance with the gravity meter, since the instrument is insensitive to small nearby features. As, however, it is suitable for large deep-seated bodies, it readily detects the density changes necessary to produce the isostatic compensation for mountains, etc., and over a large surveyed area changes arising from this cause are difficult to assess.

The interpretation of a gravity anomaly in terms of density changes is rarely unique. Even in the simple case of a buried sphere, an analysis shows that only the depth and total excess mass can be determined, the size of the sphere cannot be obtained without additional information—*i.e.*, the density difference. The same drawback applies to other simple features, such as a dyke or horizontal block. Here the results can only be interpreted as a sheet of a certain mass excess per unit area, but again the density difference allows the thickness to be determined. In the more general case the interpretation is even more uncertain. If it is found that an anomaly can be accounted for by a feature at a certain depth and excess density, then it can be equally well explained by a deeper feature of greater horizontal extent but smaller density difference. Thus it is apparent that other data are required, such as the depth of the boundary at some point, the density excess of the feature, etc.

Results of Gravitational Surveys.

The value of the gravitational method was demonstrated quite clearly by events in the Gulf Coast region of the U.S.A. Sawtelle's data show that from 1902 to 1923 saltdome discoveries averaged little over one per year, but since the introduction of geophysical methods the rate of discovery has been much higher. In the first few years after their introduction the torsion balance, supplemented by refraction prospecting, scored many successes. The prominent low-density salt cores, surrounded by denser sediments in an area of low relief, frequently provided especially favourable conditions for the application of the torsion balance. Eby and Clark[7] give a series of examples of the gravity pictures of Gulf Coast domes, and it is interesting to note the gravity minima over deep-seated domes and the maxima over the shallow domes caused by the relatively high-density cap-rock. The Moss Bluff Dome shows the combined effect for such a feature at an intermediate depth, being characterized by minimum gradients around the dome and large gradients above it.

Gravity surveys on a regional basis can often give a useful, although not complete, picture of the geology of an area. The regional gravity anomalies are due to major warping of the basement, by which is implied either igneous and metamorphic rocks, or a series of well-consolidated beds, lying on the crystalline rocks, the basement being cloaked by less dense sediments. Thus the regional framework of central Southern Oklahoma, and the adjacent parts of Texas, as displayed in a gravity map, agrees well with, and even goes beyond, the known geological data.[13]

Electrical Coring.

Of the many electrical methods of geophysical prospecting, the only one of any importance in oil prospecting is the method of electrical coring developed by Schlumberger. Originally, it consisted of making a survey of the resistivities * of the rocks penetrated by a bore-hole, but this is now supplemented by measurements which reveal changes in the porosity of the rocks. Combining these two sets of observations allows important information to be obtained concerning the nature of the various rocks.

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* The resistivity of a material is defined as the resistance of a piece of the material of unit cross section and unit length, the current flowing in the direction of the length. It is measured in ohm. centimetres, ohm. metres or ohm. feet, depending on the unit of length adopted.

Most minerals, except a few base metal sulphides and oxides, are non-conductors of electricity, and the electrical conductivity of rocks in nature depends entirely on the solutions present. The two factors which control the resistivity of a rock are the amount of solutions present and the conducting properties of the solutions, the latter increasing as the salt content increases. Both these factors vary through a wide range; the amount of solutions present varying from less than 1 per cent. by volume for a

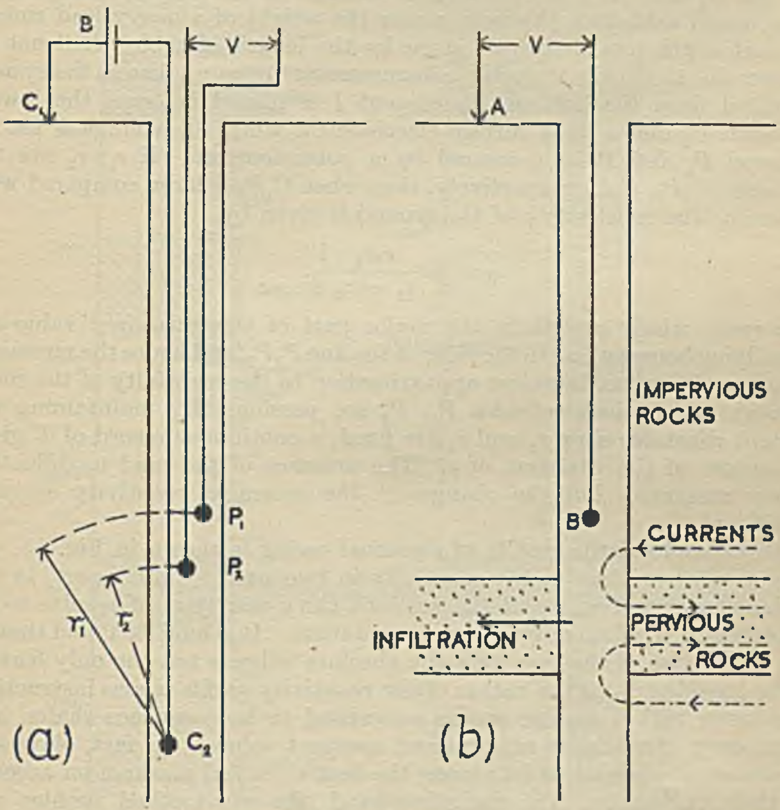

Fig. 17.

THE PRINCIPLES OF (*a*) RESISTIVITY MEASUREMENTS IN BOREHOLES, AND (*b*) PERMEABILITY MEASUREMENTS.

compact crystalline rock up to about 50 per cent. for loose sand, while the resistivity of the solutions changes from some 300,000 ohm. cm. for fresh waters down to 20 ohm. cm. for saturated solutions. Accordingly, rock resistivities are not characteristics of the rock itself, but characteristics of the conditions under which it occurs. Generally speaking, crystalline rocks possess the highest resistivity values, consolidated sediments fill an intermediate range, while recent unconsolidated sediments have the lowest values, the whole covering a range from 10,000,000 ohm. cm. down to 200 ohm. cm. It should be noted that the three groups indicated above overlap in their resistivity ranges. The presence of oil, replacing the saline solutions, within a rock will reduce considerably its conducting properties, an oil-saturated sand having in general a high resistivity.

Only one of the methods of measuring rock resistivities in boreholes will be described here: the three-electrode method, which is the one normally employed. The observations can only be made in an uncased borehole which is filled with a loose mud. Three contacts, or electrodes, P_1, P_2, C_2 (Fig. 17), are lowered at the end of a suitably strengthened triple-cored cable into the mud, under the weight of a heavy lead sinker. So that depth measurements, given by the length of cable, shall not be in error due to slack in the cable, measurements are only taken as the system is raised from the bottom. A current I is passed between the lowest electrode C_2 and a fixed surface electrode C_1, while the voltage V set up between P_1 and P_2 is measured by a potentiometer. If r_1, r_2 are the distances C_2P_1, C_2P_2, respectively, then when C_1P_1 is large compared with r_1 and r_2, the resistivity ρ of the ground is given by

$$\rho = 4\pi \frac{r_1 r_2}{r_1 - r_2} \frac{V}{I}.$$

The rocks which contribute the major part of this measured value are those lying between and to the sides of the line P_1P_2, and hence the measured value can be taken as a close approximation to the resistivity of the rocks through which the electrodes P_1, P_2 are passing. By maintaining the current constant, since r_1 and r_2 are fixed, a continuous record of V gives a measure of the variation of ρ. The presence of the mud modifies the values measured, but the changes in the measured resistivity are still significant.

An example of the results of electrical coring is shown in Fig. 18. It depicts the variation in the resistivity in two wells, ¾ mile apart, in the Oklahoma City Pool,[9] and the sections show the type of results to be expected in the case of regular sedimentation. It should be noted that in the correlation of the two wells the absolute value is not the only feature to be considered, for the nature of the resistivity profile is also instructive. The zones with a regular profile correspond to homogeneous shales, and often clays give similar uniform and constant values. In fact, clays and shales are considered to be among the best electrical markers on account of their uniformity. On the other hand, the saw-toothed profiles corresponding to limestone and sandy shales are not such good markers. If the geological column at one well is known, and the lithological changes can be associated with resistivity variations, the structure can be obtained from the electrical measurements. Well-marked contacts have been traced for tens of miles in this way.

Even if the precise significance of the resistivities is not known, considerable information can be obtained from the electrical diagrams alone. If, however, an attempt is made to identify the rocks from even outstanding resistivity values, serious errors are likely to arise. Thus a high resistivity value may correspond to an oil-sand, a fresh-water sand, gypsum, or some limestone. By introducing the second parameter, the porosity, some of these formations may be distinguished, particularly if the probability of occurrence of certain beds can be eliminated geologically. The porosity

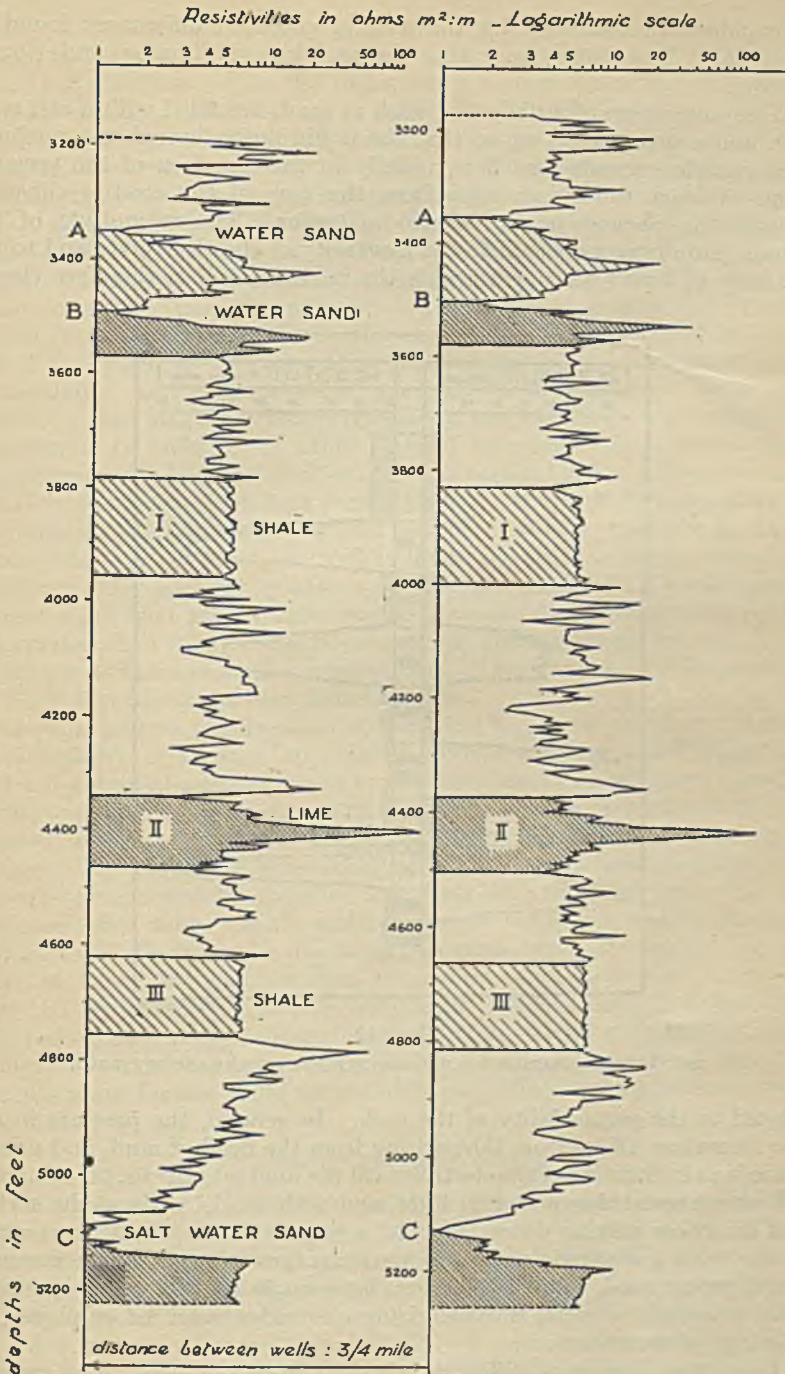

FIG. 18.

RESISTIVITY MEASUREMENTS IN BOREHOLES.

is examined qualitatively by the natural potential differences found in boreholes. They arise from two causes, *electro-infiltration* and *electro-osmosis*.

If the interstices of a dielectric, such as sand, are filled with a salt solution, and a pressure set up so that the liquid flows through the medium, then electric currents also flow, usually in the direction of the pressure drop. Voltage differences arise from the flow of the electric currents. This is the phenomenon of *electro-infiltration*. The magnitude of the voltage drop is proportional to the resistivity of the electrolyte and to the quantity of liquid filtering through the medium, and is therefore closely

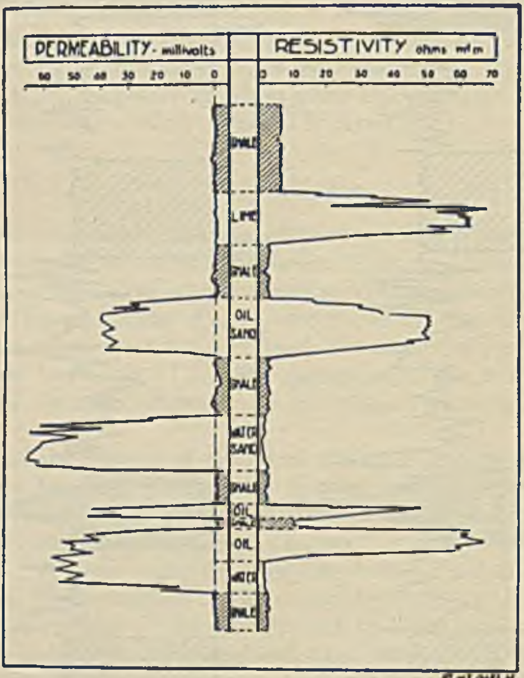

FIG. 19.

THE INTERPRETATION OF RESISTIVITY AND PERMEABILITY LOGS.

related to the permeability of the rock. In general, the pressure in any one formation differs from that arising from the head of mud, and usually there is an infiltration of the electrolyte of the mud into the rocks. Currents will be set up as shown in Fig. 17(*b*), and with an electrode at the surface and the other moving down the hole, a negative voltage will be recorded as the moving electrode passes the pervious formation. The phenomenon is well pronounced, voltage differences between 50 and 100 millivolts having been recorded. Special non-polarizing electrodes must be employed for this type of measurement.

When two liquids of different salt content are brought into contact, there is set up between them a voltage difference. In weak solutions the voltage difference is a function of the ratio of the electrical conductivities. Again, in general, the salinity of the solution, present in the mud, differs from that contained within the rocks, and a voltage arises from this cause. In most cases it is found that the two effects are additive, giving an increased measured difference. The main result is that the voltage is not a direct measure of permeability. By changing the pressure head of mud, or the salinity, the two effects could be separated, but in practice this is unnecessary. Large voltage differences are found to correspond to permeable media, and low values are associated with impervious strata. It should be noted that these effects are also observed when oil is the liquid within the rocks, as this is usually contaminated by a small amount of salt solution.

The interpretation of .the combined resistivity and natural potential logs [10] is typified by Fig. 19. Here the first bed has a low resistivity and permeability, and corresponds to a shale. This is followed by a high-resistivity bed having a low-permeability and, in this case, indicates a limestone. In addition to other beds of limestone, there are oil-sands characterized by high resistivities and high permeabilities, and water-sands with low resistivities and high permeabilities. It should be noted that the combination of high resistivity and low permeability would be given by other beds—*e.g.*, gypsum—as well as limestone and the combination high resistivity, high porosity by a fresh-water sand. Although it would appear, at first sight, that these measurements are more definite and more readily interpreted than many geophysical surveys, the conditions are not always as simple as these examples suggest, and in some cases no interpretation of the observations has been found possible.

Another process closely allied to electrical logging is the newer method of radioactive or gamma-ray logging. When wells are cased, resistivity and self-potential measurements are useless, due to the effective shielding of the metal casing. To some extent the radioactive method can be used instead, since the radioactivity can penetrate through several strings of casings. Most rocks contain very small amounts of radioactive minerals—*i.e.*, uranium, actinium, thorium, and their disintegration products—and the occurrence of the weakly active elements, potassium and rubidium, is widespread. During their disintegration three types of rays are emitted and, of these, the gamma rays, extremely short-wave X-rays, can be detected by suitably sensitive equipment lowered down the borehole. The radioactive minerals in sedimentary rocks varies considerably, limestones and sandstones being nearly inactive, while shales contain the most, the important feature being the possibility of differentiating between sands and shales.

Results of Electrical Logging.

While the ability of electrical logging to locate oil, gas, water-sands, and other features which are of prime importance in the individual wells, is generally recognized to be of great value, from the broader view of geophysical surveying its main utility lies in its application to electrical correlation. Numerous examples of correlation by electrical logging have been recorded, not only for individual fields, but also for much wider areas. Within fields, it has facilitated the unravelling of structural complexities, and it has shown frequently that faults are far more numerous than has been suggested by other means (*e.g.*, Surakhany). In this connection it has proved most useful in exploring the flanks of saltdomes. Lenticularity and wedging are also revealed.

As an example of correlation over long distances by means of electrical logs, sections described by Deussen and Owen [14] may be noted. In these sections, correlation is based on the electrical characteristics of the formations, in addition to their foraminiferal content, and by these means several formations have been traced through from deep underground to outcrop. The presence of a non-outcropping wedge of Oligocene marine shale is also well displayed. Thus, in its ability to correlate formations over long distances under certain conditions, the cautious application of electrical logging provides an additional aid in the location of all-important stratigraphic traps.

Magnetic Prospecting.

It is well known that one magnet, placed in the vicinity of another, will experience a force of attraction or repulsion depending on their relative

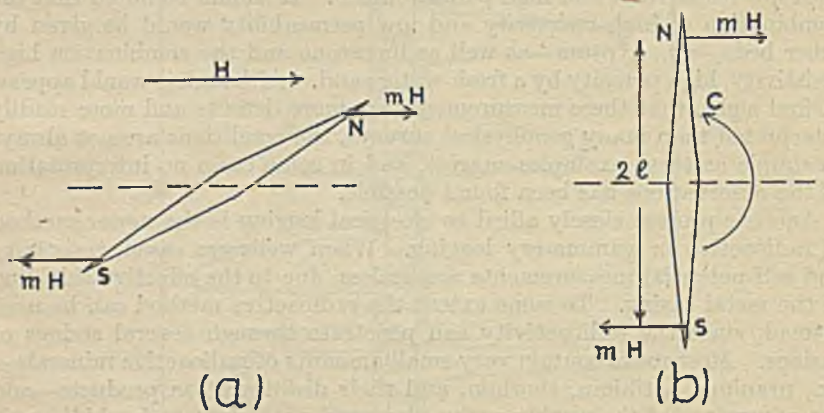

Fig. 20.

THE MEASUREMENT OF MAGNETIC FIELD STRENGTH.

positions. The region around a magnet in which these forces are apparent is called the magnetic field of the magnet. To measure the strength of the magnetic field at any point, it is convenient to consider the force acting on unit magnetic pole instead of a magnet, the magnetic intensity, or field strength, being defined as the force on unit pole placed at the point in question. Since the intensity is essentially a force, it has both magnitude and direction, and can be resolved into components, or compounded with other fields, using the same rules for the resolving and compounding of mechanical forces. The unit of magnetic field strength is the oersted, which is equivalent to a force of 1 dyne on unit pole. In geophysics, however, the older term of gauss is usually retained. For geophysical prospecting, the gauss is inconveniently large, and a smaller one is universally adopted called the gamma (γ) where an intensity of $100{,}000\gamma$ is equal to 1 gauss.

Although for purposes of definition it is convenient to consider the force or unit pole, all the necessary information concerning the field can be obtained from a freely suspended magnet. In a field of intensity H, the forces acting on the two poles constitute a couple tending to rotate it into the direction of the field (Fig. 20). Thus, when the magnet is in equilibrium, under the magnetic forces only, the line joining the poles gives the direction of the field. To rotate and hold the magnet at right angles to its equilibrium position requires a couple to counterbalance the magnetic couple of $2mlH$ (Fig. 20(*b*)), where m is the pole strength and $2l$ their separation. The product $2ml$ is the moment of the magnet and is a constant, and so for a

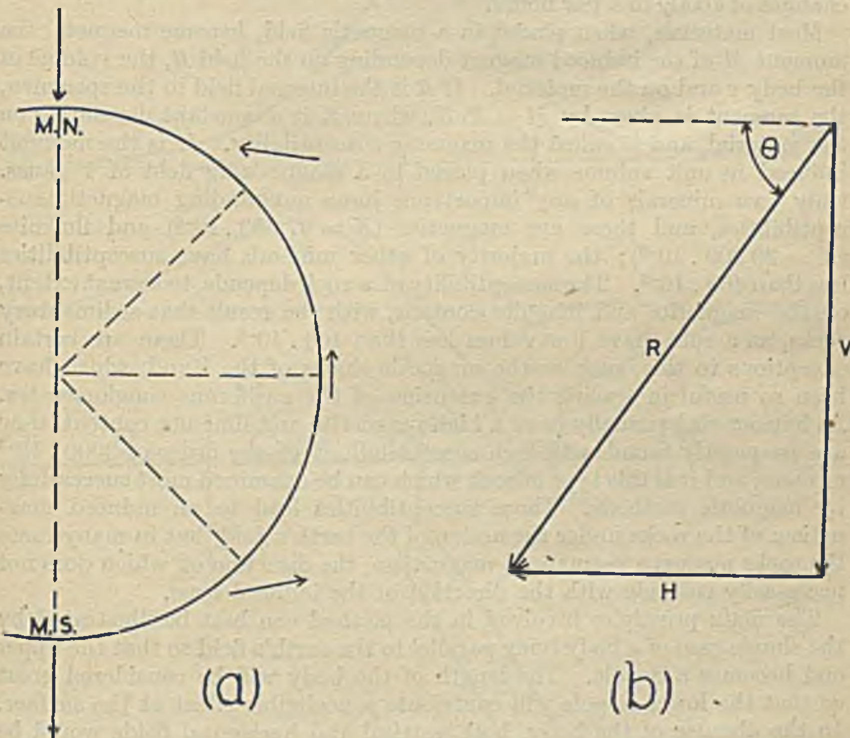

Fig. 21.
(*a*) THE MAGNETIC FIELD OF THE EARTH, (*b*) THE MAGNETIC ELEMENTS.

given magnet the couple required to maintain the magnet perpendicular to the field is a measure of the field strength.

The magnetic field of the earth, which forms a background for all geomagnetic surveys, can be represented approximately by that of a small magnet of large moment at the earth's centre, with its south pole pointing to the magnetic north pole of the earth. This does not coincide with the geographical pole, so that a magnet does not point true north, the difference, which varies over the earth, being defined as the declination. At the magnetic pole the intensity is vertical (Fig. 21(*a*)), and at the magnetic equator it is horizontal. At other points the intensity R is inclined to the horizontal by an angle known as the dip θ, and in the northern hemisphere the N pole of a magnetic dips downwards. The total intensity R is usually resolved into a vertical component V and a horizontal component H (Fig. 21*b*). The vertical field varies from a maximum of 0·6 gauss at the poles to zero at the equator, while H changes from zero (at the poles) to 0·3 gauss (at the equator). This is only an approximation to the earth's field; it is far more irregular than this simple picture, and the normal variation cannot be represented accurately by simple formulæ. Superimposed on this steady field, there are fairly regular daily variations in the intensity of 20–30γ, with occasional magnetic storms which may cause changes of 1000γ in a few hours.

Most materials, when placed in a magnetic field, become magnets, the moment M of the induced magnet depending on the field R, the volume of the body v and on the material. If R is the internal field in the specimen, the moment is given by $M = RvK$, where K is a constant depending on the material, and is called the magnetic susceptibility. It is the moment induced in unit volume when placed in a magnetizing field of 1 gauss. Only two minerals of any importance have outstanding magnetic susceptibilities, and these are magnetite ($K = 97{,}000 \,.\, 10^{-6}$) and ilmenite ($K = 30{,}000 \,.\, 10^{-6}$); the majority of other minerals have susceptibilities less than $400 \,.\, 10^{-6}$. The susceptibility of a rock depends, to a great extent, on the magnetite and ilmenite content, with the result that sedimentary rocks, as a rule, have low values less than $400 \,.\, 10^{-6}$. There are certain exceptions to this, such as the magnetic shales of the Rand, which have been so useful in tracing the extension of the auriferous conglomerates. As igneous rocks usually have a high magnetite and ilmenite content, they are frequently found with high susceptibilities of the order of $3000 \,.\, 10^{-6}$ or more, and it is this type of rock which can be examined most successfully by magnetic methods. These susceptibilities lead to an induced magnetism of the rocks under the action of the earth's field, but in many cases the rocks possess a permanent magnetism, the direction of which does not necessarily coincide with the direction of the induced type.

The main principles involved in the method can best be illustrated by the simple case of a body lying parallel to the earth's field so that the upper end becomes a S pole. The length of the body will be considered great so that the lower N pole will contribute a negligible effect at the surface. In the absence of the body, both vertical and horizontal fields would be constant as indicated by the broken curves (Fig. 22) and by the arrows H and V. To this simple field must be added the attraction between unit pole at the surface and the S pole of the body, a force which always points towards S and varies inversely as the square of the distance. At A this extra intensity will be negligible, and the normal values of V and H will be observed. At B, C, and D, however, it will make an appreciable contribution, and its vertical component will increase up to D when the vertical field will be a maximum giving the curve KLM. The horizontal component of the additive force at first increases, but due to the changing direction it falls away and at D it is zero; to the north of D the horizontal component opposes the earth's field. Thus the change in horizontal intensity will follow the curve RTW.

The pole distribution produced by the interaction of the earth's field, and the body is rarely as simple as this, and the resulting anomaly is more complex. The distribution depends on a number of factors, including the shape and size of the body, the magnitude of the earth's inducing field, and the susceptibility involved. The relation of the body and the direction of the earth's total field is a most important factor. A dyke, for example, with its strike length in the magnetic meridian would have poles induced only on its upper surface, while if it is perpendicular to the magnetic meridian there will be, in addition, poles induced on the walls. Although

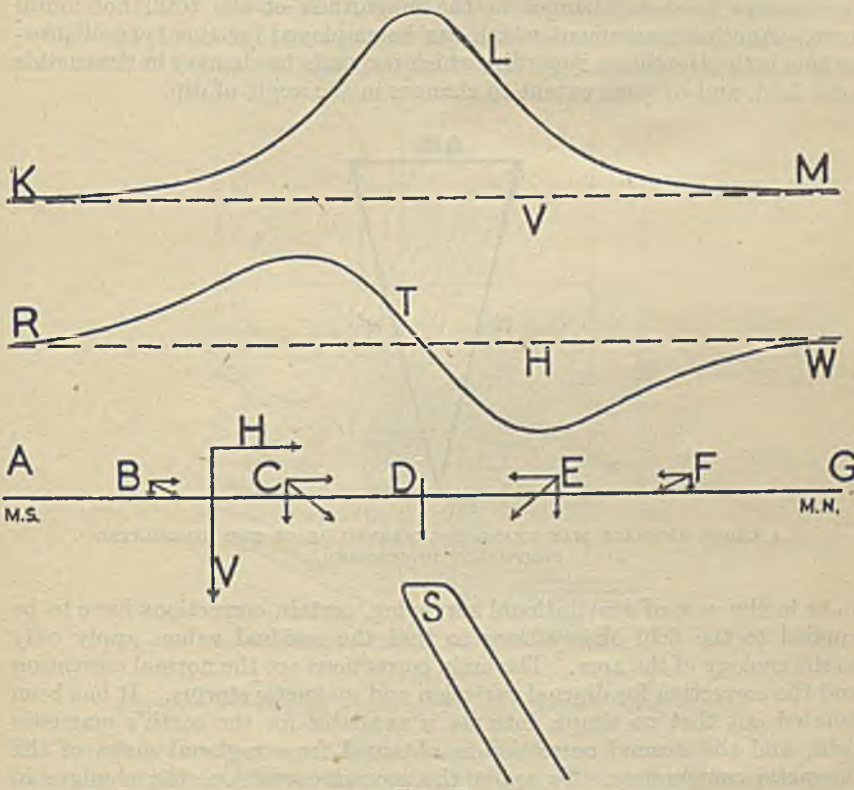

Fig. 22.

MODIFICATION OF THE EARTH'S MAGNETIC FIELD BY A BODY OF HIGH SUSCEPTIBILITY.

in the two cases the dimensions, susceptibility and total field may be identical, the nature of the anomalies may differ considerably. Again, the same body at different latitudes will yield differing results. Thus a sphere at the magnetic pole would give a maximum in the vertical field immediately over its centre, while at the magnetic equator the vertical field would show a smaller maximum to the south of the sphere, and an equal minimum to the north. Immediately above its centre there would be no anomalous vertical field.

To measure the anomalies instruments known as magnetic variometers are employed, and these measure differences between the fields at various points. The most useful instrument is the vertical variometer which measures changes in the vertical field, but horizontal variometers are also available. The former, however, are more reliable and, in general, yield results which are more readily interpreted. This arises from the fact that a considerable anomaly can be present without causing any appreciable change in the magnitude of the horizontal field; but only in its direction as shown in Fig. 23. Here H is the normal field, ΔH the anomaly and these combine to give a resultant field H' equal in magnitude to H. Horizontal variometers measure changes in the magnitude of the total horizontal force. Another instrument which can be employed for this type of prospecting is the Hotchkiss Superdip, which responds to changes in the earth's total field, and to some extent to changes in the angle of dip.

Fig. 23.

A LARGE ANOMALY MAY LEAVE THE MAGNITUDE OF THE HORIZONTAL COMPONENT UNCHANGED.

As in the case of gravitational surveying, certain corrections have to be applied to the field observations so that the residual values apply only to the geology of the area. The main corrections are the normal correction and the correction for diurnal variation and magnetic storms. It has been pointed out that no simple formula is available for the earth's magnetic field, and the normal correction is obtained from regional maps of the magnetic components. To apply the second correction, the changes in the earth's field with time can be obtained from an observatory, if one is sufficiently close, or one instrument in a fixed position is used to observe the changes. In surveys over large anomalies and in the absence of large magnetic storms, it is sufficient to return at intervals to a fixed station and estimate the time change during the intervals between repeated observations.

Interpretation and Limitations of the Magnetic Methods.

The representation of results is most conveniently done by constructing lines of equal magnetic component, or by magnetic profiles which show the variation of the measured component along a traverse. A qualitative interpretation is usually possible by inspection, taking into account the direction of the earth's field. A more detailed interpretation can be made involving tedious computation. It can be shown that there is a simple relation between the magnetic anomaly and the gravitational anomaly produced by the same body. Accordingly, many of the remarks on the interpretation of gravitational surveys are applicable here and, in particular, the same ambiguities arise. On the whole the interpretation of a magnetic anomaly is more difficult than a gravitational anomaly, for the latter is a characteristic of the body, while the former arise from the interaction of the external field and the body.

Application of the Magnetic Methods.

Although the magnetic method has been used extensively, mainly on account of its cheapness, it has only a limited application to oil prospecting.

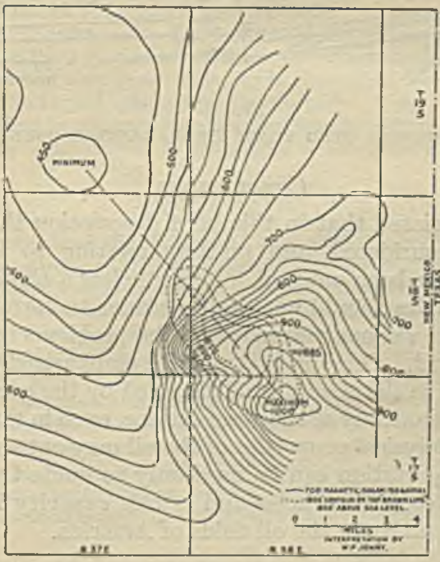

FIG. 24.

MAGNETIC SURVEY AT HOBBS FIELD, LEA COUNTY, NEW MEXICO.

The search here becomes mainly a search for basement uplifts which may arch the superincumbent sediments into a suitable oil-trap. It should be noted that such a movement is not necessarily associated with an oil structure, since this implies that the movement has taken place after the sedimentary deposition. Frequently, magnetic anomalies appear to be due to changes in the susceptibility of the basement itself and have no relation to structure. Serpentine plugs, which have an appreciable susceptibility, have been found useful for the location of certain faulted zones, as in Texas.

Examples of the results of magnetic prospecting are given in Figs. 24 and 25. The former, over Hobbs Field, Lea County, New Mexico, gives an anomaly in the vertical field of the earth produced by a basement uplift,[11] the basement being at a depth of approximately 10,000 feet. The structure is revealed magnetically by a maximum vertical field in the south-east and a minimum in the north-west. It will be seen that the maximum does not coincide with the crest in the anticline shown by the contours of the "Brown Lime" horizon, the displacement being due to the inclination of the inducing field. The latter shows a magnetic profile over a serpentine plug associated with a fault in the Yoast field, Bastrop County, Texas.[12]

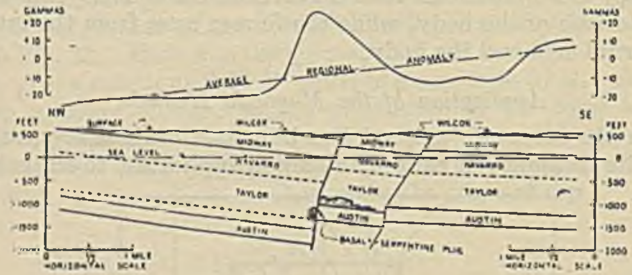

Fig. 25.

MAGNETIC PROFILE OVER YOAST FIELD, BASTROP COUNTY, TEXAS.

Conclusions.

It will be appreciated that in this brief description the main principles only have been considered, and matters relating to instruments, field technique, etc., have been omitted. Nevertheless a thorough understanding of these principles should enable the reader to form some judgement of the utility of the various methods and the problems in which they may be usefully employed. Once more it must be emphasized that the presence, or otherwise, of oil in the structures delineated by the geophysical methods cannot be inferred from any of the observations, even in the case of electrical coring, where the physical properties of the oil may enter into the measurements. The interpretation can be used only to guide the selection of the most promising sites for boreholes and in this capacity it has been found of great use, particularly in the oil fields of America.

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Illustrations.

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THE INSTITUTE OF PETROLEUM.

A MEETING of the Institute of Petroleum was held at Manson House, 26, Portland Place, London, W.1, on Friday, 28th April, 1944, when the President, PROFESSOR F. H. GARNER, was in the Chair.

The following paper was presented by Dr. J. McGarva Bruckshaw: "Geophysical Methods Applied to Oil Prospecting." (See pp. 271–310.)

THE AUTHOR, before reading his paper, said that he thought he should start with a word of explanation which, in some respects, was an apology for some of the deficiencies which he was sure would be fairly prominent in this paper. It was not written for the purpose of being delivered to a meeting of this kind. In fact, he had been asked to write a chapter covering the methods of geophysical prospecting that could be read by the layman and to form part of a handbook covering the whole aspect of fuel technology. As such, he had very great difficulty in presenting the information he wished to impart in the limited space allotted for the purpose. Now his task was even more difficult, because he had to compress an already abbreviated Section of a Handbook into an account which he could deliver in something of the order of 50 minutes or so.

DISCUSSION.

THE PRESIDENT said that the author had said that this paper was a chapter from a book which was being prepared by the Institute on "Modern Petroleum Technology," and the main purpose of this book was to give information of various branches of the industry to people engaged in the industry and he thought that it would be agreed that this is a very useful summary of the work on geophysical prospecting. One point he would like to ask the author about was his references in the paper to Sawtelle's data, which probably exclusively referred to the American data. It would be useful if the author would give the full reference in his bibliography.

THE AUTHOR said that he was under the impression that he had given the reference, but if he had omitted to do so it would be well worth while adding that to the list of references at the end. Sawtelle [1] had published one review of the application of geophysics and the achievements that have been obtained, and he felt it would be a good thing to place that at the disposal of people who had a general interest in the method and its application.

MR. J. C. TEMPLETON said that he would like to take this opportunity of congratulating the author on the lucid and eloquent manner in which he had described a very complex subject, and would like also to emphasise some of the outstanding points on which the author had touched. Geophysics alone did not provide a complete picture of the sub-surface conditions, nevertheless, it was of considerable assistance in prospecting for oil and was specially valuable to the geologist. The problem, as they knew, was essentially geological. By means of physical measurements, however, additional data were obtained wherewith to elucidate and determine the underground conditions. As the author had stated, this method was for the most part indirect and did not locate oil, as such, but assisted in locating the conditions favourable to the accumulation of oil. There was probably one exception to the indirect approach which deserved mention at this time. It was not strictly geophysical, but in large measure it came within the purview of the geophysicist and was likewise of great interest to the geologist. The object of the geo-chemical method was to determine the percentage of hydrocarbon gases, peculiar to petroleum, present in the sub-surface, particularly the sub-soil. At the present time we had not sufficient data on which to assess the full value of this method, but it opened up a new field of investigation, which had some promise of success.

There was another point on which he would like to touch, namely, the limitations of the various methods, which had been described very clearly by the author. Some oil technologists expected very little from geophysics, others expected far too much. Frequently they oscillated between these two extremes. Probably a little too much emphasis was placed on structural determination. He thought a clearer picture was

[1] *A.A.P.G., Bull.*, 20, June 1936, 726–735.

presented if it was remembered that they were endeavouring to determine the configuration and position of interfaces in the sub-surface, and that such interfaces were not necessarily structural. He referred to the interfaces between rock formations or rock bodies having different physical properties. These might be unconformities. As the geologist was well aware, the physical properties might vary quite rapidly within a single formation, in which case it was not possible to elucidate the structure by purely physical means.

The physical measurements as such were reasonably accurate and, from a purely physical standpoint, the determination of the sub-surface structure might seem straightforward. The determination of the shape or configuration of the concealed rock masses, or the geological interpretation of the measured data and the assessment of the conditions deduced, in relation to the accumulation and concentration of petroleum—the ultimate objective—was, however, not so simple.

One hundred per cent homogeneity was seldom realized in the sub-surface formations or rock masses. This and other physical irregularities frequently set the limit to the useful application of any particular geophysical method. It behoved one, therefore, to consider fully the known geological facts, at the outset in selecting the most suitable geophysical method or methods, and finally in determining the significance and value of the physical data.

Therefore, he would stress the importance, in future developments, of greater co-operation between physicist and geologist. Only by the geologist acquiring more knowledge of physics and the technique of geophysical measurements and the physicist realizing something of the geological complexities, of which the geologist was all too well aware, should we attain the maximum success in the application of geophysics. Today we were not only concerned with structural traps for oil, but also with stratigraphic traps. By knowing something of the difficulties and limitations, the oil technologist would better understand and appreciate the scope and value of geophysical prospecting methods.

The Author said that he would like to thank Mr. Templeton for his very kind remarks and he would also like to associate himself with the last part of his speech because he found it very difficult to alternate between the magician who could produce anything out of the hat or the charlatan who could not do anything right. As far as geo-chemical methods were concerned, he was not very familiar with the latest developments but it had always seemed to him that one was still going to have the same difficulty because the presence of suitable hydrocarbons in the subsoil was no criterion of the amount of oil which might be within the structure; although it might indicate the presence of a certain amount of oil it would not indicate the quantity, and so the whole problem was by no means solved by certain observations by the application of geo-chemical methods themselves.

Mr. Templeton agreed that the geo-chemical method was not complete in itself, but it might be of great assistance.

The Author replied that that was so.

Mr. Templeton said that when we had determined that hydrocarbons—gaseous or liquid—were present in a structure, the oil possibilities were enhanced very considerably. Without that knowledge we might drill into a structure with completely negative results.

Mr. Campbell Hunter asked the author what he regarded as the most satisfactory method of approach for structures say in rocky mountainous country? He was referring particularly to the foothills in Alberta where he understood they had tried geophysical methods but he did not think with any great success.

The Author said that he did not know very much about the work in Alberta but the most promising method there appeared to be either the refraction seismic method or the reflection seismic method. A certain amount of correction had to be applied for irregularities at the surface but these could be applied with sufficient accuracy not to mask the significance of the results in terms of geology. In all probability the surfaces would be far too erratic for the application of the gravitational method, and the magnetic method required certain features to be present before it could be used with any great success. Therefore, one was more or less forced back on to the seismic method, but without further details of what had been done and of the problem to be solved, he was afraid he was not in a position to make any definite comment on this particular problem.

WATER FOR OILFIELDS DEVELOPMENT.

By G. W. Halse (Member).

Before drilling for oil can be commenced in undeveloped countries, one of the first problems which must be solved is the provision of a water supply.

The following notes show how water was found by Trinidad Petroleum Development Co., Ltd., British Controlled Oilfields, Ltd., and Ecuador Oilfields, Ltd., respectively :—

Trinidad Petroleum Development Co., Ltd., Trinidad.

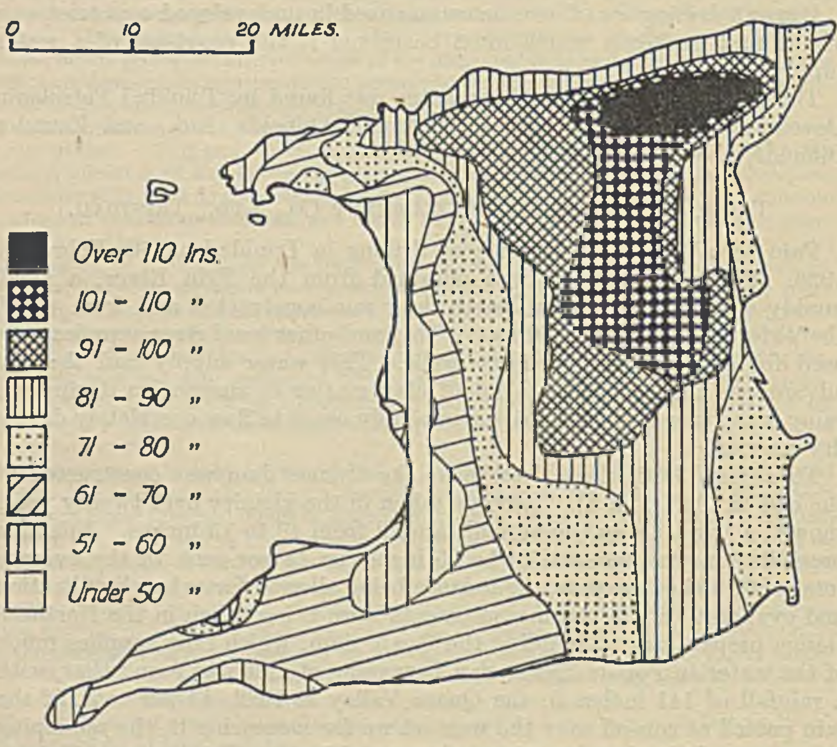
Palo Seco Well No. 1 commenced drilling in Trinidad on 5th February, 1926. Water for drilling was obtained from the Erin River, a small muddy stream, in which an earth dam was constructed and from which the water was pumped 1350 feet. This and other local river supplies were used for drilling the first forty wells. This water supply had the disadvantages that it carried a lot of clay matter in suspension during the rainy seasons, and that the rivers generally cease to flow completely during dry seasons.

To obviate both these drawbacks the Cyrnos dam was constructed at the end of 1928 (Fig. 1). Records taken in the vicinity over twenty years showed a variation in the annual rainfall from 49 to 73 inches. Effective precipitation was assumed to be 25 inches or 41 per cent. of the average total of 61 inches per year, the balance being allowed for as loss by filtration and evaporation. When measurements were being taken in the Northern Range preparatory to building the Quare dam, which now supplies much of the water to Port-of-Spain, San Fernando, etc., it was found that, with a rainfall of 141 inches in the Quare Valley in 1922, 43 per cent. of the rain passed as run-off over the weir set up for measuring it, the remaining 57 per cent. being lost by evaporation and filtration (Trinidad and Tobago Council Paper No. 48 of 1924). The accompanying map (Fig. 2) shows the truly remarkable variations of rainfall within very short distances in Trinidad. It is only 50 miles across the island from the north coast to the south coast.

The catchment area for the Cyrnos dam is 50 acres. It is entirely wooded or covered with cocoa plantations, so that soil erosion, which would silt up the reservoir, is at a minimum. The height of the dam is 17 feet. When full it contains nearly 30 million Imperial gallons. The assumed effective rainfall of 25 inches on 50 acres in a year would accumulate 28 million gallons. From this must be deducted evaporation from the surface of the water itself, together with a certain amount of leakage. In the Quare Valley it is stated in the Council Paper quoted above that small-scale measurements indicated that an evaporation rate of 1 inch per week from reservoir surfaces should be assumed.

Field requirements at the time at Palo Seco with four drilling strings in operation were estimated at 200,000 Imperial gallons per day (5700 barrels) or 73 million gallons per year. Thus it is seen that not only was the total rainfall inadequate to fill the reservoir in a year, but that when full, allowing for evaporation, it contained barely sufficient water to last for four months.

The frequent anxiety caused by the small reserve of water in the dry weather was found to be justified during the first few months of 1931,



Copied from "The Rainfall of Trinidad"
by F. M. Bain, Department of Agriculture, 1934.

Fig. 2.

RAINFALL DISTRIBUTION IN TRINIDAD.

when there was an exceptionally prolonged dry season. The Cyrnos reservoir became exhausted, and the only water available consisted of some small pools still remaining in the rivers. By moving pumps to one pool after another, a limited and precarious supply was obtained. Drilling was disorganized and several stoppages occurred until the rains commenced.

The inadequate size of the catchment area would normally be overcome by finding an alternative site, but the local topography, position of roads, houses, and well locations were such as to preclude the use of suitable sites which were found. The situation was generally saved by the fact that the local rivers do not dry up immediately the rains cease, but continue to flow for from one to two months. Pumps were therefore set up permanently in four of the local rivers, not only to supplement the insufficient rainfall and fill the reservoir during the rains, but also to continue to supply water to it into the dry season as long as the rivers lasted. The drawback still remained, however, that a four-months' dry period, after the rivers had dried up, was the longest which the water supply would last.

On the 19th July, 1932, the first Schlumberger Electric Survey of an oil-well in Trinidad was made. This was at T.P.D. Palo Seco Well No. 126. In addition to oil and salt water, the diagram showed what the Schlumberger Engineers interpreted as fresh-water sands at shallow depth.

Although drilling shallow wells for water had previously been discussed, it was not actually carried out until after the important evidence of the Schlumberger device was obtained. Then the drilling of shallow " pup " water wells was commenced from the same derricks as oil wells in which the Schlumberger Survey for oil had also indicated shallow fresh water. These pup wells start about 4 feet from the main well at surface, and are drilled without moving anything except the rotary table (Fig. 3). They commence with an initial deviation of 3°, the rotary table being canted this amount. Sufficient weight is kept on the bit during drilling to ensure deviation away from the main well near the surface. Their depth is usually about 600 feet. In the soft sands and shales penetrated, dipping at 15–30°, a considerable number of directional surveys have shown a general tendency to deviate fairly straight up dip. For instance, in one T.P.D. field fifteen directional surveys to depths up to 6400 feet gave over-all deviations on bearings from 100–180°, the straight-up dip direction bearing 160°. Even wells with an initial deviation down dip have been found to curve round to an up-dip direction.

The result of drilling these water wells (Fig. 4) was that a supply of fresh water adequate for the expanding needs of the company was quickly established, and the previous frequent anxiety as to whether the water would last until the next rains was entirely eliminated.

The sands supplying the water are all monoclinal, and outcrop within 1500 feet or so of their respective wells. Rain falling on these outcrops fills up the sands with water which is tapped in the wells. Under these conditions any sand would fill with water, but in the area under consideration there are two geological horizons which are particularly suitable. At Palo Seco and Coora the Morne L'Enfer sands (sometimes called Upper Moruga) of Upper Miocene age supply the water. This formation in general is sandy, but is characterized by a considerable admixture of thin bedded argillaceous matter. It does, however, contain sands fairly free of clay, particularly in its upper horizons, which make good water sands.

At Los Bajos, the " Porcellanite Beds," of Pliocene age, contain excellent water sands (Fig. 5). Their name is due to their containing lignites which, when sufficiently near the surface to be reached by atmospheric oxygen, have ignited spontaneously and have baked the adjoining clays. In 1938 one of these localities was smouldering at Cedros, due to a bed of lignite 9 feet below the surface. The overlying clay was burnt to the characteristic bright red colour. These "Burnt Clays" or "Porcellanites" which occur at intervals over a distance of 15 miles are of great economic importance in south-west Trinidad, and are extensively quarried, since they provide the only locally available supply of road metal. In both cases the water sands are continuous or sheet sands, as contrasted with the Forest and Cruse oil-bearing sands of Middle and Lower Miocene age which are highly lenticular.

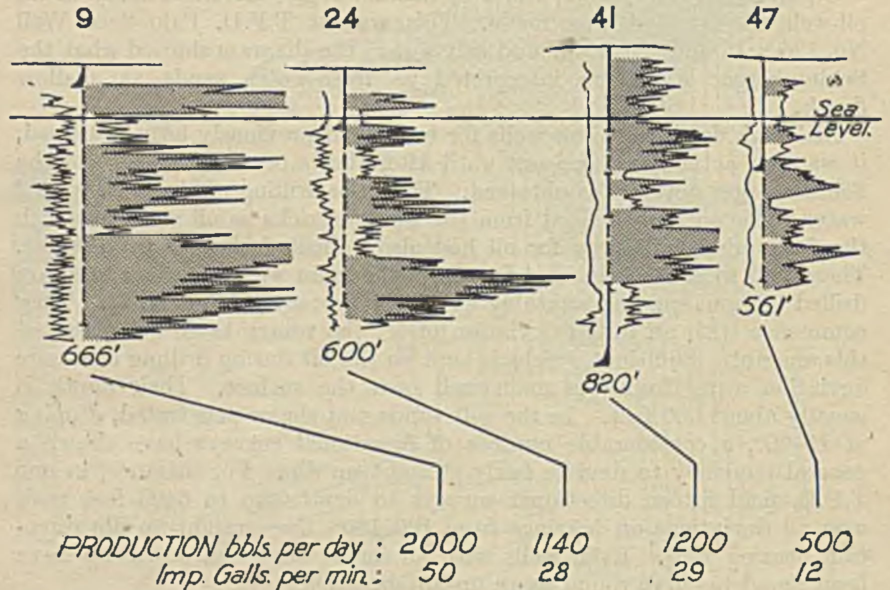


Fig. 6.

SCHLUMBERGER DIAGRAMS, LOS BAJOS.

The accompanying Schlumberger diagrams show typical water sands of the Porcellanite (Fig. 6) and of the Morne L'Enfer beds (Fig. 7). The output and chemical analyses of the waters are added in each case. The casing in practically all wells is a 5⅝ inch combination string with ⅜ inch perforations, fifteen holes per foot. None of the wells are gravel packed. The water is produced by gas lift using surplus almost dry gas from high-pressure separators. This gas is delivered through reducing valves to the wells at pressures varying from 60 to 165 lbs. per square inch. The input string is either 1 inch or 1¼ inch diameter, and from 175 to 420 feet deep. The water flows through the annulus between this and 3 inch or four inch pipe which is set not less than 50 feet deeper than the input pipe. The total production of water by this means is about 14,000 barrels (490,000 Imperial gallons) per day from some eleven wells. In a few cases the output of water cannot be increased without fine sand entering the well, but in some cases there is little doubt that a considerable increase would be possible.

The water is quite suitable for general purposes, but is rather hard. Treatment to prevent the formation of hard scale is necessary before it can be used in boilers or water-jackets. The addition of 1 lb. of Quebracho to each 11,000 Imperial gallons of feed-water is found to be adequate for softening and reducing scale to a satisfactory degree.

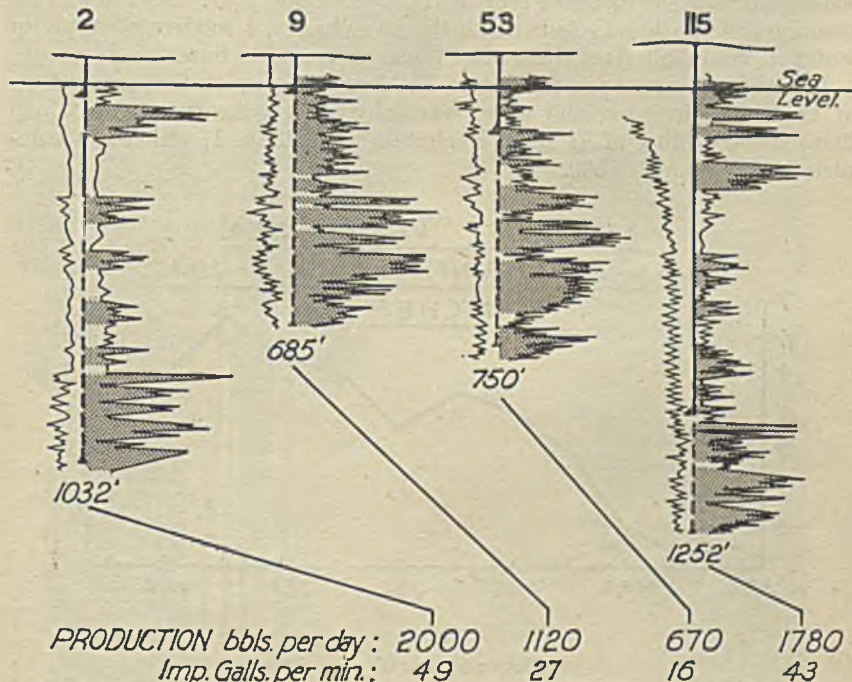


Fig. 7.

SCHLUMBERGER DIAGRAMS, COORA.

British Controlled Oilfields, Ltd., Venezuela.

The El Mene oilfield of B.C.O., Ltd., is situated in semi-arid country 40 miles east of the town of Maracaibo. When drilling commenced in 1919 there was only one inhabitant at El Mene, as compared with some 4000 people now. The only water supply was from a hand-dug well or two which gave a little brackish water, and from small ponds made by excavation and banking.

Figures taken over eighteen years show that the rainfall at El Mene averages $40\frac{1}{2}$ inches per year. The annual totals in inches are :—

Year.	Rainfall.	Year.	Rainfall.	Year.	Rainfall.
1925	34·7	1931	44·6	1937	31·3
1926	36·5	1932	46·4	1938	55·1
1927	51·2	1933	54·3	1939	28·7
1928	38·6	1934	44·6	1940	41·6
1929	29·4	1935	40·0	1941	27·9
1930	38·3	1936	43·7	1942	42·7

The average monthly distribution of this rain is shown in the accompanying curve (Fig. 8).

In 1919 the River Maticora formed the only suitable supply of water for oilfield work. Although running water ceases in the lower reaches of this river a couple of months or so after the commencement of the dry season, some pools of water remain throughout the year. As these pools communicate with gravels beneath the river banks, a moderate supply of water is obtainable from them after the river ceases to flow.

In order to commence drilling at El Mene, a pump-station was set up at the river Maticora, and water was delivered 4 miles through a 2-inch line for the drilling of El Mene Exploitation Well No. 1, which was completed in September 1920.

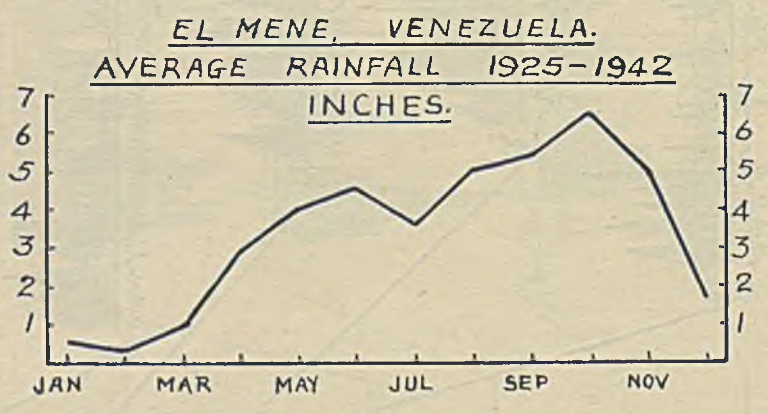


Fig. 8.

EL MENE RAINFALL CURVE.

Regular development drilling commenced in 1923. To obtain additional water in a convenient situation two water wells 450 feet deep were drilled near No. 1 well, and they produced steadily some 200 barrels of water per day each.

During the years 1923–1927 there was usually a shortage of water in March, owing to the drying up of the River Maticora after three or four months of dry season. In this period ten more water-wells between 400 and 500 feet deep were drilled within the oilfield, and occasionally an oil-well would be stopped at shallow depth in order to utilize temporarily the fresh water passed through. In April 1924, after seven dry months, it was found that the output of the shallow water wells fell off considerably. A falling off was noticed late in the following year also.

In 1925 a 6 inch oil line for delivering oil to the lake shore was completed, and the previous 4 inch oil line was used for pumping water from Lake Maracaibo, 35 miles to El Mene. The main supply, however, was still from the Maticora River (Fig. 9).

From 1925 to 1928 inclusive forty-seven wells were completed in El Mene each year. Drilling was entirely by the Cable Tool System, and wells rarely exceeded 1000 feet in depth, so sufficient steam was supplied by

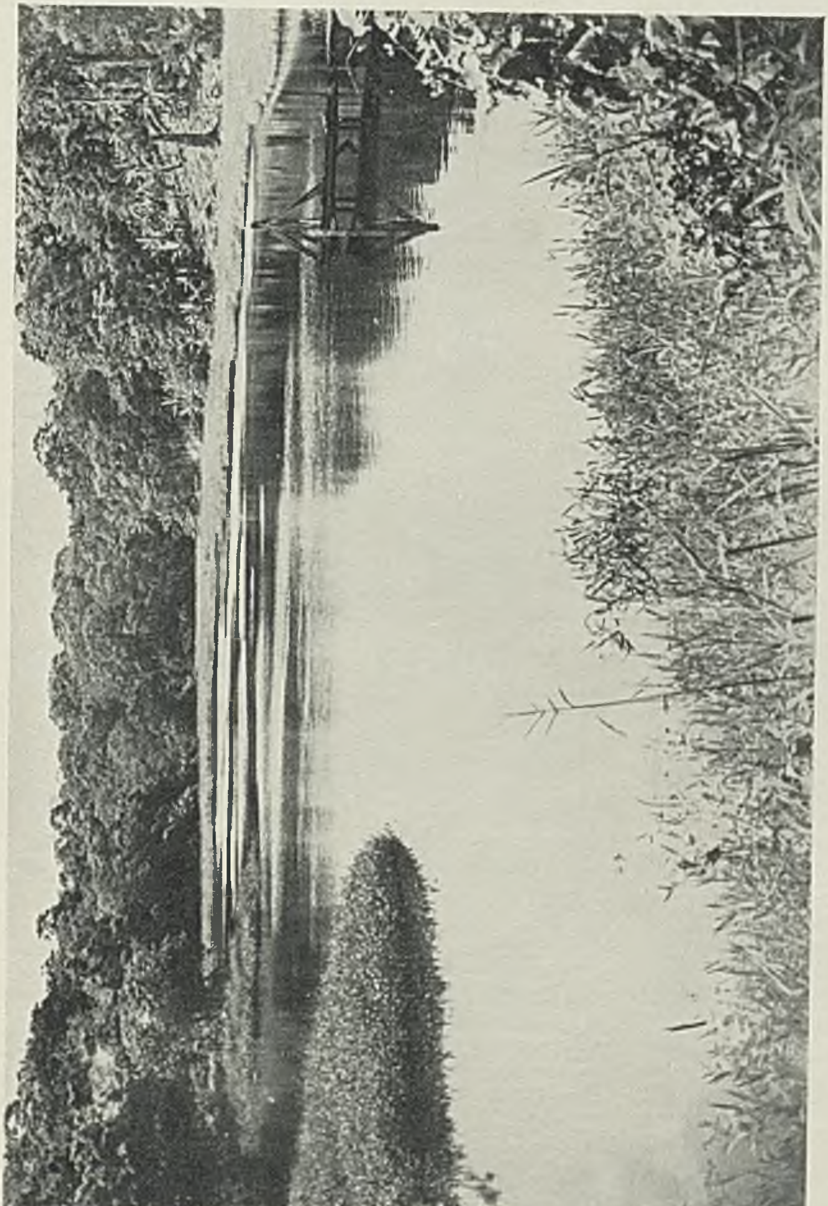


Fig. 1.
CYRNOS DAM.

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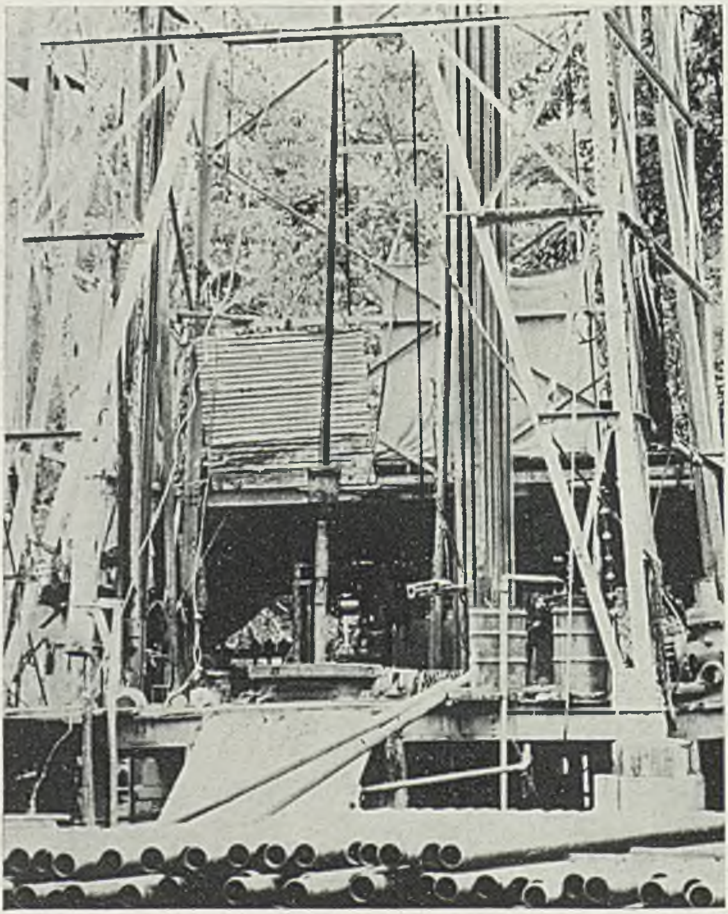


Fig. 3.

PUP WELL DRILLING.

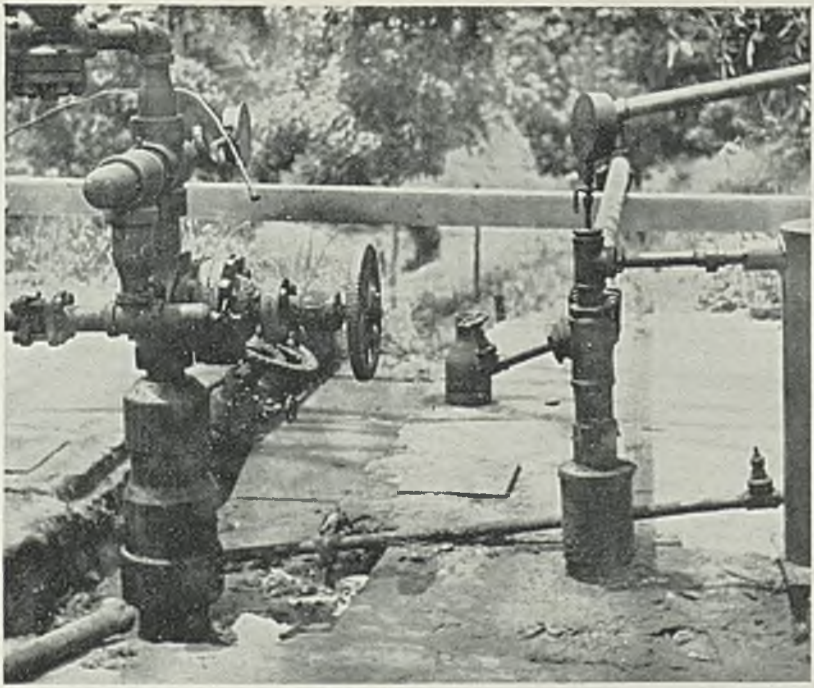


Fig. 4.

COMPLETED WATER AND OIL WELLS.

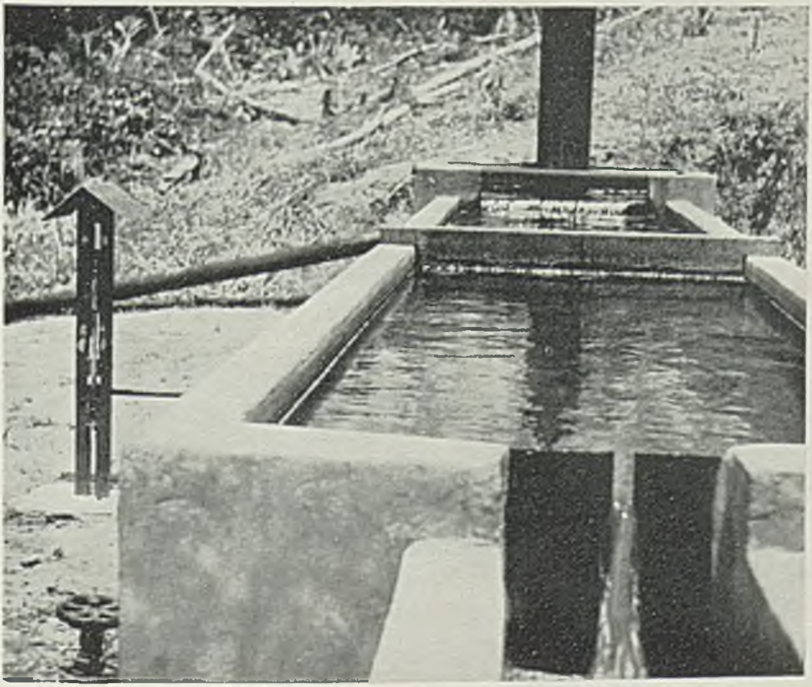


Fig. 5.

MEASURING WEIR FOR WATER WELL.

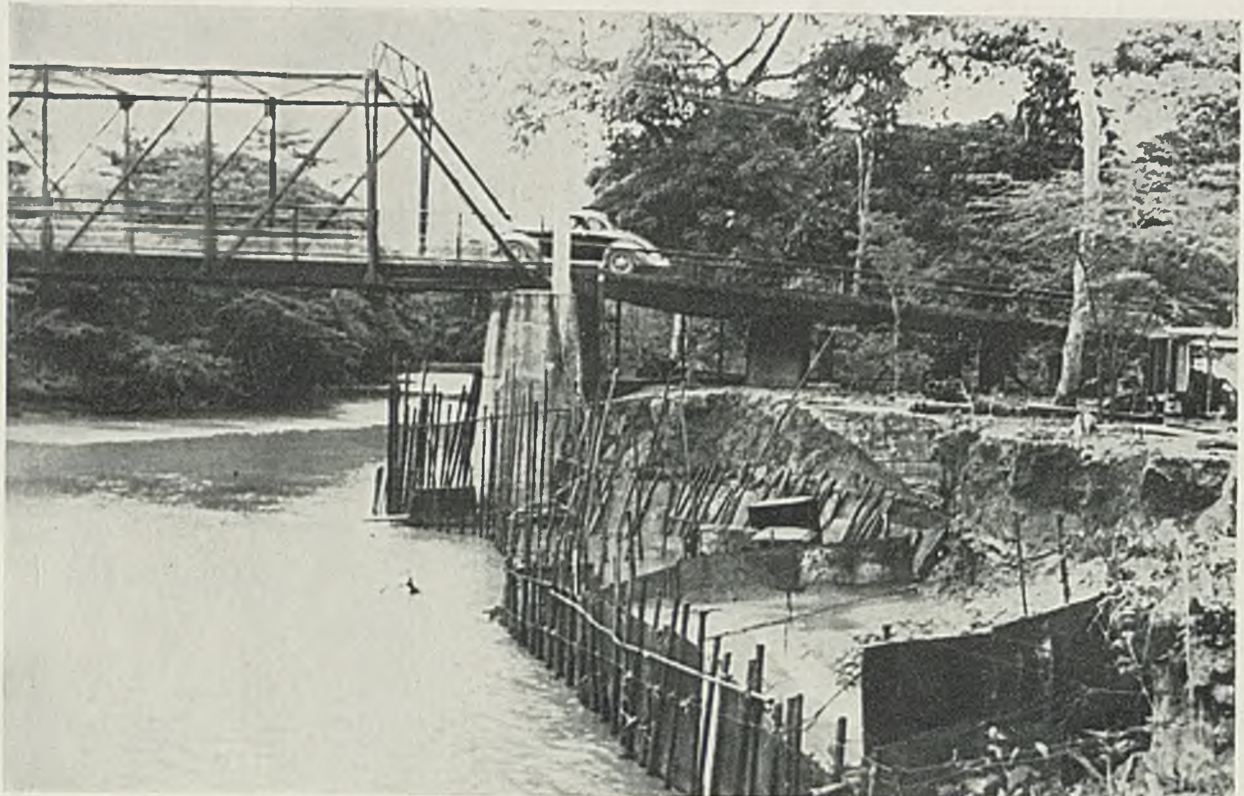


Fig. 9.

RIVER MATICORA.

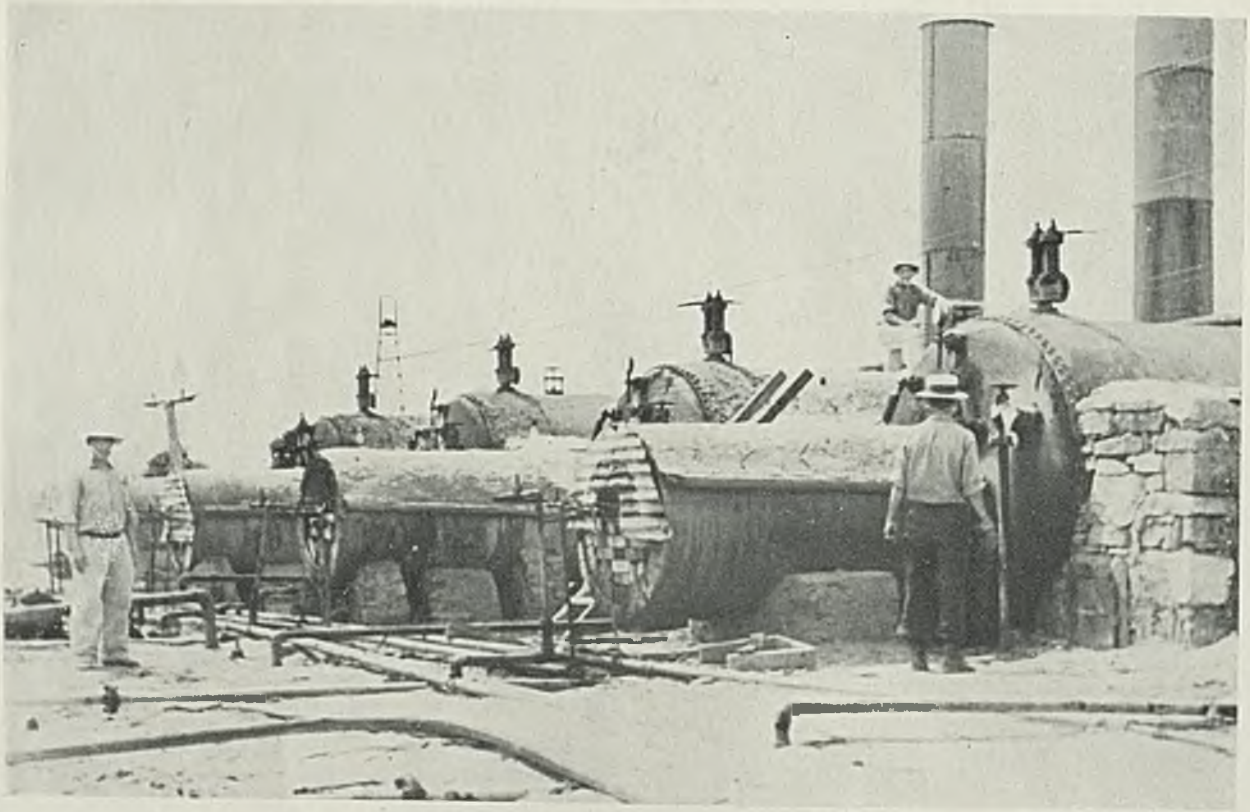


Fig. 13.

BATTERY OF CORNISH BOILERS.

Fig. 14.

SEA WATER SUCTION LINES.

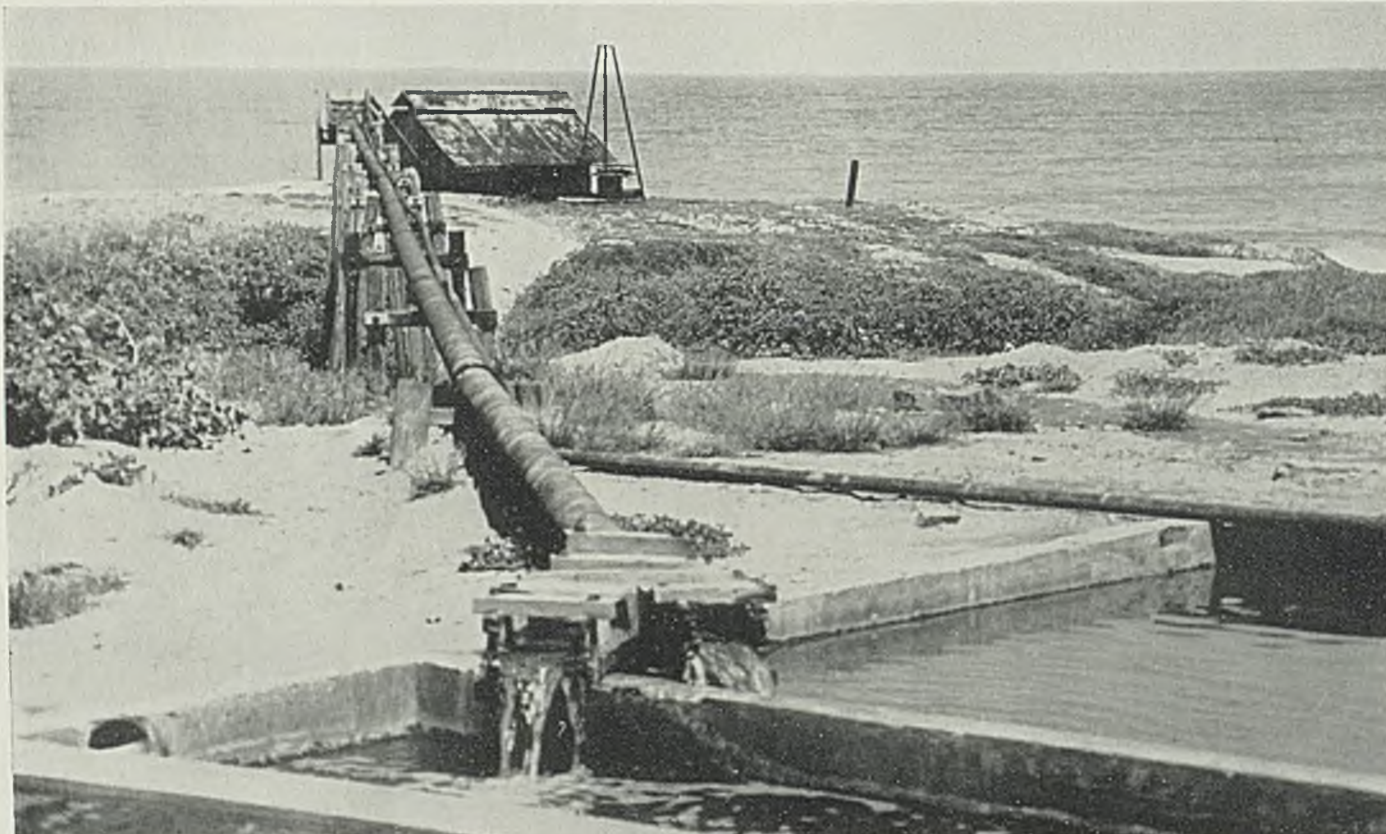


FIG. 15.

SEA WATER SETTLING TANKS.

Fig. 16.

HEAT EXCHANGER.

one boiler for each well. Water consumption therefore was very low as compared with rotary drilling requirements.

In 1928 rotary drilling with the latest-type rigs then available was standardized for exploratory drilling. In addition, a recovery plant for extracting light ends from rich gas was erected at El Mene. This extra equipment called for a greatly increased water supply. Furthermore, the mud which was always present in the water when the river was in flood could no longer be tolerated. Various pits, 5 feet × 5 feet × 25 feet deep, were sunk beside the Maticora river, but 50–150 feet away from the bank. The object of these was not only to increase the supply of water, but also to obtain clear water when the river was in flood and muddy. The intervening gravels and sand formed a natural filter, and clean water was obtained at an initial rate of 75,000 gallons (2100 barrels) per day per pit, but the supply fell off through gradual clogging of the communicating beds with clay.

It was not until the Llanitos well was completed in 1929 that the water supply problem was really satisfactorily solved. This well was drilled for oil, which it failed to find, but none the less it turned out to be highly profitable. It is situated 3½ miles east of El Mene on the south side of the fold axis, and was drilled by cable tools. This system allowed the collection of samples of water struck in the well as follows :—

Depth, ft.	Salinity, Parts per 100,000.	Geological Formation.
1375	8	Upper Miocene
2620	960	Miocene
2938	1179	Miocene
3130	1190	Eocene ?
3324	23	Eocene ?

The deep-seated fresh water, below salt water, indicates the structural complexity of the region. Furthermore, the temperature of the fresh water from 1375 feet is 120° F. To have reached this temperature it appears that this fresh water must have come from a depth of not less than 4000 feet. It flows naturally at the rate of 1300 barrels per day, and has a slightly sulphurous smell as it emerges, but this quickly disappears, and cannot be detected where the water is used.

Compressors and pumps were installed at Llanitos in 1929, and the well has given some 8000 barrels of water per day ever since by air-lift. 4-inch tubing is set at 200 feet, and air is introduced outside this, between it and the 12½-inch casing. The kick-off pressure is 125 lb. per square inch, and the running pressure 60 lb. per square inch. The only interruptions in nearly fourteen years of production have been of a few hours' duration, when it is necessary to change the tubing once a year because the bottom 80 feet becomes furred up by the deposition of scale, and so restricts the output of water. Total production of water during this period has been some 41 million barrels, or about 8½ million cubic yards, and there is no apparent reason why it could not go on producing at this rate indefinitely.

In 1930 the demand for water rose to over 10,000 barrels per day. Analyses of the water from the La Ceiba well showed it to be unsuitable for boilers, so two water wells were drilled to 400 feet depth at Mono Bluff, between El Mene and Llanitos. Together they yielded over 5000 barrels per day of excellent water by air-lift from sands of the La Puerta formation.

The dominating geological feature of this region is the Barranca Basin (Figs. 10 and 11), a saucer-shaped synclinal basin 16 miles in diameter. This rigid unit has resisted compression, but older beds outcropping from

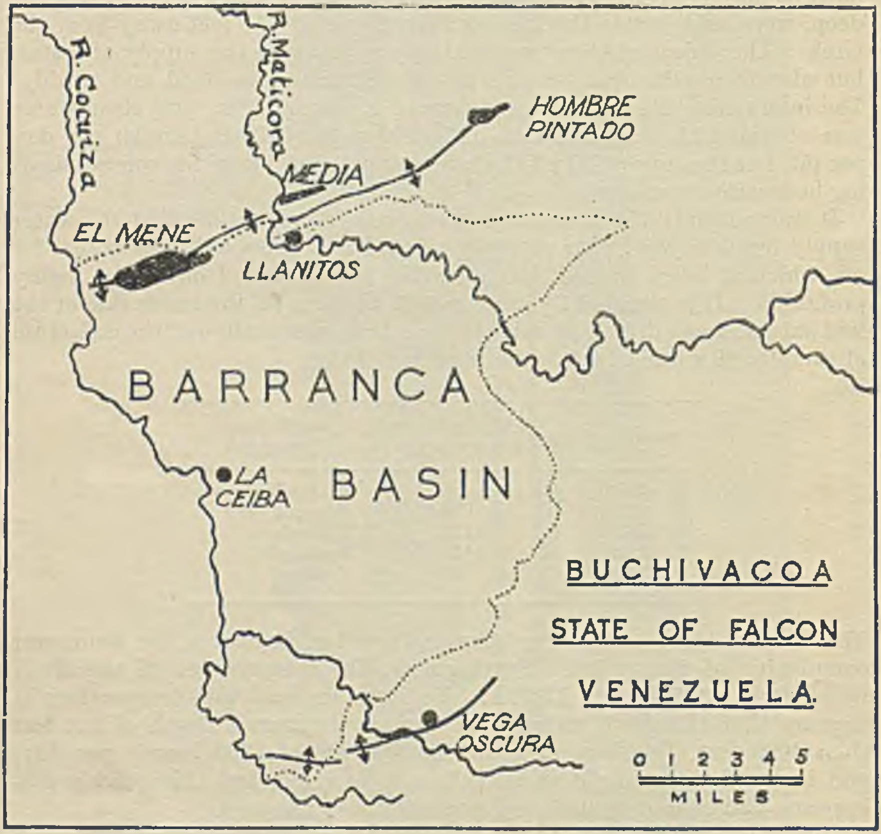


Fig. 10.

BARRANCA BASIN.

beneath it on the north, east, and south sides have been sharply folded and crushed.

The Llanitos well is on the north-east rim of the basin where the main east-north-east fold axis of the region passes tangentially from the rim. At the southern circumference of the basin Vega Oscura Well No. 2, completed in 1936, found at 4300 feet depth a flow of 3000 barrels per day of water of salinity 5 parts per 100,000 and temperature 147° F. This came from rocks of Oligocene age. La Ceiba No. 1 well, down the slope of the basin, 6 miles from its northern edge, was drilled to 4648 feet depth in 1925 and 1926. It struck an estimated flow of 4000 barrels per day of "hot flowing fresh water" at between 1600 and 2300 feet and salt water at 4638 feet. This fresh water was reported to be unsuitable for use in boilers.

The results of these wells show that a very large supply of bacteriologically innocuous water is obtainable in this region, though in some cases high mineral content precludes it from being classified as good potable water. Furthermore, artesian flow of considerable magnitude was found. This is no doubt because the La Puerta formation covers most of the Barranca Basin, and the mottled clays which it contains form an efficient impervious cover to hold in the water, while the hills and mountains south-east of the Basin afford ample opportunity for accumulating the head necessary for artesian flow.

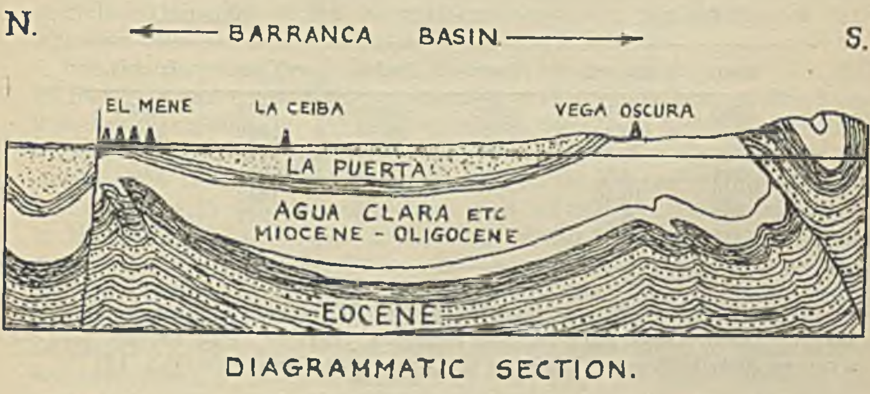


FIG. 11.

SECTION, BARRANCA BASIN.

It was at one time thought that the extensive south dipping flank of the Barranca Basin, culminating northwards in the El Mene anticline, had given rise to migration of oil up the flank and accumulation near the crest at El Mene. If this were so, waters now associated with the oil would be expected to be fresh, but they are not; they are salt. Furthermore, the waters in the northern part of the field run about 450 parts of salt per 100,000, whereas those down the flank and more into the fresh water saturated Barranca Basin are more saline—namely, 900 parts per 100,000. This is the reverse of what would be expected had the soil migrated up dip from the basin, and is a strong indication, if not a proof, that the Barranca Basin is not the source of the El Mene oil.

The Llanitos well is situated on the south edge of a complex faulted anticlinal core. The high temperature of the water produced from 1375 feet is suggestive that it may be the same fresh water which occurs at 3324 feet, and which may reach the higher level through a fault channel. The anticlinal core has been mapped in considerable detail, but all geological evidence immediately to the south of the well is concealed by alluvium. There was no specific reason for anticipating a prolific water supply here—in fact, the faulting might well have been thought to have formed a barrier preventing access of water from the Barranca Basin. It may be stated, therefore, that all the geological evidence available, including that from the Llanitos well itself, would not have enabled the striking of a big supply of fresh water there to have been predicted.

Ecuador Oilfields, Ltd., Ecuador.

The Santa Elena Peninsula, where the only oilfields at present developed in Ecuador are situated, is almost on the Equator, and consists of semi-arid, low-lying country with a very variable rainfall confined to the first four months of the year. Anglo-Ecuadorian Oilfields, Ltd., have kindly furnished the following figures for rainfall at Ancon :—

Rainfall.		Rainfall.		Rainfall.	
Year.	Inches.	Year.	Inches.	Year.	Inches.
1925	40·15	1932	30·10	1938	5·58
1926	26·62	1933	20·70	1939	44·91
1927	3·60	1934	6·70	1940	5·81
1928	2·53	1935	7·55	1941	19·97
1929	16·80	1936	7·46	1942	2·75
1930	3·96	1937	7·20	1943	15·12
1931	2·82				

The annual variation, between 2½ and 45 inches, is seen to be very large. The average rain for the nineteen years is 14·23 inches, and its average distribution is shown on the accompanying curve (Fig. 12).

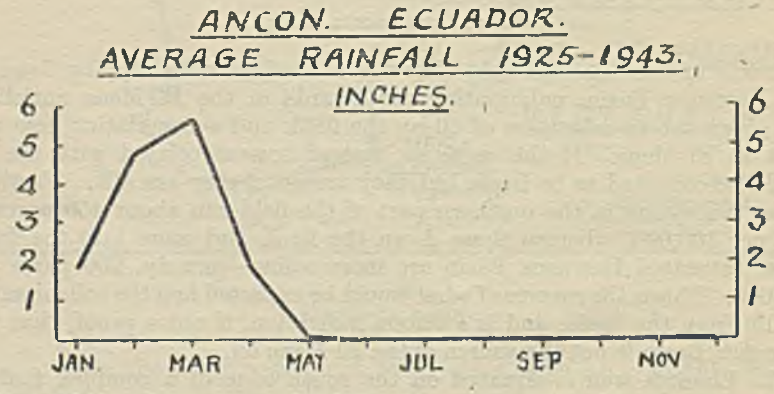


Fig. 12.

ANCON RAINFALL CURVE.

Probably during the period of Inca colonization, which was extensive in this area, and certainly since the time of the Spanish Conquistadores, water supply was obtained exclusively from hand-dug pits and dams. The water in the pits is often brackish and is liable to be polluted from nearby houses. The reservoirs formed by the dams afford a supply which is variable and precarious. They frequently dry up completely, as may well be understood from the rainfall figures given above.

The value of water reservoirs is greatly enhanced by the unusual climatic conditions of the Santa Elena Peninsula. The Rumboldt Current of cold sea-water from the South Polar region impinges on the Pacific Coast at Santa Elena and greatly reduces the temperature. It also causes the region to be covered with fog or low-lying cloud, which almost entirely excludes sunshine from May to October. The fog is locally known as "Garua." It is a most important factor in reducing evaporation from reservoir surfaces, and results in the water lasting much longer than it would under normal tropical conditions.

As local fresh-water resources are entirely inadequate for oilfield development, and specially for rotary drilling, Anglo-Ecuadorian Oilfields, Ltd., introduced the use of sea water for steam-raising for drilling in 1919. Ecuador Oilfields, Ltd., started a similar practice in 1937.

For this purpose Cornish-type boilers are used. They consist of a shell 22 feet long and 6 feet 6 inches diameter with a single internal flue 3 feet 3 inches diameter (Fig. 13). Every eleven days each boiler is shut down for men to enter and remove the scale, which chips off easily. The amount recovered is from 100 to 150 lb. per boiler. It consists mainly of $CaSO_4$ and $CaCO_3$ with only just over 1 per cent. of salt, yet the sea-water used in the boilers contains over 3 per cent. of salt as compared with about 1 per cent. of other constituents. In other words, the boiler concentrates the lime, etc., some 300 times more than the salt. This shows how effectively blowing down removes the salt: it is done every one or two hours. In practice over a number of years the use of sea-water in these boilers has been found to be quite satisfactory. Perhaps the main disadvantage is that the boilers are not easily portable, since they have to be bricked in so that the flue gases can heat the outer shell after passing through the internal flue.

For withdrawing water from the sea (Fig. 14) a diaphragm-type pump is used, as this can handle sand, which cannot be avoided with suction lines on an exposed coast. This water is delivered into settling tanks (Fig. 15), from which it is pumped to the field. Corrosion of pipe-lines is severe.

While the use of sea-water solves part of the problem of water supply, fresh water is essential for rotary mud and for general purposes. It was found that Schlumberger diagrams could not be taken satisfactorily in wells using mud made with sea-water, because its resistivity was too low. This alone, therefore, is a sufficient reason why fresh water is essential for drilling mud.

Geological conditions in the Peninsula are unfavourable for the accumulation of water in quantity. The surface formation is composed of a thin Recent Shelly sand and beach deposit called the Tablazo, which lies horizontally in patches on folded Oligocene and Eocene beds. The Eocene consists mainly of impervious clays and cherts which cover most of the Peninsula proper. The prospects of water in this region are small because of the thinness of the Tablazo, which connotes lack of volumetric capacity in the possible reservoir beds.

Notwithstanding these conditions, in 1929 Ecuador Oilfields, Ltd., drilled some wells 120 feet deep and obtained a supply of fresh water. The wells have been on production ever since, and particulars are as follows :—

Well:	No. 1.	No. 2.	No. 3.	No. 4.
Production, barrels per day .	100	200	100	100
Sp. G. of water at 29° C. .	0·9975	0·9960	0·9965	0·9970
Total solids per 100,000 . .	213·0	81·8	201·0	244·7
Sodium chloride per 100,000 .	128·9	37·5	114·8	152·3
Sulphates at SO_4 per 100,000 .	24·19	10·37	22·20	28·64

(*Analyses by Anglo-Ecuadorian Oilfields, Ltd.*)

The wells are spaced at 600 ft., and the differences in the above analyses indicate that each well enters a separate reservoir. This is quite in accordance with the known geological conditions.

The fresh-water supply is augmented to the extent of 100 to 150 barrels per day per rig by condensing the exhaust steam from mud-pumps and drilling engines. The steam is passed through a simple heat exchanger (Fig. 16), in which it gives up its best to the incoming sea-water for boiler-feed. The condensed steam is collected in a tank for use at the rig.

Apart from being insufficient in quantity, the existing fresh-water supply has the following defects :—

Source.	Remarks.
Shallow drilled wells	Rather high mineral content.
Hand-dug pits	High mineral content and contamination.
Earth reservoirs	Contaminated by animals and dry up completely some years.
Condensation of sea water	Good.

Geological investigation was recently undertaken with the object of finding flat dipping sandstones which would form a reservoir beneath the Tablazo. Such an area was found, and by drilling 6 wells 100 feet deep each a supply of 2000 barrels per day of good water was quickly developed. The lasting powers of this supply are dependent on the degree of porosity of the underlying sandstone and can only be ascertained by trial over an extended period. In the meantime, it is a good indication that the withdrawal of water for the first few months failed to lower the fluid level.

From the foregoing it is seen that the provision of a water supply for drilling is a subject as wide in its scope as it is interesting and important.

OBITUARY.

JOHN GILLESPIE.

Many old friends of Mr. John Gillespie, in the Institute of Petroleum and in the Burmah and Anglo-Iranian Companies, will be very sorry to hear of his death, which occurred on May 27th at the age of 79. Mr. Gillespie, who for over thirty-one years was head of the Burmah Oil Company's Engineering Department, retired in September 1928, and it will interest his friends to read the following extract from the note which appeared in *The Naft* of November, 1928 :—

> " Mr. Gillespie's retirement recalls the early days of the Anglo-Persian Oil Company when, as Consulting Engineer to the Burmah Oil Company in Glasgow, he prepared the first plans for plant in Persia and selected many of the early employees of the Anglo-Persian Oil Company's technical staff. His connection on the engineering side with operations in Persia even ante-dates the present Company, going back to the days of the Concession Syndicate, when he was associated with the late Mr. G. B. Reynolds who, as our readers will recall, subsequently brought in the first oil well at Masjid-i-Sulaiman. Later, on the formation of the Anglo-Persian Company, Mr. Gillespie, in collaboration with Mr. Andrew Campbell, prepared the first plans for the Abadan Refinery, and similarly worked in collaboration with the late Mr. Charles Ritchie in connection with the laying of the original Persian pipe-line."

He was elected a member of the Institute in 1920 and served on Council from 1931 to 1933.

JAMES CUTHILL, O.B.E.

It is with deep regret that we have to record the death of Mr. James Cuthill, Chairman of the Northern Branch. Mr. Cuthill joined the Institute in 1924, and became a Fellow in 1939.

Mr. Cuthill was born at Motherwell, and served his apprenticeship with The Steel Company of Scotland and Duncan Stewart & Co., Ltd., Glasgow, after being educated at Uddingston Grammar School.

He was subsequently with Mirrlees Watson & Co., Ltd., Glasgow, and J. R. Houston & Co., Ltd., Greenock, before returning to the Blochairn works of The Steel Company of Scotland, where he became Chief Engineer and Assistant Works Manager.

In 1921, he joined The Oil Well Engineering Co. of Stockport, as Works Manager, at the time when the changeover from cable tool to rotary drilling was getting into its stride.

In 1939, on the death of Mr. W. L. Mackenzie, he was appointed General Manager of the Company, and in the New Year Honours of 1943 was awarded the O.B.E. in recognition of his outstanding work in the war effort.

Mr. Cuthill was a man of many interests. He was a Rotarian, Past-President of Stockport Rotary Club; a member of various Youth Committees, National Savings Committee, Air Training Corps, and St. John Ambulance Brigade. He was a man of notable personality and personal achievement.

Throughout the existence of the Northern Branch of the Institute, Mr. Cuthill has taken the keenest interest in its activities and organisation. His loss will be felt keenly by all who knew him.

ABSTRACTS.

AUTHOR INDEX.

The numbers refer to the Abstract Number.

The original papers referred to in the abstracts marked with an asterisk may be borrowed by Members from the Institute Library.

Geology and Development.

1128. Newhall-Potrero, Aliso Canyon, Del Valle, and Oak Canyon Oil Fields. F. C. Hodges and E. R. Murray-Aaron. *Calif. Oil Fields*, Jan.–June 1943, 29 (1), 5.—This report traces the development of the Newhall district during the past six years.

The area lies in the western part of Los Angeles County, California, extending south from Castaic to the south boundary of Township 3 North and east from the Ventura–Los Angeles County line to about a mile east of San Fernando Pass at the base of the San Gabriel Mountains. Development of the numerous known producing areas was practically completed by 1915, and the area lay dormant until 1937. In that year, however, commercial accumulations of oil were discovered at Newhall-Potrero, and subsequently fresh reserves were found at Aliso Canyon, San Martinez Grande Canyon (Del Valle), and Oak Canyon. On 1st July, 1943, it was estimated that the total future production to be obtained by primary production methods in these four fields amounted to 54,930,820 brl. of oil and 107,413,082 Mcf. of gas.

Newhall-Potrero field lies about 6¼ miles west and slightly north of the town of Newhall, in a small valley or potrero in the northern foothills of the Santa Susana Mountains of the Transverse Ranges, at an altitude of 1200 ft. above sea level. Structurally it is a long, narrow, faulted, asymmetrical anticline, the axial part of the fold being fairly narrow and flanked by plunging limbs which dip much more steeply on the south-west than on the north-east.

Oil and gas accumulations in the upper 1000 ± ft. of the Miocene have been designated First, Second, and Third Zones, respectively. The First Zone attains a thickness in the central area of about 350 ft. and occurs between 150 and 200 ft. below the top of the Miocene.

The Second Zone occurs as a sandy phase in the shaly interval between the First and Third Zones and attains a thickness of approximately 120 ft. It does not persist throughout the whole field, but pinches out, and is not present in the north-western part. The Third Zone occurs between 750 and 800 ft. below the Pliocene-Miocene contact and is 300 ft. thick in a number of wells. It is separated from the overlying Second Zone by 70–100 ft. of shale.

Statistics indicate that 37 producing wells had been completed in the Newhall-Potrero field by 1st July, 1943. Total production to that date was 4,593,522 brl. of oil and 4,583,895 Mcf. of gas, or an average gas–oil ratio of about 997 cu. ft. of gas/brl. of oil. Average production per well per day during the six months ended 1st July, 1943, was 208 brl. oil, 0·3 brl. water, and 258 Mcf. of gas.

Aliso Canyon field is situated nearly 6 miles north-west from Fernando and about the same distance north-east of Chatsworth, on the south slope of the Santa Susana Mountains. It forms a southerly dipping homocline with structural closure on the east and south and closure on the north provided by the Santa Susana thrust-fault. This fault, which dips northwards at about 40° in the southern part of the field, increases to approximately an 80° dip just beyond the northern productive limits of the field.

The upper (Porter) producing zone occurs between 4700 and 5400 ft. below the surface and 150–3800 ft. below the base of the Santa Susana fault zone. Productive thickness varies from 40 to 810 ft. and averages 450 ft. Initial production rates have ranged between 160 and 2467 brl. oil per day, the gravity range being from 20·3 to 26·7° A.P.I.

The top of the lower (Sesnon) zone is found between 300 and 425 ft. below the top of the Miocene or 6900–8900 ft. in drilled depth in the three completed wells. Large amounts of gas and comparatively small amounts of 53° A.P.I. gravity oil were obtained from the first two wells, but in November 1942 a third well was completed as a producer of 23° gravity oil.

Up to 30th June, 1943, 18 wells had been completed in the Porter Zone and 3 in the Sesnon Zone, with 2 in course of drilling in the latter zone. Total production from the field at that date was 2,791,999 brl. oil, 170,886 brl. water, and 3,827,470 Mcf. gas.

Del Valle oil-field is situated about 9 miles north-west of Newhall, just north of the Santa Clara River. The structure of the field is that of a narrow, easterly plunging anticline with closure on the north, south, and east. Sufficient data are not available definitely to determine closure at the western end. Major oil and gas accumulations so far exploited occur within the upper Miocene formations, but known reservoir sands include some 180 ft. of Lower Pliocene sediments. The total petroliferous section is approximately 2550 ft. thick, and comprises the Sepulveda Zone, Vasquez Zone, Videgain Zone, Del Valle Zone, and the lowermost Bering Zone.

By July 1943 23 wells were producing in the Del Valle field and total production to that date amounted to 1,693,985 brl. oil, 199,066 brl. water, and 4,674,801 Mcf. gas.

Oak Canyon field lies approximately 3 miles north of the Del Valle field and 14 miles north-west of the town of Newhall. It comprises part of a plunging anticlinal fold which forms a ridge of hills extending for over 5 miles in a south-easterly direction from Oak Canyon. Oil and gas appear to have been trapped in a small, slightly asymmetrical, anticlinal dome which is probably a secondary fold on the larger anticlinal structure. The two productive zones are termed Wickham and Lechler. The Wickham Zone occurs 1300–1500 ft. below the top of the Miocene. About 4500 ft. of Upper Miocene strata separate this zone from the lower and more prolific Lechler Zone.

On 1st July, 1943, 7 wells were producing in Oak Canyon oil-field and total production amounted to 338,474 brl. oil, 16,626 brl. water, and 227,752 Mcf. gas. Average daily production per well for the six months ended 1st July, 1943, was 112 brl. oil and 95 Mcf. gas. H. B. M.

1129.* Wildcat Drilling in 1942. F. H. Lahee. *Bull. Amer. Ass. Petrol. Geol.*, June 1943, **27** (6), 715–729.—See Abstract No. 621—1943. A. L.

1130.* Developments in 1942. Gulf Coast of Upper Texas and Louisiana. G. J. Smith. *Bull. Amer. Ass. Petrol. Geol.*, June 1943, **27** (6), 730–738.—This area covers productive trends in the Wilcox (Eocene), Cockfield (Eocene), *Marginulina*-Frio (Oligocene), and undifferentiated Miocene. In 1942, special attention was paid to the Wilcox trend in Texas and the Miocene in Louisiana. The area has already been intensively explored by seismograph and gravity meter. Extensions and new sands on old domes are more important than new producing fields. Wildcat drilling declined to 164 operations in 1942 against 189 in 1941, while field drilling fell from 1433 to 800.

New discoveries were 22 in 1942, as contrasted with 30 in 1941, and of the new domes only 3 seemed to have first-class possibilities. Future new discoveries are expected at great depths, and in relatively poor sands which will not be of economic importance for some time to come. A. L.

1131.* Developments in South Texas in 1942. F. C. Owens and E. A. Taegel. *Bull. Amer. Ass. Petrol. Geol.*, June 1943, **27** (6), 739–746.—Development was cut down owing to uncertain conditions in the oil industry. Lack of material and of transport facilities resulted in non-development of proved leases. Field development and wildcatting showed a marked decline, the amount of drilling being curtailed 45% compared with 1941. Of 31 fields discovered, 9 were on the Wilcox trend (Eocene); 7 producing gas and condensate and 2 producing oil. Depth range from which production may be expected varies from 2800 to 8750 ft. The Yorktown field seems to offer best prospects.

Six new fields were found on the Eocene Yegua–Jackson trend, but they are mostly small with only 1 well.

Ten oil- and 4 gas-fields were penetrated on the Frio–Vicksburg trend (Oligocene). The Mayo field was the most important, with production from the 5400-ft. Frio sand, and possibilities in the 4980-ft. Marginulina sand and in the 5500-ft. Frio. Gas in the Penitas field, Hidalgo County, is believed to be the deepest commercially produced from the Vicksburg of South Texas, in that it is several hundred feet below the *Textulari warreni* layer at the top of the Vicksburg.

On the Upper Oligocene–Lower Miocene trend only 1 field was discovered. It is in the Oakville sand at 2435 ft.

One new field—Imogene, Atascosa County—was found in the Edwards limestone (Lower Cretaceous) at 7570–7572 ft., in a fault system downdip from older producing fault structures.

Fifteen new producing sands were found by electrical surveys and deeper drilling in old fields. Such new sands and extensions to older fields added more reserves than the combined estimated recovery from the 31 new fields. The latter do not bid fair to be of major importance, especially when compared with extensions of the Seeligson field, Jim Wells County, and the Odem field, San Patricio County.

During 1942 production was 72,200,000 brl., against an average of 81,000,000 brl. in the previous three years. Production will increase again when new pipeline outlets are available. A. L.

1132.* Developments in West Texas and South-eastern New Mexico in 1942. R. I. Dickey and B. A. Ray. *Bull. Amer. Ass. Petrol. Geol.*, June 1943, 27 (6), 747–770.—In West Texas the number of wells drilled and deepened was 1320, or 44% fewer than in 1941. The number of wildcats was 134, or only 1 less than in the previous year; and 33 were completed as producers opening up 17 new areas of production, 10 extensions of over a mile from known areas, and additional producing horizons in 6 fields. The last include a new producing dolomite in the Lower Leonard (Permian), Andrews County, and a producing Leonard sand in Big Lake field, Reagan County. The first producing Cambrian sand was struck in northern Pecos County. The Tubb zone of the Leonard was developed in Ward, Andrews, and Gaines Counties; and a new area of Holt zone production from the basal San Andres (Permian) was opened in southern Gaines County.

Pre-Permian drilling and exploration made a record in the history of the Permian basin; 126 wells being completed. Of these, 51 (with only 7 failures) were drilled in the Abell pool. The total pre-Permian producing wells completed was 89, of which 10, though dry in the older rocks, were plugged back to give a yield from the Permian. Of 30 pre-Permian wildcats, 6 were completed as producers.

In south-eastern New Mexico 339 wells were drilled, representing a decline of 8·7% on the 1941 figure. Wildcats, at 35, were 4 fewer than in 1941. Of these, 23 were in Eddy County, and the other 12 in Lea, Chaves, Roosevelt, and De Baca Counties. Six wildcats resulted in producers—*viz.*, 3 in new areas of production and 3 in extensions of known areas. These were all in Permian zones (Yates, Queen, Grayburg, and San Andres).

The most important pre-Permian stratigraphical results were in De Baca County, where topmost Pennsylvanian was reached at 3710 ft. and the well abandoned at 4779 ft. in pre-Cambrian schist, and in south-east Lea County, where the bottom of the Permian is at 7460 ft. and the Ellenburger occurs at 8000 ft. Encouraging porosity and saturation were noted in the basal San Andres (Permain) from 4800 to 5000 ft.

At one time or another 86 different geophysical crews were at work in West Texas and south-eastern New Mexico, as compared with 69 crews in 1941. A. L.

1133.* Developments in North and West-Central Texas in 1942. Contributed by the North Texas Geological Society. *Bull. Amer. Ass. Petrol. Geol.*, June 1943, 27 (6), 771–781.—During 1942 the north and west-central Texas area had 38 new discoveries and 12 extensions of proved fields or completions in new pay-zones in already productive areas. This compares with 33 new discoveries and 11 extensions in the previous year. The methods of discovery, so far as has been ascertained, were in 3 cases random drilling, 4 surface geology, 11 sub-surface geology, 14 seismograph, 1 geochemical, and 5 a combination of two or more methods.

The only important new field in Clay County was the Watson, where initial production was 88 brl. of 43° gravity oil in 3 hours from a porous limestone about 250 ft. below the top of the Caddo, at 5454–5485 ft. Production is also obtained from the Strawn (Middle Pennsylvanian) at about 3650 ft. The top of the Ellenburger (Cambro-Ordovician) is dry.

In Coleman County 4 new oil-pools and 2 new gas-fields were discovered. Extension of the Santa Anna gas-field shows interesting association of heavy oil with extensive 0·67 gravity gas. The oil is 26° gravity A.P.I. with high lubricating-oil content, in a zone which normally produces 40° gravity oil. Accumulation occurs where 100 ft. of limestone changes to shale on a broad structural feature dipping north-west at 75 ft./ml. The same formation—Big Saline—also produces oil from a chert-conglomerate at Gayle pool. In 1942 Coleman County produced 787,612 brl. from 424 wells, about 80 of which are still flowing, bringing total production for the county to over 12,000,000 brl.

In Young County shallow drilling is in decline; and of 17 deep tests, 1 was completed as a producer in Strawn sandstone, 3 oil wells, and 1 for gas in the Caddo limestone (Pennsylvanian), 1 in the Marble Falls (Lower Pennsylvanian), and 4 in the Chappel limestone (Mississippian), while 7 were failures. None of these is very important, though in its restricted occurrences the Chappel should prove profitable.

One deep test in Wise County was successfully plugged back to yield from basal Pennsylvanian arkoses.

Jack County was particularly active, with producing wells in 6 areas. The Bend (Lower Pennsylvanian) is one of the yielders, and first production for the county was obtained from the Ellenburger, which on pumping had an initial yield of 30 brl. oil and 170 brl. water *per diem*. This county should give further results.

Montague County gave 7 new discoveries, the outstanding successes being in porous Marble Falls limestone and in Simpson (Ordovician) sands; both seismographic discoveries.

In Jones County the new Grogan pool yielded an initial 100 brl./day from Cisco (Upper Pennsylvanian) sand at 2129–2135 ft.

Shackelford County provided 2 discoveries in the Strawn.

Taylor County produced its first discovery for 1942 in the Trent pool, with 517 brl./day, while later the Reddin pool, located by geochemical survey, had an initial production of 857 brl./day.

Archer County contributed 3 shallow discoveries in the Cisco, and deep discoveries in the basal Pennsylvanian conglomerate overlying the Barnett shale (Mississippian) and in the Ellenburger limestone, from which the initial well yielded 73 brl. of 41° gravity oil and 8 brl. salt water in 3 hours.

In Wilbarger County the Potts–Ellenburger pool is the only new one. The discovery well traverses K.M.A. (Middle Pennsylvanian) limestone, Caddo limestone, Mississippian limestone, and ends in Ellenburger at 4539 ft. A. L.

1134.* **Developments in East Texas in 1942.** R. M. Trowbridge and T. J. Burnett. *Bull. Amer. Ass. Petrol. Geol.*, June 1943, 27 (6), 782–789.—Drilling activity declined approximately 70%, with only 411 holes drilled in 1942 as against 1145 in 1941.

New fields were :—

Bazette gas-field, Navarro County, yielding from the Woodbine, Gulf Series (Cretaceous). Productive area probably small.

Coke oil-field, Wood County, with initial flow of 320 brl. 27½ gravity oil in 4 hours through 2-in. tubing from perforations opposite the Paluxy, Comanche Series (Cretaceous). Gas-oil ratio 107 to 1. Elongate east–west dome.

Concord oil-field, Anderson County, pumped 201·3 brl. 12·2° gravity oil in 24 hours from open hole at 4520–4540 ft. in Woodbine. Faulted dome.

Kildare oil- and gas-field, Cass County, produced an initial 185 brl. 40·8° gravity oil in 20½ hours through ¼-in tubing choke from perforations at the Rodessa zone of the Lower Glen Rose, Comanche Series; gas–oil ratio 1343 to 1. Low relief, elliptical, anticlinal dome.

Larissa oil-field, Cherokee County, flowed 37·31 brl. 48° gravity oil in 24 hours through ¼-in. choke from perforations in uppermost Pettit porosity of Lower Glen Rose : amber oil, paraffin base ; gas–oil ratio 1811 to 1. Broad anticline, major axis north–south.

Quitman oil-field, Wood County, flowed an initial 181·5 brl. 43° gravity brown oil with paraffin base in 6 hours through casing perforations at 6280–6310 ft. in the Paluxy; gas–oil ratio 316 to 1. Anticline with axis trending north-east and south-west.

Wieland oil-field, Hunt County, yielded 266·12 brl. 37·5° gravity oil in 24 hours through ¼-in. choke from perforations at Woodbine horizon ; gas–oil ratio of 50 to 1. Fault-structure field. Paluxy beneath has no showings.

Exploratory work has also been done in the Travis Peak, Comanche (basal Cretaceous), Smackover (Jurassic), as well as in the Wilcox (Eocene), in which last a Houston County well pumped 14 brl. 26° gravity oil and 70 brl. salt water in 24 hours from a thin sand. A. L.

1135.* **Developments in Oklahoma in 1942.** J. L. Borden. *Bull. Amer. Ass. Petrol. Geol.*, June 1943, 27 (6), 790–805.—Oklahoma produced 137,997,267 brl. of crude oil in 1942, or 14,016,675 brl. below 1941 output. This was 7,014,133 brl. short of the State allocation of 145,011,400 brl., based on the State Corporation Commission's estimate of demands for 1942. Declines were recorded in most of the important producing counties, but 88% of the total fall occurred in the five leading counties—Oklahoma, Seminole, Osage, Pottawatomie and Carter—which produced 55·9% of the State total. The 14,016,675 brl. loss of production represents a decline of 9·2%, which is much in excess of the national decline of 5·3%. This decline threatens Oklahoma's rating as the third producing State of the U.S.A., and Louisiana may outpace her.

New pools and extensions in 1942 were located in the following formations:

Pennsylvanian.—Tonkawa, Layton, Prue, Skinner, Earlsboro, Bartlesville, Hartshorne, Atoka, Gilcrease, Deaner, Dutcher, Wapanucka, Cromwell, Springer.

Mississippian.—Burgess, Mississippian, Misener.

Siluro-Devonian.—Hunton.

Ordovician.—Viola, Dolomite, " Wilcox," 2nd. " Wilcox," Bromide, McLish.

The most important new pools were:

Eastwatchorn pool, Pawnee County, drilled direct to Simpson (Ordovician); flowed from "Wilcox" 2528 brl. 43° gravity oil in 24 hours through 7-in. O.D. casing with 100-lb. casing pressure and 1415-lb. bottom-hole pressure. Gas gauged 11,520,000 cu. ft. daily.

Crescent pool, formerly productive from the Simpson, has been revived in the Layton sand. Initial production 834 brl. 44° gravity, from well ½ ml. east of eastern limit of Simpson production.

Hickory Grove pool, between Stroud and Deep Fork pools, produced gas with spray of oil from Bartlesville sand, but oil increased as the well was deepened, until it flowed 228 brl./24 hours, together with 13,200,000 cu. ft. gas. Oil is 47° gravity. A second pay occurs in the Prue sand (Pennsylvanian).

Pauls Valley pool, 20 ml. north-west of the Arbuckle mountains and on a westward-plunging, arch extending from them, yields oil from Pennsylvanian sands and detritals, and Bromide sand is oil saturated. Trap is an anticline, with steep north-east and south-west flanks, and about 180 ft. of closure. The area had been under examination since 1912.

The Ardmore pool, Caddo pool, and Aylesworth pool, have all been developed on anticlines south of the Arbuckle mountains. Portions of the structures, as was shown by C. E. Decker (*Oklahoma Geol. Surv. Bull.*, 40, vol. i, p. 74), are reflected in Pennsylvanian deposits, but for the most part the latter are completely buried by the Cretaceous. Obvious structures at the surface had been shunned because of the steep dips exhibited.

New discoveries and extensions increased the estimated reserves by 73,797,000 brl., but this was offset by the production of 137,997,267 brl. Remaining estimated reserves at end of December 1942 were 968,927,000 brl.

While production and reserves declined, there was an increase of exploration, particularly in the seismographic and stratigraphical fields. Seismographic-crew time at 358 crew-months showed an increase over 1941 of 27%. Stratigraphical holes were 44 instead of 23.

In all, 1191 borings were completed, a decline of 45%. On the other hand, wells of an exploratory nature decreased only 7%. 75 out of the 253 exploratory wells were a success, *i.e.* 29·6% in 1942, as against 29·9% in 1941. 39 discoveries were classed as new pools, compared with 41 in 1942.

Present producing horizons, chiefly in Pennsylvanian and Ordovician sands, are inadequate to the heightened war-time demand. The discovery of a new productive formation or a new oil province in Oklahoma would best meet the emergency. One looks to the Ordovician. The Arbuckle limestone is present, except on a few granite hills and " bald-headed " anticlines, throughout the State. This formation is the principal producer on the Central Kansas uplift. It also yields oil in northern Texas—not to mention the quantities obtained from the Oklahoma City pool and other Arbuckle pools of the Tulsa area. Yet in the entire Seminole district—itself at one time a new oil area of the magnitude now desired—there are only 3 Arbuckle tests.

A. L.

1136.* Developments in North Mid-Continent in 1942. E. A. Koester. *Bull. Amer. Ass. Petrol. Geol.*, June 1943, 27 (6), 806–813.—Thirty new oil-pools and 3 new gas-pools were found during 1942. The most active area was on the Peace Creek–Zenith trend, where 6 new discoveries have been joined into one producing area now almost completely drilled on a basis of 40-acre locations. The producing horizons are Ordovician (Viola limestone) and Carboniferous. In Pratt County the Iuka pool has been extended in highly prolific Simpson (Ordovician) sand and dolomite, and north-east of this the Carmi pool has established a maximum potential for the Arbuckle (Cambro-Ordovician) dolomite.

None of the Kansas discoveries of 1941 developed into a major field. In 1942, though the number of wildcats increased, the general class of prospects was poorer than before, and extensions of old pools rather than new discoveries were the order of the day. Increase of wildcatting and wider spacing sent the percentage of dry holes up to 40·7, as against 26·9 in 1941. Partly because of shortage of equipment, but also because of the 40-acre spacing, the number of holes drilled fell from 1818 to 1353. Daily allowables per well continued to increase, and some prolific fields were being produced at a rate approaching the limits of good production practice.

Kansas produced 98,907,986 brl. in 1942, or an increase of 15,000,000 brl. over 1941. Production early in 1943 was 300,000 brl./day, which was almost equal to the pipeline capacity of the State.

In Iowa 3 new deep tests have been incompletely reported on.

In Missouri, the first deep producer in the Forest City basin drew 16 brl. of 28° gravity oil, and 335 brl. water, from a sand in the Cherokee shale (Mississippian), but few other encouraging shows of oil have been found in the Missouri pre-Pennsylvanian. Hunton (Siluro-Devonian) was met with at 2425 ft. in Atchison County; and Arkbuckle at 3513 ft. in Holt County.

In Nebraska, 43 wildcat tests were completed—all unsuccessfully. Many were located by chance and drilled either to the Arbuckle or to the pre-Cambrian. The abandonment of 3 tests in Harlan County was disappointing, in that 2 of these wells had given some indication of the first commercial production of oil in western Nebraska. The cumulative production for Nebraska to the end of 1942 was approximately 3,430,000 brl., of which 2,929,000 brl. was due to Fall City pool and 384,000 brl. to the Barada pool. Unless additional reserves are found soon, Nebraskan output will continue to decline. A. L.

1137.* Developments in Eastern Interior Basin in 1942. A. H. Bell. *Bull. Amer. Ass. Petrol. Geol.*, June 1943, 27 (6), 814–821.—Nearly all the 54 new pools, all of which are small, produce from the Chester (Upper Mississippian) Series and the Iowa (Lower Mississippian) Series. Only 3 produce from Pennsylvanian sands, and 1 each from Devonian limestone and Ordovician ("Trenton") limestone. In Illinois itself oil production for 1942 was estimated to have been stratigraphically distributed as follows:

System.	Brl.	%.
Pennsylvanian	3,000,000	2·8
Mississippian	96,644,000	90·7
Devonian	5,626,000	5·3
Ordovician ("Trenton")	1,320,000	1·2
	106,590,000	100·0

The new St. Jacob pool in the "Trenton," Madison County, excited a revival of drilling in the Ordovician of western Illinois, and 20 wildcat tests were put down to that formation in Madison, St. Clair, Clinton, and Monroe Counties. In the east part of the basin, 7 Devonian tests and 1 St. Peter were drilled in Edgar, Coles, Clark, and Crawford Counties. The deepest Devonian tests were in Jefferson County in the centre of the basin.

In Illinois the largest new pools, as measured by number of wells at the end of the year, were the Covington pool, Wayne County, with 32 wells and a total yield to the end of 1942 of 1,070,000 brl., and the Biblo Grove pool, Clay County, with 32 wells and a total yield of 55,000 brl. The Markham City pool, Jefferson County, with 12 wells at the end of 1942, had a total output of 143,000 brl.

The number of completions, including both wildcat and pool wells, in the entire Eastern Interior Basin was 2518 (excluding gas-input and salt water disposal wells), as compared with 4680 in 1941, a decline of nearly half. The reduction of drilling in pools was probably mainly the result of Federal Conservation Order M-68, issued on 23rd December, 1941, which limited drilling to 1 well to 40 acres. A modification of this Order on 31st August, 1942, M-68–5, permitted closer spacing for sandstone wells. With the wider spacing there was a notable increase in the percentage of dry holes from 27% in 1941 to 44% in 1942.

Production in the Eastern Interior Basin in 1942 was approximately 117,671,000 brl., a decline of 19% from the 1941 figure. Of this, 6,641,000 was from Indiana, including a small proportion from north-east Indiana, which is outside the Eastern

Interior Basin. Kentucky also contributed, and in that State there were interesting developments at horizons ranging from Silurian to Pennsylvanian. 70% of the new production in western Kentucky was in Chester sands. The McClosky (Lower Mississippian) was also important.

In western Kentucky drilling is to comparatively shallow depths, but the low price of crude oil has discouraged the amount of wildcatting which is necessary if large new reserves are to be proved quickly. A. L.

1138.* Developments in Michigan in 1942. H. J. Hardenberg. *Bull. Amer. Ass. Petrol. Geol.*, June 1943, 27 (6), 822–834.—War-time restrictions and the failure of discoveries to locate important pools led to a decrease of 28% in well-drilling operations as compared with 1941. Footage drilled, however, in the 682 borings which were completed, was down only 12%, or 240,000 ft. The " Basin " with two-thirds of the State's completions continued to be the most active district.

During 1942, 21 oil-fields and extensions were discovered, mainly in Devonian formations like the Detroit River and Traverse. In the former, 2 zones—the " sour oil " horizon and the " Richfield-Sylvania " at the base of evaporite beds—proved important as producers. The " sour oil " is high in sulphur and is held rather firmly in a brown limestone, or dolomite, of low permeability. In the Skeels field, Clare County, the " sour oil " had an initial flow of 50 brl. after treatment with acid. In the South Adams field, Arenac County, the " Richmond-Sylvania " gave 500 brl./day after acid. Total production, following completion of 6 wells, was 14,343 brl. at the end of the year. East Norwich field, Missaukee County, and McClain No. 1 well, Clare County, also struck oil at this horizon.

Other discoveries were: the Evart field, Osceola County, which in December 1942 averaged 1769 brl./day from 13 wells sunk to the Dundee formation; the Prosper field, Missaukee County, from the same formation, which flowed 187 brl./day from 3841 ft.; the Fork field, Mecosta County, which depends on a pay-zone near the top of the Dundee.

Extensions were most notable in the Reed City and Kawkawlin fields, which produce mainly from the Dundee, and the Headquarters field, which draws on the Traverse except for 3 deep wells to the Detroit River. Peak production at Reed City reached 28,557 brl. daily; at Kawkawlin 1727 brl.; and at Headquarters 8382 brl.

In south-western Michigan the South Zeeland and North Bangor fields—both in Traverse—were discovered.

Total oil production was 21,750,000 brl., or an advance over 1941 of 23%, and only 1,750,000 brl. less than Michigan's greatest production in 1939.

Gas-well completions decreased, but 2 new fields were those of North Adams, Arenac County, where a well sunk to barren Dundee was plugged back to the Berea sandstone and had an initial open-flow of 300,000 cu ft. with well-head pressure of 830 lb./sq. in., and Fork, Mecosta County, where a " Michigan Stray " sandstone gave open-flow of 1,010,000 cu ft. and a reported well-head pressure in excess of 500 lb./sq. in.

The proving of the deep commercial producing zones opens up a new prospect of development in at least 6 areas in the " Basin " district. The Dorr field, Allegan County, in south-western Michigan, also has a pay-zone near the Bass Island—Salina contact (Silurian). The age of the producing stratum has not been determined, but is above the Salina salt. This heralds more deep drilling, in the Middle Devonian Traverse areas.

Core-testing activity was greater during 1942 than at any previous time. Approximately 300 tests were drilled, principally in the north and north-west parts of the Southern Peninsula. A. L.

1139.* Developments in Appalachian Area in 1942. Contributed by the Appalachian Geological Society. *Bull. Amer. Ass. Petrol. Geol.*, June 1943, 27 (6), 835–853.—*New York.* New development work during 1942 was aimed at additional Oriskany gas supplies, and 29 wells were drilled in the south-west part of New York State. Of these, 9 were producers with a combined open-flow of 6,311,000 cu. ft. Two wildcats discovered the two parts of Groton field, Tompkins County, but this is not expected to add greatly to the depleted gas reserves. Scarcity of the latter, combined with Order

M-68 and closer co-operation between companies, is likely to lead to increased exploratory drilling.

Pennsylvania. The number of wells completed in the shallow gas and oil territory of western Pennsylvania (Upper Devonian or higher) was about 3% less than in 1941. Of the wells drilled for gas, 80% were producers and 20% dry. The 738 new gas-wells had a total initial open-flow of 240,353,000 cu. ft. *per diem.* The Armbrust pool, Westmoreland County, opened in 1941, was the scene of greatest activity. The pool lies in a lenticle of Fifth sand (Upper Devonian) on the south-east flank of the Fayette anticline, and the total initial open-flow capacity from 75 wells was 48 million cu. ft. a day. The Big Injun (Mississippian) gas sand-field of Fayette and Greene Counties also continued active. Shallow well completions in northern and central Pennsylvania numbered 382, of which 328 productive wells gave initial average open-flow of 151,000 cu. ft./day from an average depth of 2513 ft.

Apart from the Bradford field with 3113 new wells (about half for intake), there was little drilling for oil. In the Bradford field production was 11% up on 1941 and accounted for 54·6% of the total Pennsylvania-grade crude oil from the Appalachian province. Production at Music Mountain pool is in decline, after a yield of 3,796,000 brl. since 1937. In Titusville—Oil City area, where secondary recovery by means of air and gas-drives is under way, 340 new wells were drilled. In the central and south-western oil districts of Pennsylvania production declined by 11%.

Four out of 7 deep wells were successfully completed in the Summit gas-pool, Fayette County, where there is a domal closure of 1000 ft. Three ended in salt water. One which encountered a fault was abandoned. The productive area was not extended. One deep test in Erie County reached Trenton limestone (Ordovician) and salt water, while 2 in Mercer County and 1 in Lawrence County were drilled through the Lockport dolomite (Middle Silurian). One of the Mercer County Silurian wells produces moderate quantities of gas.

Ohio. Tests in Ohio completed during 1942 numbered 998. This was 36% fewer than in 1941. Of these, 454 were gas-wells, 194 were oil-wells, and the remaining 35% were failures. Total initial open flow of new gas was 316,446,000 cu. ft. A total of 3,663,872 brl. of oil was produced, of which 1,751,566 brl. were of Pennsylvania grade. Shallow, Berea, Oriskany, Newburg, Clinton, Trenton, and Sub-Trenton were all tested. Sub-Trenton was unproductive.

West Virginia. During the year, 229 wells were drilled into or through the Oriskany. Of these, 197 were gas-wells with a combined open-flow of 1,011,096,000 cu. ft., and 32 were dry holes. The Elk-Poca and Sandyville field, continuous as it is now seen to be, was clearly defined, and activity has become centred in edge drilling. The area is 125,000 acres, but no new areas of Oriskany production were opened, though at the end of 1942 interesting exploratory borings were being put down in Tucker, Wyoming and Raleigh Counties. Incomplete figures set the 1942 number of wells at 758: 514 with gas; 73 with oil; 20 with combined production; 2 with brine; and 149 dry holes. In the same period 300 gas-wells, 430 oil wells, and 23 combination oil- and gas-wells, were abandoned. New initial oil volume developed was 2234 brl.

Below the Oriskany, and 135 ft. above the Newburg sand, a new gas pay was found in Boone County at 4937–4954 ft. This is a dolomite-anhydrite rock of brown to tan colour and fine to medium grain size. Near the crest of the Warfield anticline flow was 100,000 cu. ft. and rock pressure perhaps 2000 lb. There are clear dolomite crystals and small, well-formed quartz crystals. At 4918 ft. sulphur water occurs in the sand body, and there are also scattered small fluor crystals.

Kentucky. Most of the development in eastern Kentucky has been for the purpose of obtaining additional gas reserves. Federal regulations have tended to reduce the amount of drilling for oil, but, since modification of M-68, the adverse effect on gas exploration has been less marked. New oil reserves are small, but during 1942, 1,808,000 brl. were produced from stripper wells.

Tennessee. In Tennessee east of the Cincinnati arch there were 6 completions: 2 gas; 4 dry holes. The most significant test was the Stanolind wildcat in Putnam County, which was abandoned in the upper part of the Knox dolomite at 2130 ft., after logging a showing of oil at 1653–1661 ft. in the Knox. Most active leasing was in the northern part of the Cumberland plateau. A. L.

1140.* Developments in Rocky Mountain Region in 1942. R. M. Larsen. *Bull. Amer. Ass. Petrol. Geol.*, June 1943, **27** (6), 854–861.—In Colorado, Montana, Utah, and Wyoming, 501 wells add up to 1,065,082 ft. This was 83% of the number of the previous year, and 87% of the footage. Of the wells, 82 were wildcats, as against 108 in 1941. Oil and gas production increased about 8% to 43,642,126 brl.

Discoveries in Wyoming were more important than any since 1938. At Big Piney a new gas-well in the Wasatch (Lower Eocene) was suspended, because of the distance factor in marketing. At Horse Creek, south-eastern Wyoming, on a seismic "High," the Muddy sand (Upper Cretaceous) was found to be saturated, but tight, the Dakota (Upper Cretaceous) dry, but the Lakota (Lower Cretaceous) productive at 5451–5515 ft., 7000 brl. 30° A.P.I. gravity oil and 10,000 brl. water being produced in a 2-months test. A second well found more permeable Muddy sand. At Northern Hiawatha 10–12 brl./day were tested from the Wasatch. At Sherard Dome the Tensleep sandstone (Pennsylvanian), which produces in the neighbouring Lost Soldier district, was found tight and water-bearing, and the well was plugged back for gas from the Lakota. At Sulphur Creek oil was found in the Bear River formation (?) (Upper Cretaceous) at 686 ft.

Important oil was found at deeper levels in old fields. Elk Basin, which has produced light oil from the Frontier (Upper Cretaceous) since 1916 and gas from the Cloverly (Lower Cretaceous) since 1920, yielded an initial 2500 brl./day from the Tensleep, while some saturation was reported in the superjacent Embar (Permian and Triassic). Pilot Butte was also drilled to the Tensleep, and 714 brl./day of 26·1° A.P.I. gravity oil were obtained as initial production. This field has exploited oil from the Cody shale (Upper Cretaceous) since 1916, and gas has been available from the Muddy sand since 1931.

In Montana, Conrad Butte has much gas in the Colorado shale (Upper Cretaceous), but at negligible pressure. At Conrad-Midway there is oil in the Sunburst sand of the Kootenai (Lower Cretaceous), but below it the Madison limestone (Mississippian) only yields water. In Fred and George Creek nose, gas under 200 lb. shut-in pressure is reported in the Blackleaf sand of the Colorado shale. At Twin Rivers nose (Reagan), oil has been found in the Madison, with initial output of 85 brl. of 36·4° A.P.I. gravity oil.

Prospecting in Colorado, North and South Dakota, north-western New Mexico, and Utah, was less successful; and extensions of known fields contributed little to known reserves. Wildcats declined 25%. Pipeline activity consisted of a few extensions, replacements, and short gas lines. A. L.

1141.* Oil Development Activities in California, 1942. G. R. Kribbs. *Bull. Amer. Ass. Petrol. Geol.*, June 1943, 27 (6), 862–873.—The Office of Petroleum Co-ordinator, now changed to the Petroleum Administrator for War, surveyed the reserves of oil in the State under 24° Be. gravity. The California Oil Administrator then made a survey of reserves of oil over 24° Be. Drilling in this survey was allowed in a residential district of Los Angeles by the City Council. This exploration was at shallow depths for heavy oil and allowed of the mapping of extensions to known fields. As a result of the survey it is possible to estimate the total Californian developed reserves at 3,300,000,000 brl. of crude oil. A shortage of available oil is threatened, as the following estimate shows:

	Available Reserves in Millions of Brl.		
	1943.	1944.	1945.
Heavy oil . . .	106	92·5	82
Light oil	181	165	150
	287	257·5	232

Under war conditions the yearly Californian demand has risen to 288,000,000 brl. The new reserves established in 1942 do not exceed about a tenth of this figure if we consider only the likely output from the discovery areas, *viz.*, Antelope Hills (Middle Miocene) and East Strand (Upper Miocene), both in Kern County; Buena Park (Lower Pliocene), Los Angeles County; Holser Canyon (Upper Miocene), Ventura County; and Zaca Creek—10° gravity oil—from fractured chert (Upper Miocene), Santa Barbara County. Extensions and deep sand discoveries in older fields have, however, probably added considerably to the reserves.

New gas-fields were found at South Buttonwillow, Kern County, (Upper Pliocene);

and in the Sacramento Valley at Roberts Island, in McDonald Island (Paleocene) sand, and at Suisun Bay (still testing).

Lack of man-power, equipment, and a low crude market materially diminished Californian activity in 1942. But the Petroleum Administrator for War may help to obtain a higher price for heavier grades of crude oil which could not be developed at 1942 prices. A. L.

1142.* **Calculating the True Thickness of a Folded Bed.** G. D. Hobson. *Bull. Amer. Ass. Petrol. Geol.*, June 1943, **27** (6), 874.—Corrections of previous article of same title in *Bull. Amer. Ass. Petrol. Geol.*, December 1942. (See Abstract No. 508, 1943, for original article.) A. L.

1143.* **Discovery Thinking.** A. I. Levorsen. *Bull. Amer. Ass. Petrol. Geol.*, July 1943, **27** (7), 887–928.—See Abstract No. 620, 1943. A. L.

1144.* **The Petroleum Geologist and the War.** Fritz L. Aurin. *Bull. Amer. Ass. Petrol. Geol.*, July 1943, **27** (7), 929–937.—The parade of progress of the geologist in the petroleum industry began when I. C. White expounded the anticlinal theory of oil accumulation. Later the geophysicist entered the scene. The attack on Pearl Harbour (7.12.1941) disrupted the lives of many of the 4000 geologists of the Western Hemisphere engaged at home or abroad in the oil business. To increase day-to-day supplies, especially by the discovery of new pools, became most urgent. The very limited number of unemployed geologists should be used. In the absence of new tools for oil discovery, the old ones must be improved. Stratigraphical-trap investigations (with reference to the most recent geographical discoveries about coastal sands, etc.) and geophysical studies are pre-eminently important. Electrical techniques are also advancing.

Wildcatters are needed with the nerve of E. W. Marland, Tom Slick, and Dad Joiner. Co-operation in interpretation of dry holes is required for successes like that near Pauls Valley, Garvin County, Oklahoma. Speculative as well as logical reasoning powers are essential. Independent geologists, company geologists, managements, and estate agents must learn to collaborate. Such co-operation often helps, incidentally, to put a free-minded geologist in a top executive position.

Most of the industries have at present, for war reasons, unlocked their caches of research. But much local information is still restricted to the few, in matters where co-operation is necessary. Something must be done where lease ownership is so diversified that there is no one individual or company upon whom the onus of exploration rests. Where, for example, eight or ten companies have protective acreage, information should be pooled between the various consultants of the companies, so that prospecting and utilization of sites be as economical as possible. In an extreme emergency, Aurin favours pooling even of personnel. A. L.

1145.* **Lower Ordovician and Cambrian Oil Possibilities in Illinois.** S. Folk. *Oil Wkly*, 20.3.44, **113** (3), 13.—Many hundreds of feet of marine Lower Ordovician and Cambrian dolomites, shales, and sandstones underlie the St. Peter in Illinois. These were folded and partly eroded before the deposition of the St. Peter sands. Some of the subsurface dolomites and sandstones are porous and permeable, and are reported to have oil-traces in Illinois. Few tests have reached these beds, and none have been drilled through them. Equivalent beds elsewhere in U.S.A. produce oil commercially.

In northern Illinois the Lower Ordovician formations are, in descending order, the Shakopee, New Richmond, and Oneota formations of the Prairie du Chien group. The Cambrian formations are the Trempeleau, Franconia, Galesville, Eau Claire, and Mt. Simon. Oil-shows have been reported in beds of Prairie du Chien and Trempeleau age in tests in west-central and south-western Illinois. The older beds are not known to have been penetrated in southern Illinois, but a well in St. Louis, Missouri, went through them into pre-Cambrian granite. In northern Illinois the Shakopee and Oneota consist largely of dolomite with some thin interbedded sandstones. The New Richmond consists mainly of sandstone with lenses and layers of dolomite, and thin beds of shale. To the east it grades into dolomite or wedges out, and the Shakopee lies directly on the Oneota. Over much of northern Illinois the Prairie du Chien is absent, and the St. Peter rests on Cambrian. The Prairie du Chien thickens southwards and may be 800–900 ft. thick in south-western Illinois.

The Trempeleau is dominantly dolomite in Illinois, but consists of sandstone and siltstone in Iowa and Wisconsin. The dolomite has large cavities, developed in post-Trempeleau and pre-St. Peter times. In northern Illinois the Trempeleau ranges up to 260 ft. in thickness. The Franconia includes glauconitic sandstone, sandy shale. and sandy dolomite, and ranges 50–200 ft. in thickness. The beds are lenticular. The Galesville consists of porous sandstones with interbedded sandy dolomite. The average thickness in northern Illinois is nearly 200 ft. The Eau Claire formation includes shales, siltstones, sandstones, and dolomites, some of the sandstones being quite porous and permeable. It averages 400–500 ft. in thickness. The Mt. Simon formation is almost wholly sandstone, some of it porous and permeable. Beneath the Mt. Simon are conglomeratic and arkosic sandstones and sandy shales, which are mainly red.

The Lower Ordovician and Cambrian strata of Illinois were subjected to several periods of movement: (1) post-Shakopee and pre-St. Peter; (2) Devonian; (3) post-Mississippian and pre-Pennsylvanian; (4) post-Pennsylvanian. Thus structural traps suitable for oil accumulation could have been formed at several dates.

It is not known whether the form of the Lower Ordovician beds can be used as a guide in the search for oil in older beds. The productive Waterloo-Dupo structure has been tested to the Cambrian in a test on the flanks of the structure.

Two areas of Illinois seem especially favourable for Lower Ordovician and Cambrian prospecting. They are: (1) Eastern Illinois, from Ford and Iroquois Counties south to Wabash County, and (2) Western Illinois, from Henderson and Warren Counties south to Randolph County. In Eastern Illinois none of the features with good closure has been tested below the St. Peter, south of Ford County. There are several anticlines in Western Illinois on which the Lower Ordovician and Cambrian merit testing.

Possibilities for Lower Ordovician and Cambrian production may be as good in the Illinois Basin as in Eastern and Western Illinois, but the depths will be much greater (8000 ft. compared with 4000 ft.).

The oil shows reported in Lower Ordovician and Cambrian formations in Illinois are listed, and a graphic cross-section of these strata in north-eastern Illinois is given. There is also a tentative correlation chart of these formations in Illinois, Missouri, Oklahoma, and Texas. G. D. H.

1146.* Hitherto Unexplored Areas Best Bet for Finding New Reserves. L. J. Logan. *Oil Wkly*, 20.3.44, **113** (3), 34.—The results of exploratory drilling in U.S.A. in February 1944 indicate that wildcatting must be increased to achieve the results desired by the Government. A 25% increase in wildcatting will not be especially gratifying unless better discoveries are made than in January and February 1944. So far wildcatting has been about 8% above the level at the beginning of 1943, and most of the discoveries have been of poor calibre. For the first nine weeks of 1944 the rate of exploratory well completions has been 67 per week. Wildcatting has increased compared with 1943 in California, Colorado, Kentucky, North Louisiana, South Louisiana, Mississippi, Montana, and most districts of Texas. 15·9% of the exploratory wells have found new oil, gas, or condensate fields, established new pay horizons in known fields, or provided major field extensions. In the corresponding period of 1943, 16·6% of the exploratory wells were successful. During February a new oil-field was found in Mississippi, and one in Alabama. The new Heidelberg field of Jasper County, Mississippi, is rated as a major find. Although drilled to 6578 ft., the discovery well was completed in the Eutaw at 4958–4968 ft. No important shows were noted in the Marine Tuscaloosa at 4992 ft. or in the Davis zone at 6024 ft.

The Alabama field is in Choctaw County, 15 ml. south-west of Butler. The well flowed 60 brl./day of 20-gravity oil from the Selma Chalk at 2800 ft. The well was drilled to 5380 ft.

One of the best discoveries in February was in Barber County, Kansas. The well produces from the Viola limestone at 4624–4640 ft. on a large structure. A third pay has been found in the Travis Peak at 8156–8190 ft. in the New Hope field of Franklin County, eastern Texas. It is 300 ft. below the Pittsburg pay.

Three new oil-fields and two gas-fields were opened in California in February, but none of them shows very great promise at present. The Clarks Lake black-oil discovery of Latimer County, Colorado, has only a small production. The Home pool was the February discovery in Michigan. The productive area is expected to be less than 300 acres. Several relatively unimportant oil-field extensions and new pays were found in Illinois in February. G. D. H.

1147.* New Oil- and Gas-Fields and New Pay Horizons Discovered in United States in February, 1944. Anon. *Oil Wkly*, 20.3.44, **113** (3), 36.—A table lists the new oil- and gas-fields, the new pay horizons, and the major extensions to established fields discovered in February 1944. The data include the company, location, date spudded, date completed, total depth, completion horizon, name, character and age of producing horizon, initial production method and choke, oil gravity, structure, method of discovery, and preliminary estimate of reserves. G. D. H.

1148.* Results of Exploratory Drilling in February and First Two Months. Anon. *Oil Wkly*, 20.3.44, **113** (3), 38.—A table summarizes by States and districts the results of exploratory well completions in U.S.A. during February and the first two months of 1944. G. D. H.

1149.* Western Canada to Have Busiest Year in 1944 ; Much Work Under Way. Anon. *Oil Wkly*, 20.3.44, **113** (3), 65.—Some seismic work and general geological investigations have continued in southern Alberta during the winter. New regulations have come into force, and they will encourage drilling.

In the Texas-Pinhorn well of south-east Alberta, north of the Whitlash field of north-east Montana, several heavy flows of wet gas have been reported. One in the basal Ellis at 3211–3231 ft., flowed 4,000,000 cu. ft. of gas/day, and another at 2970 ft. gave 5,000,000 cu. ft./day. The well will be drilled to the Madison.

Pacific 1 in the Del Bonita field, just north of the Cut Bank field of Montana, is testing a porous zone at 5080 ft. This is giving a light oil. The Taber field has a capacity of 10,000 brl./day of 19-gravity crude, but it is temporaily closed in. The Taber sands are about 3200 ft. deep, and have given two 500-brl. wells.

In the foothills of south-western Alberta the Arrow–Marjon well is drilling at 1700 ft., while the Maxmount–Lundbreck well has reached 9700 ft. This record cable-tool well has passed several promising oil zones which are temporarily cemented off. The deep Madison is the objective.

A wildcat is being drilled at Wildcat Hills, north-west of Cochrane, and when this is completed a test will be drilled on the Coalspur structure, a large outer foothills fold. On this the Rundle limestone is expected to be about 10,000 ft. deep. A well is to be drilled on the east side of the Erickson Coulee structure, east of Coutts, on the Montana border. A wildcat is under way near Vauxhall, north-east of the Taber field. G. D. H.

1150.* Colombian Petroleum Developing New Field. Anon. *Oil Wkly*, 20.3.44, **113** (3), 65.—Eight producers have been completed in the field opened by the Colombian Petroleum Company, 20 km. north of the old Petrolea field. The structure is 15 ml. long and 3 ml. wide. The sand thickness and porosity have been found to be very variable. Six of the wells produce from the Eocene, and two from the Cretaceous. G. D. H.

1151.* American Companies Busy with Santo Domingo Tests. Anon. *Oil Wkly*, 20.3.44, **113** (3), 65.—The first drilling in Santo Domingo began in 1939, and resulted in the Maleno discovery, which blew in at 600 ft., and gave 600 brl. of oil/day with large amounts of water. It was drowned out after giving 17,000 brl. of oil. Dry holes have been drilled all around the discovery.

The nearby Higouto structure has many oil-seeps, and dry holes have been drilled on it. Unsuccessful tests have been made near Quita Carizza (4500 ft.) and on the El Magote structure (7000 ft.). Wildcat locations have been selected on the Las Hormigas structure and in the big El Commendadora area. G. D. H.

1152.* Classification of Exploratory Wells. F. H. Lahee. *Oil Gas J.*, 23.3.44, **42** (46), 78. (Annual Meeting of A.A.P.G. and affiliated Societies, 21–23 March, 1944.)—A pool is an underground accumulation of petroleum in a single and separate natural reservoir. It is bounded on all sides by geological barriers which effectively separate it from any other pools in the same district or on the same structure. A field may be a single pool, or it may consist of two or more pools, all on or related to the same structure. The pools may be in the same or different horizons; they may be separated by faults, synclines, or lithological conditions; they may or may not overlap.

Development drilling is the drilling of wells within or close to the limits of a producing or producible pool, as the limits are known at the time of drilling, the object being to complete such wells in the pay horizon of the pool. Other drilling is exploratory drilling. Field wells come under the heading of development drilling; exploratory drilling covers new-field wildcats and new-pool wildcats, outpost wells and deeper-pool tests. A new-field wildcat is a hole drilled on a geological structure or in a geological environment where petroleum has not yet been discovered. A new-pool wildcat is a hole drilled on a structure or in a geological environment where other pools have been found, but where the complexities in the underground geological conditions are so great that searching for a new pool is very hazardous. An outpost well is a hole drilled with the thought that it will extend by a considerable distance a pool already partly developed. It is far enough from the pool, as known, to make its outcome uncertain, but not so far away as to be considered a wildcat. A deeper-pool test lies within the known limits of a pool and seeks new producible horizons below the deepest pool. An extension well is an outpost well or a wildcat which extends the productive or producible area of a pool, though the demonstration of its nature may require additional drilling.

In order that the statistics of exploratory drilling may be as consistent as possible between different areas, and as nearly comparable as possible in successive years, it is suggested that the above definitions should be adopted.

A successful wildcat may first be classified as a discovery well, but later it may prove to be an extension well. Similarly, a successful outpost well first thought to be an extension well may turn out to be a discovery well of a new pool. G. D. H.

1153.* Have Oil Reserves Been Diminished by Expediency? S. F. Shaw. *Petrol. Engr*, June 1944, **15** (9), 108.—Estimates of the total oil reserves of U.S.A. are placed at slightly over 20,000,000,000 brl. by two different authorities, but these two authorities differ somewhat in estimates for individual States, while agreeing in the case of Texas, which accounts for 55% of the total. 35 of the principal U.S. fields account for about 50% of the total reserves. For fields which have yielded over 75% of their estimated recoveries there is unlikely to be any serious revision of estimates, but the same is not necessarily true for those which have not yet given 50% of their estimated recovery. Some fields have had estimates which reached a peak and then suffered downward revision, and there are indications that in some cases the early estimates can have been little more than intelligent guesses. It may be that recovery factors employed in estimating reserves developed since 1930 have been influenced too much by the factors found to apply in estimates made prior to 1930, when there was closer spacing, completion practices differed, and daily withdrawals were greater than under the later severely restricted production.

The recovery, spacing, estimates, etc., are discussed for a number of fields.

Low prices do not attract wildcatters, and do not contribute to the use of methods of drilling, completion, and production which will give the maximum recovery of the developed reserves. Many wells are being abandoned prematurely because it is uneconomic to lift oil with large proportions of water from great depths.

Tables give the A.P.I. and *Oil and Gas Journal* estimates of reserves by States at the beginning and end of 1944, the estimated reserves of the principal U.S. fields at different dates, and the estimated ultimate recoveries of fields the reserve estimates of which have been revised downwards. G. D. H.

1154. Wells Completed in United States in Week Ended June 17, 1944. Anon. *Oil Wkly*, 19.6.44, **114** (3), 79.—370 field wells and 90 wildcats were completed in U.S.A. in the week ended 17th June, 1944. 246 of the former produced oil and 19 gas, while 18 of the latter produced oil and 2 gas. The field and wildcat results are summarized by States and districts for the above week. G. D. H.

1155.* Rich Oil Deposits Found in Tatar Republic, Russia. Anon. *Oil Gas J.*, 24.6.44, **43** (7), 62.—The discovery of rich oil deposits in the Shugarov Raion (county) of the Tatar Republic of the U.S.S.R. is reported. It is estimated that this area could produce 10,000–20,000 metric tons of oil/day.

Three wells have recently been completed in a new oil-field in the Bashkir Republic, their output being "hundreds of tons daily."

In 1943, the Kirghiz Republic produced twice as much oil as in 1942. G. D. H.

1156.* Summary of May Completions. Anon. *Oil Gas J.*, 24.6.44, **43** (7), 139.—1034 oil-wells, 169 gas-wells, and 700 dry wells were completed in U.S.A. in May 1944. The total footage drilled was 6,515,068 ft., and the initial daily outputs of these completions totalled 228,997 brl. 33 of the wells were over 10,000 ft. deep.

The results of the U.S.A. well completions in the four-week period ended 27th May, 1944, are summarized by States and districts. G. D. H.

1157.* Wildcat Completions and Discoveries. Anon. *Oil Gas J.*, 24.6.44, **43** (7), 143.—In the week ended 17th June, 1944, 90 wildcats were completed in U.S.A., 7 finding oil and 2 finding gas. The results of the wildcat completions in this week are analysed by States and districts, and cumulative totals for 1944 are given to the above date. G. D. H.

1158. Phillips Opens New Field in the East Texas Area. Anon. *Petrol Engr*, July 1944, **15** (11), 157.—Early in July, the Phillips Petroleum Co. opened a new field in Smith County, Texas, about 5 ml. south of Tyler. It is 20 ml. west of the East Texas field, and near the top of the structure. Oil is obtained from the porous Coquina limestone of the Lower Glen Rose, between 9865 and 9960 ft., the saturated section totalling 65 ft. In the initial production test with a $\frac{1}{8}$-in. choke, through perforations at 9918–9929 ft., the well flowed 95 brl. of 40-gravity crude in $12\frac{1}{2}$ hours, with a gas–oil ratio of 2800, and a tubing pressure of 4600 lb./in.^{2}.

Below the present producing level possible additional productive zones in the Pettit lime and in the Travis Peak zone of sands remain to be tested. G. D. H.

1159.* Development of Soviet Oil Speeded Despite War Handicap. L. Turner. *World Petrol.*, July 1944, **15** (7), 37.—For twenty years before the outbreak of war, the U.S.S.R. oil output was being increased by increasing the efficiency of the working of old wells, and by the discovery and working of new areas, mainly those of the Urals. In 1941, Maikop and Grozny produced some 30,000,000 brl. of oil, but complete wrecking prevented Germany's benefitting from their capture. Both fields are now being brought back into production.

In 1938, fields east of the Urals yielded 7,000,000 brl. (4·3% of the country's output); in 1942, the production was 98,000,000 brl. Fields east of Kuibyshev gave 40,000 brl./day in 1939, and 40,000,000 brl. during 1942. In these fields the oil is 250–300 m. deep.

By 1939 the U.S.S.R. had 3,877,000,000 metric tons of proved oil deposits, with some 6,376,000,000 tons of geological oil deposits. In 1942, oil production from shale was 28,000,000 brl.; the remaining oil-shale reserves are large.

Oil is known in the Pechora region at Oukhta, in Kamchatka, and northern Sakhalin. The Fergana valley area yields oil, and in recent years substantial production increases have been made south of Krasnovodsk.

A map shows many of the oil-fields of the U.S.S.R. G. D. H.

1160.* Disposal of Surplus Crude Is Immediate Post-War Problem. J. P. O'Donnell. *Oil Gas J.*, 1.7.44, **43** (8), 40.—It is estimated that if projects planned are put into operation, the world's post-war oil producing potential will be about 7,500,000 brl./day, 1,800,000 brl./day more than in 1939. It is unlikely that the impoverished world will be able to consume 30% more oil in the first years after the war than in the relatively prosperous year when war began. Hence curtailment of production will be necessary as soon as the war ends. This requires an international oil policy. The major European countries, excepting Russia, were large oil importers, and will not be in a position to consume oil immediately after the war at their pre-war rates. Hence the outlook for producing countries which depend largely on exports is not encouraging from a short-term point of view.

It seems likely that by the end of the war the Argentinian potential will approach 70,000 brl./day, but the country's consumption exceeds its output. Bahrein's production is not expected to increase substantially, and Canada's output may remain at its present level of 27,000 brl./day. Egypt's potential of 25,000 brl./day is likely to be double its consumption. Germany's expansion is small, and will not contribute significantly to the world's total. Hungary's potential of 15,000 brl./day is well above her domestic needs. Expansion of refinery capacity will raise the Iranian potential to 350,000 brl./day, but the country's potential is far in excess of this. Expansion of refinery and pipe-line capacity may raise Iraq's output to 150,000 brl./day. After rehabilitation Mexico should be able to produce 125,000 brl./day. The East Indian potential may be only 50,000 brl./day, while no great change is expected in Peru. Rumania's potential may fall to 75,000 brl./day. Saudi Arabia's production is expected to have expanded to 75,000 brl./day. Only a slight expansion to 60,000 brl./day may take place in Trinidad. U.S.A. may average 4,500,000 brl./day, while an estimate of the U.S.S.R. output is 750,000 brl./day, and a total of 1,000,000 brl./day may be attained in Venezuela.

The 1939 daily averages and probable potentials are tabulated. G. D. H.

1161.* Wildcat Completions and Discoveries. Anon. *Oil Gas J.*, 1.7.44, **43** (8), 107.—66 wildcats were completed in U.S.A. in the week ended 24th June, 1944. 7 found oil, 2 found gas, and 2 found distillate. 1683 wildcats had been completed in U.S.A. in 1944 up to 24th June; 1423 of these were dry.

A table summarizes by States and districts the results of wildcat drilling in the week ended 24th June, and for 1944 to that date. G. D. H.

1162.* Peru makes Air Survey of Oil Areas. Anon. *Oil Gas J.*, 1.7.44, **43** (8), 44.—In 1943, the Peruvian Government made aerial surveys of four unexplored petroliferous areas which are regarded as promising. Little encouragement was obtained by drilling in the Pirin field, near Lake Titicaca. This is in a faulted and folded area, running from Puno to the Ramis River, and it involves schists, sandstones, limestones, and conglomerates. The faults have permitted escape of oil, gas, and water. The Pirin field, which produced 284,000 brl. of oil between 1906 and 1915, was abandoned because of large water-flows.

60% of Peru's production is obtained from fields in the north-west coastal area. Agua Caliente is Peru's only other important field. 7 wells have been drilled in it since 1937. In the first five months of 1943 this field produced 30,500 brl. of oil. Lack of storage and absence of transport facilities have prevented the development of a market for this oil.

During the first nine months of 1943, Peru produced 10,965,537 brl. of oil, 9% more than in the corresponding period of 1942. The 1942 total was 13,628,459 brl. The 1944 output is expected to be about the same as in the two preceding years.

G. D. H.

1163.* Barco Revealing True Productive Potentialities. Anon. *Oil Gas J.*, 1.7.44, **43** (8), 38.—The Barco discovery well, Colombian Petroleum Co. 2 Petrolea, came in in 1933, flowing 2500 brl./day of high-gravity oil from only 708 ft. There was further drilling to this and deeper horizons, and after the completion of the Barco pipe-line oil was moved from the field in 1939. Soon afterwards the production began to decline rapidly. During 1940 and 1941 there was unsuccessful wildcatting. Later, oil was found on the Tibu structure (Tres Bocas-Socuavo area), and this appears to have good prospects.

130 wells have been drilled on the Petrolea North Dome, and 93 are now producing over an area of about 4000 acres. The 46-gravity crude is obtained from five different horizons in the Cretaceous. The current production is about 11,500 brl./day, and the cumulative production is 14,000,000 brl. Drilling on the Petrolea South Dome structure has been disappointing. To the east the Carbonera field produces a much heavier oil. Three wells have been completed at depths ranging from 2234 to 3359 ft. The initial potentials have averaged less than 100 brl./day. In the extreme north of the concession is the Rio de Oro field, on a narrow, tight anticline. 13 wells have been drilled on it, the aggregate potential being about 1000 brl./day from the 1500-ft. horizon. There is no pipe-line outlet.

6 of the 8 producing wells at Tibu are completed in the Tertiary at about 5000 ft. The other 2 wells produce from the Cretaceous below 9000 ft. The Tertiary sands are lenticular, rendering correlation difficult, and the wells in them give little gas. The productive area probably covers several thousand acres. The 2 Cretaceous wells are very gassy, and gave 51-gravity oil on short production tests. One of these wells is not considered to be commercial. These 2 wells are 8 ml. apart, and in the crestal regions of the structure. They are separated by a 500-ft. deep syncline.

A map of the Barco concessions is included. G. D. H.

1164. Gaspe Well Nearing Completion Depth. Anon. *Oil Wkly*, 3.7.44, **114** (5), 61.—Continental Petroleum's No. 2 well on the Gaspe peninsula of Canada, has reached a depth of 1955 ft., and will be cored to the expected total depth of 2058 ft. In 1896 a well 113 ft. away found high-gravity oil at 2058 ft., and is still flowing. G. D. H.

1165. Oil Discovery in Turkey. Anon. *Oil Wkly*, 3.7.44, **114** (5), 61.—An unconfirmed report states that oil has been found at great depth to the west of Burdur in the Geronis valley of southern Anatolia, Turkey. G. D. H.

1166. Peruvian Government Oil Work Unpromising. Anon. *Oil Wkly*, 3.7.44, **114** (5), 61.—During the past twelve months the Peruvian Government has drilled a number of wells in the Pirin area near Lake Titicaca. In this zone, from the Ramis river to Puno, there is anticlinal structure broken by faults. The formations include schists, sandstone, limestone, and conglomerate. Seepages of oil, gas and salt water have been found along the faults. No important commercial oil production has yet been obtained in this area, although from 1905 to 1915 wells in the Pirin field produced 284,000 brl. of oil, before going over to water. G. D. H.

1167. Wells Completed in the United States in Week Ended 1st July, 1944. Anon. *Oil Wkly*, 3.7.44, **114** (5), 63.—366 field wells and 72 wildcats were completed in U.S.A. in the week ended 1st July, 1944. 271 of the former wells found oil and 25 found gas, while 15 of the latter found oil and 3 found gas. The field and wildcat completions in the above week are analysed by States and districts. G. D. H.

1168.* Wildcat Completions and Discoveries. Anon. *Oil Gas J.*, 8.7.44, **43** (9), 169.—There were 91 wildcat completions in U.S.A. in the week ended 1st July, 1944, 7 finding oil, 1 distillate, and 7 gas. The total of wildcat completions to that date in 1944 was 1774, which figure included 196 oil discoveries, 17 distillate discoveries, and 64 gas discoveries.

A table analyses by States and districts the results of wildcat completions in the week ended 1st July, 1944, and gives cumulative totals for 1944 to that date.

G. D. H.

1169. Russia's "Second Baku" Region Covers Wide Area. Anon. *Oil Wkly*, 10.7.44, **114** (6), 26.—Petroleum discoveries in a stretch of territory running 500 ml. in a curving line from the Saratov region north-east almost to Perm are said to constitute Russia's "Second Baku." More than 100 fields have been opened since the first important discovery in 1932—Ishimbaevo—50 ml. north-east of Ufa. These fields are now reported to yield over 50,000,000 brl. of oil/year, and transport and refining facilities are available for dealing with this. There are refineries at Ufa, Syzran, and Saratov. The reserves of the area are estimated at 20,000,000,000 brl. G. D. H.

1170. April Production Figure Nearly Hits All-Time High. Anon. *Oil Wkly*, 10.7.44, **114** (6), 32.—During April 1944 the U.S.A. crude production averaged 4,453,000 brl./day, almost reaching the all-time record figure established in November 1943. The daily demand averaged 4,549,400 brl. in April.

During the first four months of 1944 the total initial production of new wells was almost double the comparable 1943 figure. April had 953 completions, 25% more than in April 1943.

Crude runs to stills were 4,411,000 brl./day in April 1044, and stocks at the end of the month included 234,694,000 brl. of gasoline-bearing crude, 6,473,000 brl. of heavy crude in California, 4,213,000 brl. of natural gasoline, and 226,678,000 brl. of refined products. G. D. H.

1171. Russian Production and Refining Expand. D. L. Carroll. *Oil Wkly*, 10.7.44, **114** (6), 36.—In Azerbaidzhan the oil production is considerably above pre-war levels, and output of aviation gasoline has been tripled in the last two years. The mapping of a series of submarine structures is almost complete. These structures run parallel to the coast, north-east, and south of Artem Island, and they are believed to have good oil prospects. Similar favourable offshore areas are thought to exist from Putinsk Bay to Shikova Kosa, south of Peschany Island, and off the Bibi-Eibat area. Stratigraphic traps have been discovered at Kala, Chakjnaglyar, Kalinsk, Buzovny, and in the Yasaman Valley.

In February, a new oil-field was opened in the Bashkir Republic, on a large structure on the west flank of the Urals. The first three wells gave more than 1000 brl./day each.

The Dossor field of Kazakhstan is steadily increasing its output, and excellent new fields have been discovered nearby. One is a few miles north of Dossor and another is at Paskuduk. The leading fields in descending order are Sagiz, Dossor, Makat, and Komsomalsk.

Important new pools were found in the vicinity of Bashkiria in 1942. A major field was discovered in the Kinzebulatovsk area in the summer of 1943. The combined output of the Kuibyshev Province oil-fields is reported to be nearly three times as great as in 1938.

The Kim oil-field of Tadzhikistan is said to have quadrupled its output in the last quarter of 1943 as a result of considerable drilling activity. The Changyr-Tash field of Kirgizia now has 2 producing wells, and the Shugarov sub-province of the Tatar Republic has been the scene of the discovery of a rich oil-field this year. This last field's ultimate potential is estimated as 135,000 brl./day.

The Vannovskaya refinery in the Fergana Province was enlarged to 40,000 brl./day capacity in 1943. Ozokerite mining is in progress in the Fergana region, and at Kim, Tadzhikistan. A refinery has been completed at Ust-Ukhta, with a capacity of 40,000,000 brl./year, in the expectation that adequate production will be developed in the area east of the Timan Hills. Geological and geophysical work, and drilling, have been in progress in the Petchora basin for several years, and are believed to have confirmed the presence of oil in prolific amounts at relatively shallow depths.

In 1941, the U.S.S.R. produced 268,600,000 brl. of crude. It is estimated that the 1944 production may exceed 300,000,000 brl. G. D. H.

1172. Wells Completed in the United States in Week Ended 8th July, 1944. Anon. *Oil Wkly*, 10.7.44, **114** (6), 69.—339 field wells and 75 wildcats were completed in U.S.A. in the week ended 8th July, 1944. 222 of the former found oil and 33 found gas, while 8 of the latter found oil or distillate and 3 found gas. The field and wildcat completions in the above week are analysed by States and districts, and cumulative totals for 1944 are given to 8th July, 1944. G. D. H.

1173. Wildcat Completions and Discoveries. Anon. *Oil Gas J.*, 15.7.44, **43** (10), 137.—During the week ended 8th July, 1944, there were 11 oil discoveries and 1 gas discovery among the 92 wildcats completed in U.S.A. These wildcat completions are analysed by States and districts, and cumulative totals for 1944 are given to the above date. G. D. H.

1174. Eastern Canada Presents Oil Possibilities. L. J. Logan. *Oil Wkly*, 17.7.44, **114** (7), 17.—While Canada looks mainly to the west and north-west for its future oil-fields, there are possibilities in the east. The areas of established and potential production in the east are mainly in a narrow belt centred round Lakes Erie and Ontario, the St. Lawrence River, and the Gulf of St. Lawrence. A further prospective oil-producing area is in northern Ontario and north-east Manitoba, bordering James and Hudson Bays. This latter area is part of a basin of Palaeozoic sediments in the middle of the Canadian Shield, while the chain of narrow basins along the St. Lawrence waterway system is between the south-east flank of the Shield and the north-west flank of the Appalachian mountain system. In eastern Canada the Palæozoic rocks yield oil and gas in southern Ontario and south-east New Brunswick, and they are the only potential producing rocks in the prospective areas.

Exploratory drilling and other sub-surface investigations have been rather limited, and the producing possibilities of many areas have not been conclusively tested.

In the James and Hudson Bay area prospects do not appear favourable, because the sediments are relatively thin, there are no seeps, and a test found no showings. In much of the area the Ordovician and/or Silurian cover over the pre-Cambrian is less than 500 ft. thick, and to the south the Devonian, sometimes with Lower Cretaceous, does not bury the pre-Cambrian by more than 1000 ft. in most places.

West and east of the Frontenac axis oil possibilities exist in two pre-Cambrian basins of Palæozoic sediments. In the eastern basin marine Ordovician beds range up to 2100 ft. in thickness, and in the eastern half of this basin the main oil and gas possibilities are in a large down-faulted block. Wells south and east of Ottawa have found gas shows, but no commercial production has been obtained. In the western basin are Ordovician, Silurian, and Devonian beds, dipping gently south and south-west. In southern Ontario these beds are covered by glacial drift up to 500 ft. thick. In the east only Ordovician occurs, in thickness not exceeding 1000 ft., and while a little gas has been found along the Lake shore, the oil and gas possibilities are not rated highly. The established oil- and gas-fields are in the west, where the Ordovician-Devonian beds range up to 4500 ft. in thickness. The gas production in the eastern part of the productive belt is mainly in the Silurian (Guelph, Clinton, Grimsby, and Whirlpool). About 20 shallow oil-fields occur to the west, the bulk of the oil coming from Middle Devonian limestones (Delaware-Onondaga). Oil- and gas-showings have been found in tests north of the old producing belt, but the thinness of the sediments limits the producing prospects. At the beginning of 1944, Ontario had 1728 producing wells. 132,492 brl. of oil was produced in 1943, making the cumulative total 39,034,158 brl. Canada's oldest field, Oil Springs, has produced one-fifth of this, and is still giving nearly 30,000 brl./year from depths of 150–400 ft.

In Quebec prospects of oil production are confined to two areas along the St. Lawrence—the St. Lawrence Lowlands and the Gaspe Peninsula. In the former area are Ordovician beds up to 5000 ft. thick. Oil- and gas-showings have been found in the Trenton by limited drilling. The Gaspe Peninsula is part of the Appalachian mountain system. So far only non-commercial oil production has been found there. Silurian, Devonian, and Ordovician beds occur, all three showing evidences of oil. The basins of the York and St. John rivers show greatest promise (in the Devonian and possibly in the Silurian also). About 60 wells have been drilled, some as deep as 3000 ft. Most were dry, but a few had small outputs of gas or oil. Few were favourably located structurally. A recent test has had oil- and gas-showings. Some favourable structures still require test drilling.

There are possibilities of new oil-fields in Nova Scotia and New Brunswick around the Stony Creek area. In this area the principal formations are Pennsylvanian and Mississippian, and are believed to be mainly non-marine. These beds are folded and faulted, generally with north-east–south-west trends. Stony Creek yields gas from about 1200 acres, and oil from about 275 acres. It lies on the south flank of a fold, the oil and gas coming from sandstone lenses in shales of the Albert formation, Horton series. Drilling depths are 1500–3000 ft., and current production is about 60 brl. of 37-gravity oil/day, with 1,650,000 cu. ft. of gas. The field produced 25,405 brl. of oil in 1943, and 600,000,000 cu. ft. of gas, the cumulative oil production being 344,425 brl., and the cumulative gas production over 19,000,000,000 cu. ft.

There are various oil-shows associated with the Albert formation in the Stony Creek area. Some tests have been drilled in New Brunswick and Nova Scotia without finding more than traces of oil.

Newfoundland has oil-seeps and producing possibilities in a narrow lowlands belt of Cambrian, Ordovician, Devonian, and Mississippian beds along the west coast. Absence of gas pressure in the small wells is an unfavourable feature. Oil-shales and seeps occur on the north-east coast, where there is a small fringe of Mississippian, but the commercial possibilities are not rated highly. G. D. H.

1175. Wells Completed in the United States in Week Ended 15th July, 1944. Anon. *Oil Wkly*, 17.7.44, **114** (7), 59.—364 field wells (214 giving oil and 43 giving gas) and

84 wildcats (16 giving oil and 8 giving gas) were completed in U.S.A. in the week ended 15th July, 1944. Up to that date 11,994 wells had been completed in U.S.A. in 1944.

The completions are analysed by States and districts for the week ended 15th July, 1944, and cumulative totals are given for 1944. G. D. H.

1176.* Regional Play Extends from Connecticut to Florida. Anon. *Oil Gas J.*, 22.7.44, **43** (11), 39.—Possibly 20,000,000–25,000,000 acres are covered by leasing activity along the Atlantic coast-line from Connecticut to Florida, and westwards along the Gulf Coast to the proven oil-fields of Louisiana. A thin veneer of sediments covers the Atlantic coastal plain in the west, and it thickens to the east. A number of major oil companies hold leases in this region. Much of the acreage is held without drilling obligations.

There is the possibility that detailed geological and geophysical investigations will reveal structural conditions favourable for oil accumulation. G. D. H.

1177. Petroleum Possibilities North of "Sixty-One." H. G. Cochrane. *Oil Gas J.*, 22.7.44, **43** (11), 42.—Following developments at Norman Wells, the oil search is being extended northwards over the whole Mackenzie River basin and the Yukon. The Mackenzie River basin, extending 750 ml. north from the Slave Lake to the Arctic, has 150,000 sq. ml. of sediments between the Pre-Cambrian Shield on the east and the Mackenzie Mountains on the west. The sediments vary widely in thickness. Many areas have promising oil prospects, and seepages, mainly from Devonian rocks, are well known. The Norman Basin is a large syncline, 20 ml. wide, and about 250 ml. long, containing pronounced folds. The eroded edges of the Bosworth formation give many oil-seeps on the east side of the river. The total oil-bearing area at Norman Wells is expected to be about 4000 acres, and the maximum oil recovery is estimated as 35,000,000 brl. There are 32 producing wells, yielding oil from depths of 1025 to 2700 ft.

West of Great Slave Lake, Upper Devonian beds outcrop along the Hay River, and there are seepages at outcrops along the north-west shore of Slave Lake. Two wells in this region have failed to find commercial oil production, though one had a strong water flow from the Middle Devonian.

Upper Devonian beds occur beneath the Cretaceous in the Arctic Red River and upper Peel River areas. Seepages have been reported in the Wind River area. Access to these areas has been improved by the road-building activities of the U.S. War Department.

The U.S. War Department does not propose to increase the producing capacity of the Canol undertaking, and suggests the discontinuing of exploration. It proposes to retain an option to purchase 10% of the Norman Wells area production after the war, up to 30,000,000 brl., plus an equal quantity from future discoveries in the Mackenzie River Basin.

The Canadian Government has opened 100,000,000 acres of the Mackenzie Basin and Yukon Territory for leasing. One applicant may apply for 2,000,000 acres, which will be reduced to 1,000,000 acres after three years, and from this 350,000 acres will be selected for development in the sixth year. Imperial Oil has taken up acreage, and has a three-way arrangement with the U.S. War Department and the Canadian Government. The aim is to find reserves up to 300,000,000 brl., sufficient to support commercial production. Details are given of the agreement with the Canadian Government, and of the possible ways in which the oil obtained would be used in this region. G. D. H.

1178. Wildcat Completions and Discoveries. Anon. *Oil Gas J.*, 22.7.44, **43** (11), 103. —During the week ended 15th July, 1944, 56 wildcats were completed in U.S.A., compared with 92 in the preceding week. 6 found oil, 2 distillate, and 2 gas. The results of the wildcat completions are summarized by States and districts for the week ended 15th July, 1944. G. D. H.

Geophysics.

1179.* Soil Analysis for Prospecting. H. I. Henderson. *Petrol. Engr*, June 1944, **15** (9), 116.—In the very slow escape of gaseous hydrocarbons to the surface from underground oil reservoirs, most of the molecules enter the atmosphere unchanged, but some, especially those which are unsaturated, are transformed and remain in the soil. The transformation by oxidation is brought about by contact with air under the influence of sunlight in the presence of certain catalysts which are commonly present in soils. In addition to oxidation there may be polymerization and photosynthesis. Some oils from shallow depths, with unconsolidated overburden, ultimately yield considerable amounts of transformed hydrocarbons—*e.g.*, the paraffin-earth over the shallow Gulf Coast salt domes. Accumulations of but a fraction of 1% can readily be detected in the laboratory.

Methane can be generated near the surface by decaying vegetable matter, and must be distinguished from hydrocarbons arising from oil at depth.

If the surface is water-covered the transformation products either are not formed, or are removed. If the surface is considerably above sea-level the transformation products are adsorbed by the soil particles, and are not leached out by subsequent inundation. Thus marshland in a subsiding area may be workable by soil analysis, but it may not be workable in a rising area. G. D. H.

1180.* Electrical Prospecting Method Used in Gulf Coast Search for New Reserves. E. H. Short. *Oil Gas J.*, 15.7.44, **43** (10), 70.—During the past four years an electrical prospecting method, which offers new possibilities, has been developed, and it is now being used in the oil search on the Gulf Coast. By means of low-frequency commutated currents, measurements of the average resistivity of a layer of the earth may be obtained for sections 800–1200 ft. thick, centred at pre-determined depths, which range 3000–9000 ft. on the Gulf Coast. A portion of the section containing oil has an appreciably higher resistivity than those portions where oil is not present.

The Elflex field equipment consists of an instrument truck with two operators, and a cable truck, also with two operators. Stations are usually 1500 ft. apart. The electrodes are placed in small holes, which are deep enough to ensure good contact with the earth, and salt water is poured into the current electrode holes, and fresh water into the potential electrode holes.

The effective depth of penetration depends on the frequency of the exploring current, lower-frequency measurements being affected by deeper formations the effects of which become negligible with increase in frequency. The commutating switches in the current and potential circuits are motor-driven, operating singly and 90° out of phase. They are adjusted so that when the galvanometer is connected to the potential circuit no current flows through the current electrodes.

An instrumental diagram is given, and two examples of the method's use are briefly described. G. D. H.

Drilling.

1181. Preparation and Use of Casing Selection Charts. H. M. Cooley. *Oil Wkly*, 8.5.44, **113** (10), 33.—Certain assumptions or conclusions must be made before the chart is started. For example, company policy with respect to safety factors must be decided on. Also, where there are several methods for handling some of the design factors, the one must be selected which best meets the ideas of those responsible for casing-string design. An example is the question of whether to give consideration to the effect of tension stresses in reducing collapse resistance of casing. If the decision is affirmative, the method by which this consideration will be given, as well as its magnitude, must be decided on. A further factor which may or may not be given weight in preparing a chart is the buoyant effect of drilling mud in reducing the tension stresses in the string. The question of limiting the number and length of the sections in a casing string will also require an answer. The form of the finished chart will be appreciably affected by these decisions. In deriving the charts presented, the following assumptions were made. (1) Casing size, 5½ in. (outside diameter). (2) Setting depth properties, and casing weights and grades, were taken from A.P.I. code 5-C-2, second edition. (3) Safety factor in collapse, not less than 1·125 on the minimum A.P.I. properties. (4) Safety factor in tension, not less than 1·8 on the minimum A.P.I. properties. (5) Collapsing medium, 9·6 lb./gallon. (6) No consideration was given to the buoyant effect of drilling mut. (7) Reduced collapse strength due to tension stresses was determined by the Wescott–Dunlop–Kemler "Effect of Tension" curves, as shown in "A.P.I. Drilling and Production Practice," 1940, p. 138. (8)

The demonstration stopped at 10,000 ft., but the method can be expanded to greater depths, if desired. The chart and the calculations on which it is based are considered in detail.

The versatility of casing selection charts is one of the main points favouring their use. Any important matter of company policy can be incorporated in the charts, making a clear, concise, and understable record for permanent use by designing and specifying engineers, purchasing departments, and field-material and operating personnel. Although a chart for only one casing size has been developed here, the identical procedure is applicable to charts for each size used by an oil company. The charts, in blue-print or white-print form, can be given wide distribution among company personnel, with the result that the confusion and ambiguity of long and tedious written recommendations (or, in many cases, no recommendations at all) can be eliminated.

A. H. N.

1182. Doubling Swivel-Stem Service through Metalizing Operation. E. Sterrett. *Oil Wkly*, 8.5.44, **113** (10), 56.—The conditions of wear and tear at the pack-off surface of the swivel shaft are described. To recondition this important part of the swivel, one operator dismantled the swivel, had the stem centred carefully in a lathe—driving the shaft through wooden blocks forced tightly against the upper thread by jaws of the lathe face-plate—and had the abraded surface built up by metallizing with 12-chrome wire. The stem was first turned down with a roughening tool throughout the packing zone and for a short distance either way from the actual contact zone. This turning was carefully done to remove as little metal as necessary, yet to insure the removal of all rust and a clean surface for the new material. The metal removed ran as high as 3/32 in. through the two grooves shown on either side of the relatively high centre of the abraded area. Following the operation to clear away the rust and corrosion, the turned section was gone over with a thread-cutting tool, set below centre and with negative rake to form a jagged thread, in this case 16 to the inch. The thread depth was varied to follow the irregular contour of the surface left after turning off the rust, so as to preserve as much of the parent metal of the stem as possible.

Following the threading operation, and as quickly thereafter as possible, to prevent any contamination of the clean metal by dust, rust, or oil, the entire area and some ½ in. on either side of it were sprayed with 12-chrome metal, applied by a metallizing gun mounted in the lathe tool-post and fed slowly across the zone by the lathe feed. The rate of wire feed, progress across the face of the cut, and rotating speed of the stem in the lathe were so regulated as to give a dense coating of the chrome alloy of a thickness sufficient to replace all the metal which had been removed, and to allow a margin of about 1/32 in. for rough turning and final grinding to size. The sprayed metal, though molten by the flame as it issued from the nozzle of the gun, was instantly cooled by the relatively great mass of the stem, and at no time during the rebuilding operation was the stem heated to a temperature which could not be borne by the hand, and therefore no change was effected in the original heat-treat of the steel. The success with which the spray of molten metal was localized is evidenced by the fact that the thrust-bearing assembly at the collar of the stem was not wrapped or covered, and was ready for reassembly in the swivel simply by being washed clear of old lubricant and dried thoroughly before applying a new coating of grease. The packing-area surface left after applying the extremely hard chrome coating, turned to proper diameter by a tool-post grinder, is much harder than the original steel, and thus better able to resist the initial abrasion of mud-carried grit, and consequently in better condition to continue to afford the smooth cylindrical surface for packing fit demanded by the extreme service at this point. A. H. N.

1183. World's Deepest Casing String Set at 15,278 ft. E. Sterrett. *Oil Wkly*, 29.5.44, **113** (13), 18.—The paper consists of a number of photographic illustrations supplemented by description of the casing programme, and procedure adopted in Phillips Petroleum Co.'s Ada Price No. 1 Well when landing a record depth of string. This string of pipe, just short of 3 miles in length, weighs 155·92 tons, and is the heaviest casing load ever carried on a 10-line string-up. The string, to meet collapsing pressures under bottom-hole conditions and also to withstand the tremendous tensile stress of placing, was of the double-taper type, being made up of the following weights of pipe :—

Depth (ft.).	Wt./Ft. Lbs.	Footage Run.	Total Wt. of Section.	Type of Joint.
0– 4,024	23	4024	92,552	6-thd. Acme
4,024– 5,786	20	1762	35,240	Long collar.
5,786–10,079	17	4293	72,981	,, ,,
10,079–12,916	20	2837	56,740	,, ,,
12,916–15,278	23	2362	54,326	,, ,,

The string carried a standard cement whirler-type guide-show on bottom, with float-shoes between the first and second, and again between second and third joints of the 23-pound bottom section. The first 5200 ft. of pipe run was handled with a light elevator and the usual rotatory-table type slips. With completion of the running of the lower 20-lb. section, a heavier elevator was put on, and carefully adjusted to suspend the joints of pipe exactly perpendicular for quick and accurate stabbing.
A. H. N.

1184. World's Deepest Oil Test. C. A. Daniels. *Petrol. Engr*, June 1944, **15** (9), 59.—In a fairly long paper the drilling of A. C. Price No. 1 is described. See Abstract No. 959.
A. H. N.

1185. Application of Radioactivity Logging to Special Drilling Problems. W. A. Sawdon. *Petrol. Engr*, June 1944, **15** (9), 66.—The gamma ray curve, which records the measurement of gamma rays originating in the formation and passing through casing and cement, when present, was first used alone to procure formational data in cased or open hole. Later the neutron curve, measuring the effect of bombardment on the formations by a strong source of neutrons, was introduced. This neutron curve is used widely as a companion curve to the gamma-ray curve, and will frequently locate strata in which irregularities in radioactivity make the gamma-ray curve inadequate when used alone. An example of the combined use of the gamma-ray and neutron curves for a specific purpose is in defining porous zones in areas such as West Texas where there is consolidated sedimentation. By using the two curves both the type and physical character of the formation are disclosed. Where limestone formations are present the neutron curve is run in conjunction with the gamma ray to indicate definitely the porous strata containing fluid. Hard dense formations such as anhydrites, impervious limestones, and the like are indicated by high intensity readings of the neutron curve, whereas the porous formations are shown by low or moderate intensity. The gamma-ray curve differentiates between the porous formations indicated by the neutron log and the shales.

One unusual application of radioactivity logging is for locating permeable zones with the aid of radioactive material placed in the drilling fluid. A gamma-ray curve is first run and then a radioactive material is thoroughly mixed with the drilling mud and forced into the formation under pressure. The gamma-ray log is then run again at the same sensitivity as that used with the first run and by a comparison of the two curves, the permeable strata are identified.

Use of these logs for determining points of entry of water into well and also in connection with carnotite, a radioactive material incorporated in cements, is illustrated. In passing from a string of casing while running a neutron log, a definite shift occurs on the curve. This is true, whether the casing is an inner, intermediate, or an outer string and thus provides the means of locating the shoes of one or more strings of pipe when records are not reliable. In one recent case, it was desired to locate the bottom of each of five strings with which the well was cased, so a neutron log was run to furnish this information. Other special applications are indicated. A. H. N.

1186. Standardization in Compiling Data on Exploratory Drilling and Crude Oil Reserves. F. H. Lahee. *Petrol. Engr*, Reference Annual, 1944. **15** (10), 35–39. *Paper Presented before American Petroleum Institute.*—Terms used in exploratory drilling are defined and wells and reserves are classified.
A. H. N.

1187. Blowouts—Causes and Prevention. M. T. Works. *Petrol. Engr*, Reference Annual, 1944, **15** (10), 42. *Paper Presented before American Petroleum Institute.*—See Abstract No. 1196.
A. H. N.

1188. Coring with a Reverse Circulation Rig. L. Finch, Jr. and W. M. Elias. *Petrol. Engr*, Reference Annual, 1944, **15** (10), 56. *Paper Presented before American Petroleum Institute.*—Three factors led to conducting the experiment on a reverse circulation rig, in preference to a large rotary rig. (1) In many operations in West Texas reverse circulation rigs, using oil as a circulating medium, drilled the pay-section after the oil-string had been set. The equipment was simple and relatively light, and could be economically adapted to reverse circulation coring. (2) The size of the formation cutting recovered with normal reverse circulation rigs indicated that normal circulation volumes and pressures in the fluid stream were sufficient to raise a core fragment to the surface. (3) The proved feature of providing a quick reversal of fluid input from the annulus to the drill pipe also appeared attractive as a means of dislodging "bridged" core fragments from the drill-pipe, without a pulling job. Experiments are reported and comparisons with ordinary coring made.

In conclusion, results of experiments indicate that continuous coring with reverse circulation, using either oil or mud, may prove both feasible and beneficial in certain consolidated sand and limestone sections. The application of the same process in more friable sections will be considerably more complicated. A. H. N.

1189. Drilling Fluid for the Completion of Shallow Wells. W. H. Farrand and W. A. Clark. *Petrol. Engr*, Reference Annual, 1944, **15** (10), 60. *Paper Presented before American Petroleum Institute.*—See Abstract No. 1110. A. H. N.

1190. A Method of Drilling in Deep Water. H. E. Gross. *Petrol. Engr*, Reference Annual, 1944, **15** (10), 68. *Paper Presented before American Institute of Mining and Metallurgical Engineers.*—See Abstract No. 957. A. H. N.

1191. Positive Colloid Muds for Drilling Through Heaving Shale. D. C. Bond. *Petrol. Engr*, Reference Annual, 1944, **15** (10), 85. *Paper Presented before American Institute of Mining and Metallurgical Engineers.*—See Abstract No. 864. A. H. N.

1192. Casing Scraping Removes Dangerous Inside Obstructions. R. S. Kail. *Oil Wkly*, 12.6.44, **114** (2), 26.—Causes of obstruction on the inside of casing are various. After cementing, it is probable that some cement will remain on the wall of the pipe even when a maximum gauge-bit has been used to drill out the tailings. Gun perforating may leave burrs on the inside face of the casing. There may be other foreign material, such as paraffin, clinging to the inside of the pipe. Softer obstacles may not damage equipment being run through the casing, but they will often prevent passage of tools, pack in and around slip wickers, or cause tools to trip prematurely. Strings of casing or liner may be hung up by any kind of obstruction on the inner wall of casing previously set in the well, and with the same small clearance between strings now frequently used it should be made certain that the inner walls of the outer strings are clean.

Scraping operations are described, together with the Baker type of casing scrapers. A. H. N.

1193. Preventing Core Contamination. Anon. *Oil Wkly*, 19.6.44, **114** (3), 54.—Results of experiments indicate that the introduction of high-concentration modified starch drilling mud offers a method of preventing flushing of cores by drilling mud filtrate. A. H. N.

1194. Design of Casing Strings. J. L. Ward, Jr. *Oil Wkly*, 26.6.44, **114** (4), 46.—In a long paper the various factors affecting the design of casing strings are analysed. It is claimed as much as 20% of pipe can be saved by substituting lower classes of pipe in middle section of a casing string, and this without sacrifice of overall strength. A. H. N.

1195. Casing Bridge in Gas Well Removed under Pressure. C. C. Pryor. *Petrol. Engr*, July 1944, **15** (11), 51–54.—Recently a well in the Chapel Hill field was drilled to approximately 8200 ft. and cased with 5½-in. pipe through the Pettit lime. When the casing was perforated with about 80 shots the well unloaded a 10-lb. mud column before the gun could be pulled from the hole. Bottom-hole pressure of the well was estimated at 3600 lb. The well was equipped with a conventional blow-out preventer and a stuffing-box for the perforator line. A thread leak in the stuffing-box resulted in the box and line becoming so badly cut that 8000 ft. of line and the perforating gun dropped into the hole and the well completely unloaded. The operator immediately closed the blow-out preventer and shut in the well. An attempt was made to kill the well by pumping in 14-lb. mud; however, the well would take only about 55 brls. of fluid, indicating that the line had pumped down the hole and bridged the casing approximately 2700 ft. below the surface. The bridge formed by the line and the drilling mud were sufficient to hold the well, until a service company specializing in such operations could rig up to recover the line and gun and bring the well under control. The methods used are described and illustrated. A. H. N.

1196. **Blowouts—Their Causes and Prevention.** Part I. M. T. Works. *Oil Wkly*, 10.7.44, **114** (6), 57. *Paper Presented before American Petroleum Institute.*—The causes of blowouts are listed under two classifications. (1) *Causes under control of management:* (*a*) Use of improper drilling mud. (*b*) Failure to provide an ample reserve supply of mud. (*c*) Inadequate mud pumping equipment. (*d*) An inadequate casing programme. (*e*) Inadequate, obsolete, or worn-out control equipment. (*f*) Lack of periodic inspection of vital equipment and failure to authorize necessary repairs. (*g*) Failure to give complete and concise instructions to subordinates, and insufficient supervision. (*h*) Lack of practical educational and safety programme.

(2) *Causes under control of subordinate personnel.* (*a*) Drilling gas sands too fast. (*b*) Pulling drill-pipe off bottom too rapidly. (*c*) Bailing up the bit or drill-collar by drowning in sticky formations.. (*d*) Using too large a diameter drill-collar. (*e*) Pulling pipe out of the hole before the mud is in proper condition. (*f*) Failure to run fill-up pump frequently while pulling pipe from hole. (*g*) Use of low-pressure fittings in high-pressure control manifolds. (*h*) Procrastination in making rig repairs. (*i*) Continuing to drill or circulate during a heavy rain. (*j*) Failure to maintain the reserve mud supply in condition for use. (*k*) Lack of general vigilance for the unmistakable signs of gas. (*l*) Failure to obey specific instructions.

These items are discussed. A. H. N.

Production.

1197.* **Dual Completion With Crossover Packer in Dorcheat Pool, Arkansas.** P. Reed. *Oil Gas J.*, 30.3.44, **42** (47), 93.—Dual completion is practised in Columbia County, Arkansas. In most dual completions there, provision is made for producing from Smackover lime at depths of approximately 9000 ft. and from one of the series of Cotton Valley sand-lenses above an approximate depth of 8000 ft. Because of obstacles encountered in efforts to obtain commercial production in the customary manner, several departures were made from the usual procedures of the area. Among these is provision for producing from two Cotton Valley sands by dual completion with a crossover packer, making it possible to bring oil from the upper sand to the surface through the tubing. To facilitate this movement, gas-lift operations are now conducted which utilize gas from the lower formation. This is permissible because both upper and lower formations are characteristic sweet formations of the Cotton Valley series.

This method was adopted because the 42-gravity oil from the upper sand is produced with a low 200 to 1 gas–oil ratio, while gas and 66-gravity distillate from the lower sand is produced with an 18,000 to 1 gas–oil ratio. It was regarded as desirable to arrange for producing oil from the upper sand through tubing so that swabbing, pumping, or gas lift might be safely and conveniently applied when desired. Moreover, installation of the crossover packer was a means of avoiding "corkscrewing" of the tubing under conditions of high differential pressure. Tendency to corkscrew was also reduced by use of 2½-in. instead of 2-in. tubing between the two packers. Tubing down to the crossover packer is 2 in. A description of the various steps of completing the well indicates the manner in which routine methods are applied in dual completions in the Dorcheat–Macedonia area, and the particular measures which are peculiar to this well. Since the company is contemplating discontinuing producing from the upper sand and seeking production from another more profitable formation in the Cotton Valley series, it may be said that the well is still in the process of being completed.

The process is described in some detail. A. H. N.

1198. Application of Unit Operations to Fractionation and Other Vaporization Processes. R. L. Huntington. *Refiner*, May 1944, **23** (5), 188–191.—The applications of the law of conservation of mass and energy to the studies of material balance in gas reservoirs, is discussed and illustrated by a typical problem. Material balance is also applied to solved fractionation problems. A. H. N.

1199. Off-Balance Repressuring. F. R. Cozzens. *Oil Wkly*, 8.5.44, **113** (10), 55.—The principle is carried out first by cutting (temporarily) the driving force on certain induction wells in a given pattern, while force upon wells in adjoining patterns is materially increased; second, by eventually making each emptied oil-trap a pressure area which becomes a factor in squeezing out other traps in various parts of the project. The result is a 10–20% increase in recoverable oil; less labour and materials are required to produce it, and in many cases recovery time has been reduced one-third to one-half. Off-balance pressuring is put into effect when the first wells in a recovery pattern show signs of an oil decline. This is learned by daily gauging of individual wells. Granting that a continuous pressure has become reasonably stabilized in the sand over a period of time, the initial step is to reduce induction force on the input nearest the weakening wells as much as one half. The input may be throttled to cut the force, or excess pressure may be " blown off " at the casing head. Estimating (approximately) this cut in pressure in pounds, a like amount is promptly added to all inputs adjoining the weakened pattern. Thus, if 500 lb. of pressure have been released from the first input, an additional 500 lb. are added to each neighbouring input. The objective is to temporarily unbalance the former pressuring schedule in that immediate area, while driving force is directed towards the weakened pattern. The method is further detailed.

Unbalanced pressuring is not to be confused with intermittent injection (slugging), and is never in any case meant to replace uniform or continuous pressuring. The unbalancing process cannot function successfully until after a reasonable, stabilized pressure has existed in the sand for a period of time, and its sole purpose is to complete the recovery job. The volume of oil recovered depends, of course, on the amount of trapped oil in the sand, but almost without exception results justify the process. Finishing off is abrupt as well as effective, and eliminates the tedious, dwindling oil decline so commonly experienced when a project is terminated by regular uniform pressuring. Not only is the oil produced in less time, but more oil is recovered.

A. H. N.

1200. Drowning and Revival of Gas Wells. Parts I and II. S. T. Yuster and K. J. Sonney. *Oil Wkly*, 15.5.44, **113** (11), 22.—See Abstract No. 970. A. H. N.

1201. Treating Gas-Sands to Prevent or Overcome Bad Effects of Water. K. J. Sonney and C. E. Williams. *Oil Wkly*, 22.5.44, **113** (12), 18.—Laboratory experiments indicate that the harmful effect of water on gas-sands may be alleviated or obviated by the injection of certain fluids into the sand. Sands previously flooded with water were treated with alcohol, acetone, and acetone plus 10% ether, separately, and it was found that each hastened the removal of water from the sand pores. Further, when it was desired to " kill " a well entirely, other substances than water were used, thus preventing the harmful effects associated with water on the sand. This paper described large-scale experiments in which a gas-well was " killed " by using drip gasoline, gasoline, acetone, and water successfully. Least harm was observed with the gasoline, most with water. Other wells were also " killed " and revived. One of these had an open flow of 380,000 cu. ft./day and a rock pressure of 655 lb. gauge. Enough acetone was lubricated into the well to cover the producing sands, so that the uppermost sand was covered to a depth of 20 ft.; the remainder of the hole was then filled with water to a point sufficient to balance the formation pressure. The well was then bridged below the pipe depth but above the producing sands, and was completely dead for a period of seven days, during which time casing repairs were made. After the casing was repaired, the tubing was fished out and the bridge removed. Between the seventh and fourteenth days the wells started gassing slightly, but no fluid was added to stop the gas-flow. After the well was cleaned out, the fluid removed, and the well put back on production, the open flow was gauged at 346,000 cu. ft./day, a decrease of only 9% from the flow before filling. This compares with decreases in flow as great as 59% when other wells have been "killed" with water alone.

Results of these tests substantiate in a way the laboratory findings. It is believed that there is a wider field for application of this process, and further investigation should yield other suitable materials and methods of application. A. H. N.

1202. **Selective Plugging of Oil Sands.** Part I. S. T. Yuster and J. C. Calhoun. *Oil Wkly*, 29.5.44, **113** (13), 32. *Paper Presented before Independent Petroleum Association of America.*—Selective plugging is one of four main techniques used to overcome troubles in production due to variation of permeability in producing horizons. The paper discusses this technique as it is applied in water-flooding by using cement, wax distillate, or paper pulp. Another group of plugging agents depend on a chemical reaction for their sealing effect. This chemical action may take place between two chemicals which are injected separately or together into the formation, or the reaction may be between a chemical and some material in the sand. In the case of two injected chemicals, almost any two that will form a precipitate can be used. For example, calcium chloride and sodium carbonate could be reactants. The calcium chloride could be injected first, and it will go to the more open sections in greatest amount. This should probably be followed with a small amount of water to wash it off the sand face. The sodium carbonate solution would then be injected. A precipitate would form wherever the two solutions came into contact. Since this contacting must take place in the sand itself, the mixing of the two solutions will be definitely limited and will be further retarded by formation of any precipitate. It is felt that any plug formed under such conditions will not be too selective. A. H. N.

1203. **Equipment Corrosion in High-Pressure Wells.** W. F. Rogers. *Oil Wkly*, 29.5.44, **113** (13), 37–38.—Waters from condensate wells have been analysed and the results presented and discussed. The most serious corrosion reported to high-pressure well equipment has been to the top few joints of tubing and to the Christmas tree and associated equipment. This is evidently the result of precipitation of water from the gas prior to and in reaching this area, the precipitation resulting from the lowered temperature of the gas through both expansion from pressure drop and heat loss to the walls of the confining equipment. This precipitated water develops acidity through contact with the carbon dioxide of the gas. The constant impingement of this acid water against the metal equipment results in bathing these metal parts with an acid solution. This action combined with the high temperature of the gas and a relatively high gas velocity results in rapid corrosion attack. This, in general, explains the cause of the severe corrosion obtained. One remedy, therefore, is the use of alkaline treating materials to raise the pH of the water, which should be brought to at least pH 8·0. Even under this condition some corrosion will occur because of the high temperature and velocity of the gas, but its severity will be greatly diminished. While the general conditions which result in corrosion are as outlined, there may be apparent anomalies among wells which on the basis of incomplete data do not conform to any consistent corrosion theory. It is believed, however, that when the facts as to the carbon-dioxide content, the area and amount of water precipitation, and the temperature are known, the corroded areas will be found to be a function of these factors. A. H. N.

1204. **Treatment of Gas Sands.** K. J. Sonney and C. E. Williams. *Petrol. Engr*, June 1944, **15** (9), 90.—The use of special fluids instead of water in treating sands is discussed on the basis of experimental data. See Abstract No. 1201. A. H. N.

1205. **Oil Field Operation With Co-operative Engineering Committees.** V. E. Cottingham. *Petrol. Engr*, Reference Annual, 1944, **15** (10), 75. *Paper Presented before Interstate Oil Compact Commission.*—See Abstract No. 602. A. H. N.

1206. A Review of Porosity and Methods for its Determination. P. M. Phillips. *Petrol. Engr*, Reference Annual, 1944, **15** (10), 81. *Paper Presented before Independent Petroleum Association of America.*—Porosity is defined and discussed. Bulk volume determination by one of 4 methods is studied, followed by a study of determination of pore volume by one of 8 methods. A. H. N.

1207. Reservoir Performance. J. J. Mullane. *Petrol. Engr*, Reference Annual, 1944, **15** (10), 93. *Paper Presented before American Petroleum Institute.*—The chief factors controlling reservoir performance—including well spacing—are discussed. While the details of the analysis of any specific reservoir are often somewhat difficult, particularly when it is considered that, due to the vagaries of nature, each reservoir presents new problems, the basic principles are essentially simple and of considerable generality. Variations in the nature of the reservoir appear to modify only the details of its history, rather than the fundamental character. The fundamental features of the performance are, in a large measure, in the hands of the operator and the engineer. As has been shown, it is possible to determine in advance or at an early stage of production, in many, if not in most, fields, just what type of recovery mechanism is to be utilized. Accordingly, the broad, general outlines of the history of the operation can be laid out. Thereafter, what is required is the accumulation of accurate measurements of the properties of the system and accurate records of the production and performance, in order to maintain a detailed and uniform control of the operation. It is to be stressed that efficient operation of the reservoir means proper control of the entire reservoir, and not merely parts of it. As has been stated by S. E. Buckley, good practice on one lease and bad practice on another does not necessarily average out to give a reasonably good average performance. A. H. N.

1208. High-Pressure Production Equipment Corrosion. T. S. Bacon. *Petrol. Engr*, Reference Annual, 1944, **15** (10), 108. *Paper Presented before American Petroleum Institute.*—See Abstract No. 1218. A. H. N.

1209. A New Application of Water Injection for Maintaining Reservoir Pressure and Increasing Natural Water Drive. W. L. Horner and D. R. Snow. *Petrol. Engr*, Reference Annual 1944, **15** (10), 120. *Paper Presented before American Petroleum Institute.*—See Abstract No. 351. A. H. N.

1210. Flowing Producing Wells in Secondary Recovery. R. B. Bossler. *Petrol. Engr*, Reference Annual, 1944, **15** (10), 130. *Paper Presented before Independent Petroleum Association of America.*—The various factors affecting the behaviour of a flowing well are discussed. Whilst the number is large, most of them are of minor importance. It is believed that flowing producers under secondary recovery may result in economies. A. H. N.

1211. Fundamental Procedures in Estimating Costs for Second Water-Flood Recovery of Petroleum. A. C. Simmons. *Petrol. Engr*, Reference Annual 1944, **15** (10), 136. *Paper Presented before Independent Petroleum Association of America.*—The long paper analyses the various factors which influence costs of a secondary water-flood recovery. Those water-flood operating projects which have been unprofitable or which may become unprofitable may be segregated into three groups: (*a*) Low oil recoveries; (*b*) low unit prices, and (*c*) high operating costs. It is, of course, never possible to provide, with any degree of certainty, against failure of business enterprises, but with adequate investigation and preparation of thorough estimates it is hoped that future water-flood operations, particularly in the Mid-Continent area, will attain a higher ratio of financial success. Advance estimates of oil recovery can only be made through core analysis, and core-analysis interpretations are definitely improving, so that more accurate estimates of recoverable oil are now being made. A. H. N.

1212. Rôle of Connate Water in Secondary Recovery of Oil. P. A. Dickey and R. B. Bossler. *Petrol. Engr*, Reference Annual, 1944, **15** (10), 150. *Paper Presented before American Institute of Mining and Metallurgical Engineers.*—The hydrodynamics of reservoir fluids is discussed. The importance of critical water saturation is emphasized.

Although the discussion is speculative and is based largely on laboratory work on unconsolidated sands, which cannot be applied quantitatively to field operations, there is some evidence that critical water saturations exist and are important. In the Bradford field of Pennsylvania the average oil saturation is 40%, and the average water saturation 30%. Gas-drives in this field have caused a much smaller and slower recovery of oil than have water-drives. The inefficiency of gas-drives was due in part to the low permeability, which averages 10 millidarcys. Water-drives have been notably successful in this pool. In certain sections of the pool, however, the water saturation is higher than the average. It has been found that if the water saturation exceeds about 40%, no " bank " is formed, and oil is produced at uneconomically high water–oil ratios. In one district, where the water saturation was about 60% and the oil saturation about 30%, the initial water–oil ratio on flooding was about 20 to 1.

In the Venango field of Pennsylvania the normal oil saturation ranges between 25% and 35%, and the water saturation between 40% and 60%. In spite of very numerous attempts, no water-flood operation has been successful in these sands. In almost every case the water came through, bringing very small and uneconomical quantities of oil. Gas driving, on the other hand, has been quite successful. Recoveries as high as 100 brl./acre-foot have been obtained, and 50 brl./acre-foot are obtained frequently. This amounts to a reduction in saturation of 5–8% of the pore volume, which is remarkable considering the low initial oil saturations.

A. H. N.

1213. Factors Influencing Well-Spacing in Condensate Fields. E. O. Bennett. *Petrol. Engr*, Reference Annual, 1944, **15** (10), 158. *Paper Presented before American Petroleum Institute.*—A survey of spacing in distillate pools shows that these, up to date, have varied from field to field. No general spacing rules can be set up, as spacing is an integral part of the programme and not subject to separate economic rules.

A. H. N.

1214. Many Economies Effected by Exclusion of Water from Wells. E. A. Stephenson. *Oil Wkly*, 5.6.44, **114** (1), 29–32. *Paper Presented before American Petroleum Institute.*—While the complete elimination of water from all oil-wells may not be possible, and in many instances not wholly desirable, the deleterious effects of salt water when present in large quantities are unquestioned. Of the many procedures which have been tried for the purpose of excluding it from wells, some have proved highly effective. Notable among these have been the use of mud-laden fluid and cement slurry pumped into wells under pressure and allowed to either gel or set while the pressure is maintained on the fluid system. Cement has also been pumped through perforations, especially prepared for the purpose. Plugging back to impervious beds, such as thin shale layers, has eliminated the water more or less successfully. Bottom-water has been shut off successfully by means of lead wool matted at the bottom of the hole, or by the use of oakum, hemp rope, wooden plugs, or various combinations of all of these. Packers have also proved effective for this purpose. Chemicals which react with water and form impervious sheaths or membranes between the mineral grains have proved beneficial in certain formations and wells. More recently plastic compounds in liquid form have been placed in the bottoms of oil-water wells. The latter form a bond with the walls of the hole and become solid under the influence of the high well temperature.

The merits of the water exclusion treatment may be summarized as follows: (1) Lower lifting costs/barrel of oil. (2) Reduced investment in salt-water-disposal equipment. (3) Saving in wear on pumping equipment. (4) Curtailment of corrosion and its attendant expenses for maintenance and replacements. (5) Reduction in cost of treating oil, since much clean oil is produced instead of emulsion. (6) Treatment is relatively inexpensive. (7) Practically impossible to damage a well by this procedure. (8) Readily adapted to successive low-cost applications as bottom or edge-water encroachment make repeated treatments desirable. A. H. N.

1215. Selective Plugging of Oil Sands. Part 2. S. T. Yuster and J. C. Calhoun. *Oil Wkly*, 5.6.44, **114** (1), 34.—Selective plugging is further studied and plugging by emulsion is discussed. Selective plugging in air and gas driven is described briefly. In summary, it is stated that there are a large number of selective plugging methods open to the oil industry, but in general (except in special cases) the most effective agents are those which are miscible with the flow fluid in all proportions. A further condition for success is that these materials are permeability reducers and not sealers or pluggers. A. H. N.

1216. **Possibilities of Production from Lime Formations Given the "Acid Test."** F. Squires. *Oil Wkly*, 5.6.44, **114** (1), 42.—The author prepared in 1936 a paper on the "Present Status and Future Possibilities of Acid Treatment in Illinois." In the present paper he takes the 1936 paper paragraph by paragraph and compares to-day's performance with the prediction made. A. H. N.

1217. **How Different Size Gas Caps and Pressure Maintenance Programmes Affect Amount of Recoverable Oil.** J. Tarner. *Oil Wkly*, 12.6.44, **114** (2), 32.—Calculations can be made for reservoir performance that are typical for any reservoir and can be made to forecast the performance of a particular reservoir when the relative permeability ratios have been established from past production records. Next to the mechanical manipulation of producing wells the relative permeability ratios have the most critical effect on calculation of reservoir performance. There can be no mathematical treatment that will account for the overall change in the gas–oil ratio of a particular field accompanying the shut down of all high gas–oil ratio wells. A change caused by this condition can only be caught by the foresight of the engineer making the calculations. These calculations cannot be made a mechanical operation, but must necessarily depend on the judgment of the engineer and his familiarity with the problem concerned. The amount of recoverable oil from any reservoir is unique for that reservoir alone. Similar reservoirs containing fluids having similar properties will not necessarily have the same amount of recoverable oils, as the recovery is dependent on the size of the gas-cap and to what extent the energy of that gas is utilized. These calculations show that there is a definite advantage to the unitized production of oil-fields, even though no pressure maintenance programme is started. Unitization should be especially desirable in those fields where the gas-cap forms an appreciable part of the total reservoir volume. Pressure maintenance programmes where a portion of the produced gas is returned to the reservoir should generally result in an appreciable increase in the volume of oil recovered. The earlier the programme is started and the greater the volume of gas returned to the reservoir, the greater will be the increase in recovery. However, the rate of production, desirability of flowing the wells, volume of reserves, conditions of gas sales, and the type of reservoir should all be considered before it can be said that there is an advantage in starting a pressure maintenance programme at any particular time.

An appendix gives by the derivation of the formula for calculating instantaneous producing gas–oil ratios. A. H. N.

1218. **Corrosion of High-Pressure Gas Production Equipment.** T. S. Bacon. *Oil Wkly*, 19.6.44, **114** (3), 34.—This long paper describes the types of corrosion obtained, corrosion tests, and remedial work. Future work is outlined. The main conclusions are: The problem of corrosion of high-pressure production equipment is a very real problem, insofar as the petroleum industry is concerned. Information regarding the exact causes of this corrosion is not presently available. No generally satisfactory methods of combating this corrosion have been proved. The problem can best be attacked by the co-operative efforts of the petroleum industry. A. H. N.

1219. **Determining Wall Thickness of Tubing in Wells.** W. A. Sawdon. *Petrol. Engr*, July 1944, **15** (11), 55–56.—An instrument is described which can give the thickness of the tubing hanging in the well for classification purposes in deciding which section of the tubing should be rejected from further service. This classification is determined by Dia-Loy tubular surveys, which are usually run while the tubing is in the well, but which can be made when the pipe is on the rack. The surveys can also be made on casing to be salvaged, as mentioned in a previous article. In making the survey in the well, the instrument is run on a 5/16-in. steel wrapped cable, through which current is conducted from batteries at the surface. The cable is raised and lowered in the well with a winch that is driven through a power take-off by the engine of the truck in which the equipment is mounted. A measuring device measures the cable in and out of the hole, and also drives an automatic recorder in synchronization with the cable, so that the vertical scale on the record chart remains constant at 50 ft. of depth/inch, regardless of the speed at which the survey is made. Surveys are made from the bottom up to assure greater accuracy.

The instrument and the charts produced are illustrated diagramatically. A. H. N.

1220. Exclusion of Water from Wells. E. A. Stephenson and P. T. Amstutz, Jr. *Petrol. Engr*, July 1944, **15** (11), 57. *Paper Presented before American Petroleum Institute.*—See Abstract No. 1214. A. H. N.

1221. Well Completions Facilitated by Liner Shut-Off Equipment. H. G. Abadie. *Petrol. Engr*, July 1944, **15** (11), 101.—The bypass port coupling is the essential part of the equipment. There are three or four holes in the body of the coupling of sufficient size to provide the desired area for return flow. On the inside of the coupling is a threaded pack-off sleeve with projecting keys. These keys are engaged by the projecting ridges of the splined nipple. Rotation of the run-in string to the right moves the bypass sleeve downward until the lower end seals in the recess of the port coupling. The design of the splined nipple permits complete freedom of movement through the sleeve at all times without danger of hanging up. The length of the splined nipple is sufficient to permit safe positioning opposite the keys of the port coupling. The pack-off coupling is essentially a nipple with an internal rubber sleeve held in place by metal retaining rings. It is used to provide a positive seal around the tailpipe hanging below the run-in string. To complete the assembly, a pack-off liner hanger is required. It may be either a screw-down type or weight-expanding type of hanger. Lead is preferred as the packing elemnt, since it is more stable than packing rings when subjected to oil and heat. The liner hanger adapter used has been the J-slot adapter. Screw releasing type adapters have been used successfully, however.

The method of installation and operation are given. A. H. N.

Transport and Storage.

1222.* Cleaning and Gas Freeing Cargo Compartments on Tankers. G. D. Washburn. *Oil Gas J.*, 24.6.44, **43** (7), 101.—The procedure adopted by the Standard Oil Co. of California is described. The most important part of cleaning operations is the planning of the operations. Where " dirty " oil has been carried, cargoes of cutting or cleaning oils should be carried, as in this manner tanks can be brought to any desired degree of cleanliness. Cleaning should be planned to be carried out whilst the vessel is in ballast if time allows. Mast high vents are fitted with pressure and vacuum valves. All tankers are fitted with a flue-gas system which is used during the discharge of the cargoes and prevents the formation of explosive vapours, every possible precaution being taken to prevent sparks being formed at all times. Before cleaning commences, the flue gas and any vapours in the emptied tanks are removed by running the steam air-injector. A carbon dioxide tester is used to ensure that the tank is safe for men to enter. A tank may be free of noxious gases, but if left closed for any considerable time, may become unsafe through depletion of oxygen by rust formation. Specific safeguards are discussed. Constant supervision of the men is necessary when cleaning tanks. The Standard Oil Co. employ portable washing machines using hot water at 185° F. at 175 p.s.i. through two rotating nozzles. The machines are lowered into the tanks for working at different levels and are connected to the water supply by a heavy bonded rubber hose. After washing and draining and after sure knowledge that there is a pure atmosphere, men may enter for hand flushing so as to get behind beams, etc., and hand hose the bottoms. Brass scoops and buckets and brushes are used to remove rust and dregs. When steam or hot water has been used, the steam air-ejector is employed to remove any volatile vapours, etc., the ullage plug being left open for the entry of air. Wind sails or a portable air-blower can be used for the smaller vessels or shallow tanks. Combustible gas indicators are also part of the equipment for use as required. W. H. C.

Crude Petroleum.

1223.* Cracking of Latin American Crude Oils. 1.—Eastern Venezuela. G. Egloff. *Oil Gas J.*, 24.6.44, 43 (7), 74.—Venezuelan crude oils are of the three general types, they have A.P.I. gravities from 13·5 to 35·3, their sulphur content varies from 0·1 to 2·4%, and their gasoline content ranges from 0 to 50%, the higher gravity crudes contain large amounts of paraffin.

The paper gives the results of cracking reduced crudes in a Dubbs two coil pilot plant from (1) an Oficiana crude, and (2) from mixed Eastern Venezuelan crudes.

(1) Oficiana reduced crude of sp. gr. 0·9408, containing 1·65% sulphur, yielded 29·3% of cracked gasoline with a gas and loss of 5·6%, under operation at 890° F. and 960° F. and 200 and 250 p.s.i. at the exits of the heavy and light coils, respectively.

The cracked gasoline had an octane value of 7·05 A.S.T.M. and contained 0·25% sulphur and 0·035% mercaptan sulphur and 5·2% butylenes from which high-octane alkylate could be formed equal to 2·3% of the cracking charge. The gas contained C_3 and C_4 olefins, which on polymerization would give polymer gasoline equal to 2·0% of the cracking charge. The yield summary shows :

Cracked gasoline, vol. % of charge	29·6
Polymer gasoline	2·0
Alkylate	2·3–33·9%
Fuel oil residue	65·1

The cracked gasoline after clay treatment, caustic wash, and Doctor treatment is a marketable product, having a sulphur content of 0·02%, mercaptan sulphur 0·01%, and a copper dish gum figure of 9 mg. Its octane value is 69·5. The induction period before refining is 205 minutes without inhibitor, and after refining 390 without, and with 0·0025% No. 4 inhibitor 660 minutes.

(2) The mixed reduced crude charge stock had 1·2% sulphur, and a gravity of 0·9446 was cracked in two ways, (*a*) operation for a normal viscosity fuel at 915° and 950° F. and 215 and 250 p.s.i., respectively, for the heavy and light coil exits; (*b*) "cutback" method, *i.e.* producing a higher viscosity residue and reducing it with a side cut from the plant. The yield for these operations are :

	Operation.	
	Normal.	Cut back.
Gasoline, vol. % of charge	26·2	31·0
Gasoline sulphur	0·26%	0·25%
Mercaptan sulphur	0·042%	0·041%
Octane value, A.S.T.M.	68·3	69·1
Gas and loss	3·3%	4·7%

Proportioned mixtures of the receiver and stabilizer gases from both runs were separately analysed. From these analyses by calculation for a 75% conversion of the C_3 and C_4 olefins to polymers 2·0% and 2·3% would be obtained, and alkylate from the C_4 olefins in the unstabilized gasoline could be produced amounting to 1·0% and 1·7% to augment the gasoline produced.

The yield summary shows :

	Operation.	
	Normal.	Cut back.
Cracked gasoline, vol. % of charge	26·22	31·0
Polymer gasoline	2·0	2·3
Alkylate	1·0—29·22%	1·7—35·0%
Fuel-oil residue	70·5	64·3

W. H. C.

1224.* Cracking of Latin American Crude Oils. 2.—Western Venezuela. G. Egloff. *Oil Gas J.*, 1.7.44, 43 (8), 64.—The Lake Maracaibo Basin (asphaltic base) crude oils are described and the results of cracking operations on these are given. (A) Lagunillas crude has a gravity of 0·9535 and contains 2·37% sulphur and 7·5% gasoline. Cracking was conducted to produce gasoline and (1) three types of residuum and a coke (at 910–935° F. and 200 p.s.i. at coil exit) in a one-coil pilot plant, and (2) coke in a two-coil unit (at 900–935° F. and 200 and 400 p.s.i., respectively, at the exits of the heavy and light coils.)

(1) The untreated gasoline had A.S.T.M. octane values of 72 for the less mild cracking and 71 for the coking product, the yields being :

For residue of sp. gr.	0·9902.	0·9986.	1·079.	Coke.	Coke.
Gasoline, %-vol.	24·7	30·8	46·5	67·0	58·0
Residuum, %-vol.	75·0	68·0	46·2	—	—
Gasoline :					
Sulphur, %		0·30		0·33	
Gum (copper dish), mgr.		39		52	
Reid vapour pressure, p.s.i.		11·8		—	

Treatment of the gasoline was made with (1) H_2SO_4, 4 and 7 lb./brl., and plumbite; and (2) the Gray process. The products, all marketable, had octane values ranging from 70 to 72, sulphur from 0·14 to 0·19% for the acid treatments and 0·23% for the Gray-treated material, and the gum content (copper dish) 3–24 mgr. without and with inhibitor 2–12 mgr. The induction period of the treated gasolines are given for the uninhibited and for 0·025% No. 1 inhibitor :

	Residuum.		Coking.	
	Without.	With.	Without.	With.
Gray-treated	85	225	—	—
4 lb. H_2SO_4	55	220	80	465
7 lb. H_2SO_4	70	425	90	660

(2) The untreated gasoline from the two coil-coking operation had an octane value of 75, the yield being 58%.

(B) La Rosa crude is asphaltic in character, had a gravity of 0·9141, and contains 1·7% sulphur and 15% gasoline. This was cracked in three ways in a Dubbs single-coil pilot plant to produce gasolines and an 12 A.P.I. fuel, a No. 6 A.S.T.M. fuel, both at 930° F., the former at 260 and the latter at 280 p.s.i. with lower charge rates; the third operation was two-coil recycling cracking at 902° and 954° F. with 250 and 400 p.s.i. in the light and heavy coils respectively. The yields were :

For Residuum of—	12° A.P.I.	A.S.T.M. No. 6 Fuel.	Coking.
Gasoline, vol.-%	39·2	44·5	60·1
Residuum, vol.-%	58·8	52·8	—
Gasoline :			
Sulphur, %	0·19	0·18	0·19
Gum, mgr.	69	27	17
Octane number	69	69	74
Induction period without	120 min.	135 min.	120 min.
Induction period with, 0·025% No. 1 inhibitor	165 ,,	215 ,,	265 ,,

Treatment of the gasoline from the 12° A.P.I. operation by NaOH and then H_2SO_4, 4 lb./brl., gave a product of 67 octane value, containing 0·09% sulphur, with a gum content of 6 mgr. and induction period of 95 without and with 0·025% No. 1 inhibitor, 550 min. The same refining of the gasoline from the other runs required 0·025% of inhibitor to reduce the gum content to 10 mgr., but this amount with the 12° A.P.I. fuel gasoline only reduced the gum from 6 to 5 mgr. W. H. C.

Gas.

1225. How Will the New Processes Affect the Postwar Light-Ends Situation? D. P. Barnard and J. H. Forrester. *Refiner*, May 1944, 23 (5), 165–170. *Paper Presented before Natural Gasoline Association of America.*—Statistical data are presented on the supply and demand of various components of natural gas in the U.S.A. The national butane balance will not be greatly changed by the introduction of the new facilities constructed during the war. It is true that the extensive catalytic-cracking operations will produce greater amounts of butanes than heretofore, but it is also true that there will be increased uses for such butanes. The indicated net result is that the new consumption will exceed the new production—but not by an amount sufficient to make possible utilizing all recoverable butanes for purposes other than fuel. No great change in average front end motor-gasoline volatility is to be anticipated from the various combined factors, although local instances of large front-end volatility increase may develop. It is emphasized that front-end volatility must be kept within reasonable limits if best results are to be obtained by the gasoline user. Butanes from natural gasoline apparently will have at least as large a field of use as before the war, but there will probably still be substantial amounts that can find no use other than as refinery fuel. To the extent that larger amounts of C_4 fractions can be incorporated in motor gasolines, they should be so used in the interest of oil conservation, but they must be used judiciously. It must be remembered that a reasonable degree of uniformity of motor fuels is essential, particularly in volatility characteristics, if the automobile industry is to produce vehicles which will utilize gasolines most efficiently and with freedom from those difficulties associated with fuel properties. If it appears that relaxing of present vapour-pressure limits of motor gasoline to make possible utilization of surplus butanes is of sufficient advantage, the question should be considered thoroughly and promptly by both the petroleum and automotive industries. Certain limitations to raising the volatility of the petrol are discussed. A. H. N.

1226.* Incompressible vs. Compressible Flow in Pipes. R. C. Binder. *Chem. Met. Engng*, June 1944, **51** (6), 99–100.—When an incompressible fluid flows adiabatically in a pipe the relations are simple and well understood. Flow of a compressible fluid, however, is much more complex. On this account it is often the practice, when dealing with a small pressure drop of compressible fluid, to assume that the result will be close enough for engineering purposes, and apply the incompressible fluid laws. Professor Binder shows mathematically, and then by plotted results, just how different the two relations are, and what errors may be introduced if the simpler law is used for gases at high velocity or large pressure drop. He also presents a type of chart enabling use to be made of the simpler relation, with the introduction of a correction which can be obtained from the chart. A. H. N.

Cracking.

1227.* Suspensoid Catalytic Cracking System Gives Nearly 60% Yield. A. L. Foster. *Oil Gas J.*, 4.5.44, **42** (52), 43–46.—The process developed by the Imperial Oil Co., Ltd., and operated in its refinery at Sarnia, Ontario, consists of mixing a small quantity of pulverized clay catalyst with the charging stock and pumping the mixture directly through the heater coils. The plants used are thermal cracking units of the tube and tank type which have been in operation for several years and which had a total nominal capacity of 17,500 brl. a day of charging stock of gas-oil type. U.S. and Canadian patents have been obtained to cover the new method of operation. The additional equipment required included clay storage capacity in the form of steel cone-bottomed clay hoppers, slurry mixing-tanks fitted with stirrers, special pumps to handle the slurry and discarded catalyst, various special metering devices, piping and valves, three special pressure precast Oliver rotary filters for recovery of spent catalyst, a screw conveyor and bucket elevator for handling recovered catalyst and clay bins, accessory piping, etc. Spent Filtrol from the lubricating-oil contact plant (100% through 100 mesh) is transferred to the cone-bottomed hoppers situated over the slurry tank in which the clay is mixed with a portion of the oil-feed. The oil-feed normally consists of about 75% gas-oil fractions and 25% of heavy naphtha. En route to the heaters via heat exchangers, the main oil-feed picks up a measured quantity of the slurry so that the final charge consists of about 2 lb. of clay per brl. of feed. The combined charge is heated to 1040–1060° F. in the coil under a pressure of 400–500 lb./sq. in. and is discharged directly into the flash-chamber. The charge is quenched with cracked gas-oil to about 750° F. at the coil outlet, requiring 35–40% of cracked gas-oil based on feed-stock. The vapours from the flash-chamber pass to fractionating equipment, the bottoms from which are used as furnace oil or low-cetane diesel fuel. The unvolatilized tar-catalyst mixture from the flash chamber passes via receivers to the rotary filters for removal of catalyst at a temperature of 450–500° F. The recovered tar is used as fuel or for manufacture of asphalt. The spent catalyst is at present dumped, but plans for regeneration have been prepared for installation when equipment is obtainable.

Erosion of equipment is said to be little more than when operating as a thermal unit. If pressure is allowed to drop to about 200 p.s.i., however, serious erosion may occur. A special orifice was designed to substitute the pressure release valve which gave trouble, and other desirable modifications are described. Further research on improvement of gasoline octane rating is planned. The best results from both operational and product quality aspects have been obtained when using the lowest temperature and the longest time at cracking temperatures that ensure complete vapourization of the high boiling components in the system. Yields and qualities obtained from the feed stock previously mentioned are : Gasoline 52·3% of E.P. 400° F., R.V.P. 10 lb., O.N. (A.S.T.M.) 73·2 ; excess C_4 4·5%, heating oil 12·7%, fuel oil (10° A.P.I.) 20·2%, dry gas 12·5% wt. With production of non-selective polymer, the yield of gasoline increases to 58·6% of 75·5 O.N. (A.S.T.M.). The O.N. by the 1939 Research method of this gasoline is 85·1 clear and 93·2 after addition of 3 mls. T.E.L. per AM. gal.

R. A. E.

1228.* **Catalytic Dehydrogenation of Natural Gas Hydrocarbons.** C. H. Riesz, T. L. Pelican, and V. I. Komarewsky. *Oil Gas J.*, 15.7.44, **43** (10), 105.—The results are given for single pass dehydrogenation of *n*- and *iso*-butane, propane, and ethane in the presence of a co-precipitated Cr_2O_3–Al_2O_3 catalyst at 450°, 500°, and 550° C. under atmospheric pressure and compared with the results obtained by other workers using Cr_2O_3–Al_2O_3 and SiO_2–Cr_2O_3, both prepared by impregnation, and other catalysts. The co-precipitated catalyst at 450–500° C. gave results closely approximating the calculated equilibrium dehydrogenation concentrations for *n*- and *iso*-butanes. With propane 80%, and ethane roughly 50%, of the calculated figures was obtained. At 450° and 500° C. it was found necessary to allow the reaction to undergo an induction period before maximum catalyst activity was attained at a given contact time. The induction period varied with the reaction conditions and increased in the order *n*-butane, *iso*-butane, propane, and ethane. The induction period can be reduced by the passage of *n*-butane over the catalyst before the dehydrogenation of any one of the other hydrocarbons. The results obtained at 550° C. show that side reactions occurred and the catalyst activity for dehydrogenation decreased. The data of the reactions at 450° and 500° C. shows that at the optimum and shorter contact time for a given temperature the products of the dehydrogenation were practically all the mono-olefins anticipated by the reaction equations and that no appreciable amounts of other products were formed.

W. H. C.

1229. **Patents on Cracking.** M. Pier, K. Peters, and G. Free. U.S.P. 2,331,930, 19.10.43. Appl., 15.2.39. To convert higher-boiling hydrocarbons into normally liquid hydrocarbons of lower boiling point, they are intially cracked by passing them at splitting temperature over a catalyst, for such a time that only a non-exothermic reaction takes place. The hydrocarbons after they have left the catalyst are mixed with a gas heated to a temperature substantially higher than that of the hydrocarbons. Afterwards the hydrocarbons are further split in the absence of a catalyst.

G. Free and W. V. Fuener. U.S.P. 2,334,871, 23.11.43. Appl., 5.8.39. A process is described for the production of hydrocarbon oils by catalytic cracking of higher-boiling hydrocarbon oils at a temperature between 300° and 700° C. in the presence of a silica gel catalyst. The catalyst is obtained from a silicic acid sol, and at least one compound of a polyvalent metal. During its preparation a silica hydrogel is formed while the hydrogen-ion concentration of the sol is maintained between pH = 4 and pH = 6·5 throughout the duration of the hydrogel formation.

H. B. M.

Polymerization and Alkylation.

1230. **Patent on Polymerization and Alkylation.** A. V. Grosse and C. B. Linn. U.S.P. 2,335,507, 30.11.43. Appl., 17.11.41. In the synthesis of hydrocarbons an *iso*-paraffin is reacted with an olefin in the presence of an alkylating catalyst consisting essentially of hydrogen fluoride as its active ingredient. The hydrogen fluoride is generated *in situ* by interaction of a strong mineral acid with a fluoride under conditions suitable for alkylating the *iso*paraffin.

H. B. M.

Refining and Refinery Plant.

1231.* Heat Transfer by Conduction, Radiation and Convection. H. J. Stoover. *Chem. & Met. Engng*, May 1944, **51** (5), 98.—In a special section on heat transfer in this issue of *Chenical and Metallurgical Engineering*, this paper deals with the equations of heat transfer in conduction, radiation and convection. Examples illustrate the use of the formulæ. A. H. N.

1232.* Film Coefficients for Liquid. Anon. *Chem. Met. Engng*, May 1944, **51** (5), 102–103.—Tables and nomographs are given for different cases. To obtain the desired film coefficient, a base factor corresponding to the liquid and temperature under consideration is taken from the proper table and multiplied by a correction factor read from the nomograph accompanying that table. The following assumptions apply in each case: (1) The system is in equilibrium—that is, there is no change in temperature gradient with time; (2) radiation is negligible or has been taken into account by other calculations; (3) film temperature is defined as the arithmetic average of the temperatures of the retaining wall and the main body of the liquid. A. H. N.

1233.* Film Coefficients for Gases, Condensing Vapours, and Boiling Liquids. Anon. *Chem. Met. Engng*, May 1944, **51** (5), 104–105.—A similar treatment to the previous abstract is given here. Several special cases including an equation for scale coefficients are given. A. H. N.

1234.* Film Coefficients for the Condensation of Vapours. R. F. Benenati and D. F. Othmer. *Chem. and Met. Engng*, May 1944, **51** (5), 107.—A short description, followed by a nomograph, is given. A. H. N.

1235.* Heat and Cold Production and Application for Processes. W. J. Shore. *Chem. and Met. Engng*, May 1944, **51** (5), 109–117.—The paper describes in some detail the various processes available for generation or abstraction of heat in industry. Combustion and cooling phenomena are studied in particular. Heat transfer principles are described. A. H. N.

1236.* Special Media for the Transfer of Heat. Editorial Staff. *Chem. and Met. Engng*, May 1944, **51** (5), 118–119.—Water, Dowtherm, and Mercury are studied in relation with heat transfer characteristics. A. H. N.

1237.* Equipment for Heat Transfer and Heat Application. M. W. Schwarz. *Chem. and Met. Engng*, May 1944, **51** (5), 120–128.—Eighty-two types of equipment for heat transfer are illustrated and briefly described. Gas, electric, and other methods of heating and cooling are described for solids, evaporation, drying, condensation, and for fusion and freezing. A. H. N.

1238. How to Train Plant Personnel in Fire Prevention and Fire Fighting. A. W. Trusty. *Refiner*, May 1944, **23** (5), 159–164.—Statistics of fire losses and the causes of fires in the U.S.A. are given. Smoking caused the greatest number, whilst the greatest monetary loss was due to electrically caused fires. Elements of combustion theory and practice are given, together with suitable demonstrations of the laws of combustion by simple experiments. Fire extinguishers and extinguishing methods are then described, giving the chief characteristics and limitations of each. Electrical hazards encountered in extinguishing fires are also detailed. A. H. N.

1239. Centrifugal Compression of Hydrocarbon Gases. E. O. Bennett. *Refiner*, May 1944, **23** (5), 181–185. *Paper Presented before Natural Gasoline Association of America.*—An historical sketch of the development of rotary prime movers and pumps is given. The same fundamentals of design enter into both centrifugal pumps and centrifugal compressors except that the centrifugal compressor, due to the necessity of handling compressible fluids of less density than normal centrifugal pumps handling liquids is, in most cases, operating at considerably higher rotating speeds. Higher speeds in centrifugal compressors, such as used in turbine practice, call for large diameter shafts that make a very rugged type machine. Steel discs are used in the construction of the rotary members to provide adequate strength. Where several stages of compression are required, thin metal labyrinths are used to prevent leakage between stages. The labyrinth seal is very effective, and is practically frictionless. Such seals have been used in steam turbines for many years, and there is nothing new or radical in their use. No metal contacts exist in the labyrinth seals. The only parts of a centrifugal compressor subject to mechanical wear are the two main-shaft bearings, and it is a well-known fact that with proper design and lubrication the life of a high-speed bearing is very great, and the shafts and bearings will retain their original dimensions for a great many years. Reciprocating machines of modern design have bearings that last much longer than those of the early machines, but cannot begin to compare with the life of high-speed centrifugal equipment. Due to its simplicity of design and minimized number of wearing parts, the mechanical efficiency of a centrifugal turbine is found to be over 99%. The mechanical efficiency of a reciprocating-type unit is somewhat less.

Characteristics of centrifugal compressors are discussed in general terms.

A. H. N.

1240. Applications of Nickel-Containing Corrosion-Resistant Alloys in the Petroleum Industry. B. B. Morton. *Refiner*, May 1944, **23** (5), 186–187. *Paper Presented before National Association of Corrosion Engineers.*—Different types of corrosion in refineries are discussed, and the appropriate alloy to resist the particular corrosive is recommended. The short paper deals with corrosions from sulphur, naphthenic acid, electrolytic attacks, hydrochloric acid, sulphuric acid, hydrofluoric acid, phosphoric acid, solvents, caustics, and general refinery corrosion. A. H. N.

1241.* Practical Refinery Engineering.—1. Heat Transfer by Conduction. P. Buthod and E. W. Whiteley. *Oil Gas J.*, 17.6.44, **43** (6), 99.—This is the first of a series of papers covering all important aspects of heat transfer. This article briefly discussed the mechanism of heat transmission and gives the fundamental equation of heat transfer: (1) $q = UA\Delta t$ where q = amount of heat transfer in B.t.u. per hour; U = overall coefficient of heat transmission, B.t.u. per hour, per sq. ft., °F; A = area of heat transfer, sq. ft.; t = true mean temperature difference °F. Calculation of the overall heat transfer coefficient is usually based on film and metal wall resistance.

A heat transfer conduction chart is given which may be used to facilitate the calculations for cases of pure conduction or for obtaining metal wall resistance for overall heat transfer coefficients. W. H. C.

1242.* Piston-Balloon Vapour Unit Saves $16,000 Annually. R. B. Tuttle. *Oil Gas J.*, 17.6.44, **43** (6), 113.—Owing to high naphtha vapour losses incidental to increasing temperatures in the manufacture of certain lubricating oil stocks, a comparative study was made of two vapour recovery systems, *i.e.* a conventional compressor type and the Wiggins Piston-Balloon tank.

A 20,000 cu. ft. piston-balloon tank is tied in with all the naphtha tanks by lines from their tops which slope towards the balloon tank, all entering a common vapour line fitted with two pressure reducing valves and, as a safety measure, glycerine-sealed pressure regulators for 1½-in. water operation. The piston-balloon tank is briefly described, and the operation of this unit is discussed.

The temperatures of some of the tanks in the system often run as high as 160° F. and frequently 140° F. is maintained over long periods. Large naphtha vapour volumes, including some water, are produced during these periods. Roofs of tanks last nearly twice as long with this system as compared with the compressor type method.

Maintenance costs and savings on tank-roof corrosion are shown; the potential net earnings over eight years are estimated to be $128,227·80. W. H. C.

1243.* Practical Refinery Engineering.—2. Determination of Mean Temperature Difference. P. Buthod and B. W. Whiteley. *Oil Gas J.*, 24.6.44, **43** (7), 84.—In calculationg heat exchange for refinery and commercial equipment, the true mean temperature difference Δt, used in the fundamental equation, (1) $q = UA\Delta t$, should take into consideration any variation of temperature of the hot and cold fluids throughout the length of the exchanger. Δt is dependent to a large extent on the conditions of flow within the exchanger unit. Temperature-distribution curves for counter-current flow, parallel flow, and for constant heating and constant cooling systems are given in a chart for the calculation of log mean temperature difference, for single pass tubular exchangers. Charts are also shown by which correction factors for log mean temperature differences can be obtained for multi-pass heat exchangers.

W. H. C.

1244.* Tannin Solutizer Process Practically Automatic; Saves 6·5 Cents Per Barrel. J. P. O'Donnell. *Oil Gas J.*, 1.7.44, **43** (8), 45.—The Socony-Vacuum Company has developed an improvement of the Shell Solutizer Process which has proved most satisfactory. The improvement is due to the addition of a small amount of an alkali-soluble tannin to the solutizer solution. Tannin acts as a catalyst in the air oxidation of the soluble mercaptans to insoluble disulphides. In this development, regeneration by oxidation replaces regeneration by steam stripping and has the following advantages : (1) equipment needs are reduced ; (2) lower temperatures are employed, which reduces plant deterioration ; (3) the most expensive feature—*i.e.*, steam stripping—is practically eliminated. By the tannin treatment, the total mercaptans in a gasoline, containing 0·065% mercaptans, are reduced to 0·002%.

The clear octane number is unaffected and the lead susceptibility improved. A flow diagram of the process is given and its operation and control is described. The solutizer solution is described as being composed of 4·6% N. NaOH, 0·9 N. NAK (the solutizer), and 1% tannin. A comparison of the operating costs of the tannin : doctor processes is tabulated, and discussed. It shows that the doctor treatment, formerly used, including the detrimental effect of lead susceptibility, costs 2·75 cents per barrel, whereas the tannin process, taking into consideration the improvement in lead susceptibility, results in a return of 3·68 cents per barrel. The value in the improvement in lead response of the latter more than offsets the direct operating costs. By converting an operation involving expense to one producing an income, the net advantage amounts to 6·45 cents per barrel. W. H. C.

1245.* Practical Refinery Engineering.—3. Practical Heat Transfer Calculations. P. Buthod and B. W. Whiteley. *Oil Gas J.*, 1.7.44, **43** (8), 50.—A simple case of heat transmission is discussed for a heat exchange between a hot and a colder fluid in an exchanger. Heat transmission of the hot fluid takes place chiefly by convection; next to the metal walls, however, the heat encounters a stagnant film of fluid through which it must flow by conduction, as the heat passes through the stagnant fluid film it meets a further, though slight, resistance in the metal wall, and again more resistance is met with in the stagnant film and body of the fluid on the cold side of the wall.

Heat-transfer calculations consist principally of the computation of these thermal resistances and the true mean temperature difference which causes the flow of heat. Equation (1) becomes

$$q = \frac{A\Delta t}{R1 + R2 + R3}.$$

Many difficulties which arise in the calculations are avoided by the use of a mass-velocity term, which is the product of velocity and fluid density. It is expressed in pounds per hour per square foot, and this term remains constant throughout the length of the exchanger.

A chart is given from which the mass velocity can be directly determined for cases where the flow rate is given in barrels per day, gallons per hour, pounds per hour or 1000 cu. ft. per day units. Examples of its use are shown. W. H. C.

1246.* Apparatus for Screening Catalyst. Anon. *Oil Gas J.*, 1.7.44, **43** (8), 69.—A home-made shaker for sifting regenerated catalyst is briefly described. The assembly consists of a platform under which a screen is slung on long hangers. The screen is vibrated by a slow-moving air motor by means of connecting rods actuated by cams on the motor shaft. Fines pass through the screen to barrels, and the clean catalyst pellets float over the screens and drop into hoisting drums (described) for transfer, by air-actuated hoists, to the top of the reactor columns. The screening platform is movable from one column to another as required, so that screening and filling the columns is continuous. This equipment enables the catalyst to be kept at the highest possible efficiency. W. H. C.

1247.* Practical Refinery Engineering.—4. Heat Transfer Calculations. P. Buthod and B. W. Whiteley. *Oil Gas J.*, 15.7.44, **43** (10), 105.—Heat transmission by forced convection inside pipes is discussed, and formulæ are given : (1) an equation involving the three dimensionless groups known as the Nusselt, Reynolds, and Prandtl numbers ; (2) the equation for the computation of the film coefficients of petroleum liquids used with the Morris and Whitman data, in which the product is a function of the Reynolds number and is determined from their graph. All the thermal properties of the oil are evaluated at the average fluid temperature. The computation of the film coefficient can be avoided by the use of the charts presented, in the first of which the Reynolds number can be determined and in the second the thermal resistance (the inverse of the film coefficient). The chart can be adapted to the flow of oil through other than circular shapes. An example of the use of the charts is given.

W. H. C.

1248. Patents on Refining and Refinery Plant. G. E. Phillips. U.S.P. 2,331,343, 12.10.43. Appl., 17.12.40. Objectionable sulphur compounds are removed from petroleum oils by passing the oil in vapour phase through a bed of bauxite. The heat of reaction is removed by the introduction of a cooling fluid, the total amount not being greater than 0·5% based on the quantity of oil being treated.

W. M. Stratford. U.S.P. 2,331,438, 12.10.43. Appl., 30.9.41. Light hydrocarbons containing unstable, unsaturated hydrocarbons comprising potential gum-forming constituents are refined by subjecting them to a polymerizing treatment in contact with a solid adsorptive catalyst. The treatment is carried out at a temperature between 300 and 500° F. for 10–50 seconds to effect selective polymerization of conjugated diolefins. The polymer product is separated from the treated hydrocarbons and a gum inhibitor is added.

M. Wiggen. U.S.P. 2,332,284, 19.10.43. Appl., 4.10.39. To remove waxy constituents from petroleum oils, a refrigerant is mixed with the feed oil. The mixture is then passed into an initial dewaxing zone. It is chilled by vaporizing the refrigerant, and then passed to a second dewaxing zone where it is again chilled. Waxy constituents are removed from the chilled oil. Next the dewaxed oil is further chilled, and is flowed countercurrently through the chillers in such a way that it contacts the vaporized refrigerant and condenses it. Afterwards the mixture of dewaxed oil and refrigerant is treated to remove the refrigerant which is again condensed and passed to the initial dewaxing zone with fresh feed oil.

C. W. Berger. U.S.P. 2,334,378, 16.11.34. Appl., 8.6.40. A method is described for refining cracked hydrocarbon distillate having a boiling range between 300° and 600° F., and liable to be rendered unstable and of higher boiling range if treated with sulphuric acid. The distillate is contacted in liquid phase with phosphoric acid at a temperature below 200° F. Afterwards the treated distillate is separated from the acid to produce a gum-stable refined cracked distillate of substantially the same boiling range as the initial distillate.

R. Rosen. U.S.P. 2,335,029, 23.11.43. Appl., 7.12.40. An alkylated meta-dioxane is used as a dewaxing solvent in the refining of mineral oils. H. B. M.

Chemistry and Physics of Hydrocarbons.

1249. Solubility of Water in Liquid Hydrocarbons. Anon. *Refiner*, May 1944, **23** (5), 170.—A table is presented giving the solubility of water in butadiene, butene-1, butene-2, *iso*butylene, *n*-butane, *iso*butane, *n*-pentane, *iso*pentane, benzene, and *n*-heptane. A. H. N.

1250.* Improving Solids-Gas Contacting by Fluidization. J. C. Kalbach. *Chem. Met. Engng*, June 1944, **51** (6), 94–98.—The principle of fluidization can be studied when a stream of gas is passed upward through a bed of suitably sized particles, when the particles will be observed to be thrown into a state of extreme agitation. The bed of solids will be found to expand under the influence of the rising gas, so that each of the particles is individually suspended in the gas-stream and all of its surface is available for contact. There exists what is called a pseudo-liquid level above which a comparatively small amount of the finer material which is carried out of the solid bed, or pseudo-liquid, remains in suspension. This interface presents much the same appearance as the surface of a boiling liquid. The extremely turbulent action within the pseudo-liquid may be demonstrated by adding to it particles of a dissimilar colour. It is then observed that the fluidized solids approach homogeneity with great rapidity. Similarly, if heat is added through the walls of the chamber or by the continuous addition of hot solid particles, an unusually uniform temperature condition is observed throughout the fluidized mass. The pseudo-liquid possesses many of the properties of a true liquid in that it may be withdrawn from or added to the main body of fluidized material through pipe-lines and valves. Thus, a continuously operating system can be designed by providing a hopper or standpipe from which the solid material is picked up by a moving gas stream and carried into the fluidizing chamber, while the pseudo-liquid is continuously withdrawn from another connection. Usually a cyclone separator is connected to the gas outlet to recover line solids which are carried above the pseudo-liquid level.

The author describes some of the earliest inventions utilizing this principle—*e.g.*, C. E. Robinson's U.S. Patent of 1879, describing an improved furnace for roasting oars—and finally describes some of the latest methods of fluid catalysts. A future method of desulphurizing gas is also discussed. A. H. N.

1251.* Fluorine Compounds in Organic Syntheses. G. C. Finger. *Chem. Met. Engng*, June 1944, **51** (6), 101–103.—A study is made of fluorine in organic synthesis, but with particular attention being paid to two developments : the manufacture of Freons and of Aviation gasoline alkylates. Freons are chlorofluoro-derivatives of methane and ethane, and are prepared from carbon tetrachloride, chloroform, and hexachloroethane, depending on the compound desired. For illustrative purposes, the commercial synthesis of dichlorodifluoromethane (F-12) is described. Freon is a trade name of Kinetic Chemicals Co., for the new refrigerants. Since there are a number of these compounds, they are differentiated by symbols. The most common is F-12, CCl_2F_2 (loosely spoken of as Freon), in addition there is F-11, CCl_3F ; F-21, $CHCl_2F$; F-22, $CHClF_2$; F-113, CCl_2FCClF_2 ; and F-114, $CClF_2CClF_2$. Due to their outstanding properties of stability, non-toxicity, non-flammability, and non-corrosiveness, they are used extensively in refrigeration and air-conditioning equipment. Fumigation of tents, barracks, air-planes, tanks and military installations, especially in the tropics, has become a simple operation as the result of a new aerosol fumigator called " bug bomb." Such insects as mosquitoes, flies and other disease carriers are readily exterminated in a matter of several minutes. This bomb, which can be carried in one hand, contains a mixture of pyrethrum, sesame oil, and liquid Freon. All of the components are harmless to humans. By opening the ejection valve, the Freon begins to boil (its boiling point is about $-19°$ F.) expelling the insecticidal mixture and virtually exploding it as a fine mist which remains suspended in air for a long time. One bomb contains sufficient material to fumigate a space of 150,000 cu. ft.

Alkylation is then described, followed by a brief study of dyes, polymers, and condensation reactions. A. H. N.

1252.* The Coming Search for Synthetic Motor Fuels. J. L. Marsh, G. H. Fremon, R. D. Glenn, V. D. Luedeke, and D. J. Porter. (Technical Committee, Amer. Inst. of Chem. Engrs.) *Chem. Met. Engng*, June 1944, **51** (6), 107–111.—The Senate has authorized expenditure of 30,000,000 dollars to develop processes for obtaining motor fuels from coal, shale, and forest products. The authors study the different possible sources for synthetic motor fuel, and draw the following conclusions :

The petroleum supply for the United States, if the possibilities for importing crude oil and for improving present gasoline yields are exploited, seems to be assured for the next 25–50 years. Carbonization processes will yield small amounts of gasoline to supplement the supply, but cannot be expected to produce significant quantities. Shale oil is the most promising substitute, which will probably be developed as soon as the cost of petroleum rises to 2 dollars/brl. If the shale-oil resources are completely developed, enough oil should be produced to supply the country for at least another fifty years. Tar sand, too, are a source of vast amounts of petroleum which can possibly be recovered very cheaply. Synthetic fuels from coal are at present expensive, and the cost of building large plants to use these processes is very high. Until the processes are improved and the costs are reduced, there will be no economic incentive to use these processes. In view of the adequate supplies of other raw materials from which motor fuels can be obtained, it seems unlikely that there will be large-scale production of synthetic fuel from coal in the U.S.A. within the near future.

A. H. N.

Analysis and Testing.

1253. Oil Test Engine Passes Initial Development Stage. E. W. Jacobson. *Petrol. Engnr*, May 1944, **15** (8), 196–202.—A test engine is being developed in the laboratories of the Gulf Research and Development Co. for evaluation of crankcase oils for suitability in full-scale engines. The objective is to reproduce all or only a few of the operating conditions of a multi-cylinder commerical engine, while certain other conditions affecting oil performance are controlled as required—*viz.*, mechanical condition, temperature, piston speeds, oil consumption rates, power output, manifold pressures, etc. It is a 2-cyl. 90°-V design engine with a single throw crankshaft, which is basically well balanced for operation at speeds up to 4500 r.p.m. without use of auxiliary balancing mechanism. It may also be operated as a single-cylinder engine. The assembly consists of a unitized crankcase on which can be mounted a variety of cylinders, heads, pistons, oil-sumps, oil-heaters, heat exchangers, etc., to control test conditions as desired. The engine has been designed and built in three basic types: L-head liquid cooled, I-head liquid cooled, and I-head air cooled. Design and construction of a diesel set-up is contemplated. Development and testing on the L-head liquid cooled engine has progressed to the point where success of the design of the test engine seems assured.

Development testing of the two overhead valve designs is under way applying data obtained from the L-head development. The general design has been worked out with the idea of using standard stock automotive parts wherever possible to reduce replacement costs. Examples are given. Further details of design and methods of control of variable factors are given and illustrations and sectional diagrams of the engine provided. Tables show typical engine design data for cylinders and valves. It is thought that, although designed originally for use in the Gulf laboratories, the engine may eventually become the basic design for a standard test unit for lubricants in the automotive and oil industries. R. A. E.

Motor Fuels.

1254. Patents on Motor Fuels. P. J. Gaylor. U.S.P. 2,331,386, 12.10.43. Appl., 3.11.39. A motor fuel is prepared from a major proportion of a hydrocarbon liquid base having an initial boiling point of at least 300° F. and a small amount of a soluble dialkyl ester of carbonic acid to lower the surface tension of the fuel.

D. G. Brandt. U.S.P. 2,332,051, 19.10.43. Appl., 8.11.40. A method is described for converting hydrocarbons to produce hydrocarbons of high anti-knock value. The conversion is carried out in a pipe-still furnace provided with radiant heating chambers separated by a convection heating chamber. The chambers are provided with tubes for heating the hydrocarbone to be converted.

G. Egloff. U.S.P. 2,332,564, 26.10.43. Appl., 30.11.40. Substantially saturated gasoline is produced by mixing a low-boiling *iso*paraffinic fraction with a metal halide alkylating catalyst. The resultant mixture is passed in a restricted stream through a reaction zone maintained under alkylating conditions. To the stream is introduced at a number of spaced points a hydrogen halide and olefinic hydrocarbons boiling in the gasoline range. The effluent is fractionated to separate gasoline fractions from it.

J. A. Chenicek. U.S.P. 2,333,294, 2.11.43. Appl., 31.5.40. To prevent deterioration of cracked gasoline a pheonlic gum inhibitor is added and a compound of the general formula

$$\begin{matrix}R\\H\end{matrix}\!\!>N—CH_2—(CH_2)_x—N\!\!<\!\!\begin{matrix}H\\H\end{matrix}$$

R is alkyl group and *x* is an integer. The amount of the compound is insufficient in the absence of the inhibitor, to effect any appreciable gum inhibition of the gasoline.

M. M. Holm. U.S.P. 2,334,006, 9.11.43. Appl., 16.12.40. A high anti-knock motor fuel consists of *iso*paraffinic hydrocarbons of the type produced by the alkylation of *iso*paraffins with normally gaseous olefins and a small amount of an ester selected from the group consisting of saturated aliphatic esters of formic and acetic acid containing 3·7 carbon atoms and boiling within the range 130–300° F.

V. Haensel and V. N. Ipatieff. U.S.P. 2,335,246, 30.11.43. Appl., 18.12.42. The olefin content of a hydrocarbon boiling in the gasoline range is reduced by contacting the fraction with a catalyst containing boron oxide, at a temperature between 400 and 600° F., and at a pressure such that a substantial proportion of the hydrocarbon fraction in the reaction zone is in the liquid phase. A liquid product is obtained which boils substantially in the gasoline range and has a bromine number of less than half of that of the original hydrocarbon material. H. B. M.

Gas, Diesel and Fuel Oil.

1255. Patents on Gas, Diesel and Fuel Oils. E. M. Nygaard and F. M. Seger. U.S.P. 2,333,029, 26.10.43. Appl., 16.4.42. A diesel fuel has incorporated with it a small amount of the sulphur- and chlorine-containing reaction product obtained by reacting perchloromethylmercaptan with a compound having the general formula

$$\mathrm{M{-}X_1{-}\underset{\underset{\displaystyle X_2}{\|}}{C}{-}X_3{-}R}$$

M is selected from the group consisting of hydrogen and the hydrogen equivalent of a metal; X_1, X_2, and X_3 are selected from the group consisting of oxygen and sulphur; and *R* is an alkyl radical. The reaction product is present in sufficient amount to decrease the ignition delay period of the fuel.

W. A. Proell. U.S.P. 2,333,817, 9.11.43. Appl., 30.9.41. Existent and latent oil-insoluble impurities in nitrated fuels are removed by adding a low-molecular-weight alkane to the oil. In this way impurities are rendered entirely oil-soluble and latent impurities are developed. Afterwards they are removed from the oil.

J. H. McCracken and E. M. Nygaard. U.S.P. 2,335,953, 7.12.43. Appl., 2.5.42. A diesel fuel has incorporated in it a small proportion of a product obtained by the reaction of perchloromethylmercaptan with a compound selected from the group consisting of a dialkyldithiophosphoric acid, a diaralkyl-dithiophosphoric acid and an alkyl-aralkyl-dithiophosphoric acid. H. B. M.

Lubricants and Lubrication.

1256. Heavy Duty Engine Oils. R. M. Welker. *Petrol. Engr*, May 1944, **15** (8), 204–208.—Engine developments have necessitated the use of additives in lubricating oils to improve certain properties. Four general types of additives are in common use: (1) Materials that increase load-carrying ability; (2) Materials that retard the rate of oxidation of the oil under engine operating conditions; (3) Materials that promote engine cleanliness, *i.e.*, detergents; (4) Anti-foam materials. More recently anti-rust agents have been employed to minimize the tendency of engines to rust during prolonged storage.

The desirable functions of each type of additive are outlined, and indications given of the types of materials used for each purpose. Further research has led to the development of new formulæ, which include oxidation and corrosion inhibitors as well as detergents, thus producing detergent oils suitable for every type of bearing metal.

Five engine tests have been developed and recognized by the Co-ordinating Research Council to evaluate the service performance of oils, three using Caterpillar engines, one a General Motors engine, and one a Chevrolet engine. The special conditions required for each test are tabulated.

An oil may pass some of the tests with addition of a good oxidation inhibitor only, but to pass all, a good detergent additive also appears necessary. The need for a single laboratory test engine of adequate flexibility to perform all required tests is stressed and reference is made to the engine mentioned in Abstract No. 1253. Careful selection of base oil as well as inhibitor is essential for heavy-duty oils, and the test-engine results indicate that solvent refined naphthenic base oils are better suited than such oils conventionally refined, and that with appreciable bright stock content, oils may form abrasive carbon, giving rise to cutting and scratching of piston and cylinder walls in one of the Caterpillar tests.

The widest application of the new heavy duty detergent type oils is made by the U.S. Armed Forces. To simplify testing, the engine tests are applied to a brand of oil. If the oil meets requirements, then so long as the make-up remains constant subsequent deliveries are only required to meet specifications in respect of conventional laboratory tests. Since field experience has indicated a tendency for lubricating oils to foam in certain engines, a foaming test has been developed and incorporated in Army specifications. The most advanced types of detergent oils now incorporate an anti-foam agent.

Special precautions are necessary when a detergent oil is used in an engine previously operated on straight mineral oil, or the detergent action of the new oil may cause trouble due to its washing action on accumulated deposits in the engine or in the filter. A recommended procedure is described. Filters also require attention, since ordinary earth types may be expected to remove additives more rapidly than the bag or waste types. A change of filter cartridge with each change of oil is also advisable. R. A. E.

1257. Heat Effects in Lubricating Films. A. C. Hagg. *J. Appl. Mech.*, June 1944, **11** (2), A-72–A-76.—Heat effects in lubricating films are analysed on the basis of simple shear of the lubricant, Reynolds logarithmic formula relating lubricant viscosity and temperature, and an equation relating the heat generation and heat flow in the film. The film-temperature dependence on velocity is determined, and the result is used to obtain the shearing stress and shearing rates. The formulæ thus derived are useful in analyzing the performance of oil-film bearings. Experiments have been carried out with measurement of shaft- and bearing-surface temperatures, as well as friction; the tests support the analytical results. An approximate means for judging the importance of film heating in a given case in terms of velocity and lubricant viscosity is suggested.

[It should be noted that the paper assumes

$$\mu = ae^{-\beta\theta}$$

whereas the generally accepted formula is

$$\mu = ae^{\frac{\beta}{\theta}}$$

where μ = viscosity; θ = temperature; a, β, e = constants. The temperature differences involved, however, are only between 11·5 and 33·0 F., and probably the two formulæ will give nearly equivalent results.] A. H. N.

1258. Measurements of the Adhesion Component in Friction by Means of Radioactive Indicators. B. W. Sakmann, J. T. Burwell, Jr., and J. W. Irvine, Jr. *J. Appl. Phys.*, June 1944, **15** (6), 459–473.—In friction experiments material is exchanged between the sliding surfaces. A study of this transfer of material was made possible by the development of a radioactive tracer method by means of which one could detect quantities of metal as small as 10^{-4} microgram. Spherical or hemispherical specimens were slid over an activated base surface. After the friction experiments, the riders were tested for the presence of radioactive material, and the quantity of metal deposited on the rider was determined as a function of various parameters. A copper–beryllium base surface was used for all measurements reported here. For the materials investigated it was found that the amount of base metal adhering to the rider was proportional to the load and increased with the distance of travel. Under otherwise identical conditions, the amount of base metal deposited on the rider depended on surface finish and hardness of the rider. If the rider was harder than the base, the transferred material increased with surface roughness. If, on the other hand, the rider was softer than the base, surface finish was found to be of secondary importance. Measurements made with steel specimens showed that the amount of metal deposited on them was inversely proportional to their Brinell Hardness. For riders of different materials, but having the same hardness and surface finish, the amount of transferred metal increased with the solid solubility of the base metal in that of the rider. Lubrication decreased the transfer; the reduction depended on load and, for the same load, on the material of the rider. The influence of lubrication was greater for smaller loads.

A. H. N.

1259. Patents on Lubricants and Lubrication. A. E. Calkins. U.S.P. 2,332,202, 19.10.43. Appl., 19.8.41. A lubricating material is prepared by mixing together a saponifiable material, a saponifying agent, and a small amount of mineral oil. Relatively small amounts of the resultant mixture are heated outside of the mixing zone to a temperature at least as high as the saponification temperature. Afterwards it is recycled continuously to the mixing zone.

A. J. Morway and J. C. Zimmer. U.S.P. 2,332,247, 19.10.43. Appl., 12.9.41. An anhydrous reversible grease is prepared from lubricating oil and grease-forming proportions of aluminium soap and a non-basic barium soap. The ratio of non-basic barium soap to aluminium soap varies between 1 : 1 and 10 : 1.

J. C. Zimmer and A. J. Morway. U.S.P. 2,332,825, 26.10.43. Appl., 21.11.41. A lubricant consists of an aromatic-free coastal mineral oil, 15–30% of a saturated fatty acid soap of an alkaline-earth metal and an oil-soluble linear olefinic polymer having a molecular weight between 6000 and 15,000.

B. H. Lincoln and G. D. Byrkit. U.S.P. 2,333,871, 9.11.43. Appl., 10.4.41. A lubricant consists of a major proportion of hydrocarbon oil and a small proportion of an organo-boron ester having the formula $RnB(OR')_{3-n}$ in which R is an organic radical, R' is an organic radical containing a carboxylic ester group, and n is an integer less than 3.

R. S. Barnett. U.S.P. 2,334,239, 16.11.43. Appl., 30.12.41. A stabilized grease composition consists of a mineral oil, a sufficient quantity of lime soap of high-molecular-weight fatty acids to impart the consistency of grease to the oil, and a small proportion of a stabilizing agent. The stabilizing agent comprises a mixture of castor oil and an ester of a higher fatty acid and a polyhydric alcohol from the group consisting of partial esters and esters containing ether linkages.

G. R. Gilbert. U.S.P. 2,334,549, 16.11.43. Appl., 5.7.41. Sulphur compounds are removed from mineral oil fractions by contacting the oil in the first place with an alkali metal plumbite solution under conditions designed to form lead mercaptides. Thereafter the oil is separated from the plumbite solution and distilled in the absence of steam and under vacuum to remove a sweetened product.

E. Lieber and M. E. Thorner. U.S.P. 2,334,565, 16.11.43. Appl., 31.10.41. A lubricant is prepared from a waxy mineral oil and a pour-depressing amount (between 0·1% and 10·0%) of a polymerization product of glycerol. The polymerization product is obtained by polymerizing 1 mol. of glycerol with ½–3 mols. of aluminium chloride at a temperature between room temperature and 350° F. It is substantially non-volatile at 500° F. and is soluble in the waxy lubricating oil.

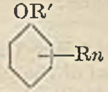
B. H. Lincoln. U.S.P. 2,334,566, 16.11.43. Appl., 11.3.40. A lubricating oil has incorporated in it a minor proportion of a derivative of an organo-metallic compound having at least one carbon-metal bond and containing halogen and sulphur, both of which are in the organic radical.

J. C. Zimmer and G. M. McNulty. U.S.P. 2,334,594, 16.11.43. Appl., 29.1.41. A lubricant consists of a mineral lubricating oil, a small proportion of an organic halide containing halogen in an active form, and a sufficient proportion of a resinous condensation product to function as an anti-corrosive agent.

J. Wulff. U.S.P. 2,334,738, 23.11.43. Appl., 3.6.40. A high pressure lubricant consists of a mineral oil to which has been added a small amount of bismuth in flake form.

G. H. B. Davis. U.S.P. 2,334,996, 23.11.43. Appl., 29.6.40. A thickened lubricating oil has incorporated in it at least 0·5% by weight of a high molecular weight, substantially saturated, linear *iso*-olefinic hydrocarbon polymer. The addition agent is of plastic consistency, normally resistant to oxygen, and has a molecular weight above 10,000.

J. G. McNab, C. J. Wilson, and C. Winning. U.S.P. 2,335,017, 23.11.43. Appl., 31.12.41. A lubricant is prepared from an oil base and a small quantity of a compound of the formula



R is an organic radical, *R′* is a tertiary aliphatic radical, and *n* is an interger. A small quantity of an organic containing a metal and the element sulphur is also incorporated.

L. L. Davis and B. H. Lincoln. U.S.P. 2,335,261, 30.11.43. Appl., 21.3.38. A hydrocarbon oil has incorporated in it between 0·25% and 15% by weight of a metal soap of an aliphatic substituted fatty acid.

D. L. Wright and C. W. Bohmer. U.S.P. 2,335,331, 30.11.43. Appl., 14.5.41. A chemically resistant lubricant consists of 50–85% mineral white oil, 10–50% petrolatum (light oil-free), 0–10% of paraffin wax, and a small amount of a substantially saturated aliphatic hydrocarbon polymer.

A. W. Burwell. U.S.P. 2,335,733, 30.11.43. Appl., 24.10.40. A lubricant is prepared from 99·25–94% by weight of a mineral lubricating oil and 0·75–6% by weight of an oil-soluble addition agent consisting essentially of alkyl esters of petroleum acids with a small content of alkaline earth metal soaps of petroleum acids. H. B. M.

Asphalt and Bitumen.

1260. Patents on Asphalt and Bitumen. S. M. Hjelte. U.S.P. 2,331,394, 12.10.43. Appl., 30.9.41. A method is described for preparing a composition of bituminous material and calcium carbonate filler. The bituminous material is heated to about 150° C., and lime sludge having a particle size predominantly in the range 10–100μ is added in such quantities that the temperature of the bituminous material is not appreciably lowered. In this way the sludge particles are disrupted into primary grains with a particle size of about 1μ.

J. C. Rolidiger. U.S.P. 2,332,260, 19.10.43. Appl., 30.11.39. A damp mineral aggregate is coated with 0·5–1% of hydrated lime and afterwards asphalt is added in fluid condition. The asphalt at the time of contact of the aggregate contains 1–3% of lead naphthenate and 1–3% of naphthenic acid.

L. R. Fadden. U.S.P. 2,332,311, 19.10.43. Appl., 24.5.40. A coloured mastic flooring composition consists of approximately 208 parts by weight of an emulsified residual asphalt, 112 parts by weight of a slaked hydrated dolomitic lime, 1700 parts by weight of a river bank sand, and 50 parts by weight of a pigment per ton of the composition.

V. E. Watts and P. E. McCoy. U.S.P. 2,332,542, 26.10.43. Appl. 31.7.40. A process is described for the manufacture of a fluid bitumen-in-water type emulsion, stable in storage and to fluctuations of temperature, additions of electrolytes and Portland Cement. The emulsion owes its emulsification substantially to the reaction products of naturally occurring asphaltogenic acids and an alkali. H. B. M.

Special Products.

1261. Military Needs Stimulate Development of Insecticidal Aerosols. L. D. Goodhue. *Chem. Ind*, May 1944, **54** (5), 673.—Fine dispersions (aerosols) of insecticides can be produced (*a*) by spraying concentrated solutions on to a hot plate; (*b*) by mechanical high pressure atomization; or (*c*) by evaporation from a solution in a liquefied gas. Method (*c*) is now in general use for military and industrial purposes, mainly in the form of 1-lb. dispensers which carry a solution of pyrethrum extract and sesame oil in Freon 12 (dichlorodifluoromethane). The original pyrethin content (1·0%) has been reduced to conserve supplies and various adjuvants are being added. The spraying properties of the solution are very important, it being found that with Freon 12, the optimum particle size is obtained when 15% of non-volatile matter is present. In aerosol form pyrethrum is twice as toxic to flies as when applied in a spray, though the knockdown is slower. Aerosols should have many important applications in future, *e.g.* in the control of mosquitoes and flies in factories, pests in greenhouses, and on outdoor garden and field crops (which will require a rapid settling rate) and in fungicides, germicides and plant hormones. C. L. G.

1262. West Coast Synthetic Rubber Industry Unveiled. Anon. *Refiner*, May 1944, **23** (5), 193–196.—A description is given of the plant designed to produce 90,000 tons of GR-S (Buna S) rubber. Photographs illustrate the paper. A. H. N.

1263. Acrylonitrile. Little Giant of the Rubber Programme. Anon. *Chem. Ind.*, June 1944, **54** (6), 835.—A brief description is given of the method of manufacture of acrylonitrile, used in the production of Buna N synthetic rubber, at the Rohm and Haas plant at Bristol. Pa. Ethyleneoxide is reacted with HCN to give ethylene cyanohydrin which on dehydration gives acrylonitrile. The plant has a capacity of several million pounds of product per annum, and is one of three producing acrylonitrile for 24,500 tons of Buna N. The present high cost (40 c. per lb. compared with 18 c. per lb. for styrene) has limited the development of Buna N, although its high oil resistance has led to its use for self-sealing tanks, hoses, engine mountings, gloves, shoe soles and heels, etc. It is used in butadiene-copolymers such as Hycar OR, Perbunan, and Chemigrim to improve oil resistance, but its polymers cannot be used alone for making continuous films or castings owing to their insolubility in the monomer, from which they are precipitated as a finely divided solid. It has, however, great possibilities in the field of chemical synthesis. C. L. G.

1264. Relative Effects of Several Base Oils Used in Livestock Sprays on the Skin of Cattle. F. W. Atkeson, A R. Borgmann, R. C. Smith, and A. O. Shaw. *J. Econ. Ent.*, June 1944, **37** (3), 419.—The results are given of a series of tests carried out during two years to determine the effects of the properties of 17 different base oils in livestock sprays. 10 c.c. of each of 4 sprays were applied to areas of each animal for 30 consecutive days and the skin reactions noted. It was found that all oils containing 87·5% or less unsulphonated residue gave unsatisfactory skin reactions, whereas all those containing 92·5% or more, with one exception, were satisfactory. The viscosity of the oil did not appear to be an important factor. C. L. G.

1265. Comparative Toxicity Under Barn Conditions of Livestock Type Fly Sprays Made from Various Combinations of Toxic Ingredients and Base Oils. F. W. Atkeson, R. C. Smith, A. R. Borgmann, and H. C. Fryer. *J. Econ. Ent.*, June 1944, **37** (3), 428.—A review is given of published literature on the toxicity of fly sprays prepared from various oils and toxic ingredients, towards livestock flies, and the results given of a toxicity test in a dairy barn of 16 livestock sprays against houseflies, using half the rate of spray recommended in the Peet Grady test. The highest knockdown (99%) and kill (81%), was given by 5% of 20 : 1 Pyrethrum concentrate plus 5% of D.H.S. Activator, a similar spray but containing only 3·75% of pyrethrum giving figures of 96 and 77, respectively. 5% of pyrethrum without activator gave poor results (78 and 25, respectively). Of the single toxicants tested, Thanite gave the best results, 3% in different oils giving knockdowns of 92–98 and kills of 63–76, but in water it was less efficient (82 and 42, respectively). Lethane solutions gave good knockdowns (84–97), but poor kills (22–42). Of two widely used commercial sprays one gave a high kill (65) and a poor knockdown (41%), while the second gave a fair knockdown (87) but a poor kill (38%). The base oils with the lowest viscosity (32 secs. S.U.) gave the best knockdown, but the unsulphonated residue content did appear to affect the result. The results indicate that a high knockdown may be misleading, as far as final kill is concerned, and that the latter factor should be taken as the criterion rather than the knockdown. C. L. G.

1266. Chemicals to Destroy Overwintering Codling Moth Larvae in the Soil at the Base of Apple Trees. M. A. Yothers and F. W. Carlson. *J. Econ. Ent.*, June 1944, **37** (3), 448.—The results are given of tests to determine the effectiveness of various emulsion sprays containing toxic materials, and of dusts in controlling overwintering codling moth by application to the soil at the base of apple trees in May. Of the sprays, 5% dichloroethyl ether in cotton seed or stove oil gave the highest kill (95–98%). 20% paradichlorbenzene in the same oils also gave very high kills, but the toxicant is difficult to dissolve. 1% of nicotine sulphate or 2% of pyrethrum extract in stove oil gave poor kills, as did ethylenedichloride, except when used in concentrations over 50%. Good results were obtained with 4 : 6-dinitro-orthocresol, 0·25%, 0·5%, and 1·0% giving kills of 92, 91, and 96, respectively. Calcium cyanide and paradichlorbenzene dusts gave almost complete control at 4 ozs. per tree, the latter giving 96% control at 2 ozs. per tree. C. L. G.

1267. **Insecticide Testing.** Part I. A. J. Cox. *Soap*, June 1944, **20** (6), 114.—A review is given of the procedures to be adopted for (*a*) the rearing of houseflies and the testing of the toxicity of fly sprays according to the Large Group Modification of the Peet Grady Method, (*b*) the rearing of clothes moths and the testing of materials for the moth-proofing of clothes, low volatility fumigants, repellents, and other materials for the control of clothes moths. C. L. G.

1268. **A New Dielectric for Cables.** H. C. Crafton and H. B. Slade. *Modern Plastics*, July 1944, **21** (11), 90.—The value of polyethylene as a cable-insulating material is discussed and its general properties compared with those of polystyrene, poly*iso*butylene, and rubber. In addition to its good electrical properties it possesses superior toughness, flexibility, dimensional stability, and resistance to brittleness at low temperature and distortion at high temperatures, extremely low moisture absorption, and high chemical resistance to solvents. The only limitation is that outer cable coverings must be applied without heating to over 104° C., thus confining such coverings to thermoplastics or self-airing vulcanisates. For high-frequency cable it is unequalled, but its rigidity in thick layers is a disadvantage when particularly flexible cables are required. C. L. G.

1269. **Analytical Aspects of Plastics. Part I.** H. Baron. *Brit. Plastics*, August 1944, **16**, 339–348.—Tabulations are given of the behaviour of a number of plastics under various analytical procedures, including effect of heat (inflammability, colour and odour); fluorescence in ultra violet light; specific gravity and specific volume; behaviour on dry distillation; saponification number; nitrogen, sulphur, phosphorus, and chlorine content; and solubilities in toluene and methanol. C. L. G.

1270. **Tygon.** Anon. *Brit. Plastics*, August 1944, **16**, 373.—The name Tygon is applied to a variety of corrosion resistant synthetic products marketed by the U.S. Stoneware Co. and derived from modified halide polymers, new condensation resins, and diene derivatives. It was first developed as a liquid coating for tanks, similar to hard rubber, which is resistant to all acids except fuming nitric acid, all inorganic salts, all organic acids except glacial acetic, alkali solutions, and most hydrocarbons and solvents. It is also immune to the oxidizing effect of air and sunlight. Tygon has now been developed in sheet form for application with a special adhesive, and is also made in paint form for spraying, dipping, or brushing; it air dries to a hard lustrous finish and is used for the manufacture of shoe soles and rubber sundries such as bathmats, icebags, etc. It also has many applications in aircraft construction.
C. L. G.

Detonation and Engines.

1271. **The Combustion-Gas Turbine.** F. K. Fischer and C. A. Meyer. *Refiner*, **23** (5), 171–179.—Advantages of the gas-turbine cycle as compared with the conventional steam system include: (1) no boiler is used; (2) water is not required for the simple open-cycle system; (3) promises greater efficiency improvement at high temperature, and (4) high horse-power per pound output for short-lift applications. Present disadvantages include: over-optimism; fuel limited to high-grade oils instead of low-grade oil and coal; little field experience and need of time to complete technical developments in metallurgy and component parts of the gas-turbine system. To a large degree, the future application of the gas turbine depends on developments in the field of metallurgy, aerodynamics, combustion, and heat exchange. Present knowledge in these fields permits building and operating simple gas turbines for certain purposes. Experience with some of the simple forms of gas-turbine plants has been successful and encouraging. The operation of a simple cycle turbine is described and illustrated graphically. Various cycle combinations are then briefly studied and compared. The application of the gas-turbine to various forms of power consumers—*e.g.*, locomotives, airplanes, ships, and power generation in general is discussed. In drawing conclusions it should be remembered that the cycle has only had practical application in very special cases. The full possibilities of any cycle can only be evaluated from successful proof of its economy, first cost, maintenance cost, and reliability. The addition of elements which improve the fuel economy, and arrangements of the cycle for large capacities, are obtained at a sacrifice in simplicity and at a price. The development of the best system is expected to be costly in time and money.

Metallurgy plays an important part in the gas cycle as the efficiency increases rapidly with increase in top temperature. To obtain materials suitable for operation at higher temperatures, the metallurgists are looking at materials similar to the non-forgable and non-machinable tool steels. The method of forming these alloys to shape, such as prevision casting to size, may revolutionize accepted methods of manufacture. To apply such materials their additional first cost and manufacturing cost must be justified. Any application of such materials must be preceded by careful tests. For heavy-duty apparatus these tests must extend over long periods before the designer can use them with safety. Careful differentiation between applications as to required length of life of apparatus is necessary. The fact that a piece of equipment is operated at 1800° F. for a life of a few hours does not mean temperatures of that order can be used for heavy-duty applications. A. H. N.

BOOKS RECEIVED.

British Standard No. 1093 : 1944.—Pitch Mastic Flooring. Pp. 13. British Standards Institution, 28, Victoria Street, London, S.W.1. Price 2*s*. net.

This specification was originally prepared at the request of the Ministry of Works arising from the necessity for using alternatives to the imported materials specified in previous specifications for the asphaltic cement, and it has now been modified in the light of experience. Recommendations are now given for laying pitch mastic floors, and the working temperatures and the time during which the material is heated have been amended.

British Standard No. 1771 : 1944.—Pitch Mastic Flooring incorporating Lake Asphalt. Pp. 13. British Standards Institution, 28, Victoria Street, London, S.W.1. Price 2*s*. net.

This specification has been prepared to provide for a pitch mastic in which the binder consists of a combination of coal-tar pitch and lake asphalt. It is intended for use as an alternative to pitch mastic flooring as covered by B.S. 1093.

INSTITUTE NOTES.

October, 1944.

PERSONAL NOTES.

The following message, dated Paris, 3rd September, 1944, has been received from Colonel L. Pineau, Hon. Member of the Institute :—

> A l'heure de la délivrance de la France par les vaillantes armées alliées, notre pensée toujours fidèle va vers nos Collègues et amis de l'Institute of Petroleum et leur exprime notre reconnaissance et notre admiration.
>
> (*Signed*) Louis Pineau,
>
> *President d'Honneur de l'Association Française des Techniciens du Petrole.*

MEETINGS OF COUNCIL.

An Ordinary Meeting of Council was held at Manson House, 26, Portland Place, W. 1, on Wednesday, 13th September, with Professor F. H. Garner (President) in the Chair. There were also present : Messrs. Ashley Carter, G. H. Coxon, A. F. Dabell, T. Dewhurst, A. E. Dunstan, E. A. Evans, E. B. Evans, A. C. Hartley, H. Hyams, J. A. Oriel, C. A. P. Southwell, H. C. Tett, A. Beeby Thompson, R. R. Tweed, W. J. Wilson, C. W. Wood, the Chairman of the Stanlow Branch, Mr. J. S. Parker, and the Secretary of the South Wales Branch, Mr. E. Thornton.

Reports were received from the Branches, Election, Finance, Publication and Awards Committees.

Five Members and four Associate Members were elected.

The publication of an Index of Proceedings of the Institute since its formation was approved.

On the recommendation of the Awards Committee, the Council decided to award a Students' Prize of £5 5*s*., together with consolation prizes of £1 1*s*. The Council also approved the recommendation to award the Burgess Prize of £5.

ELECTION TO COUNCIL.

The attention of Members is drawn to the following extracts from the By-Laws governing election to the Council of the Institute :—

(*a*) The Council of the Institute shall be chosen from the Fellows and Members only.

(*b*) Every Fellow, Member, and Associate Member of the Institute may send in writing to the Council the name of a Fellow or Member whom he desires to recommend for election to the Council. This nomination must be signed by at least nine other Fellows, Members, or Associate Members and delivered to the Secretary not later than 30th day of November in any year. No Fellow, Member, or Associate Member may sign more than one Nomination Paper in any one year.

NEW MEMBERS.

The following elections have been made by the Council in accordance with the By-Laws, Sect. IV, Para. 7.

Elections are subject to confirmation in accordance with the By-Laws, Sect. IV, Paras. 9 and 10.

As Members.

JOYCE, George Thomas.
LEACH, Kenneth M.
MOORE, Philip Harold.
NEPPE, S. Louis.
SCHIFFMAN, Eric Charles.

As Associate Members.

FARBER, Louis Nathan.
HOBLYN, Edward H. T.
ROSE, Gerald G.
WATSON, Noel E.

APPLICATIONS FOR MEMBERSHIP.

The following have applied for admission to the Institute. In accordance with the By-Laws, the proposals will not be considered until the lapse of at least one month after the publication 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 candidates' proposers and seconders are given in parentheses.

CLARKE, John William, Chemist, Anglo-American Oil Co., Ltd. (*E. B. Evans; A. Matsell.*)

CLIFTON, Frederick Walter, Branch Manager, Shell-Mex & B.P., Ltd. (*A. E. Hope; H. V. Clark.*)

EADIE, Alastair Gordon, Analytical Chemist, Assam Oil Co., Ltd. (*R. J. Hayman; N. C. Sen Gupta.*)

JACKSON, John Sharp, Engineer, Alexander Duckham & Co., Ltd. (*J. S. S. Brame; Alexander Duckham.*)

KELLY, Eric James Kellas, Analytical Chemist, Smith Bros. & Co. (Oil Distillers), Ltd. (*C. B. Wingfield; J. F. N. Webb.*)

PEEL, David Hallam Primrose, Chemist, Anglo-Iranian Oil Co., Ltd. (*F. H. Garner; Hugh C. Tett.*)

THOMSON, Alexander Francis, Assistant Chemist, Anglo-Iranian Oil Co., Ltd. (*D. A. Howes; A. E. Dunstan.*)

HONOURS.

Among Honours conferred by H.M. The King is the following:—

M.B.E.

Alfred William Henry Phelps, A.M.I.Mech.E. (Fellow).

STUDENTS' PRIZE.

The Council has decided to offer a Prize to the value of £5 5*s*. in books for the most meritorious essay submitted by a Student Member of the Institute on a subject connected with petroleum technology.

Consolation prizes of £1 1*s*. each will be awarded in addition.

Students may select their own subject.

Entries must be received by the Secretary of the Institute not later than 31st March, 1945.

No maximum length is specified, but, in general, essays should be from 3000 to 5000 words.

Entries must be typed and one carbon copy must be furnished in addition to the original copy.

BURGESS PRIZE.

Entries are also invited from Student Members of the Institute for the Burgess Prize (of value up to £5 in books) for an essay dealing with some aspect of the economics of the petroleum industry, including the transport and distribution of petroleum products.

The conditions of entry for the Burgess Prize are the same as for the Students' Prize.

The Council reserves the right to withhold the award of either of these prizes, or to award prizes of such lesser values as it may decide.

HARRISON MEMORIAL PRIZE, 1944.

The Chemical Society intimate that, in accordance with the Trust Deed governing the Harrison Memorial Fund, the Selection Committee consisting of the Presidents of the Chemical Society, the Royal Institute of Chemistry, the Society of Chemical Industry and the Pharmaceutical Society, will proceed to make an award of the Harrison Memorial Prize in December 1944, subject to the condition that the Selection Committee shall be of opinion that there is a candidate of sufficient distinction to warrant an award of the Prize.

The Prize, not exceeding £150, will be awarded to the chemist of either sex, being a natural born British subject, who, in the opinion of the Selection Committee, shall, during the previous five years, have conducted the most meritorious and promising original investigations in Chemistry and published the results of those investigations in a scientific periodical or periodicals.

Applications, five copies of which must be submitted, should contain the following information :—

(*a*) Name (in full).
(*b*) Age (birth certificate must accompany application).
(*c*) Degrees (name of University where obtained).

(*d*) Other qualifications.
(*e*) Experience.
(*f*) Titles of published papers, with authors' names, including full references to publication.
(*g*) Where research was carried out.
(*h*) Testimonials and references.
(*i*) Any other particulars bearing on the application.

The Selection Committee is prepared to consider applications, nominations, or information as to candidates eligible for the Prize. Any such communication must be received by :—

The President,
The Chemical Society,
Burlington House,
Piccadilly, W. 1.

not later than Friday, 1st December, 1944. Candidates must not be more than thirty years of age at this date.

ARTHUR W. EASTLAKE,
ASHLEY CARTER,
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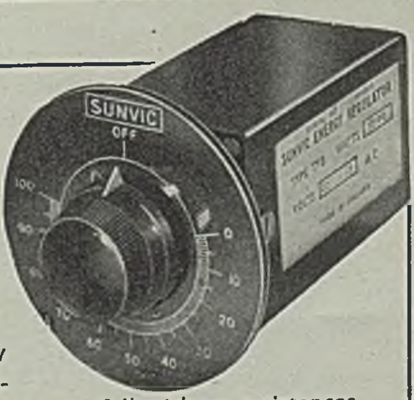

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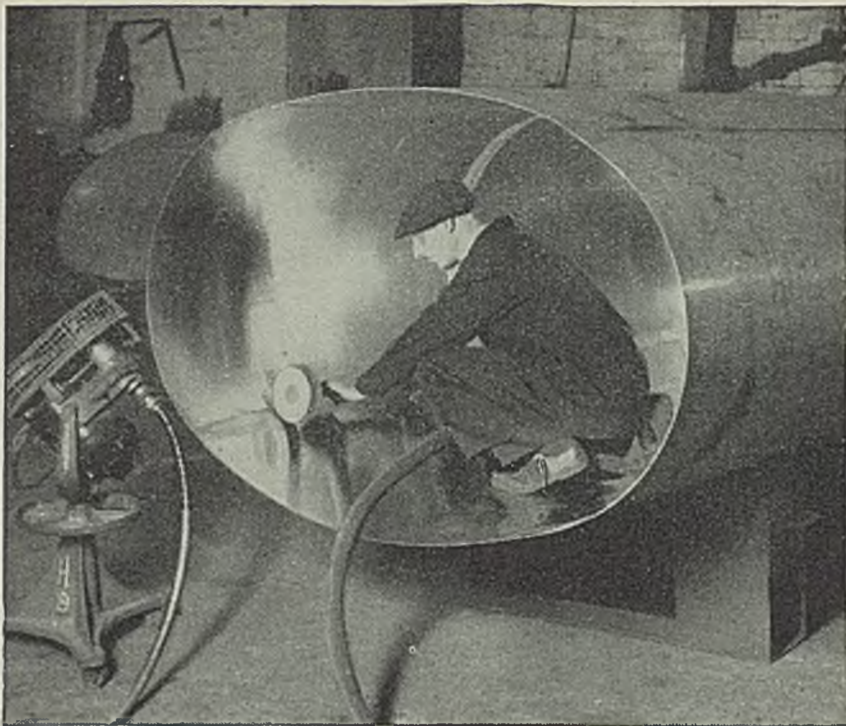

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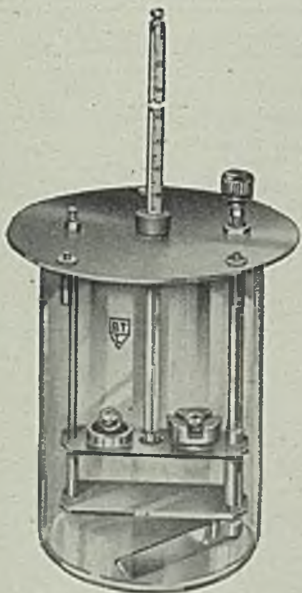

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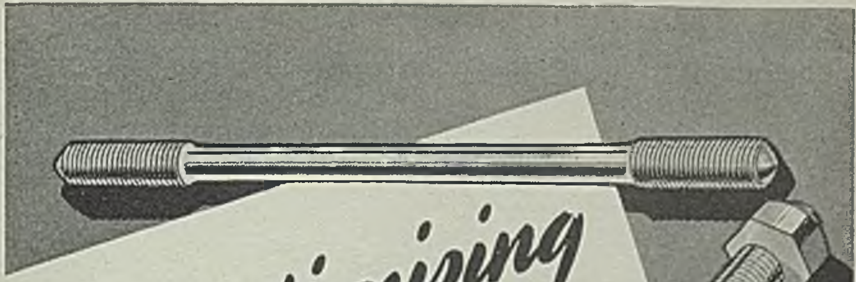

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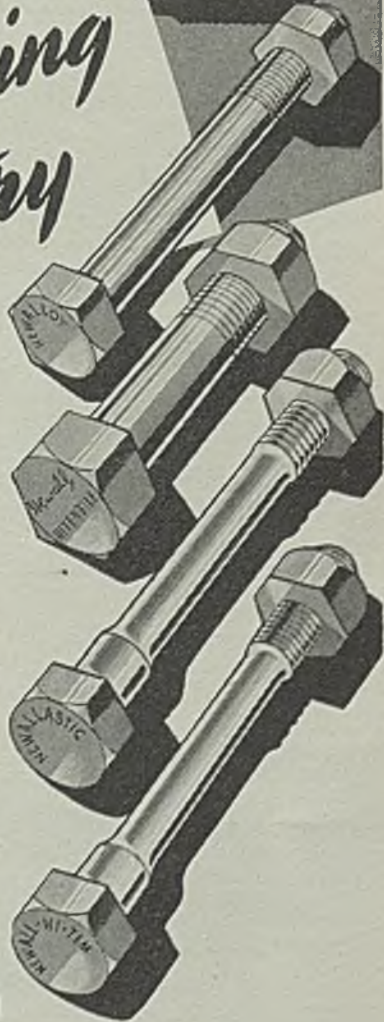

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