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THE DEVELOPMENT OF A CAPILLARY VISCOMETER—TO MEASURE VISCOSITIES IN EXCESS OF 10 POISES.

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INTRODUCTION.

ABSOLUTE capillary viscometers exist, capable of yielding high degrees of accuracy when the viscosity of the liquid to be measured is comparatively low. As the viscosity increases, the degree of accuracy decreases, due to the larger effect small errors in the measurements assume in the result. For instance, the change of viscosity with temperature is governed by the general approximate equation

$$\eta = Ae^{B/T}$$

where η = viscosity in poises,
T = absolute temperature,
A and B = constants,

or
$$\log_e \eta = \log_e A + \frac{B}{T};$$

i.e.,
$$B/T = \log_e \left(\frac{\eta}{A}\right). \quad \therefore \frac{d \log_e \eta}{dT} = -\frac{B}{T^2} = -\frac{\log_e (\eta/A)}{T}$$

Hence the magnitude of the change in viscosity with temperature is larger the larger the value of η—a well-established fact. Thus when the value of η is greater than, say, 20 poises, the viscosity may assume 100 per cent. increase on a drop of only 10° C. In other words, even when controlling the temperature of the bath to 0·05° C. the maximum error introduced in the viscosity measurement may be 0·5 per cent., due to temperature variation only. Even this loose analysis illustrates the need for elaborate precautions to be taken with the temperature control and measurement to ensure a reasonably accurate determination of viscosity in the upper ranges.

The general principles of operations taken in the apparatus were as follows: The liquid under investigation was forced through a horizontal straight glass tube while the pressure drop across the tube, the rate of flow of the liquid, and the temperature of the bath were recorded. The pressure was applied by means of compressed air passing through a regulator, and being further controlled by a leak-valve mercury regulator. The level of the outlet of the liquid was kept the same as the level of the inlet by a weir at the outlet and a constant-level arrangement at the inlet. The rate of flow was measured by letting the liquid flow into a reservoir and measuring the rate of flow of the displaced air. A calibrated flow-meter was used for the latter purpose. The temperature of the liquid was controlled and measured by controlling and measuring the temperature of the large bath in which the apparatus (including the flow-meter) was immersed.

Fig. 1 is a photograph of the general layout of the apparatus, before immersion in the bath. A compressor, not shown, filled the cylinder (1), through filter (2), with air under pressure. When the pressure was required, air was passed through regulator valve (3) and filter (4) to manifold (5). The manifold consisted of valves connecting the air to either a water, inclined-mercury, or vertical-mercury manometer and/or to a steel gauge (6) (the inclined manometer is not seen in the photograph) and to mercury-tube pressure regulator (7). The irregular variations in the pressure due to the regulator were damped by incorporating a packed cylinder between the manifold and mercury regulator (8). The other end of the manifold carried the air through a rubber hose (9) to a brass cylinder (10), which would be clamped over the inlet end of the viscometer—*i.e.*, over the constant-level arrangement (11). This consisted of a reservoir of liquid inverted over the main inlet reservoir of the viscometer and, having two tubes, admitted liquid when the level fell. (Details of the viscometer and viscometer head are in Figs. 3 and 6, respectively.)

The liquid from the reservoir flowed through the tube (12) and over a "sharp-edge" weir (13) into the outlet reservoir (14). Air in (14) was displaced, and its rate of flow could be measured by flow-meter (15), which consisted of a capillary tube and an inclined toluene manometer, which measured the drop of head across the flow-meter capillary. The whole apparatus was immersed in the bath in a similar manner to the way it is shown suspended.

The temperature control is shown in Fig. 2, and will be discussed in a special section.

As the fundamental details of the design employed here are of paramount importance in assessing and controlling the degrees of precision and accuracy of the apparatus, the paper will consist merely of an extended analysis of these details. Thus any desired improvement may be accomplished by tackling the component or factor most readily adaptable to improvement.

The method and purpose of presentation may be better appreciated after the following special analysis :—

The viscosity is obtained from the formula

$$\eta = \frac{\pi P R^4}{8Ql}$$

assuming the temperature is ideally constant and that no need exists to consider kinetic energy and Couette corrections,

where η = viscosity of liquid in poises;
P = pressure differential across the capillary in dynes/sq.cm.;
R = radius of capillary in cm.;
Q = rate of flow of liquid in capillary in c.c./sec.;
l = length of capillary in cm.

By applying the methods of small corrections and approximations, found in every text-book on the Differential Calculus, it is known

$$\delta\eta = \frac{\partial\eta}{\partial P}\delta P + \frac{\partial\eta}{\partial Q}\delta Q + \frac{\partial\eta}{\partial l}\delta l + \frac{\partial\eta}{\partial R}\delta R$$

where $\delta\eta$ = overall error, or correction, in η due to small errors δP in P, δQ in Q, etc.

$\frac{\partial\eta}{\partial P}$ = differential coefficient of η with respect to P, assuming all other factors constant;

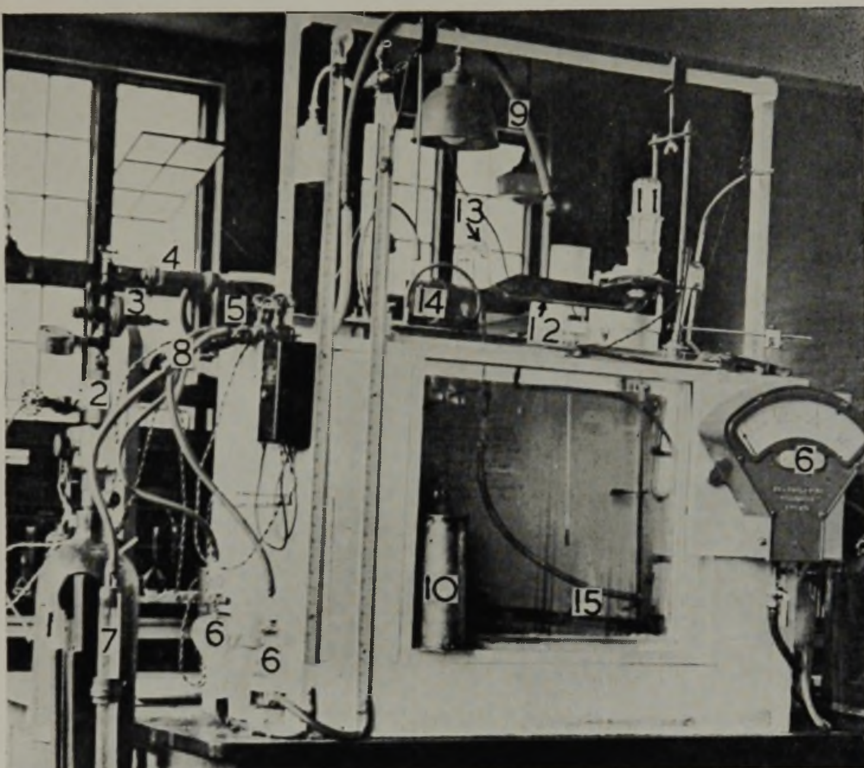

Fig. 1.

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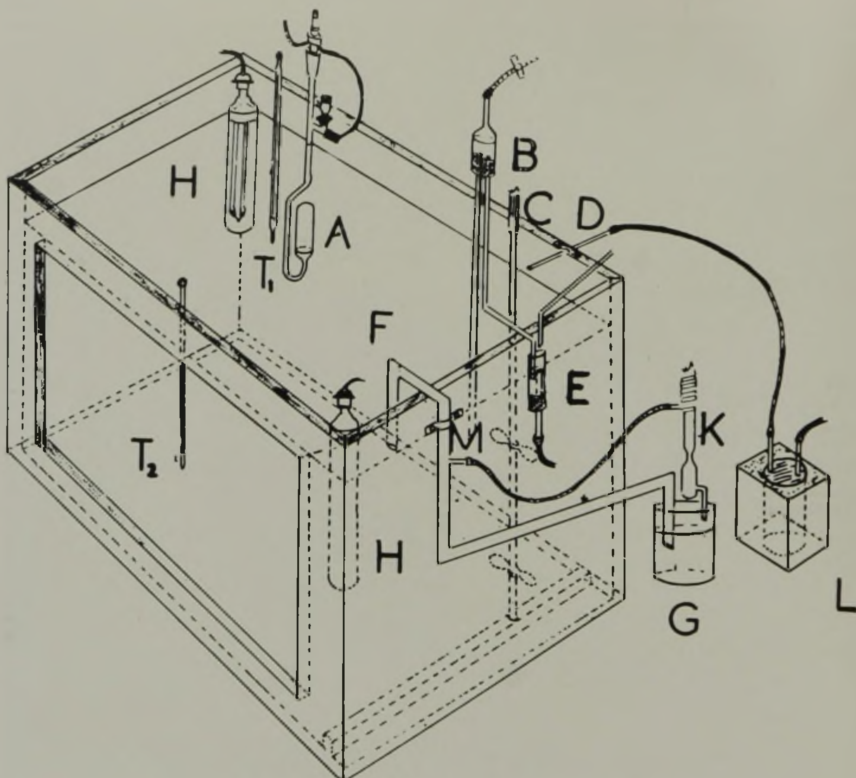

Fig. 2.

Similarly $\frac{\partial \eta}{\partial Q}$, $\frac{\partial \eta}{\partial l}$ and $\frac{\partial \eta}{\partial R}$ are partial differential coefficients of η with respect to Q, l, and R.

$$\therefore \quad \delta\eta = \frac{\pi R^4}{8Ql} \cdot \delta P - \frac{\pi R^4 P}{8Q^2 l} \cdot \delta Q - \frac{\pi R^4 P}{8Ql^2} \cdot \delta l + \frac{\pi R^3 P}{8Ql} \cdot \delta R,$$

or

$$\frac{\delta\eta}{\eta} = \frac{\delta P}{P} - \frac{\delta Q}{Q} - \frac{\delta l}{l} + 4\frac{\delta R}{R}$$

Since the errors in Q and l may be $\pm\,\delta Q$ and $\pm\,\delta l$, respectively, it follows then that

$$\frac{\delta\eta}{\eta} = \left|\frac{\delta P}{P}\right| + \left|\frac{\delta Q}{Q}\right| + \left|\frac{\delta l}{l}\right| + 4\left|\frac{\delta R}{R}\right|,$$

for a maximum limiting value. In other words, the maximum fractional error in viscosity measurement will be the sum of the maximum fractional errors of pressure, rate of flow, and length measurements, plus four times the maximum fractional error in radius measurements. Thus, assuming that each of the four factors was measured with a maximum fractional error of χ

i.e., $\delta(\phi) = \chi\phi$

where ϕ = factor measured

then the error in viscosity obtained is $7\chi\eta$.

It is important to realize that this analysis is merely a statement of facts, and not an assumption to be proved by experiment. No check determinations of η are necessary if each of the four factors has been measured and controlled, under conditions identical with those existing in viscosity measurement, and checked by measurements to maximum accuracy.

To this analysis must be added the short analysis on temperature effects already discussed. Thus, the subjects of this report were divided into :—

(1) Temperature.
(2) Pressure.
(3) Flow-meter.
(4) Viscometer tube.

TEMPERATURE.

A tank of welded steel was constructed, 3 ft. × 2 ft. × 1 ft., with a large glass window in the front. The bottom and sides, excepting the window, were insulated to a thickness of 3 inches by a special asbestos insulating cement contained in a wooden exterior. Two immersion lamp-heaters (H in Fig. 2) were used to heat and maintain the temperature of the bath, the heaters being controlled electrically by mercury regulator A, actuating a relay switch when the temperature tended to rise.

The regulator operated the two heaters simultaneously. To increase the rate of heating the water in the bath, an independently operated large heater was used during the heating period only.

It was essential to keep the temperature ideally uniform throughout the bath, despite the exposed top and front. Stirrer C, rotated by a motor which is not shown, was constructed with two vanes, the upper vane forcing the water upwards and the lower vane downwards. There was no observable difference in the temperature between any two points at any time. The water then was at a uniform temperature.

Tests were next performed upon the constancy of the temperature. The incorporation of the constant-level arrangement (*E*, *B*) maintained the level of the bath constant at all periods and eliminated the trouble of slight temperature rise over long periods. It was only necessary that the tube leading to *E* let water flow at the rate of a drop a second.

Thus, with these arrangements the temperature of the bath could be maintained constant to $\pm$ 0·01° C. for any period, provided the temperature was at least some 10° C. above room temperature. To be able to work at room or lower temperatures, tube *D* was incorporated, running fresh water from the tap through a coil in a cooling-bath *L* to a point just above the upper blades of the stirrer in the bath. In order to keep the level in the bath at a constant height, syphon tube *F*, of 1-inch iron pipe, was used. To start the syphon, water-pump *K* was kept running continuously into the water-seal *G*. The only requirement in constructing this self-operating syphon tube was the condition that the height of the bend in the syphon from the level of the water in the bath should be smaller than the height of the suction tube *M* from the level of the water-seal in *G*. Tests showed that flooding was impossible with this arrangement.

With ice surrounding the cooling-coil temperatures of 10° C. below room temperatures could be easily maintained to $\pm$ 0·01° C.

Conclusion on Temperature Control.

The arrangements of Fig. 2 were necessary and sufficient to keep the temperature of the bath (and hence of any object completely submerged in it for a reasonable period),

(1) uniform at all points of the bath;
(2) constant to $\pm$ 0·01° C. maximum deviation.

The lowest temperatures tested were 10° C. when the room temperature was about 20° C., and the highest temperature was 30·00° C.—for fear of the glass cracking.

Assuming the viscosity would change by 100 per cent. per 10° C. rise or fall, then the maximum fractional error,

$$\frac{\delta\eta}{\eta} = \frac{100}{10} \times 0{\cdot}01 = 0{\cdot}1 \text{ per cent.}$$

This error appeared to be reasonable, considering the extra precautions necessary to reduce it, and was accepted as inevitable in measurements of high viscosity coefficients.

Pressure.

Pressure on the inlet end of the viscometer was supplied by a compressor which stored high-pressure air in the cylinder (1) (Fig. 1), and from thence through the manifold to a brass cylinder surrounding the glass reservoir. Air was filtered first at the suction end and then at the outlet of the compressor, then through the inlet to the cylinder (2), and again through tube (3). These filters consisted of brass cylinders containing felt at both inlet and outlets and cotton wool in between. Finally the inlet to the glass reservoir of the apparatus (Figs. 3 and 6) consisted of a small hole in the side, which was always covered by wrapping a fine silk cloth around it. It was assumed that no solid particle could enter the oil reservoir with these precautions.

To supply air at constant pressure to the viscometer two regulators were used. Regulator (7) was used when the pressure was from 10 cm. water to 50 cm. mercury, by filling the long glass tube with water or mercury up to the necessary level. To eliminate the small inevitable fluctuations of pressure due to the formation and release of bubbles, the brass cylinder (8) was packed with cotton wool and incorporated between the bubbler and the reservoir. With this arrangement the pressure was maintained constant to the accuracy of the reading on the manometer. For higher pressures than 50 cm. of mercury the diaphragm regulator (3) with the damper (4) was found sufficient. Thus the pressure was kept constant to the accuracy of the reading throughout the range deemed necessary for any viscosity measurements likely to be met.

The lower limit to the pressure to be used was set by the accuracy of reading the scale. As a mm. scale was used, 0·25 mm. was considered the highest accuracy of reading possible. Thus, to ensure that the error of reading did not exceed 0·25 per cent., the lowest pressure permissible was 100 mm. of water. Lower pressures could, of course, be used by an inclined water manometer; but it was not considered safe to assume that the fluctuations due to bubbling could be neglected with such low values of pressures without further elaborate precautions. Again, fluctuations in the hydrostatic head in the reservoir itself would assume larger proportional errors with lower values of pressure than 100 mm. water. The vertical water manometer was used, therefore, to record from 100 mm. up to 900 mm. water.

The upper limit for pressure was set by the fact that the variation of viscosity with pressures usually begins to assume a considerable value above five atmospheres. Thus, the limit was set at 300 cm. mercury, and was considered safe. To measure the higher pressures a steel gauge was used—after detailed study of its behaviour was made.

For intermediate pressures, an inclined mercury manometer was used to measure pressures between 60 and 150 mm. of mercury, and a vertical manometer for measurements between 130 and 900 mm. mercury. The manometers and gauge thus overlapped to ensure concordant readings when the readings were transferred from one to the other.

In incorporating and using the manometer, each point of the analysis of the sources of error enumerated by Barr [1] was studied and all necessary precautions taken.

The back pressure exerted by the flow-meter on the outlet of the viscometer had to be considered. The inclination of the flow-meter manometer was 1 : 16·6. The liquid used was toluene. The correction applied was equal to $(0{\cdot}056x)$ mm. water, where x was the reading in mm. on the flow-meter.

The steel gauge was calibrated by the makers in cm. of mercury. When it was tested, however, even at relatively low pressures, a great error was evident. Setting the zero point to read correctly on the gauge, it was found that the error in reading was progressively greater; thus, the gauge had greatest error where it was mostly needed—*i.e.*, at higher pressures. The artifice was therefore followed of setting it to read correctly at 100 cm.

mercury and calibrating it over the entire range of 50–300 cm. mercury. Since the gauge will not be used below 90 cm., this arrangement made it possible to have low proportional errors both where the gauge was mostly used (90–150 cm.) and also where the higher values of pressures made the bigger errors at the upper range proportionately smaller. Calibration shows that whilst the magnitude of the difference between the gauge reading and the correct pressure is considerable between 200 and 300 cm., this difference is practically constant—to 0·5 per cent. The curves for the various calibrations were plotted on one chart of 50 × 50 inches, and it was seen that all the points fell substantially on one curve. The calibration was made against an absolute mercury manometer, 3 metres length, on different days and by two persons.

It was found that, provided a calibration chart be constructed from a great many points of calibration and always used in conjunction with the gauge, the error of pressure reading need not be greater than 1 per cent., taking all sources of errors into account.

A similar conclusion has been reached with regard to the water, inclined-mercury, and vertical-mercury manometers when readings were taken on all three simultaneously and compared with each other—*i.e.*, maximum error introduced in the viscosity measurements due to all causes of errors in the pressure measurement shall not be greater than 1 per cent.

In viscosity measurement by this method the greatest cause for error is in regulating and measuring the pressure. The error due to imperfect pressure regulation and measurement is ten times as great as the error due to thermal sources. Thus, up to this point, it cannot be expected that the method can give a viscosity measurement with a greater accuracy than 1 per cent., even if all other sources of discrepancies were completely eliminated. This explains the need for elaborate precautions to be taken in the temperature regulation and measurement and flow-meter construction, calibration, and use. To have reduced the error in the pressure regulation and measurement to less than a maximum of 1 per cent. would have meant the incorporation of unwieldy and intricate refinements, which would not be compatible with the nature and scope of the work.

Flow-Meter.

Fig. 3 shows the arrangement of the flow-meter, which was completely immersed in the bath. The displaced air, after going through a water-trap, passes through the capillary to the atmosphere. The pressure drop across the capillary is read on the toluene inclined manometer. Benzene was tried first, but it was found to evaporate rapidly, necessitating frequent refilling. Toluene was found an ideal liquid for the purpose.

The flow-meter was rigidly connected to a brass frame, which was suspended by two brass rods fixed rigidly to the side of the tank. By experiment it was proved that the setting of the manometer was the same in every case, when the flow-meter was taken out of the bath, emptied, dried, and refilled. By this arrangement both the inclination and the temperature of the flow-meter were therefore accurately controlled. The air flowing through the instrument was always 100 per cent. saturated with water vapour. Analar toluene was used throughout from one bottle. No change in the calibration curve could be detected, even when " technically pure " toluene was tried. Thus both the material flowing and the fluid used for measuring the pressure drop were of constant properties.

To derive the curve of calibration it was decided to calibrate the flow-meter under identical conditions which would exist in viscosity measurement. The set of experiments undertaken are outlined here.

Fig. 4 shows the calibrating arrangement. The purpose was to provide a constant rate of flow of air from an apparatus similar to the viscometer through the flow-meter at temperatures which could be accurately measured and kept constant. The calibrating apparatus consisted of tube *A* withdrawing water from the bath and some 3 inches below the surface from a space included in tube *B*, which was open at both ends. Thus the water

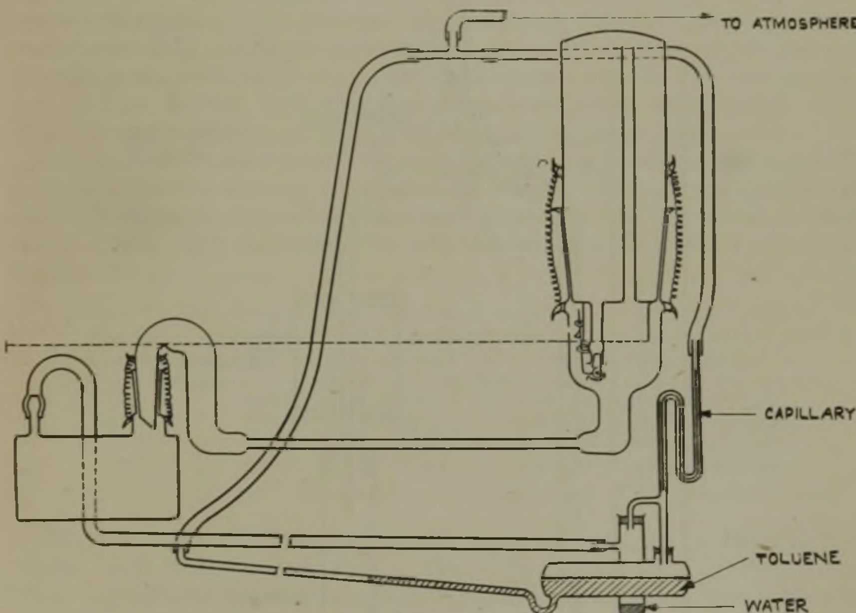

Fig. 3.

withdrawn was clean bath-water at the temperature of the bath. By using the bath-water, a constant level for inlet pressure was assured. At the time of taking the reading the stirrer was stopped momentarily to provide a steady head. This practice was therefore followed in viscosity measurements.

The water was withdrawn from *A* through syphon *C* into the nozzle *D*, which discharged into an N.P.L. calibrated burette *E*. The burette had a capacity of 10 c.c. The total error of the burette capacity was less than 0·2 per cent. The air displaced passed through tube *F* to the flow-meter. By raising or lowering the outlet level of the nozzle and fixing it vertically at any one position, the head driving the water through was varied, and hence the rate of the flow of water was varied. A clip was placed on the rubber tubing leading to the nozzle to start or stop the flow by the syphon action.

Experiments were made to determine whether the flow was constant or not. Starting the flow below the 10-c.c. mark, the time was taken as zero at 10-c.c. mark, and read at every 1-c.c. mark, the watch being stopped at the zero-c.c. mark. The rate of flow was then calculated over intervals of time taken to fill 5, 6, 7, 8, 9, and 10 c.c., respectively, starting at different marks. An unsteadiness of flow would be revealed. It was not considered sufficient that the flow-meter registered a steady head, as the sensitivity of the flow-meter was unknown.

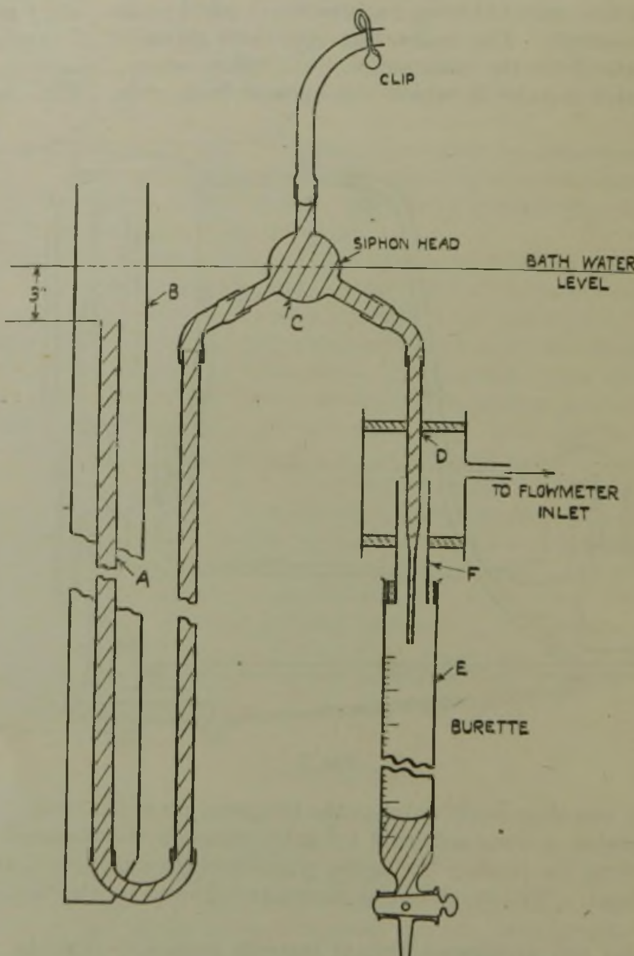

FIG. 4.

It was found that for volumes filled greater than 8 c.c. the flow results were constant. Hence it was concluded that the deviation observed over the smaller volumes filled were due to imperfect observations, and not to the unsteady nature of the flow of water in the syphon. It was also made obvious that taking the time for 10 c.c. to be filled up would yield more accurate results, or at least as accurate, as Gauss's method for averaging the rate of flow for different intervals. Hence, in all further experiments the time to fill 10 c.c. was measured by starting and stopping the stop-watch, and an average of a number of such measurements was considered to be the time of flow of 10 c.c. of air through the flow-meter.

When points were plotted on a graph having "rate of flow, c.c." for an abscissa and "head lost" for ordinate, these were found to lie on a straight line for each one temperature. The scale of the chart was large (50 × 50 inches) in order to plot the points with an accuracy at least equal to those of the readings.

Similar results obtained afterwards yielded points which fell on the same line within 0·5 per cent. To make certain that the results were reproducible, the toluene was evaporated under vacuum at 30·00° C., the flow-meter removed from the bath, and the joint between the reservoir of the flow-meter and capillary tube broken. Fresh toluene was put in, and the flow-meter assembled and fixed again in the bath. The flow-meter was left for 3 hours in the bath at 30·00° C., the calibrating assembly was joined to it, the syphon started, and the flow-meter completely recalibrated. The calibration curves were straight lines, and fell on the previous ones.

All the straight lines passed through the origin. Therefore one point on each line, passing through the maximum number of points determined at that temperature, represents the characteristic of the flow-meter at that temperature. The following four points were thus derived for the flow-meter :—

Temperature, ° C.	"Head lost."	Rate of flow, c.c./sec.	Characteristics of flow-meter at that temperature.
15·00	250·0	0·1115	1 div. = 0·0004460 c.c./sec.
20·00	250·0	0·1095	1 div. = 0·0004380 c.c./sec.
25·00	250·0	0·1079	1 div. = 0·0004316 c.c./sec.
30·00	250·0	0·1057	1 div. = 0·0004228 c.c./sec.

Fig. 5 is a plot of these four points, and it is seen that a straight line passes fairly well through them. Thus, the straight line in Fig. 5 was taken to represent the characteristic of the flow-meter in preference to any of the four curves obtained individually. The difference between the straight line and the individual points obtained is maximum at 25° C., where it is 9 in 4310 or 0·2 per cent.

A check calibration at 20·00° C. gave a maximum deviation from the value obtained from the line of Fig. 5 of 0·48 per cent. and an average deviation of 0·35 per cent.

Hence, it was accepted that with the arrangements and precautions described for the temperature, pressure, and flow-meter employed in this apparatus, a maximum error of 1·6 per cent. may appear in viscosity measurements, this maximum error being independent of the viscometer itself. In other words, even if the viscometer tube and reservoirs contributed no error at all, a viscosity measurement taken by the apparatus might be 1·6 per cent. in error. Of course, the average error will be of a smaller dimension; as in the analytical method of finding the maximum possible error, the worst conditions are assumed to be operating—*i.e.*, the errors are additive. In practice, there is a tendency for the errors to cancel each other to a great extent.

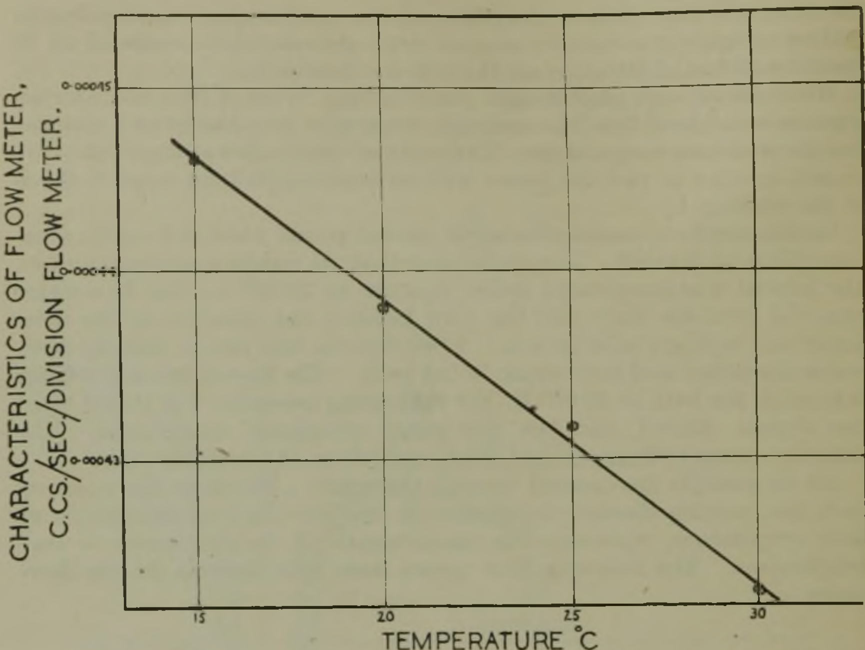

FIG. 5.

THE VISCOMETER TUBE.

The viscometer used is shown in Fig. 3. The essential parts of a viscometer of this type are : (1) a reservoir for holding liquid at the inlet of the tube, (2) a long, narrow tube, and (3) a reservoir for holding liquid at the exit end of the tube. The last part was made to hold 600 c.c. of liquid and to have an inlet for the liquid and an outlet for the displaced air. The conical end of the viscometer tube went into an enlarged space, so that the liquid went directly into the reservoir. The air outlet was connected to the flow-meter inlet via a water-trap, which also acted to saturate the air with water vapour at all times, and thus duplicate the calibration conditions.

The viscometer tube itself was designed to be used in measuring the viscosity of liquids possessing a coefficient of viscosity ranging between 10 and 750 poises. The limitations imposed were : (1) no greater pressure than 300 cm. mercury should be required to produce a rate of flow of 0·01 to 0·25 c.c. per second, with the most viscous liquid to be used ; (2) no lower pressure than 100 mm. water should be required to produce rate of flow sufficiently low to be measured by the flow-meter (0·01–0·25 c.c. per second) when the lightest liquids are studied, of approximately 10 poises ; (3) the ratio of length to radius of tube should be approximately 100. After trial calculations have been made a tube of 250 mm. length and 0·26 mm. radius was specified.

With this tube and rates of flow limited to 0·01 and 0·25 c.c. per second, it became impossible to have turbulent flow in the tube even if water was used as the flowing medium—of one centipoise viscosity.

Again, considering the kinetic energy correction, it was found that it was negligible.

This fact is important, as the value of m varies with the type of approach and exit ends of the tube. With the conclusion reached it became immaterial whether square or bell-shaped ends should be incorporated in the tube, provided the length of the tube was sufficiently determinable by direct measurements.

The Couette correction for end effects was the next factor considered. This is usually incorporated as an added length to the actual length of the tube, the correction being a certain ratio of the radius, thus

$$l' = l + na$$

where l' = corrected length to be incorporated in the Poiseuille formula, cm.

l = actual length of tube, cm.
a = radius of tube, cm.
n = a factor.

The correction amounted to some 0·6 per cent. of the length, and hence could not be neglected; this necessitated, however, the direct measurements of the tube. Certain other considerations made it more appropriate to take the length as measured and assume the correction to be incorporated in the value of the radius. The method adopted here was to measure accurately the length of the tube, and then to calibrate the tube with oil, and thus obtain a mean hydraulic radius which would incorporate all corrections automatically. The reasons for this procedure will be apparent from the following discussion.

The two chief items to be considered in designing the inlet reservoir and the outlet end of the viscometer tube were : (1) the hydrostatic head and (2) surface-tension effects. These were both solved in a practical manner by incorporating a constant head arrangement at the inlet and a relatively sharp weir at the outlet. Thus by filling the viscometer reservoir and suspending the entire assembly on three adjustable rods, the levels in the inlet and outlet of the tube were made the same, and hence any surface tension effect was eliminated. This was checked by suspending the viscometer and adjusting the lengths of the rods so that no flow took place when no pressure was applied. By closing the outlet end of the flow-meter capillary, the toluene inclined manometer acted as a most sensitive leak-detector. Thus, by observing that not the slightest increase in pressure in the outlet reservoir took place, the viscometer was assumed to have the two levels at the inlet and outlet the same. The level of the liquid at the weir was visually observed.

The final difficulty was to design a "constant"-head arrangement which gave no important fluctuations. After some six attempts on designs similar to the present one, the arrangement shown was found to be entirely satisfactory. Fig. 6 is a detailed diagram of this arrangement.

Measuring a radius of 0·26-cm. tube accurately to the fourth significant figure was impracticable with the usual mercury-thread procedure, requiring much more elaborate methods. Further, even this constant-head arrangement, which gave no signs of fluctuation in pressure at the inlet, must of necessity provide a slightly fluctuating head. These facts were responsible for calibrating the tube with a liquid of a known viscosity. Thus, all the small errors would be combined into one, and be taken into consideration automatically. Hence, it was decided to take the N.P.L. viscometry as a standard, and, by using an oil tested by the National Physical Laboratory as a calibrating oil, find the overall accuracy of the apparatus. The overall maximum error minus 1·6 per cent. gives the maximum error due to fluctuation in head and other incidental errors.

The following experiments will illustrate the use and accuracy of the viscometer.

The viscometer was cleaned with cleaning acid, then washed with water, and finally with absolute alcohol and drained dry. By applying suction to the outlet end of the reservoir, air was sucked in through a fine silk cloth, which covered the air inlet to the viscometer (*see* Fig. 6). The

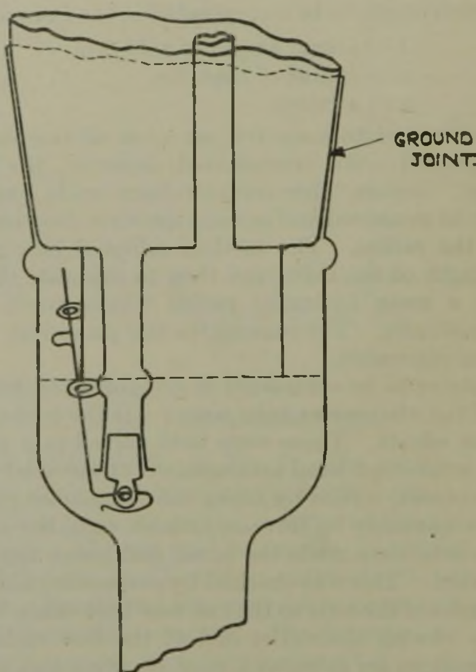

Fig. 6.

viscometer was dried with air for a period of 24 hours. (No smell of alcohol could be observed after that period.) The viscometer was then suspended over the upper cross-bar of the bath (as shown in Fig. 1), and the outlet connected to a two-way tap, making connection to the atmosphere or the flow-meter inlet as necessary. The upper cylinder of the inlet reservoir was removed, the tap opened to the atmosphere, and air-free oil poured into the inlet reservoir, slowly, to avoid trapping air-bubbles in the viscometer tube, until the oil was nearly at the level of the weir.

The ground-glass stopper of the upper portion of the constant-head arrangement was removed and oil poured through the large entry tube until the cylinder was almost completely filled. The ground stopper was then replaced and the cylinder inverted till the oil drained from both the long, enclosed tube and the external wide tube. The cylinder was replaced over the reservoir, and the springs attached to the hooks; thus, the upper and lower portions of the constant-head arrangement were assembled. A short, stout wire was then thrust through the hole in the side of the reservoir and engaged the loop in the wire holding the stopper. With a thrust downwards, the stopper was removed from its socket, and oil flowed to the reservoir until the level rose to the edge of the wide outer tube. Flow stopped at this point.

When a thick oil is used, it is proposed not to use the constant-head arrangement, but to plug the hole in the reservoir and fill the reservoir to the top. As higher pressures will be required, it is only necessary to take the mean hydrostatic head into account and apply the appropriate corrections.

A silk cloth was wrapped around the reservoir to filter the air going through the hole, and a rubber band kept the cloth in place.

The brass cylinder was bolted down on a hard rubber washer, the joint between the glass apparatus and the brass plate having been permanently sealed by a stuffing-box arrangement using rubber washers, and with wax on the upper side. Connections were then made between high-pressure hose and the top of the brass cylinder. All this time the apparatus had the surface of the oil inside the inlet reservoir at a lower level than the weir.

When the apparatus was completely assembled it was lowered to the lower cross-bar and bolted down by two butterfly nuts, keeping the weir still higher than the level of the oil. The bath was maintained at the temperature required. The air expanded directly to the atmosphere at first; then the tap was turned to connect the outlet reservoir with the flow-meter. The apparatus was left in the bath for 1 hour, so that both the temperature of the oil and the air and the saturation of the air with water vapour were as required.

The next step was to level the apparatus. This was done by tilting the tube, through the use of the suspending rods as levelling screws, until oil began to flow over the weir, then tilting it back until the oil just ceased to flow, and yet the oil was still at the weir. By stopping the outlet of the air capillary on the flow-meter with a rubber clip, the toluene manometer indicated even very minute rates of flow. When there was no evidence of flow, it was considered that surface-tension effects had been fully balanced, any flow resulting therefrom being too small to affect the results. Similarly, it was considered that the level of the oil both at the inlet and outlet was sufficiently the same not to introduce any measurable error.

When all these preparations were made, readings were taken for pressure of the air and rate of flow on the flow-meter. The stirrer was stopped for the reading to be taken in a quiescent bath. The temperature was constantly checked. Previous tests showed that the rate of cooling of the bath was far too slow to affect the temperature over the period of reading.

Oil having viscosity of 14·6 poises at 21·1° C.
Temperature of the bath 21·10° C. throughout the experiment.
Temperature of the laboratory—18·0° C.
Zero point on water manometer—49·0 mm.
Zero point on flow-meter—407·0.
Characteristics of flow-meter at 21·1° C.—0·0004369 c.c./sec./division.

TABLE I.

No.	Pressure reading, mm. H_2O.	Uncorrected pressure, mm. water.	Flow-meter reading.	Flow-meter "head."	Back pressure, mm. water.	Corrected pressure, mm. water.	Rate of flow, (c.c./sec) × 10^{-2}.
1	140	91	311	96	5·4	85·6	4·20
2	150	101	296	111	6·2	94·8	4·85
3	154	105	294	113	6·3	98·7	4·94
4	162	113	281	126	7·1	105·9	5·50
5	162	113	283	124	7·0	106·0	5·41
6	170	121	273	134	7·5	113·5	5·85
7	170	121	274	133	7·5	113·5	5·81
8	190	141	253	154	8·6	132·4	6·72
9	199	150	242	165	9·2	140·8	7·20
10	200	151	242	165	9·2	141·8	7·20
11	210	161	233	174	9·7	150·3	7·60
12	220	171	219	188	10·5	160·5	8·21

For Newtonian flow all that is required to obtain the characteristic of the apparatus is to calculate k, a constant by which the ratio of pressure to rate of flow is multiplied to give the viscosity of the fluid. Thus let

$$\eta = k \cdot \frac{P}{Q} \text{ or } k = \eta \frac{Q}{P}$$

where η = viscosity in poises.
P = pressures in mm. water.
Q = rate of flow (c.c. sec.) 10^{-2}.

The following set of values of k are then obtained :—

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
0·717	0·748	0·730	0·757	0·746	0·752	0·747	0·741	0·748	0·743	0·737	0·747

Neglecting the first point, as the pressure was far too low for accurate reading (100 being a minimum), the average value for k is 0·745, with a maximum error of approximately 2 per cent. Thus, the oil was Newtonian, and the precision of the apparatus is of about 2 per cent. maximum error for any one single reading. For Newtonian liquids the error would be considerably lower, as an average might be obtained for a whole set of points falling on a straight line. For non-Newtonian flow, however, the points for a rate of shear-shearing stress diagram fall on a curve, and hence each point has to be taken to a greater extent than in the former case as individually important.

To calculate the radius, the average value of k was taken and introduced in the formula

$$\frac{R^4}{l} = \frac{8Q\eta}{\pi P} = 0{\cdot}0001934$$

where Q = rate of flow in c.c./sec.
η = viscosity in poises.
P = pressure in dynes/sq. cm.

l was measured, and found to be 25·00 ± 0·02 cm. Hence R^4 is equal to 0·004835 cm., and R becomes 0·2636 cm.

Two types of errors have to be studied here :—

(1) The errors due to fluctuation in the hydrostatic head, surface-tension effects, and general irregularities in the design or manipulation of the viscometer tube and reservoirs. These errors are independent of the value of the viscosity of the test oil. It can be estimated from the maximum variations of the twelve determinations of k from the mean value, or simply from the maximum variation of the individual points of a plot of the rate of flow *vs.* pressure from the straight line passing through the mean position of these points (Fig. 7). This error is seen to be 2 per cent. Since it is possible that 1·6 per cent. was due to irregularities in temperature, pressure, and flow-meter readings, then the viscometer is responsible for at least 0·4 per cent. error.

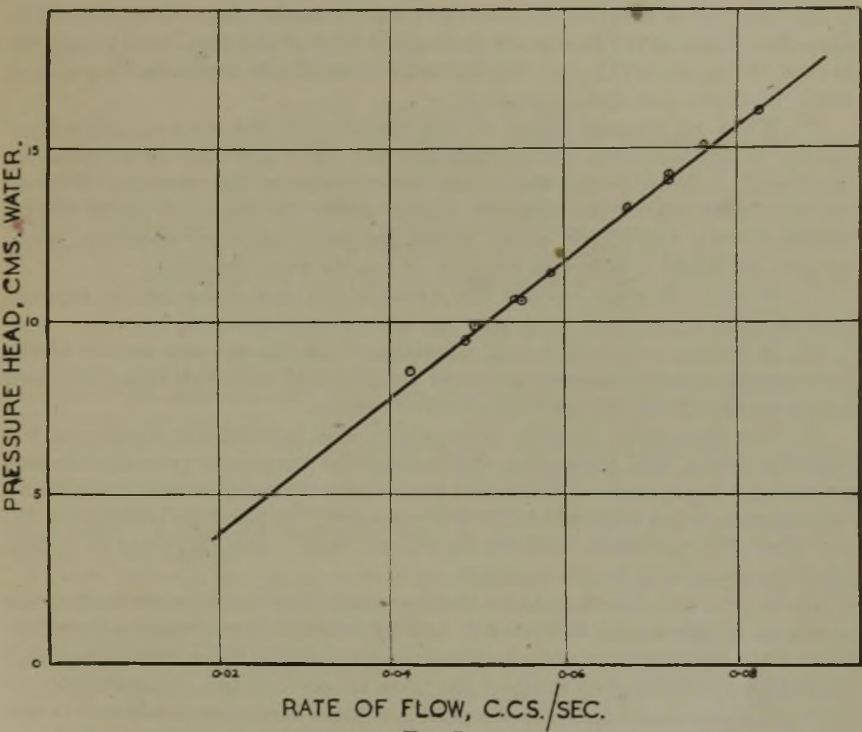

FIG. 7.

(2) The actual value of k to be used in measuring the viscosity of Newtonian liquids and of R for the calculation of rates of shear and shearing stresses at the glass/oil interface is affected by the value of the viscosity of the calibrating oil and by the errors of the present viscometer. It is true that, since the figure 14·6 poises was taken from a National Physical Calibration, it is accurate to the limits of the present apparatus. Nevertheless, it has been decided as a good policy to doubt this figure, in case the cleaning of the apparatus, for instance, has not been complete, and also in case the setting of the apparatus has an influence over the results obtained.

Hence it was decided to empty, clean, and refill the apparatus and set it up and measure the viscosity of an N.P.L. calibrated oil at 17·5° C. This was performed in exactly the same manner as employed before in obtaining the twelve results for the calculation of k and R.

The following data were supplied from experiment :—

Viscosity of oil at 17·50° C.	19·4 poises.
Temperature of bath	17·50° C. throughout the experiment.
Temperature of the laboratory	19·0° C.

The results of twenty experiments were that (1) summation of errors was zero, (2) maximum values of individual errors were ± 1·6 per cent.

Conclusions.

The following conclusions became evident :—

(1) A value of 0·745 for k, the constant of the instrument, gave the viscosity of an oil of 19·4 poises correct to 1·6 per cent. in twenty determinations. Since the value of 0·745 was an average of twelve previous determinations, in fact, the figure 0·745 gave the viscosity correctly, to 2 per cent. maximum error, in thirty-two determinations.

(2) When an average value of the viscosity of the oil was taken from twenty determinations, the average did not differ from the figure given by the N.P.L. Thus, if average values were taken for the viscosity of an oil by this instrument, the average might safely be assumed to be nearly identical with the figure which would be given by other absolute viscometers, provided a sufficient number of results were obtained.

(3) In such average results the average did not differ by an amount greater than 2 per cent. from any one individual result.

(4) It was seen that if R was calculated from the average results of the last twenty determinations, it would be identical with the value obtained as an average from the previous twelve results.

(5) The maximum possible error which was beyond the control of the operator using this apparatus and taking the constants provided in this report was 2 per cent. Of this the irregularity in temperature control and measurement was responsible for 0·1 per cent.; in pressure control for 1·0 per cent.; in flow-meter control for 0·5 per cent.; and therefore in hydrostatic head control for 0·4 per cent.

(6) It was not practicable to change conditions in order to reduce the errors in temperature, flow-meter, and hydrostatic head control considerably. Hence any attempt to improve the accuracy of the present apparatus should be in the improvement of the pressure control and measurement.

(7) It was realized that the viscosities studied here were conducive to the maximum percentage errors, as the pressure readings were low, and therefore the effects of any variation in the hydrostatic head in the inlet reservoir assumed its maximum degree of importance. Even when the viscosity was raised from 14·6 to 19·4 poises, the maximum error dropped from 2 to 1·6 per cent.; the small variation in hydrostatic head became less important. Thus, with higher viscosities, necessitating pressures greater than, say, 100 cm. water, it is believed that the constant-head arrangement would function with a negligible difference from the ideal, and the total error would become 1·5 per cent. at its maximum.

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Reference.

[1] Barr, G., " A Monograph of Viscosity." Oxford University Press. (1931.)

PARLIAMENTARY AND SCIENTIFIC COMMITTEE.

LUNCHEON.

3rd February, 1942.

A Luncheon of the Parliamentary and Scientific Committee was held at the Savoy Hotel, London, on Tuesday, 3rd February, 1942. The Institute of Petroleum, which is a supporting member of the Committee, was represented at the Luncheon by Mr. C. Dalley, Mr. T. Dewhurst, Dr. A. E. Dunstan, Dr. E. R. Redgrove, and Mr. A. E. Evans (members of Council). We reproduce below two speeches of particular interest to scientists, by Lord Hankey, G.C.B., G.C.M.G., and Sir Henry T. Tizard, K.C.B., F.R.S. (Hon. Member), respectively.

The Rt. Hon. Lord Hankey.

I have been asked to propose the Toast of "Science." In these parlous times this means Science in War. That is a vast subject, the more so because in war the financial limitations which hamper science in times of peace are relaxed, and funds become available on an almost unlimited scale. The extent of present scientific activity may be judged from a note which my friend Captain Plugge was good enough to send me about your Committee's work. Referring to wartime difficulties the note says :

> "The technicians and scientists are so immersed in war work that they have little time for political activity."

That is the bare truth. In spite of what has been said to the contrary, most of our scientists have been harnessed into war work; perhaps I should say have harnessed themselves, because I know of no part of the community which has responded more readily to their country's call. The problem to-day is not to find jobs for scientists, but scientists for jobs.

I suppose I owe the honour of proposing this Toast to my association with the Scientific Advisory Committee, the Engineering Advisory Committee, and the Technical Personnel Committee, devoted to the provision and training of men and women for radiolocation and other technical equipment for the Services, for research and for industry. I could not attempt to describe the work of these bodies in the few minutes at my disposal.

I recall, however, that when the Scientific Advisory Committee was set up, there was some discussion, in which your committee took a part, as to whether it should include representatives of applied science. The Government decided to confine it to representatives of pure science, partly in order to limit the numbers in the interest of efficiency. A few months later, however, the Engineering Committee was set up to advise the Government on that branch of applied science. Both bodies have found plenty to do within their respective spheres. But they work in close association, and from time to time questions crop up in the borderland between pure science and applied science. In view of your interest in the matter, you may like to hear that we deal with these cases by *ad hoc* joint conferences composed of appropriate members of both bodies, often with the aid of best scientists or engineers from outside our own membership. We seek the best available scientific help.

We have no difficulty in obtaining it, for we receive enthusiastic co-operation from the numerous scientific and research organizations of Government Departments, from the Royal Society, the great Engineering Institutions, Universities, and independent scientific workers. I take this opportunity to place on record our indebtedness to the whole scientific world in this respect.

We have also arranged for ever-increasing co-operation with the Dominions and the United States of America, with its vast scientific resources. The United States, Canada, and Australia have established scientific agencies in this country, and there is a constant stream of individual scientists and of scientific information between this country and America and the Dominions, so as to ensure a united effort in research development and the application of science. They have also given us substantial aid with technical personnel.

I am told that some enthusiasts maintain that the Government itself ought to be run by scientists; that, if that were the case, we should soon win the war; or, as some would have it, that there would have been no war. That is going too far. There is, of course, a science of war and a science of government, but in both there is a good deal more than that.

War is sometimes referred to as an art. It is also called "the sport of kings"—perhaps we ought to say Dictators to-day. Whether it is itself a science or an art, however, war, with its nice calculations of fleets, armies, and air forces, each with its own ramifications, with its problems of time, space, speed, striking power, protection, and training, to say nothing of production, agriculture, food supplies, health and man-power—all this, I say, requires the co-operation of scientists at every phase.

So anxious are the Departments for first-class scientists that my friend, Sir Henry Tizard, is a member not only of the Air Council, but also of the Aircraft Supply Council. All three Fighting Services are tremendously science-conscious. Scientists are being employed more and more, even in the operational side of their work; not only individual scientists, but, what is even more important, teams of scientists, some of which I have myself seen at work. In addition, our Universities and Technical Colleges are giving intensive scientific training to great numbers of men and women to operate the mass of scientific war apparatus that Industry is producing.

This reliance on science in our hour of need to-day is, I believe, going to have a tremendous effect on statesmen and officials after the war.

So far none of my scientific friends, neither Sir William Bragg, the late President of the Royal Society, nor Sir Henry Dale, the present President, nor the presidents of any of the great Engineering Institutions, have evinced to me the slightest desire to take Mr. Churchill's place !! In these days, however, not the least important of the functions of government is to place science on the war map. That is what we are doing our utmost to accomplish, and you will agree that it is essential to victory.

Sir Henry T. Tizard.

Looking at things as a whole, no one can deny that the influence of science is now greater than it has ever been, and that the present Government and Parliament attach a value to the help and guidance of scientists that no previous Parliaments have ever done. Lord Hankey has already told you something of the work of the Scientific Committees over which he presides. There are many more such Committees that I could mention. There is hardly a phase of the national life now with which scientists are not associated. In fact, a fighting friend of mine said that he could hardly walk in any direction in this war without tumbling over a scientist who had got in the way. In the Royal Air Force, where the concentration of scientists is perhaps greatest, they have a pet name for them. They call them "Boffins." Why, I do not know. I said to a young friend of mine in the Air Force, "Why do you call scientists 'Boffins'?" He said, "I don't know. What else would you call them?"

And then, what previous Prime Minister of England ever had a scientific adviser continually at his elbow? He is not the only Minister who has a scientific adviser. Even Commanders-in-Chief have them, as General Pile, who is here, would blushingly admit.

I am sure that it has not escaped the notice of those members of your Committee who are not scientists that we scientists are a very critical lot. We see with the greatest clearness the shortcomings of other people! Indeed, we are brought up to be critical; it is part of our education to accept things only on evidence, and not merely on the unsupported authority of older men. There is no such thing in the scientific world as authority based merely on position and seniority. It is true that we are brought up to be constructive critics, but human nature being what it is, I will not claim that we are always constructive, though we generally try to be. And let me let you into a secret. We scientists and scientific advisers do not always agree among ourselves. Your quick wit and ready perception will at once lead you to deduce that sometimes some scientists are wrong. This profound fact should always be borne in mind by your Committee.

What is the general result of this widespread intrusion of scientists into the affairs of the war? Let me try to explain my views with the help of an analogy. There are not so many people who really understand the methods and processes of science, but we all think we know a good deal about war. Science, like war, has its strategy and its tactics. Tactics come in when the plan is settled, the task decided, and the problem set: and in science—as in war—success in tactics depends on good command, good organization, an adequate amount of up-to-date equipment, and an adequate amount of highly trained men. Judged in this way, the tactical strength of science in this country is very great. There are many well-run and well-equipped research and experimental establishments up and down the country under direct or indirect Government control or under independent control. Above all, thanks to the progressive policy of education in the last twenty years, and also, I like to think, to the innate qualities of our race, there is a large supply of able young men who are now rendering, by their scientific work, great service to the State.

I fancy that the amount and quality of the scientific and technical ability available in this country has surprised even some of the older generation of scientists. It has certainly surprised our foreign friends and foes. Perhaps it was because peace-time conditions in this country did not give these young men a real chance to show what they were worth. If so, we have a problem to deal with after the war. Or perhaps it is because, as a nation, we have a habit of keeping our best goods away from the shop-windows. I remember a well-known aeronautical engineer, who came over to this country from the United States shortly before the war. He was very depressed at what he thought was the state of aeronautical science in this country. Our science was bad; our engineering was bad; and our design was bad. Being a real friend of this country, he expressed his gloom to me. He thought we were a long way behind Germany, let alone America. He went out of his way to give his views to people in more influential positions. About eighteen months ago I met him again, in the United States. I reminded him of our conversation, and he said, with that impulsive generosity which we find so attractive in Americans, "Oh, don't remind me about it; I take it all back."

My considered opinion is that, so far as the tactics of science are concerned, we have nothing to fear in comparison with any other nation.

So far as the strategy of science is concerned, I am not so confident. Much has been done to improve it, but much remains to be done. The strategy of science is again similar to that of war. The strategy of pure science is to attack at the weakest spot of the barrier to knowledge. The secret of science is to ask the right question, and it is the choice of the problem, more than anything else, that marks the man of genius in the scientific world. The strategy of science applied to war is to attack at the point where the dividends are greatest in results in relation to the effort. Our tactical strength is great, but it is not unlimited. We cannot afford to dissipate our efforts over things that do not matter or do not matter much, and we must remember, too, that any technical advance, to have a decisive effect in war, makes big demands on the productive capacity of the country. All this you may say is common-sense; but it is not common-sense that is very apparent. Few people have any idea of the spate of inventions that have to be considered and dealt with in the Service Departments. Most of them are, of course, worthless, and just waste time. I have been told that only one in every thousand patents has any likelihood of being used and only one in every ten thousand is of any real value. The official in the Patent Office is in a happy position. All he has to do is to satisfy himself that any suggestion, however stupid, has never been made before, and then charge the individual who made it a fee for the privilege of having it registered, and there the business ends. How the individuals in Government Departments who have to deal with inventions in war would rejoice if they were in the same happy position! But it is not the worthless inventions that are the real trouble. The real trouble and waste of time are caused by inventions and proposals that have something to be said for them, that are not technically impossible, and that might conceivably be of some use in some circumstances: such proposals are often pressed with great force by all sorts of influential people—scientists, Members of Parliament, and even Ministers. If we try to do all these things, we dissipate our efforts and end by doing nothing well. Someone has to decide, having all the facts in mind, what is worth doing and what is not; and the decision is not an easy one to take, and involves great responsibility. Strategical decisions in war are taken by the Cabinet on the advice of the Chiefs of Staff of the Service Departments. We may all have ideas about war strategy, but we know that the decision must be left to them. There was certainly something to be said for attacking on the Western Front some months ago, but all those who urged it must realize now what a mistake it would have been.

Who, then, is to decide the strategy of scientific war, to settle what are the things that really matter, where we are to devote our scientific strength to get the greatest results in the shortest possible time? Certainly not scientists alone, working in the void, however eminent. Nor, in my opinion, can it be safely left to the staffs of the Fighting Services, even though each Service Department may contain officers of high scientific ability. Nor, I say, can it be left to a War Cabinet, however fertile in ideas. The safest way of reaching the right decision is to have scientists working side by side and in the closest collaboration with those who have the administrative and executive responsibility. And the first thing that the scientist learns when he has the benefit and privilege of such collaboration is that he has a lot to learn.

When the history of this war comes to be written, I hope that due credit will be given to those senior members of the staff of the Air Ministry, and to the then Minister, Lord Swinton, for adopting this policy. Since that time it has been greatly developed. The technical needs of the Royal Air Force, its staff plans, even its operations, have been submitted freely to the scrutiny and criticisms of scientists. One may safely say that good dividends have resulted, so much so that the example has spread to other Departments. But not yet enough. Let me earnesly recommend to the Parliamentary and Scientific Committee that they can do no greater service than to ensure this kind of co-operation. Let the Committee concern itself rather with the general strategy of science than with its tactics.

One last comparison before I conclude. What are the two great driving forces of our moden civilization? Science and Christianity. You may well think that is an odd, if not a preposterous, remark for a scientist to make, so I hasten to say that it is not original, and it was not first made by a scientist. When I was at school there was a youngish-looking Canon of Westminster Abbey, whose sermons were listened to even by boys, and who often had a kindly word or a smile for the small boys he passed in Dean's Yard. So when I picked up in a bookshop the other day a little volume entitled "Last Words in Westminster Abbey," by Hensley Henson, I thought that the least thing that I could do was to add a trifle to his royalties. This is what I read in one of the sermons :

> "Science and Christianity are the distinctive features of the civilization which has been cradled in Europe, and from Europe extended over the world. The principle of both is liberty, the expression, in unshackled freedom, of the innate powers of the human spirit, the expression and vindication of individuality."

Is it not of interest, especially when we recall the supposed antagonism between science and Christianity some fifty years ago, that it should be left to a leader of the Church to express, in so few and striking words, the fundamental strength of science? It set me thinking how few people see beyond the material benefits that science brings. The House of Commons seems at its best when the Whips are taken off and some subject is discussed that touches the religious life or convictions of the people they represent. In all the best social legislation Parliament is sustained and guided by the great principles of Christianity. In fact, one may say that there is hardly a member of either House of Parliament who does not understand and respect the motives and ideals of Christianity, even if he does not believe in it; whereas how few there are who understand the motives and ideals of science, even though they all believe in it. I have heard it said that this war has been brought about by the progress of science, and that it would be better for humanity if scientific research were stopped. I answer that in the past the progress of Christianity was responsible for many bloody wars: would you have stayed it for that reason? Make no mistake: this is a war of science. In these days we are witnessing how the scientific resources of Germany—and they are great indeed—are devoted to the object of destroying that intellectual freedom which is the very breath of science. So also in the Middle Ages did the Inquisition, on professedly religious grounds, strive to destroy, by the infliction of untold suffering, that liberty of conscience which is the fount of true Christianity. The tyranny of the Inquisition has long since vanished into the past, beaten down by brave men to whom death was preferable to life without freedom; who were at first disorganized and ill-equipped for the fight, and discouraged by the policy of timid Governments. So also will the present tyranny be beaten and die away, maybe sooner than we dare hope, maybe only after many years of suffering; but when it passes let us hope that scientific men, administrators, and legislators, tempered in the furnace of war, will continue to work side by side, with respect for each other's knowledge, and tolerance for each other's ignorance, to restore a stricken world and to lead us to better things.

OBITUARY.

DR. L. EDELEANU.

We take the following brief account of Dr. L. Edeleanu's life from an article by our distinguished foreign member Professor L. Mrazec in the *Moniteur Du Pétrole Roumain*, 9th April, 1941.

"During the morning of the 7th April, 1941, Dr. L. Edeleanu passed away at the age of eighty, in his home at Bucharest, in the serene evening of an existence devoted to science and to technical progress.

"The commencement of his scientific life was at the University of Berlin in the laboratories of Professors A. W. Hofmann and C. Rammelsberg, which led him to the Chemical Section of the Royal Artillery College of Woolwich, where he became the assistant of Professor Hodgkinson.

"On his return to Rumania, he was welcomed by Professor Istrati, with whom he collaborated, thence to become Director of the Chemical Laboratory of the Mines Department. In 1906, when this laboratory was taken over by the newly established Geological Institute of Rumania, Dr. Edeleanu was attached to this Institute, where he assumed the direction of the chemical work. Here very fruitful activity developed, especially in the domain of petroleum chemistry, as much by his own work as that of those whom he directed around him.

"His work and that of his collaborators bore the distinctive character of a methodical fathoming of scientific truth, which led him, amongst others, to the discovery of the important rôle which can be played by liquid sulphur dioxide as solvent and selective agent in the technology of the complex hydrocarbons contained in petroleum. This Rumanian discovery is perhaps the most important in the record of scientific and technical progress of the petroleum chemical industry. Tens of thousands of petroleum derivatives are subjected each day to the Edeleanu process in the great petroleum regions of the world—with the exception of Rumania, which, itself, should particularly require the application of this process, and whose petroleum itself gave rise to these researches.

"Of all the distinctions which have honoured Edeleanu, the Redwood medal of the Institution of Petroleum Technologists in London (1932) represents the most eminent award.

"With this distinguished scholar passes a man and a character, a jewel of Rumanian science, and an example of indefatigable and rational work, dedicated to the search for truth and the progress of science."

A. E. D.

PROFESSOR A. R. ANDREW.

The death is announced from New Zealand of Dr. Arthur Robert Andrew on 14th December, 1941, at the age of 60. Dr. Andrew was Professor of Mining at Otago University and Director of the Otago School of Mines. He was an Original Member of the Institution of Petroleum Technologists, having been elected a full Member in 1914. He retained his connection with the Institution up to 1931.

He was born and educated in New Zealand and graduated B.Sc. from Otago in 1902. Two years later he came to England, and undertook research work at the University of Birmingham. He took his M.Sc. degree in 1906 and D.Sc. (New Zealand) in 1911. For a number of years he was mineral surveyor to the Nyassaland Government, and was later employed in South America on petroleum geology. In 1914 he was appointed geologist to the Anglo-Saxon Petroleum Co. at Miri, Sarawak, and subsequently worked at The Hague and in various European countries. In 1926 he returned to New Zealand for family reasons, and shortly afterwards was appointed to the Otago School of Mines. He was geologist for the Dominion oil-fields, and published many works on mining and geology.

In his younger days Dr. Andrew was an active Rugby footballer. He was Captain of the Birmingham University Rugby Football Club. He played for the " All-Blacks " on at least one of their tours in Great Britain. Dr. Andrew was a fine man in every sense of the word, a scientist, a sportsman, and an excellent companion. A. C.

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

204.* Tansill Formation, West Texas and South-Eastern New Mexico. R. K. DeFord and G. D. Riggs. *Bull. Amer. Ass. Petrol. Geol.*, September 1941, **25** (9), 1713–1728.—The junction of the Tansill formation above with the Yates sand below is widely used in plotting structures of the Permian in the area where the Pecos river crosses the boundary between New Mexico and Texas. The Tansill consists of 6–18-in. magnesian limestones, marls, and silts, with average dip of 12°, S. 36° E., and is defined for 60 miles. Measurements of the type section on the Carlsbad dome, descriptions of the insoluble residues, and details of the contained Octillo silt member, grey in places, red in others, traceable for 100 miles, are provided. Along strike the Tansill thins on anticlines to 95 ft. at the Getty pool and 115 ft. at Lake Avalon, but thickens to 165 ft. on the side of the Vickers synclinal. South-eastwards the Tansill increases to 300 ft., with gastropods, before grading into the Capitan limestone, in the top of which fusilinids, crinoids, and algæ are recognized. To the north-east, the layers of Tansill limestone, or at least the diastems between them, give place to beds of anhydrite.

If the Permian is taken as having lasted 40,000,000 years, it is suggested that the Tansill covers 500,000 years. On dividing this by 250 " horizons of interruption," it seems that each 6-in. stratum of limestone with associated interval of non-deposition represents 2000 years.

The top of the Tansill is equal in age to that of the Capitan, and corresponds with the Guadalupe–Ochoa break. To the south-east the Castile formation overlies the Capitan, and in part of the district north-east of Carlsbad laps against the Capitan reef-front. Elsewhere the Salado, and probably the Rustler, rest directly on the Tansill with disconformity. R. C. W.

205.* Geology of Southern Part of La Barge Region, Lincoln County, Wyoming. A. J. Bertagnolli, Jr. *Bull. Amer. Ass. Petrol. Geol.*, September 1941, **25** (9), 1729–1744.—The Palæozoic rocks of the north–south La Barge Ridge, west of the La Barge oil-field, are divided up for the first time. The Cambrian (more than 1160 ft.) begins with limestone, succeeded by thick shales with thin, glauconitic, worm and trilobite limestone bands, followed by brachiopod–trilobite limestone with edgewise conglomerate. After an angular unconformity of 3–6° comes the Ordovician Bighorn limestone (890 ft.), dolomitic but easily eroded, containing *Endoceras*. Next, after slight discordance, there is the Devonian Jefferson limestone (498 ft.), magnesian and sandy, with occasional *Atrypa reticularis*, and finally, above a likely unconformity, the Lower Carboniferous Madison formation (715 ft.), of platy and arenaceous limestones characterized by *Spirifer centronatus*. These Palæozoics are driven eastward by overthrusting along the Darby fault, and rest on Upper Cretaceous, which comprises the Hilliard Series (4200 ft.) of shales and sands with *Scaphites*, and the Adaville cross-bedded sands and lignites (1000 ft.). Unconformable over all the preceding is the Almy (600 ft.), of red and white conglomerates, sands, and clays, seemingly Eocene. Secondary thrusting from the west now took place on the site of La Barge, and in front of the thrust an anticline was developed in the rudaceous Almy. On a probable erosion surface, the Knight formation (300 ft.), of soft red and grey shales and sandstones, was next deposited. The Green River sandstone and shales (700 ft.) conclude the Tertiary, and show gentle arching, probably due to differential compaction.

The oil of the La Barge field appears to have migrated from the Upper Cretaceous into the anticline of basal Eocene under the post-Almy thrust-plane. S. N.

206.* Correlation of Cross' La Plata Sandstone, South-Western Colorado. M. I. Goldman and A. C. Spencer. *Bull. Amer. Ass. Petrol. Geol.*, September 1941, **25** (9), 1745–1767.—The Upper Jurassic La Plata sandstone described by Cross in 1898 is taken to consist of five distinguishable units : (1) Entrada sandstone, yellowish to red in colour, massive, partly cross-bedded ; (2) Pony Express limestone (maximum 15 ft.), dark grey to black, bituminous, discontinuous, and variable ; (3) Bilk Creek sandstone (about 20 ft.), topped by $1\frac{1}{2}$–2 ft. calcareous sands with nodules of red chert—" Carnelian sandstone "—recognizable, however, without chert ; (4) Wanakah marl (50–100 ft.), argillaceous and sandy beds, characterized by concretions of barytes and by deposition of layers of a dark green mineral, either chloritic or glauconitic, on red chert ; (5) Junction Creek sandstone (up to 500 ft.), whitish, with considerable rounding of grains and æolian false-bedding. (2)–(5) belong to the Morrison formation.

Two problems are tackled—namely, to find the relations of the units to one another, and to correlate them with related beds of South-Eastern Utah and Northern New Mexico.

In Southern Utah the Bluff sandstone belonging to the Morrison is taken as equivalent to the Junction Creek beds. The Todilto limestone of Todilto Park is not considered to represent Pony Express, since it is overlain by Novayo sandstone. But a limestone of the name Todilto in the north-west corner of New Mexico is accepted as equal to Pony Express, since it is succeeded by beds similar to Wanakah marl and lies on Entrada sandstone. A section on the Cimarron river, New Mexico, is suggested as synchronous with the Colorado section, but sideritic sandstones seem to occur at a horizon above the top of the Junction Creek and below overlying Morrison sandstones.

S. N.

207.* Well-Logging by Radioactivity. W. L. Russell. *Bull. Amer. Ass. Petrol. Geol.*, September 1941, **25** (9), 1768–1788.—Since electric logging is a comparatively recent development, many cased and cemented wells have never been accurately logged. Because electric logging is limited to uncased holes, logging by radioactivity is the only known method of making lithological records through the casing and cement. The gamma rays used in radioactivity surveys are produced chiefly by the members of the uranium–radium and thorium series, and by potassium. Gamma rays from potassium are particularly penetrating; and shales, since they have more potassium than sandstones and limestones, are found to have relatively high radioactivity. Of the igneous rocks the light-coloured acidic rocks are most radioactive, while the heavy basic rocks are least so.

The instrument, which is lowered in the well, consists of a metal cylinder, the lower part of which (*i.e.*, ionization chamber) contains a gas under pressure. The gamma rays ionize the gas and decrease its resistance to the passage of an electric current, so that the current passing through the ionization chamber indicates the relative amounts of radioactive material in the formation surveyed. The current, after amplification, operates an automatic pen-recorder, which plots the log in the field while the survey is in progress.

At present these logs are used chiefly to determine the position of the producing sands behind casing, in order that the pipe may be perforated to drain them most effectively. Other applications are for determining the amount of sample lag, mapping subsurface structure for deeper drilling, making correlations and cross-sections, and for surveying potash deposits. A similar process may be employed in making radioactivity surveys at the surface and in mines. J. T.

208.* Pre-Cretaceous Sediments in Cordillera Oriental of Colombia. P. A. Dickey. *Bull. Amer. Ass. Petrol. Geol.*, September 1941, **25** (9), 1789–1795.—On the east side of the Cordillera Oriental, the Quétame Series, with Carboniferous fossils, south-east of Bogota, and a shale of Onondagan age (Lower Devonian), at Floresta, have already been recognized as Palæozoic. Great upthrusts are common, like that west of Santa Rosa (Boyacá), but here the eastward section to Floresta appears to be normal, and includes: Tablazo limestone and shale (Middle Cretaceous); La Paja shale and Rosa Blanca limestone and shale (Lower Cretaceous); the Girón Series (? Jurassic or Triassic), comprising red-beds not less than 1000 in. thick and forming much of the western face of the Cordillera; Floresta shale (Lower Devonian); and, near Corrales, metamorphic rocks with igneous intrusions.

Graptolites have been reported, but without confirmation, on the west side of the Magdalena valley, where Philip Merritt's Suratá Series, with productids, is succeeded by his Bocas Series, containing thin, metamorphosed coals. Phyllites, probably Palæozoic, outcrop in several places, and at Meseta de Los Santos appear to underlie the Girón, although the actual contact may be faulted.

In the eastern part of the area, where the Girón is absent, the Cocuy sandstones are not of Girón age, but seem to be equal to the Lower and Middle Cretaceous limestones and shales of the west. R. C. W.

209.* Photogeology. H. C. Rea. *Bull. Amer. Ass. Petrol. Geol.*, September 1941, **25** (9), 1796–1800.—It is argued that in geological mapping of a new area, most rapid progress is made by first preparing aero-photographs overlapping at least 60% at the sides, 30% at the ends, and on a scale of 1 in. to about 1650 ft. These will usually show exposed outcrops, obvious dips, possible faults, and will distinguish reflecting values of contrasting rocks and soils. Different types of natural vegetation and cultivation, drainage patterns, watersheds, reservoirs, quarries, and railways are also represented. The photos may be studied stereoscopically, and should be interpreted from the geomorphological—see Lobeck's text-book—as well as the geological point of view. Areas of complication can usually be picked out at once.

Salt domes have been located from anomalous drainage patterns, and mud-volcanoes in dense jungles by means of a "timber halo." Ancient stream-courses filled by younger deposits are marked by vegetation and soil changes. Kelp adheres to under-sea outcrops of Monterey shale, so as to delineate the Ellwood anticline, off Santa Barbara, California. Lodes and igneous patterns are also often made clear. Where loess, wind-blown sand, or glacial deposits provide a covering, photogeology encounters the same difficulties as normal field-mapping. A. L.

210.* Crude Oils and Stratigraphy in Parts of Oklahoma and Kansas. L. M. Neumann, N. W. Bass, R. L. Ginter, S. F. Mauney, C. Ryniker, and H. M. Smith. *Bull. Amer. Ass. Petrol. Geol.*, September 1941, **25** (9), 1801–1809.—In South-Eastern Kansas and North-Eastern Oklahoma, oil-pools in Burbank sand extend to form a curving belt, 150 miles long and 10–20 miles wide. The sands are hummocks with flat bases, and represent sand-bar accumulations of the Upper Carboniferous sea. In thirty-seven pools crude oils of similar composition are found. The only noteworthy variation is a slightly greater residuum in Oklahoma oil, with a perceptibly higher A.P.I. gravity than in the Kansas oils, due to a loss of light hydrocarbons over a long period. That the source-beds had a limited vertical extent within the Cherokee shale is indicated by the fact that the Rock sand, 50 ft. above the Burbank, and the Bartlesville sand, 100 ft. below it, yield different types of oil. It is likely that the oil originated in the organic sediments deposited in swamps behind the sand-bars, the thickness of these sediments usually not exceeding the height of the "sand-hills." The oil may have formed under pressure from later Pennsylvanian deposits. Structural movements which formed local anticlines did not affect the composition of the oil; neither did the tilting of the Prairie Plains homocline, nor recent differential erosion, since in Woodson County, Kansas, at 350–400 ft. below sea-level and at a depth of 1400 ft., the oil is similar to that in South-Eastern Butler County, at 1300 ft. above sea-level and under a cover 2700 ft. thick. A. L.

211.* Cementing Materials in Sandstones and their Probable Influence on Migration and Accumulation of Oil and Gas. W. A. Waldschmidt. *Bull. Amer. Ass. Petrol. Geol.*, October 1941, **25** (10), 1839–1879.—In a study of sandstones from the Minnelusa (Upper Carboniferous) to the Mesaverde (Upper Cretaceous) of the Rocky Mountain region, two general groups of cementing materials have been recognized: (1) argillaceous matrix, (2) minerals crystallized from solution. Argillaceous material is most abundant from the top Sundance (Jurassic) upwards, and, as in the Dakota and Cloverly, Frontier and Second Wall Creek (Colorado Group, Cretaceous) and Mesaverde (Montana Group) sandstones, often prevents solution of grains at points of contact, so that interlocking is absent or only partial; and consolidation is chiefly due to pressure, indicated by distorted mica-flakes, and to silicification which may make the matrix abnormally anisotropic. In some crystalline matrices the cement is quartz, or occasionally calcite alone; or initial quartz may be followed by one or more, in different orders, of the following: dolomite, calcite, anhydrite. Pressure of later deposits leads to solution of sand-grains at points of contact, with almost immediate reprecipitation of quartz, either in optical continuity on sand-grains or as independent crystals. Dolomite acts as a binding material in the Second Leo, Leo, and Converse sandstones of the Minnelusa, and in the Sundance. The dolomite follows quartz and, like the latter, is evenly distributed, so as to fill pore-spaces between smaller grains, but leaving some voids among coarser grains. With the exception of the Lakota (Lower Cretaceous) and the lower Dakota and basal Cloverly (base of Upper Cretaceous), calcite was found in all sandstones from the Sundance upwards, and took the form of anhedral grains. Foraminifera and limestone fragments are probably dissolved with rising temperature and pressure, and solubility is increased by decomposition of organic material and accompanying formation of carbonic acid and ammonium carbonate. Additional carbonates are obtained from ground-water, and precipitation in voids follows on release of pressure or fall of temperature. Sands originally rich in carbonates finally show sand-grains completely isolated in a calcite and/or dolomite matrix. Appreciable anhydrite, in poorly to well-cleaved crystals with one to three straight sides, is found in the Tensleep, Converse, and Leo (Upper Carboniferous) and in the Third Sundance. It is the last mineral to crystallize, usually following quartz and dolomite, rather than calcite. In fact, a sequence of quartz and calcite is characteristic in the Jurassic and Cretaceous sandstones, whilst quartz, dolomite, and anhydrite are confined to those between the Bell (Pennsylvanian) and the Sundance.

Non-argillaceous sandstones in which recrystallized quartz is the only important precipitate tend to have relatively high porosity and permeability. They may be very rigid, due to partial interlocking of grains and to bridging of gaps by recrystallized quartz—*e.g.*, parts of the Dakota Sandstone. Argillaceous material and calcite both contribute to reduce porosity, especially where indigenous carbonate material is recrystallized under pressure into intergrown calcite grains. These factors are important in oil migration, which is also promoted by pressure due to volume increase when minerals, like anhydrite, are precipitated from solution. If water contains droplets of oil, from organic decomposition, too small to coalesce under static conditions, these are likely to unite when moved through sand, as in Meredith's process for sand-filtration of emulsions. The coalesced oil no doubt follows the water to low-pressure areas. The water may by-pass the oil, and, if it contains calcium carbonate, deposit the latter as a seal where there is marked release of pressure in tensional parts of anticlinal folds, in joints, in faults, and near the surface.

In a closed system increase of pressure due to crystallization may cause gas to be absorbed by oil and water. To this much of the initial high pressure in oil-fields may be due. Crystallization around an oil area may also so isolate it that during production the pressure may fall to zero, or below it. This is expected to happen in parts of the Sundance sands. In the Dakota sandstone, however, which has more uniform porosity, encroachment of water will maintain pressure. A. L.

212.* High-Pressure Yates Sand-Gas Problem, East Wasson Field, Yoakum County, West Texas. A. S. Donnelly. *Bull. Amer. Ass. Petrol. Geol.*, October 1941, **25** (10), 1880–1897.—Gas is found near the top of the Yates sand (Permian) over a large area of the Wasson Field, West Texas. In the north-north-east axis it is 92½–97% nitrogen, the remainder being mainly methane. It seems to be completely sealed in by local cementation. Pressures up to 2800-ꝑ, but averaging 1800-ꝑ, have given trouble by unloading drill-holes and by blowing off the mud-cake on red beds, so that the water in the latter escapes with accompanying erosion and bridging of the well-sides. The tight place is approximately 120 ft. below the top of the Yates, where, against a solid stratum of anhydrite, the casing is dented in a sharp kink. This is done either by beds sloughing, or by movement of the anhydrite itself when above and below it salt and sand are dissolved and washed out. A deeper "air" may also be met with in porous dolomite or sandy beds at the top of the Yoakum "Brown lime." By some this is ascribed to downward migration of Yates "air" following caving of overlying red beds in holes, but Alden Donnelly thinks it is of separate origin.

One precaution is to drill 11-in. holes, so increasing the volume of the hole and decreasing the possible velocity of the mud column. High-carbon-content steel may also be used in casing opposite the zone of collapse. Pulverized salt should be added to the drilling fluid before salt-beds are reached, so as to prevent solution of the walls. Moreover, a saturated salt solution 11 lb./gal. allows the "air" to bubble through in cases where a mud slurry of the same density is erupted. The "air" pressure reaches a maximum of 18 lb./gal. If a bit is changed at an unsuitable place it is possible for a bridge to form and for pressure to build up below it, followed by a break through with terrific water-hammer. Such outbreaks have been controlled by means of Baroid. The "air" horizon must not be penetrated while red beds are open. The string of casing should be secured in a seat of anhydrite, and the "air" horizon then be squeeze-cemented. "Stub" strings for permanent control of the gas may also be set. A. L.

213.* South Cotton Lake Field, Chambers County, Texas. J. M. Wilson. *Bull. Amer. Ass. Petrol. Geol.*, October 1941, **25** (10), 1898–1920.—A blanket torsion-balance survey over a large section of Chambers County in 1934 indicated a prominent minimum, centred slightly north of the present producing area. The dry well, Lawrence No. 1, was then drilled and abandoned at the depth of 7005 ft. It had, however, sufficient showings to justify drilling the Lawrence No. 2, which was also abandoned at a depth of 7300 ft. The area was then surveyed with the reflection seismograph, using the continuous profile method. As a result of this work, the location for the discovery well was found, and subsequent surveys showed the true picture of the structure, a faulted dome elongate east to west.

The three producing sands are the *Marginulina*, Frio No. 1, and Frio No. 2, with an average of 7½ ft., 10 ft., and 5 ft. effective sand, respectively. These occur in the Oligocene within an interval of 100 ft., and the average total depth of wells is 6500 ft. The maximum producing area may be about 1200 acres. At present there are fifty-one oil wells and two gas wells in this area, and development is almost complete. As at January 1, 1941, the total production derived from three producing sands was 1,573,400 brl.

The Vicksburg or *Textularia warreni* zone has been penetrated at 8301 ft. J. T.

214.* Relation of Organic Matter to Colour of Sedimentary Rocks. H. W. Patnode. *Bull. Amer. Ass. Petrol. Geol.*, October 1941, **25** (10), 1921–1933.—After crushing and drying at room temperature, powders from more than 3000 samples of grey sediments were examined for reflectivity. Smooth surfaces were obtained, and these were compared with surfaces of known reflecting power in a reflectometer. In comparison with magnesium oxide, taken as 100% and lampblack as 2% reflective, it was found that results for the rocks varied from 8% to 66%. Nine-tenths were between 18% and 49%, and half between 25% and 35%. The nitrogen and the reduction number of the samples were also determined as rough indices of organic content which is not directly measurable. The reduction number is the number of c.c. of 0·4 normal chromic acid that is reduced by 100 mgm. of sediment under standard conditions. In general, dark sediments with low reflection give high reduction numbers, and highly reflective sediments have low reduction numbers. Dark sediments have also relatively high nitrogen content. The average reduction number is about 1·00; and the ratio of 100 times the nitrogen content to the reduction number is called the nitrogen-reduction ratio. The average reduction number of samples having a nitrogen-reduction ratio less than 5·0 is consistently greater than the average reduction number of those having a nitrogen-reduction ratio greater than 5·0. Sediments of like colour are relatively poor in nitrogen when the reduction number is high.

For a given reflectivity, coarse sediments have a smaller reduction number, and therefore contain less organic matter than fine sediments. Finely divided calcium carbonate probably causes limestone and chalk to be more reflective than clastic sediments with equivalent organic content. Ferric and ferrous compounds are also important. The average reduction number for Californian deposits is greater than that of Mid-Continent sediments of the same colour. This may be due to one or more causes—*e.g.*, texture of samples and nature of organic constituents.

Colour values from reflectometer work can be used to supplement other forms of well-logs. A graph of reflectivity recordings for the Upper Devonian shale section, from the top of the Onondaga limestone to the base of the Berea Sand in West Virginia, is provided, and also a graph of the reduction numbers to show the close relationship between the two. A. L.

215.* Migration of Oil from Arbuckle Limestone into Chattanooga Shale in Chetopa Oil Pool, Labette County, Kansas. G. E. Abernathy. *Bull. Amer. Ass. Petrol. Geol.*, October 1941, **25** (10), 1934–1939.—The Chetopa Pool, in South-Eastern Kansas, lies at or near the unconformable contact of the Arbuckle limestone (Ordovician) with the Chattanooga shale (? highest Devonian). Over most of the field the oil is in porous dolomite and is separated by a "cap rock" of denser, more cherty dolomite from the 8–20-ft. black, fissile shale. Where the "cap rock" is absent, oil has migrated into the shale, which is less porous than the Arbuckle, but is waterless, and probably has many joints at points of folding. The oil has some of the lighter fractions (gasoline) common in most crude oil of the region. Associated water has a very low content of dissolved solids—1583 p.p.m.—mainly sodium chloride and bicarbonate.

A. L.

216.* Carboniferous Foraminifera of the Samara Bend [U.S.S.R.], by D. Rauser-Černoussova, G. Beljaev, and E. Reitlinger. Summary by S. W. Muller and H. G. Schenk. *Bull. Amer. Ass. Petrol. Geol.*, October 1941, **25** (10), 1943–1949.—Foraminifera have been identified from a complete section of Carboniferous in a 1471-m. well, near Syzran, on the Volga. Below 1099 m. Devonian *Endothyrae* were recognized.

In the Lower Carboniferous, in beds taken as Tournaisian, the species are few (as in England), and include *Endothyra* aff. *bowmani*, *E.* sp., *Hyperammina elegans*, and *Spirillina* sp., while the Visean yields characteristic species—*Staffela struvei*, *E. crassa*, *E. globulus*, *H. vulgaris*, and *Archaediscus karreri.* These are most numerous in the Middle Visean, in which special levels are marked by *Cribrospira panderi*, *E. omphalota*, and *Samarina operculata*. Middle Visean, also (much as in England), sees the largest *Endothyrae* appearing in greatest numbers. In the late Visean of Russia the microfauna becomes impoverished. The Transition Beds, between Visean and Middle Carboniferous, show *Bradyina cribrostomata*, similar to *B. potanini* Ven. from Mongolia, and *Climacammina* acting as rock-formers. In the Middle Carboniferous, fusilinids become dominant with genera like *Fusulinella* and *Schubertella*; *Fusulina* and *Wedekindellina* come in later than the other two; spheroid staffelids are also important. The Upper Carboniferous provides the lowest stratigraphic occurrences of *Triticites* and *Quasifusulina*.

The Russian Lower Carboniferous corresponds with the Mississippian in whole or part. Middle Carboniferous seems to be equal to Lower Pennsylvanian, Upper Carboniferous synchronizing with the American marine Upper Pennsylvanian.

A. L.

217.* Oligocene Stratigraphy of East White Point Field, San Patricio and Nueces Counties, Texas. P. F. Martyn and C. H. Sample. *Bull. Amer. Ass. Petrol. Geol.*, November 1941, **25** (11), 1967–2009.—Subsequent to the discovery of oil in the 5600-ft. sand (Frio) in 1938, some 240 wells have been drilled, and nearly 5,500,000 brl. of oil produced. The basis of this stratigraphic study has been the correlation of sand and shale intervals by interpretation of electric logs, with the help of accurate sampling, isopach maps, and palæontological information. The beds considered are those between the 4100-ft. sand (zone A) at the top of the Middle Catahoula and the 5600-ft. sand of the Frio, which is the principal oil-producing zone. They are subdivided, in descending order, into six zones: Zone A, the 4100-ft. sand, is a near-shore deposit of a regressive sea; Zone B, 4500-ft. shale, was deposited under quiescent conditions, with little continental or structural deformation; Zone C, *Heterostegina* sand, 4900 ft., shows progressive thickening westward, and was deposited by a sea transgressing eastward from the ancient gulf of Mexico which lay to the south-east of the oil-field area; Zone D, 5300-ft. shale, thickens from east to west and is a lagoonal deposit following the drowning of the ancient Nueces valley; Zone E, 5400 ft. sand, thins from west to east and shows terraces, slopes, and meander scarps which display typical features of degradation and planation common to the erosional cycle of a river in an area of uplift, three movements being suggested by the terraces of the ancestral Nueces river which lay to the west of the producing area; Zone F, 5500-ft. shale, thickens towards the north-west, and was deposited as an accompaniment to continental downwarping and tilting.

The alternation of sand and shale suggests shallow-water conditions. The unconformity at the top of the 5400-ft. sand (Zone E) marks the top of the Frio, and is important stratigraphically. A geologic correlation chart is included in the paper, which, in addition to electric logs and isopach maps, contains isometric perspective block diagrams.

R. C. W.

218.* Marine Sedimentation and Oil Accumulation on the Gulf Coast. 1. Progressive Marine Overlap. D. S. Malkin and D. A. Jung. *Bull. Amer. Ass. Petrol. Geol.*, November 1941, **25** (11), 2010–2020.—Progressive marine overlap provides ideal conditions for oil formation, migration, accumulation, and production; a transgressive sand is a lithological unit, composed of graded sands passing down dip into finer sands, sandy shale, and shale, and passing laterally seawards into finer sediments and shale which act as a good impervious seal. The numerous overlaps in the Gulf Coast Tertiary are found in Upper Wilcox, Cockfield, Marginula-Frio, and Lower Miocene sands, being formed by minor fluctuations of sea.

The Cockfield sand (Eocene) is studied with the aid of electric logs, and shows almost ideal conditions. One point stands out: the top of the Cockfield formation has been hitherto regarded as being marked by the foraminifer *Nonionella cockfieldensis*, but on comparison with sections drawn from electric logging, this is found to be incorrect. Thus, the Cockfield sand-body represents a lithological unit, and not a time unit. It is diachronous. In dealing with transgressive sands, it is to be expected that the palæontological index-fossil will be found above the sand in downdip wells, if a fossil is used which was not limited to one environment. Thus, the occurrence of palæontological markers, representing time units, must be at variance with the electric loggings of the sand tops. R. C. W.

219.* Activity in Texas Panhandle Maintains Upward Trend. H. F. Simons. *Oil Gas J.*, 18.12.41, **40** (32), 14.—The Panhandle is generally considered as one large field having several producing zones, and it has the largest area of any oil- or gas-field in the world. For more than fifteen years it has been a major influence from an oil production standpoint, and has given about 2,000,000 brl./month for the past six years. To date it has produced more than 400,000,000 brl. of oil, while the present reserves are about 700,000,000 brl.

The oil-producing area varies from 1 to 10 miles in width, whereas the gas area ranges from 10 to 40 miles wide. It lies on the northern flank of the buried Amarillo mountains. Oil comes from three main horizons—the white and brown dolomites, and the granite wash. The pay-zones are commonly 75–150 ft. thick, and in general the oil is produced from younger beds in the north than in the south.

5200 wells are now listed as producing oil. The allowed production has been rising during 1941, and on a 30-day month basis has averaged 85,000 brl./day, although it is believed that the field could produce from 150,000 to 300,000 brl./day without waste.

The field is well situated with regard to pipe-lines and refineries. The 40° A.P.I. crude is all sour. There are thirty-eight gasoline plants and thirty carbon-black plants in the area.

The completions per month are listed, and a table gives the system of determining well allowables. G. D. H.

220.* World-Wide Oil Possibilities. W. V. Howard. *Oil Gas J.*, 25.12.41, **40** (33), 81.—The petroleum possibilities of the world outside the U.S.A. are much greater than those of the U.S.A., and some districts may eventually be as rich per unit area. A series of maps has been prepared in which the continental areas have been subdivided according to the relative likelihood of finding oil in them. The most favourable areas are those where oil and gas are now found, either as seepages or as fields. They comprise areas with sediments of sufficient thickness to permit the existence of several reservoir horizons. The less favourable areas include remote areas about which little is known, areas with a thin cover of sediments and a lack of definite structural trends, and areas which may prove too strongly folded or where potential reservoirs are overlain by great thicknesses of continental deposits or ice and snow. Areas considered " impossible or improbable " are those with strongly folded mountain ranges, great masses of intrusive igneous rocks, or pre-Cambrian rocks.

The western hemisphere and the U.S.S.R. contain the largest areas of potential oil land.

South America.—The mountain ranges are so disturbed as to have removed the chances of finding oil, but between individual chains and in the area between the shield and the mountains there are great thicknesses of sediments providing potential reservoirs. The four most favourable belts are the trough between the Andes and the shield, the Pampas region, the coastal plain west of the Andes, and the coastal plain east of Brazil. The sub-Andean trough has production at both ends—in Trinidad and Eastern Venezuela in the north, and in Bolivia and the Salta–Jujuy region of Argentina in the south. Recently production has been found in the centre in Eastern Peru. The Comodoro Rivadavia and Mendoza fields are in the Pampas region. In the Pacific Coastal plain is the Ecuadoran and most of the Peruvian production. The possibilities are problematical at present in the Atlantic coastal area. The great thickness of alluvium has caused the Amazon valley to be classed as less favourable.

Mexico and the Caribbean.—Three types of petroliferous areas are known in this region—the coastal plain of Mexico and Yucatan, the intermontane valleys of the Andes, and patches and strips of sedimentary rocks flanking mountain chains or fragments of chains. All three types have been partly prospected, and two of them yield important amounts of oil. In the coastal plain area are some salt domes, but these are of little importance at present. The main production has come from great limestone "highs." Near the Rio Grande small amounts of oil and large quantities of gas come from the Tertiary. Yucatan is virtually untested. The intermontane valleys provide the oil of Colombia, Venezuela, and Trinidad.

Europe.—The areas favourable for prospecting are the foreland of the northern chain, the Russian platform, the North German plain, and irregular areas of little disturbed sediments caught up within loops and between chains of the Tertiary mountains. In the foreland of the Alpine chains there are showings in front of the Pyrenees, the new fields of the Vienna basin, the Polish and Rumanian fields, and the Maikop, Grozny, and Baku areas of the U.S.S.R. These areas are progressively richer towards the east.

In spite of the discovery of important fields, the Russian platform area is virtually untested. The North German plain, including the Rhine Vâlley, contains small oil deposits, of which many are associated with salt masses. The intermontane plains yield small quantities of oil in Italy, Albania, and Hungary.

Asia.—Some of the areas most favourable for prospecting are extensions of two European zones. The foreland belt crosses the Caspian from Baku, and is found in the Fergana region of Southern Siberia. The Russian platform passes south of the Urals into the Aralo–Caspian area, where the Emba district provides important oil production. The foreland of the southern looped chains is productive in North-west India and Burma, and fragments of the sedimentary rocks protected from collapse by close proximity to the backbone of the island festoons give oil in Sakhalin, Japan, Taiwan, and Borneo.

In Szechuan and Shan-si there are seeps and some production. The Arctic and Lena areas are practically unknown, but the presence of slightly folded Tertiary rocks is a matter of interest.

Africa and the Near East.—Probably the only areas which afford a possibility of large oil production are along the northern margin of the continent in the intermontane valleys of the Atlas region, and in the foreland of the Zagreb mountains of Iran. In the former area there are some small fields and many seeps. The fields of the foreland region of the Zagreb mountains form the most important group yet found in continental Asia, and recent work in Iraq, Bahrein, Kuwait, and Saudi Arabia has extended the petroliferous zone away from the mountains.

The coasts of Mozambique and Western Madagascar appear to have the best possibilities for production in Africa proper; the bulk of the continent is unlikely to yield oil. Of secondary importance are the Lake Chad depression, the Niger embayment, and the Sahara–Sudan area.

East Indies and Australia.—The fields of the Netherlands East Indies differ from the other major fields associated with the southern looped chains of the Alpine–Himalaya systems in that they are situated in the backland rather than in the foreland. Australia and the associated island arcs have few oil possibilities, and the best of these are in down-faulted marginal blocks and in the depression between the shield and the Australian Alps. In the sediments flanking the mountains in New Zealand and New Guinea there are oil indications, but no important oil production has been obtained.

Dominion of Canada.—The area offering the best oil possibilities is the Plains region or the valleys of the Mackenzie and Saskatchewan rivers. There are the sharp structures of Turner Valley and broader folds, as well as the tar sands of Athabaska. The prospects of Ontario are not good, and the same appears to be true of Gaspé. New Brunswick has shallow oil and gas production, and extensive deposits of Mississippian oil shale. G. D. H.

221.* Venezuela's Oil Industry Exceeding Pre-War Output. L. H. Figueredo. *Oil Gas J.*, 25.12.41, **40** (33), 90.—From the beginning of 1941 there has been an almost continuous increase in Venezuela's oil production, from 489,595 brl./day to 681,050 brl./day. The 1941 production will probably exceed 220,000,000 brl., almost 33,000,000 brl. more than in 1940. Crude oil exports for 1941 are expected to be about 194,000,000 brl., and refined product exports 25,000,000 brl.

Four new fields were being developed in Eastern Venezuela in 1941. Two wells have been completed at Santa Barbara in Northern Monagas with about 1200 brl./day of 30–32° A.P.I. oil. In the Leona region, north-east of Oficina, eight wells have been brought in, with an average of 1100 brl./day of 26–30° A.P.I. oil. One well has been completed at Santa Rosa, east of El Roble. It is capable of giving 1800 brl./day of 42° A.P.I. oil. On concessions adjoining Santa Rosa and El Roble two producing wells have been drilled which averaged 1150 brl./day of 39–48° A.P.I. oil, in tests.

Three of the five wildcats started in Eastern Venezuela in 1941 have been abandoned. Substantial oil showings have been encountered in Mercedes 1 in Central Venezuela, and this promises to be the first commercial producer in that region.

A table shows the production by fields and companies in the January–September periods of 1940 and 1941. G. D. H.

222.* Shell's Discovery on Yondo Block is Colombian Feature. E. Ospina-Racines. *Oil Gas J.*, 25.12.41, **40** (33), 94.—Casabe 1, a wildcat on the Yondo concession near Barranca Bermeja, encountered several oil horizons in drilling to 7150 ft., and one of them has shown a potential of about 500 brl./day. A second well is to be drilled on the crest of the structure. Cimiterra 1 reached the basement rock at 1091 ft., and has had showings of heavy oil. A well on the Gutierrez concession entered the Cretaceous at 5861 ft., and has been taken to 7800 ft. without any showings being reported.

At the beginning of October on the Barco concession, Petrolea No. 99 was at 1395 ft.; 1 Sardinata was at 4717 ft., having given 150 brl./day on test; 1 Socuavo had reached 9850 ft.

Of twenty wildcats since 1937, only one has shown promising results—1 Casabe.

In the first nine months of 1941 the Colombian oil production was 9% below that for the corresponding period of 1940. No drilling has taken place on the Infantas structure since 1932, and the La Cira structure, with 681 wells, has been completely drilled and defined. The Petrolea structure has 163 wells and the Rio de Oro field seventeen.

About a sixth of the total area of Colombia is classified as prospective oil land, and of this half is difficult of access, being east of the Eastern Cordillera of the Andes.

Tables give the area of prospective oil land in the different districts, the areas of the concessions, and the oil production in the first nine months of 1940 and 1941. G. D. H.

223.* Argentina's Crude Output Reaches 21,755,000 Brl. Anon. *Oil Gas J.*, 25.12.41, **40** (33), 99.—It is estimated that Argentina's 1941 output will be 21,735,000 brl., a rise of 5%, the bulk of the increase having come from Mendoza. 35% of the output is from Comodoro Rivadavia. Twenty-nine exploratory rigs were in action in 1941.

Efforts to develop deeper oil-pays below those previously known in the El Tordillo area were unsuccessful in a well drilled to 7750 ft. In the Bella Vista zone, 8 ml. north-east of the town of Comodoro Rivadavia, a well taken to 4370 ft. had only slight oil-showings. There were five unsuccessful wells in the Golfo de San Jorge, two stopping in basalt. A large gas well was completed in the Santa Cruz area, giving 12,350,500 cu. ft./day from 2713 ft., with a closed-in pressure of 940 lb./in.^{2}. No further showings were found down to 4756 ft. Eleven miles north-west of the Plaza Huincul region a well encountered oil- and gas-shows. A second well had similar results. A new discovery was made at Portezuelo, 20 ml. west of Plaza Huincul. Four other wells in Neuquen were abandoned.

Substantial production was obtained in a well in the Tranquitas field. Only small showings were found in a well on the western flank of the Santa Barbara anticline in Jujuy. Extensions were made to the Tupungato field, and to the north-west considerable oil was found, without, however, sufficient pressure to give flow. At Barrancas a producer was completed in the Lunlunta pay, and on the north dome, five miles north of previous production in the Lunlunta field, two good oil wells were brought in. A gas well was drilled at Pampa Palauco, north of Ranquil.

Considerable geological and geophysical work was carried out in 1941.

A map is appended, and tables show the production by districts for the first eight months of 1940 and 1941, the total output during the first eight months of the years 1937–41, and the distribution of the production between the Y.P.F. and private companies in 1940. G. D. H.

224.* Survey of World Oil-Fields. Anon. *Oil Gas J.*, 25.12.41, **40** (33), 117.—The number of producing wells, daily average production, producing depths, gravity and base of the crude, outlet, age of field, and number of wells drilling are tabulated for the various districts of the oil-producing countries. G. D. H.

225.* Cretaceous Tested West of Petrolea Production. Anon. *Oil Gas J.*, 25.12.41, **40** (33), 132.—Active oil seeps at La Petrolea attracted attention, and in 1906 a small refinery was built to refine seepage oil. Intensive geological work was not undertaken on this, the Barco concession, until 1931, and drilling began in 1933. At present the major producing area is the North Dome, with 101 operating wells. A small well is productive on the South Dome, and two small wells yield oil at Carbonera.

The Upper Cretaceous limes are being tested in Socuavo 1, which encountered metamorphics at 9850 ft. Other wells are expected to test the Tertiary and Cretaceous, the latter being productive at Petrolea. The Carbonera wells obtain oil from strings of Tertiary sand, but Tres Bocas 1, Socuavo 1, and South Sardinata 1 failed to obtain commercial production on the Tertiary sands.

A 12-in. pipe-line conveys oil from the Barco concession to Covenas. The production in 1940 was 4,207,770 brl., of which 3,964,921 brl. was transported by pipe-line to the coast. G. D. H.

226.* Blue Goose Development May Open Amazon Industrial Era. T. P. Sanders. *Oil Gas J.*, 25.12.41, **40** (33), 137.—The Agua Caliente structure is about 6 ml. west of the Rio Pachitea and some 10 ml. from where the Rio Pachitea enters the Rio Ucayali. It is ringed by sandstone dipping at 14–25°, and runs north-west–south east for about 15 ml. The closure is estimated at 3500 ft. A smaller structure lies 20 ml. to the south-east. The beds are of Cretaceous age, the outcropping Sugar sandstone rests on the limestones, marls, and shales of the Chonta series. The oil-bearing beds are in the Agua Caliente series of sandstones and shales, which are of Upper Middle Cretaceous age.

Six wells have been completed, although two have unsatisfactory bottom-water shut-offs. A second oil sand has been penetrated but not tested in one well. About 90 ft. of oil sand occur in the interval 1020–1174 ft. The well gave 750 brl./day on a ½-in. choke, whilst a short test on open 3-in. tubing gave oil at the rate of 2500 brl./day. Other wells have given oil at the rate of 42–100 brl./hr. The 45° A.P.I. oil is accompanied by little gas.

The six wells have proved an area of about 1 sq. ml. Little oil has been produced, owing to the lack of outlet.

A short account is given of the history of development, living conditions, and the problems involved in exploiting this remote field. G. D. H.

227.* Mexico's Oil Production Suffers Further Decline. Anon. *Oil Gas J.*, 25.12.41, **40** (33), 137.—Owing to the lack of adequate finance and modern equipment, the Mexican oil properties have suffered some deterioration during the past few years. Drilling operations have declined more than 75% since 1934. Forty-four wells were completed in 1940, and there will be about the same number in 1941. The 1941 production will average about 117,000 brl./day, nearly 3000 brl./day fewer than in 1940. At the end of July 1941, fifteen wells were being drilled in Vera Cruz, eight being in the El Plan district, and seven in Poza Rica. Six wells were being drilled in the Ebano-Chapacao section of San Luis Potosi.

Of the Mexican production, 60–65% comes from Poza Rica, which has less than forty completed wells. The gas output is approximately 80,000,000 cu. ft./day, indicating a gas–oil ratio of about 10,000 cu. ft./brl.

Seven refineries are in operation, with a total crude capacity of 141,500 brl./day, and cracking facilities of 19,700 brl./day. In the first seven months of 1941 the exports to U.S.A. averaged 41,650 brl./day. G. D. H.

228.* Drilling Shows Likely Prospects in Brazil. E. de Carvalho. *Oil Gas J.*, 25.12.41, **40** (33), 154.—42·7% of Brazil has outcrops of the basement complex. Devonian beds occur at depth over a large area, and seem to have considerable oil prospects. They rest on the Silurian in much of Amazonas, and also occur south of the Amazon, at Tapajos south of Itailuba, in Mato Grosso, Sao Paulo, Parana, Santa Catarina, and Rio Grande do Sul. Carboniferous beds are not nearly so widespread as the

Devonian, occurring in Amazonas, Para, Sergipe, Baia, Sao Paulo, Parana, Santa Catarina, and Rio Grande do Sul. The Triassic, Jurassic, and Cretaceous are found in almost every State in Brazil. Immense beds of Triassic are seen in the eastern basin. The Cretaceous is found along the coastal belt from Baia to the Amazon, in the Amazon basin along the border of the Andes, and extensively in the central plateau. Tertiary beds are most common and best known along the coastal belt.

de Oliveira estimates that 492,650 sq. km. of the country fall into the category of having good oil possibilities; a further 2,335,850 sq. km. are of interest, and 934,250 sq. km. are of secondary interest.

The Brazilian laws do not encourage exploration. G. D. H.

229.* Vermilion in Alberta Gets Important Well. Anon. *Oil Wkly*, 29.12.41, **104** (4), 46.—Princeville 2 has been completed at 35 brl./day at a depth of 1797 ft. The Vermilion field now has nine producing wells, two flowing and seven pumpers. Two other wells await testing. G. D. H.

230.* Drilling Reduced in Final Month of Active Year. Anon. *Oil Wkly*, 12.1.42, **104** (6), 34.—In December 1941 completions in U.S.A. averaged ninety per day—a higher level than for any previous December except 1939. In July, August, September, October, and November 1941, completions were consistently around 100 per day. In 1941, 32,292 wells were completed, 1653 fewer than in 1937 and 1619 fewer than in 1920.

Tables show by States or districts the total rigs in operation on 1st January, 1941, 1st December, 1941, 1st January, 1942, and their status on 1st January, 1942; the completions for December 1940, and November and December 1941, with the details for December 1941; the cumulative completions for 1940 and 1941, with details for the latter year. G. D. H.

231.* Oil Producer Completed in Mulata Field, Venezuela. Anon. *Oil Wkly*, 12.1.42, **104** (6), 48.—Mulata 2, the first oil well in the Mulata field of Monagas, has given, on test, 570 brl./day of 34·7-gravity oil through a $\frac{3}{8}$-in. choke from two levels between 4590 and 4751 ft. A test of the upper zone alone showed 327 brl./day of 28·5-gravity oil through $\frac{5}{16}$-in. choke. Mulata 2 lies 1400 yds. south of Mulata 1, which was completed as a gasser showing 2,500,000 cu. ft./day through a 3-in. orifice.

It is expected that an area of several thousand acres will be developed in this field, which is at the extreme western end of the Amana River concession, and is on a line between the Santa Barbara and Jusepin fields. G. D. H.

232.* Lone Colombian Strike in 1941 Making 340–400 Barrels. Anon. *Oil Wkly*, 12.1.42, **104** (6), 48.—Casabe 1, reported to be the only successful wildcat drilled in the Magdalena Valley in 1941, has been completed for 340–400 brl./day on gas-lift, and is on regular production. G. D. H.

Geophysics and Geochemistry

233.* Recent Developments and Success in Geodynamic Prospecting. S. J. Pirson. *Oil Wkly*, 12.1.42, **104** (6), 20.—In ten months since the introduction of geodynamic prospecting seven wildcat or semi-wildcat wells have been drilled as a result of surveys made in or near regions surveyed. Three are commercial oil and gas producers, and one found an accumulation of 10,000 brl./acre, which was not recoverable economically. All the tests were in Northern Pennsylvania.

The geological requirements for an oil accumulation are a source-bed, trap, and cover rock, although these do not guarantee the existence of commercial accumulations, and even with a combination of the improved prospecting methods of geology and geophysics, successes in wildcat drilling do not exceed 25%. Part of the failure of these methods is a consequence of their being indirect.

The realization that oil-fields may be indicated by visible seepages or "micro-seepages" of hydrocarbons, and also by "micro-leakages" of gases through apparently solid ground, led to the investigation of soil air with some success, and later to the examination of the gases retained by soil particles.

It appears that soil sample concentrations of hydrocarbons are more influenced by soil adsorption characteristics than by the amount of gas leakage. The pattern of the leakage is a manifestation of the change in soil-adsorption properties resulting from leakage of oil-field waters. The halo pattern is generally associated with the edges of the fields, but does not necessarily mean the presence of an oil-pool, for only a small percentage of the haloes drilled have resulted in oil discoveries. The soil hydrocarbon distribution cannot be correlated with the depth of the source, and the patterns are permanent, not disappearing when the field is depleted.

Attempts have been made to measure the rate of gas leakage by permeation, diffusion, and effusion, and to apply it to the discovery of fields. According to theory and as measurement shows, the maximum rate of leakage is over the accumulation, and an actual case gives a maximum rate of leakage inside the " soil-halo."

In preparing for a geodynamic survey the first line of stations should be approximately at right angles to the expected geological trend, and about 1000 ft. apart, although for stratigraphic traps, which are often narrow, half this spacing is advisable. The line should extend ½–1 ml. beyond the edge of the land under consideration. The results of such a survey would be indicative of accumulations at depths up to 3000 ft. or more, and absence of anomalies of gas leakage would condemn the area. If the results are favourable, parallel lines of tests should be made 1000–2000 ft. from the first line. The results are more definite in their implications than are those of soil analysis.

The field work in geodynamical prospecting is simple. G. D. H.

Drilling

234.* Hardening Times for Casing Cementation. N. Healey and S. L. Pease. *J. Inst. Pet.*, January 1942, **28** (217), 1–14.—A discussion is made of the effects of various factors, such as time, water–cement ratio, temperature, acceleration, etc., on the hardening times of cement. The curves presented show that oil-well cements at present in use in Trinidad are a good deal better than is required. A. H. N.

235.* Progress in Drilling. Anon. *Oil Gas J.*, 25.12.41, **40** (33), 179.—Advances in drilling during 1941 are reviewed. No strikingly new achievement is reported. Types of portable rigs are briefly described. Methods used to raise these derricks vary widely. Hydraulic power, screws, or gin-poles and lines are most commonly employed. These derricks usually have their bases attached to the frame of a truck or skid, and this portion stays in place while moving. When it is desired to raise the derrick, the upper sections are bolted to the base and raised as a unit. When moving from location to location within a field, it is not necessary to take the derrick apart ; it is simply laid down over the truck or skid and a trailer used to support the crown-block end. When moving over public highways, road regulations make it necessary to take the taller derricks apart in several sections.

Cementing and types of special cements are discussed. An innovation has been the bulk delivery of cement to the well when casing is being set. The cement is hauled in large covered trucks and trailers equipped with screw-feeds. This allows the cement to be fed into the hopper and a more even water–cement ratio maintained throughout the operation. Other improvements include those obtaining better bonds between cement and formation than was possible hitherto.

Mud-fluid problems are discussed. One of the most difficult of these—the maintenance of a low filter rate in the presence of salt—may be solved through the work done with gums (tragacanth, karaya, and ghatti), kelp (Irish moss), and starch. Because of the war, all except starch are becoming increasingly difficult to obtain, but the gums demonstrated a remarkable ability to reduce the water loss of salt-water muds.

It should be noted that raw starch will have no beneficial effects, but that the starch must be boiled with caustic soda. The starch is first mixed with water, caustic soda added, and the mixture heated with steam until a viscous, straw-coloured mixture results. The composition should be about 89% water, 10% starch, and 1% caustic soda. When only a small amount of starch is added, the viscosity and filtrate are increased, but further additions reverse the trend.

Slim-hole drilling, rotary speeds, and bit weights are reviewed. An interesting experiment is being conducted in California to determine the feasibility of using drill-casing. The casing is used for a drill-stem, and is then run in the hole as the oil-string to complete the well. The casing used has been 4½ and 5½ in. pipe, and no outstanding trouble was experienced with the threads. It should be noted, however, that this experiment was conducted in an area where the formations were relatively soft and the strain on the drill-pipe was light. Removable casing is briefly studied.

Reverse circulation is being more widely used for the completion of wells having a high or medium formation pressure. The circulating medium (oil) is forced down the casing and up through the tubing, the increased velocity obtained being sufficient to carry out even large pieces of steel. The bit has no water-courses, but a single large opening. By keeping pressure from the formation and minimizing exposure to water or mud, a better completion is obtained. There is also a saving in time, as a well can be completed in 46 hrs. if no shot is used, or 120 hrs. if a shot is placed.

Detailed rules for hard facing of tool-joints are given.

The paper is in both English and Spanish. A. H. N.

236.* Difficulties of Completion in Central Louisiana. W. R. S. Jones and R. M. Sanford. *Oil Gas J.*, 1.1.42, **40** (34), 52. *Paper Presented before American Petroleum Institute.*—The greatest difficulties are due to the fact that the well walls consist of very soft "rotten" shales and argillaceous, unconsolidated sands. This condition makes it almost impossible to obtain a firm bond between the cement and the wall of the hole. A definite cause for subsurface failure is hard to establish absolutely, but it is generally accepted that this lack of bond causes more poor cementing jobs in the area than any other defect.

There is an unusually fine natural mud in the area, and very little artificial agents have to be added to the drilling fluid, with the possible exception of about 8 gal. of viscosity reducer/well to keep down the viscosity. The mud is maintained at about 28–30 sec. viscosity A.P.I. and about 10·2 lb./gal. After reaming down in preparation to running casing, only about 7 or 8 hrs. is lost before landing and cementing the string. Casing centralizers are always spaced above and below the producing sand, thus eliminating the chance of the pipe lying against the side of the hole. A casing programme in one of the fields concerned is detailed.

If gas and/or water are encountered, squeezing at the top of the pay and a squeeze job at the base of the pay are employed. This guards against possible migration of gas or salt water up or down the pipe to the oil-sand. It also helps to create an artificial break at the oil–water or gas–oil contact point. On these squeeze jobs the bradenhead method is used (one set of perforations at a time), but on various occasions a squeeze tool has been used when pressure greater than 2000 lb. was desired. Breakdown pressures on these formations vary from zero to 1400-lb. surface pressure.

Salt water mixed with the cement has been tried in several instances, but with comparatively poor results. The slurry tended to fluff up considerably, and, when set closely, resembled a porous sponge. The theory or practicability of the procedure has not been entirely abandoned. One service company in the field is at present experimenting with this idea, and hopes to arrive at some definite conclusion soon. It is thought there might be a solution of brine with just the proper amount of salt to produce a good slurry.

Four attempts to solve the problem of shutting off salt waters are described in detail. Temperature and gamma-ray surveys are used. A. H. N.

237.* New Type of Slim-Hole Rotary Rig. H. F. Simon. *Oil Gas J.*, 15.1.42, **40** (36), 33.—The rig is designed for drilling economically to 7500 ft. and beyond with 3½-in. drill-pipe, is entirely wheel-mounted, and can be assembled in a few hours after arrival at the location. Because the equipment will be moved less often than on shallower drilling, the actual hole-making operation was stressed in construction rather than the moving feature.

The entire rig is a departure from standard practice, as are many of the parts. This is the first rig mounted on wheels to be propelled by the drilling engines instead of being pulled or driven by a separate engine. It is also the first on which the carriage-frame serves as the frame for the hoisting machinery, the compounding drive, and the engines. The 120-ft. mast, which can be used for pulling thribbles, is the first of that height designed with a base which comes within the highway limit of 8 ft.

The rig is equipped with supercharged drilling engine and with special air controls which have both an automatic and flexible speed regulation. There is only one jaw-clutch in the entire assembly, and this is really not used as a clutch, but as a shifting mechanism between the two sets of gears. All other clutches are of the friction type, the majority of them being air-actuated. The drilling rig is entirely chain-driven, the only gear being in the rotary table.

The derrick base, the method of handling the crown-block, and the provisions for raising the derrick are also unusual. The crown-block is described partly by the term "floating."

It is estimated that the rig may have to be moved between fifteen and twenty times a year. These figures indicate the importance of reducing the rigging-up time to the minimum. Normally rigs used to drill beyond 5000 ft. cannot be moved and rigged up in a day's time, most of them requiring 2 days before drilling of the surface hole is begun. The new rig is designed so that it may be moved a reasonable distance, rigged up, and put in operation in less than 8 hrs. This means that in a year's time it will be possible to drill an additional well over what could be drilled if conventional equipment were used. However, the saving in moving time would not be justified, or gained, unless the efficiency during the drilling operation was at least equal or superior to the conventional rig.

Details are given of the engines and transmission and of the pumps and other items in the rig. The rig was completely assembled for the first time on the location. Only minor adjustments were necessary, and these were readily made. Fitting of pump suctions and other such details were necessary on the first job, but will not have to be repeated. So far the rig has never been moved, except to drive it from the factory, and there is no test as to just how long it will require to rig up. As the crew becomes more familiar with the job, the moving and rigging-up time will be reduced to a minimum.

The rig has been drilling for several weeks and has come up to expectations. Drilling time and time for making trips are comparable to rigs of standard design operating in the area, and it is evident that when the crews get used to the operations, a decrease in well time will be effected. A. H. N.

238.* Improved Rebuilding Methods Extending Tool-Joint Life. E. Sterrett. *Oil Wkly*, 22.12.41, **104** (3), 16.—In an extensive paper, all phases of rebuilding tool-joints are discussed. A joint in a 4½-in. drill-string under certain drilling conditions is considered as having suffered maximum safe reduction in cross-sectional area if the diameter of the outer surface has been reduced by ⅜ in., or if the wear, assuming uniform attrition, is 0·1875 in. Below this margin the joint is a potential location of failure through splitting or swelling when torque exceeds the normal safe amount for the type of string being run.

The amount to be built up, being only $\frac{3}{16}$ in. in thickness, lies well within the practicable working limits of a single bead with ¼-in. welding rod. Usual practice is to apply circumferential beads at both ends of the tool-joint as a rolling weld, using a copper chill-ring if the elevator shoulder is cut away enough to require more building up than can be obtained by a single bead. With the two ends thus brought out to size or slightly in excess of the original nominal diameter of the joint, longitudinal beads are laid up from end to end of the joint until an entirely new surface is completed. To prevent spatter or damage to the pin-threads they are covered by a thread protector before beginning the welding. Possible distortion of the threads is also minimized by using copper chill-rings at both ends of the job during welding.

The ridges left on the tool-joint by the parallel series of beads are not detrimental to tool-joint wear, the abrasion in service tending to grind the surface again to a true cylinder. Tonging, especially the first few runs of the pipe, is appreciably slowed down, it being necessary to engage the tongs carefully to prevent slippage and consequent breakage if the die engage on top of one of the bead-ridges.

When hard-facing material is used in conjunction with the usual high-carbon rods used for such a rebuilding job, it is customary to build up the ends with the hard facing, extending the width of the band covered by the circumferential bands from the width of at most two beads to as much as 1 in. "Half-soling" the tool-joint is also resorted to. This method is discussed.

Any tool-joint, before reconditioning, should be checked for eccentricity, and discarded as unsuitable if found to be more than 0·05 in. out of round from use on crooked pipe. This eccentricity may best be determined by spinning the joint in a lathe or between centres, in which the actual joint support is obtained through the jaws gripping the threads, or special threaded fittings into which the pin, box, or double ends fit accurately. Bearing face width variation is also a true indication of this condition. Eccentricity troubles are discussed at length. Hard facing methods and requirements are detailed. Elevator shoulder and wear subs are similarly discussed *in extenso*. The paper ends with a report on flame-hardened wear subs. The flame-hardened subs, checked at the 28,000-ft. mark, were found to have sustained an average wear at point of maximum attrition of 0·049 in., and at 65,000 ft. showed a reduction in diameter at the upper end checking point of only 0·08 in. Over the entire run up to the time of the second check, it was determined that the feet of hole drilled for each 0·01 in. of maximum wear was, for the old joints (untreated) 2400, for the hard-faced 3600, and for the flame-hardened 6100 ft. These figures, of course, are not over the hard-faced band, which, after all this running, still showed within 0·08 of its initial diameter. Wear of the band below the hard-faced band indicates that the protection is most effective at the shoulder, and the band at that point is in position to give maximum shielding effect. A. H. N.

239.* Design of Casing Strings. Part 4. E. N. Kemler. *Oil Wkly*, 22.12.41, **104** (3), 36.—Factor of safety is that term used to cover the discrepancy between actual practice and theory. The size of the factor of safety to be used will be determined by what it must cover. Some of the things it must take into account are discrepancies between test data and actual performance, inability to determine actual loads to which casing is subjected, and ignorance of designer as to properties of product, application conditions, or theory.

As far as collapse is concerned, the prediction of loads can be made with very good accuracy. The pressure which normally causes failure is the result of a hydrostatic pressure of a column of mud, and is not normally subjected to any dynamic loading. Under normal conditions the collapsing pressure can be very closely predicted. For normal conditions, no additional allowance need be made for calculated loadings if all factors are known.

The evaluation of the strength of the product is a more difficult problem. Two methods of approach are possible in this connection. One, which has been widely used in the past, has been to base the strength on average properties or strength values. The other, which has been introduced recently, is to base all values on minimum values. The use of 75% of the average value as the minimum value for casing collapsing pressures shows why relatively high factors of safety have been necessary in the past. For example, a factor of safety of 2 based on average values would be equivalent to a factor of safety of 1·5 based on the minimum values. The designer has had to introduce a factor of 1·33 in order to reduce average values to minimum values.

The arbitrary setting of a minimum value is not guaranteed to meet the situation. In order to be able to evaluate the meaning of the minimum value, the designer must know something about the control exercised by the manufacturer. The theory of statistics forms one method of evaluating the strength of commercial casing.

The rest of the paper illustrates the principles by working out an illustrative example in detail. A. H. N.

240.* Design of Casing Strings. Part 5. E. N. Kemler. *Oil Wkly*, 20.12.41, **104** (4), 34.—A decrease in temperature of the casing string or an increase in internal pressure would result in an increase in tension in the string after the cement has set. In some cases tension failures both of pull-out and fatigue type have occurred. It has been contended by some that a release of tension after the cement has set would eliminate these failures. Since it is physically impossible to measure stresses and observe load changes down the string, it is difficult to determine the actual cause of such failures. This article gives charts and methods by which the amount of load and tension to release for a given set of conditions can be calculated.

If the combination initial and these secondary stresses exceed the pull-out strength, the string will fail. If the above combination of stresses does not exceed that required to cause pull-out, failure can occur due to fatigue, provided a variation in stress occurs. This variation in stress can occur because of whipping of the drill-pipe. The magnitude of these stresses is indeterminate. The fact that some failures occur by fatigue indicates that the drilling operation introduces in some form variations in stress of sufficient magnitude to cause failure. Failure by fatigue requires a variation in stress. Failure can result from a high direct stress with little variation or a low direct stress with a large variation. If the direct load or tension is kept to a minimum, the danger of failure because of fatigue will obviously be kept to a minimum. The direct load can be controlled by release of tension after the cement has set.

If, however, too much tension is released, there is danger of failure by buckling, and perhaps some danger from fatigue in the region of zero or compression stress, since a little force perpendicular to the pipe could cause a considerable sideway deflection and bending stress. If the pipe were free of the hole for its entire length there would be little danger in tension release as far as danger of introducing a compression section is concerned. Since, however, caving or settling of formation can occur in many of the formations encountered very shortly after the casing is cemented, it is difficult to know how much tension to release.

The length of free casing can be determined by releasing part of the load and measuring the corresponding change in length of the string. Formulæ to be used are given.

A. H. N.

241.* Statistical Data on Drilling in 1941 and Estimates for 1942. Various Authors. *Oil Wkly*, 26.1.42, **104** (8), 50.—This issue of the *Oil Weekly* is devoted to statistical data and forecasts on drilling in the U.S.A. for 1941 and 1942, respectively.

A. H. N.

242.* Determination of Slot Sizes for Liners in Argentine Oil-Fields. D. F. R. Ruiz. *Petrol. Engr*, November 1941, **13** (2), 23–28.—Experience in the fields of Argentina has shown the necessity of maintaining the walls of the drilled well intact, so as to avoid changes in its productivity during production. This is accomplished ordinarily by inserting pipe in the bottom of the well, with openings of various designs, which permit passage of the oil, but impede the permanent flowing of the grains of sand carried with the oil. This procedure is in general use, and is indispensable when the casing show of the well has been cemented above the productive zone. Other systems are employed that obtain the same results, although it may be because the sandstones are sufficiently consolidated to make the setting of perforated pipe unnecessary. In some cases the casing is run and cemented all the way to bottom, and is then perforated through the oil-zone; in others the lower part of the string is made up of casing previously perforated.

A discussion of slot design is given particularly applicable to the fields studied. It was found by Coberly that uniform grains of sand were retained almost entirely by slots of double the diameter of the grains. If the width of the slot was made equal to three times the diameter of the grains, all the sand passed through the slot. With the width of the slots understood to be between these two limits, a certain amount of sand passes before the forming of the bridge, the amount being greater as the size of the slot approaches the maximum limit. With the objective of establishing whether the angular form of the grains of sand had some influence on these results, a test was made with steel balls. These behaved in like manner, the sole difference being that the extreme limits of the slot were found to be between 2 and 2½ times the diameter of the steel balls.

It was found at the same time that in sands composed of grains of different sizes a small percentage of coarse grains modifies the action greatly and considerably increases the width of the slot on which the bridge is formed. Coberly introduces a new concept that may be called the " effective diameter of the grain," which states that the correct width of the slot is determined by multiplying the " grain " diameter by two. Experiments show that the effective diameter of the grain is not represented by the largest grains that are present in the sample, but by the grain that corresponds to a certain point on a curve of accumulated percentage compiled from a screen analysis. This percentage varies from 5 to 20 on the curve, and the form it assumes influences the establishment of the critical point at which the bridge is formed after a few grains may have passed through the slot.

Curves of uniform gradient, or those that show a regular distribution in the individual percentage of the sizes, will have critical points nearer to 5%. An irregular curve, on the contrary, will place the critical point nearer to 20%; but in all cases the critical point will be found between these two figures.

A standard procedure is described for choosing slot designs and dimensions in the light of these and certain other experimental results. Completion practices are described.

A. H. N.

243.* New Drilling Time Recorder Provides Effective Well-Log. W. A. Sawdon. *Petrol. Engr*, November 1941, **13** (2), 29.—The instrument, which is semi-automatic, consists essentially of a visual depth-chart across which a pen or stylus moves at a constant speed until re-set to its zero position by pressing a trigger. Each time the trigger is pressed the stylus carrier is lifted from the constant-speed drive and is instantly returned to the left margin by a spring. Pressing the trigger also advances the chart a fixed distance, so that the time lines of various length are evenly spaced.

The chart itself is 6 in. wide, and feeds upwards through the recorder from a roll in the lower part of the instrument. Perforations in the edges of the paper provide a means of moving the chart vertically, leaving 5 in. of width for the drilling-time record. The drilling-time curve is recorded in a 3-in. strip on the left, which is ruled vertically with six timing lines, each line representing 5 min. of stylus travel. The 2-in. column to the right of the drilling-time record is available for writing in depths, dates, and any notes that may be desired on the record.

The stylus is carried across the chart at constant speed by a chain driven by a clock mechanism. The clock has a conventional escapement movement, but winding is automatic; on pressing the trigger, which causes the stylus to return to the left margin, all energy taken to make the stylus travel to the right is put back into the clock-spring. When the stylus travels the full distance across the chart, the clock automatically stops.

For direct correlation with electrical logs, the chart is designed to move 2 in. for each 100 ft. of hole drilled, or $\frac{1}{50}$ in. per ft. The usual constant-depth interval is 1 ft., and the ratchet advances the chart $\frac{1}{50}$ in. each time the trigger is pressed.

When the interval for timing is 1 ft., the driller has the kelly marked or "striped" at 1 ft. intervals. The chart is then set so that the depth of the hole is correctly indicated on the depth-scale of the chart and the recorder is set in motion simultaneously with the beginning of the drilling. The stylus begins making a drilling-time line at the proper depth on the chart, and runs continuously across the chart at the rate of 1 in. each 10 min. When the first 1 ft. mark on the kelly comes down to the rotary table, indicating that the first 1 ft. interval has been drilled, the driller presses the trigger. This re-sets the stylus at zero time and moves the chart the equivalent of 1 ft. in depth. The stylus now starts across the chart again, drawing a line the length of which will be a measure of the time taken to drill the second 1 ft. interval.

A. H. N.

244.* Improved Method for Changing Blow-Out Preventer Rams. R. M. Lilly. *Petrol. Engr*, November 1941, **13** (2), 108.—To facilitate the changing of Cameron type S.D.A. blow-out preventer rams, the engineers of a major oil company have designed and developed an improved hydraulic method that permits this changing operation to be accomplished with a speed, ease, and convenience of manipulation hitherto unapproached.

Apart from the elimination of the manual effort involved in changing rams by the use of hand-operated mechanical jacks and clamps, the points of superiority of the improved hydraulic over previously used methods are as follows: (1) lower initial cost of equipment; (2) it is much faster and safer; (3) equipment is unitized and portable, being very small, compact, and light. The material used consists of three $1\frac{1}{2}$-in. by 1-in. short-swage nipples, a short piece of high-pressure wire-wrapped steam hose with special short steel couplings, a 4-way valve of suitable type and pressure rating, three 2-in. by 6-in. wooden blocks of varying lengths to press the dressed ram out, and a steel chain and socket arrangement to pull the replacement ram in. All this equipment is of the heaviest possible character, in order to withstand drilling-rig abuse. Four 1-in. hammer-lug unions are positioned in such a manner that the parts may be quickly assembled and dis-assembled.

The equipment is housed in a small metal tool-box, fitted to accommodate the various parts. The internal construction of this box is such that there is a specific place for each piece of equipment, and, when the lid is closed, each part is securely locked in place, and cannot be damaged by striking other objects contained therein.

To change the rams, the valve in the opening manifold is closed. The bolts are removed from one cylinder, and the control valve is connected thereto. The valve is manipulated so as to permit fluid to enter this dismantled cylinder, shoving cylinder and head off as a single unit. The valve is now unioned to the active side. Wooden spacer blocks of various lengths are placed between the rams, and the control valve manipulated as necessary to shove the dismantled ram from the bore. While this ram is being stripped, the replacement ram is picked up, aligned, and drawn into the preventer bore by the simplified draw-chain and socket arrangement. It is then dressed, and the cylinder and head are picked up, aligned, and drawn to position in the same manner.

The control valve is now moved to the re-assembled side, and the operation enters the second phase, the routine of which is exactly as described above.

Results of tests are given in detail which show that the time taken with this method is shorter than with mechanical methods. A. H. N.

245.* Medium Weight-Drilling Equipment Employed in Deeper North Texas Drilling. H. L. Flood. *Petrol. Engr*, December 1941, **13** (3), 29–32.—The rig, designated as a 7500-ft. assembly, is relatively new, and incorporates several features in its design that are extremely interesting. Despite the size and weight of equipment required for 7500-ft. drilling, the rig is easily and quickly moved. The draw-works, two of the 325-h.p. engines, and the transmission are mounted on an 8-ft. substructure. Both 15-in. mud-pumps are mounted at ground level, one being driven by V-belts from a sheave on the shaft of one of the two drilling engines. The other pump, serving as a stand-by unit, is powered separately by a third 325-h.p. engine.

The draw-works has a selection of six hoisting speeds and three rotary drive speeds. The heavy-duty transmission unit has three forward speeds and one reverse speed, and includes a counter-shaft and a jack-shaft. All power to and within the draw-works is transmitted by means of sprockets and chains, and all shafts are mounted on self-aligning roller bearings. Double chain having a 2-in. pitch is used for all drives except the engine and combination rotary and high-speed drum drives, which are $1\frac{1}{2}$-in. pitch triple and $3\frac{1}{2}$-in. pitch single chain, respectively. The cat-shaft is powered by 2-in. pitch single chain from the jack-shaft.

The use of hydraulic couplings on the two main engine drives is perhaps the most unusual feature of the entire assembly. The coupling is mounted on the engine shaft between the clutch and the belt-sheave. Completely enclosed by screen wire-guards, the couplings require very little additional floor space, and virtually no attention is required by the operator, except for occasional routine inspections.

The hydraulic drive endeavours to combine the torque-speed characteristics of the electric transmission with the high flexibility, high efficiency, low weight, and simple controls of the gear-box transmission. The advantages obtained with a hydraulic drive are as follows : (*a*) smooth starting ; (*b*) absorption of shock loads ; (*c*) absorption of engine torsional vibration ; (*d*) limiting torque capacity ; (*e*) high torque capacity at low r.p.m.

The mud system and other equipment are described. A. H. N.

246.* Drilling Practices. C. W. DeLancey. *Petrol. Engr*, December 1941, **13** (3), 98. *Paper Presented before American Association of Oil-well Drilling Contractors.*—The requirements put by operators to contractors are discussed. First of these is blow-out prevention. To be certain that failures do not occur, it is a good policy to require each crew to operate the preventer equipment once during their respective tours. Top control equipment will not be effective unless the casing to which it is attached is in good condition. Crooked kellys and eccentric motion of the rotaries are the chief causes of excessive wear near the surface. It is safe to assume that a motion similar to that of the swivel and tackle will occur under the rotary. In fact, it may be amplified in a manner similar to that of a rope artist, wherein a slight motion of the wrist is increasingly amplified in the rope. A study of wear was made in casing recovered from abandoned wells, and it was found that the point of greatest wear was not in the top joint, but between 100 and 200 ft. below the surface.

On wells where conductor pipe is not used, and where it is not possible or advisable to cement the surface casing to the top, many operators have found it advisable to cement the top 100 ft., in order to prevent sag and vibration. This can be done with small expense while the cementing equipment is on location.

Stuck-pipes are also discussed. Inasmuch as pipe usually sticks near the drill-collar assembly, it has become a general practice to install a safety joint at or near that point. Of necessity, the joint is designed with loosely fitting threads, and because of this fact some failures have occurred. It is probably advisable to run the safety joint one joint above the drill-collar to procure flexibility between it and the stiff-collar assembly, and at the same time retain the advantage of having the minimum amount of assembly to recover by wash-over or other means.

The driller should always bear in mind that the function of a safety joint is to provide a means of quickly freeing a large part of the drill-pipe, and to prevent further sticking until necessary tools have been obtained and a satisfactory plan has been adopted.

Other problems discussed are bridging of soft formations, key-seating, drill-pipe connections, cementing, and mud treatment. A. H. N.

247.* Trends in Rotary Drilling Machinery and Equipment. J. M. Shimer. *Petrol. Engr*, December 1941, **13** (3), 129. *Paper Presented before American Association of Oil-well Drilling Contractors.*—The past and present practices are briefly reviewed and recent innovations are mentioned. Probably the most outstanding improvement in rotary rigs in the last few years is the independent drive to the rotary table, in which a separate prime mover is used instead of the hoisting engine. This type of drive was first used on steam-rigs where there are two types, one being the unit type in which rotary table, gear-box, and twin vertical engine with flexible coupling connections are mounted on a skid-frame and placed on the derrick floor in a position where there will be the least interference when bringing in, racking, and laying down the drill-pipe. Another type of independent table drive on steam rigs consists of placing the twin steam engine below the derrick floor in the cellar, when sufficient space is available, and driving from the engine to the rotary pinion-shaft by chain. In both types the steam engine has a remote throttle control and reverse located at the driller's position.

Rotary table speeds of 500 r.p.m. and higher are uncommon in the Mid-Continent area, but are used quite generally in the deep wells in California. This type of service is very severe, especially when taking into consideration the fact that the horse-power requirements are usually calculated to be 1 h.p./revolution/minute, or 500 h.p. at 500 r.p.m. This figure obviously represents high torque combined with high bearing speeds, and calls for rugged, precision-built rotary tables adequately lubricated, perfectly balanced, and made of the very best materials. The modern rotary table represents probably the greatest advance in drilling machinery design. Having anti-friction bearings throughout, spiral bevel, accurately cut, surface-hardened gearing, and complete oil-bath lubrication, it performs the most difficult job on the rig with a minimum of maintenance cost. It is not inconceivable that before long, table speeds of 1000 r.p.m. may become quite common.

Prime movers, swivels, and hoists are discussed. A. H. N.

248.* Advances in 1941 Drilling Equipment Demonstrated in California. N. A. D'Arcy, Jr. *World Petrol.*, January 1942, **13** (1), 44–49.—Light drilling equipment made great strides, and many refinements were introduced in heavy drilling equipment. Internal-combustion engine-power units were practically unanimously chosen by operators in all fields, with California operators showing a decided preference for independently powered slush-pumps. Increased attention was given to mud-pumps and mud conditioning, as much of the drilling was in difficult localities. Three principal types of portable derricks or masts proved their worth in California within the past year. These are the jack-knife, the telescoping, and truck-mounted units.

A large three-cylinder steam pump made its appearance in 1941. This pump, having an 18-in. diameter steam cylinder, 20-in. stroke, and liners up to 7½ in. in diameter, provides maximum fluid from but a single pump. The pump is designed for 3000 lb. working pressure, and was actually working against a 2700-lb. manifold pressure on much of the first hole on which it was used. It is reported that the three cylinders so smooth the pumping action that the pump has the appearance of idling even when operating against high pressures at comparatively fast speeds. Mud treatment and cooling are discussed.

Developments in draw-works are reviewed, including the type designed to guide wire rope satisfactorily over the third layer.

The water-tube boiler-power plant in California was in operation 240 days drilling one test-well, approximately 12,900 ft. deep. During this period the boilers did not cause a single shut-down, nor was there a single boiler-maker or boiler-maker's helper on the job. A complete elimination of stay-bolts, seams, flue sheets, corrosion, and scale was responsible for this trouble-free service. The boilers operated on evaporated water, thus eliminating the deposit of scale in the tubes. The evaporator itself was not opened for cleaning during the entire 240 days. It was cleaned by temperature changes and the flushing out of the released scale. Boilers are not yet operating with their recommended size burner, yet they have yielded 300% of their rated capacity of steam with 60% efficiency and a stack temperature of only 620°. The elimination of seams and stay-bolts greatly reduces a common boiler hazard, and the safety angle of Type S.A. water tube oil-field drilling boilers should be considered together with economies in operation. A. H. N.

249. Patents on Drilling. D. E. Batchelder. U.S.P. 2,265,978, 16.12.41. Appl. 4.10.39. Alternating-current electrologging of well-bores.

R. F. Bolton. U.S.P. 2,265,982, 16.12.41. Appl. 6.11.39. Directional drill-bit having an inclined lower portion of the body.

R. G. Piety. U.S.P. 2,266,071, 16.12.41. Appl. 31.5.39. Well-surveying device for electrically logging wells.

A. C. H. Cooke. U.S.P. 2,266,357, 16.12.41. Appl. 21.11.39. Releasable cable-head for multi-strand cables.

W. K. Edwards. U.S.P. 2,266,361, 16.12.41. Appl. 9.5.40. Weight unit indicating apparatus using deflection of cable.

H. J. Quintrell and B. F. Irwin. U.S.P. 2,266,382, 16.12.41. Appl. 11.12.39. Setting tool for bridging plugs.

H. J. Quintrell. U.S.P. 2,266,383, 16.12.41. Appl. 2.1.40. Well-bore deflecting tool with a knuckle joint.

S. W. Gurasich. U.S.P. 2,266,623, 16.12.41. Appl. 14.9.38. Method of surveying bore-holes and locating tools therein.

A. T. Cooper. U.S.P. 2,266,739, 23.12.41. Appl. 13.1.40. Well fishing-tool with a member having a central opening.

C. E. Lang. U.S.P. 2,266,873, 23.12.41. Appl. 21.11.38. Overshot.

M. W. Lukes and S. G. Davies. U.S.P. 2,266,883, 23.12.41. Appl. 14.10.38. Rope socket.

J. A. Pitsch. U.S.P. 2,267,252, 23.12.41. Appl. 19.11.40. Hose coupling.

N. Johnston. U.S.P. 2,267,683, 23.12.41. Appl. 10.1.39. Use of fusible metals in drilling wells.

C. R. Athy. U.S.P. 2,267,705, 30.12.41. Appl. 27.1.41. Oil-field apparatus comprising a unitary derrick made of separately united sections.

A. Boynton. U.S.P. 2,267,716, 30.12.41. Appl. 23.6.39. Threadless drill-pipe.

T. E. McMahan. U.S.P. 2,267,833, 30.12.41. Appl. 9.2.40. Well-bit guide having roller cutters.

A. E. Johnson. U.S.P. 2,267,923, 30.12.41. Appl. 16.9.40. Shear-reducing dual verge thread for tool-joints, etc.

V. E. Baum. U.S.P. 2,268,010, 30.12.41. Appl. 15.4.39. Method of and means for cementing well formations.

H. M. Evjen. U.S.P. 2,268,137, 30.12.41. Appl. 11.12.39. Electrical well-logging system.

H. M. Evjen. U.S.P. 2,268,138, 30.12.41. Appl. 11.12.39. Electrical well-logging system.

A. C. Lusher and A. J. Scholtes. U.S.P. 2,268,142, 30.12.41. Appl. 27.9.39. Coupling with collapsible nipple flange for hoses.

W. S. Knouse. U.S.P. 2,268,256, 30.12.41. Appl. 3.2.40. Apparatus for surveying deep wells.

E. S. Davis and J. H. Reynolds. U.S.P. 2,268,385, 30.12.41. Appl. 20.12.39. Hose coupling.

G. T. Oberwetter. U.S.P. 2,268,514, 30.12.41. Appl. 15.7.40. Side-wall core-taking apparatus.

D. Silverman. U.S.P. 2,268,627, 6.1.42. Appl. 6.10.39. Well-logging by means of two liquids.

E. R. Webb. U.S.P. 2,268,682, 6.1.42. Appl. 9.10.37. Well-surveying instrument using a pendulum.

M. J. Potvin. U.S.P. 2,268,775, 6.1.42. Appl. 29.5.40. Drill-bit with a single plane cutting face.

W. Brauer. U.S.P. 2,268,796, 6.1.42. Appl. 5.8.39. Sectional derrick for oil-field work.

F. W. Jessen. U.S.P. 2,269,269, 6.1.42. Appl. 15.7.40. Well-logging for locating the discontinuities of a metal conduit, using an electrolytic solution.

D. Hering. U.S.P. 2,269,717, 13.1.42. Appl. 13.12.40. Well-surveying device, using a marking liquid and siphons in a multiple chamber unit. A. H. N.

Production

250.* Trends in Production Practices. Anon. *Oil Gas J.*, 25.12.41, **40** (33), 202.—A review of the new developments and practices evolved in 1941 for the production of oil and gas is given. The past year saw development of a new liner cleaner. The washing fluid is pumped down from the surface, emerging from the washing tool at a point between two opposed swab rubbers about 1 ft. apart, so that the entire flow of fluid can be forced through a selected interval of the liner. A recording pressure gauge at the surface shows how much pressure is required to force fluid through any given set of perforations, thereby showing when the liner has been sufficiently cleaned, and also providing a check on the setting of the liner's perforated sections. The method is applicable to perforated, slotted, or pre-packed gravel liners. Other cleaning practices, including the use of explosives, are given.

Present emphasis in the gravel packing of liners is on proper placement of the gravel. It has been recognized that careful selection of gravel of the proper size will be of no avail if the placement job does not result in a tightly packed envelope of gravel completely surrounding the perforated pipe. Failure to cover the liner properly in just one place may prevent the remainder of the gravel pack from accomplishing its purpose. A study of wells in the Wilmington, California, field has revealed that the gravel-packed and pre-packed liner wells show greater product ionrates than do the conventionally completed wells. This, however, does not clearly establish their greater productivity, because the wells are prorated, and are not ordinarily allowed to produce at maximum capacity, even on potential tests. The data merely indicate either that the gravel-lined wells can be produced at rates more nearly approaching their capacity without detrimental effect, or that when restricted by a given-size choke, they will produce more oil than their neighbours.

The side-inlet choke is being used very successfully for controlling the gas–oil ratios in flowing wells where the gas is mainly derived from a sand above the oil-pay. In wells of this type the gas sand is cemented off behind the casing or the liner during completion, but is opened up by several holes shot through the pipe by a gun perforator. When the tubing is run, a packer is installed with a side-inlet choke above it. The packer is set in the blank portion of the pipe, just below the gun perforations. Gas entering the hole is then available above the packer, whilst the oil enters the tubing below the packer. The side-inlet choke then provides a means of admitting gas from the casing into the tubing at any desired rate.

Production restoration and the maintenance of good efficiency in lifting oil are discussed.

The paper ends with a discussion of lease-tank batteries. Even on the most simple of vapour-tight batteries it is possible to avoid admitting oxygen during drainage of the tank by merely installing a small line to the top of the tank from some source of supply where gas will be available while the tank is on the line. The gas may be supplied from a separator which discharges into a different tank, or from a residue line, or from a well.

Other rules for tank care include immediate repair of seam leaks, frequent inspection of bottoms to guard against the start of corrosion, and regular application of paint. Proper drainage at the base is important, as water within the fire-walls tends to increase corrosion from the outside. For maximum life the tank should be mounted on a raised foundation of concrete, or a steel platform. If such a foundation is not used, the setting should be prepared by placing a level bed of gravel on solid ground and covering it with tar paper or other waterproof material.

The paper is given in both English and Spanish. A. H. N.

251.* La Gloria Condensate Recovery Plant Unusual Joint Enterprise. N. Williams. *Oil Gas J.*, 1.1.42, **40** (34), 30.—This paper comprises a section of the present issue of the *Journal* devoted to the operations in La Gloria. Operations providing for the maintenance of reservoir pressures and recovery and distillation of condensate from high-pressure gas-producing horizons are under way in La Gloria field, located in Jim Wells and Brooks Counties, South Texas. In volume of gas to be processed, this project is the largest of its kind yet undertaken. It is also an outstanding example of a large-scale conservation programme initiated in the very early development and productive stages of a field.

Installation of a processing plant for the extraction of condensate from the wet gas produced and for the return of the dry residue gas to the producing sands has been the essential phase of the project. Highly diversified lease and royalty ownership within the prospective limits of the productive reservoirs has made the pooling of interests and unitization of the field a major factor and pre-requisite.

The plant, owned and operated by La Gloria Corporation under a life-of-property contract with leaseholders in the field, has facilities for handling more than 225,000,000 cu. ft. of gas daily. Operations cover two adjoining, unitized blocks totalling approximately 6475 acres. Embraced in the unitization is a subdivision of lands adjoining the townsite of La Gloria, composed largely of tracts of 40 acres or smaller.

Participating in the blocks are ten separate leaseholders and sundry royalty interests.

Early development is reviewed. Producing wells are being spaced at approximately equal distances on the periphery of a circle around the rim of the blocks, constituting roughly the outline of the condensate-producing area of the structure. The plant is located near the centre of the circle. Like the input wells, each of the producing wells is a double completion to produce from two of the four sands. This makes La Gloria the first field in which all wells are dual completions.

The gathering system will ultimately contain more than 9800 ft. of 8-in. main line with approximately 23,000 ft. of 6-in. secondary lines, and more than 32,000 ft. of 4-in. secondary and feeder lines. The main line extends northward and southward across the field from a juncture just west of the plant with the plant intake line. Connecting at different points on this main line are the 6-in. secondary or lateral lines serving various sections of the field. The latter are fed by the 4-in. feeder lines from the individual wells.

Composition of the gases in this field is discussed, together with characteristics of the gathering and separation plants. The absorption system as used is detailed. The paper ends with a list of the equipment used. A. H. N.

252.* Cost Study of Fort Collins-Wellington Field, Colorado. F. N. Bosco. *Oil Gas J.*, 15.1.42, **40** (36), 50.—The cost of producing oil in Colorado has already been shown to exceed the net value of the reserves plus oil produced. The following are also shown : A cost of 25 cents/brl. in excess of the field value of the crude and reserves when produced. The proven-oil reserves plus production for the 70 years preceding 1932 (the last year in which complete cost data were available) equalled 54,154,000 brl. The oil had a field value of $43,721,753, although the total cost of producing this amount of oil is $56,837,000. The net loss of $13,115,247 has been paid by wildcatters and others who may or may not have benefited by the sale of the oil. Certainly any fair determination of the cost of finding and producing oil should include the cost of wildcatting.

A study is presented of one of the best fields in Colorado—the Fort Collins-Wellington field, which is 6 miles north of Fort Collins, in North-Eastern Colorado. Production is from an approximate depth of 4300 ft., and the producing horizons are the Muddy and Dakota sands in the Dakota formation. The structure is a closed anticline, with two separate highs. The pool was opened on 11th November, 1923, the first well yielding only gas. The entire field will be discussed in an article on Eastern Colorado which will appear in an early issue of the *Oil and Gas Journal.*

It has been found that, for the 20-year period following discovery, using reasonable cost data as presented in this article, the net loss to the producers would have been approximately $1,400,000 while producing 5,275,000 brl. For the study it was assumed that market value was $1 a barrel ; actually some of the oil sold for $2.50 a barrel, so that the field may have shown a profit.

Drilling, as well as production costs, are given in some detail and are tabulated.

A. H. N.

253.* Back-Wash by Gas-Lift Increases Efficiency of Salt-Water Injection. G. B. Nicholson. *Oil Wkly*, 29.12.41, **104** (4), 19–21.—To clean the formation face of salt-water injection wells, one company in a field in coastal Louisiana installed a tubing string equipped with flow-collars to permit back-washing by gas-lift. Favoured by presence of a shallow salt-water-bearing sand which receives the injection water under a vacuum, the company periodically augments infiltration by applying pressure from a nearby gas-well into the tubing, flushing water through the casing to the salt-water pit, and carrying accumulated sand and residue from the formation face. Washing action expurgates the receiving formation, opening pores and removing materials which deter movement of input water into the sand.

The history and peculiarities of the field are briefly given. Salt-water treatment is described in some detail. The most troublesome element to remove from the water is iron oxide, which, reduced from a ferrous to a ferric state by aeration, is insoluble, but reluctant to precipitate. Experiments show that this substance, when a solution is allowed to pass through a sand-core, is caught on the face of the sand, and clear water filters through. Such experiments also show that iron oxides do not penetrate into the sand, but stick chiefly on its face, to account for plugging the formation pores in input wells. This has been determined in actual wells by washing, with water removing the deposited oxides from the formation and reopening the sand for injection. As a result of these experiments all salt water is filtered before injection, to remove all solid particles.

After a period of operation, a gradual decline in vacuum at the well-head indicates that the formation is no longer taking the water as freely as under normal conditions, usually attributable to a partial sealing of the face by deposition of the solids, including iron oxides formed by the corrosive water passing through the steel pipe, the natural tendency to react aggravated by aeration. Continued injection would further reduce the vacuum and necessitate additional pump pressure to increase the hydrostatic pressure applied against the formation.

To prevent complete clogging of the sand-face, water injection is temporarily suspended while the formation is cleaned by back-washing. Already permanently connected with the gas-well, gas is readily admitted to the tubing, circulating the water from the casing back into the pit, and washing the filters by the reverse circulation. In this manner the sealing solids and accumulated sands are quickly washed from the well, opening pores to facilitate further injection. In the meantime water from the gun-barrels continues to empty into the reservoir. A. H. N.

254.* Complete Flow-Tank Vapour-Recovery System. Anon. *Oil Wkly*, 29.12.41, **104** (4), 22–23.—The paper describes, with illustrations, a system of vapour lines on tanks to provide freedom of passage of vapours from one tank to another, to compensate for the variation in pressure while one or more are being filled and others being emptied. This is accomplished without infiltration of air into the battery or loss of vapours. The system is separate from the traps on the wells, but the vapour recovered from the tanks is fed into a gathering system, which conveys the gas to a gasoline plant.

Town-lot locations and complicated royalty interests make it necessary to equip many individual wells with separators, but as measurement of both oil and gas is accomplished with approved meters, grouping of separators and flow-tanks at convenient centralized points permits this type of vapour-saving equipment to be used. Each well and its separator are furnished with at least two flow-tanks. The vapour system is connected to all the tanks in the battery, and contains equipment and control instruments to maintain a predetermined pressure on all tanks alike.

The methods of construction and other details are briefly given. A. H. N.

255.* Modification of Permeability Measurements. H. Krutter and R. J. Day. *Oil Wkly*, 29.12.41, **104** (4), 24.—The paper directs attention to Klinkenburg's paper on permeability of rocks to air, and explains the calculations used. Klinkenburg showed that permeabilities, as ordinarily measured, using air, varied, depending on the mean pressure used in the measurements. The higher the mean pressure used, the lower the calculated value of the permeability. This variation is most striking for low-permeability cores, and decreases with increasing permeability. At very high mean pressures (essentially infinite mean pressure) and low differential pressures, so that there is no question of turbulence, the value of the permeability, as determined using air, agrees with that obtained using various liquids. In this work care was taken that the question of swelling did not take place. The large differences obtained between the liquid permeability and the air permeability as ordinarily determined indicate that the swelling of clays does not play so important a rôle as was once thought.

Klinkenburg's results are briefly summarized by the equation $K_a = K\left(1 + \frac{b}{Pm}\right)$, where K_a is the permeability obtained with air at a mean pressure, Pm. The constant b depends on the pore pattern of the core, and decreases with increasing permeability. K will be the new defined permeability, and will also be the permeability which should be obtained if liquids were used as flooding mediums. The quantity which is a characteristic of the core is therefore K, and not K_a.

A graph correlates the constant b with the permeability of various samples for Venango second sand. The relation is given as a straight line.

A nomograph is given to facilitate calculations. A. H. N.

256.* Widely Spaced and Varying Depth Wells Pumped Efficiently by Large Centralized Hydraulic Plant. G. M. Wilson. *Oil Wkly*, 5.1.42, **104** (5), 17.—Ten widely spaced wells are pumped from a central plant housing six triplex units. The ten wells operated by this central power plant had been on gas-lift and ordinary rod-pumps until two years ago, when it was decided to equip them with hydraulic pumps. The pumps in four of the wells are set at 4500 ft., four at 6000 ft., and two at 6500 ft. They are located in the fairly precipitous terrain characteristic of this portion of the field. The well most remote from the plant is more than 2500 ft.

All the units are connected to a single outside cooling tower, making it possible to close the building tightly during heavy rain-storms or other bad weather. The 25-ft. high, 12 × 12 × 20 cooling tower has ample cooling capacity for the units. At the base of the tower are four 2-in., 60 gal./minute-capacity electric circulating pumps. Two of them circulate all the water through the units, one is a stand-by, and the other circulates water through the tower itself. A water-softening unit is used in connection with the tower, which helps to reduce scale troubles to a minimum.

Before entering the intake line serving the triplex units, the heated power oil, coming from the dehydrator plant, is run through a trap. Here any vapour is removed from the oil, so that only dead oil enters the pumps. The fluid-level is automatically maintained at a certain line in this trap. A pressure of 15 lb.—just enough to charge the pumps—is held on the intake line.

The 2-in. trunk-line coming out of the plant extends uphill, and approximately bisects the area taken in by the wells. The single pump pressure of 3000 lb. is held on this line. From this main line laterals take off to serve the various wells. Not more than two wells are served on each lateral. When a single lateral takes off to one well, 1-in. pipe is used; when two wells are served from one lateral, 1½-in. pipe goes to one well, the second well being operated through a 1-in. pipe extension. The pipe is high-pressure seamless, galvanized inside and out. All lines are buried. The power oil leaves the plant at 140° F., in order to keep the paraffin in solution through all the power-oil and lead lines. Other data, together with advantages of the plant, which has been running for two years, are given. A. H. N.

257.* Statistical Data on Production in 1941 and Estimates for 1942. Various Authors. *Oil Wkly*, 26.1.42, **104** (8), 40.—This issue of the *Oil Weekly* is devoted to statistical data and forecasts on production in the U.S.A. for 1941 and 1942, respectively.
A. H. N.

258.* Critical Analysis of the Application of the Back-Pressure Method in Studies of Gas Reserves. Part 2. J. W. Ferguson. *Petrol. Engr*, November 1941, **13** (2), 50.—The paper continues with discussion of White's method, and solves numerical examples fully, to reveal certain points in White's arguments. Four hypothetical cases have been chosen in which a range of values of C and n have been considered, such as would be likely to be encountered in actual practice. The composite curve has been calculated for each of these cases, and comparison made between the conventional curves and the curves obtained by White's methods. The errors in White's methods have been calculated for these four examples, which should be sufficiently general to cover the actual experience with well-curves as to prove the basic errors in his work. A. H. N.

259.* Subsurface Pressure Recorders and Equipment. H. G. Abadie. *Petrol. Engr*, November 1941, **13** (2), 69.—Details of a depth-pressure instrument are given, together with illustrations. Pressure admitted through the inlet port of the foot-piece acts on the end of the spring plunger and causes the extension of the spring. A stylus attached to the upper or free end of the spring records its extension on the longitudinal axis of a chart contained in a drum. Rotation of the chart-drum by means of a thermal motor or clock causes the stylus to be drawn laterally across the chart. The resultant trace of the stylus provides a record of pressures that may be correlated with the depths at which they were obtained.

It is a practice to run a combination mercury-filled sinker bar and thermometer well with the instrument. This assembly weighs 29 lb., is 92 in. in length overall, and has an O.D. of 1¼ in. The mercury-filled sinker bar is not standard equipment as supplied by the manufacturer. In lieu of a sinker bar, some operators run recorders in tandem, thereby obtaining check records, or at least one record, should the other for any reason be illegible. The instrument is easily and quickly assembled and dis-assembled. All pressure joints are of permanent bronze-to-steel fit. Details of each part of the instrument are given.

Chart-carriers are rotated by a thermal motor or clock. The motivating element and chart-drum comprise a unit.

The thermal motor consists essentially of a bimetallic helix, one end of which is connected to the carrier case and the other end to the drum-shaft. A change of temperature causes differential expansion of the metal strips of the helix, thereby rotating the shaft. For each degree rise in temperature the motor turns approximately 2½°. The position of the motor in the instrument shows that heat transfer from the well-bore must take place through four mediums before reaching the helical spring. In making the survey, this insulation insures an appreciable heat lag, and thus enables the motor to continue turning sufficiently to inscribe a well-defined lateral line each time the instrument is brought to rest. The thermal motor is therefore used in surveys where a temperature gradient can be utilized to actuate the motor. This means making a continuous traverse of a well from the surface to the bottom stop of the survey. Under optimum conditions, a survey consisting of eight stops may be made and still have all points legible. In general, only five or six stops may be necessary to define fully the pressure traverse. The operator must exercise judgment regarding the time to be allowed at each stop, according to the rate of descent, status of well, stop programme, and anticipated temperatures.

The clock is used to advantage when it is necessary to make a large number of stops, when the stops are close together, or to obtain a time-pressure relationship. In a time-pressure survey the bomb is usually suspended at one point for the entire period. Clocks are available with running times to 72 hrs., and with various rates of rotation.

Calibration and field procedure are described in full. A. H. N.

260.* Small Gun Perforator Aids in Solving Production Problem. H. L. Flood. *Petrol. Engr*, November 1941, **13** (2), 90.—The paper deals with a small gun perforator designed for use inside tubing strings as small as 2 in. Its interest lies in the fact that it can be employed for a number of different purposes, not the least important of which involves getting out of trouble when the tubing string is stuck in the hole.

The external diameter of the gun-body is only $1\frac{3}{4}$ in. Until this gun was developed, no one had successfully designed so small a gun, because the thinking was still in terms of placing the powder charge horizontally, normal to the long axis of the gun. In a small gun the limited space prohibited use of a sufficiently large charge of powder to be effective. In the new gun this difficulty was circumvented by placing the powder charge vertically, parallel with the long axis of the gun.

The $1\frac{3}{4}$-in. gun perforator was developed in the West Texas area primarily in answer to the need for a means of perforating tubing for gas–oil ratio control purposes without the necessity of removing the tubing from the hole. In many of the older fields in West Texas canvas or other types of packers were installed in wells. Although these packers in many instances have served effectively for years, it is not economically feasible to re-run such packers, assuming that they could be removed without destroying them. The removal of these old packers has also proved to be a very costly operation in some areas, and after their removal difficulty has been experienced in obtaining another packer seat.

Although the method is not so widely used in other areas, in West Texas, following the leadership of one of the larger operators, it has been the practice for several years to pull the tubing string, and drill small orifices in the tubing collars. When the tubing is re-run, these drilled collars are spaced in the string, to serve as points of admission for gas from the annular space into the tubing, to aid in lifting the fluid.

Because the amount of gas admitted through even a small orifice represents a considerable volume, the holes drilled in the collars are not large. As a part of developing the $1\frac{3}{4}$-in. gun for this service, two new bullet sizes were designed, $\frac{1}{16}$-in. and $\frac{1}{8}$-in. in diameter, respectively. The largest bullet that can be fired from the small gun is $\frac{15}{32}$ in. in diameter. An important requirement in designing the small gun was to specify a powder charge having sufficient explosive energy to fire the bullet through one tubing wall without penetrating or damaging other tubing or casing strings.

The methods of perforating for gas admission and for freeing stuck pipe and other purposes are described. A. H. N.

261.* Some Aspects of Mechanical Pumping at Comodoro Rivadavia. E. M. Seifer. *Petrol. Engr*, November 1941, **13** (2), 116.—The formulæ giving rod acceleration and impulse loads, as well as the effect of viscosity of oil on pump-loads, are briefly discussed. The introduction of insert type of pumps has solved a number of pumping problems, and their use proved of value from the operating and economic standpoints. It is worth noting, in the case of the Escalante sector, where many wells the production of which by pumping with pumps of the common type encountered difficulties, that after being equipped with pumps of the insert type they operate normally.

Among the advantages of this type of pump it is shown that the time consumed in changing pumps shows an average of 32 hrs. for the common pump and 8 hrs. for the insert pump. This reduction in time has the following advantages : (*a*) The well is shut down for less time, and in consequence the loss of production is less. (*b*) The cost of the operation is less. (*c*) The efficiency of the hoists is increased now that each of them can attend to a larger number of wells. (*d*) Inasmuch as it is easier to change pumps, changes may be made more frequently, and therefore the production of the wells may be maintained. Other advantages are analysed.

The rod-hanger for use during the pulling and running-in of rods offers a number of advantages : (1) An appreciable economy in time used in the operation is obtained. (2) The workers can manipulate the rods more easily. (3) The system is simpler, cleaner, and less dangerous. (4) The possibility that the threads may become covered with sand is minimized. (5) The construction of a concrete trough is not required. (6) Inasmuch as the rods are hung up, there is no danger that vehicles when arriving at the well will run over them. (7) The risk of bending, which is frequent when the rods are pulled and stacked in double stands outside the derrick without a hanger, is eliminated. The flexibility of the double stand puts considerable strain on the central joint, and is one factor contributing to the breakage of the pin. In this respect it is pointed out that in the " El Trebol " area all the fishing for rods that occurred in wells equipped with $\frac{7}{8}$-in. rods has been caused by breakage at the pin.

Other items discussed are concrete floors for derricks, improvements in central power rod-lines, and heat treatment of auxiliary equipment. A. H. N.

262. Patents on Production. R. S. Charles. U.S.P. 2,266,000, 16.12.41. Appl. 7.10.40. Well-strainer with a soluble bonding material holding aggregates together.

A. Hollander and V. A. Hoover. U.S.P. 2,266,039, 16.12.41. Appl. 11.6.40. Submersible motor structure.

W. F. Tebbetts, Jr. U.S.P. 2,266,094, 16.12.41. Appl. 18.11.40. Hydraulic pump in combination with a well-tubing.

L. J. Vetrano. U.S.P. 2,266,289, 16.12.41. Appl. 3.4.39. Pump-operating mechanism, having a pair of cylinders of unequal cross-sectional area.

L. Spencer. U.S.P. 2,266,341, 16.12.41. Appl. 6.2.41. Gun perforator.

L. Spencer. U.S.P. 2,266,342, 16.12.41. Appl. 6.2.41. Gun perforator.

L. Spencer. U.S.P. 2,266,343, 16.12.41. Appl. 6.2.41. Gun perforator.

D. Staerker. U.S.P. 2,266,344, 16.12.41. Appl. 11.3.38. Coupling in combination with a well-pump.

G. F. Turechek. U.S.P. 2,266,345, 16.12.41. Appl. 19.2.41. Gun perforator.

A. J. Zschokke. U.S.P. 2,266,351, 16.12.41. Appl. 1.11.40. Gun-perforator construction.

A. J. Zschokke. U.S.P. 2,266,352, 16.12.41. Appl. 27.1.41. Gun perforator.

M. E. Chun. U.S.P. 2,266,355, 16.12.41. Appl. 29.10.40. Electrical generators for gun perforators.

C. J. Coberly. U.S.P. 2,266,356, 16.12.41. Appl. 18.5.38. Automatically governed pump to control rate of flow of high-pressure fluid.

P. M. Rea. U.S.P. 2,266,384, 16.12.41. Appl. 9.11.39. Polish-rod packing of resilient nature.

J. M. Hait. U.S.P. 2,267,459, 23.12.41. Appl. 9.1.39. Deep-well pump with a sand-trap.

E. Berl. U.S.P. 2,267,548, 23.12.41. Appl. 31.1.36. Art of extracting oil from the earth by means of soluble substances.

R. R. Thompson. U.S.P. 2,267,627, 23.12.41. Appl. 19.10.40. Gun perforator.

L. C. Chamberlain. U.S.P. 2,267,855, 23.12.41. Appl. 15.3.37. Treatment of wells producing mineral fluid.

R. P. Grayson. U.S.P. 2,267,910, 30.12.41. Appl. 25.11.39. Power-producing apparatus, being a fluid-operated motor for a well-pump.

R. A. Lamb and W. H. Waring. U.S.P. 2,268,041, 30.12.41. Appl. 4.2.39. Flow device for wells.

C. J. Coberly. U.S.P. 2,268,543, 6.1.42. Appl. 18.7.32. Method of assembling fluid-operated pumps.

J. H. Whitehead and C. Mathiesen. U.S.P. 2,269,046, 6.1.42. Appl. 12.7.38. Apparatus for screening sand and gravel mixtures.

P. T. Tarnoski and E. H. Uhlmann. U.S.P. 2,269,134, 6.1.42. Appl. 2.6.39. Desalting and demulsifying compound for petroleum emulsions.

H. R. Downs. U.S.P. 2,269,189, 6.1.42. Appl. 20.3.39. Fluid-pump with fluid-driven motor.

M. Williams. U.S.P. 2,269,569, 13.1.42. Appl. 27.9.39. Process for analysis of core-samples containing oil and water by means of an absorption train and a heating coil.

C. M. O'Leary. U.S.P. 2,269,729, 13.1.42. Appl. 23.12.40. Pitman gearing.

C. M. O'Leary. U.S.P. 2,269,730, 13.1.42. Appl. 5.3.41. Central power.

W. E. Saxe. U.S.P. 2,269,787, 13.1.42. Appl. 9.4.40. Counterbalancing apparatus for pumping wells, with adjustable counterbalance.

B. F. Schmidt. U.S.P. 2,269,789, 13.1.42. Appl. 28.9.37. Fluid piston-pump for deep-well pumping.

W. W. Kemphert and D. E. Tessendorf. U.S.P. 2,269,821, 13.1.42. Appl. 16.10.40. Sheave for use in a power-transmission drive.

H. T. Kennedy. U.S.P. 2,270,006, 13.1.42. Appl. 17.4.37. Sealing porous formation by injecting a polyvalent metal the oxides and hydroxides of which are insoluble.

J. O. Steele. U.S.P. 2,270,146, 13.1.42. Appl. 13.3.40. Well-pump for shallow wells, possibly applicable to water wells only. A. H. N.

Gas

263.* Developments in the Use of Natural Gas Fuel in Italy. E. A. Bell. *Petrol. Times*, 29.11.41, **45** (1157), 700.—It is believed that the total domestic natural gas (methane) yield reached a figure of 26,000,000 cub. m. in 1940, and that this source, together with gas produced by the metallurgical industry, will yield a supply of about 40 million cub. m. in a not too distant future.

The great handicap in the utilization of this supply as a motor fuel, however, is the general uncertainty of location of the more important gas deposits, and in the rapid exhaustion of some of the wells even in the most important zones.

A further handicap is that the consuming centres are generally too far distant from the producing areas. Distribution also gives rise to great difficulties, since the cylinders used, whether of molybdenum steel or of aluminium–magnesium, are too few in numbers and their production has been curtailed.

The question of developing an extensive pipe-line system has recently been considered, but the financial outlay can be risked only where the yield is regular and not likely to cease altogether within a short time.

A number of short pipe-lines such as Pietramela (31 miles from Bologna) to Florence—34 miles long; pressure 25 atmospheres; Podenzano to Piacenza—10 miles—25 atmospheres pressure are in existence, but no long pipe-lines have as yet been constructed. This, however, is under consideration.

Liquefaction has been discussed as a solution to the problem, but no success has yet been achieved on a commercial scale.

The effort to develop the use of methane over a wide field is handicapped by the uncertainty as to the post-war position in regard to Italian fuel supply. It is possible that gas will then revert to the rôle it played before the war within the chemical industries, and that its use as a motor fuel will decline. D. L. S.

Refining and Refinery Plant

264.* New Chart Solves Heat Transfer Calculations for Fluids in Viscous Flow Region. D. O. Hubbard and J. V. Roth. *Chem. Met. Eng.*, January 1942, **49** (1), 100.—A method of correlating heat-transfer data in the viscous flow region, which is of special significance in the petroleum industry, where transfer in this region is commonly experienced, is presented here. When fluid flows through a pipe in viscous flow, its viscosity at the heat-transfer surface varies widely from the average viscosity. Sieder and Tate (*Industr. Engng Chem.*, 1936, **28**, 1429) introduced a corrective factor which takes into account the viscosity gradient by means of the ratio μ_a/μ_w—that is, the ratio of average viscosity of the main fluid stream to its viscosity at the temperature of the tube wall.

The mathematical relationship is :

$$G = \frac{hD}{12K}\left(\frac{2{\cdot}42C_p\mu_a}{K}\right)^{-\frac{1}{3}}\left(\frac{\mu_a}{\mu_w}\right)^{-0{\cdot}14}$$

A. H. N.

265.* War-Time Protection of Industrial Plants. Anon. *Chem. Met. Eng.*, January 1942, **49** (1), 102–108.—The paper deals specifically with sabotage and its prevention, protection against incendiarism and against air raids, all discussed from the viewpoint of chemical plants. The conclusions reached are : Sabotage by fire is the most dangerous of all war-time enemies of American chemical and process industries. Fortunately, protection against such damage can be had by strict adherence to orthodox methods of fire prevention, although it will be necessary to double and treble normal peace-time measures. Common sense and stern precautionary steps are the best protections against all types of sabotage and espionage of industrial chemical and process plants.

Enemy air raids may consist of efforts to cripple or destroy certain industrial plants by the use of incendiary bombs. Magnesium incendiaries are relatively harmless if properly understood and fought. A fine spray of water can quickly extinguish them and prevent damage in most cases. However, it is first necessary to have proper equipment in sufficient quantities, properly trained personnel, and many sources of water, in order to fight such bombs successfully.

Reasonable protection of equipment and personnel from distant effects of high-explosive bombs can usually be obtained from light-weight shutters and other simple methods. Black-outs can best be accomplished by the use of proper screens or baffles, although most plants require individual study before protective steps are taken.

A. H. N.

266.* Alloy Steel Characteristics for Oil-Refinery Service. W. G. Hildorf. *Nat. Petrol. News*, 3.9.41, **33** (36), R. 275.—The article sets forth the characteristics which steel must possess if it is to be satisfactory for high-temperature service, and indicates how these characteristics may vary in different applications. The more common alloying elements are classified according to their effect on the steel, which effect is shown to be specific. Certain elements tend to produce a two-phase structure. If this is undesirable, the so-called ferrite and austerite formers must be balanced, so that the resulting steel is single-phased. The number of steels now available is large, but a need for steels capable of withstanding still higher temperatures in service exists. This is particularly so for continuous service at 1500° F. and higher, and also at lower temperatures where the permissible deformation is of a small order.

H. G.

267.* Hot Clay Treatment for Removal of Sulphur from Gasoline. H. Bottomley. *Nat. Petrol. News*, 15.10.41, **33** (42), R. 330.—The paper discusses the five principal processes for the removal of sulphur bodies from gasoline. The hot clay process is applicable only to straight-run products. With cracked gasolines some polymerization occurs, to the detriment of the product. Tabulated data indicate that in the hot-clay process mercaptan sulphur is removed completely, and that the total sulphur content is reduced to a lower figure than by the other process in the case of the examples chosen. If judged either from the point of view of T.E.L. savings or by the appreciation of quality, the process is indicated to be very attractive economically.

H. G.

268.* Precise Commercial Fractionation in 1000 Barrel Stedman Unit. L. B. Bragg and F. Morton. *Nat. Petrol. News*, 12.11.41, **33** (46), 355.—Trinidad Leaseholds, Ltd., required a distillation unit capable of producing a number of well-fractionated cuts from light petroleum distillates. A continuous-distillation battery containing a number of bubble-tray towers was first considered, but the scheme was abandoned in favour of a batch-distillation unit.

It was decided to use a packed column, and Stedman packing was chosen because it has a lower hold-up than other packings of equal capacity and plate efficiency.

The unit was designed to operate on debutanized light gasoline f.b.p. 248° F., and to separate this into seven overhead fractions and a still residue. The odd-numbered fractions were to contain substantially all the *iso*paraffins, naphthenes, and aromatics, while the even numbers and residue were to contain substantially all the normal paraffins.

The unit consisted primarily of a still, heated by internal steam coils, a Stedman packed column, a horizontal overhead condenser, a reflux distributor, and the necessary product and residue coolers. Drawings and a full description of the unit are included in the paper.

The packing used in the column had a fractionating ability corresponding to about four theoretical plates per foot of height, and the packed portion of the tower was 7 ft. in height. The liquid and vapour hold-up under operating conditions amounted to approximately 25 brl.

Three different types of operation of the unit are described, and in all cases the still was first charged with 1000 brl. feed-stock, steam being then admitted to the heating coils at the desired predetermined rate. One set of data indicates that a naphtha cut (212–273° F.) might be separated to provide one fraction (219–250° F.) containing 34% toluene (b.pt. 231° F.). D. L. S.

269.* Mixed-Solvent Extraction. A. V. Brancker, T. G. Hunter, and A. W. Nash. *J. Inst. Pet.*, January 1942, **28** (217), 15–25.—Experimental work is discussed. The conclusions reached are that when the refining, by the batch extraction of a stock of fixed composition, produced by a single solvent only partly miscible with the stock and by a binary solvent mixture consisting of the same solvent as principal solvent, together with an auxiliary solvent completely miscible with both stock and principal solvent, is compared, the following results are obtained : (1) At equal solvent/stock ratios better-quality raffinates are obtained with the single solvent than with the mixed solvent. The addition of auxiliary solvent to the principal solvent results in a decrease in the quality of the raffinate produced. (2) At equal solvent/stock ratios better yields of raffinates are obtained with the single solvent than with the mixed solvent. The addition of auxiliary solvent to the principal solvent results in a decreased yield of raffinate. (3) A better yield of higher-quality raffinate is obtained by the use of a single solvent than would be obtained by the use of mixed solvent of the type being considered. (4) At equal principal solvent/stock ratios an increase in the amount of auxiliary solvent present in the mixed solvent results in a decrease in both quality and yield of raffinate. A. H. N.

Gas, Diesel, and Fuel Oils

270.* Evaluation of Diesel Fuels in Full-Scale Engines (Co-operative Fuel Research Committee Report). W. G. Ainsley. *J. Soc. Aut. Engrs*, 1941, **49** (4), 448–460.—The Full Scale Engine Group (C.F.R.-Automotive Diesel Fuels Division) was organized to clarify the issue of fuel specifications by engine tests. Tests were made on four representative fuels in fifteen engines of seven different makes. The effects studied were : engine deposits, smoothness, starting, smoke, power output, consumption, and odour of exhaust.

It is concluded that ignition quality affects starting and smoothness, and to a lesser extent carbon deposits, smoke, and exhaust odour. High-ignition quality gives an improvement in all these factors. The more volatile the fuel the less smoke and combustion-chamber deposits. A higher specific gravity gives better volumetric fuel consumption, power output being a function of calorific value per pound. Gravity, viscosity, carbon residue, and flash point are all related to volatility, and consequently show effects on exhaust smoke and combustion-chamber deposits which may or may not be independent effects.

Viscosity has some effect on smoothness and smoke, an increase being detrimental. It also involves consideration of ease of circulation, atomization, pump plunger leakage, etc. The carbon residue on 10% bottoms (A.S.T.M.) correlates with engine deposits and smoking tendency.

An appendix offers recommendations for a specification for a universal diesel fuel suitable for mobile Army and certain high-speed Navy equipment. The following is a summary :

Viscosity, 33–43 sec. Saybolt at 100° F. 31 secs. minimum for temperatures below +10° F.
Volatility, 90% point, 650° F. max.
End point, 700° F. max.
Flash Point, 140° F. min.
Carbon Residue on 10% bottoms (A.S.T.M. Method D-189–39), not exceeding 0·15%.
Ignition Quality, 47 cetane, min.
Pour Point, 0° F. max. for average daily minimum temperatures above +10° F.
Sulphur, 1% max.
Corrosion, 3-hr. copper strip test at 212° F. K. A.

Lubricants and Lubrication

271.* Reclamation of Lubricating Oil in Britain a National Necessity. R. B. Hobson. *Petrol. Times*, 15.11.41, **45** (1156), 659.—The recovery of used lubricating oil on a large scale is advocated as an essential feature of the country's war effort. It is pointed out that processes which include only the mechanical separation of solids and water are unsuitable because the diluent remains in the oil. In a process described, the oil, after blending and settling, is distilled in batch stills in the presence of a substance which coagulates colloidal contaminants and removes acidic and oxidized bodies. Tabulated data representing diesel engine oil, turbine oil, transformer oil, general motor-transport oil, and aircraft oil (D.T.D. 109) before and after treatment indicate that satisfactory recovery is achieved. Yields are indicated to be at least 85% vol.
H. G.

Asphalt and Bitumen

272. Metal Protection with Asphalt. Anon. *Chem. Trade J.*, 31.10.41 (109), 218.—Asphaltic bitumen dissolved in a light spirit and emulsified with emulsifiers containing " passivating agents " among which are potassium dichromate, barium chromate, sodium silicate, and a mixture of sodium nitrate and rosin. Fine sand and cement are mentioned as additives. Only multi-layer coatings are said to be effective.
H. G.

273.* Uses and Testing of Gunned Asphalt. D. C. Broome and L. Bilmes. *J. Soc. chem. Ind.*, 1941, **60**, 146–153.—For use in the building industry gunned asphalt, essentially a blend of bitumen with fine mineral matter, has been developed to replace the more tediously applied mastic asphalt. The asphalt blend is pulverized and applied by means of the Schori flame-gun, using compressed air, the mixture passing through a flame of propane and oxygen. The thickness can be regulated, and ⅛–¼ in. is most suitable; the temperature at impingement does not exceed 150° C., thus avoiding overheating of the bitumen. The asphalt requires a thin base course, consisting of emulsion or cutback, even on dry surfaces. Seventeen applications, tried already and found satisfactory, are given. The principal factors affecting the success of the process are the relative caking value of the powdered materials before and after storage, the flow properties of the asphalt immediately after passage through the gun, the degree of adhesion obtained on bases of various types, etc. The asphalts are made as soft as is consistent with non-caking, pulverization, and avoidance of " sag " after application. The characteristics of suitable bitumens, softening points 88–96° C., are discussed, and careful blending with " oxidized " bitumens is practised. A mineral powder, generally silica, is ground to give about 80% passing 300-mesh B.S. sieve and 99% through 100-mesh. A certain percentage of " separator " (unspecified mineral matter) is added to prevent caking, particularly on storage; this appears to act by coating the bitumen particles, thus preventing adhesion under pressure. A caking test is described as well as a test for flexibility after gunning. The fundamental rheological properties are touched on, but are described in full in a later paper. Impact tests described are used to determine whether the material will withstand sudden shocks and still adhere after gunning. The most satisfactory test is one in which a strip of gunned asphalt is clamped so that 5 cm. is free, and is then struck by a rigid weighted pendulum, and the amount of "follow through" readily gives the work done in fracturing the asphalt. The paper also includes a preliminary study of permeability, and it is shown that a good gunned asphalt is impermeable to 90 lb./sq. in. water pressure. It is resistant to 30% concentrated hydrochloric and sulphuric acids, 20% nitric acid, and to any concentration of phosphoric acid if silica is used as the mineral in each case. H. G. W.

Detonation and Engines

274.* Heat Transference in Internal Combustion Engines. Anon. *Gas Oil Power*, October 1941 (36), 193.—A study of the heat loss from I.C. engines shows that the subject of heat transfer from engine cylinders is more involved than in other heat exchanges because of the large cyclic variations taking place.

During the suction stroke the cylinder gases or air are at almost constant temperature. Compression raises the temperature of the charge by an amount depending on the rate of heat transference from the heated charge. Combustion presents numerous complex conditions, depending on the rate of flame growth, flash point, and calorific value of the charge, etc. During expansion the phenomenon is greatly simplified, although even then the problem is by no means a simple one.

Most heat is lost from the charge during combustion and the subsequent parts of the cycle. During the first stage of combustion, when activation of a minute charge in the immediate vicinity of the seat of ignition takes place, the flame nucleus gains heat from the combustion process and transmits it by radiation. The second stage is described as the condition when, after a "delay" period, the flame grows until all combustible vapour has been consumed.

Heat transference during the expansion stroke is seriously affected by variations in the gas temperature, surface area, specific heat, and density of the working gases. Specific heats change considerably with temperature, and the density of the gas during the expansion stroke varies according to the law of expansion, and thus rather complicated relationships are involved. Heat is transmitted from the hot gases through the cylinder walls, head, and piston crown, and it is necessary to regulate the coolant supply to the cylinder walls to avoid distortion due to irregular expansion. It has been shown that the intensity of temperature variations decreases rapidly as the thickness of the wall increases, until at a depth of ½ in. the temperature oscillations due to cyclic variations of temperature in the cylinder practically die out.

The question of air cooling of engine cylinders is discussed, and a formula is given for calculating the fin area necessary for efficient cooling under certain given conditions.

As regards liquid cooling of cylinders, the question of radiator design is not discussed in detail, but it is indicated that there is an optimum water circulation rate above which the rate of heat dissipation increased only very slowly. D. L. S.

275.* Supercharging the Compression-Ignition Engine. C. B. Dicksee. *J. Instn Auto. Engrs*, 1941, **10** (1), 1–27.—The power developed by any I.C. engine is dependent on the quantity of air utilized and the thermodynamic efficiency. One method of increasing the rate of air supplied is supercharging. Many engines to which supercharging has been applied were not designed with this end in view, and it is therefore necessary to limit the maximum pressure of combustion.

Usually a proportion of the fuel is burnt at constant volume, and the remainder at constant pressure, the latter entailing some loss of efficiency. The proportion burnt at constant volume, and hence the maximum efficiency, will be determined by the maximum pressure which can be tolerated. The author analyses the P, V, T relationship for the working fluid, and concludes that for optimum output and economy the highest compression ratio capable of developing the desired output should be used. The maximum pressure should be the highest which existing conditions permit.

The net output is profoundly influenced by the type of blower used and its efficiency. The economic limit for the Roots type is a boost ratio of around 1·5. For maximum fuel economy the expansion ratio in the power cylinder should be as high as possible consistent with the ability to develop the desired output. K. A.

276.* Mercedes-Benz DB-601 A Aircraft Engine. R. W. Young. *J. Soc. Aut. Engrs*, 1941, **49** (4), 409–431.—Several of these engines have been made available in the U.S.A., and this paper is a detailed description with illustrations and comments. Performance is compared with that of other well-known liquid-cooled types. German and French designs tend towards larger displacement and lower speed for a given power than British and American practice. Among features of special interest on the DB-601 A are the Bosch fuel-injection system and the supercharger fluid drive, which automatically adjusts the boost during climb. The power output at sea level and altitude, fuel consumption, and weight are on a par with contemporary power plants of the same general type. K. A.

277.* Engineering for Better Fuel Economy. H. T. Youngren. *J. Soc. Aut. Engrs*, 1941, **49** (4), 432–441.—This paper reviews ten years' experience in developing one make of American car to give better fuel economy in spite of the demand for increased performance and the rising trend of car weight. The author is confident that further progress can be achieved.

Appreciable economies can be effected through weight reduction, provided the axle ratio is adjusted to maintain a constant performance factor; rolling and wind resistance are major factors in economy. Specific fuel consumption at road load is much higher at part-throttle low car speeds than at wide-open throttle. This is due to the lower percentage of power output in proportion to engine friction. It appears that an attempt to reduce engine friction deserves much effort. In the engine under consideration the apparent pumping loss is the largest component of total friction. Pistons and rings are a large contributor.

Higher compression ratios will continue to be contributing factors to better fuel economy, given suitable high-octane fuel. To realize the full potential gain in economy, advantage of the power gain from increased compression ratio must be taken to reduce either engine size or speed. At 40 m.p.h. an increase from 65 to 100 octane number allowed a 25% improvement with the same axle ratio and a 40% improvement with the axle ratio modified to maintain the same low-speed performance. Instead of reducing the axle ratio a smaller engine could be used, but comparative data show a marked superiority in economy for the larger engine running slower, particularly at the higher vehicle speeds.

Another well-known factor in fuel economy is air/fuel ratio. The trend in recent years has been towards ratios of about 15 : 1. Beyond this the field needs further exploration. Fuel injection with a stratified charge may offer a means of further progress. Improved operation at lean mixtures might be obtained with greatly advanced spark timing. At wide-open throttle, with a mixture ratio of 19·2 : 1, the spark was advanced to 80° B.T.C. for maximum power. Improved scavenging also aids the utilization of part-throttle lean mixtures to reduce consumption.

At part loads a wider than normal spark-gap promotes economy and steady operation over a wider range of air/fuel ratios. With a wide gap the discharge lasts longer and is multiple or oscillatory rather than a single arc. This increases the probability of ignition. A higher-capacity coil is necessary.

A high axle ratio gives improved miles per gallon at the expense of hill performance and acceleration. Automatic transmissions provide increased economy or increased performance, as the occasion warrants, without violating the American public demand for non-manual gearshift performance. K. A.

Coal and Shale

278.* Development of Alternative Fuels in Sweden. Anon. *Petrol. Times*, 15.11.41, **45** (1156), 674.—Blockade conditions have cut off Sweden's fuel oil imports completely, and considerable progress has been made in the production of substitute fuels. Large numbers of vehicles are now running on producer-gas, wood being the fuel. Smaller numbers use, acetylene, illuminating gas, methane, or electric power. The production of shale oil is being developed under State sponsorship. Heavy and light fuel oil, gasoline, and sulphur are being produced from this source. Shale-oil production cannot compete on a cost basis with imported fuel except under the present conditions. It is estimated that proved reserves of shale are sufficient for the country's needs for 500 years, but its development must obviously depend largely on political considerations. H. G.

Economics and Statistics

279.* Petroleum's Past, Present, and Future. R. P. Russell. *Chem. Met. Eng.*, January 1942, **49** (1), 84–85.—The petroleum industry in the United States in 1941 will have refined about 1,400 million brl. of crude oil, which is at the rate of about 200 million tons/year. About 44% by volume of the crude run to stills will wind up as gasoline, making the 1941 gasoline production approximately 90 million tons. This gasoline will be sold at about $16/ton as it leaves the refinery. The steel industry, which is generally looked on as the greatest of the "tonnage" industries in 1941, will make about 84 million tons of steel, which will sell at the mill gates for approximately $38/ton. Aluminium tonnage amounts to about 1/150th of the gasoline tonnage.

In the refining of oil, rapid advances in the technology of chemical engineering have made it possible to produce increasingly greater yields of more valuable products, and at the same time effect substantial improvements in quality. Twenty years ago gasoline yields on crude were 26%, whereas to-day they are 45%. Over this period crude runs have increased four-fold and gasoline production has increased seven-fold. Quality has steadily improved to meet the requirements of high compression motors characterized by improved performance and economy. Accepting A.S.T.M. octane number as a measure of anti-knock quality, the average gasoline supplied to the American public in the last 16 years has increased from approximately 50 cetane number to 73 octane number to-day, accompanied by increase in volatility to improve starting and acceleration. In regard to aviation fuels, the development of 100 octane gasoline has given an increase of approximately 20% over the 87 octane grades in commercial use at present, and an increase of 50% over the 70 octane gasolines in use 10 years ago.

Prices are compared as they exist to-day and as they were 20 years ago. The future of catalytic cracking is considered to be of vital importance. A. H. N.

BOOKS RECEIVED

Institution of Chemical Engineers. Transactions. Vol. 18 (1940). The Institution. $10\frac{3}{4}$ in. × $8\frac{1}{2}$ in. 147 pp.

Contains six papers read to the Institution in 1940 and the address of the President (Mr. F. Heron Rogers) on "Oil." The latter contains some interesting illustrations, including a reproduction of a poster issued by Messrs. Carless Capel and Leonard in 1899, claimed to be the first appearance of the word "petrol." A lengthy paper by E. Owen summarizes the methods of measuring the flow of liquids and gases.

Institution of Mechanical Engineers. Proceedings. Vol. 145 (January–June 1941). The Institution. $11\frac{1}{4}$ in. × $8\frac{3}{4}$ in. 252 pp.

Dr. S. F. Dorey's historical survey of the classification of ships and its influence on marine engineering is included in this volume, which also contains papers of topical importance on Munitions Labour Supply Organization, Acceptance Test Charts for Machine Tools, and Gun Run-up Springs. The Institution is to be congratulated on maintaining its pre-war high standard of paper, printing, and general appearance of its *Proceedings*.

Institution of Automobile Engineers. Proceedings. Vol. 35 (1940–41). The Institution. $8\frac{3}{4}$ in. × $5\frac{1}{4}$ in. 312 pp.

Two papers of particular interest to the petroleum industry are T. C. Worth's "Notes on Filtration and Distillation of Lubricating Oil," and W. Allen's "Notes on Tests of Creosote Mixtures in C.I. Engines." (A small error noted in Mr. Worth's paper was a reference to the "Institute of Petroleum Technology's handbook.")

U.S.A. Supreme Court. Report of Proceedings in the Case of the Standard Oil Companies of New Jersey, 1909–10. Verbatim report of the Standard Oil case, copies of the brief, list of witnesses, etc., 25 volumes. (*Presented by Messrs. Whitehall Securities Corporation, Ltd.*)

The Modern Diesel. J. Iliffe & Sons, Ltd. 6th edition, 1941. 7½ in. × 5 in. 238 pp. *5s.* nett.

The sixth edition of this handy summary of first principles and engine types, the first edition of which appeared in 1930, has been extensively revised and brought up to date to 1939. Subsequent developments are necessarily omitted owing to absence of published information. Road and rail transport, aircraft and marine diesel engines are all discussed, and frequent comparisons made between British, American, and German pre-war practice.

High-Speed Diesel Engines. Arthur W. Judge. 4th edition, 1941. Chapman & Hall. 8¾ in. × 5½ in. 536 pp. 25*s.*

A review of the 2nd edition of this book (*J. Inst. Petrol. Tech.*, **23,** 1936, 31A) referred to it as "dealing very comprehensively with the whole subject in a way calculated to be of the most use to the student from a theoretical and practical point of view," and offered one or two constructive suggestions for the chapter on fuel and specifications. The 4th edition, to which over 100 pages have been added, preserves the balance between the experimental and theoretical aspects and the purely descriptive side, and incorporates much up-to-date information on fuel-injection systems and new types of two-cycle engines. The chapter on fuels has been considerably extended. It now covers work published up to 1939 on diesel index, cetane and cetene numbers, and ignition quality tests, as well as recent specifications, including an approximate specification for Pool Diesel Oil.

Junior Institution of Engineers. Journal. Vol. 51 (1940–41). Percival Marshall & Co. 8¾ in. × 5⅝ in. 308 pp.

This volume maintains the standard of its predecessors in providing short informative papers on many unusual aspects of engineering ranging from "Tide Mills" to "Electrical Music." The Presidential Address by Viscount Falmouth reviews the engineer's rôle in war.

A.P.I. Specifications. Additions and Supplements. November 1941. Obtainable from the American Petroleum Institute, Division of Production, 1205 Continental Buildings, Dallas, Texas, U.S.A., and 50 West 50th St., New York (not stocked by the Institute of Petroleum).

The following specifications have been received :

Casing, Drill-pipe and Tubing. Supplement No. 1 to A.P.I. Std. 5-A (11th edition). August 1941.

Setting Depth Properties of Casing. 1st edition A.P.I. Code 5-C-2. August 1941.

Line-pipe. Supplement to A.P.I. Std. 5-L. August 1941.

Oil-well Pumps. 6th edition A.P.I. Std. 11-A. October 1941.

Information on A.P.I. Std. 11-A. September 1941.

Steel Geared Speed Reducers. 4th edition. A.P.I. Std. 11-E. August 1941.

Chain-drive Speed-reducers. 2nd edition. A.P.I. Std. 11-E-1. August 1941.

Rating of Hoisting Tools. 2nd edition. A.P.I. Std. 11–9. August 1941.

Endeavour. Quarterly periodical published by Messrs. Imperial Chemical Industries, Ltd. Vol. 1, No. 1, January 1942. 11 in. × 8½ in. 48 pp. (At present only available for export, owing to restrictions on paper supply.) 5*s.*

The purpose of this new periodical is to lay emphasis on British science. A Foreword by Sir William Bragg is accompanied by messages of goodwill from other distinguished British scientists. These are followed by ten articles on scientific subjects and four pages of book reviews. Prof. John Read, F.R.S., contributes a short note on the library of James Young, now housed at the Royal Technical College, Glasgow, and the bibliography of this library prepared by Prof. D. Ferguson. A note by Dr. J. W. Baker on "Work in Progress" deals with polar effects of alkyl groups.

INSTITUTE NOTES.

March, 1942.

DEATH OF PROFESSOR A. W. NASH.

It is with deep regret that we have to record the death of Professor A. W. Nash, President of the Institute, on Saturday, 14th March, at the age of fifty-five.

Professor Nash had been ill since the autumn of 1941, and in November last he underwent a serious operation.

The Council tenders its sincere sympathy to Mrs. Nash and the members of the family in their bereavement.

JOINT HONORARY SECRETARY.

The Council has appointed Mr. Ashley Carter, A.M.I.Mech.E., F.Inst.Pet., to be Joint Honorary Secretary of the Institute with Mr. Arthur W. Eastlake.

VICE-PRESIDENTS.

The Council has elected the following to be Vice-Presidents of the Institute for the Session 1942–43 :

Mr. Ashley Carter.
Mr. G. H. Coxon.
Dr. F. H. Garner.
Mr. A. C. Hartley.
Prof. V. C. Illing.
Dr. F. B. Thole.

RETIRING MEMBERS OF COUNCIL.

The following members of Council retire at the Annual General Meeting, 1942, and offer themselves for re-election : Dr. E. B. Evans, Mr. J. S. Jackson, Mr. H. C. Tett, and Dr. A. Wade.

NEW MEMBERS.

The following elections and transfers 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 Fellows.

Burroughs, Leland Clare ... ... U.S.A.
Tipler, Francis ... ... England.

Transfer to Fellows.

Fischer, Raoul Konrad ... ... England.
Matheson, Niels ... ... ,,

As Members.

Paterson, Leonard Andrew	England.
Scott, Roland	,,
Wilson, Wilfrid John	,,

Transfer to Member.

Land, Edwin Jacob	England.

As Associate Members.

Hall, Reginald Harold	England.
Hobbs, John Francis	,,
Johnson, Joseph James	,,
Oldfield, Arthur Edward	,,
Proctor, Wilfred Ernest	,,
Strawson, John William	,,
Weston, Reginald Alfred	,,

Transfer to Associate Member.

Lorne, Henry Thomas	Scotland.

CANDIDATES FOR ADMISSION.

The following have applied for admission to the Institute or transfer to another grade of membership, and in accordance with the By-laws the proposals will not be considered until the lapse of at least one month subsequent to the issue of this *Journal*, during which 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 any candidate.

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

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

Heckman, Maxwell, Cracking Plant Foreman, Bahrein Petroleum Co., Bahrein.

Hollingsworth, Clifford, F.I.C., Experimental Officer, Ministry of Supply. (*J. S. Jackson ; D. L. Samuel.*)

Witard, S. L., Production Manager, Messrs. Le Grand, Sutcliff & Gell, Ltd. (*J. Cuthill ; N. Matheson.*)

ARTHUR W. EASTLAKE,
ASHLEY CARTER,
Joint Honorary Secretaries.

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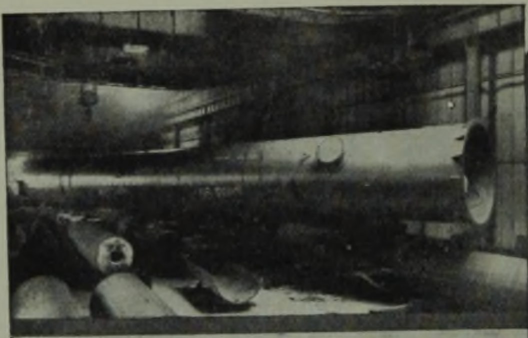

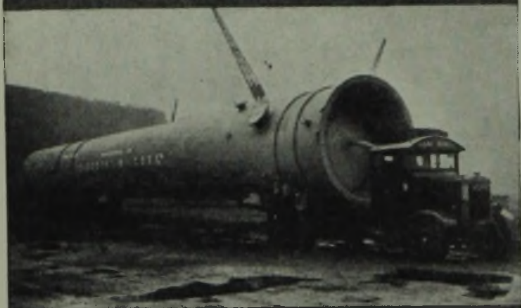

WELDED PRESSURE VESSELS

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THE illustrations depict the various stages in transport of one of a number of recently constructed Special Vessels.

This electrically welded vessel, 92 feet in length, with a diameter of 9 feet and a weight of 56 tons was constructed in one piece in our shops, so consequently some interesting transportation problems had to be faced.

The top photograph shows the first " lift "—by the shop cranes—on to rail bogies, thence to a convenient siding (second photograph) for transfer to road transport and final delivery.

The lower photographs show the vessel during its journey by road.

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