

FLYING DISPLAY OF BRITISH AIRCRAFT.

(Continued from page 343.)

LAST week we described briefly some of the new military aircraft which appeared in the flying display of the Society of British Aircraft Constructors, held from Tuesday, September 11, to Sunday,

to-chord ratio and a high degree of structural stiffness.

The control and stability characteristics of delta-wing aircraft over the whole speed range are the subject of intensive full-scale investigation; the handling of these low aspect-ratio aircraft at low speeds differs somewhat from that of conventional aircraft. In order to achieve the necessary lift, take-off and landing are performed at rather

Limited, Wolverhampton, which flew for the first time in October, 1950. It is propelled by a Rolls-Royce Nene engine developing 5,000 lb. thrust, having a nose intake and a tail exhaust nozzle, and has a span of 33 ft. 6 in. and a length of 26 ft. 1 in. The height over the tail is 12 ft. 6½ in. It is controlled by elevons. The main wheels of the tricycle undercarriage retract inwards into the wings, and the nose wheel folds backwards.

Fig. 8 illustrates the Avro 707B, built by Messrs. A. V. Roe and Company, Limited, Greengate, Middleton, Manchester; the steep landing attitude noted above is well shown. It appeared in the static park at last year's display, but had not then completed the requisite number of flying hours for taking part in the flight demonstrations. The Avro Company consider the delta-wing layout to be the ideal configuration for the long-range bomber or transport aeroplane, since it offers a large stowage capacity in conjunction with low drag at transonic speeds. The present aircraft is purely experimental. On Friday, the pilot gave a particularly interesting demonstration of its satisfactory slow-flying capabilities in gusty conditions. The Avro 707B has a Rolls-Royce Derwent jet engine, developing 3,600 lb. static thrust, installed in the rear fuselage, with a bifurcated air intake on each side of the dorsal extension of the fin; it has a span of 33 ft. and an overall length of 41 ft. 10½ in. Control is effected by separate aileron and elevator flaps, and air brakes are fitted. A retractable tricycle undercarriage is employed.

The Avro 707A, illustrated in Fig. 9, is a more refined and slightly larger version of the 707B, capable of higher speed, which made its first flight this summer. It will be observed that the air intakes for the Derwent engine have been installed in the wing roots, instead of on the top of the fuselage, as in the 707B. This has resulted in considerably cleaner fuselage lines. It will be observed also that the wing, which has a span of 34 ft. 2 in., is set farther back on the fuselage. The engine air intakes are provided with boundary-layer fences and bleeds. The overall length of the 707A is 42 ft. 9 in.

Two interesting power units made their first appearance this year—the Nomad compounded compression-ignition gas-turbine engine, and the Snarler liquid propellant rocket motor. Fig. 10, page 354, shows the Nomad, designed and constructed by Messrs. D. Napier and Son, Limited, Acton, London, W.3, which was on view in the static exhibition and was also demonstrated in flight, installed in the nose of an Avro Lincoln flying test-bed. Although compounded petrol engines have been constructed in the United States for some years, the Nomad, illustrated in Fig. 10, is the first compounded compression ignition aero engine, and is designed primarily for extremely long range. It consists of a highly-supercharged two-stroke 12-cylinder horizontally-opposed engine driving one half of a contra-rotating propeller. The other half of the propeller is driven by a gas turbine which converts the heat in the exhaust gases from the piston engine into useful work. The high thermal efficiency of this arrangement has resulted in a specific fuel consumption of 0.36 lb. per effective horse-power per hour at maximum continuous power. To provide maximum power for take off, two auxiliary combustion chambers, in which additional fuel may be burned, and an auxiliary turbine are fitted. The compression-ignition engine is supercharged by an axial compressor and a centrifugal compressor in series; it is believed that this is the first example of a piston aero-engine with an axial supercharger. The Nomad has a maximum sea-level static power of 3,000 shaft horse-power plus 320 lb. thrust, and a net dry weight of 4,200 lb. The overall length is 126½ in., the width 58½ in., and the depth 49½ in.

Fig. 11, page 354, shows the Snarler power unit, which was exhibited by the constructors, Messrs. Armstrong Siddeley Motors, Limited, Coventry, installed in the tail end of a Hawker P.1072 aircraft which, however, did not take part in the flying display. It was also on view on the Armstrong Siddeley stand. This aircraft is, basically, a P.1040, and was described on page 258 of our 166th volume (1948); the main power unit is a Rolls-Royce Nene engine. The Armstrong Siddeley Snarler has been developed for combat use, to give additional power for climb and level-speed flight at very high altitude.



FIG. 7. P 111 AIRCRAFT; BOULTON PAUL AIRCRAFT, LIMITED.



FIG. 8. AVRO 707B AIRCRAFT; A. V. ROE AND COMPANY, LIMITED.



FIG. 9. AVRO 707A AIRCRAFT; A. V. ROE AND COMPANY, LIMITED.

September 16, at Farnborough aerodrome. Noteworthy events in the display were flight demonstrations of two delta-wing research aircraft, the Boulton Paul P.111 and the Avro 707B; a third, the Avro 707A, was on view in the static park. The delta-wing arrangement makes possible the low wing loading which is essential for high-altitude operation at transonic speeds, in conjunction with a marked leading-edge sweepback, a low thickness-

high angles of incidence. Both the aircraft flown were fitted with tail parachutes to reduce the landing speed, but the Avro 707B was demonstrated without the parachute in action. In this case, the aircraft landed at an angle that appeared incredibly steep to those spectators unfamiliar with these aircraft. Another feature which was most marked was the high manoeuvrability in flight. Fig. 7 shows the P.111, built by Messrs. Boulton Paul Aircraft,

AIRCRAFT AT FARNBOROUGH DISPLAY.

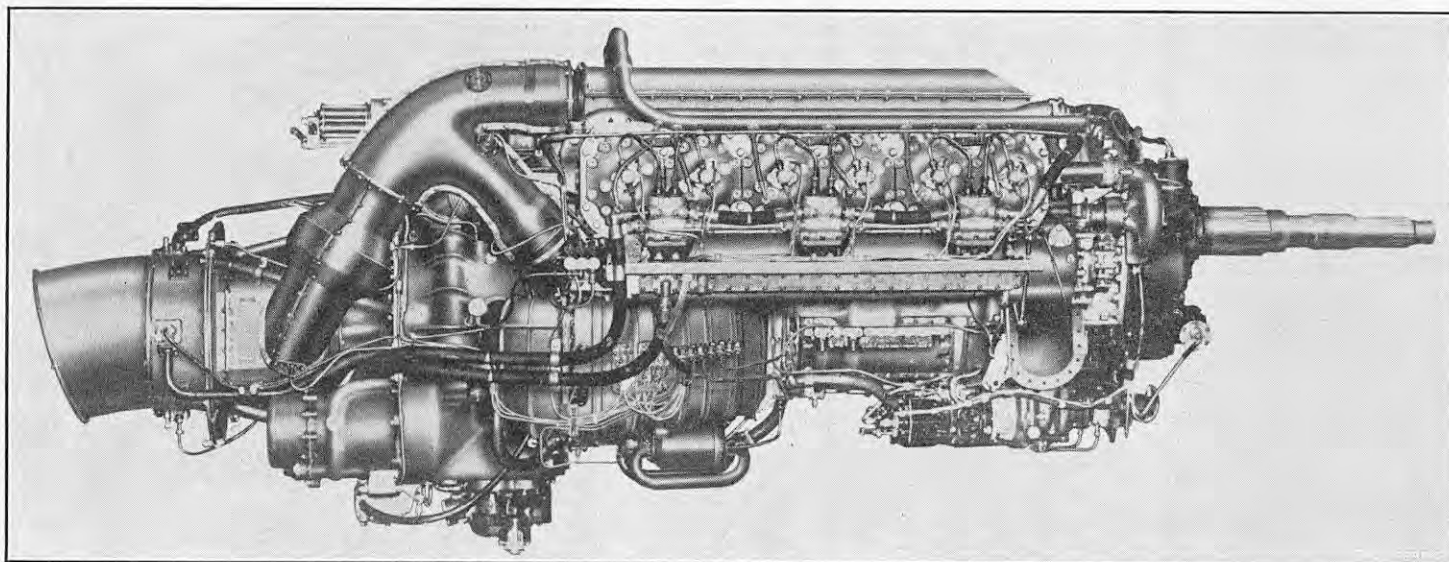


FIG. 10. "NOMAD" COMPOUNDED PISTON AND TURBINE ENGINE; D. NAPIER AND SON, LIMITED.

It can also be used for providing extra thrust for take off, developing 2,000 lb. thrust at sea level. The unit weighs 215 lb., and is very compact. The propellants used in the Snarler are liquid oxygen and a methanol water mixture; the tanks can be stowed in any convenient position in the aeroplane.

Recent versions of the jet fighter aircraft which first appeared towards the end of the Second World War are capable of giving highly impressive performances. One of the more interesting research aircraft of this type demonstrated was a Venom I single seat interceptor fighter entered by the de Havilland Engine Company, Limited, Edgware, London. It is powered by a Ghost engine fitted with reheat, i.e., equipped for burning additional fuel in the jet pipe aft of the turbine for providing extra power for combat or take-off. It may be recalled that the first reheat demonstrations were given at Farnborough two years ago, one of the aircraft so fitted being a de Havilland Vampire with a Goblin engine. A paper on reheat by a member of the de Havilland research staff was reprinted in *ENGINEERING*, on page 191 of volume 169, (1950). No information has been released on the additional thrust available due to reheat, but the sudden substantial increase in thrust as the additional fuel injection is brought in was obvious to spectators, both audibly and visibly.

The Sea Venom 20, which was ordered by the Navy earlier this year, took part in the flying display for the first time. Designed and constructed by the de Havilland Aircraft Company, Limited, Hatfield, Hertfordshire, the Sea Venom, which is illustrated in Fig. 12, is a development of the Venom 2 night fighter, which was shown for the first time at last year's display and was described briefly on page 239 of our 170th volume (1950). It differs principally from the night fighter in having folding wings and deck-arrester gear. It is propelled by a de Havilland Ghost centrifugal turbo-jet developing 5,000 lb. static thrust at sea level. The wing span is 41 ft. 9 in. and the overall length 35 ft. 3 in. The Sea Venom carries a crew of two and is provided with radar and navigational aids for all-weather fighting. The manoeuvrability of this aircraft, as on earlier versions of the Venom and Vampire, appears to be outstandingly good. The Sea Venom has been ordered for the Royal Australian Navy, and it is also to be built under licence in France.

The Vampire trainer, which was shown by the de Havilland Aircraft Company, Limited, in the static park last year, took part in the flying display this year. It is powered by a de Havilland Goblin engine developing 3,350 lb. static thrust at sea level, and has an all-up weight of 11,030 lb., a span of 38 ft. and an overall length of 34 ft. 5 in. The Vampire trainer, which has been adopted by the Royal Air Force, is equipped for instruction in the handling of a high-speed aircraft in high-altitude

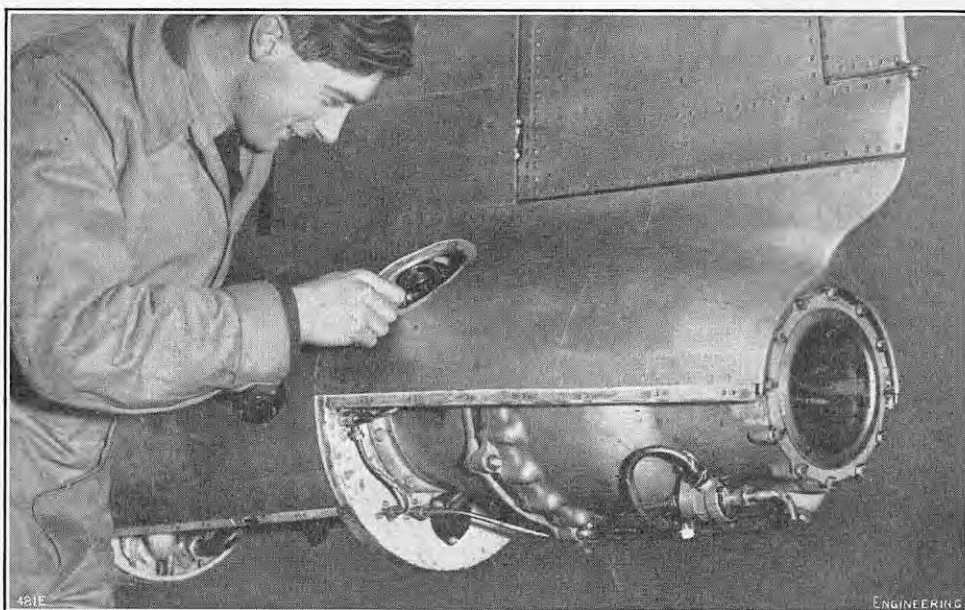


FIG. 11. "SNARLER" ROCKET MOTOR IN TAIL END OF HAWKER P.1072 AIRCRAFT; ARMSTRONG SIDDELEY MOTORS, LIMITED.

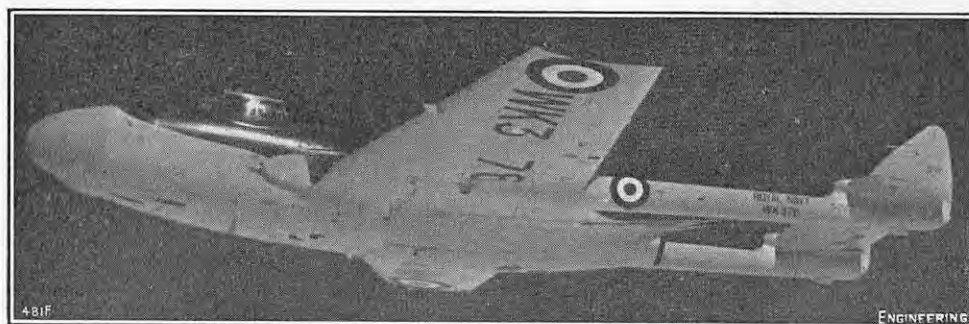


FIG. 12. "SEA VENOM" AIRCRAFT; DE HAVILLAND AIRCRAFT COMPANY, LIMITED.

combat and gunnery, in ground-attack with rockets or bombs and in high-speed navigation. The cockpit, which is pressurised, is provided with side-by-side seating and duplicated flying and armament controls and instruments. The aircraft can carry a military load of four 20-mm. cannon, plus eight rockets and two 500-lb. bombs, or, alternatively, two 100-gallon drop tanks and two 1,000-lb. bombs in addition to the guns. It has a maximum speed of 549 m.p.h. at an altitude of 20,000 ft.; the rate of climb at sea level is 4,500 ft. per minute, and the operational ceiling is 40,000 ft. At 30,000 ft., the aircraft has a maximum endurance of 2.15 hours and a range of 840 miles.

Last year, the Meteor ground-attack aircraft, built as a private venture by the Gloster Aircraft Company, Limited, Hucclecote, Gloucestershire, was shown in the static park. This year the aircraft appeared in the flying display, and demonstrated its handling qualities by performing several remarkable "cartwheel" aerobatics and spins with a full load of 24 rocket projectiles and wing-tip tanks. The spinning of aircraft carrying external loads, it will be realised, is not usually a manoeuvre recommended to pilots. The ground-attack Meteor is developed from a standard Meteor 8 airframe and is powered by two Rolls-Royce Derwent engines. It can carry the following alternative loads:

twenty-four 95-lb. rocket projectiles and two 100-gallon wing-tip tanks; or four 1,000-lb. bombs with two 100-gallon wing-tip tanks; or 580 gallons of fuel in ventral, underwing and wing-tip tanks, giving an operational range of approximately 1,500 miles. An arrester hook and rocket-assisted take-off gear can also be fitted, thus enabling the aircraft to be operated from improvised airfields.

(To be continued.)

LITERATURE.

Mathematics of Relativity.

By PROFESSOR G. Y. RAINICH. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, U.S.A. [Price 3.50 dols.]; and Chapman and Hall, Limited, 37, Essex-street, London, W.C.2. [Price 28s. net.]

In some branches of applied mathematics the analytical methods have obviously no connection with the physical processes. The lunar theory is an important instance; it is inconceivable that the processes by which the moon finds out where it ought to be are in any way analogous to those by which the computer solves the same problem. It is part of the attraction of Einstein's theory that the mathematical methods correspond step by step with physical processes, so that the form, as well as the result, of the analysis is significant. The better the student's understanding of the tensor calculus, the deeper will be his insight into the structure of the world. There may be some who cherish the hope that ultimately simpler mathematical methods of dealing with these problems will be devised; but even if this hope were fulfilled the simplification would be at the expense of the requisite emphasis being placed on the physical significance of each analytical operation. Further, as Professor Rainich's treatment shows, it is easier for the beginner to grasp the essentials of relativity theory when mathematical and physical types of propositions are utilised together as required.

In the first of the five chapters of the book, the re-formulation of the principal equations of physics presents to the uninitiated new ideas of matter, based on operations with vectors and tensors. This is preparatory to the analytical geometry of four dimensions expounded in Chapter 2, where the peculiarities of such geometry are disclosed by early study of two cases: first, with all the co-ordinates real, and second, with one co-ordinate imaginary. The transition from the first to the second of these geometrical systems receives careful consideration, before attention is drawn to the question of invariance of the equations of physics. Thus, guided by the view that the formulæ ought to be expressed in terms of four dimensions, the reader is led, in Chapter 3, to the interpretation of the motion of a particle as a curve in space-time, a simple problem of special relativity. The treatment is characterised by conciseness, as is perhaps best indicated by the concluding section of this chapter, where the author shows how gravitation together with electromagnetism fit exactly into the original theory of curved space.

Chapter 4, on the general theory of curved space, thus starts with the recognition of two defects in the special theory of relativity: first, that space-time lacks structure and, second, that it does not provide an invariant treatment of gravitational phenomena. Both of these defects can be remedied by the same modification, as is shown in the various sections of this chapter dealing with the curvature of curves and surfaces, Riemann's tensor, geodesics, and the equations of physics in terms of curved space. The discussion of these topics clearly indicates that, if all the components of the Riemann tensor were required to interpret matter and electricity, it would mean that, in the absence of matter and electricity, space-time would be flat so far as internal properties were concerned. This would imply that matter acted only where it was situated. But this would be contrary to the fact that matter makes itself felt outside the region it occupies, as in the case of a gravitational field. It is therefore of interest to notice the identification of certain quantities in Chapter 4, as the result of which only part of the components of Riemann's tensor vanish where there

is no matter, so that the remaining components may be interpreted as corresponding to gravitational effects. The treatment proceeds, in the final chapter, to a short account of general relativity, involving consideration of the law of geodesics and solution of the related equations, planetary motion, the bending of a light-ray as it passes through the gravitational field of the sun, the shift of spectral lines, and other matters. The treatment as a whole gains much from the easy style in which more complicated questions are introduced in a series of steps, so as to acquaint the reader gradually with the more powerful mathematical tools; and changes in fundamental concepts and the refinements of the analytical technique are introduced only when they are needed. Further indication of the careful arrangement of the work is to be found in the numerous exercises which have been inserted at appropriate places in the text.

Welded Deck Highway Bridges.

Edited by PROFESSOR JAMES G. CLARK. The James F. Lincoln Arc Welding Foundation, Cleveland, Ohio, U.S.A. [Price 2.50 dols., outside U.S.A.; 2 dols. in U.S.A.]

THIS stimulating and original volume surveys the features of special interest which emerge from a design competition sponsored by the Lincoln Arc Welding Foundation, on the subject of "Welded Bridges of the Future, 1949 Award Program." The requirement of an all-welded design for a two-lane highway bridge, supported on two end piers 120 ft. apart, may seem prosaic to those who have been led to look for structural novelty in a Dome and a Skylon, but this simple utilitarian "program" has produced an astonishing variety of novel and ingenious, yet workmanlike, designs and design details. The immediate effect of this book on the reader of commonplace structural engineering texts is not unlike that of a Jules Verne on the reader of history and biography.

On casual inspection, some of the proposed innovations might be dismissed as reversions to discarded forms of earlier days, for it is easy enough to give classical illustrations of tubular members and triangular cross-sections and even of "New Angels," as in Fig. 78; but here there is a difference. Modern welding technique enables the tubular members to be connected by conventional parallel gussets (Figs. 18 and 19) instead of by complex intersections. The girder of triangular section is used, in several designs, the right way up, with the base in compression and the apex in tension; the new "angels," or angles, which differ but slightly from standard rolled angles, are immediately weldable into cruciform, square, channel or T sections. These few technical details are taken at random as a small sample of the many novelties introduced by the competitors, who, it is recorded, represent 24 States and the District of Columbia (in the United States) and 19 other countries. On page 17, reference is made to a design submitted by W. P. Dumbleton, of London, England, whose special innovation is the "Bobbin Plate," in which the thickness varies from 2 in. at the edges to a quarter of an inch at the centre, "giving a smooth stress flow and eliminating the common difficulty of welding thin plates to thick due to unequal heat capacity."

The editor, Professor James G. Clark, of Urbana, Illinois, has done his job well, not only in bringing to notice the principal points of novelty, ingenuity and interest, but in the general arrangement of the book. In it he first outlines the conditions and results of the award and then proceeds under the consecutive headings—structural types, floor systems, new sections, special connections and details, and quantities and costs. In preparing the text, he has made good use of the descriptive notes which each contestant was encouraged to submit "to call attention to and briefly describe any special feature of his design that he believes to have special merit." Some of the illustrations are necessarily reduced considerably from the originals, but the paper is of fine quality and the closest details are easily made out with a reading glass. An omission is the lack of an index, which might well have been added in view of the large number of competitors' names, as well as the numerous novel designations such as

"teed flange," "Y-stringer," and "pipe-adaptor-bar."

It will be interesting to note the adoption, in course of time, into structural engineering practice of some of these new designs and ingenious devices. For the moment, it appears that they exist only on paper, and the next stage may well be that of testing in structural engineering research laboratories; for, in spite of the repute, and even renown, of some of the contestants, the consulting engineer or architect, acting for a highway authority, cannot give the same weight to novelty as can the sponsors of a design competition. Whether little or much of the new work is ultimately adopted, however, the book is of direct interest to all practising structural engineers and particularly, perhaps, to teachers of structural engineering, who must encourage their pupils to look to the possibilities of the future no less than to the established practice of the present and the past.

Elementary Theory and Design of Flexural Members.

By PROFESSOR JAMISON VAWTER and PROFESSOR JAMES G. CLARK. John Wiley and Sons, Incorporated, 440, Fourth-avenue, New York 16, U.S.A. [Price 4 dols.]; and Chapman and Hall, Limited, 37, Essex-street, London, W.C.2. [Price 32s. net.]

IN spite of all the virtuosity of the mathematical professors who apply their genius to the solution of complex problems, the fact remains that building construction depends primarily on two units—the compression member and the flexural member. It must, therefore, be counted quite in order for two professors of civil engineering to devote over 200 pages to the study of a detail that is commonly wiped off the blackboard in two or, at most, three lectures in most engineering schools. At the same time, it must be admitted that this is a specialist treatise for the structural engineer who is definitely committed to a career as a practical designer; for, as H. G. Wells pointed out in an address to the Educational Section of the British Association in 1937, the hours available for education from the kindergarten to the university are very limited and must be closely rationed. In the British view of an engineering syllabus there can hardly be found time in the undergraduate stage for so broad an attack on so narrow a front. In this country, the book may perhaps make its widest appeal to teachers in technical colleges, who have the duty of instructing the fairly large body of engineering apprentices and draughtsmen incapable of assimilating the more abstruse and scientific doctrines of the higher technology and the universities. An uncommon feature of this book, which is wholly commendable from the educational point of view, is the treatment of steel and concrete, with an appendix on timber, under one cover. Apart from two references to time-yield in concrete, there is no mention of plasticity, and many potential readers in this country must now be looking to a book of this kind for a simple guide to the theories of plastic design which, for several years past, have been so widely purveyed in professional proceedings and technical periodicals.

THE INSTITUTE OF MARINE ENGINEERS.—The next examinations for admission to the Institute of Marine Engineers will be held from Monday, April 28, to Wednesday, May 21, 1952, for the graduateship, and from Monday, April 28, to Thursday, May 22, 1952, for the associate membership. The graduateship examination comprises sections A and B of the associate-membership examination. Copies of the syllabuses and further information are obtainable from the secretary of the Institute, 85, The Minories, London, E.C.3.

BROADCASTING IMPROVEMENTS IN SOUTH-EAST ENGLAND.—The first three of the 12 low-power transmitting stations which, as already announced, the British Broadcasting Corporation propose to erect to improve the reception in certain areas were brought into service on Sunday, September 16, at Ramsgate, Hastings and Brighton. The Ramsgate station is radiating the London Home Service on 202 m. (1,484 k.c.) and the Hastings and Brighton stations the West of England Home Service on 206 m. (1,457 k.c.). The stations are designed for a power of 2 kW, but a lower output is being used temporarily. The Hastings station will eventually be replaced by a permanent station near Bexhill, which will include Eastbourne in its service area.

TESTS ON CONCRETE, WITH ELECTRICAL-RESISTANCE STRAIN GAUGES.

By N. S. J. GRASSAM, B.Sc. (Eng.), Ph.D., and
DAVID FISHER, B.Sc. (Eng.), Ph.D., A.M.I.C.E.

SINCE electrical-resistance strain gauges were introduced in America some ten years ago, they have been widely used for measuring local strains on test surfaces. Most work has been carried out on machined metal surfaces, and the possibility of using them on cast surfaces appears to have attracted little attention. This is partly due to the desire amongst many experimenters to prove to sceptics that the gauges are highly scientific instruments and, as such, should only be used on ideal surfaces. However, it has been shown by the authors that results of considerable value can be obtained with the gauges on a relatively poor surface such as that of concrete. The attractive features of the gauges for use on concrete are their simplicity and smallness combined with a remarkably high sensitivity. Other advantages are that they may be fixed to a surface without materially disturbing the strain distribution and they can be used in places inaccessible to other types of strain gauges.

During the period 1946-49, a satisfactory technique was developed by the authors in the engineering laboratories of the Battersea Polytechnic, London, for using the gauges on a smooth, dry concrete surface.* To prove this new method of strain measurement, tests were made on concrete specimens subjected to simple compressive and tensile loading, in which the strains recorded electrically could be verified by mechanical instruments. The work, although incidental to a main research on the strength of concrete in combined bending and torsion, revealed several interesting features of the behaviour of plain concrete under direct loading. This article sets out the more unusual features of the strain-gauge technique and describes the preliminary tests and observations.

The concrete was of the conventional 1:2:4 loose volume mix, of rapid-hardening Portland cement (Ferrocrete), Thames Valley sand, and graded crushed Thames gravel ballast of $\frac{3}{8}$ -in. maximum size. A water-cement ratio of 0.55 and a water-total dry mix ratio of 7.5 per cent., both measured by weight, were used. In general, specimens were released from the moulds 24 hours after casting and were then water-cured for two weeks. After this, they were allowed to dry out for at least a week before the gauges were applied, in order to allow sufficient time for the glue to harden; a further week elapsed before testing.

The differing stiffnesses of the component materials in concrete make it necessary to use a gauge sufficient in length to cover a representative sample, and thus ensure that a fair measure of the average strain in the concrete will be obtained. Former-wound gauges of 200-ohm resistance, made by the British Thermostat Company, with a nominal length of 1 in. and a width of $\frac{1}{4}$ in., were used on the concrete. It was found that, for gauges nominally placed in fields of equal strain, readings within 4 per cent. could be obtained.

If faulty readings from the gauges are to be avoided, it is essential that the adhesive used for fixing the paper carrier to the test surface shall obey Hooke's Law and achieve constant physical properties as rapidly as possible. It is also desirable that it shall be easy to use. Dampness from the atmosphere, which affects some adhesives, can be prevented from entering by a suitable covering, but to seal off the moisture in the drying concrete is more difficult. In an attempt to avoid trouble from such moisture, waterproof adhesives were used. For example, melting sealing wax was tried but it set too quickly

* The full reports of investigations on concrete carried out by the authors are embodied in Ph.D. theses approved by the University of London, namely, "The Use of Electrical Strain Gauges on Concrete Specimens under Simple and Complex Loading," by N. S. J. Grassam; and "The Strength of Concrete under Combined Bending and Torsion," by David Fisher. University of London, 1950. The latter thesis was the subject of an article in *ENGINEERING*, vol. 171, page 21 (1951).

COMPRESSION TESTS ON CONCRETE.

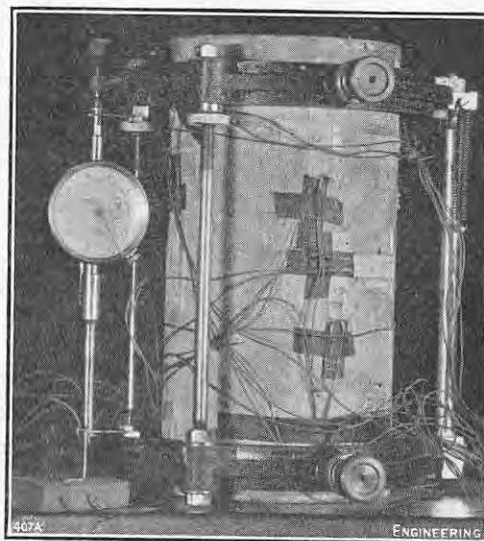
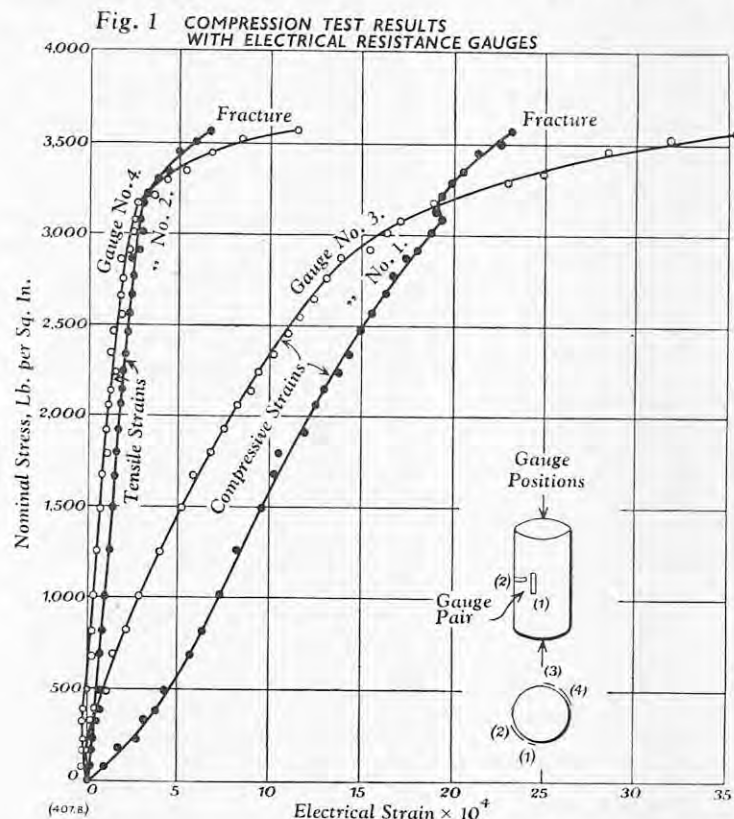
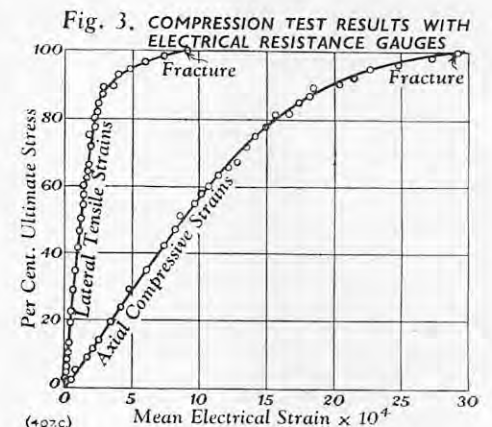


FIG. 2. COMPRESSION SPECIMEN.

for the gauge to be securely attached. As an alternative, sealing wax dissolved in methylated spirit to form a paste was used, but the spirit did not evaporate quickly enough. Shellac dissolved in methylated spirit or alcohol proved more suitable, and this paste was spread on to the concrete surface, set on fire, and the gauge pressed into the tacky substance that remained. The paste eventually became hard, and, after 14 days, gauges so fixed successfully withstood an axial compressive strain of 5×10^{-4} , corresponding to a stress of 1,500 lb. per square inch, which was 50 per cent. of the ultimate compression strength; several loading cycles were completed and consistent readings were obtained. This method of fixing the gauges was, however, very messy. It was, therefore, decided to avoid the dampness factor by allowing the concrete to dry out by air-curing for a week, and to use Durofix—a cellulose-acetate solution—which had proved very satisfactory when used on metal surfaces. However, the limited experience gained suggested that the shellac paste could be used successfully on damp concrete.

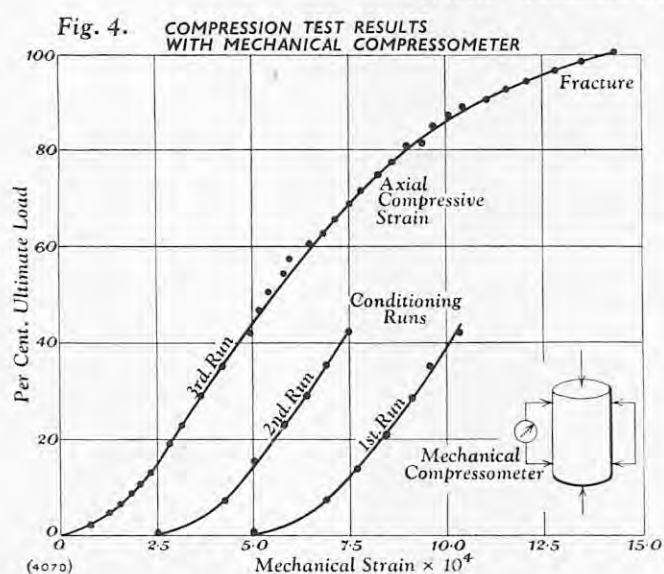
High Solids Durofix proved to be eminently satisfactory when the following method of preparation



had been developed. A reasonably smooth portion of the surface of the specimen was chosen in which there were few blow-holes. The selected area was rubbed gently with sandpaper to remove the top cement and to roughen the surface. Any blow holes in the area were filled with plaster of Paris, and when this had dried out the surface was again rubbed down with a fine sandpaper. Any grease present was removed with acetone, after which a thin coat of High Solids Durofix was applied and left to dry. Similarly, a coat of Durofix was applied to the gauge. When both these coats had hardened, a second was applied to the surface of the specimen and the gauge dipped in acetone to soften the glue film. The gauge was then pressed firmly on to the specimen, and after covering with blotting paper for protection, surplus adhesive and air-pockets were squeezed from the centre of the gauge by an outward pressure with the thumb. After pressing for about a minute, the whole was left to dry prior to soldering on the leads. Before the gauges were used, the leads were insulated and secured against an accidental pull and the whole assembly covered with a felt pad which was itself covered by a waterproof transparent tape. This adhesive was found to give consistent results after only three days, but it was the normal practice to allow at least seven days to elapse before testing.

The active gauges, and the dummy gauges used for temperature compensation, were connected to a multi-channel strain-gauge set having a modified Wheatstone-bridge circuit. This circuit used the

COMPRESSION TESTS ON CONCRETE.

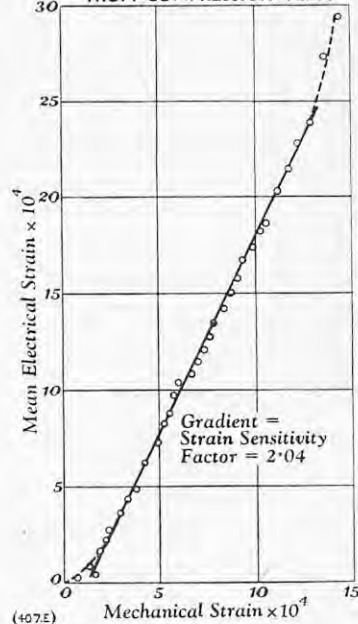


same artifices for eliminating unwanted resistance changes as were used by H. Tomlinson* in 1877 when making original researches on the effect of strain on the conductivity of wires. High-ratio arms were used in the circuit (10,000 ohms with 200-ohm gauges), as this enabled the fractional change in the active gauge resistance to be measured easily without using high-accuracy resistances. The loss in sensitivity incurred in the circuit by this arrangement was offset by using a highly sensitive moving-coil galvanometer and by working with higher gauge currents (15 to 20 milliamperes) than is customary. The long leads from the set to the gauges and all the switch contacts were in series with the high resistances so that variations in these would not affect the balance of the circuit.

Zero drift was minimised by two methods. First, in order to allow the circuit to reach thermal equilibrium before it was used for measurements, two resistances were substituted for the active and dummy gauges and were switched into the circuit for about an hour before the test. During a test the gauges were switched into the circuit only for the two or three seconds required to take a reading. Secondly, as far as was possible with the discrimination available on the resistance box, a null method was used as this eliminated changes in the resistance of the galvanometer. Also, the gauges were well covered to prevent resistance changes due to a varying moisture content causing the gauge paper carrier to act as a variable shunt resistance to the gauge wire. These precautions were such that zero drift was not more than that corresponding to a strain of 1×10^{-5} , even with strains as high as 150×10^{-5} . It was considered that it was possible to detect a resistance change of two parts in a million, equivalent to a strain of about 1×10^{-6} .

In the early tests with the strain gauges it was found that, if readings were taken on the first cycle of loading, even to a load well below the ultimate, there was a scatter of observations and a zero shift which could not be attributed to permanent set. With successive cycles of loading, the readings became more regular and the zero drift smaller, until, after several applications, the effects became negligible. It is probable that virgin concrete specimens require a few proof loadings before achieving a "state of ease," and also that the gauges themselves require "conditioning" before working regularly. This phenomenon has also been observed in gauges used on metal specimens, by Gibbons† in America, and by E. R. Jones‡ in this country.

Fig. 5. STRAIN SENSITIVITY OF GAUGES FROM COMPRESSION TEST.



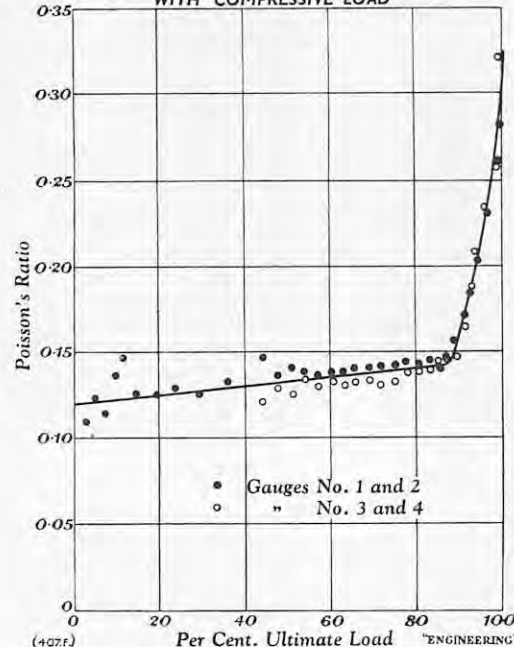
It became a normal practice therefore to "exercise" the gauges before taking measurements for record purposes.

Compression Tests.—A cylindrical specimen, 10 in. high by 5 in. in diameter, was used for the compression test: it had been made in a machined steel mould fitted with release arrangements. Four strain gauges were fitted to the specimen by the method already described, and were arranged in two pairs arranged diametrically at the mid-height of the cylinder. In each pair, one gauge worked parallel to, and the other transversely to, the axis of the specimen, as shown in the drawing inset in Fig. 1, opposite. Four similar gauges were affixed to a second cylinder to act as dummies and were kept as close to the working specimen as was convenient, so that both were subjected to the same ambient conditions. The specimen was tested in a 100,000-lb. Riehle vertical-screw compound-lever testing machine reading to ± 50 lb. Testing was done between two substantial machine-faced steel platens. To assist in obtaining a uniform loading pressure, a single sheet of soft rubber, $\frac{1}{8}$ -in. thick, was placed above and below the concrete specimen, which was capped top and bottom by a $\frac{1}{4}$ -in. thick cement-sand mortar.

The test was carried out on a specimen 45 days old which had been air-cured for the last 26 days after an earlier period of water-curing. Two preliminary loading runs were made to about 45 per cent. of the ultimate load, in order to condition the gauges and the concrete specimen. The third and final loading was by 33 load increments until fracture occurred at a nominal stress of 3,560 lb. per square inch. Strain observations were made over the 1-in. lengths of the electrical gauges, and also over the 8-in. gauge length of a mechanical compressometer. The latter worked on the same principle as the Ewing extensometer, with a 2:1 lever magnification; the instrument had been specially made for this type of specimen. The clamping screws pivoted on the heads of four brass pegs which were rigidly fixed into the specimen. A typical specimen with electrical gauges and compressometer in position is shown in Fig. 2, opposite. The readings obtained on the electrical gauges are shown graphically in Fig. 1.

Assuming that plane sections before loading remain plane after loading, the effect of eccentricity can be eliminated by taking the mean of the readings obtained from the similarly-aligned electrical gauges. The stress-electrical strain curves so obtained for both the axial and lateral gauges are plotted in Fig. 3, and the stress-strain curve obtained from the mechanical compressometer is shown in Fig. 4. The ratio of the electrical strain $\frac{dR}{R}$, to the mechanical strain, gives the strain-sensitivity factor for

Fig. 6. VARIATION OF POISSON'S RATIO WITH COMPRESSIVE LOAD



the gauges as 2.04, as shown in Fig. 5, herewith. Divergence from this figure at very low and very high loads was due to local strains. The figure compares favourably with 2.08 obtained with other gauges from the same batch on a concrete tension specimen, and 2.10 obtained on a steel tension specimen.

The shape of the compression stress-strain curve is normal for such a concrete so loaded, showing a slight stiffening with the load to about 20 per cent. of the ultimate, followed by a gradual softening until fracture occurs. The curve obtained approximates quite closely to a parabola with its vertex at the ultimate point. Over the load range from zero to 50 per cent. of the ultimate, the secant value of Young's Modulus is 4.3×10^6 lb. per square inch. At 87 per cent. of the ultimate load the beginning of the final breakdown of the concrete is clearly shown by the abrupt increase in the readings of the transverse gauges. Fracture was by a hoop-tension failure which caused axial cracks in the specimen.

The variation in the ratio of the lateral to the longitudinal strains with the load is shown in Fig. 6, on this page, for each pair of gauges. It will be seen that the ratio increases linearly with load from 0.120 to 0.142 over the load range zero to 87 per cent. of the ultimate. Above this load the ratio increases rapidly to 0.32 just before the fracture; this was most probably due to a re-distribution of stress caused by a local crack in the material. The agreement between the two sets of gauges was perfect during the last stage, showing that the eccentricity of loading had been reduced to zero. It is to be noted, however, that the value of Poisson's ratio is affected by the end constraint, offered by the loading platens, that gives rise to a barrelling effect, but it may be that the specimen was sufficiently long for the effect of end constraint to be negligible at the mid-height where the gauges were situated. The test was completed in 90 minutes, so that the average time for each load increment was 3 minutes. Self-release of load due to creep of the concrete was not noticeable under 70 per cent. of the ultimate load, and was only about 2 per cent. of the load above 90 per cent. of the ultimate.

Tension Tests.—Tensile tests on concrete by the authors, as well as by other experimenters, have shown large variations of the order of ± 20 per cent. in the mean value obtained for the ultimate strength of a particular mix. It is generally accepted that eccentricity of loading accounts for a large part of this discrepancy, and the following test was made to investigate this factor. The test enabled a detailed stress-strain curve for a concrete in tension to be obtained, together with its ultimate capacity for tensile strain. The specimen used was cast in a

* "On the Increase in Resistance to the Passage of an Electric Current produced on Certain Wires by Stretching," by H. Tomlinson. *Proc. Royal Soc.*, vol. XXVI, June, 1877.

† "Stability of Strain Gauges," *S.R.4 News Letter* (1945). Baldwin-Southwark Division, Baldwin Locomotive Company, 940, Simpson-street, Eddystone 42, Pennsylvania, U.S.A.

‡ "Some Physical Characteristics of Wire Resistance Strain Gauges,"—*Measurement of Stress and Strain in Solids*. Inst. of Physics (1948).

TENSION TESTS ON CONCRETE.

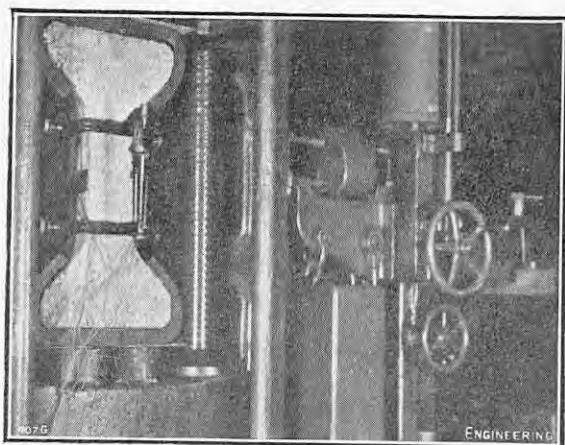


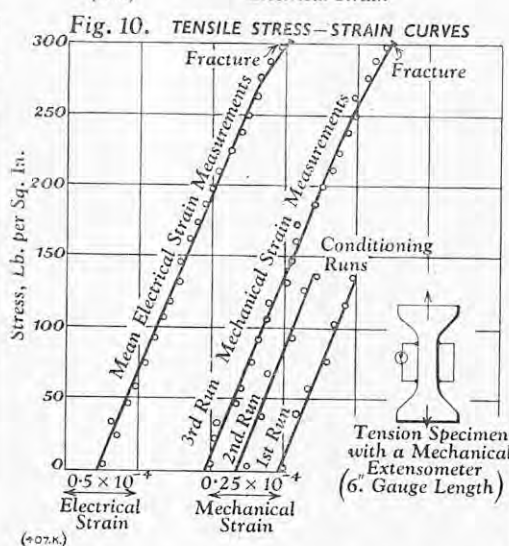
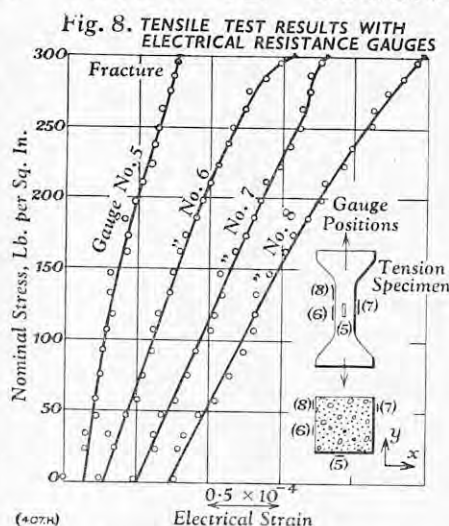
FIG. 7. TENSION SPECIMEN.

collapsible wooden mould and was of a flat dumb-bell shape with an effective cross-section of 3 in. by 3 in. over a parallel length of 6 in.; it is illustrated in Fig. 7, herewith. It was completely released 12 hours after casting to avoid cracking due to the shrinkage being resisted by the shoulders of the mould.

Four strain gauges were fixed to suitably smooth portions of the specimen in the positions shown in Fig. 8, and dummy gauges were fixed to a cylindrical concrete compression specimen. A mechanical extensometer designed by Mr. V. C. Davies* was also used in the test. It had a gauge length of 6 in. and worked on the Ewing principle with further magnification obtained from a bell-crank arm which tilted a small concave mirror. Observations were made by viewing a scale in the mirror through a telescope. It is claimed by the designer that errors due to friction and backlash correspond to an extension much less than 5×10^{-6} in. The screws which carried the extensometer pivoted against four steel bars strapped round the specimen in pairs at the appropriate gauge length, as shown in Fig. 9, on this page. In this way, no damage, which might cause a fracture, was done to the concrete. The test was made in the Riehle machine already described, the machine being fitted with special claw grips mounted in spherical seatings. By using a half-weight jockey on the weigh-beam, it was possible to measure to about ± 30 lb. In order to obtain a uniform pressure between the specimen and the claw grips, soft rubber pads, $\frac{1}{8}$ in. thick, were inserted between the loading faces. The arrangement is shown in Fig. 7.

The specimen, which was made from the same batch of concrete as was used for the compression test, was 47 days old when tested, having been air-cured for the last 26 days. In order to exercise the electrical gauges, and to ensure that the extensometer was working satisfactorily, two preliminary loading runs were made to 45 per cent. of the ultimate load. During these runs, observations were recorded only from the mechanical instrument. The third and final loading was by 23 load increments until fracture occurred at a nominal stress of 301 lb. per square inch. During this test, strain measurements were taken on the four electrical gauges of 1-in. length, and on the mechanical extensometer over a 6-in. length. The readings of the gauges are shown graphically in Fig. 8.

In order to eliminate the effects of eccentricity of loading, the mean electrical strain $\frac{\Delta R}{R}$ was estimated on the assumption that plane sections remain plane, and is shown plotted against stress in Fig. 10. The curve giving the strain as measured by the extensometer is plotted against stress on the same graph for comparison. The readings of the four gauges were not exactly compatible with Navier's hypothesis, but it will be noted that, whereas the gauges Nos. 5, 6 and 7 were all arranged at approxi-



mately the same cross-section (Fig. 8), the fourth gauge, No. 8, was situated close to a shoulder of the specimen where stress concentrations may be expected. For this reason, the eccentricity of loading was calculated from the readings of gauges Nos. 5, 6 and 7, which made the readings on gauge No. 8 a few per cent. higher than that required for compatibility. The estimated eccentricity of loading up to 45 per cent. of the ultimate was $x = 0.06$ in., $y = 0.29$ in., which is such as to cause a maximum stress of 1.7 times the average—a very large factor indeed. Thereafter, the eccentricity remained almost constant, until the final period of breakdown began at 90 per cent. of the ultimate load. Just prior to fracture the eccentricity was $x = 0.08$ in., $y = 0.24$ in., so that the maximum stress was 1.64 times the average. Fracture may be inferred from the gauge readings to have started on the flank to which gauge No. 7 was fixed.

The agreement obtained between the average strain as measured electrically and mechanically was very satisfactory, as shown in Fig. 11. The strain sensitivity factor for the gauges was 2.08, which agreed very well with the value of 2.10 obtained with similar gauges on a steel tension specimen.

Young's Modulus for the linear part of the stress-strain curve, up to 45 per cent. of the ultimate, was 5.55×10^6 lb. per square inch, and the whole curve has the generally accepted form. The strain capacity of the concrete, estimated from the strain distribution just prior to failure, was 90×10^{-6} . The test was completed in $1\frac{1}{2}$ hours and creep under load was not noticeable.

The eccentricity of loading in this test was excessively high, but in a second test of the same pattern, in which more care was taken in setting the specimen into the loading shackles, an eccentricity of $x = 0.02$ in., $y = 0.08$ in., was obtained, which corresponds with a maximum stress of 1.2 times the average. However, the first test showed that the gauges would respond consistently to the very small tensile strains experienced and that they could

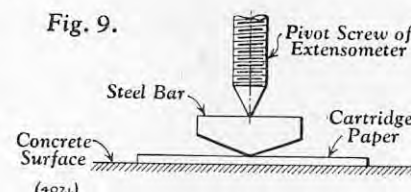
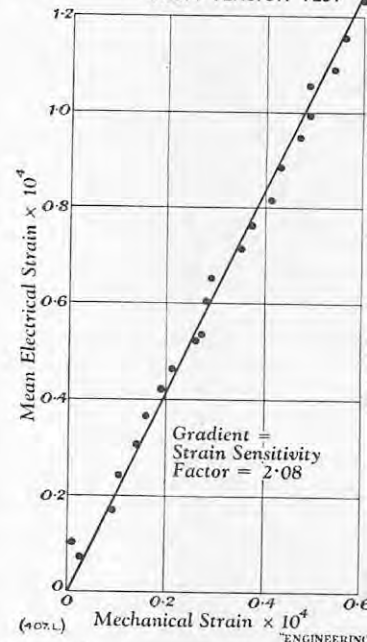


Fig. 11. STRAIN SENSITIVITY OF GAUGES FROM TENSION TEST



be used to gain a measure of the eccentricity of loading, and, furthermore, that the arrangement used for these tensile tests needed modifying to reduce the chance of eccentricity.

Thus, in conclusion, electrical-resistance strain gauges of 1-in. length can be used successfully on concrete made with an aggregate of $\frac{3}{8}$ -in. maximum size, and they will have a strain sensitivity factor which is about the same as that obtained on steel specimens. It was found that strains of 1×10^{-6} could be detected quite easily, which is small enough for most practical purposes as it corresponds to about 1 per cent. of the ultimate tensile-strain capacity of concrete. The consistency of the readings as shown by the smooth curves on the graphs was very good indeed and leaves little to be desired. In particular, the compression test showed that Poisson's ratio for a concrete may increase with load by as much as 18 per cent. before failure occurs. The tests show that the amount of eccentricity of loading may be measured with strain gauges. Finally, the investigations have justified the use of electrical-resistance strain gauges on a dry concrete, and have enabled the strain characteristics to be measured more conveniently than has been possible hitherto with mechanical instruments. This method of strain measurement will allow experiments on concrete specimens and structures to be made which, by checking the strain distribution, will enable the full value of the results of ultimate strength tests to be determined.

GERMAN SCIENTIFIC AND TECHNICAL BOOKS.—Messrs. Lange, Maxwell and Springer, Ltd., have recently opened new showrooms at 188, Shaftesbury-avenue, London, W.C.2. They are distributors for several well-known German publishers of scientific and technical books: they undertake also to search for out-of-print publications for their clients.

PRICE OF COPPER.—The Ministry of Materials announce that from September 13 the price of electrolytic copper, delivered to customers' works, has been reduced by 77. to 227l. per long ton. The reduction has been made possible by the Ministry's decision not to buy copper for the time being at prices exceeding the American f.a.s. export price as quoted in the *Engineering and Mining Journal*. Corresponding adjustments in the controlled maximum prices of scrap and unwrought brass have been made by the Minister of Supply; full details are given in the "Non-Ferrous Metals Prices (No. 7) Order S.I. 1951 No. 1650 (H.M. Stationery Office).

* "Extensometer for Determining Young's Modulus for Concrete," by V. C. Davies. *ENGINEERING*, vol. 125, page 131 (1928).

THE ANGLO-AMERICAN AERONAUTICAL CONFERENCE.

(Concluded from page 342.)

WE conclude our summary of some of the papers presented at the Anglo-American Aeronautical Conference, held at Brighton from September 3 to 7, with three of the papers on aerodynamic subjects.

DRAW REDUCTION BY SUCTION.

Two papers were presented on boundary-layer control by suction. The first of these was given on Tuesday, September 4, by Mr. T. S. Keeble on the "Development in Australia of a Thick Suction Wing." The use of the thick suction aerofoil, said Mr. Keeble, had been suggested for comparatively slow but highly efficient all-wing cargo- and passenger-transport aircraft. The suction aerofoil was shaped so as to have a rising velocity over a great portion of its surface so that the major portion of the boundary layer remained laminar; towards the rear of the aerofoil the boundary layer was sucked away at suitably-placed slots, which eliminated the adverse pressure gradient on the rear of the aerofoil. The Australian experiments had been carried out by the Aeronautical Research Laboratories on a de Havilland military glider fitted with a cambered suction wing, the aerofoil section being chosen to have safe characteristics in the event of a suction failure. The forms for the suction slots were determined by wind-tunnel tests; a three-slot arrangement was chosen.

In the full-scale glider, the suction plant was accommodated in the crew bay behind a soundproof bulkhead. Air from the wing passed through a centrifugal fan, discharged into the fuselage and thence through gilled exits to the airstream. The original wing plan-form and conventional ailerons were adopted. The slots were of constant width spanwise and measured 0.09 in., 0.05 in. and 0.05 in., respectively, for front, middle and rear slots; they led into a common suction duct. A 30-instrument photographic observer was installed in the fuselage, and about 150 static-pressure vents were provided in the starboard wing and connected to a manifold box near the photographic observer. Flight tests had shown that the glider could be flown, with or without suction, sufficiently well for an experienced pilot to approach and land safely, but insufficient suction caused lateral instability in flight. This was due to a local separation just ahead of the front slot. The poor handling qualities at partial suction, however, could be immediately improved by using full suction or no suction. The aircraft behaved well when the flow was properly stabilised. Full-scale lift, drag, and pitching-moment measurements agreed well with wind-tunnel tests, but the pressure losses in the suction system of the glider were higher than expected.

A design study of an all-wing medium-range transport aircraft, for 72 passengers, with a suction wing had been made. The projected aircraft had a sharply swept-back wing and was propelled by two 2,900-h.p. gas turbines driving pusher propellers. Suction was supplied by a 1,500-h.p. engine. The estimated gross weight was 70,000 lb. Comparing it with a conventional aeroplane designed for the same specific range, said Mr. Keeble, the all-wing aircraft could carry a 40-per cent. greater passenger weight 40 per cent. faster. It was proposed to construct and test in flight a half-scale model glider of the air-liner project.

On Wednesday afternoon, September 5, Sir B. Melville Jones and Squadron Leader T. R. Head presented a paper on "The Reduction of Drag by Distributed Suction." Any substantial reduction in drag on the modern aircraft, the paper stated, could only be achieved by maintaining a laminar boundary layer over large areas of the aeroplane's surface. One method was to make the aircraft surface porous and to suck air through it. They then described recent experiments carried out on porous aerofoils at the University of Cambridge, which, they said, had shown that it was possible to maintain laminar flow over practically the entire surface of a smooth porous surface, using a suction velocity no greater than that required to maintain

the stability of the layer. The velocity distributions in the laminar boundary layer thus produced agreed well with those predicted theoretically. In order to maintain the laminar flow, however, the surface near the front of the body would have to be smooth and free from small obstructions, such as flies. Farther back, the surface could probably be appreciably rougher without causing transition, but this would have to be determined by tests at the appropriate Reynolds number.

There appeared to be no fundamental reason why laminar flow could not be maintained by distributed suction applied over almost the whole surface of the aeroplane. If transition could not be prevented at discontinuities, such as doors and windows, laminar flow could be restored at these points by concentrated suction. It would be possible thus to achieve a profile-drag coefficient about one-tenth of that of the Comet—which had one of the lowest drag coefficients yet realised—at the same Reynolds number appropriate to the cruising speed of the Comet at 40,000 ft.

TRANSONIC RESEARCH.

At the final technical session on Friday afternoon, September 7, Mr. John Stack described "Experimental Methods for Transonic Research" that had been developed by the American National Advisory Committee for Aeronautics (N.A.C.A.). Experiments at Mach numbers of 1, he said, were impossible in the conventional wind tunnel, on account of choking. Free-falling bodies with a density of 300 lb. per cubic foot and a fineness ratio of 12 to 1 were dropped from heights exceeding 30,000 ft.; they reached a maximum Mach number of about 1.3. They were tracked by a combined radar and optical unit. The body contained a longitudinal accelerometer; the wing was mounted on a balance within the body, and a tail boom contained the tail-drag balance. The relative motion between the spring-mounted sensitive elements and the body regulated variable inductances controlling the oscillator frequencies in the telemetering system. Ground-launched rocket-propelled models were used for studying control effectiveness, drag, and longitudinal stability and control, below 15,000 ft.; the Reynolds number was, therefore, high. Their velocity-time records were obtained by continuous-wave Doppler radar, at the launching site. The model for stability studies required much internal instrumentation, and so was propelled by a booster rocket.

In "wing-flow" technique, a model wing, aircraft, or missile was placed in the supersonic-flow region on the wing of a subsonic aircraft flying above its critical Mach number: the main-wing surface usually had to be modified to give satisfactory results with this technique. A similar method had been applied in wind-tunnels capable of a Mach number of the order of 0.9. The model was mounted on a "bump" on the tunnel floor or wall, in a region of local supersonic flow; the bump shape had to be carefully determined. These methods had the disadvantage of a low Reynolds number.

In the transonic research tunnel at Langley Aeronautical Laboratory, the model was mounted on the rim of a 5-ft. diameter rotor, driven at high speed. The model travelled in an annular space between an inner and outer housing. An inducer fan, located a considerable distance downstream, removed the wake of the model from the plane of rotation, and provided for changing the incidence of the model. Boundary-layer control was provided on the walls of the annular space. To reduce the choking range in the Langley 8-ft. high-speed wind tunnel, symmetrical model supports had been developed, and studies of supersonic nozzles had been carried out. It had also been established that open-throated or semi-open wind tunnels would give a significant reduction in the choked range.

Full-scale flight tests had been carried out very successfully by the U.S. Air Force, Navy, aircraft manufacturers, and the N.A.C.A. in co-operation. Fears of unknown phenomena in the transonic range had been dispelled. Although extensive research had not yet been carried out on correlating the various methods, it appeared that, with the exception of the "bump" technique, reasonably good agreement had been shown, in spite of large differences in Reynolds number.

ENGINEERING, MARINE AND WELDING EXHIBITION AT OLYMPIA.

(Continued from page 329.)

THE organisers of the exhibition at Olympia, which closed last week, on Thursday, September 13, report that more genuine inquiries and definite orders than ever before were handled by the 500 exhibitors. Seventy-five per cent. of those who attended the exhibition were directly connected with the engineering industry, and buyers came from many countries overseas. There were also numerous works parties and students who visited Olympia. Engine makers reported slightly fewer inquiries from abroad, but there was a large increase in the demand for industrial generating sets, as the result of the need to safeguard the supply of power to factories.

The products of Messrs. Slack and Parr, Limited, Kegworth, near Derby, which were on view at Olympia, included multiple drilling heads of both geared and gearless types, metering pumps and fluid-flow continuous mixing units for the rayon and chemical industries, and variable-pitch reversing marine propellers for small towing and fishing vessels powered by internal-combustion engines. Among the latter, they were showing for the first time a three-bladed propeller with a 15-in. diameter hub capable of carrying blades from 45 in. to 60 in. in diameter. The maximum blade-angle range is 65 deg., and the maximum speed is 400 r.p.m. The propeller can absorb a maximum torque of about 3,500 lb.-ft. The pitch is manually controlled and is installed at the steering position. The entire hub assembly is of non-ferrous material.

The detachable propeller blades are bolted to circular crank-rings; the bending loads from the base of each blade are transferred to the blade-bearing housing, attached to the hub, by two thrust-bearing plates in an annulus formed by the blade and the crank-ring. Each crank-ring has a pin formed on its lower face, offset from the hub axis. The pins carry sliding blocks which transmit the movements of the pitch-changing rod to the pins, causing the blades to rotate about their vertical axes. Each blade root is sealed against the entry of water and oil by a synthetic-rubber seal. The tail-shaft, on which the propeller hub is mounted, is tubular, and houses the pitch-changing rod, which is also hollow and forms a conduit for lubricating oil.

The operating gear is built integrally with the helical reduction gearing, which is available in any ratio between 3 to 1 and 1.5 to 1. The gears run in a water-cooled oil bath. The pinion is carried on a solid shaft running in roller bearings. The gearwheel runs in two steep-angle taper-roller bearings which take the propeller thrust and the reaction from the operating jack. The latter, at the forward end of the gearbox casing, is on the same axis as the propeller shafting. The pitch-changing rod, which passes through the hollow gearwheel shaft, projects into the operating-jack housing, which is screwed, and works in a fixed nut. The housing is rotated through a splined sleeve and wormwheel drive; the axial motion of the housing thus obtained is transmitted to the pitch-changing rod through a pair of taper-roller bearings. The control shaft, which transmits, through bevel gearing, the movements of the control handwheel to the wormwheel drive, is provided with universal joints and, by the use of bevel gears may be installed in any part of the ship.

The exhibits on the stand of Messrs. Mawdsley's, Limited, Dursley, Gloucestershire, included a range of their fan-cooled alternating-current motors, a 240-h.p. direct-current motor with a four-to-one speed range, a capstan motor with a disc brake and a multi-purpose direct-current generator. Special mention may be made of the firm's compensated alternator, two of which, with an output of 10 kVA, were shown operating on a load which included fluorescent lamps. One of these machines was also shown testing a 9-h.p. squirrel-cage induction motor against a torque-reaction electro-dynamometer which was equipped with Desynn remote indication, thus enabling the starting and load charac-

teristics to be obtained. As regard the design of this machine, as is well known, the de-magnetising magnetomotive force produced by the load current in an alternator causes a voltage droop. In a rotating-armature machine this magnetomotive force is stationary and at unity power factor is at nearly 90 electrical degrees to the main flux. As the power factor becomes more lagging the magnetomotive force moves from its original position until at zero power factor it directly opposes the flux generating it, thus causing a drop in the output voltage. This drop is normally corrected by adjusting the field current. In the alternator exhibited, however, compensation is effected by providing a second direct-current voltage which is connected in series with the excitation voltage and thus automatically increases the field current in relation to any increase in load current or any decrease in power factor. The ratio of this correction is such that the alternating-current output voltage is maintained virtually constant irrespective of the system load or power factor.

The direct current necessary for exciting the compensated alternator is generated by a winding which is placed in the same slots as the alternating-current winding and is connected to a commutator. Automatic regulation is obtained from a second similar but very short armature, which is mounted on the main shaft and surrounded by an unwound and unslotted stator. The main alternating-current winding is carried through this second armature and, when the machine is on load, produces an independent secondary field in the unwound stator. The magnitude of this field varies with the load current and its position moves through 90 deg. according to the value of the power factor. The small direct-current winding is also extended through the second armature, but is offset by one pole pitch. As it cuts the stationary field this part of the winding generates an additional direct-current voltage, the value of which is proportional to that of the load current and to the position of the flux in the unwound stator relative to the fixed brushes. The actual value of this additional voltage is chosen so that the increase in the field current exactly neutralises the demagnetising effect of the load current in the main armature winding.

The Westminster Engineering Company, Limited, Victoria-road, Willesden Junction, London, N.W.10, were showing their scaling machines for cleaning around the edges of plates of an uneven thickness, so that the resulting surfaces can be resistance-welded without further preparation. These machines consist of either four or two grinding wheels which are separately driven by 1-h.p. enclosed three-phase squirrel-cage motors through duplex chains, so that there is no slip. The wheels, which are carried on hard steel spindles running in ball bearings, therefore always run at their best speed. Adjustment of the wheels in a floating condition is effected by suspension springs. A bridge spring is then regulated to give about 12 lb. to 15 lb. pressure between their faces, which are held just clear of one another by an adjustable stop, thus enabling both thick and thin plates to be scaled. The scaling speed is about 40 ft. to 45 ft. per minute and one pass is usually sufficient to scale the edges of well-annealed plates.

The standard four-wheel machine is designed to accommodate plates up to 6 ft. 3 in. wide, the scaling heads and supporting trolley being adjustable for that purpose. Four surfaces can be scaled simultaneously on two edges of the plates up to a length of 3 ft. 4 in. The trolley is hand operated and runs on machined rails. It is provided with machined faces on which the plates are supported, the edges of the latter being held close to the grinding wheels. Two balanced pressure clamps, which are operated by a single lever, secure the plate in position, while it is maintained at 90 deg. to the trolley track by adjustable thrust stops. In the single-ended scaling machine, the plate is fed through the two grinding wheels against two roller thrust stops and guided through an adjustable fence. Any length can be scaled and the overhanging edge of large and heavy plates can be supported on a separate metal-faced table. A third type of machine is fitted with a rotating table to carry plate discs. This table, which is driven by a motor, is adjustable in

the direction of the grinding wheels, so that discs smaller than the maximum diameter can be supported. The discs are held in contact with the driving table by a screw-operated spring-controlled clamp, and are centred by three grooved rollers carried on ball bearings. One of these rollers is supported on a pivoted arm, so that the discs can be rapidly mounted and withdrawn. Scaling can be effected either on the periphery of the disc or at some distance from it.

Three pump impellers were included in the exhibits of Gwynnes Pumps, Limited, 62-64, Chancery-lane, Hammersmith, London, W.6. These were intended to illustrate the difference between axial-flow, mixed-flow and centrifugal designs. The axial-flow impeller eventually will be used in a 24-in. pump driven by an 85-h.p. Diesel engine. The pump will discharge 10,000 gallons a minute against a total head of 15 ft. and is intended for use in connection with an irrigation scheme in Gambia. The mixed-flow impeller is for a 36-in. pump driven by a 300-h.p. electric motor and is designed to discharge 26,000 gallons of sea-water per minute against a total head of 27 ft. The centrifugal impeller is one of eight being supplied in 45-in. vertical-spindle pumps to the British Electricity Authority for use at the Uskmouth power station, each of which is capable of supplying 45,000 gallons of water per minute against a total head of 60 ft. They will be driven by 1,100-h.p. electric motors with grid-controlled rectifiers to give speed variation.

Gwynnes Pumps, Limited, were also showing a 2½-in. 12-stage pump which they have manufactured for British Railways, Southern Region, for the hydraulic-pumping plant at Deptford wharf. This unit, which is illustrated in Fig. 85, Plate XXIV, is of the split-casing horizontal type and is designed for a working pressure of 750 lb. per square inch. The pump casing is of cast steel and the shaft, which is fitted with gun-metal impellers, is supported by ring-oiled bearings located in cast-iron pedestals. A hydraulic plate-balance system is incorporated, but there is also a Michell thrust bearing at one end to take the axial thrust until the balance gear takes over. The pump will be driven by an electric motor through a speed-increasing gearbox, and at 2,980 r.p.m. will deliver 150 gallons per minute against the full head, the motor speed corresponding to this pump speed being 1,465 r.p.m. The equipment installed on the pump includes special air cocks designed to withstand the full pressure and a complete series of drain cocks coupled together so that they can be opened and closed from a central point.

The exhibits on the stand of Messrs. Russell Newbery and Company, Limited, Dagenham, Essex, included the new horizontal single-cylinder Diesel engine illustrated in Fig. 86, Plate XXIV. This machine is of exceptionally compact design, as the length, height and width are only 31 in., 24½ in. and 19 in., respectively; even so, it develops a maximum of 7 brake horse-power at 1,500 r.p.m. on the 12-hour rating. It is of the four-cycle type and has been designed so that it can be started easily by hand from cold without recourse to outside aids. The construction of the unit is quite straightforward, the crankcase and cylinder block being formed by a single iron casting, the lower portion of which incorporates the oil sump. It is fitted with a wet-type renewable liner and has a large inspection door to give easy access to the running gear. The cylinder head, also an iron casting, incorporates the firm's own design of combustion chamber in which the exhaust and inlet valves are arranged horizontally and fitted in such a way that they can be removed for servicing without dismantling the cylinder head. Push rods and rocking levers are used to actuate the valves, the complete valve gear being totally enclosed. An aluminium-alloy piston provided with three pressure and two oil-control rings is fitted and is joined to the crankshaft by an H-section steel connecting rod; to facilitate removal of the rod through the cylinder bore, the bottom end is split at an angle. Pressure lubrication is employed throughout, and to ensure an adequate supply reaching the little-end bearing the connecting rod is drilled centrally. Governing gear is provided and this controls the speed of the engine to the

requirements of B.S.S. 649-1935, suitable adjustment being incorporated to permit a variation up or down of 10 per cent. from the set speed. The gears driving the camshaft are of sufficient strength to permit the half-speed shaft to be used for power transmission when the reduced speed is required. Starting is by hand, a decompressing device being provided, and other equipment supplied as standard includes oil and air filters, an efficient silencer and twin flywheels.

Messrs. Russell Newbery were also showing a selection of their standard units. These included a six-cylinder Diesel engine arranged for ship propulsion; a four-cylinder Diesel marine auxiliary-generating set and an emergency Diesel-driven fire-pump. The propulsion engine, which is illustrated in Fig. 87, Plate XXIV, is known as the EM6 and is capable of developing 120 brake horse-power at 1,200 r.p.m. on the 12-hour rating, the bore and stroke being 5½ in. and 7¼ in., respectively. As will be seen from the illustration, the unit is of straightforward design. Like the engine just described, the inlet and exhaust valves are disposed horizontally and may be removed without disturbing the head or associated piping. The crankcase is an iron casting and is provided with long through-bolts and removable steel supporting columns located adjacent to each bearing and extending through to the cylinder block. This form of construction relieves the case from imposed stresses and enables the crankshaft, pistons and connecting rods to be withdrawn from one side of the engine without dismantling the cylinder heads, manifolds, water piping, etc., a valuable feature where there is limited headroom. Aluminium-alloy pistons are used and they are joined to the crankshaft by drop-forged connecting rods, circular in cross-section and drilled through the centre for top-end lubrication. Pressure lubrication is, of course, employed throughout, the system incorporating an oil cooler, together with primary and secondary filters. Standard equipment includes a fuel-lift pump, air filter, exhaust silencer, fuel-service tank and the normal range of gauges, etc. The unit exhibited at Olympia was fitted with a Russell Newbery fluid-operated reverse-reduction gear, fresh-water cooling and a clutch-operated power take-off. Separate clutches are used to select ahead and astern gear, the former using helical reduction gears and the latter multiple chains and sprockets. The design is such that the ahead clutch must be disengaged before the astern clutch can be engaged and, as oil is used as the actuating medium, engagement is remarkably smooth. The use of oil-actuated clutches also enables remote control to be employed.

The auxiliary Diesel generating set is illustrated in Fig. 88, Plate XXIV. It comprises a Russell Newbery type-D4 Diesel engine coupled directly to a 20-kW generator at one end, and then through a clutch to a 2-in. self-priming pump and an air compressor. In general, the Diesel engine is similar to that just described, having the same type of cylinder head with easily-removable valves. It differs, of course, in detail, the connecting rods, for example, being machined from H-section steel stampings. The bore and stroke are 4½ in. and 6 in., respectively, and the output is 36 brake horse-power at 1,000 r.p.m., this being the 12-hour rating. Pressure lubrication is employed throughout and the system incorporates a cooler in addition to the usual primary and secondary filters. Cooling is by sea-water or fresh water, a radiator or heat exchanger being employed in the latter case.

The emergency fire pump is illustrated in Fig. 89, Plate XXIV. It is driven by a Russell Newbery type-RD1 Diesel engine, a single-cylinder unit which develops 11 brake horse-power at 1,200 r.p.m. In common with other engines of this make, it has horizontal inlet and exhaust valves, a wet-type cylinder liner and forced lubrication, the design being such that it can be easily started by hand when cold. The engine is coupled directly to a single-stage centrifugal pump arranged for self-priming and capable of dealing with a suction lift of 25 ft. Normally, the casing is of cast iron, the impeller of gun-metal and the spindle of stainless steel, but a gun-metal casing can be supplied if required. The impeller is overhung, the spindle being supported by two widely-spaced ball bearings provided with

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(For Description, see Page 360.)

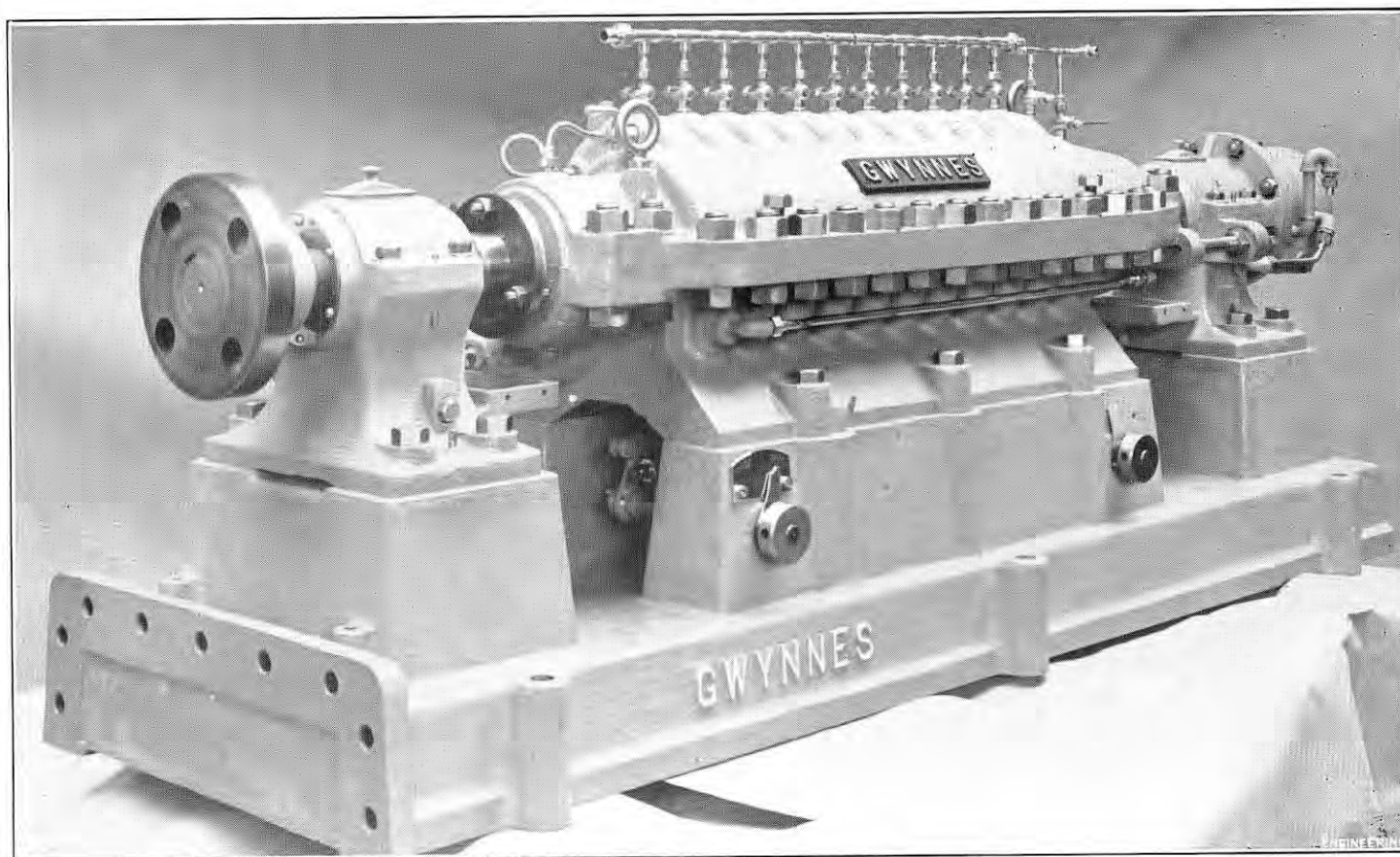


FIG. 85. 12-STAGE PUMP; GWYNNE'S PUMPS, LIMITED.

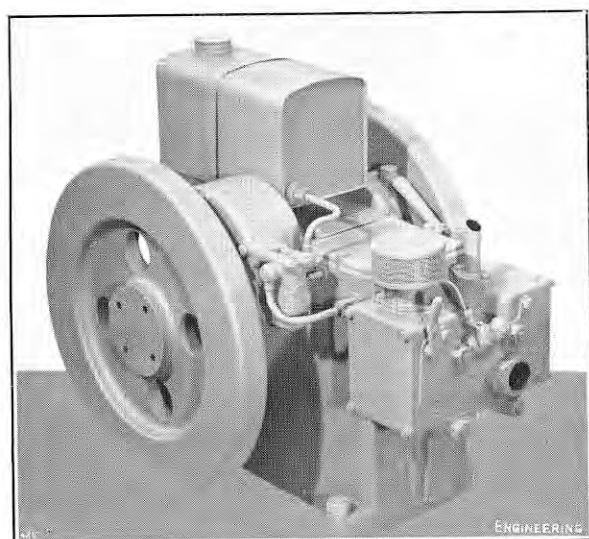


FIG. 86. 7-H.P. HORIZONTAL DIESEL ENGINE; RUSSELL NEWBERRY AND COMPANY, LIMITED.

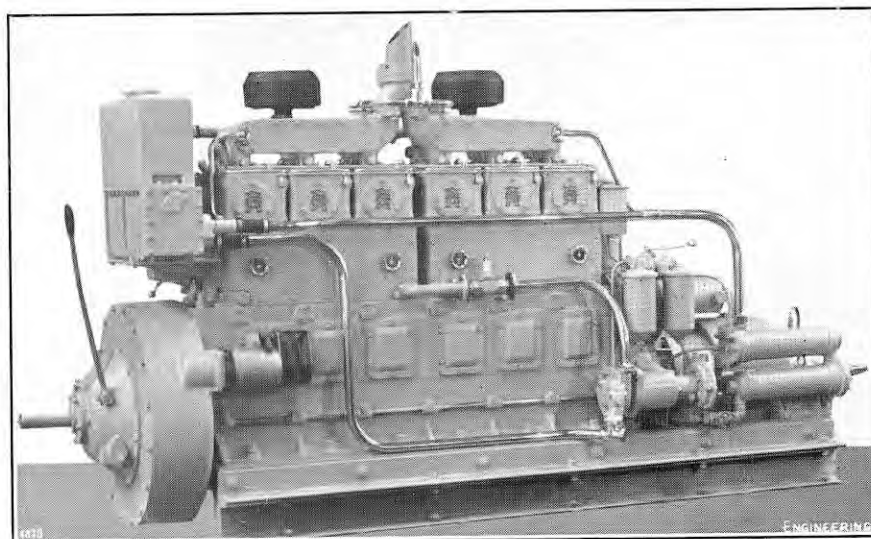


FIG. 87. 120-H.P. MARINE DIESEL ENGINE; RUSSELL NEWBERRY AND COMPANY, LIMITED.

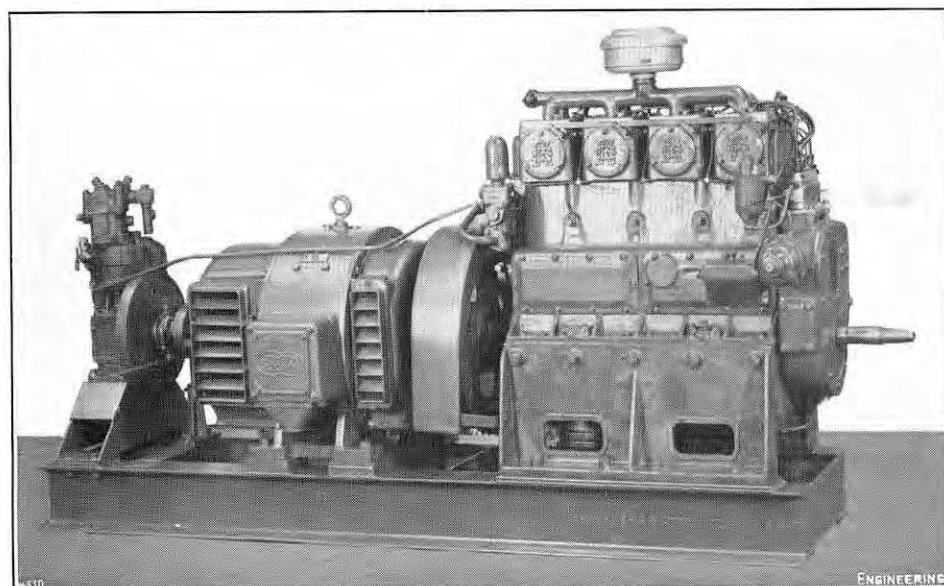


FIG. 88. 20-KW MARINE AUXILIARY GENERATING SET; RUSSELL NEWBERRY AND COMPANY, LIMITED.

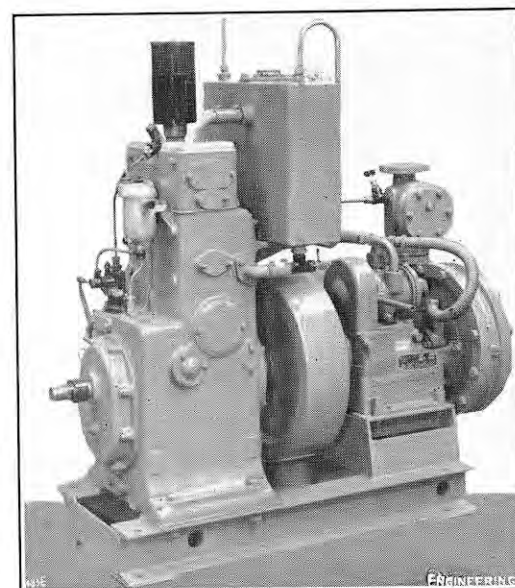


FIG. 89. MARINE FIRE PUMP; RUSSELL NEWBERRY AND COMPANY, LIMITED.

ENGINEERING, MARINE AND WELDING EXHIBITION.

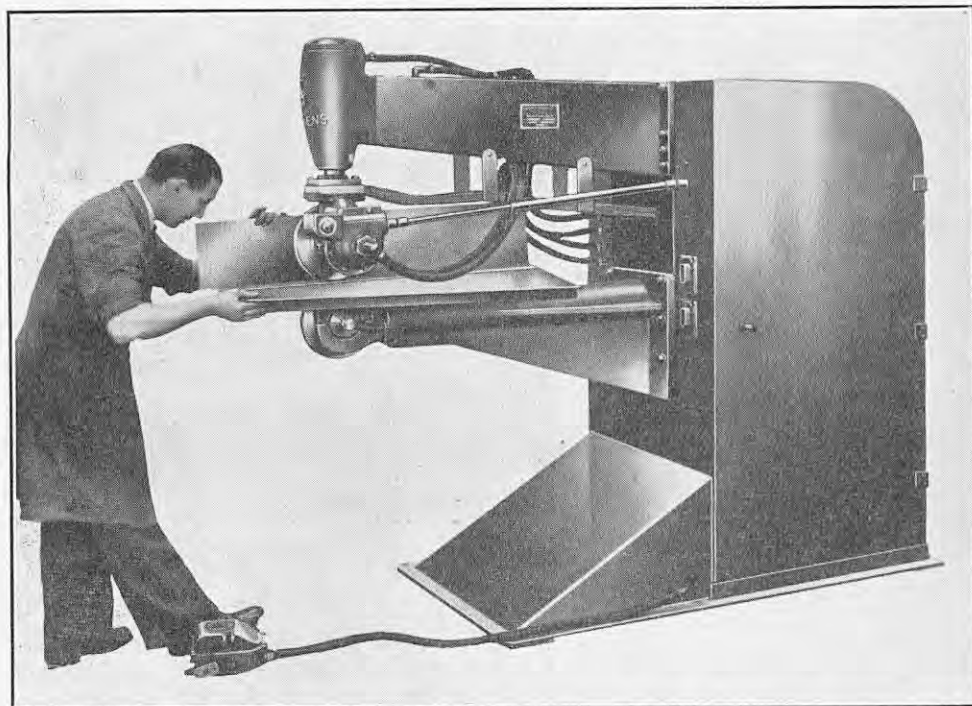


FIG. 90. 100-KV AIR-OPERATED SEAM WELDER; SIEMENS-SCHUCKERT (GREAT BRITAIN), LIMITED.

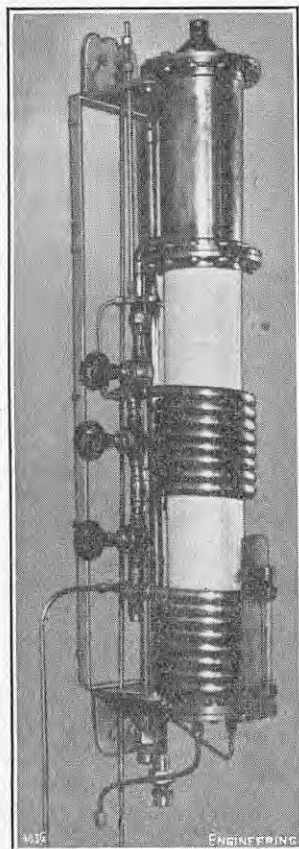


FIG. 91. DEGASSING CONDENSER; EVERSLED AND VIGNOLES, LIMITED.



FIG. 92. FORK-LIFT TRUCK; RANSOMES, SIMS AND JEFFERIES, LIMITED.

grease lubrication and located in a pedestal designed to form a substantial base for the pump. Both the engine and pump are mounted on a fabricated-steel girder base and cooling of the engine is accomplished by means of a small tank visible in the illustration; this is of sufficient size for the starting period, i.e., until the main pump is primed and supplies the tank and cylinder jacket. The performance of the pump varies, of course, with the speed and suction lift, but at 1,300 r.p.m. it is capable of delivering 32 tons an hour against a total head of 120 ft. The complete unit is particularly compact and is designed to meet the requirements of the Merchant Shipping (Fire Appliances) Rules, 1948. If re-

quired, it can be supplied for fresh-water cooling in conjunction with either a radiator or a heat exchanger.

Siemens-Schuckert (Great Britain), Limited, Great West-road, Brentford, Middlesex, were exhibiting a number of electric seam and spot welding machines. Among the former mention may be made of the 100-kVA air-operated equipment which is illustrated in Fig. 90. It consists of a welded steel frame within which all the apparatus is mounted in a dust-tight enclosure. The controls are arranged behind a large inspection door so that all the parts are easily accessible. The primary of the main transformer is designed for connection

to either a 400-volt single-phase or the two outers of a three-phase supply, and the secondary is water-cooled. The arms have a clear reach of 42 in. and the upper electrode, which is 9 in. in diameter, is driven through gearing by a motor at a speed which is infinitely variable between 2 ft. and 12 ft. per minute. The lower electrode, which is of the same diameter, is stationary and, like its arm, is water-cooled. There are two cooling circuits, one for the transformer and the other for the electrodes. An electrically-operated air valve controls the movement of a 5-in. diameter piston with a stroke of 3 in. at a maximum pressure of 80 lb. per square inch. The pressure exerted by this piston can be varied between 500 lb. and 1,500 lb.

Welding is initiated by pressing a foot switch in the 25-volt secondary circuit, thus admitting air to the piston and lowering the electrode on to the work. When the required pressure has been built up, the welding current is supplied from two ignitrons. These ignitrons are provided with thyatrons and with a device for controlling the duration of the welding and "off" times. The times can be adjusted in one-cycle steps between one and 30 cycles, and the arrangement of the control unit is such that welding always begins at the correct point on the cycle of the incoming supply. The welding current can be adjusted by a seven-step rotary off-load tapping switch. Welding continues until the foot switch is released.

The spot welders exhibited included one for fine work, from lamp filaments up to No. 12-s.w.g. mild-steel wire, as well as thin sheet work. This is a modification of the firm's well-known pedal-operated bench spot-welder in that it is operated pneumatically. A projection welder on the same stand had a capacity of 100 kVA and was capable of welding up to nine spots simultaneously, depending on the gauge of the sheet. Its welding arms were provided with slotted platens to which the fixtures for each job could be clamped.

Among a number of new products exhibited by Messrs. Evershed and Vignoles, Limited, Acton-lane Works, Chiswick, London, W.4, was the degassing condenser illustrated with its cover removed in Fig. 91, herewith. This equipment may be used in conjunction with a water-purity meter to determine the percentage of dissolved salts in a sample of water or steam. As is well known, the electrical conductivity of water depends on the percentage of such impurities, but it happens to be affected also, often considerably, by any amounts of dissolved gases, such as ammonia, carbon-dioxide, and hydrogen sulphide, which may be present. From the point of view of chemical action on superheater tubes, turbine blades, etc., it is the dissolved salts which are dangerous, and the function of the degassing condenser is to separate out the dissolved gases so that the percentage of dissolved salts can be determined by measurement of the remaining conductivity. The condenser is made to the design of Professor F. G. Straub, of the University of Illinois, and Messrs. Evershed and Vignoles are sole concessionaires for it in Britain. Briefly, its operation, when used in conjunction with a boiler, consists in first condensing some of the steam, which is fed at a controlled rate and pressure into a coil within the base of the apparatus, where it gives up part of its heat to boil previous condensate and then passes through a water-cooled coil around the centre of the column on the outside. The condensate, apart from a small overflow, is then fed to an orifice within the column, whence it drops down under gravity through a series of horizontal perforated stainless-steel plates forming a scrubber. During this process, it meets steam rising from condensate being evaporated within the base of the column by the heating coil mentioned previously. The rising steam heats and degasses the condensate and is itself condensed in a condenser at the top of the column, whence it falls back to the base. The liquid passes subsequently through the lower outer coil, which is a cooling coil, to the outlet. Meanwhile, the unwanted gases pass out through a vent at the top of the column.

Samples of gas-free condensate may be taken from the outlet pipe and non-degassed condensate may be obtained from the overflow. The samples so obtained are tested for conductivity in the water-

purity meter, the main parts of which are a conductivity tube and a chart recorder. The apparatus gives a direct reading of the electrical conductivity and is automatically compensated for variations in the supply voltage and water temperature. In a new model of purity-meter which was exhibited, a much smaller flow of water than was previously necessary suffices for the measurement, and the effects of electrolysis are reduced by operating with alternating current. Other new designs of apparatus on view included a circular disc recorder and a rudder-angle recorder.

Messrs. Ransomes, Sims and Jefferies, Limited, Orwell Works, Ipswich, showed a range of fork-lift trucks, among which was their latest truck, illustrated in Fig. 92, on page 361, and shown in public for the first time. The Forklift "10" truck, as it is called, is designed particularly for use in congested areas and narrow gangways. It is electrically driven, and provides a maximum travelling speed of $5\frac{1}{2}$ m.p.h., fully loaded; the overall turning radius is 5 ft. It has a capacity of 10 cwt., with the load centre 15 in. from the heel of the forks. It has telescopic lifting gear providing a maximum lifting height of 8, 9, or 10 ft., as desired. The lifting and tilting motions, which are hydraulically operated by a vane-type pump driven by a separate electric motor, are controlled by separate handles so that lifting and tilting can be carried out at the same time. The tilting angle ranges from 3 deg. forward to 8 deg. back, and approximately 5 sec. is required for full tilt. The control valves for lifting and tilting are interlocked with the motor starter so that no current is used until required. The maximum lifting speed is 20 ft. per minute, fully loaded, and 30 ft. per minute unloaded.

The framework and carriage are of welded-steel construction. The carriage runs on ball-bearing rollers travelling on renewable wearing strips attached inside the upright channel-section members. The truck has a front-wheel drive through a totally-enclosed worm reduction gear and spur differential gearing. The driving wheels are provided with hydraulically-operated internal-expanding double-shoe brakes. The truck is steered by the rear wheels, which have a maximum lock of 70 deg., through a worm reduction gear from the steering column.

The exhibits on the stand of Messrs. Clarke, Chapman and Company, Limited, Victoria Works, Gateshead, 6, included a number of examples of their electric, steam and hydraulic winches, pumps, pulverisers and searchlight projectors, as well as models of an electrically-driven winch for topping ship's derricks, of an electrically-driven endless rope haulage, of a water-tube boiler and a dry chain ash conveyor. Particular interest attached to the application of the Ward Leonard system to the group drive of winches as this enables a higher standard of performance to be obtained than when the direct alternating-current motor drive is used. As will be seen from the diagram reproduced in Fig. 93, herewith, there is, in this system, only one squirrel-cage motor and one starter for four winches, and the alternating-current from the mains is converted to variable-voltage direct current for controlling this group individually. The motor-generator whereby this conversion is effected usually consists of a three-phase squirrel-cage induction motor and two dual-output generators of the Ward Leonard type, which independently and simultaneously supply two winch motors. The dual-output generator is wound in the normal way and has only one commutator. There are four brush arms, spaced at 90 deg., those at opposite ends of a diameter forming a pair from which one output circuit is supplied. The field system is also similar to that of a normal four-pole machine, except that each pole carries a compensating coil, in addition to the excitation coils, to prevent the two outputs interfering with each other. There are also four interpoles, each of which carries two coils.

The speed of each winch is governed by the output voltage of the generator, to which its motor is connected. This voltage is controlled by a potentiometer regulator in the form of a pedestal controller, which can be placed at any convenient point on the deck. The winch speed is infinitely variable from creep to full speed and the load can be lowered

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Fig. 93.

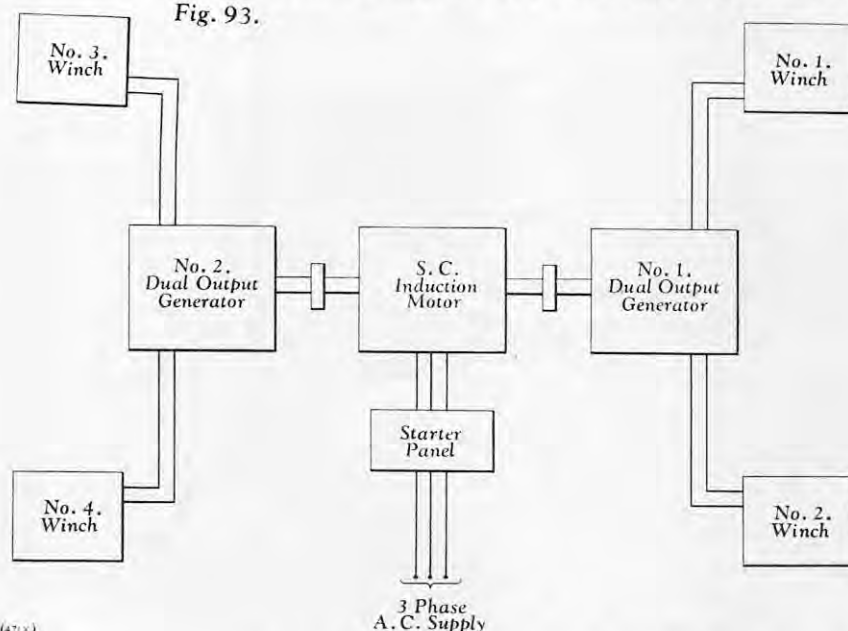
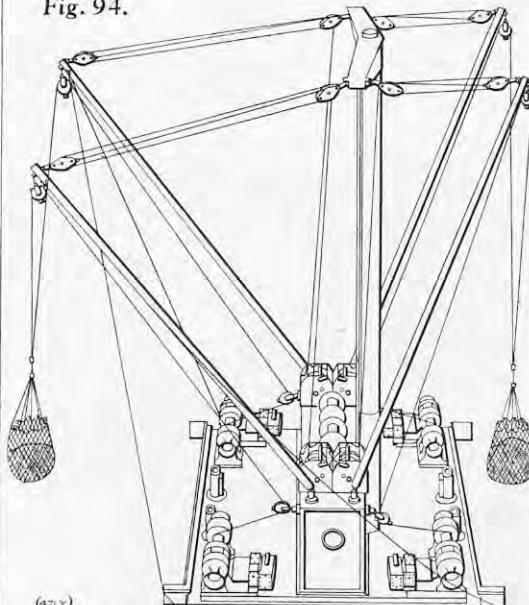


Fig. 94.



at any speed within these limits. All the winches are fitted with disc-type magnetic brakes, which are applied automatically if the power fails. These brakes, as well as the generator and motor fields, are supplied from a rectifier housed in the alternating-current starter. An arrangement of winches is shown in Fig. 94, herewith.

One of the electrically-driven winches exhibited on this stand has been designed for raising, holding and lowering derricks and reeling the wire on to its drum so that no loose coils lie on the deck. It can be fitted to the top or sides of the deckhouse if necessary. It is self-holding and the drive is through totally-enclosed worm gearing, which runs in oil. The motor is watertight and the starter is provided with a spring-loaded "dead-man" handle. A magnetic brake and self-holding worm stop and hold the derrick in position when the controller handle is turned to "off," or when the current fails. A pawl and ratchet are provided for locking the winch and holding the derrick when working cargo. The pawl is electrically interlocked so that when the derrick has to be lowered the winch will not start until it has to be disengaged. This disengagement is effected by starting the winch in the hoisting direction, after which the winch is free to lower.

The hydraulic winch being shown by Messrs. Clarke, Chapman and Company, Limited, is illustrated in Fig. 95, opposite, from which it will be seen that the complete unit is remarkably compact, the hydraulic motor taking up less space than the usual electric motor. It incorporates the Hydropulsion hydraulic system developed by Commercial Patents, Limited, Aldwych House,

London, W.C.2, and has been designed for cargo handling on board ship, the capacity being 3 tons. The advantages claimed for the winch include silence of operation, a wide range of load and speed control and low maintenance cost. It works in conjunction with a hydraulic pump which may be driven either by a squirrel-cage motor or a Diesel engine and is normally located in the engine room, together with a suitable oil reservoir. There can, of course, be more than one winch in the hydraulic circuit, which includes an unloading valve to control the pressure at a maximum of 1,600 lb. per square inch. As a safety precaution, the reservoir is provided with a low-level valve which automatically closes the system when the limit is reached and, at the same time, gives a suitable warning. To meet peak demands when handling cargo, accumulators are provided so that any winch is instantly available, the accumulators being loaded by the pump during the intervals between cargo handling. When they are fully charged, the discharge from the pump is by-passed to the reservoir by the action of the unloader valve.

Lockheed Pneudraulic air-loaded accumulators are used and it is claimed that the leakage from these is negligible, any topping-up required being accomplished by means of an ordinary hand or foot-operated pump. Alternatively, an auxiliary compressor can be arranged to boost the ship's compressed-air supply. The pump, which is illustrated in Fig. 96, opposite, is a five-cylinder radial unit designed to operate at constant speed. The winch motor is similar in construction to the pump but has nine cylinders arranged so that three, six or nine cylinders can be used at a time to give speed variation. Control of the winch is exceptionally easy and the design is such that the power must be shut off before it can be reversed. A spring-loaded brake is provided which normally is held out by the pressure in the hydraulic circuit and only comes into operation should the pressure fail for any reason; application of this safety brake is, of course, entirely automatic. The 3-ton winch illustrated can lift the full load at 100 ft. per minute, $1\frac{1}{2}$ tons at 200 ft. per minute and a light hook at 400 ft. per minute. Other sizes of winch are also available.

Standard Telephones and Cables, Limited, Footscray, Sidcup, Kent, were exhibiting two patterns of their electro-gas equipment, which is suitable for brazing, annealing, hardening and soldering operations. One of these was used to demonstrate the brazing of tricycle frames and the other illustrated various types of burners, singly and in arrays. The equipment which is illustrated in Fig. 97, Plate XXV, is operated from the normal town gas supply, but is fitted with an injector system so that it is possible to use high-intensity burners, and these can be arranged to give any heat pattern. Either single jets or multi-burner arrays can be employed and

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(For Description, see Page 362.)

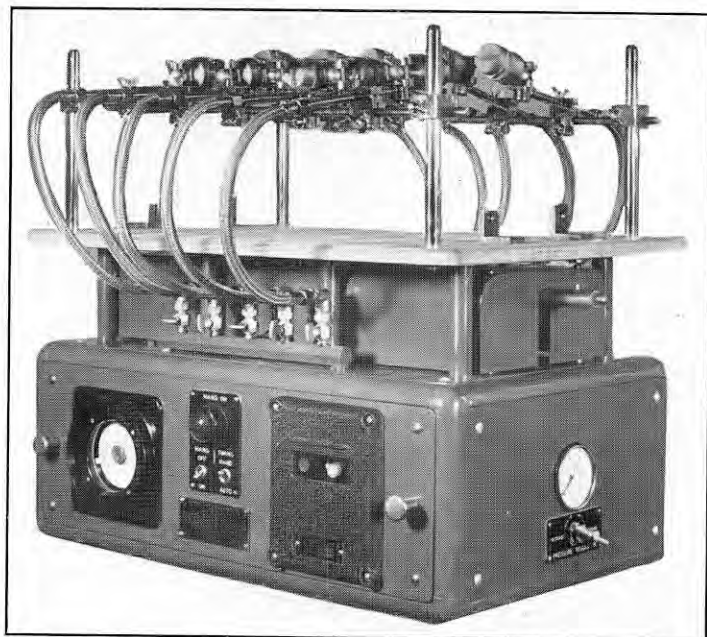


FIG. 97. ELECTRO-GAS HEATING EQUIPMENT; STANDARD TELEPHONES AND CABLES, LIMITED.

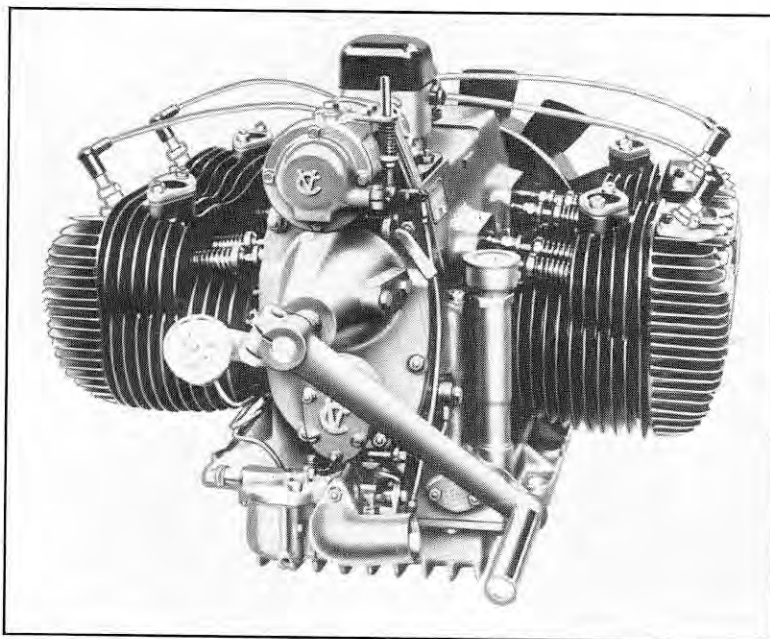


FIG. 98. HORIZONTALLY-OPPOSED AIR-COOLED PETROL ENGINE; COVENTRY VICTOR MOTOR COMPANY, LIMITED.



FIG. 99. 9-B.H.P. WATER-COOLED DIESEL ENGINE; COVENTRY VICTOR MOTOR COMPANY, LIMITED.

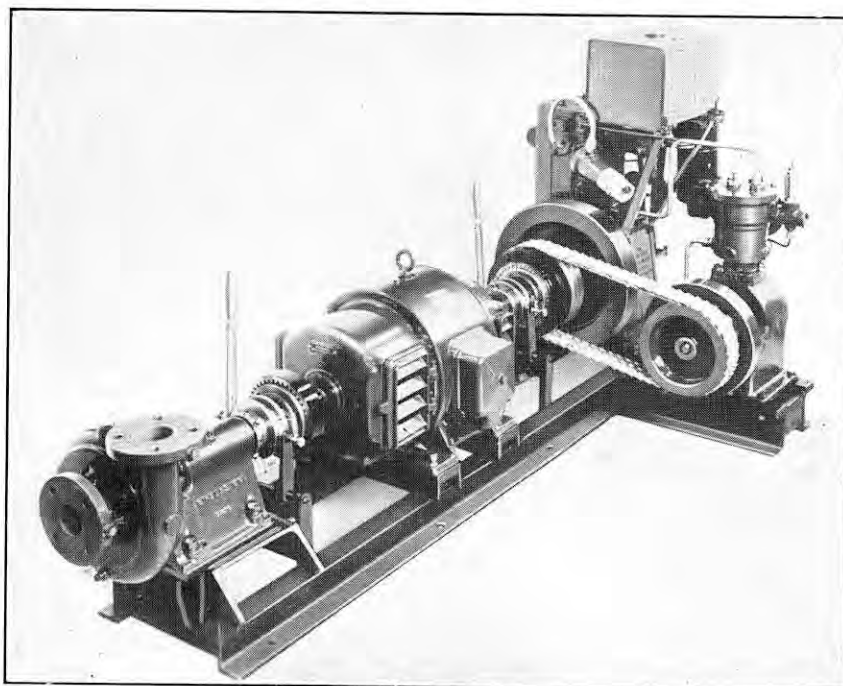


FIG. 100. COMPRESSOR, GENERATOR, PUMP AND DIESEL-ENGINE SET; COVENTRY VICTOR MOTOR COMPANY, LIMITED.

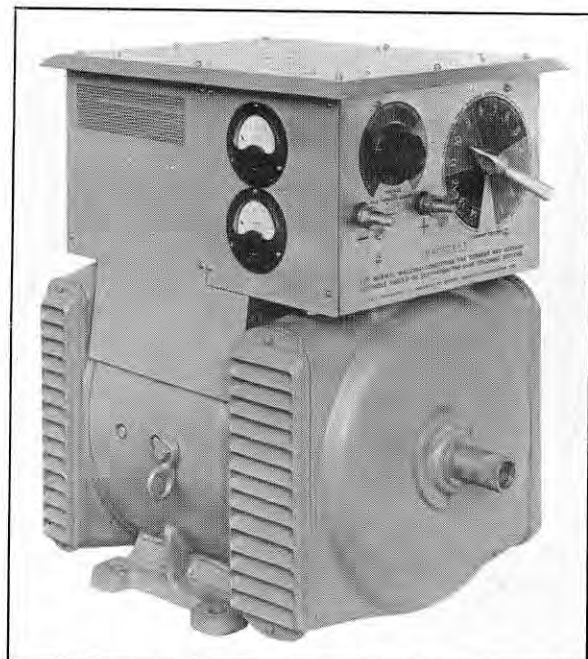


FIG. 101. DIRECT-CURRENT WELDING GENERATOR; MAX ARC AND ELECTRICS, LIMITED.

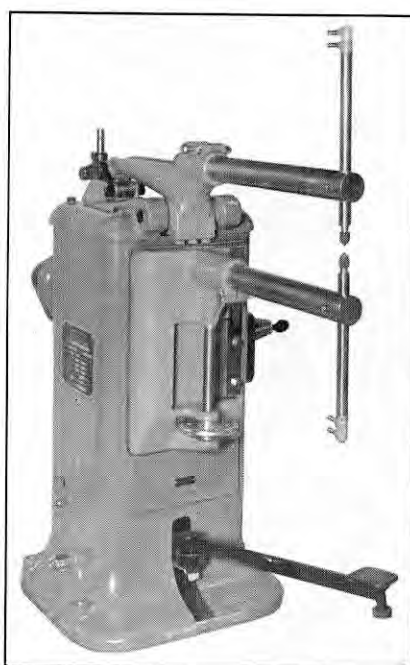


FIG. 102. 15-KVA SPOT-WELDER; HOLDEN AND HUNT, LIMITED.

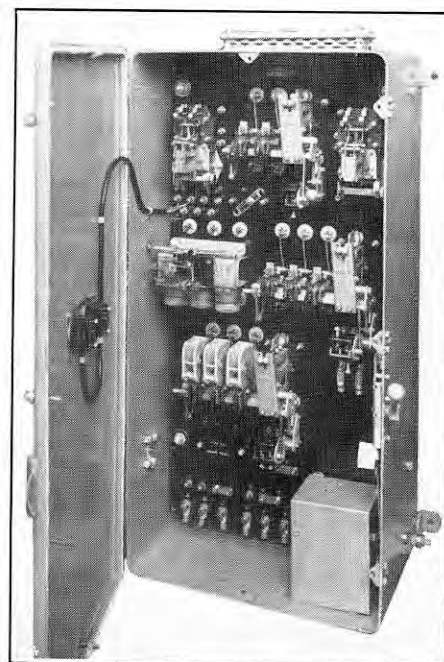


FIG. 103. AUTOMATIC STATOR-ROTOR STARTER; BROOKHIRST SWITCHGEAR, LIMITED.

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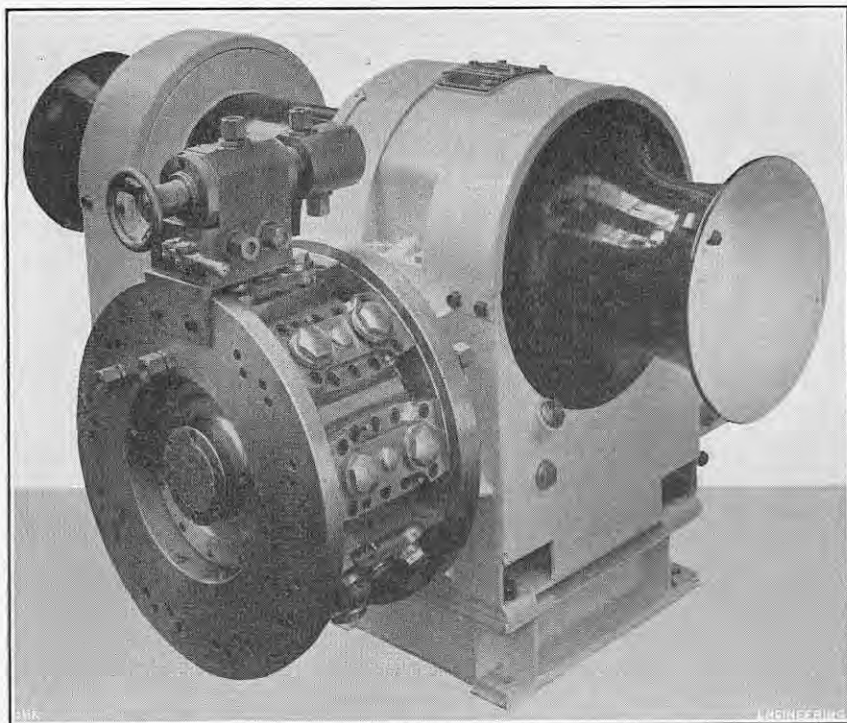


FIG. 95. HYDRAULIC WINCH; CLARKE, CHAPMAN AND COMPANY, LIMITED.

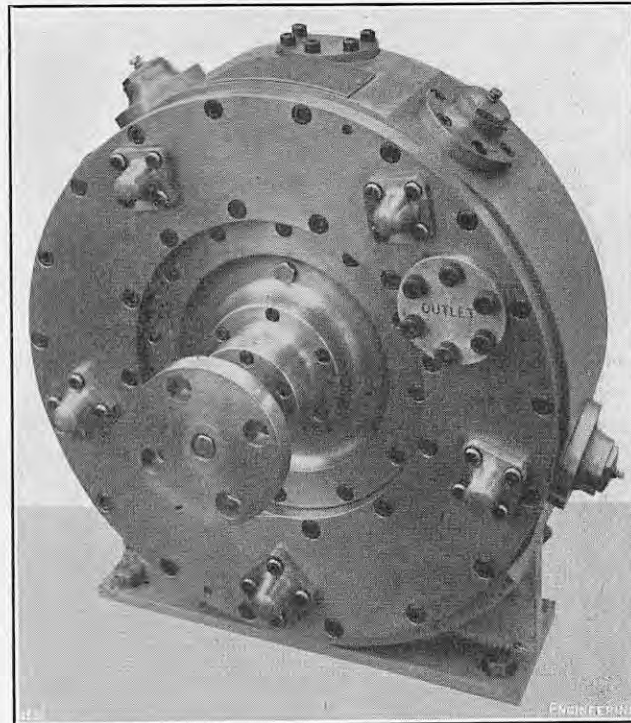


FIG. 96. "HYDROPULSION" PUMP; CLARKE, CHAPMAN AND COMPANY, LIMITED.

several areas can be treated at once. Once it has been adjusted to a predetermined heating cycle, the unit can be controlled by push-buttons by setting a process timer. The standard unit is fitted with 10 burners, but with slight modifications any number up to 30 can be used and these can be mounted either on, or at a reasonable distance from, the body of the equipment. Gas and compressed air are mixed in the correct proportions in an injector, the flow of each being controlled by electromagnetic valves. The normal gas consumption is from 10 to 20 cub. ft. per burner per hour, while the electrical consumption is 0.5 amperes at 200/240 volts and compressed air is supplied at 10 lb. per square inch.

A selection from their wide range of air-cooled and water-cooled petrol and Diesel engines was exhibited by the Coventry Victor Motor Company, Limited, Coventry. These included the new water-cooled Diesel engine illustrated in Fig. 99, Plate XXV, which was being shown for the first time. It has been designated the WD3 and, in general, follows the design and layout of the WD1 and WD2 models. The cylinder bore, however, is 90 mm. as against 85 mm. for the WD2 and 80 mm. for the WD1, and the output 9 brake horse-power at 1,500 r.p.m., the rated speed. The crankcase is cast from a non-corrodible aluminium alloy and the cylinder from high-grade cast iron, the latter being finished internally by a special process to minimise wear. An aluminium Y-alloy piston is fitted and is coupled to the forged-steel crankshaft by a steel connecting rod. Overhead valves are, of course, used and these are operated in the usual manner by push rods and rocking levers, the mechanism being totally enclosed but easily accessible. A gear-type pump supplies oil to the main and big-end bearings, the system incorporating a large oil filter of the removable type and the usual form of relief valve. Normally, the engine is fitted with a constant-speed governor having a limited adjustment, but a variable or wide-speed governor can be installed which enables the engine to operate at 800 r.p.m. Starting is by hand, the handle, which is of the safety type, engaging with the camshaft so that the engine turns over twice for each full swing of the handle. Water cooling is employed and the circuit may be connected to a static tank, a heat exchanger or a radiator, cooling being assisted by an engine-driven fan in the last-named case. The complete unit is of compact construction, the height being 28 in., the width 15½ in. and

the length, excluding the starting handle, 21½ in. The weight of the engine only is 296 lb. and in normal operating conditions the fuel consumption is stated to be 0.38 pint per brake horse-power per hour, a commendable performance.

The WD range of engines can, of course, be used for a wide variety of duties ranging from battery charging to the driving of marine auxiliaries. Their application to the latter duty was represented at Olympia by a standard engine arranged to drive a generator, centrifugal pump and air compressor. This unit is illustrated in Fig. 100, Plate XXV, from which it will be seen that the pump, generator, air-compressor and engine are all mounted on a common bedplate, the various components being driven through hand-operated friction clutches. On the normal installation of this type, cooling is accomplished by sea water circulated through the system by a gear-type pump mounted integrally with the engine, but radiator cooling is equally effective. On the other hand, if the set is a long way above the water-line, the air-cooled version of the engine may well be employed.

Other exhibits on the stand of the Coventry Victor Motor Company included the air-cooled petrol engine illustrated in Fig. 98, Plate XXV. Known as the Neptune, it is a new unit having four cylinders and developing from 12 h.p. to 26 h.p. As will be seen from the illustration, it is air-cooled and is of the horizontally-opposed type, there being two cylinders at each side of the crankcase. In common with all Coventry Victor engines, the new unit operates on the four-stroke cycle, induction and exhaust being through side-by-side valves disposed along the top of the engine and operated by a single camshaft arranged vertically above the crankshaft. The crankcase is machined from a non-corrodible aluminium-alloy casting and is fitted with a deeply-finned sump for oil cooling. The cylinder blocks are cast in pairs from close-grained cast iron and are equipped with heat-treated Y-alloy aluminium cylinder heads of the detachable type. Aluminium Y-alloy is used also for the pistons, each of which is fitted with two compression rings and one oil-control ring and joined to the crankshaft by a connecting rod machined from a nickel-steel forging. The crankshaft is formed from a solid steel forging and is supported by three bearings of the steel-backed replaceable type. There are solid balance weights to each throw and drillings are incorporated for pressure lubrication of the big-ends. The lubricant is supplied to the major

moving parts by a gear-type oil pump mounted in an accessible position on the crankcase, the lubricating system incorporating the usual form of oil filter. Cooling air is delivered by an axial-flow fan fitted at the rear of the engine, the air being led to the finned cylinder heads and barrels by removable cowlings, which, for the sake of clarity, are not shown in the illustration. The length of the engine is 35 in., the width 25 in., and the height 19½ in., and the weight is approximately 350 lb.

The arc-welding generator illustrated in Fig. 100, Plate XXV, was exhibited by Max Arc and Electrics, Limited, 190, Thornton-road, Croydon, Surrey. This machine has been designed to give stable arc conditions when welding both ferrous and non-ferrous metals under the most adverse climatic conditions, and is specially insulated so that it can safely be employed in tropical countries. It is fitted with a dual control system, so that the operator can adjust the current to suit the class of work being performed. This adjustment is effected by a selector switch with a click action so that it is locked in the chosen position. The equipment is available in several sizes for currents up to 400 amperes and can be driven at a number of different speeds by either a motor or an engine.

Other exhibits on this stand included the Max-Arclette alternating-current welding set which has been specially designed for use where lightness, portability and compactness are essential. It is capable of welding any thickness of metal and is rated at 3 kVA. The maximum intermittent demand on the mains is about 17 amperes at 380/440 volts, but it can be fitted with a condenser so that this demand is reduced by about one-third and the power factor stepped up to 0.8 lagging. The electrode holder is attached to a tough rubber-covered flexible cable and terminal plugs and the welding-current range is from 15 to 150 amperes with 24 intermediate settings.

The exhibits on the stand of Messrs. Holden and Hunt, Limited, Old Hill, Staffordshire, included a range of wire butt-welders for handling round-section mild steel from No. 20 s.w.g. up to rods ½ in. in diameter. These machines are semi-automatic in action and are arranged either for permanent fixing or for mounting on a chassis. Four spot-welders with loadings of 5, 10, 15 and 25 kVA were also shown. Of these, the 15-kVA model is illustrated in Fig. 102, Plate XXV. It consists of a cast-iron frame in which the naturally cooled transformer is enclosed and which also forms a

pedestal for the working parts. A regulator is fitted, which allows four heating speeds to be obtained according to the thickness of the material which is being treated. Both electrodes and electrode tips are water-cooled, the water connections being made with $\frac{1}{2}$ -in. rubber hose. The electrode tips are of Scaden copper alloy which, it is claimed, has a life six to eight times that of electrolytic copper. The top and bottom arms can either be of the angle type for reaching awkward corners, or horizontal for dealing with tubes and other small articles. Vice-type arms for the welding wires and studs or pins to hold sheets are available. The machine is operated by a pedal, which can be adjusted to the most convenient working position and has a very short lift. The toggle included in the mechanism ensures that a heavy pressure is applied to the weld with the minimum of effort, a point stressed by the makers, since the necessity for sufficient welding pressure is frequently overlooked. An automatic trip switch is provided and is so arranged that after light pressure has been applied to the weld the final pressure is obtained by depressing the pedal.

The exhibits on the stand of Brookhirst Switchgear Limited, Chester, included examples of their latest alternating-current and direct-current motor starters for industrial and marine service. The principle of these new models is adaptability, the basic components being designed so that they can be employed in a great number of combinations. These components include "channel-sprung" contactors, edge-pivoted thermal-overload relays, broad-base solenoid over-load relays and U-pack isolating switches. A typical stator-rotor starter incorporating these features, which has been designed for use with wound-rotor induction motors of outputs up to $27\frac{1}{2}$ h.p. at 415 volts, is illustrated in Fig. 103, Plate XXV. It is of the frequent-duty type and is suitable for up to 40 full-load starts per hour, provided the aggregate starting period does not exceed two minutes in every fifteen. It comprises triple-pole stator and rotor contactors, an escapement-controlled timing relay, a triple-pole isolating switch, a solenoid-type over-load relay, control circuit fuses and torque-adjusting links. It can be arranged for two-wire or three-wire local and remote control.

(To be continued.)

500-B.H.P. DIESEL-MECHANICAL LOCOMOTIVE.

OPERATING experience with a new machine has a way of revealing unexpected weaknesses. It is easy to be wise after the event, and the causes of such weaknesses are then usually obvious, but it is not easy to predict them at the time when attention is being directed to laboratory or bench tests, however carefully the tests have been arranged to simulate operating conditions. Credit is therefore due to the Hunslet Engine Company, Limited, for inviting recently representatives of the technical Press to observe the trials of the first of four 500-brake horse-power Diesel-mechanical locomotives which they are building for the Paita-Piura railway of the Peruvian Corporation. The locomotives have an 0-8-0 wheel arrangement, with a maximum axle loading of 14 tons, and have been designed for freight traffic. By arrangement with Mr. R. A. Riddles, of the Railway Executive, trials are being conducted on a difficult line in Yorkshire, hauling coal trains which are normally handled by steam locomotives, and manning the locomotive with crews who have been given some training but who cannot be said to "nurse" the machine.

The 500-h.p. Diesel locomotive has been hauling trains which otherwise would have necessitated double-heading, using a Class 8F 2-8-0 locomotive (Sir William Stanier's L.M.S. design) and a Class 3F 0-6-0 locomotive of the old Midland Railway. Its performance, if we may judge on the basis of a single run on severe gradients, was the complete answer to those who doubt the ability of a Diesel locomotive to haul and shunt goods trains as flexibly as a steam locomotive does, and it showed that a mechanical drive, low in capital cost, is applicable to an engine of 500 h.p. The provision of six gear ratios ensures that there is adequate overlap of both tractive efforts and speeds in successive gears, even if, on a rising gradient, the driver is slow in gear-changing due to lack of experience. Indeed, the run on the footplate last week proved that gear-changing is no bar to the use of Diesel locomotives on this class of freight traffic.

The run was on the former Midland line to Carlisle, from Stourton Junction, Leeds, to Apperley Junction; thence on a branch line to Guiseley, where, after shunt-

500-H.P. DIESEL-MECHANICAL LOCOMOTIVE.

HUNSLET ENGINE COMPANY, LIMITED, LEEDS.

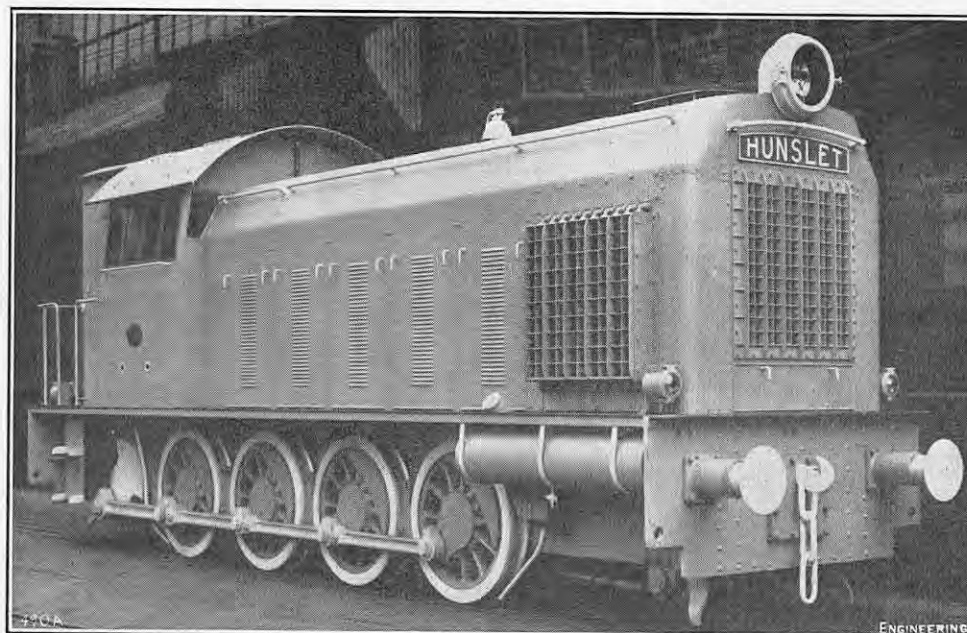
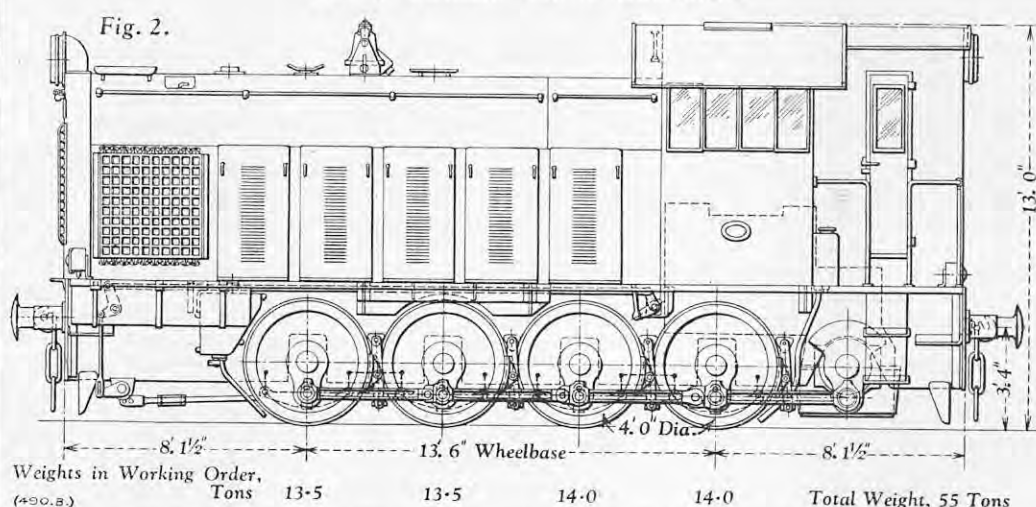


Fig. 1. GENERAL VIEW OF LOCOMOTIVE.



ing, a lighter train was taken on the single line to Yeadon. On the main line the steepest gradient is 1 in 133 (0.75 per cent.) but on the branch line there is a length of about 2 miles at 1 in 60 (1.66 per cent.), followed by a short distance at 1 in 53 (1.89 per cent.) and another at 1 in 62 (1.61 per cent.) into Guiseley station. The latter gradients are accompanied by curves of 30 to 47 chains radius, some of them reverse curves, and most of the 1 in 60 gradient is through well-wooded cuttings where greasy rails are common. The run to Guiseley is a distance of 13 miles, and one mile of the two miles to Yeadon climbs at 1 in 48, 1 in 72 and 1 in 50, with curves of 17 to 47 chains radius. The Diesel locomotive has taken a 515-ton train from Leeds to Guiseley, running at a steady speed of 4 to 4½ miles an hour from Apperley Junction to Guiseley. Using steam motive power, this load would have required two engines weighing 198 tons, compared with the 55 tons of the Diesel locomotive; alternatively, the train would have been divided. The Diesel locomotive has been on this run since August 24, and for four weeks previously it was engaged on heavy coal-train shunting at Stourton down yard. It has also hauled trains of up to 700 tons over ruling gradients of 1 in 133. In Peru the locomotives will haul cotton and general freight trains on a 62-mile line which includes a quarter-mile at 1 in 29, preceded by 2 miles at 1 in 52.56.65 and succeeded by half a mile at 1 in 44 and 2½ miles at 1 in 45.52. The 1-in-29 gradient is on a curve of 340 yards radius.

Figs. 1 and 2, on this page, show the first of the two 0-8-0 locomotives to be built; the other two of the order will have an 0-6-0 wheel arrangement, but otherwise will be similar in design. The locomotive has 48-in. wheels; its wheelbase and axle load (Fig. 2) were designed to suit the conditions on the Paita-Piura Railway, and the top speed of 53 km.p.h. (33 m.p.h.) was also chosen to suit the operating conditions on that line. The plate-frame structure below the

running-plate level is particularly robust to withstand shunting and freight service, and to maintain the alignment of the engine, driving shaft and gearbox. The side buffers and link couplings shown in Fig. 1 are for the trials on British Railways; centre couplers are to be fitted for work in South America. The suspension system comprises underhung laminated springs, compensated in two groups down each side. Ajax grease lubrication is used for the axleboxes, and also for the driving-rod and coupling-rod cranks. The cast-steel wheel centres are provided with grease lubrication for the liners on the inner faces of the hubs.

The frame structure is based on 1½-in. steel plates tied by heavy buffer beams at each end, and by horizontal and vertical stretchers, one of which is the lower half of the welded steel gearbox, which itself acts as a rigid cross-member about 7 ft. long. Above the running plate a long casting houses the engine and main transmission shafting, and at the front is a separate compartment housing the cooling fans and auxiliaries. The cab is unusually commodious, and has been designed to give the driver a clear view in each direction without leaving his swivel seat; he can see both buffer beams quite easily. The main gear-changing, throttle, direction, braking and sanding handles are duplicated. A hot-air system of cab heating, using the engine exhaust, is provided. Westinghouse air brakes apply the brake-blocks on all wheels through two 10-in. cylinders, giving a braking effort of 38 tons at a pressure of 60 lb. per square inch, and operating through fully-compensated rigging. There is also a hand brake. Hand sanding is fitted, for both forward and backward directions. At present, freight stock on the Paita-Piura Railway is not equipped with continuous brakes, but provision has been made for this, when Westinghouse automatic equipment will be installed on the locomotive. A pneumatic whistle and air-operated warning bell are fitted.

The power unit of the locomotive is a 12-cylinder

500-H.P. DIESEL-MECHANICAL LOCOMOTIVE.

HUNSLET ENGINE COMPANY, LIMITED, LEEDS.



FIG. 3. CLUTCH BEING ASSEMBLED.

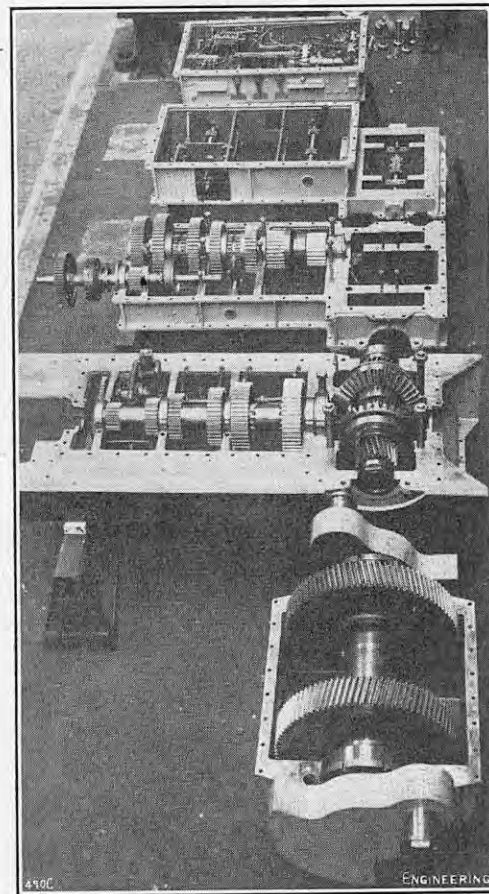


FIG. 4. GEARBOX PARTS.

Davey, Paxman four-stroke engine, type 12 RPH, with cylinders 7 in. by 7½ in., arranged in V formation, a compression ratio of 17 to 1, a dry weight of about 7,200 lb., and a maximum output of 500 brake horsepower at 1,375 r.p.m. It has a cast-iron crankcase structure, underslung main bearings secured additionally by horizontal tie-rods, a drop-forged crankshaft with main bearings composed of renewable steel shells with copper-lead linings, Y-alloy pistons, fork-and-blade connecting rods, and cylinders and cylinder heads cast in groups of three. C.A.V. fuel-injection pumps are used. At the back end of the crankshaft is a Bibby coupling to take up torsional vibrations, and on the coupling casing there is a starting ring, the engine not being equipped with a flywheel. Water-cooling is effected in two side radiators composed of Serek elements and Hunslet headers; and oil-cooling elements are provided above these. Air is drawn in through the grating at the front end of the locomotive by a belt-driven fan, and expelled through the side radiators by another two belt-driven fans. A drive from the front end of the engine shaft is taken to two compressors and two centrifugal water-circulating pumps. Electric starting by one motor at 24 volts is used; a 24-volt 550 ampere-hour Nife battery is housed in the cab and charged by a 1,100-watt dynamo driven from the crankshaft. The fuel tank is located in the top of the casing, and has a capacity of 500 gallons.

Behind the Bibby coupling the transmission comprises a fluid coupling, flexible coupling and cardan shaft, a Hunslet self-ventilated friction clutch (Fig. 3), and a Hunslet six-speed gearbox with the pre-selective mechanism, and reverse gear inside the box. The final drive is through a jackshaft, carried on roller bearings, and the side rods. Following previous Hunslet practice, the gear-changes are made by internal gear clutches operated by air pressure. The reverse gear, which comes between the change-gear and the jackshaft, is also air-operated, and the whole of the control gear is mounted in the top of the box, so that the box and controls form one complete unit. In this, the latest, design the main clutch, which is normally carried on the engine, is mounted on the input shaft outside the gearbox, so that the whole transmission, including the control mechanism, is one sub-assembly. The main self-ventilated friction clutch is able to take a 100 per cent. overload above the engine torque, and is designed to start the heaviest trains from rest without difficulty.

If a hydraulic coupling is preferred, however, it can be mounted on the engine flywheel without interfering with the remainder of the transmission. The main clutch, mounted on the input shaft, is based on previous Hunslet practice; clutches of this type have been in constant service for nearly 20 years with only routine maintenance attention. The important features include the case-hardening of all mating parts, and open construction which allows air cooling throughout the clutch and visibility of the linings at all times, so that wear can be measured and checked monthly and ample warning given for re-lining. The clutch is designed to transmit the full engine power at starting and can maintain full torque under maximum slipping conditions as long as is needed on any railway work without over-heating. The clutch is designed for use without any other slipping medium.

The gearbox is split on the horizontal centre-line of each shaft; the several sections are shown in Fig. 4, herewith. It is a welded structure, each section stress-relieved after welding. Stripping and assembling are straightforward jobs, and all shafts and wheels can be lifted from the box as assembled items without internal stripping. This feature is applicable even when the gearbox is in position in the locomotive, all the internal parts of the box being removable without dismantling the main part of the gearbox, the reverse mechanisms being lifted out from above the frame and the jackshaft being dropped out from below. All shafts and wheels run on ball or roller bearings and are made from an oil-treated nickel-chrome casehardening steel, giving a core strength of about 65 tons per square inch. In order to avoid high peripheral tooth speeds, there is an initial pair of wheels which reduce the gear-change shaft speed. The gear-change shaft of the new 500-h.p. box carries six free-running wheels mounted on ball bearings to accommodate the six speeds, these being in constant mesh with six fixed wheels on the speed shaft. All these wheels are casehardened and ground. On the gear-change shaft there are three double-ended internal-gear sliding clutches which can couple any of the six speed wheels to the gear-change shaft. Mounted on the speed shaft is a bevel pinion which mates with two bevel wheels on the reverse shaft; a further internal-gear sliding clutch on this shaft couples either bevel wheel to the shaft to give forward or reverse gear. On the extreme ends of the reverse shaft are mounted a pair of single-helical pinions, one left-hand and the

other right-hand, meshing with two mating wheels on the jackshaft. These helical wheels on the jackshaft are torsionally resilient to take shocks, and they are the only gearwheels in the box which are not case-hardened. They are made of 75-ton oil-hardened steel. The jackshaft, 11 in. in diameter, is mounted in roller bearings and carries the fly-cranks and case-hardened crankpins.

The power control unit is compactly placed within the top of the gearbox. The equipment comprises an ordinary operating air cylinder, together with main and auxiliary air valves which control not only the gear change, but the complete pre-selection of all gears by air in the correct sequence. Control and operation do not involve any use of complicated and delicate electropneumatic and electromagnetic circuits. All the control details are straightforward and are adequately lubricated by splash from the box. The lubrication of the main gear drive is by a high-pressure pump.

The chief dimensions, etc., of the locomotive, other than those already given, are as follows. The normal speeds and tractive efforts in the several gears are: first, 4½ m.p.h. and 35,400 lb.; second, 6 m.p.h. and 26,600 lb.; third, 9 m.p.h. and 17,700 lb.; fourth, 14½ m.p.h. and 11,200 lb.; fifth, 21 m.p.h. and 7,600 lb.; and sixth, 33 m.p.h. and 4,830 lb. The adhesive factor in second gear is 4.63 to 1; the lightest rail on which, it is recommended, the engine should run is 70 lb. per yard; and the minimum radius of curve the engine will traverse alone is 325 ft. Assuming a limit of adhesion of 4 to 1, a train starting resistance of 18 lb. per ton, and a train running resistance of 12 lb. per ton, the locomotive will haul, in first gear, 1,650 tons on the level, 700 tons up 1 in 100, and 430 tons up 1 in 50.

REGISTER OF INDUSTRIAL PREMISES.—Industrial firms which occupy a floor space greater than 5,000 sq. ft., but are not already heavily committed to the rearmament programme, will shortly be receiving from the Board of Trade regional controllers a letter asking them to supply certain basic information about their premises. This is to assist the Factory and Storage Premises (Defence Planning) Division of the Board, under Sir Philip Warter, to prepare for the establishment of a Control of Factory and Storage Premises organisation in the event of an emergency.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

SCOTTISH STEEL PRODUCTION DURING AUGUST.—Steel outputs during August remained appreciably below the level of a year ago, because of the scrap shortage. The production of ingots and castings for the month was at an annual rate of 2,122,600 tons, compared with 2,533,300 tons in 1950. The annual equivalent for the first quarter of the year was 2,220,800 tons, and for the first six months 2,231,800 tons. Improved arrivals of iron ore increased pig-iron production to a rate of 796,100 tons in August, in contrast with 674,900 tons in July and 756,400 tons in June. In August, 1950, however, the annual equivalent reached 823,000 tons.

NAVAL AIR STATION AT MACHRIHANISH.—An advance party of about 120 naval officers and ratings has arrived at Machrihanish, near Campbeltown, to prepare for the arrival of the main body, due there shortly to take over the war-time Royal Naval Air Station, which is to be commissioned before the end of the year. Air crews are to be trained at the station in anti-submarine operations.

BLOCHAIRN STEELWORKS.—A campaign to prevent the partial closing of Blochairn Steelworks, Glasgow, is being actively waged, and yesterday a meeting of about 100 of the men affected decided to send a protest to the Prime Minister. Mr. J. Simon, spokesman for the men, said the melting shop was the only part of the works that was old-fashioned, and it could be modernised without excessive capital outlay. The men's case is that, with a moderate expenditure, the works could be made an economical steel-producing unit.

STEEL FOR ABERDEEN SHIPBUILDING.—As a result of efforts to obtain a bigger quota of steel for Aberdeen shipyards, a "priority treatment certificate" for 115 tons of steel has been granted to John Lewis & Sons, Ltd., at whose shipyard 50 men were suspended recently because of the lack of steel. Lord Pakenham, First Lord of the Admiralty, in a letter to Mr. Hector Hughes, M.P. for Aberdeen North, and the shop stewards, explained that priority treatment certificates had been introduced to enable firms to obtain marginal quantities of steel until the general steel allocation is reintroduced at the end of the year.

INDUSTRIAL EXHIBITION AT GREENOCK.—The Greenock "Festival of Britain" Industrial Exhibition, which opened, in the Town Hall on Saturday, September 15, and closes to-morrow, was designed primarily to portray the history, development and present significance of the work of Greenock craftsmen. Shipbuilding and marine engineering are prominent features, the exhibits including the steering gear for an Atlantic liner, by John Hastie & Co., Ltd.; a Doxford opposed-piston oil engine, by Scott's Shipbuilding & Engineering Co., Ltd., and a model Doxford engine by J. G. Kincaid & Co., Ltd.; models of Clan liners built by the Greenock Dockyard Ltd.; and coaster models by George Brown & Co., (Marine), Ltd.

CLEVELAND AND THE NORTHERN COUNTIES.

STEEL RESTRICTIONS IN CLEVELAND.—Bigger supplies of steel and iron are urgently needed here, and the announcement this week of the curtailment of operations at the Cargo Fleet works, Middlesbrough, of the South Durham Steel and Iron Co. is a bitter disappointment to customers as well as to employees. The call by 400 of the men affected for a full inquiry into the internal organisation of the firm might tend to give the wrong impression that the announcement might have been avoided by local action. The origin of the action, however, was the decision, by the Iron and Steel Corporation, to close the ingot works at Stockton.

EXTENSIONS TO HEATON WORKS.—The September issue of the works *News Letter* of C. A. Parsons & Co., Ltd., Heaton, Newcastle-on-Tyne, records that the new bay for the construction of large power transformers is now practically completed. The two 100-ton overhead travelling cranes, delivery of which is overdue, are expected to be erected towards the end of November. Work has begun on the preparation of foundations for the new research and design block, to be erected on the site of the former "top shop," recently demolished. Piling is almost completed and a retaining wall is being built round the perimeter of the building. When it is finished, the excavation of the basement will begin.

LANCASHIRE AND SOUTH YORKSHIRE.

UNEMPLOYMENT PAY.—A difficult position results from the displacing of about 500 steelworkers at Sheffield and Rotherham, deprived of their usual work by the closing of melting furnaces which are short of materials. Some of the men have accepted labouring jobs as an alternative, but many have refused the alternative employment at the works and protest against the decision that they are not entitled to unemployment pay. Test cases are to be heard.

COAL OUTPUT RESTRICTION.—Coal production in the Yorkshire coalfield would be much greater if the miners completed the necessary number of shifts to qualify for their bonus. About 25 per cent. of Yorkshire coal-face workers and about 18 per cent. of the surface workers do not qualify. If every miner put in all his shifts, it is stated, the additional wages would be about 4,000,000l. a year. In the case of the younger men especially, liability to income tax appears to be the deterrent.

EXPORTS RESUMED.—Exports of slag from the North Lincolnshire steelworks have been resumed, with shipments from Immingham to Ghent, where the slag is required as a fertiliser and for road repairs. One of the big stacks of slag at the Redbourn steelworks of Richard Thomas and Baldwins, Ltd., is the source of the exports. It is expected that the removal of the slag will bring to light some much-needed steel scrap.

ELECTRICITY CHARGES.—It is regarded as probable that electricity charges in Yorkshire will be increased. The Yorkshire Electricity Board already bear 200,000l. a year in extra costs resulting from the last rise in coal prices, and there has been a wage increase which will cost an extra 130,000l. a year. Other applications for wage increases are probable.

STEEL FOREMEN IN CONFERENCE.—Three conferences, each of a week's duration, have been arranged for steelworks foremen, to take place at Hope, Derbyshire. Foremen will attend from Sheffield, Chesterfield, Rotherham and the West Riding, and representative foremen from other training areas of the British Iron and Steel Federation will be invited. Members of the executive staffs of steelworks, as well as trade-union officials, will address the sessions and initiate discussions on the foreman's work. The arrangements are being made by the West Riding and North Derbyshire Training Committee of the Federation.

COURSE IN RADIO-ISOTOPES.—A post-graduate course in radio-isotopes in research and industry is to be held at the Department of Engineering, College of Commerce and Technology, Pond-street, Sheffield, 1, on Monday evenings from October 1 to November 5, inclusive. The lecturer will be Mr. H. S. Peiser, M.A., of Messrs. Hadfields, Ltd. The fee for the course, payable on notification of acceptance, is one guinea; an application form can be obtained from the Head of the Department.

THE MIDLANDS.

THE LATE SIR W. H. WIGGIN.—The death is announced of Lieutenant-Colonel Sir William Henry Wiggin, K.C.B., D.S.O., T.D., D.L., J.P. Sir William, who was born at Birmingham in 1888, was a director of W. & T. Avery, Ltd., William Hunt & Sons, The Brades, Ltd., and other Midland companies. He was formerly connected with the family business of Henry Wiggin & Co., Ltd., of Birmingham.

PROPOSED "FLATTED" FACTORIES FOR COVENTRY.—Coventry City Council have under consideration the building of three factory blocks on the principle of residential flats, to accommodate small manufacturing firms. The city's central re-development area contains a number of these small firms, which will be displaced by the reconstruction. The proposed factory blocks will be several stories in height, and will each contain ten factory flats. A similar scheme was suggested for Birmingham some years ago, but it did not materialise; if the Coventry plan is carried out, it will be the first of its kind in the Midlands, though the small self-contained workshop in a large building has been a feature of Sheffield industry for a century or more.

LARGE ROLLER LEVELLING MACHINE.—The Bronx Engineering Co., Ltd., of Lye, Stourbridge, have despatched to France an eleven-roll plate-levelling machine weighing 64 tons, and capable of dealing with steel plates from $\frac{1}{8}$ in. to $\frac{3}{4}$ in. thick. The machine is claimed to be the largest yet made in the district.

THE COST OF GAS FIRING IN THE POTTERY INDUSTRY.—The British Pottery Manufacturers' Federation have approached the West Midland Gas Board for a reduction in the preferential rate for gas used in kiln firing. North

Staffordshire, the traditional home of the coal-fired "bottle" kiln, has adopted gas firing increasingly in the past 20 years, until, at present, 57 per cent. of the output of the Etruria gasworks, Stoke-on-Trent, is used for kiln firing.

ALUMINIUM FABRICATING FIRMS' AGREEMENT.—The London Aluminium Co., Ltd., of Birmingham, and the Midland Metal Spinning Co., Ltd., of Wolverhampton, have concluded an agreement whereby the services of the latter company's managing director, Mr. F. P. Webster, will be available to re-organise the Birmingham company's works and plant. The agreement is for a minimum period of three years.

NOTTINGHAM TRADES EXHIBITION.—A Trades Exhibition, arranged as part of the Festival of Britain, was opened yesterday by Mr. A. G. Bottomley, O.B.E., M.P., Secretary for Overseas Trade, and will remain open until September 29. It has been organised under the auspices of the Nottingham Chamber of Commerce.

ANOTHER INDUSTRIAL COURSE FOR SCHOOLTEACHERS.—Another Midland firm have held a short training course for schoolteachers, similar in scope to the two already conducted by Stewarts and Lloyds, Ltd. The previous courses took place in Bilston; the recent one, of two days duration, was at the Witton works of the Metals Division of Imperial Chemical Industries, Ltd.

THE LATE MR. E. M. W. BOUGHTON, M.C.—We regret to record the death of Mr. E. M. W. Boughton, which occurred in Birmingham on Saturday, September 8, at the age of 65. He was educated at Wyggeston school and Leicester municipal technical school and joined the staff of the British Thomson-Houston Company as a jig and tool draughtsman in 1910. After serving in the Royal Corps of Signals during the 1914-18 war, he rejoined the B.T.H. Company as head of the production department at their Birmingham works and was appointed manager of that works in 1941. He was a member of the Institution of Production Engineers.

COURSE FOR WORKS AND PLANT ENGINEERS.—A refresher course for works and plant engineers is to be given at the College of Technology, Birmingham, on Friday evenings for a period of 23 weeks, commencing on October 12. The papers will be presented by specialists drawn from industry throughout the country, and each will be followed by a discussion. The course is sponsored by the West Midlands Advisory Council for Technical, Commercial and Art Education, and the fee is 63s. A brochure is obtainable from the Registrar, College of Technology, Birmingham, 1.

SOUTH-WEST ENGLAND AND SOUTH WALES.

PROPOSED RESERVOIRS FOR CARDIFF WATER SUPPLY.—Urging that action be taken on a proposal for a new reservoir, which has been estimated to cost 750,000l., the Cardiff city water engineer (Mr. G. W. Cover) said that the city's daily water consumption of 14,000,000 gallons would increase by a further 1,000,000 gallons per day in three years' time and by 4,000,000 gallons in ten years. The waterworks committee, he said, would not be able to meet the demand in a few years, especially in time of drought; already the city had less than 100 days' supply in reserve. It was stated that the Corporation would deposit soon with the appropriate Ministry a formal application for sanction of the new Blaen Taff reservoir. The committee also decided to take action to acquire a site in Radyr, near Cardiff, for a new reservoir, though it was indicated that there would be opposition to the scheme at the Ministry inquiry.

RELIEF OF CARDIFF TRAFFIC CONGESTION.—A new road through Cardiff Castle grounds, skirting the walls of the Castle, has been suggested by the city engineer (Mr. E. C. Roberts) as the most effective method of relieving traffic congestion in the city centre. The scheme was presented as part of a long-term highway plan for the city, and was regarded as the most promising of three which have been under consideration between the engineer and the Ministry of Transport. The new road would divert north-south traffic and the construction costs would be relatively small, but the Ministry stated that it was unlikely that the work could be sanctioned under present economic conditions.

COAL PRODUCTION.—Returns issued by the National Coal Board for the second quarter of the year show that the South Wales coalfield produced 5,844,784 tons of saleable coal, which brought in 16,991,947l. The total costs of production, however, were 17,274,652l., a loss of 283,605l., or 11.6d. per ton raised. In the Somerset coalfield, the output was 130,467 tons, produced at a loss of 127,722l., or 19s. 7d. per ton. In the Forest of Dean, the loss was 76,871l., or 8s. 2.9d. per ton, on an output of 186,623 tons.

NOTICES OF MEETINGS.

It is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

INSTITUTION OF WORKS MANAGERS.—*Manchester Branch*: Monday, September 24, 6.30 p.m., The Grand Hotel, Manchester. "The Task Ahead" by Mr. E. J. Holford Stevens. *Northampton Branch*: Monday, September 24, 7.30 p.m., The Franklins Gardens Hotel, Northampton. "Financing a Small Company," by Mr. D. G. Petrie. *Notts and Derby Branch*: Monday, October 1, 7.30 p.m., The Welbeck Hotel, Nottingham. "My Own Experience in America," by Mr. J. A. Warner.

INSTITUTION OF PRODUCTION ENGINEERS.—*Manchester Section*: Monday, September 24, 7.15 p.m., College of Technology, Sackville-street, Manchester. "We Must Do Better," by Mr. E. C. Gordon England. *Luton Section*: Tuesday, September 25, 7.15 p.m., Town Hall, Luton. "Some Applications of Rubber in Engineering," by Mr. G. W. Trobridge. *Dundee Section*: Thursday, September 27, 7.45 p.m., Mathers Hotel, Whitehall-crescent, Dundee. "An Assessment of Production Engineering Training," by Mr. T. B. Worth. *Reading Section*: Tuesday, October 2, 7.15 p.m., The Great Western Hotel, Reading. "Industrial Incentives," by Mr. R. N. Marland. *Nottingham Section*: Wednesday, October 3, 7 p.m., Victoria Station Hotel, Nottingham. "The Fatigue of Metals," by Professor J. A. Pope. *South Essex Section*: Wednesday, October 3, 7.30 p.m., South East Essex Technical College, Barking. "The Problems of Modern Management," by Mr. Lewis C. Ord. *Dundee Section*: Wednesday, October 3, 7.30 p.m., The Imperial Hotel, Abroath. "Cast Iron as an Engineering Material," by Dr. H. T. Angus.

INCORPORATED PLANT ENGINEERS.—*West and East Yorkshire Branch*: Monday, September 24, 7.30 p.m., The University, Leeds. Film Evening. *South Yorkshire Branch*: Thursday, September 27, 7.30 p.m., The Grand Hotel, Sheffield. Film Evening. "Electronics in Industry." *Birmingham Branch*: Friday, September 28, 7.30 p.m., Imperial Hotel, Birmingham. Symposium of Films on "Welding." *London Branch*: Tuesday, October 2, 7 p.m., The Electric Light Manufacturers' Association, 2, Savoy-hill, Strand, W.C.2. "Planned Maintenance," by Mr. J. T. Bromley. *Southampton Branch*: Wednesday, October 3, 7.30 p.m., The Polygon Hotel, Southampton. "How the Institution Functions," by Mr. L. G. Northcroft. *Peterborough Branch*: Thursday, October 4, 7.30 p.m., Offices of Eastern Gas Board, Church-street, Peterborough. Discussion on "The Manufacture of Electric Lighting Fittings."

INSTITUTION OF HEATING AND VENTILATING ENGINEERS.—*Scottish Branch*: Tuesday, September 25, 6.30 p.m., Engineering Centre, 351, Sauchiehall-street, Glasgow, C.2. Annual General Meeting. "School Heating," by Dr. J. C. Weston. *Birmingham Branch*: Thursday, September 27, 6.30 p.m., The Imperial Hotel, Birmingham. Annual General Meeting. "Heating and Hot-Water Service for Moderate Rental Flats," by Mr. A. F. Myers. *Manchester Branch*: Friday, September 28, 6.30 p.m., Engineers' Club, Albert-square, Manchester. Annual General Meeting. *East Midlands Branch*: Wednesday, October 3, 6.30 p.m., Victoria Station Hotel, Nottingham. "Refrigeration with Special Reference to Air Conditioning," by Mr. F. L. Pettman.

INSTITUTE OF ROAD TRANSPORT ENGINEERS.—*North Eastern Centre*: Tuesday, September 25, 7 p.m., Dunelm Hotel, Old Elvet-street, Durham City. "Garage Equipment and Service Tools," by Mr. R. M. Walker. *Scottish Centre*: Monday, October 1, 7.30 p.m., Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank-crescent, Glasgow, C.2. "Heating and Ventilation of Public-Service and Heavy-Goods Vehicles," by Mr. F. Duncombe. *Institute*: Wednesday, October 3, 6.30 p.m., Central Hall, Broadway, Westminster, S.W.1. Annual General Meeting.

INSTITUTION OF MECHANICAL ENGINEERS.—*Southern Branch*: Wednesday, September 26, 7 p.m., Technical College, Brighton. Discussion on "Britain—Liquid Fuel—Engineers," to be opened by Engineer Captain H. Moy. *North Western Administration and Production Group*: Thursday, September 27, 6.45 p.m., Engineers' Club, Albert-square, Manchester. "Some Problems in the Manufacture of Experimental Gas Turbines," by Mr. L. H. Leedham. *East Midlands Provisional Graduates' Section*: Thursday, September 27, 7.15 p.m., The Midland Hotel, Derby. "The Marine Gas Turbine from the Viewpoint of an Aeronautical Engineer," by Mr. A. H. Fletcher. *North Western Branch*: Thursday, October 4, 6.45 p.m., Engineers' Club, Albert-square, Manchester. "Industrial Design and Its Relation to Machine Design," by Mr. H. G. Conway. *Institution*: Friday, October 5, 5.30 p.m., Storey's-gate, St. James's Park, S.W.1. Special General Meeting (Open to Corporate Members of the Institution only).

INSTITUTION OF MINING AND METALLURGY.—Thursday, September 27, 5 p.m., Geological Society's Apartments, Burlington House, Piccadilly, W.1. "Work in High Air Temperatures in a Fire in Mysore Mine, Kolar Gold Field," by Dr. W. B. Roantree.

ILLUMINATING ENGINEERING SOCIETY.—*Bradford Group*: Thursday, September 27, 7.30 p.m., Offices of Yorkshire Electricity Board, 45-53, Sunbridge-road, Bradford. "Lighting of Trains and Public-Service Vehicles," by Mr. S. Anderson and Mr. C. Dykes Brown. *Leeds Centre*: Friday, September 28, 7 p.m., Guildford Hotel, The Headrow, Leeds, 1. Chairman's Address, by Mr. J. Sewell. *Sheffield Centre*: Monday, October 1, 6.30 p.m., The University, Western Bank, Sheffield, 10. Chairman's Address, by Mr. G. L. Tomlinson. *Newcastle Centre*: Wednesday, October 3, 6.15 p.m., Minor Durrant Hall, Oxford-street, Newcastle-upon-Tyne, 1. Chairman's Address, by Mr. W. H. Dodgson.

INSTITUTION OF ELECTRICAL ENGINEERS.—*Mersey and North Wales Centre*: Monday, October 1, 6.30 p.m., Royal Institution, Colquitt-street, Liverpool. Chairman's Address, by Mr. E. W. Ashby. *North-Western Centre*: Tuesday, October 2, 6.30 p.m., Engineers' Club, Albert-square, Manchester. Chairman's Address, by Mr. G. R. Polgreen. *Southern Centre*: Wednesday, October 3, 6.30 p.m., British Electricity House, 111, High-street, Portsmouth. Chairman's Address, by Mr. A. L. Ashton.

INSTITUTE OF MARINE ENGINEERS.—Tuesday, October 2, 5.30 p.m., 85, The Minories, E.C.3. Presidential Address, by Dr. S. F. Dorey, F.R.S.

SHEFFIELD METALLURGICAL ASSOCIATION.—Tuesday, October 2, 6.15 p.m., The Grand Hotel, Sheffield. "World Survey of the Iron and Steel Industry," by Mr. R. A. Hacking.

ROYAL AERONAUTICAL SOCIETY.—Thursday, October 4, 6 p.m., Institution of Civil Engineers, Great George-street, Westminster, S.W.1. Seventh British Commonwealth Lecture, on "Air Transport in New Zealand and the South Pacific," by Air Vice-Marshal Sir L. M. Isitt.

INSTITUTE OF FUEL.—*South Wales Section*: Friday, October 5, 6 p.m., South Wales Institute of Engineers, Park-place, Cardiff. "Fuel Efficiency in the Oil Industry," by Mr. M. J. Stradling.

CONTRACTS.

MARCONI'S WIRELESS TELEGRAPH CO., LTD., Chelmsford, Essex, have received an order, valued at nearly 50,000l., from the British Broadcasting Corporation, for television equipment for their new studios at Lime Grove. The material to be supplied will include six complete Marconi Orthicon image camera chains, nine 10-in. picture monitors, one 16-in. picture monitor, one complete set of inter-communication equipment, vision mixing, relaying and amplifying installations, wave-form generators and test equipment, six Monoscope cameras and camera channels, and one supervisory desk.

JOHN READHEAD AND SONS, LTD., South Shields, have obtained orders recently for the construction of a cargo vessel of 8,000 tons deadweight for the Stag Line, Ltd. [Managers: Joseph Robinson and Sons], North Shields; one cargo steamship of 10,000 tons deadweight for Mr. Nicolas G. Nicolaou, Athens; and two cargo vessels, of 10,000 tons deadweight each, for other overseas owners. The vessel for Mr. Nicolaou will be propelled by triple-expansion engines working in conjunction with a Bauer-Wach exhaust turbine, to be supplied by Readhead and Sons.

COOK, WELTON AND GEMMELL, LTD., Grovehill, Beverley, Yorkshire, have secured an order from the Boston Deep Sea Fishing and Ice Co., Ltd., Fleetwood, Lancashire, for two motor trawlers of 155 ft. in length; and a contract from J. Marr and Son, Ltd., Fleetwood, Lancashire, for the construction of a motor trawler of 123 ft. in length and a steam trawler of 185 ft. in length. The propelling machinery for the three motor trawlers will be supplied by MIRELEES, BICKERTON AND DAY, LTD., Stockport, Cheshire.

POWER CUTS AND MAINS-OPERATED CLOCKS.—In a letter to the *Electrical Times*, Mr. M. Gaughan makes the useful suggestion that any difference between electric and Greenwich times caused by power cuts and frequency reduction might be broadcast during the 9 p.m. and 1 p.m. news, so as to facilitate the re-setting of synchronous clocks. As it is, he points out, during the last winter there were days when "electric time" was slow for 12 hours or more and there were several occasions when the leeway was not made up within 24 hours. In such circumstances re-setting is difficult, especially where there are a large number of clocks as on business premises.

PERSONAL.

SIR HENRY TIZARD, G.C.B., A.F.C., F.R.S., F.R.Ae.S., F.Inst.P., SIR ROWLAND SMITH, M.I.Mech.E., F.R.S.A., and Mr. J. F. LOCKWOOD have been appointed by the President of the Board of Trade to be members of the National Research Development Corporation. Other members of the Corporation, whose initial terms of service expired recently, have been reappointed, and, in addition to the foregoing, the Corporation now comprises SIR PERCY H. MILLS, K.B.E. (chairman), LORD HALSBURY (managing director), PROFESSOR P. M. S. BLACKETT, F.R.S., M.A., PROFESSOR E. C. DODDS, M.V.O., F.R.S., D.Sc., F.R.I.C., SIR JOHN MCL. DUNCANSON, SIR EDWARD H. HODGSON, K.B.E., C.B., MR. W. E. P. JOHNSON, and SIR EDWARD DE STEIN.

The Redwood Medal of the Institute of Petroleum has been awarded to PROFESSOR F. H. GARNER, O.B.E., Ph.D., M.Sc., M.I.Mech.E., and will be presented at a meeting of the Institute at 26, Portland-place, London, W.1, on October 3, commencing at 5.30 p.m.

MR. C. H. DAVY, M.I.Mech.E., has been appointed works director at the Renfrew and Dumbarton works of Babcock and Wilcox, Ltd., Babcock House, Farringdon-street, London, E.C.4. Mr. Davy, who has been chief research engineer since 1932, was elected to the board of directors in July, 1947. Mr. I. M. LYON, M.B.E., B.Sc., M.I.Mech.E., will continue in his present position as general manager of the Renfrew and Dumbarton works. Mr. T. B. WEBB, B.Sc., A.M.I.Mech.E., has been appointed chief research engineer.

MR. G. H. FLETCHER, M.I.Mech.E., M.I.E.E., has relinquished his position as general manager of the Attercliffe Common works, Sheffield, of Metropolitan-Vickers Electrical Co., Ltd., on reaching the retiring age, but will remain in the company's service as consultant for the design of motors and generators for electric traction. He will also continue as a director of Metropolitan-Vickers Electrical Export Co., Ltd. MR. R. P. KNIGHT, A.M.I.E.E., has been appointed manager of the Attercliffe Common works. MR. A. H. HARLE, B.Sc., A.M.I.E.E., has been made manager of a new sub-office of Metropolitan-Vickers Electrical Co., Ltd., which has been opened at 78-80, Hanover-street, Edinburgh. (Telephone: Central 6784.)

MR. F. R. MASON, B.Sc. (Tech.), who has been the principal representative of the Metropolitan-Vickers Electrical Export Co., Ltd., at Trafford Park, Manchester, since 1948, has been elected a director of that company.

MR. PHILIP COOK and MR. FRANK RIDLEY have been appointed directors of Daralum Castings, Ltd., Longfield-road, Darlington. Mr. Cook has been promoted to the position of general manager, and Mr. Ridley to that of secretary, of the company, as well as of the associated firm of John Vickers and Sons, Darlington.

MR. A. H. HORSFIELD, district engineer at Dewsbury for the British Insulated Callender's Construction Co. Ltd., 21, Bloomsbury-street, London, W.C.1, retired on August 31 last, after spending over 37 years in the firm's service.

MR. A. E. BARTRAM, of the turbine-construction department of the British Thomson-Houston Co., Ltd., Rugby, retired on September 6, after 31 years' service with the company.

MR. D. J. YOUNG, C.A., F.C.W.A., who has been secretary of the Steel Company of Wales, Ltd., Port Talbot, since its formation in 1947, will be known in future as "secretary and comptroller," as this title reflects more accurately the range of his responsibilities.

MR. W. H. POWELL, executive transport manager for Falk, Stadelmann & Co., Ltd., 91, Farringdon-street, London, E.C.1, has been appointed by the Minister of Transport to fill the vacancy on the Transport Users' Consultative Committee for London, caused by the death of Mr. E. W. RAINER.

KERRY'S (GREAT BRITAIN), LTD., Warton-road, London, E.15, opened new showrooms at Farnival-street, Sheffield, 1, on September 17.

B.S.A. CYCLES, LTD., Small Heath, Birmingham, formed a subsidiary company in Dublin, to be known as B.S.A. (IRELAND), LTD., for the manufacture of bicycles. RALEIGH INDUSTRIES, LTD., Lenton, Nottingham, have also formed a subsidiary, IRISH BICYCLE INDUSTRIES, LTD., Dublin, for a like purpose.

The Orb Works at Newport, Monmouthshire, which have been operated hitherto as the STEEL CO. OF WALES (LYSAGHT WORKS), LTD., will be operated as the Lysaght Division of the Steel Co. of Wales, Ltd., as from October 1, 1951. The company state that no changes in management or policy are involved.

ROTARY HOES, LTD., East Horndon, Essex, announce that they have formed a subsidiary company in France for the manufacture of all Rotavator tractor attachments. The new company will be known as ROTAVATOR ET CABROL, S.A.R.L., and has offices and works at Usine Protol, Pont Ste. Maxence, Oise. Rotary Hoes Ltd. now have subsidiary or associate companies in the United States, New Zealand, South Africa and France.

CLEANING AND RESEALING JOINTS IN CONCRETE ROADS.



FIG. 1. MACHINE FOR CLEANING JOINT AND RESHAPING ARRISES.



FIG. 2. ROTARY WIRE BRUSH.

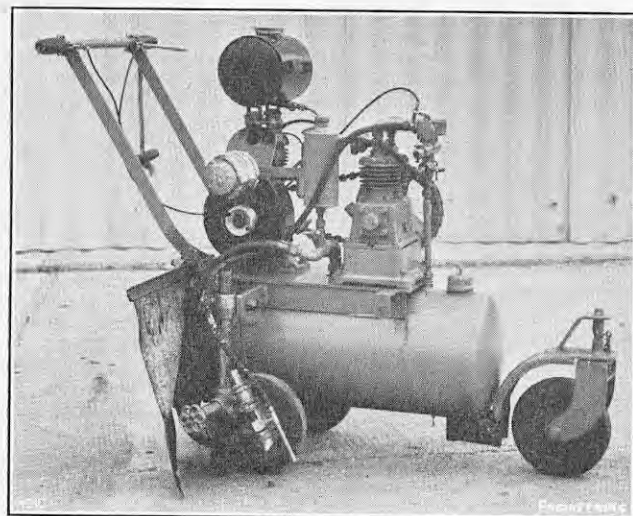


FIG. 3. COMBINED AIR JET AND PRIMING UNIT.

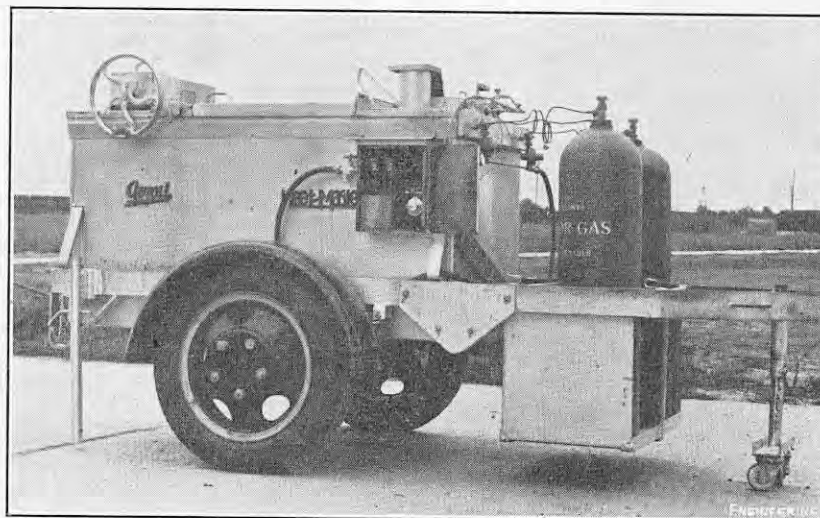


FIG. 4. THERMOSTATICALLY-CONTROLLED HEATER.

MAINTENANCE OF JOINTS IN CONCRETE ROADS.

THE cleaning and resealing of joints in concrete roadways is one of the more tedious and time-wasting jobs in road maintenance and one that lends itself readily to mechanisation. Several machines have been developed for this purpose, both here and in the United States, and in order to show the advantages to be gained from their use, the Road Research Laboratory, in co-operation with the Ministry of Transport and the County Surveyor, Surrey, have been carrying out demonstrations this week on the Kingston By-pass. These finish on Saturday, September 22, when the machines will be working between 10 a.m. and 12 noon near the Ace of Spades road house.

Four machines are being demonstrated, namely, a unit for reshaping the arrises, a rotary cleaner, a combined air-jet and priming unit, and a thermostatically-controlled heater for the preparation of the sealing compound. The reshaping machine, which also cleans out the old bitumen, is illustrated in Fig. 1, above. It is made by the G. H. Tennant Company, Minneapolis, U.S.A., and consists basically of a rotary cutter driven by a petrol engine and having six steel cutters mounted on a cutter head arranged to rotate at 2,400 r.p.m. The engine is a two-cylinder air-cooled unit developing approximately 13 h.p. and the drive is transmitted to the cutter head by triple V-belts. The cutters are built up from a series of toothed forged-steel wheels which are held between two heavy steel discs and arranged in such a way that they can be set, with the aid of spacing washers, to give cuts ranging in width from $\frac{3}{8}$ in. to 2 in. When dealing with joints in which the bitumen has spread, the routing cutters can be replaced with others designed to plane off the excess material from the surface of the road. The machine

operates at a slow walking pace and to assist the operator in following the line of the joint, a mirror is located in front of the cutter in such a way that markers showing the position of the cutter can be seen from the driving position. The complete unit is mounted on pneumatic tyres and the equipment includes an electric starter together with associated dynamo and batteries. It should be mentioned that the unit is hand-propelled, but the balance is such that handling is quite easy.

The cleaning machine is illustrated in Fig. 2; it has been developed by Expandite Limited, Cunard-road, London, N.W.10, and is used after the cutter has reshaped the arrises and loosened the old bitumen. It is of very simple construction, consisting of a steel frame mounted on pneumatic tyres and supporting a small two-stroke petrol engine arranged to drive a circular wire brush by means of V-belts. The brush, of course, rotates in the vertical plane and the machine is designed so that it can be lowered into the groove prepared by the cutter, a third wheel, the height of which can be adjusted from the handlebar, being provided for this purpose. Any dust left in the joint is removed by the combined air jet and priming unit illustrated in Fig. 3. This consists basically of a standard machine as constructed by the Tarpen Engineering Company, Limited, Ixworth House, Ixworth-place, London, S.W.3, for the application of white lines, but suitably modified by the Road Research Laboratory for spraying a bituminous primer in the prepared groove. The primer is stored in the lower part of the cylindrical vessel visible in the illustration, the vessel being also supplied with compressed air supplied by a petrol-engine driven compressor. The primer is delivered to a spray gun situated close to the ground and just behind the air jet, the two units working together, the air jet blowing out the dust prior to the application of the primer. To ensure that the primer is

not applied to a dusty surface, the spray gun is connected to the compressed-air system in such a way that it cannot operate until the air jet is in action. The engine and compressor are mounted on top of the cylindrical vessel and the equipment installed on the machine includes an automatic unloader and a separate container for holding a solvent solution used for cleaning the spray gun at the end of each working period.

The thermostatically-controlled heating tank for bituminous sealing compounds is illustrated in Fig. 4. Known as the Heetmaster, it has been developed by the Aeroil Products Company, Incorporated, South Hackensack, U.S.A., and consists of a mobile gas-fired heating tank which is oil-jacketed and can be controlled by thermo-regulators over a range of temperatures extending from 40 deg. C. to 320 deg. C. On the model illustrated, Calor gas is used for heating the oil contained in the jacket, the gas being stored at the forward end of the machine in replaceable bottles. The burners, which work intermittently under control of the thermostat, are ignited by pilot jets and, as a safety precaution, bi-metallic strips are located in the flame from the jet so that should the flames be extinguished the strips contract to shut off the gas supply to the main burners. The Heetmaster has been developed for use with rubber-bitumen compounds and is being used for heating such compounds during the demonstrations.

INCORPORATED PLANT ENGINEERS.—The Scottish branches of Incorporated Plant Engineers are arranging for a conference to be held at Dunblane Hotel Hydro, Perthshire, Friday, October 5, to Sunday, October 7. Addresses will be given by the President, Mr. D. Laey-Hulbert, B.Sc., by Mr. J. F. Field, B.Sc., and, on "Coal and Europe," by Mr. L. G. Northeroft, O.B.E., B.Sc. (Eng.). The main offices of I.P.E. are at 48, Drury-lane, Solihull, Birmingham.

ENGINEERING,

35 & 36, BEDFORD STREET, STRAND,
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We desire to call the attention of our readers to the fact that the above is the address of our Registered Offices, and that no connection exists between this Journal and any other publication bearing a similar title.

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SUBSCRIPTIONS.

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For Canada	£5 5 0

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ADVERTISEMENT RATES.

Terms for displayed advertisements on the green art paper wrapper, on the inside black and white pages and in the buff art paper two-colour supplement, as well as for insets, can be obtained on application to the Manager. The pages are 12 in. deep and 9 in. wide, divisible into four columns $2\frac{1}{4}$ in. wide. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

The charge for advertisements classified under the headings of "Appointments Open," "Situations Wanted," "Tenders," etc., is 10s. for the first four lines or under, and 2s. 6d. per line up to one inch. The line averages six words and when an advertisement measures an inch or more, the charge is 30s. per inch. If use is made of a box number the extra charge is 1s. per insertion, with the exception of advertisements appearing under "Situations Wanted." Series discounts for all classified advertisements can be obtained at the following rates:—5 per cent. for six; $12\frac{1}{2}$ per cent. for thirteen; 25 per cent. for twenty-six; and $33\frac{1}{3}$ per cent. for fifty-two insertions.

TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be received not later than first post Wednesday.

"Copy" instructions and alterations to standing advertisements for display announcements must be received at least 10 days previous to the date of publication, otherwise it may be impossible to submit proofs for approval.

The Proprietors will not hold themselves responsible for advertisers' blocks left in their possession for more than two years.

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ENGINEERING

FRIDAY, SEPTEMBER 21, 1951.

VOL. 172.

No. 4469.

GAUGING AND MEASURING
SCREW THREADS.

TOLERANCE in ethics may be tantamount to indifference; tolerance in engineering predicates a rigid specification of allowed limits. In the case of a shaft fitting in a bush, for example, apart from the question of the class of fit desired, which must be settled first, it is necessary to decide on the tolerance on the shaft, the tolerance on the bush, and the relationship between the two. From the production point of view, go and not-go gauges must be selected for the shaft and the bush, and in the toolroom the makers of the gauges must adhere to even finer tolerances, with due allowance for wear on the gauge faces. Nothing could be so unlike indifference as such systems for ensuring that the quality of the products is right, neither too low nor—of equal importance—too high. Yet there are possibly many workshops where the system and values of tolerances are not the most economical or appropriate, since an adequate study of the problem is a major task requiring a full understanding of many factors, and since new materials, new products and new production methods may invalidate the fundamentals of the existing system.

Basic data for fixing tolerances and limits, and for measuring and gauging, have been made available for many years in British Standard Specifications and publications of the National Physical Laboratory. The N.P.L. has recently commenced a series of handbooks under the general title "Notes on Applied Science," and the first to appear, *Gauging and Measuring Screw Threads*,* has been prepared by the Metrology Division—the prime source of metrological data and advice in this country. The handbook is a considerably revised and enlarged edition of the pamphlet, *Notes on Screw Gauges*, which was prepared by the N.P.L. as a result of the experience gained in testing large numbers of screw

gauges during the first World War. That pamphlet has been revised and reprinted several times in the past 25 years or so. In the new version the subject matter has been brought up to date and its scope enlarged to meet current requirements, the principal additions relating to the Unified Screw Thread System and to the measurement and gauging of tapered threads.

A screw thread has no less than seven elements of shape and size: major diameter (over the crests of an external thread or roots of an internal thread), minor diameter (over the roots of an external thread or crests of an internal thread), effective diameter (the definition of which need not trouble us here—it is approximately the mean diameter), pitch, flank angles, radius at crest, and radius at root. Of these elements the effective diameter, pitch and flank angles are perhaps the most critical and are those in which errors most frequently occur. Though it is not possible to alter one element without altering at least one other, if the major and minor diameters of an external screw thread are correct, and the effective diameter is below its basic value, the threads will be thin; conversely, if the effective diameter is above its basic value, the threads will be thick. Thus, errors in the effective diameter govern to a large extent the play between mating screw threads.

The effect of errors in pitch on the fitting together of screw threads depends not so much on the individual errors in the spacing of the adjacent turns of thread as on the additive effect of these errors, which is known as the cumulative error. Much work has been done on the examination of pitch errors, and analyses have revealed various causes, such as faulty lead-screws on lathes and eccentricity in the mounting of lathe change-wheels. To obtain a complete knowledge of the cumulative pitch error of a screw thread it is necessary to measure the error of the effective-diameter helix from one end of the thread to the other. As it is rarely convenient or practicable to do this, it is usual to measure the errors at intervals of whole pitches along a line parallel to the axis of the thread. This simplification, however, is now of much less consequence than it was formerly, since modern thread-grinding machines are so accurate that periodic and erratic pitch errors on gauges and other ground-thread products are very small.

An external screw thread with pitch error, but otherwise perfect, can be made to screw into a perfect internal screw of the same nominal size by making the threads slightly thin, i.e., by reducing its effective diameter. Likewise, errors in the angles of the flanks of an external screw thread must be accompanied by a corresponding reduction in the effective diameter if the screw is to fit a perfect internal screw thread of the same nominal size. The handbook includes formulae and tables on these two sets of relationships. Errors in the radii at the crests and roots of screw threads, particularly of gauges, are frequently of great consequence, as they may lead to superfluous metal or insufficient metal. Such defects may prevent a gauge from functioning satisfactorily, even though the measured values of the major, effective and minor diameters are correct. Where high accuracy of pitch is desired, the threads should be ground, or cut with forming tools the profiles of which have been ground. If screw threads are cut on a lathe special attention should be paid to the accuracy of the pitch generated by the screwcutting mechanism. Accuracy of pitch is particularly important where screw gauges are concerned.

The sections of the handbook relating to the measurement of screw threads are intended to refer to screw gauges, though similar methods of measurement are applicable to screw threads on components if it is necessary to measure rather than gauge them. The major diameter of a parallel plug screw gauge

* National Physical Laboratory. Notes on Applied Science No. 1. *Gauging and Measuring Screw Threads*. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 5s. net.]

is measured by an ordinary hand micrometer, or preferably a bench micrometer. The instrument is used as a comparator, in conjunction with a standard cylindrical plug of known diameter, so as to eliminate the effect of slight errors in the micrometer screw. The minor diameter is measured by means of a pair of V-pieces seating in the grooves on opposite sides of the gauge. An instrument designed for this purpose at the N.P.L., but obtainable commercially, allows the micrometer to "float" to obtain the correct alignment; it is used as a comparator in conjunction with a standard cylinder. A similar instrument and method are used for measuring the effective diameter, except that two small cylinders replace the V-piece. A formula is used to obtain the result, and corrections have to be applied for the rake of the thread and the elastic compression of the cylinders.

Normally, the pitch of screw plug gauges is measured by an N.P.L. instrument embodying a stylus which measures the pitch along a line parallel to the axis, from the first thread groove to every groove in turn. The test is repeated along a line 180 deg. round the screw from the first line, and, provided the screw is not "drunken," the maximum error in the pitch can be seen from the mean result. "Drunkeness" is a periodic pitch error which occurs during each revolution of the thread, and an N.P.L. instrument has been designed for measuring it. The error in the included angle between two flanks of a plug gauge, though not in the angle to the axis of one flank, can be determined by obtaining values for the effective diameter with two pairs of cylinders of different sizes used in succession, provided the flanks are straight.

The measurement of parallel screw ring gauges is slightly more difficult than the measurement of screw plug gauges. The minor diameter can be determined by a pair of sliding wedges (known as "taper parallels"), by a mandrel with a very gradual taper, by a range of cylindrical plugs, or by slip gauges and two rollers. Major and effective diameters must be measured by one of three special machines: a displacement machine, which employs two double-ended styli; a radial measuring machine, in which the gauge is turned through 180 deg. and the position of a stylus noted before and after; and a horizontal comparator which uses an internal-calliper principle. The diameters of screw ring gauges may be tested between limits by means of check plugs. The pitch is measured by the method used for plug gauges, and the thread form and angle are found by means of a plaster of Paris cast. Screw calliper gauges are being used to an increasing extent, and the handbook therefore describes the testing of them, as well as the use of various forms of optical projection apparatus for the examination of thread forms.

The new sections on taper screw threads will be welcomed, since the testing of such threads has not been adequately covered before. A complete set of gauges for testing a taper thread numbers ten, but, in practice, gauging is often confined to the use of a taper threaded plug gauge and a taper-threaded ring gauge, together with a plain taper plug gauge and ring gauge. The mechanical measurement of taper screw plug gauges involves the use of some of the instruments already mentioned, but it is also necessary to use a "spotting-off" technique for locating the plane in which the measurements are to be taken. For taper screw ring gauges, the major, effective and minor diameters are measured in a specified plane on the radial measuring machine already mentioned. The rate of taper, pitch, flank angle and thread form are also measured.

The handbook lives up to the customary high standard that the engineering industry has come to anticipate in N.P.L. publications. The style of the text and illustrations is as precise as the subject with which they deal.

THE TECHNOLOGY OF BROADCASTING.

It is obligatory on certain of the public and semi-public bodies which, during recent years, have been established by the wisdom of Parliament, to prepare an annual report. These documents are then laid before the House of Commons and may or may not be debated, depending upon the congestion of the political programme, the willingness of the Government to give the necessary time and other more obscure factors. In any event, the result, as far as any subsequent action is concerned, is generally meagre. Such reports are therefore mainly useful as records. Among the bodies upon whom this obligation is laid is the British Broadcasting Corporation, although this would seem to be superfluous considering the extent to which their diurnal actions are patent to all who can hear or see. Moreover, the Corporation are not averse from making public what they are doing through the Press, while the constant criticism which their commissions and omissions receive from a variety of sources afford plenty of opportunity to justify their actions and, perhaps more rarely, to amend them. Nevertheless, the annual report,* the latest of which has been published this week, is of interest since it enables the activities of the Corporation to be viewed in an atmosphere of relative calm.

The present report, which covers the year ended March 31, 1951, deals at some length with home sound broadcasting and television from the listeners' and viewers' standpoints, while the external services to Europe and other parts of the world, the monitoring service and listener research are also considered. Administration, which includes relations with external representative bodies and its own staff, as well as publicity, is also covered, as is finance, and a number of appendixes inform the curious regarding the distribution of wireless licences, the results of S.O.S. and police messages and the net sales of the *Radio Times*. The latter figures must cause envy in some publishing circles.

Further, adequate space is given to "engineering." This is as it should be, since it is upon the painstaking and imaginative work that has been carried out by Sir Noel Ashbridge and his staff that so much of the present success of the B.B.C. depends. It is clear, too, that this is likely to be equally true in the future. That this work has not been without its difficulties is shown by the fact that the position regarding the medium and long waves used for the European services has deteriorated seriously since the Copenhagen Plan was implemented in March, 1950. As will be recalled, this Plan allocated the wavelengths which might be used in the European zone and was signed by all countries on that Continent, except Russia and Spain. It has, however, practically deprived the Corporation of long-wave coverage and of the use of the medium-wavelength transmitter at Norden in Germany. The employment of short waves for the European services has, it is true, continued, but these do not provide full compensation for the other shortages. In addition, there has been considerable interference from foreign stations with the home services in certain parts of the country, particularly those in Russia and Spain. On the other hand, it is recorded that the reception of the Light Programme was improved in most home areas after the power of the Droitwich long-wave transmitter had been increased to 400 kW and that, although the limitations on capital expenditure have delayed the full carrying out of remedial projects a number of low-power transmitters, which give local coverage, have been planned, and some are now in operation.

* *Annual Report and Accounts of the British Broadcasting Corporation for the Year 1950-51* (Cmd. 8347). London: H.M. Stationery Office. (Price 4s. 6d. net.)

An alleviation, if not a solution, of these difficulties may, it is to be hoped, result from the experiments on very high frequencies, which have been carried out since July, 1950, at the high-power station at Wrotham. In the experimental transmissions from this station both amplitude and frequency modulation have been used; and a survey has been made of the field strength obtained from the two transmitters on receiving sets installed in the homes of members of the staff. These tests have now been completed and plans have been submitted to the Government which cover chains of stations for transmitting the Home, Light and Third Programmes on frequency modulation. As several of the sites suggested for these stations are the same as those chosen for existing or projected television transmitters, very high frequency aerials are being incorporated in the existing masts at those places. Once again limitations on capital expenditure will temporarily limit progress in this direction, quite apart from the fact that, before the very high-frequency service can be received, listeners will require new sets or adaptors.

It is further mentioned that improvements have been made in the acoustics of the studios and that condenser microphones, which are sensitive to sounds reaching them from one side only, have been introduced. It has also been decided to employ magnetic tape recording on a wide scale, both in the studios and for handling outside events. For dealing with such events, a lightweight transmitter which can be carried on the back of the commentator, and a microphone which can be worn on the lapel, have been brought into service.

In the section of the report which deals with television, the progress with the erection of the high-power stations at Holme Moss, Kirk o' Shotts and Wenvoe is recorded. Two new studios, equipped with modern cameras, have been opened at Limegrove, Hammersmith, and plans for three others are well advanced. It is recorded that great strides have been made in the operation of the radio links by which television signals from the outside broadcast points are conveyed to the transmitting stations. The demands for increased facilities of this kind have led to the formation of a special unit to plan and carry out the experimental and testing work entailed. It is also hoped to have an outside broadcast unit permanently stationed in Birmingham before the end of the present year and to follow this up with others in Scotland and the Bristol Channel area. This will enable a large part of the country to be opened up for the supply of television programmes. Standard 35-mm. cinematograph films can now be transmitted on equipment which has been designed by British manufacturers and is not used elsewhere in the world. This employs the "flying-spot" scanning system and enables the quality of film transmission to be raised to a level comparable with that of pictures direct from the studio. A telefilm recording process, invented by the Corporation's engineers, has also been utilised with success.

Considerable research in television is being carried out in a new building at Kingswood Warren, Surrey. Much of this work is necessarily of a long-term character and includes such problems as the improvement of picture quality, flicker and colour television. Work has also been carried out on the assessment and measurement of impulsive interference with television reception and a study has been made of acoustic conditions in the studios, where lighting and scenery may impair the quality of the sound. Some interesting figures are given under the heading of audience research from which it will be gathered that the public regard broadcasting much more as an entertainment than as a means of acquiring knowledge. For instance, of 100 evening listeners it is estimated that only one is tuned in to the Third Programme.

NOTES.

HEAT TRANSFER CONFERENCE DINNER.

At the conclusion of the three-day discussion on Heat Transfer, organised jointly by the Institution of Mechanical Engineers and the American Society of Mechanical Engineers, with the collaboration of kindred bodies, which took place in London from September 11 to September 13, a dinner was held at the St. Ermin's Hotel, Westminster, London, S.W.1, on Wednesday, September 12, which was attended by some 120 conference delegates and guests of the Institution. The President of the Institution, Mr. A. C. Hartley, C.B.E., presided. After the loyal toast and the toasts of the heads of states of the visitors from overseas, the President proposed the toast of "The Guests." Thereafter, at his request, the proceedings were largely informal, Mr. Hartley inviting various members of the gathering to respond. Those who spoke included Professor A. P. Colburn (Delaware), Professor A. L. London (Stanford, California), Mr. J. F. Alcock, Mr. L. P. Saunders (American Society of Heating and Ventilating Engineers), Dr. A. Klinkenberg (Holland), Professor J. L. Mansa (Copenhagen), Professor B. E. Short (Texas), Sir Henry Guy, Col. C. E. Davies (secretary of the American Society of Mechanical Engineers), and Mr. B. G. Robbins (secretary of the Institution of Mechanical Engineers). Mr. Robbins was presented by Col. Davies with a certificate of election to membership of the American Society of Mechanical Engineers. Professor E. A. Allcut (Toronto) proposed the health of the President, who, in the course of his reply, spoke of the ulterior value of the conference in establishing personal contacts and cementing friendships among the delegates from home and overseas, and as making for a better understanding between pure scientists and engineers. On Mr. Hartley's suggestion, the proceedings were brought to a close by the drinking of a silent toast to the various societies and institutions represented.

CHEMICAL RESEARCH LABORATORY, TEDDINGTON.

To enable those interested to see something of the work in progress at the Chemical Research Laboratory, of the Department of Scientific and Industrial Research, the laboratories were open to visitors on the afternoon of Wednesday last for a few hours. Of particular interest to engineers was the investigation on boiler corrosion which is being carried out for the British Shipbuilding Research Association. The equipment consists of four electrically-heated model cylindrical boilers, each containing six tubes 22 in. in length and 2½ in. in outside diameter, operated at working pressures representative of those used in Scotch marine boilers. Various concentrations of sea water are used for the feed and among the matters being studied are the effects of variations in pH values and dissolved-oxygen contents. Several other laboratories are engaged in work on the corrosion of metals, using interesting apparatus and techniques. For stripping oxide films from metal surfaces, iodine in methyl-alcohol is used to dissolve the metal and leave the oxide film, which can then be removed and examined in an electron microscope. Protective coatings on metals are being examined by electrochemical methods and various corrosion inhibitors are being investigated in their different applications. An interesting exhibit in the inorganic group of the laboratory was the preparation and properties of the rare metal gallium and the purification of another rare metal germanium, which has been brought into prominence recently by its application to radio apparatus, was also shown. The crude oxide of this element is derived from flue dust. The oxide is converted to a chloride, which is purified by distillation, and the purified chloride is reconverted to the oxide by hydrolysis, the oxide being subsequently reduced in hydrogen to produce the metal. A new magnetic separator for ores, known as the Franz isodynamic separator, was shown in use in the Concentration Section of the Radiochemical Group. It is used for separating small quantities of substances which are only slightly paramagnetic and, on the occasion of the visit, the machine was being used to separate a mixture of garnet, monazite and quartz. The

machine consists essentially of an electromagnet with a relatively long vibrating trough in the air gap. The trough, which is set at an angle with the horizontal and is also inclined laterally, has a central division which, however, does not extend for the whole of its length. The mixed powder is admitted at the upper end and the effect of the field is to direct it to one or other side of the central division according to its magnetic properties. When three powders have to be separated, the field strength is adjusted so that one of the substances is separated out first and the mixture of the other two is subsequently separated by passing it through again with a stronger field. There were, of course, many other processes worthy of comment, but the time available for examining them was rather too brief.

TELEVISION CONVENTION.

Further details are available regarding the Television Convention which, as has already been announced, is being arranged by the Radio Section on behalf of the Council of the Institution of Electrical Engineers. At this Convention, which will be held from Monday, April 28, to Saturday, May 3, 1952, the whole field of television will be covered in nine sessions, dealing with programme organisation, point-to-point transmission, broadcasting stations, propagation, receiving equipment (two sessions), non-broadcasting applications and system aspects. At each of these sessions, which will last about two hours, a survey paper will be presented and a number of supporting papers will be discussed. There will also be an historical paper and a broad survey paper to act as an introduction to the whole Convention. In addition to the technical sessions, there will be a number of visits to industrial and other appropriate installations. Proofs of all the papers will be available shortly before the Convention, attendance at which will be open, on payment of a registration fee, to non-members as well as members of the Institution. The proceedings of the Convention, comprising the opening addresses, the full text of all the papers and reports of the discussion, will be published in four issues of Part IIIA of the *Proceedings*, for which special application will have to be made.

BEILBY MEMORIAL AWARDS.

The Royal Institute of Chemistry announces that consideration will be given early in 1952 to the making of an award or awards from the Sir George Beilby Memorial Fund, which is administered jointly by representatives of the Institute, the Society of Chemical Industry and the Institute of Metals. The awards are made to British scientists who have done distinguished work, preferably in fields which were the special interests of the late Sir George Beilby, including fuel economy, chemical engineering and metallurgy. Workers of established repute are not eligible, in general, for the awards; they are granted to younger men in recognition of original work of exceptional merit over a period of years, which has advanced scientific knowledge or practice. They are not made as the result of any competition, and the administrators are empowered to make more than one of them in a given year if work of sufficient merit by several candidates is brought to their notice. In 1950, two awards, each of 100 guineas, were made. The administrators will be glad to receive notice of outstanding work of the type indicated, not later than December 31, 1951. All communications should be addressed to the Convenor of the Administrators, Sir George Beilby Memorial Fund, Royal Institute of Chemistry, 30, Russell-square, London, W.C.1.

THE NATIONAL SMOKE ABATEMENT SOCIETY.

The 18th annual conference of the National Smoke Abatement Society is to be held at the Winter Gardens, Blackpool, next week, from Wednesday to Friday, September 26 to 28. On the opening morning, after a welcome by the Mayor of Blackpool, Dame Vera Laughton Mathews will deliver the presidential address, and in the afternoon the second Des Voeux Memorial Lecture, on "Power and Waste in Their Social Setting," will be given by Dr. J. Bronowski, Director of the Central Research Establishment of the National Coal Board. On Thursday morning, under the chairmanship of Mr. W. A. Damon, a group of papers on "The

Smokeless Operation of Small Steam-Raising Plant" will be presented by Mr. V. R. Chadwick (hand-fired boilers), Mr. C. H. G. Hayward (chain-grate stokers), Mr. H. E. Pearsall (coking and sprinkler stokers), Mr. Colin C. Day (underfeed stokers), and Mr. G. A. G. Ive (smoke-indicating devices). "Policies for the Prevention of Industrial Air Pollution" will be the general title for a group of papers to be presented on Friday morning, with Sir Ernest Smith, C.B.E., in the chair; the authors are Mr. N. Higginson (collieries), Mr. J. W. Denton (gas industry), Dr. H. E. Crossley (electricity generation), Mr. Neil H. Turner (iron and steel manufacture), and Mr. E. Burke (cement manufacture). Three papers on "Smoke Prevention in the Home—the Woman's Viewpoint" will be presented on Friday afternoon, with Alderman Miss Mary L. Kingsmill Jones, C.B.E., in the chair; they are by Mrs. E. Fraser-Stephen (solid fuel), Miss Lovell Burgess (gas), and Dame Caroline Haslett (electricity). Several social events are also to be held. The address of the Society is Chandos House, Buckingham-gate, London, S.W.1.

LETTER TO THE EDITOR.

BRITISH ASSOCIATION
DISCUSSION ON METALS AND
ALLOYS.

TO THE EDITOR OF ENGINEERING.

SIR,—With reference to your report on my contribution to the discussion on the papers presented at the B.A. Meeting by Professor Quarrell and Mr. T. S. Robertson, in your issue of August 31, page 278, columns 2 and 3: due to the shortage of time for this discussion, I was speaking very rapidly and there are two points in the report which do not give the sense I intended.

The first is about half-way down column 2. The sentence "In his own work, for example, where steel was being held at 900 deg. C. for 30 seconds between the salt bath and quenching, the fatigue life had been halved by polishing 0.001 in. from the surface" should read "In his work, for example, where steel was being held at 900 deg. C. between the salt bath and quenching, the fatigue life had been halved. By polishing at 0.001 in. from the surface the fatigue strength of the metal was restored."

The second is about one-third of the way down column 3. The sentence "It could be assumed that the yield strength was affected by the shear stress, and the cohesive strength by the co-axial stress; so that if there were a co-axial stress, there could be no shear stress, but the cohesive stress would rise," should read "If it were assumed that the yield stress was affected by the shear stress and the cohesive strength by the maximum direct stress, then if a piece of metal were subjected to triaxial stress (hydrostatic tension), there would be no shear stress, but the maximum direct stress would increase until the cohesive strength was exceeded and the metal failed in a brittle manner."

Yours faithfully,

J. A. POPE.

Head of the Departments of Engineering,
University of Nottingham,
University Park,
Nottingham.
September 19, 1951.

MERGER OF MANAGEMENT INSTITUTES.—The Institute of Industrial Administration has been merged with the British Institute of Management, and all members of the I.I.A. become Founder Members, Associates or Students of the B.I.M. As B.I.M. membership is not intended to constitute a professional qualification, the I.I.A. has been incorporated as a general management professional institute within the framework of the B.I.M., its membership being open only to members of the B.I.M. Thus, the I.I.A. becomes, in effect, the professional wing of the B.I.M. The terms for merger between the councils of the two bodies required ratification by the written consent of at least 75 per cent. of the total membership of the I.I.A., and this was obtained within rather more than a week after the issue of the voting papers.

THE IRON AND STEEL INSTITUTE.

As already announced in our columns, the Iron and Steel Institute have been holding a special meeting in Austria at the invitation of the Technisch-Wissenschaftlicher Verein Eisenhütte Oesterreich. The meeting opened on September 6 and was concluded on September 18. The first portion of the meeting was held at Gmunden, in Upper Austria, from which excursions were made to the Vereinigte Oesterreichische Eisen und Stahlwerke A.G., at Linz (this excursion including a trip on a steamer on the River Danube), and to the Vereinigte Aluminium Werke A.G., at Mattigwerke, and the Oesterreichische Metallwerke A.G., at Ranshofen, both near Braunau-sur-Inn. On Saturday, September 8, the members left Gmunden for Graz, the capital of Styria, by special train. On the way a stop was made to visit the Veitscher Magnesit A.G., at Trieben, and to partake of lunch at these works. On Monday, September 10, the Institute was given a formal welcome in the Stefaniensaal in Graz on behalf of the Austrian reception committee, the State of Styria, the city of Graz and the University of Mining and Metallurgy, Leoben. Dr. J. Oberegger, President of the Eisenhütte Oesterreich, occupied the chair.

In the course of his speech of welcome, Dr. Oberegger recalled that, when the Institute last visited Austria, in 1907, the Austro-Hungarian Empire was in being. At the present time, Austria, the core of the former Empire, was a small country. As in Great Britain, however, Austria could look back on long years of tradition in the manufacture of iron. In spite of the fact that ore had been mined for hundreds of years, the known deposits still amounted to some 350,000,000 tons, which, at the present rate of consumption, would assure the existence of an Austrian iron and steel industry for more than 150 years. In addition to these important iron-ore deposits, Austria also possessed considerable deposits of anthracite and lignite, situated in the immediate neighbourhood of the steelworks. The large number of rapidly flowing rivers and streams not only provided a considerable source of energy, but also yielded adequate supplies of water. Other raw materials, such as limestone and quartz, and above all, the valuable refractory material magnesite, were available in sufficient quantity and adequate quality. For one raw material only, namely, metallurgical coke or coking coal, essential to the operation of blast furnaces, Austria was entirely dependent upon imports. Like the British industry, the Austrian iron and steel industry had considerably increased its output since the war. In 1937, Austria had produced 1,885,000 tons of iron ore, 388,000 tons of pig iron, and 650,000 tons of steel ingots. In spite of political and other difficulties, the production of ore was being considerably increased during 1951 and it was hoped, during that twelve months, to produce one million tons each of pig iron and ingot steel.

Professor F. Platzer, Rector of the University of Leoben and a member of Council of the Eisenhütte Oesterreich, who also welcomed the Institute of Austria, stressed the importance of close intercourse between countries to promote cultural and scientific relations. Other speeches of welcome were delivered by Dipl. Ing. Karl Waldbrunner, Minister of Transport and Nationalised Industries, and by Dr. Ing. Leopold Figl, the Austrian Chancellor.

Mr. R. Mather, the President of the Institute, thanked all the individuals and firms who had contributed, and were contributing, to the success of the meeting. He also emphasised the international character of the Institute, adding that 1,300 of the members came from countries outside the United Kingdom. Moreover, the Bessemer Medal, the highest honour in the Institute's power to bestow, had been awarded to many distinguished overseas metallurgists. In 1878, only five years after its foundation, the Medal had been presented to Peter Ritter von Tunner, the first Professor of Ferrous Metallurgy and Director of the Leoben University. At the conclusion of his speech of thanks, Mr. Mather announced that, quite recently,

the Council of the Institute had decided to offer an honorary vice-presidency of the Institute to Dr. Oberegger, in recognition of his services to industry and in connection with the Austrian meeting. In a brief speech, Dr. Oberegger thanked the Council and members for the honour conferred upon him.

After luncheon in the open-air restaurant on the Schlossberg, a hill 1,550 ft. in height, overlooking the town of Graz, the members reassembled in the Stefaniensaal, in the afternoon of September 10, for a joint technical session with the Eisenhütte Oesterreich. Mr. Mather occupied the chair and stated that two papers had been specially prepared for the meeting, namely, "The 2,000 Year Tradition of the Austrian Iron and Steel Industry," by Professor R. Walzel, of the Leoben University, and "The Present Metallurgical Bases of Austrian Iron and Steel Production," by Dr. B. Matuschka, of the Vereinigte Oesterreichische Eisen und Stahlwerke A.G., Linz. Although neither paper contained matter for discussion, they constituted records of facts and were thus valuable additions to the Institute's proceedings.

THE AUSTRIAN IRON AND STEEL INDUSTRY.

The paper by Professor R. Walzel traced the growth of the Austrian iron industry, which, he pointed out, was based on two main sources of ore, one in Carinthia and the other in Styria. The Romans had used the Styrian ore for making arms and tools. So long as the smelting of iron was carried out with charcoal, Austria held an ample supply of fuel from the large Alpine forests, and adequate water power was available everywhere for operating the blowers used in the reduction process. The development of the coke blastfurnace had been a serious blow to the Austrian iron industry, as Austria had no deposits of bituminous coking coal. The change-over to coke smelting had been made with hesitation, and not until 1870 had the first coke blastfurnace been blown in. Since then, however, a large-scale iron industry had been built up, using imported coke and coking coal. The present blastfurnaces at Donawitz and Linz were among the most efficient in Europe; the coke consumption, to which Austrian blast-furnacemen always paid great attention because supplies had to be imported, had been reduced to less than 16 cwt. per ton of iron. The comparatively cool-blow manganese-rich pig iron was an excellent raw material for the production of high-grade steels.

The effect of the invention of the Bessemer process had been comparatively small, and this process had declined and disappeared when the open-hearth process was invented. The electric-furnace process was also of great importance. The first arc furnaces in Austria had been put into operation in 1908, and, soon after the war of 1914-18, some high-frequency furnaces had been installed. An 8-ton furnace, the largest in existence up till that time, had been built at Ternitz. Electric steel-making had now completely superseded the crucible process in Austria and comprised about 16 per cent. of the total raw-steel production. The large-scale requirements for plain-carbon steels were met by the open-hearth steelworks at Donawitz and Linz, the latter containing 200-ton furnaces, and by the works at Kapfenberg, Ternitz, Diemlach, Judenburg, and Liezen. At the same time, the works at Kapfenberg, Donawitz, Linz, Ternitz, Judenburg, Liezen and Breitenfeld made electric steels in arc and high-frequency furnaces to meet the demands for special and alloy steels.

THE BASIS OF AUSTRIAN IRON AND STEEL PRODUCTION.

In his paper, Dr. B. Matuschka stated that the burden in Styrian blast furnaces consisted almost entirely of Styrian and Carinthian ores, but the coking coal had to be imported from the Ruhr, from Poland, or from Czechoslovakia. As pointed out by Dr. Oberegger in his opening speech, in 1937 the Austrian steel production had amounted to about 650,000 tons and the pig-iron output to 388,000 tons. Since the war, a plan providing for an annual steel production of 1,000,000 tons had been drawn up, and, under it, the production of rod, sections and wire was to remain concentrated chiefly

at the Donawitz works. The works at Linz, which had been newly built during the war, were to be the centre of steel production. Trials with oxygen-enriched blast had given good metallurgical results and pilot Bessemer-converter plants and oxygen generators were being erected at Donawitz and Linz. The high-manganese content of the pig iron protected the metal from over-oxidation during blowing with oxygen, and ensured the production of nitrogen-free high-quality steel, similar to open-hearth steel.

EFFECT OF INCLUSIONS ON STEEL WORKABILITY.

"Investigations into the Effect of Non-Metallic Inclusions on the Hot-Workability of Steel" was the title of the only paper to be discussed at the meeting. It was by Mr. F. Rapatz and Mr. M. Strobich, of Gebr. Böhler A.G., Kapfenberg, who stated that the paper gave the results of some investigations, and indicated the nature and quantity of inclusions that a steel could tolerate without prejudice to its hot-workability. Non-metallic compounds had been added arbitrarily to steel and this had been accomplished by mixing various quantities of the components with iron powder which contained about 3 per cent. of oxygen and about 2 to 4 per cent. of carbon. Quantities of CaO , SiO_2 , CaF_2 , Na_2CO_3 , and Na_2SiO_3 , of given sizes less than 0.1 mm., had been mixed with the iron powder and the mixture was packed into steel tubes 2 in. in diameter, 14 in. in length, and $\frac{3}{8}$ in. in wall thickness. The two ends of the tubes were sealed by welding cover plates on to them and, in all cases, a 1-mm. diameter hole had been made in the cover plate, to allow the escape of gases formed during the reactions. The filled tubes were heated for 25 to 30 minutes at 1,250 deg. C. in a gas-fired furnace and the specimens were then given a first deformation by stamping in a die at a temperature of 1,200 deg. C. Complete consolidation in the transverse direction had been achieved with only slight lengthening. The bars so obtained had been subjected to further deformation by free forging.

The results had shown that the addition of up to approximately 6 per cent., by volume, of high-melting point inclusions did not cause internal cracks under the experimental conditions; the behaviour, as regards forgeability, was like that observed when carbides were added. Non-metallic compounds having low-melting points, such as Na_2CO_3 and Na_2SiO_3 , even where present to the extent of only $1\frac{1}{2}$ per cent. by volume, made hot working impossible. The occasional poor forgeability of acid steel was attributed to the relatively low melting points of some silicates, in comparison with those of basic inclusions. Pure SiO_2 had a high melting point, and only rendered hot-workability difficult when present in large amounts. Bars prepared from steel powder by hot working had almost the same mechanical properties as those prepared by casting and rolling. There would seem to be a variety of possible new applications for hot-worked steel powder mixed with non-metallic additives.

The discussion was opened by Mr. W. Barr, who congratulated the authors on their novel method of investigating the hot-workability of steel. At the outset of their paper, the authors had said that it was usual to ascribe difficulty in hot-working to the effect of non-metallic inclusions. To this, he (Mr. Barr) would answer that, at the Colville works, casting temperature, teeming speed and other factors were also of importance. Nevertheless, inclusions provided a fruitful field for investigation. The authors had been, perhaps, rather too brief in the description of the technique they had adopted for making and forging their bars, and a few more details would clear up some doubtful points. One factor in favour of their method was that the non-metallic inclusions did "stay put" and facilitated the investigation in many respects. The authors had also stated that their results indicated the nature and quantity of inclusions that a steel could tolerate without prejudice to its hot-workability, but they had added that no final conclusions had been drawn. The important word in this statement, continued Mr. Barr, was "quantity," and in their conclusions the authors stated that up to 6 per cent. by volume of high-melting point inclusions, such as silica, had no deleterious effects on hot-workability. A steel

containing such a high percentage of SiO_2 , however, could not be used for such processes as the making of tubes by the hot rotary piercing press.

Professor F. C. Thompson, who was the only other speaker, agreed with Mr. Barr that the experimental technique employed was both ingenious and novel. For the particular purpose of the research, this technique was better than that which involved boring holes in a bar and filling these up with inclusions. The authors had demonstrated that the melting points of the inclusions were of first-rate importance, but it had been shown about 40 years before that the shape of inclusions was also of considerable importance. In conclusion, he paid tribute to the historical value of the two papers submitted by Professor Walzel and Dr. Matuschka. Their interest was by no means confined to Austria, and many of the facts presented were worthy of note by all concerned with the history of iron and steelmaking in other countries.

Mr. Strobich, in a brief acknowledgment, said that in two places in the paper as printed in the *Journal* of the Institute it had been stated that the iron powder in the 2-in. diameter tubes had been sintered and then forged down to 2 in. in diameter. This was a printer's error and should have read "forged down to 0.2 in. diameter."

RECENT ADVANCES IN BRITISH OPEN-HEARTH FURNACES.

The last item on the agenda was the delivery of a lantern lecture, entitled "Recent Advances in British Open-Hearth Furnaces," by Dr. J. H. Chesters, assistant director of research, the United Steel Companies, Limited, Sheffield. In the course of his lecture, Dr. Chesters stated that the open-hearth furnace was a complex unit, any change in which tended to react on the structure and operation as a whole. Thus the life of the furnace refractories depended on a flow pattern within the furnace and the permissible combustion practice was limited by the refractories available. During the last few years a concerted effort had been made in Great Britain to provide the fundamental data needed for the scientific design and operation of open-hearth furnaces and it was his intention, in the present lecture, to indicate the broad general line of approach. The work of Dr. A. H. Leckie and his colleagues of the British Iron and Steel Research Association, on a one-fifth scale "hot" model of an open-hearth furnace, and a co-operative investigation, by the United Steel Companies, Limited, and the British Coal Utilisation Research Association on the influence of port design on open-hearth furnace flames, had been followed by extensive work in a number of laboratories, utilising hot small-scale furnaces or models adapted to use air or water. These researches had now reached the stage at which full-size furnaces were being built on the basis of data obtained from the models. Furthermore, flow patterns, developed in two-dimensional and three-dimensional water models, were being used in the design of actual furnaces. The distribution of refractory wear had been explained in terms of flow patterns, and changes in design suggested by flow-pattern work had already led to improvements in refractory life.

For oil-fired furnaces, the general trend was towards single-uptake designs, which not only made for longer roof life, but gave faster mixing and combustion, and, consequently, greater output. Moreover, the sloping of the end walls facilitated the protection of the roof and side walls from flame impingement and substantially reduced end-wall wear. Although the main roof accounted for only 10 per cent. of the total refractories and bricklaying labour costs in an open-hearth furnace, attention was still focused on it, because it limited, more than any other section of the furnace, both the output rate and the furnace availability. Substantial improvement in roof life had been obtained by the use of low-alumina silica bricks of high bulk density and also by the adoption of all-basic refractory construction. The most remarkable results using silica had been obtained by the adoption of South African quartzite, the alumina contents of bricks made from this material being only about 0.3 per cent., and the porosity roughly 10 per cent. below the normal figure. Since the war, six furnaces in Great Britain had been converted to

all-basic refractory construction; one of these had already had a roof life of well over 1,000 heats, in spite of an increase in output rate of about 30 per cent. At other plants, however, experience had not been so favourable and considerable improvements, both in basic-brick quality and in design and operation, were required before such furnaces could become generally economic. Fast driving, at appreciably higher than normal roof temperature, was advocated to maintain the fuel costs and the overhead charges below the level of those for furnaces furnished with silica roofs.

Rapid strides had been made in instrumentation and automatic control, and it was now widely agreed that all open-hearth furnaces should be fitted with instruments to indicate, and, where necessary, to record, such quantities as fuel flow, air flow, furnace pressure, roof temperature, and chequer temperatures. With furnaces fired with liquid fuel, the steam employed for atomisation should also be measured by a meter. The intelligent use of such instruments had enabled outputs to be raised without a corresponding increase in refractory costs. Indeed, a distinct advantage of roof-pyrometer control was the improvement in life obtained where the roof was maintained below 1,650 deg. C. During the last few years, a number of firms had completed, or fitted, automatic-control equipment to govern, in particular, roof temperature, fuel flow, furnace pressure, and the chimney-stack dampers, and most of these firms claimed that the advantage gained was more than sufficient to offset the extra cost of installing and maintaining such equipment.

FLUID FLOW.

At the conclusion of Dr. Chesters' lecture, a sound colour film, entitled "Fluid Flow," was shown. This indicated the relation which existed between flow in furnaces and the flow around such structures as boats, aeroplanes and motor cars. The film indicated also that future development called for simplicity and symmetry in the flow pattern, so that the desired conditions could be specified and subsequently obtained. Time did not allow of discussion of Dr. Chesters' lecture and the meeting concluded with votes of thanks to the authors and speakers. In the evening, a reception in the Burg at Graz was given by Landeshauptmann J. Kranner, Governor of the State of Styria.

VISITS AND EXCURSIONS.

On Tuesday, September 11, a visit was paid to the Montanistische Hochschule, Leoben (the University of Mining and Metallurgy at Leoben) and the Oesterreichisch-Alpine Montangesellschaft at Donawitz, a mile or two distant. At the Hochschule, a reception was held, at which the Rector, Professor F. Platzer, and the Burgomaster of Leoben, Mr. G. Heindler, delivered speeches of welcome. In return, Mr. Mather and Sir Charles Goodeve, O.B.E., D.Sc., expressed their thanks. In the evening, a reception and dance was held in the Kammersaal, Graz, at the invitation of Dr. E. Speck, Burgomaster of Graz. On Wednesday, September 12, an all-day visit was paid to the Steirische Erzberg, the Styrian iron-ore mountain, and on the following day, Thursday, September 13, visits were made to Gebrüder Böhler A.G., Kapfenberg; Oesterreichisch-Alpine Montangesellschaft, Kindberg; Felten und Guilleaume A.G., Bruck-a.-d.-Mur; Schoeller-Bleckmann Stahlwerke A.G., Hönigsberg-Mürzzuschlag; Elin A.G., Weil; Steyr-Daimler-Puch A.G., Graz; and Andritz Measchinenfabrik A.G., Graz. On Friday, September 14, members travelled by road from Graz over the Packstrasse to Klagenfurt and, after lunch at Klagenfurt, visits were paid to the Kärntnerische Eisen-und Stahlwerke A.G., and the Guild of Gun Makers, both of Ferlach. After these visits the party proceeded to Portschach, where a reception given by Landeshauptmann F. Wedenig, Governor of the State of Carinthia, was held at the Park Hotel. On Saturday, September 15, the Oesterreichisch-Amerikanische Magnesit A.G., Radenthein, and the Bleiberger Bergwerks Union, Bleihütte Gailitz, and in the evening a dinner and dance was held at the Hotel Werzer-Astoria, Pörschach. The remaining three days of the meeting, from Sunday, September 16, until Tuesday, September 18, were spent at Zell-am-See in the State of Salzburg, during which a visit was paid to the Tauernkraftwerke A.G. at Kaprun.

ANALYSIS OF GEAR-TOOTH UNDULATION RECORDS.

By P. M. GILET.

ONE of the important tests made in the examination of large hobbled gears is the measurement of undulations. All such gears must be tested for undulations as part of their complete examination. In addition to this aspect, however, undulation measurements can give important information about the various errors of the machine on which the gear was hobbled.

When undulation measurements are made with the sole aim of determining whether the gear is satisfactory, it is only necessary to determine the maximum amplitude of the undulations; but to do this, as will be shown later, it is often necessary also to determine their wavelengths. Moreover, when the tests are made to determine the machine errors which give rise to the undulations, not only is the amplitude required, but also the wavelength, in order to distinguish between the various possible sources of error.

The National Physical Laboratory (N.P.L.) type of undulation recorder has been in use for many years and is well known. This instrument has three ball feet closely in line, each of the outer two feet bearing against both flanks of the tooth space concerned, and the middle foot being made to bear against one flank. As the instrument is traversed along the tooth space, undulations on this flank cause the middle foot to move at right angles to the line joining the outer feet. This movement is magnified by the instrument and recorded radially on a smoked-glass plate, which is rotated by an amount proportional to the distance travelled by the instrument along the tooth space.

It is clear that, with such an arrangement, the magnification factor of the record will depend on the relationship between the separation of the feet and the wavelength of the undulation. For example, if the middle foot is midway between the outer feet, and the separation of the outer feet is equal to an even number of wavelengths of the undulation, the magnification factor will be zero, i.e., the undulation will not be recorded. If the distance between the outer feet is an odd number of half wavelengths, the magnification factor of the record will be that of the instrument (about $\times 18$); and if the distance between the outer feet is an odd number of wavelengths the magnification factor will be approximately $\times 36$. The magnification factor of the record is given by the expression

$$K \left(1 - \cos \frac{\pi L}{\lambda} \right),$$

where K is the magnification factor of the instrument; λ is the wavelength of the undulation; and L is the separation of the two outer feet, the third foot being midway between them.

The procedure normally followed, to allow for the fact that the amplitude of the recorded undulation varies with its wavelength, is as follows. The possible causes of undulations are first listed. These include the possible daily change in temperature during hobbing, as well as periodic departures from uniformity in the motion of the machine table and of the hob saddle, due to periodic errors in the motions of the various machine elements, such as, for example, axial float of the main worm. From a knowledge of the way in which the machine was set up for hobbing the gear concerned, it is possible to calculate the wavelengths of undulations due to the various causes. A table is made of all these possible wavelengths, as well as of all their odd multiples up to about 5 in. Values are chosen from this table for the various settings of the outer feet of the recorder. It is usually possible to choose three or four settings such that an odd multiple of each possible wavelength is close to one or more of the setting values. In this way, it is ensured that any possible undulation will be recorded with a reasonably large magnification factor for at least one setting.

Often there is only one main source of undulations, and each record takes the form of an approximate sine curve of uniform amplitude. It is an easy matter then to determine the wavelength of this

ANALYSIS OF GEAR-TOOTH UNDULATIONS.

REPRODUCTIONS OF ACTUAL UNDULATION RECORDS

Fig. 1. INSTRUMENT SETTING 1.8 INCHES

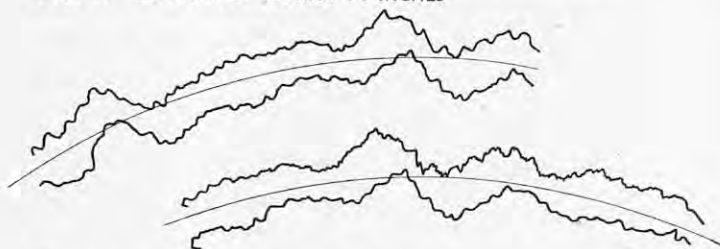


Fig. 2. INSTRUMENT SETTING 3.0 INCHES

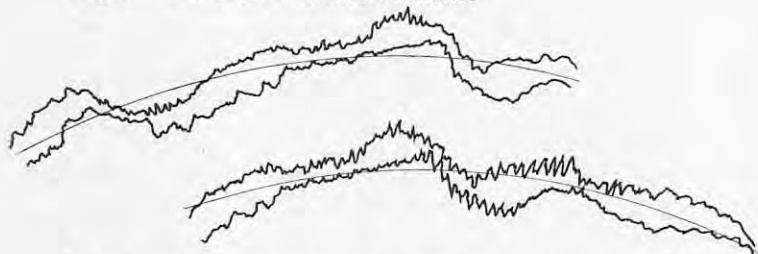
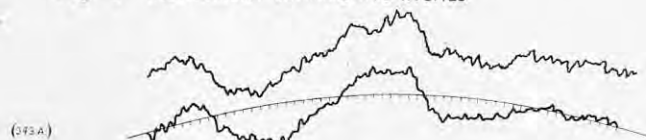


Fig. 3. INSTRUMENT SETTING 4.76 INCHES



approximate sine curve and its amplitude on the record. The wavelength and the instrument setting for that record enable the record magnification factor to be calculated from the expression given above, and hence not only the wavelength, but the amplitude of the actual undulation can be determined.

It sometimes happens, however, that two or more main sources of undulation are present, so that the actual undulation on the tooth flank takes the form of what may be described as a "beat" wave; in other words, the actual undulation has several components, each of which is an approximate sine curve, but which have various amplitudes, phases and wavelengths. The record is then also a combination of several approximate sine curves, but, whereas the component wavelengths are not affected by the undulation recorder, the amplitudes are recorded with varying magnification factors, so that the shape of the recorded composite curve may be quite different from that of the actual composite undulation. (See Appendix.)

Such a case recently occurred in the testing of a turbine reduction wheel, 12 ft. in diameter. Records had been taken at four different instrument settings, ranging from 1.8 in. to 3.0 in. An attempt was made to determine the wavelengths and amplitudes by inspection in the usual way, but this was soon discarded. It was realised that there were at least three main sources of undulations and that it was not possible by inspection to determine the wavelengths and the record-amplitudes of the component undulations.

It was clear that a procedure was required which would give definite information about the wavelength and amplitude of each component undulation, with no risk of neglecting a component because it was "masked" by the others. The method used is described below. It is not a new method, and, indeed, is used in the analysis of records of periodic errors in the table and hob-saddle motion of a hobbing machine, obtained by the N.P.L. test with smoked-glass plates. As far as can be ascertained, however, from the literature of the past few years, the method does not appear to have been applied before to the analysis of undulation records.

The method depends on the following principle. If two sine curves of different wavelength and amplitude are combined, a beat curve is obtained, the complete beat cycle having a length equal to the least common multiple of the two component wavelengths. If a length of the beat wave covering a complete cycle is divided into parts, each equal

in length to one of the component wavelengths, say, λ_1 , and these part curves are averaged, the mean curve so obtained is one cycle of the component curve of wavelength λ_1 , the effect of the other component having been eliminated. Similarly, if the beat cycle is divided into parts, each of length equal to the wavelength of the other component, the mean curve obtained is one cycle of this other component.

The undulation records are analysed, making use of this principle. The actual procedure will vary greatly, depending on the individual case, and it is not proposed to describe the method any further in general terms. An actual example is given below, to illustrate the method, and this will make clear the procedure which should be followed in any given case.

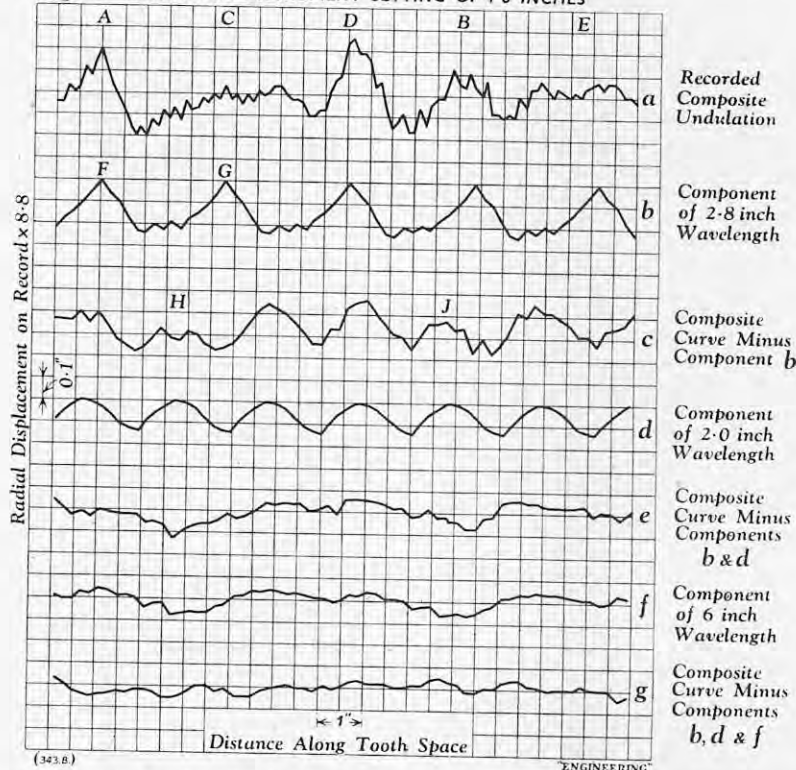
The example is taken from the work done in the examination of the 12-ft. diameter wheel mentioned above. This wheel was regarded primarily as a test gear, giving evidence of the performance of the hobbing machine. Three records were analysed in full, two of them having been taken on the same part of the same flank of a particular tooth face of the wheel. These records were quite typical of records taken on four other tooth spaces of the wheel, and it was thought unnecessary to analyse these other records in full; though a partial analysis was made, sufficient to show that the component undulations for all tooth flanks were similar in wavelength and amplitude.

Of the three records fully analysed, two were taken at instrument settings (separation of outer feet) of 1.8 in. and 3.0 in. Analysis of these records indicated the presence of a hitherto unsuspected component undulation of large amplitude and wavelength. The wavelength was, in fact, greater than the maximum setting of the available instruments. In an attempt to confirm the presence of this component, records were taken at the maximum possible instrument setting of 4.76 in. One of these records is the third record mentioned above as having been fully analysed.

For this third record, the instrument travel was $1\frac{3}{4}$ in. The other two records were, in fact, each composed of two overlapping records, the two overlapping records together covering about 14 in. along the tooth space. The single third record and the two pairs of overlapping records are shown in Figs. 1, 2 and 3, herewith. In each record there are two curves, one for each flank of the tooth space. The upper curve only of each record is dealt with in this example.

The two overlapping records at the 1.8-in. instru-

Fig. 4. CURVES FOR INSTRUMENT SETTING OF 1.8 INCHES



ment setting were measured, and from the measurements the graph of Fig. 4 was plotted. It seemed that this curve was a beat curve with at least three components, the beat cycle for two of the components extending from A to B. Now the calculated wavelengths of possible components included, among others, the values 1.94 in., 2.48 in., and 2.60 in.

It was found possible to show from the records that the component wavelength, 2.60 in., was not present. It was noted that the length AB of $8\frac{1}{2}$ in. was approximately equal to 4 in. by 2.0 in. and also approximately equal to 3 in. by 2.8 in. It was considered, therefore, that the beat wave of length AB was composed of two component undulations of wavelengths measured to be 2.0 in. and 2.8 in., which were probably the 1.94-in. and 2.48-in. components. The presence of the 2.8-in. component in curve *a*, Fig. 4, can be seen by noting the distance between the peaks A, C, D, B and E. It will be noted, however, that the presence of the 2.0-in. component is not at all evident from this curve.

The curve *a* of Fig. 4 between A and B was, therefore, divided into three parts and an average curve calculated. The calculated values are shown plotted from F to G in curve *b*, Fig. 4. The ordinates of the curve *b* were subtracted from those of curve *a*, with the results shown in curve *c*.

It is probable that the beat wave from A to B of curve *a* does not contain exactly four cycles of one component, nor exactly three cycles of the other component. Moreover, the beat wave is unlikely to contain an exact number of cycles of the other components. The averaging procedure, therefore, would not have completely eliminated the 2.8-in. component from curve *c*. It is considered, however, that the greater part of this component was eliminated.

It will be noted that in curve *c*, peaks now appear at intervals of about 2 in. These peaks were quite masked in curve *a* and, had the method by inspection been used, this component would have been missed. It will also be noted from curve *c* that the peaks at H and J are not as high as the others. This indicates that the 2.0-in. component is beating with some other component and that the beat cycle has a length HJ of approximately 6 in. The curve *c* from H to J was therefore divided into three parts and an average curve obtained as before. This curve is shown in curve *d*, Fig. 4, and is considered to be a good approximation to the 2.0-in. component.

The curve *d* of Fig. 4 was subtracted from that of curve *c*, giving the curve shown at *e*. This curve

ANALYSIS OF GEAR-TOOTH UNDULATIONS.

Fig. 5. CURVES FOR INSTRUMENT SETTING OF 3.0 INCHES

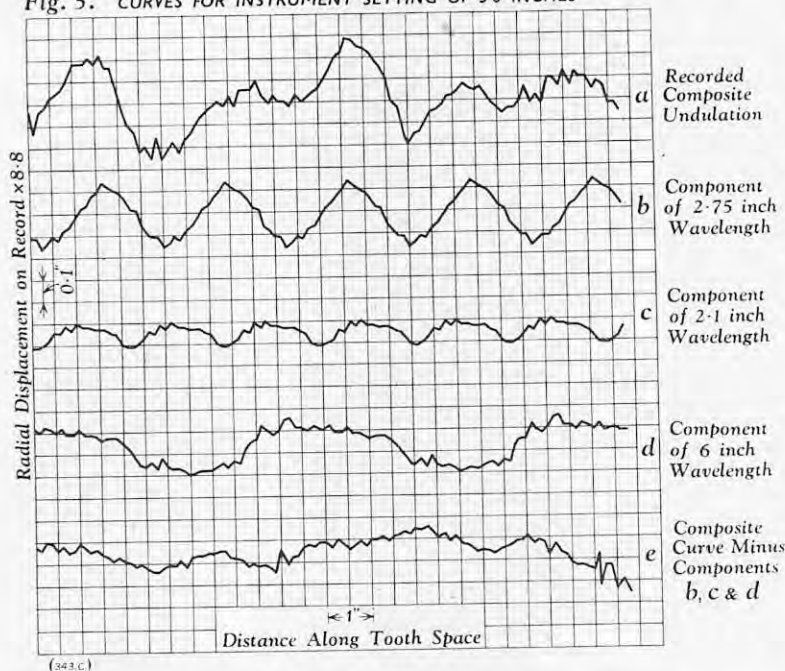
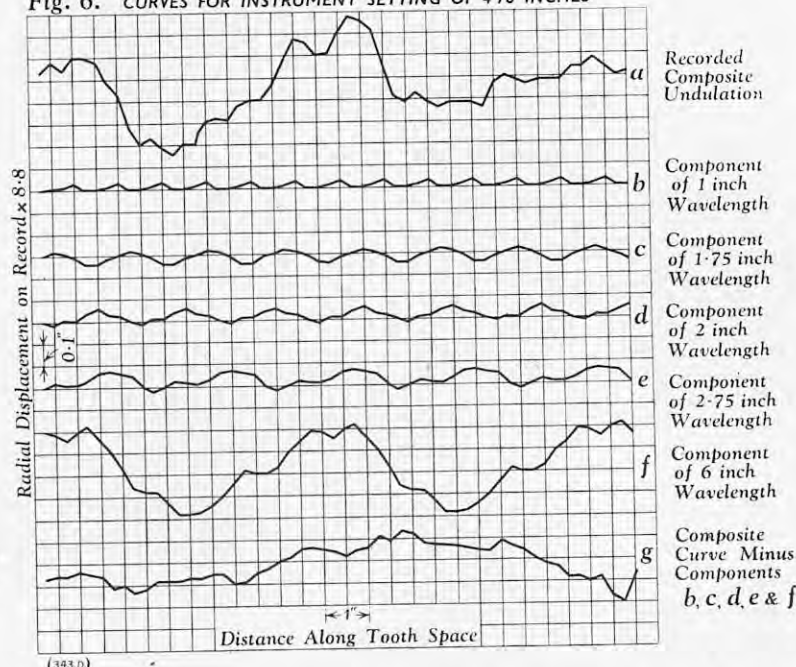


Fig. 6. CURVES FOR INSTRUMENT SETTING OF 4.76 INCHES



shows signs of a component of wavelength about 6 in., and this agrees with the evidence of curve *c* that there is a beat cycle of wavelength about 6 in. It was considered probable that the beat cycle was due to the beating of the 2.0-in. component and a 6-in. component. The curve *e* was therefore divided into two parts, each of length 6 in., and the parts were averaged to give the curve *f*, Fig. 4. Curve *f* was subtracted from curve *e*, giving the curve *g*.

It will be seen from curve *g* that there appears to be yet one more component, of very long wavelength. It is not possible to determine this component at all exactly, but it would appear to have a wavelength of about 12 in. The results obtained from the above analysis are given in Table I, herewith.

TABLE I.—Instrument Setting: 1.8 in.

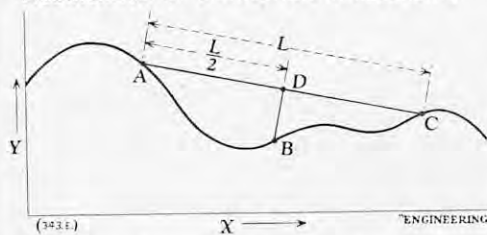
Wave-length of Component.	Amplitude from Graph.	Amplitude on Record.	Magnification Factor of Record.	Actual Amplitude.	Estimated Comparative Accuracy.
In. 1	0.14	0.016 ₀	× 33	0.000 48	± 0.000 07
2	0.24	0.027 ₀	× 25	0.001 1 ₈	± 0.000 1
2½	0.12	0.013 ₈	× 7	0.002 ₀	± 0.000 5
Approx. 12	0.06	0.006 ₈	× 2	0.003 ₄	± 0.002

The amplitudes given in Table I are all total (or double) amplitudes. The values in column 3 have been obtained from those of column 2 by dividing by 8.8, the maximum enlargement available for prints from the smoked-glass records. (In Tables II and III, herewith, the values corresponding to those of column 3 above have been omitted.) The magnification factors in column 4 have been obtained using the expression given above. In the Appendix, this expression is derived and it is shown that the record magnification for any given component is independent of the presence of other components.

Estimates of the comparative accuracies of the values given for actual amplitude are set out in the last column of Table I. These values of accuracy have been calculated on the assumption that the amplitude values from graphs could be in error by 0.02 in. and the magnification factor by 1.

The two overlapping records at the 3.0-in. instrument setting were measured and the curve marked *a* in Fig. 5, herewith, was plotted. This curve was analysed in a manner similar to that used for the curve *a* of Fig. 4. The components found are shown in curves *b* to *e*, Fig. 5, and the results are summarised in Table II, herewith. It is to be noted that the magnification factor for the component of 6-in. wavelength is 2½ times greater for this setting, and that, therefore, the accuracy

Fig. 7. MODIFICATION OF UNDULATION IN RECORDING



of the value determined for actual amplitude is much better.

TABLE II.—Instrument Setting: 3.0 in.

Wave-length of Component.	Amplitude from Graph.	Magnification Factor of Record.	Actual Amplitude.	Estimated Comparative Accuracy.
In. 1	0.12	× 17	0.000 8 ₀	± 0.000 14
2	0.30	× 33	0.001 0 ₅	± 0.000 07
6	0.26	× 17	0.001 7 ₄	± 0.000 17
Approx. 12	0.14	× 5	0.003 ₂	± 0.000 8

The record at the 4.76-in. instrument setting was measured, and the curve *a*, of Fig. 6, on this page, was plotted to the same scale as the graphs Figs. 4 and 5. In the analysis, use was made of the information already obtained from the previous analysis about the wavelengths of the two shorter components. The components found are shown in curves *b* to *g*, Fig. 6, and the results are summarised in Table III, herewith. It is to be noted that the

TABLE III.—Instrument Setting: 4.76 in.

Wave-length of Component.	Amplitude from Graph.	Magnification Factor of Record.	Actual Amplitude.	Estimated Comparative Accuracy.
In. 1	0.03	× 31	0.000 1 ₁	0.000 07
1½	0.06	× 25	0.000 2 ₄	0.000 08
2	0.07	× 12	0.000 6 ₇	0.000 20
2½	0.09	× 6	0.001 7 ₁	0.000 5
6	0.40	× 31	0.001 4 ₇	0.000 09
Approx. 12	0.20	× 12	0.001 ₉	0.000 25

magnification factors for the two largest components are much greater for this setting, and that the accuracy of the value for actual amplitude is correspondingly better. In this analysis, additional components of wavelengths 1 in. and 1½ in. were taken out. The actual amplitudes of the components are negligibly small, however, and they have, therefore, not been taken out in the two

previous analyses. The results of the three analyses are summarised in Table IV, herewith.

This method of analysis of undulation records is rather long and tedious, but appears to give fairly accurate results. It is considered that its use is warranted only if it is suspected that the undulations contain more than one component of significantly great amplitude. In such a case, however, the method is very useful in bringing to light components

TABLE IV.—Amplitudes in Units of 0.001 in.

Wave-length of Component.	Actual Amplitude (and Accuracy) of Component Deduced from Record at Setting of:			Estimated Best Value of Actual Amplitude.
	1.8 in.	3.0 in.	4.76 in.	
In. 1	—	—	0.1 ± 0.1	0.1
1½	—	—	0.2 ± 0.1	0.2
2	0.5 ± 0.1	0.8 ± 0.2	0.7 ± 0.2	0.7
2½	1.2 ± 0.1	1.0 ± 0.1	1.7 ± 0.5	1.2
6	2.0 ± 0.5	1.7 ± 0.2	1.5 ± 0.1	1.5
12	3.4 ± 2.0	3.2 ± 0.8	1.9 ± 0.3	2

of appreciable amplitude which are not at all apparent by inspection of the records. For instance, in the above example, the three records showed little, if any, trace of the components of wavelengths 2 in. and 12 in., and it was only after analysis of the records at settings of 1.8 in. and 3.0 in. that the presence of the 6-in. component was detected and the record at a setting of 4.76 in. was taken.

This work has been done as part of the research programme of the Division of Metrology, National Standards Laboratory, Commonwealth Scientific and Industrial Research Organisation. The thanks of the writer are due to members of the staff of the Division for assistance in the measurement of records, the calculation of results, and the preparation of graphs, and to Mr. N. A. Esserman, Chief of the Division, for helpful criticism in the preparation of the article.

APPENDIX.

Modification of Undulation in Recording.—Let the curve of Fig. 7, herewith, represent the surface of a tooth flank, the undulation having several components. Let A, B and C be the points of contact of the three ball feet of an N.P.L.-type undulation recorder, of which the setting is such that the distance AC is equal to L and the middle foot is midway between the outer feet. Let BD be the displacement of B from its zero position at the instant represented by Fig. 7, and let K be the magnification factor of the instrument, so that, for the position shown, the radial co-ordinate of the record on the smoked-glass plate is $K \times BD$.

Let the composite undulation of the tooth flank

be represented by

$$v = a \sin \left[\frac{2\pi x}{\lambda_a} + \theta_a \right] + b \sin \left[\frac{2\pi x}{\lambda_b} + \theta_b \right] + \dots$$

Since AC is very large compared with the difference between the ordinates of A and C, the value of BD is given to a very close approximation by the difference between the ordinate at B and the mean of the ordinates at A and C. If the point B has the co-ordinates (x_1, y_B) , the co-ordinates of A and C are respectively $(x_1 - \frac{L}{2}, y_A)$ and $(x_1 + \frac{L}{2}, y_C)$.

Now $BD = y_B - \frac{y_A + y_C}{2}$; therefore

$$\begin{aligned} BD &= a \sin \left[\frac{2\pi x_1}{\lambda_a} + \theta_a \right] - \frac{1}{2} \sin \left[\frac{2\pi x_1}{\lambda_a} + \theta_a - \frac{\pi L}{\lambda_a} \right] \\ &\quad - \frac{1}{2} \sin \left[\frac{2\pi x_1}{\lambda_a} + \theta_a + \frac{\pi L}{\lambda_a} \right] + b \sin \left[\frac{2\pi x_1}{\lambda_b} + \theta_b \right] \\ &\quad - \frac{1}{2} \sin \left[\frac{2\pi x_1}{\lambda_b} + \theta_b - \frac{\pi L}{\lambda_b} \right] - \frac{1}{2} \sin \left[\frac{2\pi x_1}{\lambda_b} + \theta_b + \frac{\pi L}{\lambda_b} \right] + \dots \end{aligned}$$

Therefore,

$$\begin{aligned} BD &= K a \left[1 - \cos \frac{\pi L}{\lambda_a} \right] \sin \left[\frac{2\pi x_1}{\lambda_a} + \theta_a \right] \\ &\quad + K b \left[1 - \cos \frac{\pi L}{\lambda_b} \right] \sin \left[\frac{2\pi x_1}{\lambda_b} + \theta_b \right] + \dots \end{aligned}$$

The last equation shows that, when the recorded composite curve is analysed, the components found will correspond to the components of the actual curve, but with a change in amplitude, the amplitude of each component having been increased by a factor $K \left[1 - \cos \frac{\pi L}{\lambda} \right]$, where λ is the wavelength of the component. It will be noted that the change in amplitude of each component is independent of the values of amplitude, wavelength or phase of any other components which may be present.

"THE USE OF RUBBER IN BITUMEN FOR ROAD SURFACING." ERRATUM.—In the above article, which appeared in our issue of August 31, on page 268, *ante*, it was stated that, "while the viscosities of rubber bitumen and ordinary bitumen are the same at 25 deg. C., at 30 deg. C. the rubber bitumen is 30 per cent. higher." We are informed by the British Rubber Development Board that the last-mentioned figure is incorrect; at 30 deg. C., the viscosity of rubber bitumen is 15 per cent. higher than that of ordinary bitumen.

FIRST MAIN-LINE DIESEL-ELECTRIC LOCOMOTIVE IN AUSTRALIA.—"Lady Norrie," the first of ten 1,760-h.p. main-line Diesel-electric locomotives for the South Australian Government Railways, completed a first trial run of over 300 miles on September 6. The locomotive went into regular service on September 10, and is the first main-line Diesel-electric locomotive to operate on regular schedules on the mainland of Australia. The motive-power equipment for the ten locomotives, including the Diesel engine, generator, traction motors and control gear, is being supplied by the English Electric Company, Limited, Kingsway, London, W.C.2, and the locomotives are being built in the workshops of the South Australian Government Railways. The wheel arrangement is A1A-A1A. Rheostatic braking is provided. The locomotives will be used in pairs to haul the Overland Limited express and 600-ton freight trains over the Mount Lofty Ranges, where the ruling grade is 1 in 40.

MESSRS. F. PERKINS, LTD., PETERBOROUGH.—On Tuesday, September 18, and Wednesday, September 19, Messrs. F. Perkins, Limited, held an "at home" at their Eastfield Factory, Peterborough, to enable representatives of the firms who supply them with materials and components to see how these are utilised in the assembly of Diesel engines for commercial vehicles and tractors, as well as for marine and industrial purposes. A description of the factory was given on page 699 of our 169th volume (1950), but it may be mentioned that it was specially laid out in 1947 for machining, assembling and testing parts obtained from outside and is now being extended. It is equipped with a number of modern tools, process planning and the jig and tool drawing office are well organised, and every effort is made to ensure a continuous flow of material. When the firm were established some 18 years ago their ideas were regarded in some quarters as revolutionary, but the results have evidently justified them.

LABOUR NOTES.

RAILWAY wage claims from the three principal railway unions for an all-round increase of 10 per cent. and the counter offer of the Railway Executive were discussed at a meeting of the Railway Staff National Council in London on Tuesday last, but no progress was made and the meeting was adjourned until this morning, to enable the unions to consider their attitude. The discussions before the Council form the second of the three normal stages in railway-wage negotiating machinery. The Council represents both sides of the railway service and consists of sixteen members, eight representatives from the Railway Executive, four from the National Union of Railwaymen, and two each from the Associated Society of Locomotive Engineers and Firemen and the Transport Salaried Staffs' Association, the other two unions involved in the joint wage claim. Should there be a failure to reach an agreement in the discussions before the Council, the next step should be to submit the claims to the Railway Staff National Tribunal for arbitration, but two of the three unions concerned have stated that that course of action will not necessarily be followed. The alternative would probably take the form of an appeal to the Minister of Labour for his intervention, either informally, or officially, under the new Industrial Disputes Order.

Following the formal submission of the demands to the Railway Executive a few weeks ago, direct negotiations took place in London between representatives of the Executive and officials of the three unions. The unions had combined to present a joint claim for an all-round increase of 10 per cent., which, if conceded in full, was estimated to increase the wage bill of British Railways by some seventeen to eighteen million pounds in a full year. A counter offer, which would have added nine and a half million pounds to the railway wage bill, was put forward by the Executive at a meeting of the two sides on September 10. This, however, was rejected by the unions. The Transport Salaried Staffs' Association claimed not only that the Executive's offer was inadequate but expressed its strong disapproval of the form in which the offer was made. The T.S.S.A. appears to have hoped that something would be done to restore the differentials which had formerly existed between the wages of its members and those of the lower grades of railwaymen. These differentials were reduced by the succession of flat-rate increases which were awarded during the war years. The National Union of Railwaymen estimated that the increases suggested by the Executive in its offer would amount to an average for all members of the three unions of less than 5 per cent., and the N.U.R. considered this quite insufficient.

Details of the Railway Executive's offer were made public on September 12. As stated above, this was estimated to cost nine and a half million pounds annually, and would have provided increases in wages and salaries for the whole of the 450,000 railwaymen belonging to the three unions. One of the more interesting clauses of the offer was the provision, for the first time, of additional flat-rate payments for full turns of duty booked to begin on Saturday afternoons. Generally speaking, the increases offered were greatest in those grades where there is the most need for obtaining new recruits. The minimum weekly rate of pay for adult men would have been increased by 4s. 6d., from 5l. 2s. 6d. to 5l. 7s. This rate applies to such grades as crossing keepers, porters, and the lower-ranking engine cleaners and labourers. At the other end of the scale, a third-year goods guard would have received an additional 15s. a week. In the salaried grades, the proposed increases would have amounted to 50l. a year in some instances. Many railway employees would have benefited from another clause, which proposed that the time taken to reach the maximum rate of pay should be reduced for certain grades.

The Confederation of Shipbuilding and Engineering Unions decided at its annual meeting to submit a claim for an increase of 20s. a week for all adult male employees in the engineering industry. Subsequently, the unions concerned with women employees decided to pursue a parallel claim. Both these demands are being put forward without prejudice to those claims which have been pressed recently for a new wage structure in the engineering industry. It is understood that the Engineering and Allied Employers' National Federation has been informed that the unions are anxious that negotiations on these claims should commence at a very early date. Pressure by the unions for an additional week's annual holiday with pay for all employees in the industry is being continued. The Confederation, at its annual meeting, expressed its determination that the whole structure of the negotiating machinery in the engineering industry should be overhauled in the near future.

Somewhat similar action is being taken with respect to the shipbuilding and ship-repairing industries. A unanimous decision was reached at the Confederation's annual meeting that a claim should be pursued for a weekly increase of 20s. for all employees in these industries. Representatives of the Shipbuilding Employers' Federation will discuss this claim with officials of the Confederation on Tuesday next, when statements in support of the demand will be presented. The same joint meeting will also consider the claims of the shipbuilding unions for extended holidays with pay and for the operation of the five-day week throughout the year. A claim by the Transport and General Workers' Union that certain grades of semi-skilled and unskilled employees in these industries should receive the same monetary allowances as skilled men was referred by the annual meeting of the Confederation to its executive council for fuller examination.

Some apprehension is felt by the Officers' (Merchant Navy) Federation at the steadily rising price of new merchant ships. The Council of the Federation states in its annual report for the twelve months ended June 30, 1951, published on Tuesday last, that it has noted with concern the continued warnings "given by those best qualified to speak" that the ever-increasing cost of replacing ships coming to the end of their operational age limits is rapidly approaching the point where new vessels are being ordered which cannot be expected, in the normal course of events, to pay their way.

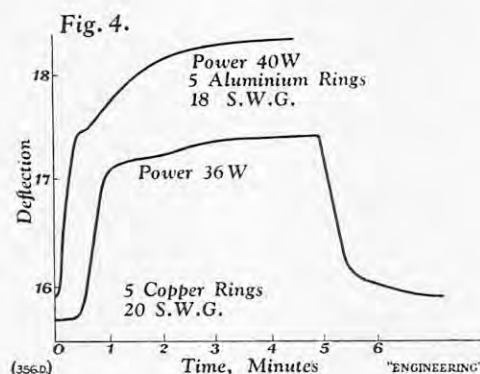
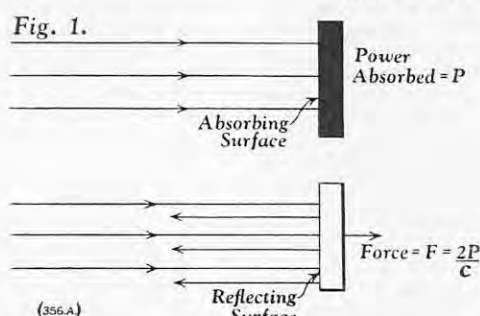
Proposals for the employment of from five to ten thousand Italians were referred to by Mr. Alfred Robens, the Minister of Labour, in the course of a speech at Stretford on Monday last at a conference of representatives of employment, labour, and disabled-persons advisory committees. Mr. Robens stated that in Italy, from which he had only recently returned, there were some two-and-a-half million unemployed persons and he considered that it should be possible to make use of some of these people in this country, with the permission of the trade unions concerned. With regard to the fears entertained in some quarters that unemployment would increase if foreign work-people were brought here, he said that he had been a trade-union official and knew what the problems were, but, in his opinion, there was no need for any British employee to be out of work during the next decade or two, at least.

There was a great need for an increase of work-people in Britain, Mr. Robens continued, and it was essential that increased efforts should be made to persuade those women who were able and willing to do so to return to employment. It was not suggested, however, that women with two or three young children should go back to industry. Employers should endeavour to find a sufficient number of women to undertake part-time work, and he appealed to them to inquire into the matter. The country had entered a most serious stage in its national economy and could not afford to lose the possibility of employing any pair of willing hands.

At the request of the British Transport Commission, a number of reports were prepared by the Docks and Inland Waterways Executive between 1948 and 1950 tendering advice to the Commission on methods considered likely to promote the efficient and economical development of the principal port areas in Great Britain. In the main, the reports have dealt with such matters as the management and maintenance of the ports, and with suggestions as to what schemes therefor should be submitted to the Minister of Transport. In some instances, however, labour relations at certain ports formed the subject of comment. Most of the reports were drawn up between May and November last year, and the complete series was published by the British Transport Commission in one volume on September 13, under the title of *Review of Trade Harbours*, at the price of 2s. net.

With respect to the Port of London, the Executive reported that labour relations there were a most disturbing factor and suggested that these tended to lessen very materially the efficiency of the port. It was considered that permanent improvement could only be obtained if the Port Authority were to be reconstituted so as to provide greater and more direct representation for labour interests and if greater responsibility were to be vested in the reconstituted Port Authority. The Executive advocated that efforts should be made to secure more cohesion between the various firms of employers at the port, and that the co-operation between the employers and the trade unions connected with the port should be improved. Other suggestions were for the standardisation of labour agreements and working conditions as a part of the port's dock-labour scheme, and for co-operation between the unions.

MEASUREMENT OF MICROWAVE POWER.



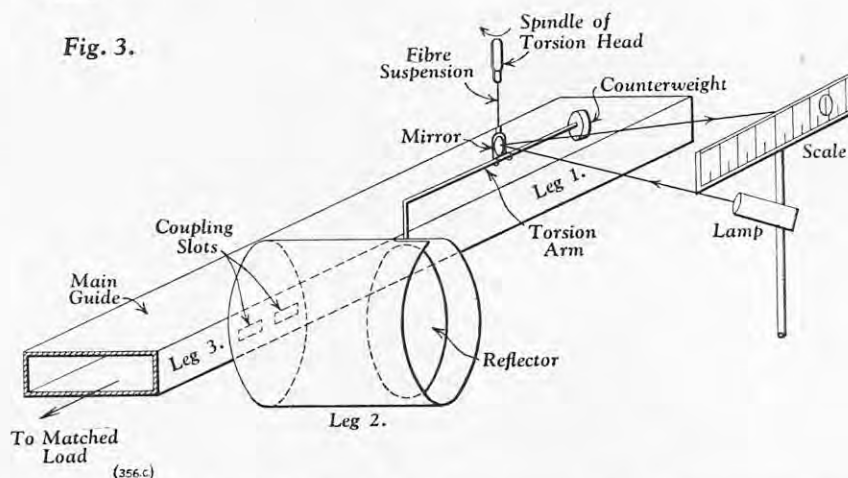
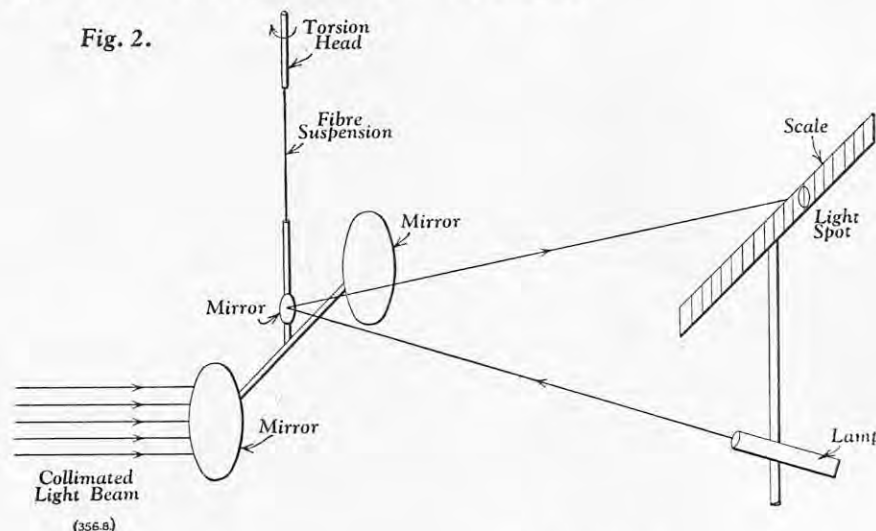
THE MEASUREMENT OF MICROWAVE POWER BY RADIATION PRESSURE.*

By A. L. CULLEN, Ph.D., B.Sc. (Eng.), A.M.I.E.E.

THE pressure of electromagnetic radiation is a phenomenon not usually encountered in engineering, and it may be best to start by describing some of its characteristics, and explaining how it is produced. When light, the commonest kind of electromagnetic radiation, falls on a reflecting surface it exerts a pressure tending to push the surface away from the source of light. This pressure is usually exceedingly small. For example, the pressure due to a beam of strong sunlight at normal incidence on a plane reflector is about 10^{-5} dyne per square centimetre, which is equivalent to a weight of about 10^{-8} gramme on each square centimetre of the surface. If the intensity of the beam were halved and the area doubled, the total power flow and the total force would remain unchanged. Moreover, the effect of radiation pressure is quite independent of the wavelength, and the same power-force relationship holds good throughout the electromagnetic spectrum. In electrical units, the power flow corresponding to "strong sunlight" is about 0.015 watt per square centimetre, and we have seen that this exerts a force of 10^{-5} dyne per square centimetre of surface. It follows from the foregoing that any homogeneous beam of electromagnetic radiation carrying a power of 0.015 watt will exert a total force of 10^{-3} dyne on a reflecting surface. The force produced is directly proportional to the power in the incident beam, and so it will be clear that a very large amount of power would be required to produce a readily measurable force. For example, to produce a force equivalent to $\frac{1}{4}$ lb. weight would require an incident wave carrying rather more electrical power than Edinburgh Corporation would have been able to supply at any time up to 1943. It should be obvious that radiation pressure does not play a very important part in everyday life.

On an astronomical scale, however, it is often of the greatest importance. Over 300 years ago, Kepler suggested that radiation pressure of light might account for the bending of comets' tails away from the sun. It is remarkable that, in spite of the revolutionary changes in our understanding of the nature of radiation since that time, modern astronomers believe that Kepler's suggestion is correct. Perhaps an even more striking example of the importance of radiation pressure in astronomy is Eddington's theory that the mass of a star is determined by the condition that radiation pressure and gas pressure shall be of the same order of magnitude. The calculation leads to the conclusion that the mass of a star should lie roughly in the range 10^{33} to 10^{35} grammes, and observation shows that this rule is obeyed by an overwhelmingly large majority of the visible stars.

* Paper read before Section G of the British Association at Edinburgh on Tuesday, August 14, 1951.



We now turn to the mechanism which gives rise to radiation pressure. It is obviously easy to explain such a pressure on the basis of a corpuscular theory of light, and Newton realised that Kepler's interpretation of the bending of comets' tails would harmonise well with such a theory. The advent of the wave theory of light led many scientists to doubt the existence of a pressure of radiation. However, in 1873, James Clerk Maxwell showed that his electromagnetic wave theory of light would also account for a pressure due to radiation. Subsequently, it was found that the overthrow of the corpuscular theory of light, which followed the many triumphs of Maxwell's electromagnetic theory, had been too complete, and that, in some circumstances, a beam of radiation behaved exactly like a stream of corpuscles. The most remarkable and convincing of these is the Compton effect, which can be explained in terms of individual encounters of photons and electrons in each of which momentum is conserved. It is quite easy to show that both classical electrodynamics and quantum theory lead to precisely the same result for the pressure of radiation.

Consider the electrodynamic argument first. We consider a plane wave normally incident on a perfectly conducting surface. If the r.m.s. magnetic field strength in the incident wave is H , the field just outside the reflecting surface will be $2H$, and just inside it will be zero. Boundary conditions require a surface current density $K = 2H$ perpendicular to the magnetic field. This current is acted on by the magnetic field H of the incident wave to produce a force $\mu H K = 2\mu H^2$ per unit area of the reflector. Note that the magnetic field due to the current sheet itself, which is responsible for doubling the field outside the conductor, and cancelling it inside, cannot produce any resultant force on the current. The power density in the incident wave is $S = EH = \sqrt{\frac{\mu}{\epsilon}} H^2$, and it follows that the force per unit area, which is the pressure due to radiation, is $2S\sqrt{\frac{\mu}{\epsilon}}$ or $\frac{2S}{c}$, where c is the velocity of light in *vacuo*.

The quantum argument treats the beam of radiation as a stream of photons, each of energy $h\nu$ and momentum $\frac{h\nu}{c}$, and travelling with the velocity of light. The change in momentum of an individual photon

on reflection is $\frac{2h\nu}{c}$. If there are n photons per unit volume in the incident beam, then cn photons cross unit area in unit time and the resulting pressure is $\frac{cn \cdot 2h\nu}{c}$. Similarly, the power flow density in the beam is $S = cn \cdot h\nu$. It follows by elimination of $h\nu$ that the radiation pressure is $\frac{2S}{c}$, as before.

It is convenient for our purpose to deal with the total force exerted on the reflector and to express this force in terms of the power in the incident beam. Referring to Fig. 1, if the beam (of light, for example) is incident on a perfectly absorbing surface, the power in the incident beam will be equal to the rate of production of heat at the surface, say P . If the same beam is then allowed to fall on a perfectly reflecting surface, the force exerted on this reflector, say F , is

$$F = \frac{2P}{c} \quad (1)$$

where c is the velocity of light. Although attempts to detect radiation pressure experimentally were made at intervals from 1750 onwards, the first reliable experiments were those of Lebedew in 1900. A much more detailed study of the problem was undertaken by Nichols and Hull a year or two later.* In both cases, the experimental arrangement was the same, and is illustrated schematically in Fig. 2.

The light beam, the radiation pressure of which is to be measured, falls on a highly reflecting mirror mounted at one end of the torsion arm of a torsion balance. A similar mirror at the other end of the torsion arm serves as a counterweight. The torsion balance is mounted in an evacuable enclosure so that gas action may be minimised. The angular position of the torsion arm is indicated by a lamp, mirror and scale in the usual way. In principle, the scale readings with and without the light source are observed, and from these readings the angle of twist of the suspension may be found. Hence, if the specific couple of the suspension is known, the torque can be calculated, and knowing the radius of action of the torsion system, the radiation force may be determined.

* "The Pressure due to Radiation," by E. F. Nichols and G. F. Hull. *Proc. Amer. Acad. of Arts and Sciences*, vol. 38, No. 20, page 559 (1903).

In practice, it is usually observed that on switching on the light source, the deflection increases immediately to a certain initial value, and then gradually drifts to a fairly steady final value which may be greater or less than the initial value. The radiation falling upon the mirror causes a slight and gradual rise in its temperature which at atmospheric pressure sets up convection currents in the enclosing vessel. These convection currents lead to spurious deflections. At low gas pressures convection currents are negligible but a different effect comes into play. Because radiation falls on one side of the mirror only, while cooling takes place over the whole surface, the back of the mirror is at a slightly lower temperature than the front. Air molecules rebounding from the hotter surface suffer a greater change of momentum than those rebounding from the cooler surface, and on the average there is a net pressure in the same direction as the radiation pressure. This is known as the radiometer effect. In Nichols' and Hull's experiments it happened that the two spurious forces could be made to oppose one another, and a suitable choice of air pressure virtually eliminated the effects of gas action. The power in the light beam was measured by a bolometer method, and the force calculated from the expression $F = \frac{2P}{c}$ (with a correction to allow for

imperfect reflection), was found to agree with the measured force to within experimental errors of 1 to 2 per cent. The radiation-pressure formula therefore rests on very firm theoretical and experimental foundations, and can be used with confidence as the basis of a method of measuring microwave power.

Carrara and Lombardini* were the first to demonstrate the existence of radiation pressure at microwave frequencies. In their experiments an aluminium reflecting blade was supported at one end of a torsion arm and enclosed in a glass corner. Radiation at a wavelength of 3 cm. was directed on to this blade, and a deflection of the right order of magnitude was observed. The method employed by Carrara and Lombardini cannot be used quantitatively because, as they point out in their note, a calculation of the force on the blade for a given power flow involves the solution of an exceedingly difficult diffraction problem, particularly if nearness of the source and the effect of reflections from the glass container and other parts of the apparatus are properly taken into account. This difficulty, which was absent from Nichols' and Hull's experiments, arises because of the relatively long wavelength (3 cm.) which prevents the formation of a narrow parallel beam of radiation such as that employed by Nichols and Hull. A further difficulty is that the net power output of the source is eventually radiated into the laboratory, and the resulting spatial standing-wave pattern will cause the observer's position to influence the results to some extent.

These difficulties could both be overcome by using a wave guide to guide the radiation on to the reflector. It is not difficult to show that the force is then given by

$$F = \frac{2P\lambda}{c\lambda_g} \quad (2)$$

where λ is the free space wavelength, and λ_g is the wavelength in the wave guide, which is always greater than λ . However, a new difficulty then arises, because the whole of the power incident on the reflector is returned to the source, and for most sources of microwave power this leads to a very inferior performance or in some cases to permanent damage. It is clear that if a radiation pressure method is to be employed, some technique must be devised which permits the oscillator to work into a matched load. This can be done by making use of a wave-guide T-junction in the way shown in Fig. 3, on page 377.

If a reflector is suitably placed in the wave guide forming leg 2 of the T-junction, power incident on the junction in leg 1 will flow past without reflection into leg 3. If the power flow is P , the force on the reflector is

$$F = \frac{P}{2c} \frac{\lambda}{\lambda_{g2}} \frac{1}{m} \quad (3)$$

In this expression λ_{g2} is the guide wavelength in leg 2, and m is a factor which takes account of the coupling between the main guide and the circular guide, and this can be evaluated either by direct calculation or by measurements of impedance transformation by the junction. To give an idea of order of magnitude, with a particular form of this apparatus, if $P = 20$ watts, $F = 0.01$ dyne.

This microwave apparatus is closely analogous to that employed in the classical experiments with light waves previously described, and forms an absolute method of power measurement at microwave frequencies. In practice, it is found necessary to replace

the solid-disc reflector by a series of concentric wire rings, which effectively reflect the microwave radiation while minimising the effects of convection currents. Some trouble with convection currents remains, however. Fig. 4, page 377, shows the gradual rise in deflection which occurs after the initial true radiation-pressure deflection, under various experimental conditions.

Measurements of power with this apparatus were compared with simultaneous measurements using a balanced water calorimeter, and agreement to within 2 watts found in the range 10 to 40 watts. The accuracy of the apparatus is limited mainly by residual convection-current effects, but experiments with an improved apparatus have shown that it is possible to overcome this difficulty, and there seems to be no reason why an accuracy of better than 1 per cent. should not be achieved.

In conclusion, it should be emphasised that the method is absolute, depending only on measurements of mass, length, and time; no secondary electrical standard is involved in the experimental procedure. Moreover, no appreciable power is absorbed by the apparatus, so that it would be particularly suitable for the purpose of calibrating secondary standards.

RECENT METALS AND ALLOYS.*

By PROFESSOR A. G. QUARRELL.

(Concluded from page 344.)

MOST of the austenitic steels then known [1943] were of the nickel-chromium type with suitable additions to prevent weld decay. An exception was the complex alloy R. ex 78 that Hatfield had developed in 1937 primarily as a corrosion-resistant steel, especially resistant to sulphuric acid. It is worth noting that nickel, chromium, molybdenum, copper, silicon, manganese, titanium, vanadium and carbon were all deliberate additions to this alloy. As a matter of routine the creep properties were determined and were found to be superior to those of any other steel then available. R. ex 78 was, in fact, the first of the age-hardening austenitic steels, and the best combination of creep and room-temperature properties was found to result when a carbide phase had been precipitated by a triple heat-treatment. Systematic study of the effects of varying the amounts of different elements in R. ex 78 showed that by adding 7 per cent. of cobalt, omitting the vanadium and increasing the carbon content from 0.1 per cent. to 0.2 per cent., the creep properties could be greatly improved. Thus, when this modified steel R. ex 337 is solution-treated at 1,230 deg. C., aged at 700 deg. C. to 750 deg. C. and subjected to a stress-to-rupture test, failure is produced at 750 deg. C. in 1,000 hours by an initial stress of 10.5 tons per square inch, whereas the corresponding stress for the original R. ex 78 is 5.5 tons per square inch.

Another attractive feature of the precipitation-hardening alloys is that they have high 0.1 per cent. proof stress values of 21 tons to 25 tons per square inch, compared with about 13 tons per square inch for the simple austenitic steels. Steels used for rotors and discs should have high proof stress to prevent undue plastic extension resulting from thermal or centrifugal stresses in service.

Another complex alloy, G.18.B., containing 13 per cent. each of nickel and chromium, 10 per cent. cobalt, 2 to 3 per cent. each of tungsten, molybdenum and columbium, and about 1 per cent. each of silicon and manganese, may be regarded as a development of an earlier austenitic exhaust-valve alloy; its mechanical properties, notably the 0.1 per cent. proof stress, can be improved by what has been called "warm-working," i.e. by work-hardening in the lower end of the forging range. This alloy has been used successfully for gas-turbine rotor discs under the most severe conditions, but, now it has been found possible to cool rotors sufficiently to keep rim temperatures below 550 deg. C., increasing interest is being shown in the ferritic steels, such as the molybdenum-vanadium and the chrome-molybdenum-vanadium-tungsten types. The ferritic steels are cheaper than the austenitic, not only because they are more economical in the use of ferro-alloys, but also because they are more readily forged and machined. Colbeck and Rait† have suggested that for good creep properties it is essential that a stable cubic carbide of the NaCl type of structure shall be precipitated in a fine state of dispersion and that it shall resist coalescence. These authors also drew attention to the fact that, although creep-resistant steels can be made containing 0 to 3 per cent. or 11 to 13 per cent. chromium, alloys containing, say,

5 to 7 per cent. chromium invariably have poor creep properties. When we understand why this should be so, we shall have a much better understanding of the metallurgical factors affecting the creep resistance of complex alloys.

Most rotor blades of British gas turbines have been made from one of the Nimonic alloys; these are essentially 80 per cent. nickel, 20 per cent. chromium alloys to which have been added titanium and aluminium to make them precipitation-hardening. Optimum creep properties result from solution treatment at 1,080 deg. C., followed by precipitation treatment at about 700 deg. C. Continuous work by a large team has enabled the maximum working stress and temperature of alloys of the Nimonic type to be raised repeatedly. The most recent addition to the series—Nimonic 90—contains 15 to 21 per cent. cobalt, an element which is playing an increasingly important part in alloys for use under the most stringent conditions at high temperatures. Some idea of the extent to which the properties of Nimonic alloys have been improved can be gained from the stresses required to produce creep extensions of 0.1 per cent. in 300 hours at 750 deg. C.; for Nimonics 75, 80, 80A and 90, which were developed in that order, the corresponding stresses are 3.1, 8.0, 11.5 and 14.5 tons per square inch.

Copper alloys have also been affected by the requirements of the gas turbine. Light alloys are used extensively for compressor blading, but the higher working temperatures involved in contemporary design are causing special interest to be shown in the complex aluminium bronzes. The single-phase aluminium bronzes are similarly of interest in connection with the heat exchangers that form an essential part of long-life gas turbines suitable for marine or land installations.

Full information has recently been published* concerning the copper-nickel-iron alloys that were developed to meet certain exacting requirements of the Navy at war. The discovery that the resistance of 70/30 cupro-nickel to impingement attack by the rapidly moving seawater was improved by the addition of 0.3 to 1.0 per cent. iron led the British Non-Ferrous Metals Research Association to make a study of the properties of alloys of copper with up to 30 per cent. nickel and 10 per cent. iron. It was found that alloys containing up to 10 per cent. nickel and up to 2 per cent. iron can be worked almost as readily as copper by the techniques used by the coppersmith and yet have excellent resistance to the impingement type of corrosion attack. These alloys have already shown their value for auxiliary piping carrying seawater, and in the United States the alloy containing 10 per cent. nickel and 1 to 2 per cent. iron is being advocated as a condenser-tube material for marine turbines.

Systematic study of the effect of alloying additions upon the properties of cast iron has considerably extended their field of usefulness; alloy cast irons have been developed with good resistance to air and to furnace gases up to 950 deg. and others have greatly improved resistance to weak acids, alkalis and many corrosive solutions. Probably even more important potentially is the development of nodular cast iron, which has resulted from a scientific study of the mode of graphite formation. By adding to the molten iron in the ladle small amounts of cerium or magnesium, the iron can be made to solidify with the graphite in nodular instead of flake form, and the mechanical properties, particularly the resistance to shock, are so much improved that they are comparable with those of steel. At the same time, the excellent casting characteristics of normal cast iron are retained. Test pieces cut from the central boss of a 5-ton flywheel casting gave the following results: tensile strength 35 tons per square inch, yield point 27.5 tons per square inch, elongation 15 per cent. The successful production of nodular cast iron calls for closer technical control than is usual in many iron foundries to-day, and another factor that is likely to restrict its use is the fact that a low-phosphorus hematite iron must be used.

Substantial progress has been made in the field of magnetic materials. If we accept the stored magnetic energy as a basis of comparison, the figure of merit for anisotropic Alcomax III is 5.0, whereas for the best alloys of 1940 and 1935 the corresponding values are 3.5 and 1.6, respectively. As in so much other alloy development, improvement in properties has been accompanied by an increase in the number of alloying elements. On the other hand, the magnetic properties of transformer steels of the 3 or 4 per cent. silicon type have been improved not by changing the composition of the alloy, but by using a controlled process of cold-rolling and annealing to produce a highly preferred orientation in the resulting strip. When there is a strong tendency for the (110) planes to be in the plane of the strip and the (001) axes parallel to the rolling direction, the permeability in this direction is greatly increased and the hysteresis losses are very

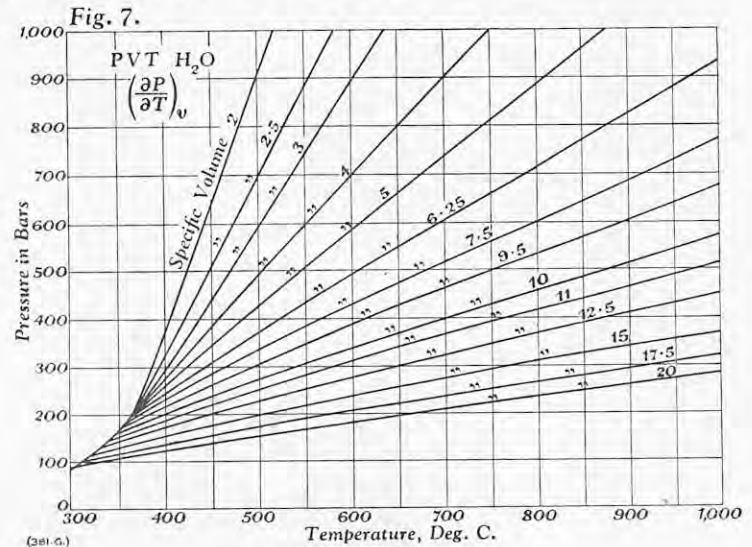
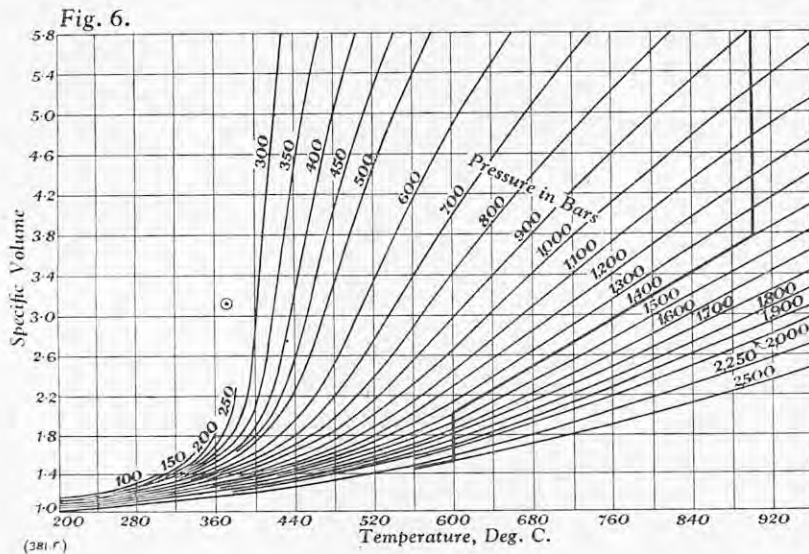
* Paper read at a joint session of Section B (Chemistry) and Section G (Engineering) of the British Association at Edinburgh, on Tuesday, August 14, 1951.

† E. Colbeck and J. R. Rait; Iron and Steel Institute, Symposium on High Temperature Steels and Alloys for Gas Turbines, February, 1951, page 107.

* "Radiation Pressure of Centimetre Waves," by N. Carrara and P. Lombardini. *Nature*, vol. 163, page 171 (Jan. 1949).

* G. L. Bailey, *Jl. Inst. Metals*, vol. 79, page 243 (1951).

PROPERTIES OF GASES OF COMBUSTION.

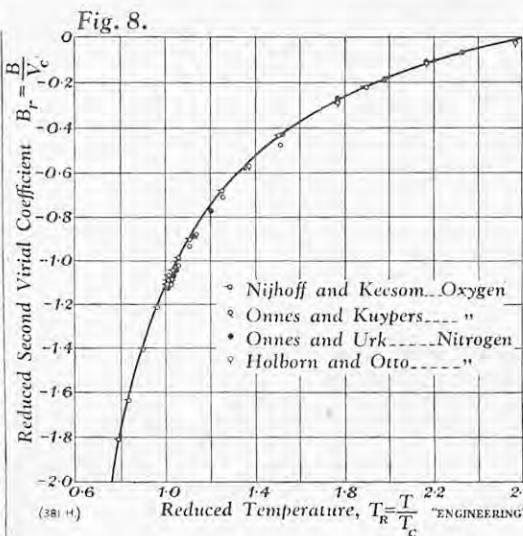


much lower. If full advantage is taken of this in design, transformers may be much smaller for the same output, with consequent saving of both steel and copper.

Some of the metals hitherto considered only as alloying elements are becoming of increasing interest as the possible bases of new systems of alloys. Thus, certain chromium-rich alloys* have good creep properties at temperatures as high as 900 deg. or 1,000 deg. C., although their practical use is at present prevented by their extreme brittleness at ambient temperatures. Again, in recent years, ductile titanium has become available in reasonably large quantities for the first time and much effort is now being devoted to assessing its potentialities. The tensile strength of annealed titanium prepared by the Kroll magnesium-reduction process varies between about 38 and 45 tons per square inch and is coupled with an elongation or 25 to 35 per cent. Strengths very much greater than this may be obtained by alloying. Other attractive features of titanium are that it is almost unattacked by seawater and other chloride solutions, and its specific gravity is only 4.5. For many applications, titanium is more suitable than any metal in common use, and in numerous others it could usefully replace an established metal and so relieve the metal shortage. Unfortunately, the present methods for extracting titanium, although successful when relatively small batches of metal are being produced, do not lend themselves to large-scale production. Large quantities of titanium ores are available, and, if improved methods of extraction can be devised, a new and important metal industry will almost certainly grow up.

No review of recent metals and alloys would be complete without some reference to the increasing shortage of metals and the way in which this will affect, and be affected by, alloy development. It is already clear that the metal shortage from which we are suffering is not just a short-term problem resulting from the rearmament programme. On the one hand, metals are being used to an ever-increasing extent in civilian life all over the world, and, on the other, some of the most important ore deposits are becoming worked out. As a result, demand is likely to exceed the supply even of such common metals as copper, zinc and lead, and everything that can be done must be done to ensure that metals are used to best advantage. The development of improved alloys offers one method of economising and the progress made in the last 10 or 15 years suggests that still further advances are possible. As mentioned earlier, an outstanding feature of the technically important alloys is their complexity; most contain between six and ten separate elements, and we may well ask if they are all really necessary. In our present state of knowledge, they undoubtedly are, but as our understanding of the factors influencing the structure and properties of alloys increases it should be possible to achieve desired properties with simpler alloys and in some cases to avoid the use of particular metals.

Again, the relative weakness of metals is explained in terms of dislocations within the crystal lattice. It is not beyond the realms of possibility that research on the plasticity of metals will show how these dislocations may be controlled. If this should prove to be so, very large increases in strength may be possible



and smaller quantities of metal may be necessary for a given duty.

Finally, the situation may be changed considerably if those working on the chemistry of extraction processes are able to devise suitable methods for the cheap and large-scale extraction of metals such as titanium and zirconium, which so far have not been used to any great extent commercially but have some very attractive properties.

PROPERTIES OF THE GASES OF COMBUSTION PROCESSES.*

By PROFESSOR JOSEPH H. KEENAN.†

(Concluded from page 348.)

ONE of the most notable recent additions to our experimental knowledge of the common vapours is the work on water vapour by G. C. Kennedy, a geologist of Harvard University.‡ He has determined the pressure-volume-temperature relation up to a temperature of 1,000 deg. C. (1,800 deg. F.) and a pressure of 2,500 bars (36,000 lb. per square inch). Kennedy's method is essentially the same as that used by Keyes in his extensive measurements on water in the decade of the 1920's. For these extreme conditions of pressure and temperature, however, he used a thick-walled bomb made of an iron-nickel-chromium-cobalt alloy. The bomb, which was maintained at the desired temperature in a furnace, was charged through a capillary connection from a cylinder held at room temperature. The position of a piston in the cylinder determined the mass of the charge in the bomb. The results of these measurements are shown by the isobars of Fig. 6, on which are also indicated the boundaries of the range of actual measurements and the critical point. Unfortunately, Fig. 6 does not cover the entire range of

measurements, in that measurements were made between 800 deg. and 900 deg. C. at pressures up to 800 bars. The precision of this work is quite remarkable considering the extreme range of conditions covered. Except in the immediate neighbourhood of the critical point the agreement with the measurements of Keyes, Smith and Gerry, which extended to 460 deg. C. and 350 bars, is to four significant figures. Fig. 7 shows isometrics for the lower-pressure portion of these measurements. They indicate a straight line for the critical isometric and slight curvature for the others at the low-temperature ends. The straightness of the isometrics at pressures and temperatures well in excess of the critical values indicates safety in extrapolation.

At the University of Pennsylvania, Andersen* has added to our knowledge of the properties of air by isothermal throttling measurements at 0, 10 and 30 deg. C. for pressures up to 4 atmospheres. The major difference between Andersen's method and that of Collins and Keyes is that Andersen used an orifice for throttling whereas Collins and Keyes used a capillary tube. Andersen expressed his results in the form of the second enthalpy coefficient β in the equation

$$h = h_p = 0 + \beta p + \gamma p^2 + \dots$$

where h denotes the enthalpy and $\beta, \gamma, \dots$ are functions of temperature only. It is evident that for zero pressure

$$\beta_p = 0 = \left(\frac{\partial h}{\partial p} \right)_T$$

Andersen formulated β as a function of temperature in terms of the corresponding function from the Lennard-Jones potential, using in addition to his own values those of Eucken, Clusius, and Berger to determine the constants ϵ_m and τ_0 in equation (1) (page 348, ante). Andersen also formulated the second virial coefficient in accordance with his formulation of β by introducing a term proportional to the temperature. The constant of proportionality was selected to satisfy the compressibility data of Holborn and Schultz published in 1932.

The work of Johnston and White† on hydrogen is of interest here because it provides an accurate pressure-volume-temperature relation for a pure substance over a wide range of reduced pressures and temperatures. The method differs from that of Keyes primarily in the manner of introducing and measuring the mass of the charge. Messrs. Schneider and Duffie‡ of the National Research Laboratories at Ottawa have made a contribution of similar value by the measurement of the pressure-volume-temperature relation for helium at pressures from 6 to 80 atmospheres and at temperatures extending to the unusually high value of 600 deg. C. The method, which is attributed to Burnett, consisted of the measurement of pressures before and after isothermal expansion in a known proportion by volume.

The synthesis of the available data on a given substance into a formulation of the relation between thermodynamic properties is an important step toward making new experimental data available for the uses of technology. A few such tasks have been performed in the past decade. In 1942, a group of workers at the California Institute of Technology§ formulated the

* Herbert Akroyd Stuart Memorial Lecture, delivered at Nottingham University on May 10, 1951. Abridged.

† Of Massachusetts Institute of Technology.

‡ *American J. of Science*, vol. 248, pages 540-564 (1950).

* *Trans. A.S.M.E.*, vol. 72, pages 759-766 (1950).

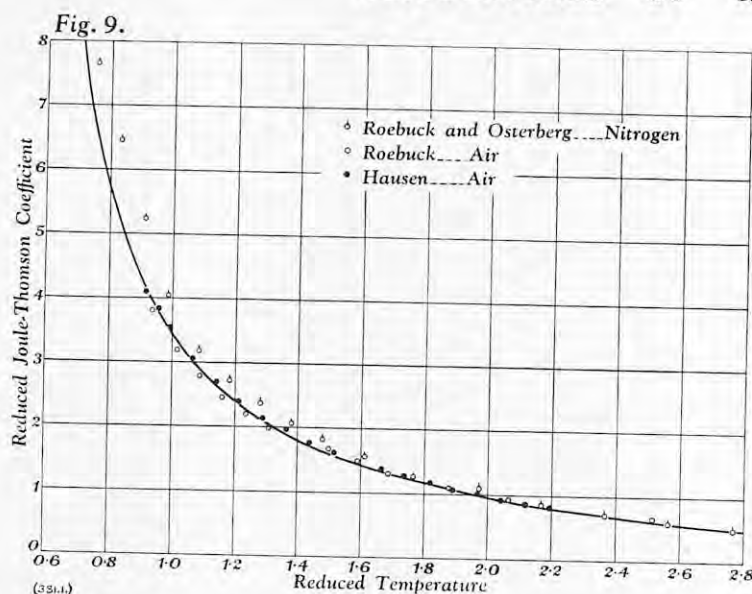
† *Trans. A.S.M.E.*, vol. 72, pages 785-788 (1950).

‡ *J. Chem. Phys.*, vol. 17, pages 751 (1949).

§ Gerhart, Brunner, Mickle, Sage and Lacey, *Mech. Eng.*, vol. 64, pages 270-274 (1942).

* E. A. G. Liddiard and A. H. Sully; Iron and Steel Institute, *Symposium on High Temperature Steels and Alloys for Gas Turbines*, February, 1951, page 243.

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properties of air at temperatures from 32 to 550 deg. F. and at pressures from 0 to 3,500 lb. per square inch absolute. Their tables are the best available information on the effect of pressure on the properties of air at temperatures in excess of room temperatures. In the lower-temperature range, Claitor and Crawford* have recently prepared charts of thermodynamic properties for air, and for oxygen and nitrogen as well. The range of pressure is from 0 to 180 lb. per square inch absolute and of temperature from room temperature down to -320 deg. F. For the three gases O_2 , N_2 and air, Claitor and Crawford employed a single equation of state in terms of the reduced density and temperature, namely,

$$\frac{p}{RT} = 1 + B_r \rho_r + C_r \rho_r^2$$

where ρ_r is the reduced density (the ratio of the density to the critical density) and B_r and C_r are functions of the reduced temperature—the same function in each instance for all three gases.

The reduced virial coefficients B_r and C_r were formulated from experimental data on specific volume, Joule-Thomson coefficient, and velocity of sound, for all three gases taken together. The success of this method is illustrated in Fig. 8, on page 379, which shows the experimentally determined reduced second virial coefficients, and in Fig. 9, herewith, which shows the reduced Joule-Thomson coefficients for pairs of these gases falling in each instance upon a single curve. It is

only because the value of $\frac{p}{RT}$ at the critical point is nearly the same for oxygen and nitrogen that this application of the law of corresponding states proves a happy one at such low pressures.

The work of S. W. Akin,† of the General Electric Company, Schenectady, on the properties of helium is of interest here for its bearing on the generalization of the properties of the pure substance. Fig. 10, reproduced from Akin's paper, shows the range of his work—namely, from 15 to 5,000 lb. per square inch absolute and from -449 to 600 deg. F. It is based on all experimental values published prior to 1945. It does not include, therefore, the more recent work of Schneider and Duffie. In pressure range it stops considerably short of the extent of the available compressibility data which goes to 15,000 lb. per square inch absolute. Akin's results are given in the form of a long and narrow temperature-entropy chart. He adds to this a formulation and a chart for the viscosity of helium for zero pressure and for 6,000 lb. per square inch absolute.

Professor Keyes,‡ of the Massachusetts Institute of Technology, has given attention to the formulation of the properties of water at intervals over the past decade. He has examined the possibilities of an equation of state of higher accuracy and broader range of applicability than that employed in the steam tables of Keenan and Keyes in 1936.§ He has also studied the implications of new determinations of temperatures on the thermodynamic scale. Since the

establishment, in 1927, of the International Temperature Scale, virtually all thermodynamic measurements have been reported in terms of that scale. Recently, Professor Beattie, of the Massachusetts Institute of Technology, has determined the relation between the International and the Kelvin scales by means of some very accurate measurements in gas thermometry.

Keyes has shown that the thermodynamic consistency between the calorimetric measurements of Osborne and his colleagues at the National Bureau of Standards and the volumetric measurements of Keyes and his colleagues at the Massachusetts Institute of Technology is improved when these are reinterpreted in terms of the thermodynamic scale of temperature. His method of testing showed consistency within one part in 3,000 from 0 deg. to 350 deg. C. The steam tables of 1936 employed specific heats at zero pressure taken from spectroscopic data. Subsequent work has shown that these values should be revised upwards by fractions of 1 per cent., which increase with the temperature. Keyes has attempted to reconcile this modification with the existing experimental data on volumes, enthalpies, Joule-Thomson coefficients, and specific heats, but without success. This dilemma has not been resolved. It would seem that either the present state of the science of band spectra is not adequate to determine the specific heat of the polar water molecule with sufficient precision, or else a curious combination of errors in the thermodynamic types of experiment has brought them into spurious accord.

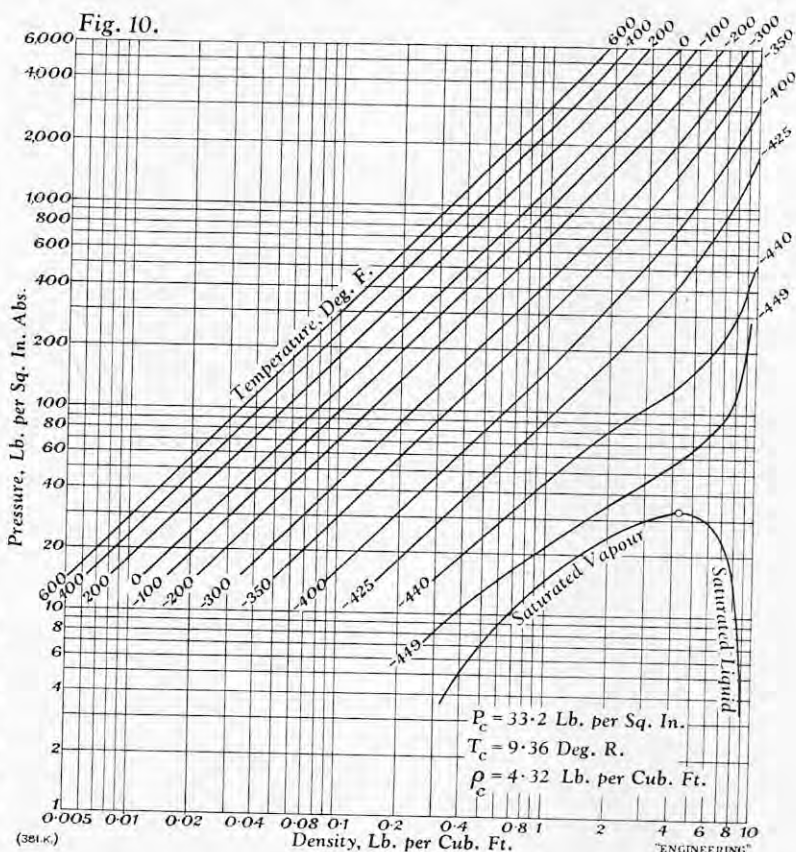
The usefulness of the material outlined above depends in no small degree upon the art of designing working tables and charts which the engineer can use with facility. A few developments along these lines will be described. The National Bureau of Standards, aided by the National Advisory Committee for Aeronautics, are engaged in two major projects for selection and presentation of existing data.* The first is a compilation of thermal properties of wind-tunnel and jet-engine gases. The properties listed when available are $\frac{p}{RT}$, enthalpy, entropy, specific heat, specific-heat-ratio, viscosity, thermal conductivity, relaxation parameters, and others. Three additional sets of tables† are being prepared and distributed covering an extremely wide range of substances and giving, in series I, enthalpies of formation, entropies of formation, etc., at 298.16 deg. K.; in series II, thermodynamic data on change of phase in fusion and vaporization, and in series III, enthalpy of formation and other chemical-thermodynamic data over a range of temperatures.

Of somewhat more immediate engineering interest are the tables for air and products of combustion of lean mixtures of hydrocarbons and air which were published in 1945 under the title *Gas Tables*.‡ The

* H. J. Hoge, *Trans. A.S.M.E.*, vol. 72, pages 779-784 (1950).

† Rossini, *Trans. A.S.M.E.*, vol. 70, pages 626-627 (1948).

‡ *Gas Tables*, by Keenan and Kaye. Wiley, 1945.



distinctive feature of this table is the quantity p_r , the "relative pressure," which makes it possible to compute processes at constant entropy from a table with a single argument, namely, the temperature. By comparison with a table with two independent arguments—for example, the steam tables with pressure and temperature—this table is of far greater convenience. For instance, the number of temperature entries can be so greatly increased that interpolation is hardly necessary. It has been shown that when the values in such a table are given per mol, instead of per pound, the table is applicable to a wide range of the carbon-hydrogen ratio in the fuel.

Hottel, Williams, and Satterfield, at the Massachusetts Institute of Technology, have published charts* for reactants and products of combustion of fuels containing hydrogen, carbon, oxygen, and nitrogen. These are for richer fuel-and-oxygen mixtures than the *Gas Tables* of Keenan and Kaye. They are calculated for the chemical-equilibrium composition of the products.

The development of power plants for missiles and other things that was stimulated so greatly by World War II has introduced into engineering activity many new fuels for which no tables or charts are available. The authors of this new set of charts have undertaken a major task of generalizing the properties of equilibrium mixtures of gases made up of the atomic species C, H, O and N. Concerning this development the authors say: "This chapter [of their book] presents a set of generalized thermodynamic data which encompass all probable compositions of interest in the four-component system, carbon-hydrogen-oxygen-nitrogen. . . . They may be used in solving problems involving chemical species which are composed of any two or more of these elements in almost any proportions. The ratios considered include those which are encountered with mixtures of fuel such as hydrogen, gasoline, alcohols, ammonia, organic amines, and hydrazine; with oxidants such as oxygen, air, hydrogen peroxide and nitric acid." The use of the charts involves first a calculation of a "fictitious" or simplified chemical composition by ready means supplied by the authors. Certain thermodynamic constants are readily determined from this fictitious composition. Small auxiliary charts are entered with ratios representing the nitrogen-oxygen, the carbon-hydrogen, and the carbon-oxygen ratios to obtain an interpolation number. This number, along with the temperature, fixes a point in another chart. The ordinate, along with the previously determined thermodynamic constants, fixes the enthalpy.

Although this procedure is hardly a simple one, it

* *Thermodynamic Charts for Combustion Processes*. Wiley, 1949.

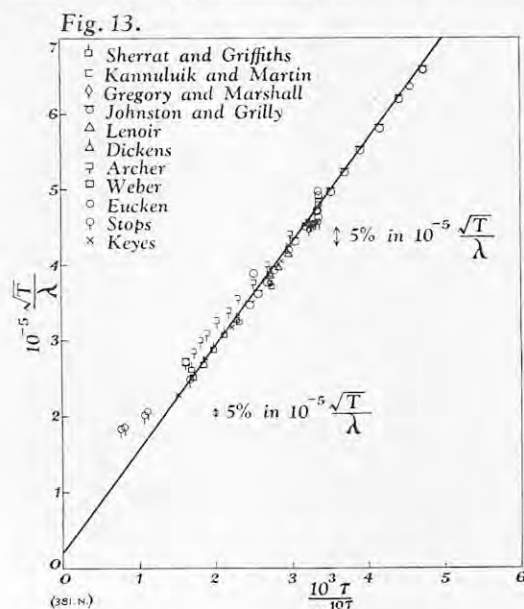
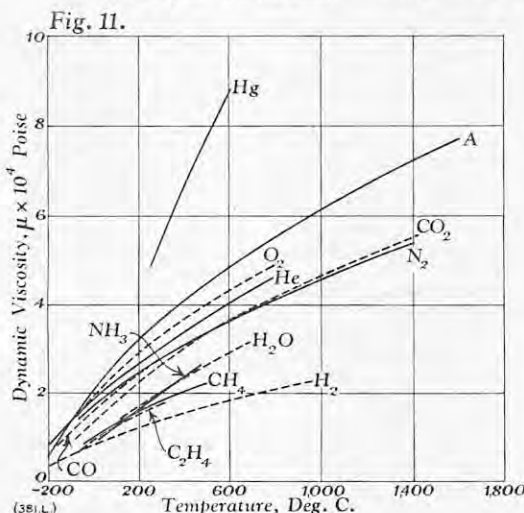
* *Trans. A.S.M.E.*, vol. 71, pages 885-895 (1949).

† *Trans. A.S.M.E.*, vol. 72, pages 751-758 (1950).

‡ *Jl. Chem. Phys.*, vol. 15, pages 602-612 (1947), and vol. 17, pages 923-934 (1949). *Trans. A.S.M.E.*, vol. 70, pages 641-644 (1948).

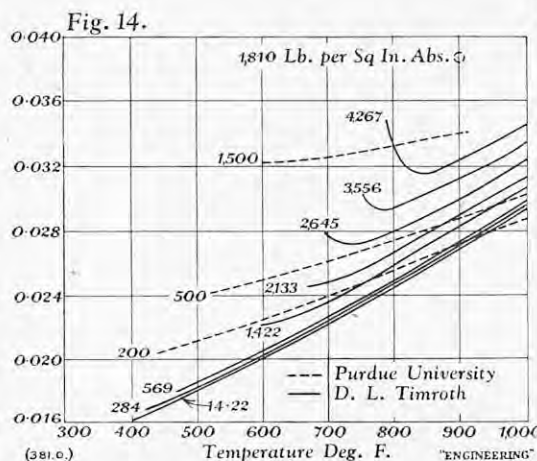
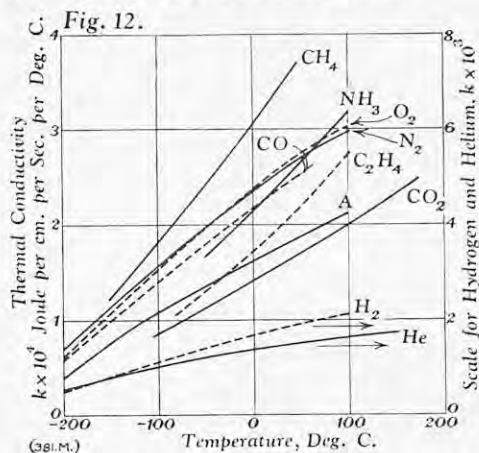
§ *Thermodynamic Properties of Steam*, by Keenan and Keyes. Wiley, 1936.

PROPERTIES OF GASES OF COMBUSTION.



will not seem too formidable to anyone who has had the experience of calculating a thermodynamic property through the usual procedure of determining equilibrium composition before embarking on the chemical-thermodynamic computations.

The present state of knowledge of the transport properties, viscosity and thermal conductivity, is far less satisfactory than that of the thermodynamic properties. Moreover, the amount of work now in progress on transport properties is utterly inadequate in view of the urgent needs of technology. In 1947, Hawkins, of Purdue University, reviewed the available data on viscosity and thermal conductivity of gases.* His bibliography includes 133 items. Fig. 11 shows his summary of viscosity data for vanishingly small pressures and Fig. 12 is the corresponding chart for thermal-conductivity data. Subsequently Keyes reviewed these data and summarised them by tabulating for each gas the constants in his empirical formulations. The empirical formulation is a modification of the Sutherland equation. It will be recalled that the Sutherland equation is derived from the van der Waals molecular model. Keyes has modified the denominator of the Sutherland equation in such a way that the modified equation approaches the Sutherland equation as the temperature approaches infinity. For helium and argon Keyes found it necessary to subdivide the temperature range into parts with different equations for the different parts. Keyes found to his surprise that the equation he had used to formulate viscosity served admirably to formulate thermal conductivity. Fig. 13 compares observations and formulation for CO₂. In this chart λ denotes thermal conductivity, T temperature, and τ the reciprocal of temperature. As regards the thermal conductivity of water vapour at low pressures, Keyes and Sandell† have recently published measurements in serious disagreement with those of the Russian investigators Timroth and Vargaftig. Keyes and Sandell discuss this disagreement at some length. They show that the data for nitrogen from the same two sources



are in good agreement and infer that the disagreement for water is related to its higher absorptivity to radiation and to electrical leakage through the water. They point out that the hot-wire method used by Timroth and Vargaftig is subject to errors resulting not only from absorption of radiation by the water vapour but also from the effects of adsorbed water vapour on the wire as a resistance thermometer. They question too whether the Thomson effect has been properly allowed for in determining the temperature of the wire.

Keyes has concluded that the two-constant formulation based on the Lennard-Jones force field does not represent the variation of viscosity with temperature within the precision of the observations. It would seem, therefore, that the force-field synthesis will serve primarily in predicting the order of magnitude of the properties of gases which have not yet been experimentally studied. Keyes shows that the viscosity of a binary mixture at low pressures can be predicted in terms of the viscosities of the pure constituents with the aid of Enskog's equation which is based on the van der Waals model. Table II compares the observa-

tions of the group at Purdue University* are shown in Fig. 14, which was published by Hawkins† of the Purdue group. The agreement is quite good at zero pressure, but there it ends.

At the University of Illinois, Comings, Mayland, and Egly‡ measured the viscosity at pressures in excess of the critical pressure for carbon dioxide and three hydrocarbons. On the basis of these measurements and of existing data on other gases they prepared a generalised chart of the ratio of the viscosity at any pressure and temperature to the viscosity at the same temperature at a pressure of one atmosphere. The independent variables are the reduced temperature, i.e., the ratio of the absolute temperature to the absolute critical temperature, and the reduced pressure. The apparent success of this generalisation is quite remarkable. In effect, it says that the ratio of the viscosity to the viscosity at zero pressure (the difference being insignificant) for any temperature is a single function of the reduced pressure and the reduced temperature for all gases. It would be more reasonable to expect a single function at these supercritical conditions for the ratio of the viscosity to the viscosity at the critical state. In the absence of information about the viscosity at the critical state the use of the viscosity at zero pressure is more realistic. Nevertheless, if we may judge by the variations in the compressibility product $p v / RT$, the generalisation based on viscosity at zero pressure is likely to prove unsatisfactory for some substances. In the meantime, however, the generalisation of Comings, Mayland and Egly is the best we have and its indications are doubtless reliable as first-order approximations. In particular it would seem to indicate that the pressure effect on the viscosity of steam as found at Purdue University is too large and that the Timroth values are of the right order of magnitude.

By an application of the Enskog equations the Illinois group§ have developed an analogous generalisation of the thermal conductivity. The Enskog equations permit the thermal-conductivity ratio to be expressed in terms of the viscosity ratio and quantities taken from the equation of state. This generalisation of thermal conductivity was tested against the observations of Vargaftig|| for nitrogen, which extend to a reduced pressure of 2.9. The agreement was found to be entirely satisfactory.

Knowledge of the pressure effect on the thermal conductivity of nitrogen is in a remarkably happy state. Keyes and Sandell (loc. cit.), at the Massachusetts Institute of Technology, have confirmed the Vargaftig data and extended the range of our knowledge in both pressure and temperature. Their results indicate an approximately linear variation of thermal conductivity along an isotherm from zero pressure to five times the critical pressure. For steam the pressure effect on thermal conductivity which was observed by Keyes and Sandell is appreciably less than that observed by Timroth and Vargaftig. Until further data appear, the values of Keyes and Sandell are to be preferred in view of their caution regarding radiation and other characteristics of water.

Keyes has measured the pressure effect on the thermal conductivity of mixtures of nitrogen and carbon dioxide and correlated it with the Enskog synthesis. At the higher pressures he encountered in the course of his measurements a periodic fluctuation of his temperature indications which he attributed to the separa-

TABLE II.—VISCOSITY OF H₂-C₂H₆.

(27-82 deg. C.)								
Per cent. H ₂	0.0	18.21	37.04	58.18	78.82	87.50	92.25	100
(η) obs*	8.20	8.40	8.77	9.25	9.84	9.92	9.71	8.92
(η) corr†	8.92	—	—	—	—	—	—	8.96
(η) calc‡	—	9.08	9.28	9.52	9.67	9.60	9.47	—
(η) calc*§	—	8.40	8.65	8.99	9.65	9.57	9.26	—
(277-48 deg. C.)								
(η) obs*	14.20	14.40	14.83	15.28	15.68	15.39	14.87	13.44
(η) corr†	14.24	—	—	—	—	—	—	13.06
(η) calc‡	—	14.42	14.62	14.81	14.75	14.45	14.11	—
(η) calc*§	—	14.41	14.46	14.90	14.93	14.69	14.40	—

* η_1 and η_2 reported by Trautz and Kurz.

† η_1 and η_2 from a correlation of all reported data.

‡ Taking S_1 and S_2 from equation of state constants and assuming S_{12} to be $\frac{1}{2}(S_1 + S_2)$.

tions of Trautz and Kurz* for hydrogen-propane mixtures with the values obtained from the Enskog equation. The agreement here is of particular interest because the viscosity of the mixture in certain proportions is very much in excess of that of either constituent. The effect of pressure on the viscosity is clouded in obscurity, largely because of the disagreement among various investigators of the viscosity of steam. The results of two extensive sets of measurements, those of the Russian investigator D. L. Timroth† and

tion of the constituents by thermal diffusion in the temperature gradient.

In conclusion, gratification may be expressed concerning recent progress in our knowledge of the thermodynamic properties. This progress may be credited very largely to the development of the science of

* *Trans. A.S.M.E.*, vol. 62, pages 677-688 (1940).

† *Trans. A.S.M.E.*, vol. 70, page 21 (1948).

‡ *U. of Illinois, Eng. Exp. Sta. Bull.* Series No. 354.

§ Comings and Nathan, *Ind. & Eng. Chem.*, vol. 39, pages 964-970 (1947).

|| N. Vargaftig, *Technical Physics (U.S.S.R.)*, vol. 4, page 343 (1947).

* *Trans. A.S.M.E.*, vol. 70, pages 655-659 (1948).

† *Trans. A.S.M.E.*, vol. 72, pages 767-778 (1950).

* *Annalen der Physik*, vol. 9, page 981 (1931).

† *Jl. of Physics (U.S.S.R.)*, vol. 2, pages 419-435 (1940).

interpreting band spectra, to direct thermodynamic experiment, and to the synthesis of the pressure effect from the theory of interaction of molecular force fields. The development of the resulting data into forms of immediate utility to the engineer has also progressed. The most difficult phase of this work is to be found in presenting the properties of products of combustion for which the equilibrium compositions are of infinite variety. Further attention to this problem would seem to be desirable.

About transport properties, however, we know the least. Every effort should be made to increase the number of experimental investigations of viscosity, thermal conductivity, and coefficients of diffusion so that material shall be accumulated on which theoretical synthesis may be constructed. If these things are done, then the successors to Herbert Akroyd Stuart in the development of power-producing machinery will have tools at hand for their work. The consequence of that work no man can foretell.

BOILER AND TURBINE TESTING.*

By CAPTAIN (E) L. F. INGRAM, R.N., and CAPTAIN (E) L. A. B. PELLE, D.S.O., M.V.O., R.N.

(Concluded from page 352.)

It is generally considered inappropriate to say much about troubles experienced with a new design, but a new design which has no troubles at all is usually one in which the advances on previous practice are very limited; the diagnosis and cure of troubles are matters of essential interest to engineers. To maintain proper perspective, let it be understood clearly that there were very few mechanical troubles throughout these extensive, and, in some instances, punishing trials. Some teething troubles were experienced with feed-pump and extraction-pump systems and boiler equipment, but these were eliminated before the trials proper had proceeded very far. The main defects on trials which entailed considerable investigation were a few cases of overheated bearings, L.P. turbine distortion (discussed previously), and wear on flexible couplings between turbines and pinions.

It is difficult to measure true bearing temperatures, and the various compromises adopted include the measurement of the bearing-shell temperature and outlet-oil temperature. In the case of the Daring bearings, the thermometers are placed in a separate outlet path from the main oil discharge. This construction was not successful in the case of most of the bearings as first fitted, since, at one or more conditions of running, the oil pressure at the bleed point was insufficient to cause the oil to be pumped up to the thermometer.

To get up to the thermometer, the bleed point must clearly be at a zone of high pressure in the journal; even at positions no more than 50 deg. away from the load line, there may be insufficient pressure for an oil jet to reach the thermometer. Pressure zones were analysed under different conditions of load and plotted on polar diagrams; these diagrams showed clearly the cause of the trouble. Fig. 9, herewith, shows a typical polar diagram from this investigation. A circumferential groove was needed to collect oil, close enough to the boundary of the bearing not to affect the oil distribution over the journal, yet not so close as to cause excessive side leakage. An oil groove $\frac{1}{32}$ in. deep effected little improvement. Considerations of oil conditions in the groove suggested that the drag of the shaft upon the oil in the groove was sufficient to prevent equal pressure obtaining all round the circumference; to overcome this drag effect, conditions of turbulent flow were required in the oil groove. To obtain a Reynolds number of 2,000 at turbine speeds below 100 r.p.m., an oil groove $\frac{1}{8}$ in. wide and $\frac{1}{4}$ in. deep was necessary. The final design was practically identical with an American method, and their practice of putting a dam in between two bleed holes was incorporated; if there is no dam, the oil moving past the pressure take-off hole might act as an injector pump and suck oil into the groove rather than pump it out.

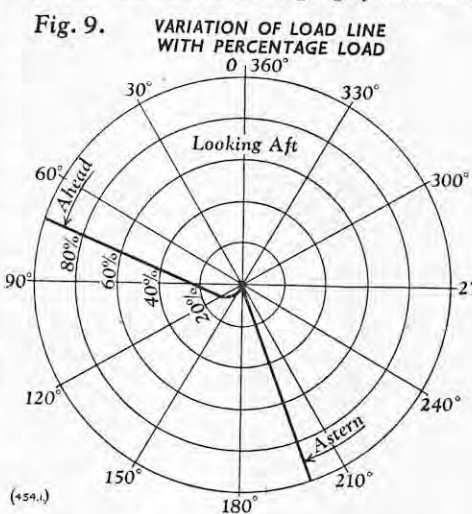
As a result of the experiments, alterations to the bearings of the whole class were afterwards effected. Since evaluation of the effects of these alterations required running of the machinery, some of the bearings were fitted with special thermocouples, as a precaution against overheating; these thermocouples proved to be very sensitive, but, owing to the requirements of robustness and simplicity, were not fitted permanently. Experience with the bearings as finally fitted has been entirely satisfactory from the lubrication standpoint, and, though the temperatures indicated on the bearings may differ appreciably from the conditions at the bearing surface, experience has shown that dangerous temperatures are readily indicated and enable immediate action to be taken.

* Paper presented to the International Conference of Naval Architects and Marine Engineers at a meeting held in London on June 27, 1951. Abridged.

The bearings as originally fitted had the following diametral clearances: primary pinion bearings (6-in. diameter), 0.007 in.; H.P. turbine bearings (6-in. diameter), 0.010 in.; all other bearings (up to 17½-in. diameter), 0.015 in. All bearings were made with oil recesses at the joints, but no "wash away" of the white metal into the oil recess was provided.

Only two bearings gave any trouble due to overheating: these were the H.P. turbine forward bearing and the H.P. primary-pinion aft bearing. In both cases, a reduction in bearing temperature was obtained by providing "wash ways" at the sides of the bearings. In addition, the oil clearance in the two H.P. primary-pinion bearings was increased from 0.007 in. to 0.010 in. In this case, the oil temperature at full power was reduced from 197 deg. F. to 190 deg. F. as a result of increasing the oil clearance, and to 183 deg. F. following the "wash away" at the bearing sides. This temperature of 183 deg. F. was the highest bearing temperature recorded during the six-hour full-power run, and is considered satisfactory.

The scoring of the faces of toothed couplings is by no means an uncommon experience; so far as is known, the problems involved are not yet fully understood, and the proper design remedy is still awaited. The Daring trials were no exception, and the teeth of the flexible couplings did show signs of distress. These couplings, which are of heat-treated 3½ per cent. nickel steel, are designed to allow axial sliding, the teeth of the male ends of the dumb-bell coupling being enlarged in diameter at the centre to give a fine clearance at the root of the female coupling, thus keeping the two parts concentric. Oil is fed to the coupling by an oil thrower



which directs oil axially to the roots of the male teeth; but it is doubtful whether an oil film would be formed between the teeth, and it is probable that most of the oil passes through the clearance between the tips and the roots of the mating teeth.

When the shafts are out of alignment, the teeth in the plane of mis-alignment can easily adjust themselves, but the teeth at 90 deg. will be under an unequal distribution of load, with concentrations at one end or the other of the teeth. Thus, each tooth will experience the change of a concentration of stress along its length and back again per revolution of the turbine.

Two different types of pitting were noted on each tooth, each definitely confined to one half of the driving or driven face. The pitting on the inside half of the teeth (remote from the oil supply) was of the nature of fret corrosion with brown-black pits about 0.001 in. deep. Fret corrosion is indicative of small movements under load in the presence of small quantities of oil. The pitting on the outside half of each tooth indicated a high-pressure welding of the mating surfaces, followed by parting of contact between the mating surfaces and a transference of metal from the male to the female component's teeth. These regions do not show any discoloration, and this seems to indicate the absence of oil. The pits are irregular in shape, being, in general, as long as they are broad, as might be expected if they are formed by the parting of welded surfaces.

These couplings were examined at frequent intervals during the trials; the areas of both fret corrosion and of torn metal extended progressively, but remained peculiar to their respective halves of the tooth surfaces. Twice during the trials the teeth were dressed with a file, and eventually the deterioration of tooth surfaces became stabilised. This phenomenon of surface deterioration arresting itself is fairly common experience with flexible coupling troubles, but it is difficult to comprehend.

In the second series of trials (Daring II), new couplings were fitted and, in each case, one end of the dumb-bell was treated with molybdenum di-sulphide. The treated ends gave markedly improved results. For Daring III, a further set of new couplings of the

same design were fitted and were also treated with molybdenum di-sulphide; the results were not so good as with Daring II, but appeared to be acceptable after some running, though signs of distress clearly remain.

The defects, whether fret corrosion or tearing of metal subsequent to welding, are clearly due to axial movements of the coupling parts. It was surprising, therefore, to find in a front-to-front test of single-helical gearing, where the pinions are located axially by thrust blocks, that fret corrosion and axial tears had both taken place. These couplings were also of 3½ per cent. nickel steel, heat-treated, and were treated with molybdenum di-sulphide. Material with considerably higher ultimate tensile stress has been specified for the flexible couplings of some machinery now under construction. Trials will also be made with a nitrided steel, and with a coupling having barrelled teeth designed to avoid end loading; but it is not felt that either hard material or a minor change in tooth profile will prove to be a complete cure for the troubles experienced in this type of coupling.

Gas-Turbine Testing.—The Admiralty have a number of gas turbines for marine propulsion under development. In the first place, each of these is being tested at the maker's works against a brake, with full instrumentation; these test facilities are of the same order of completeness as those available at Pametrada. Subsequently, it is intended that the machinery shall be installed in suitable craft, and, though the units may not become prototypes for repeat orders for naval use, the trials will be analogous to prototype-testing. With one exception, these propulsion units represent ambitious advances, even in the very new science of gas-turbine engineering. A rather more orthodox advance is the British Thomson-Houston Company's gas turbine produced for the Anglo-Saxon Petroleum Company for installation in the Diesel-electric tanker Auris.

The Admiralty were responsible for the first gas-turbine vessel in the world, when a gas turbine with the code name of Gatric was fitted into a motor gunboat and commenced trials in 1947, just 50 years after the trials of the Turbinia. Gatric is a marine version of an aircraft jet engine developed by the Metropolitan-Vickers Electrical Company, with a free power turbine fitted in place of the jet pipe; the engine develops 2,500 shaft horse-power and drives the centre propeller of a three-shaft installation through a clutch and gearbox. Two 1,350-h.p. Packard petrol engines are coupled to the wing shafts for low-speed and astern running. This machinery was installed in M.G.B. 2009, now renumbered M.G.B. P.5559, after only the minimum of preliminary shore-testing, since it was merely an experiment "to see if it worked." Two additional engines had been ordered to enable shore tests to be carried out concurrently with the trials at sea. The success of the latter was in part due to the fact that engines were available ashore for development testing.

The main objectives of installing Gatric in M.G.B. P.5559 were to gain experience of installing operating and maintaining a gas turbine at sea, and to determine the effect of a salt-laden atmosphere on the compressor blading. M.G.B. P.5559 was, in effect, a floating test bed and considerations of speed, or of the most efficient installation for the job, did not enter into the problem. It was, in fact, somewhat of an *ad hoc* arrangement, but, as such, produced most valuable results and has pointed the way for future development. The outstanding success of the preliminary trials did in fact hamper progress, as, for the first month or so, a lot of time was taken up in giving sea demonstrations to numerous visitors.

The trials were surprisingly trouble-free, apart from seizure of the disconnecting clutch, and much valuable operating experience was obtained. The trials also provided important data on noise characteristics, and the effectiveness of various silencing and heat-insulation methods. Very early in the sea trials, a noise survey was undertaken in the boat to obtain data which could be used as a basis for the design of silencing equipment. It was found that the greatest noise level in the engine-room (117 dB) originated from the gas-turbine gearbox. On deck, just aft of the bridge, the level was also 117 dB, the major source being traced to the compressor air-intake; on the bridge itself, noise from the funnel predominated, the total level being 102 dB.

The most serious component of noise was considered to be the high-frequency note emanating from the axial compressor and transmitted through the air-intake trunking and settling chamber, and experiments were carried out to reduce this. Two methods of silencing were tried; firstly, the settling chamber was lined with Fibreglass, and "splitters" of the same material were fitted in the intake; and, secondly, a reflector-absorber unit, designed and manufactured by Messrs. Vokes, was fitted in the settling chamber. The Fibreglass method gave a reduction in the compressor blade note of 39 dB, and the Vokes unit gave one of 12 dB. Various combinations of these two methods have also been tested. Reduction of the intake noise

has also made possible a more accurate evaluation of the exhaust noise, and it has been found that the compressor blade noise is present here also. Silencing equipment, including a "torpedo-type" splitter, has been fitted in the funnel, but no results are to hand at present.

Owing to the close proximity of the two petrol-driven Packard engines, great care was necessary in the design of Gatric's heat insulation, and it was finally decided to enclose the entire engine in a ventilated casing. Gatric itself was lagged with 2-in. asbestos mattresses, and a light metal casing was then fitted over this lagging, but not in contact with it. Air supplied by a small fan was blown between the casing and lagging, and exhausted up the funnel. The fan was later removed and air drawn through the casing by an engine exhaust operated ejector fitted in the funnel.

One of the principal objectives of the trials was to investigate the effect of a salt atmosphere on the performance of gas-turbine compressors, especially of the axial-flow type. The compressor blades were manufactured from aluminium alloy R.R.56 and anodised by the chromic-acid process. Examination after the first 50 hours' running revealed that the blades had been attacked by inter-crystalline corrosion. The corrosion occurred locally, the average depth being 0.005 in. to 0.010 in. As a result, the material was changed to R.R.57, which is more resistant to this type of attack. No further corrosion troubles have been experienced, though it is considered that corrosion would still occur in the absence of water washing.

After 120 hours' running, the efficiency of Gatric began to fall rapidly. The compression ratio had fallen to 94 per cent. and output to 86 per cent. of their design values. Examination showed a light snow-flake salt deposit on the compressor blades. To overcome this fouling problem, Messrs. Metropolitan-Vickers designed and fitted a water-spray ring in the compressor inlet. A ten-gallon injection of distilled water increased the compression ratio and output to 98.5 per cent. and 97 per cent. of design, and a second injection of 10 gallons restored them to their design values. It was found that injection rates lower than 100 gallons per hour were not very effective, and continuous injection was therefore ruled out. The best results were achieved by injecting 10 gallons in five minutes after every 10 hours' running time. The use of liquids other than water has not been tried.

All this information will prove to be of great value, and most of it, especially the effects of a salt atmosphere, could only be obtained from sea trials. It should be noted, however, that the maximum running time that could be achieved, even in good weather, was only about 24 hours per week, and it did, in fact, require some five months to complete the first 50 hours, of which 13½ hours were taken up in demonstration runs. These figures emphasise the difficulties of obtaining long runs at sea, and show why it was necessary to carry out simultaneous shore trials.

Two Gatric engines were available for shore tests, one installed at Messrs. Metropolitan-Vickers' works (this engine has since been presented to the Science Museum) and the other at the Admiralty Engineering Laboratory; both were used for development testing and the proving of new components. At the Metropolitan-Vickers works an investigation was made into the effects of using high-sulphur Diesel fuel; the sulphur content of this was 2.78 per cent. by weight. The sprayer shields, which were made of Inconel, were badly eaten away, but the rest of the engine remained unaffected. This was followed by preliminary tests on the combustion of naval boiler fuels. The boiler fuel used had a viscosity of 492 seconds Redwood I at 100 deg. F., a sulphur content of 2.04 per cent. and an ash content of 0.02 per cent. The major element of the ash was sodium.

The preliminary trials on heavy fuel combustion at the Metropolitan-Vickers works, which included a successful 50-hour run, were continued, on the third engine at the Admiralty Engineering Laboratory, and over 200 hours' running on two different types of boiler fuel have been completed there. After 130 hours' running, the deposits formed on the turbine nozzles were not sufficient to cause any noticeable drop in performance, and consisted mainly of sodium sulphate. During subsequent inspection, it was found that the greater part of these deposits could be washed off with cold water. A second series of trials on a high-vanadium boiler fuel has been carried out, but results are not yet to hand. The operational difficulties of heating and pumping the fuel have also been investigated. All this work, involving frequent stripping and cleaning of the engine, modification of fuel heaters, etc., would have been very difficult to carry out at sea, and progress would have been much slower.

Testing of Gears.—No summary of Admiralty trials in the marine propulsion field would be complete without reference to the testing of gears. The object of the Admiralty development programme is to obtain gearing of the minimum weight compatible with

reliability. In general, it covers two main fields, namely, machine accuracy and improved materials.

The requirements for machine accuracy have been stepped up. B.S.S. 1498/1948 and the draft B.S.S. for "Turbine Gears" provide the basis for the machine and gear accuracy now required. Instead of undulations of the order of 2/1,000 in., undulations are now required not to exceed 2/10,000 in.

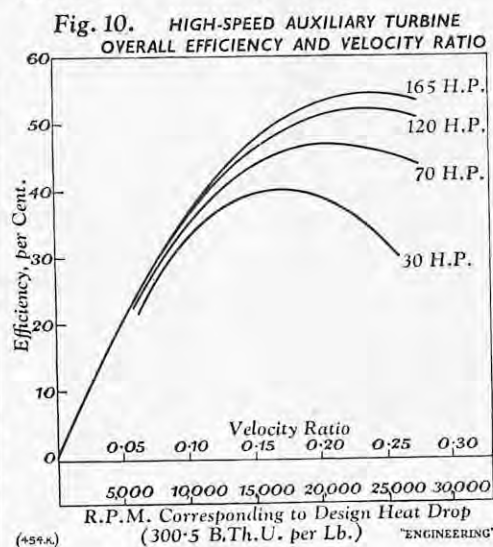
"Improved materials" covers the production of gears of the hardest materials that can be machined by hobbing machines. It is expected that materials of 60 tons to 65 tons per square inch ultimate tensile strength can be used for large secondary wheels and 70 tons to 75 tons per square inch for pinions and primary wheels. Case-hardened and ground gears are also covered.

Designs have been accepted for gears in which advantage has been taken of the expected gains from these developments. These can be summarised as follows:—

(i) Hobbed and shaved existing materials: primary wheels and pinions, 40 to 45 tons per square inch, 3½ per cent. Ni; loading, primary, 876 lb. per inch of face; loading, secondary, 1,356 lb. per inch of face.

(ii) Hobbed and shaved hardest material: primary wheels and pinions, 70 to 75 tons per square inch, E.N.26; secondary wheels, 60 to 65 tons per square inch, E.N.30; loading, primary, 1,270 lb. per inch of face; loading, secondary, 2,955 lb. per inch of face.

(iii) Hardened and ground (Design 1): primary



wheels and pinions, E.N.36 (approximately) case-hardened; secondary wheels, 85 tons per square inch, E.N.30 (approximately) air-hardened; loading, primary, 1,808 lb. per inch of face; loading, secondary, 2,582 lb. per inch of face.

(iv) Hardened and ground (Design 2): primary wheels, pinions and secondary wheels, E.N.36 (approximately) case-hardened; loading, primary, 2,170 lb. per inch of face; loading, secondary, 5,110 lb. per inch of face.

The design basis has been fixed by consideration of the large amount of data available on tests of gear materials. In the main, these have been confined to small gears. It is essential, therefore, to do some full-scale testing to determine the limiting conditions. In warships, a relatively small time is spent steaming at high powers; this permits higher gear loads to be carried than in merchant ships. To run warships for an extended period at full power to test the life of gearing is impracticable. Moreover, it is possible to run the gears to destruction when testing ashore.

Testing ashore can be done either against a brake, which is expensive, since motive power equal to the full power of the machinery is required for the trials; or two sets of handed gears can be run against each other with torque locked into the circuit by some loading device, in which case the only driving power required is that needed to overcome frictional losses. For single-reduction gearing, the two gearcases are arranged back-to-back, the main wheel shafts being coupled to each other and drives to the pinion shafts led out at the after end of the gearcase and connected to the torque applicator. With double-reduction gearing, it is not usually practicable to lead the primary drive through the after end of the gearcase. Such gears are therefore coupled front-to-front for two-cylinder layouts; in this case, no connection is made between the main wheel shafts, but torque is applied through one pair of pinions and opposed by the other pair. Front-to-front testing has the disadvantage that the loads on the main wheel are applied in opposite directions by the high-pressure and by the low-pressure drives, which tends to confuse the issue so far as testing of the main wheel teeth are concerned; it is also not

possible to vary the proportions of torque carried by the high-pressure and low-pressure pinions individually.

The following gears are being tested to destruction in order to determine their ultimate load-carrying capacity:—

(i) Standard materials: pinions, 40-45 tons per square inch, 3½ per cent. Ni; wheel, 34-38 tons per square inch forged steel; loading, 798 lb. per inch of face.

(ii) Case-hardened ground primary gears: pinions and wheels, E.N. 36 case hardened; load, 3,860 lb. per inch of face.

(iii) Case-hardened and ground secondary gears: pinions and wheels, E.N. 36, case-hardened; load, 7,620 lb. per inch of face.

(iv) Induction-hardened gears: secondary gears: pinion and wheels, E.N. 24, induction-hardened; load, 7,620 lb. per inch of face.

The tests on the first set of gears of standard materials have been concluded. The results were briefly: design load, 798 lb. per inch of face; pitting commenced at 200 per cent. load after 229 hours running at loads of 100 per cent. and above; gear failed by tooth fracture at 300 per cent. load after a further 172 hours at loads of 200 per cent. and above. A further test with the same gear design and materials, but with pinion corrected for the calculated bending and torsional deflection at 200 per cent. load, has enabled the gears to take a load of 325 per cent. without pitting, though a few random pits occurred at 340 per cent. load. The tests are being continued. It was found during these tests that the total torque to run the two gear sets at 4,100 r.p.m. on full load was 200 lb. ft., of which 170 lb. ft. was attributed to bearing losses and 30 lb. ft. to gear-tooth friction losses.

Testing of Auxiliary Machinery.—All auxiliary machinery for naval service is tested at the maker's works before acceptance. The first off any order is type-tested and the resultant performance curves accepted as typical for the whole order, though, in the case of a large order, repeat type-tests are required as the order proceeds. The bulk of the order is proof-tested only, a few check readings being taken to prove that the individual machine conforms to type-test. Any considerable innovation in design is developed and tested by the manufacturer in the first case, and, because naval requirements are so different from commercial needs, the principal features of design performance of a new auxiliary are discussed with the Admiralty at an early stage.

An interesting example of development-testing of auxiliary machinery is the small high-speed turbine for auxiliary drive at present under test at the works of W. H. Allen, Sons and Company, Bedford. It has been the practice for a considerable time in naval engineering to use non-condensing steam auxiliaries for the greater part of the propulsion auxiliaries, the exhaust steam being utilised for feed heating. This leads to small, light auxiliary machinery, which is one of the prime requirements for naval work and is, in general, economical, since these machines act as a single-stage tapping for bleed feed-heating. It is, however, essential for economy that the latent heat in the auxiliary exhaust shall be utilised either for feed heating or for distilling. As propulsion machinery advances to lower water rates, so must the steam auxiliaries improve in efficiency if excess exhaust steam is to be avoided, and this trend is accentuated by the rising power demanded of the auxiliaries to meet the needs of higher steam pressures and higher draught losses across the boiler installation.

The design of this type of turbine was therefore re-examined. It was clear that a turbine containing a number of Rateau stages was the most efficient, but its weight and space were considerably increased, while the three-row Curtis wheel had too low an efficiency. It was decided, therefore, to carry out trials on the simple two-row Curtis wheel, designed up to the maximum speed possible without recourse to very special materials.

A 3 per cent. chrome-molybdenum steel was selected for the rotor and it was decided to machine the blades integral with the rim; a pitch-circle diameter of about 9 in. was chosen as being the smallest convenient size. The steel selected had a 0.2 per cent. proof stress of 32 tons per square inch and ultimate tensile strength of 43 tons per square inch at 650 deg. F. and was considered to be safe up to 29,000 r.p.m., giving a blade speed of 1,150 ft. per second and a velocity ratio of 0.30 under the steam conditions of 540 lb. per square inch at 825 deg. F., exhausting to 10 lb. per square inch gauge.

Trials were carried out at varying powers and speeds, and the overall efficiencies obtained are plotted in Fig. 10, herewith. With the four nozzles in use, a maximum of 165 h.p. was obtained. Since the nozzle area was only 100 deg., the maximum power that could be obtained from a turbine of this size would be nearly 500 brake horse-power on a turbine weight of about 12 cwt. including gearing, but this would result in the sizes of steam and exhaust pipes and the necessary

valves becoming excessive, and it is probable that a limit of about 250 brake horse-power is desirable. The maximum blading efficiency achieved with this set was 62 per cent., the limiting factors proving to be partial admission and the small blade heights associated with this design. Further trials are being carried out with modified blade-paths and stainless-steel rotors with which slightly greater blade speeds and efficiencies will be possible.

As machinery design advances, the margins in design become less. Higher temperatures, higher speeds of rotation and higher stresses are employed and the effects of these factors become more difficult to predict. The need for rigorous testing to ensure reliability therefore becomes progressively greater. Further, it is only by accurate trial results that the performance gains from high-efficiency machinery can be demonstrated reliably, and only thus that the steps towards even higher efficiency, necessary to give increased endurance to the warship and lower fuel costs to the merchant vessel, can be consolidated.

As has already been stated, a considerable number of research schemes were included in these trials. Had the programme been restricted to recording performance, confirming design data, and proving the design for operating conditions, the cost would have been considerably less, but even so would have been of the order of two to three times the cost of two weeks' sea trials of a comparable ship. These expenses must be looked at from two aspects. Confirmation of design data is essential if further marked advances in economy or performance are to be achieved, and the ship-building industry of this country depends for its existence upon continual advances in design in order to maintain its predominant place. Secondly, reliability of performance year in, year out, fully justifies expenditure during building—owners of all classes of ship, whether mercantile or naval, demand economy of performance and 100 per cent. reliability. Only advanced designs which have been thoroughly tested can satisfy both demands.

In addition to financial expenditure, all this testing has incurred much effort, both at headquarters and at the various establishments and firms concerned. There is, however, no doubt that the improvements in performance which have been achieved, and the elimination of weak points that has been effected, fully justify all the labours and exertions involved.

PIG IRON AND STEEL PRODUCTION DURING AUGUST.—The British Iron and Steel Federation have announced that during August the annual rate of pig-iron production was 9,409,000 tons, compared with 9,205,000 tons during August, 1950. The annual rate of steel production in August was 13,855,000 tons, compared with 14,530,000 tons a year ago.

DESTROYERS FOR CANADA.—The Admiralty have announced that the two C-class destroyers *Crescent* and *Crusader*, which have been on loan to the Royal Canadian Navy since 1945, are to be presented to Canada. The Canadian Government intend to convert them for use as anti-submarine frigates, thereby increasing the number of ships suitable for anti-submarine work which can be made available shortly to the North Atlantic Treaty Organisation.

NORTHAMPTON POLYTECHNIC, LONDON.—Several series of special courses of evening lectures are to be provided at the Northampton Polytechnic, St. John-street, London, E.C.1. In the mathematics department, advanced courses on Bessel functions, computations, non-linear problems in electrical engineering, the Laplace transformation, relaxation methods, vector analyses, and other subjects, are to be given. Each course will consist of approximately 30 lectures, on one evening a week, and will commence, some on Monday, September 24, and others on subsequent days. Courses, also of approximately 30 lectures, in electronics, high-vacuum technology, applied acoustics, applied X-rays, applied spectroscopy, and photo-elasticity are to be provided in the applied physics department of the Polytechnic. Apart from that on photo-elasticity, which commences on January 8, 1952, all the courses are to begin on September 24. In the department of applied chemistry, a course of 10 lectures on refractories: their manufacture, properties and uses are to be given; they will commence on October 2. Enrolments for all the above courses should be completed by Friday, September 14. The prospectus of the part-time day and evening courses in engineering subjects and leading to National-Certificate, London University Degree, and other examinations has also recently come to hand. The autumn term commences on September 24 and prospective new students should enrol in the afternoon, from 2 to 4.30, or evening, from 6.30 to 9, on September 14. A pamphlet concerning the National College of Horology and Instrument Technology, which is accommodated at the Northampton Polytechnic, has also been received. Copies of any of the above publications are obtainable from the Principal.

2,000-KW FORCED-COOLED RESISTOR.

THE 2,000-kW forced-cooled resistor which is shown in Fig. 1, on this page, has been designed by the British Thomson-Houston Company, Limited, Rugby, for testing the generators of electric and Diesel-electric locomotives. It can also be used as part of the rheostatic braking system on such locomotives.

The elements of the resistor consist of aluminium-chromium stainless-steel strip with a high specific resistance and a low temperature coefficient. The strip is supported in a treated asbestos-compound frame (Fig. 2) and is continuous, but is arranged to provide for expansion and contraction. It is formed into a flat V-shape to ensure both maximum cooling from the air flow and rigidity. A number of frames are mounted together, either vertically or horizontally, depending on the space available, and the air passes

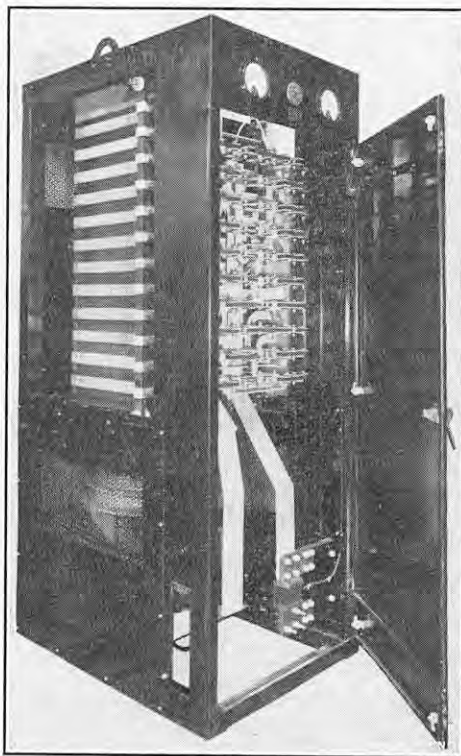


FIG. 1. COMPLETE RESISTOR.

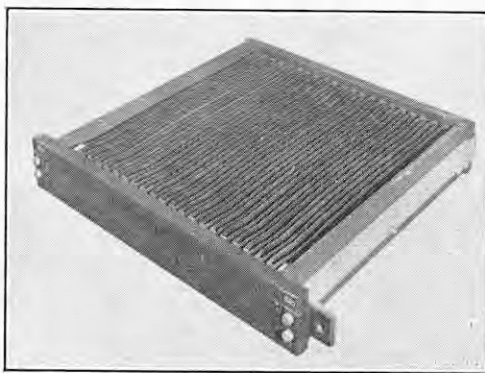


FIG. 2. INDIVIDUAL RESISTOR UNIT.

over each resistor in turn. The cooling air is supplied by a fan, which is installed at the bottom of a welded angle-iron enclosure and is driven by a 37-h.p. motor. This motor is connected in parallel with part of the resistor elements, so that the amount of cooling air supplied is approximately proportional to the load, and is evenly distributed by a diffuser.

Selector switches are fitted so that the resistors can be connected in series or parallel groups to suit particular load requirements. These switches have blades with silver button contacts which engage with silver-plated switch clips so as to give a high-pressure dome contact. They are mounted on insulated bars in front of the resistor frames and are accessible through the front door of the enclosure. The connections between the switches and the resistor terminals are made with silver-plated copper straps. All the terminals and tappings on the resistor elements are securely welded. The complete resistor with the selector switches measures 8 ft. 6 in. high, 3 ft. wide and 4 ft. 2 in. deep, and weighs nearly 1½ tons.

Although primarily designed for traction purposes, its compactness makes it suitable also for employment on engine test beds or in other places where space is at a premium and a large amount of power has to be dissipated.

BOOKS RECEIVED.

- Department of Scientific and Industrial Research. Report of the Mechanical Engineering Research Board with the Report of the Director of Mechanical Engineering Research for the Period May, 1947, to December, 1950.* H.M. Stationery Office, Kingsway, London, W.C.2. [Price 2s. 6d. net.] See page 338, ante.
- Productivity Report. Hot-Dip Galvanizing of General Work.* Report of a Visit to the U.S.A. in 1950 of a Specialist Team Representing the Hot Dip Galvanizing Industry. Anglo-American Council on Productivity, 21, Tothill-street, London, S.W.1. [Price 3s. 3d., post free.]
- Ministry of Civil Aviation. Civil Aircraft Accident. Report on the Accident to Halifax CS G-AJZY which Occurred on 8th March, 1951, at Deep Mill Farm, Great Missenden, Buckinghamshire.* H.M. Stationery Office, Kingsway, London, W.C.2. [Price 1s. net.]
- Ministry of Transport. Railway Accidents. Report on the Collision which Occurred on the 27th December, 1950, at Throstle Nest East Junction near Manchester Central in the London Midland Region British Railways.* H.M. Stationery Office, Kingsway, London, W.C.2. [Price 2s. net.]
- Department of Scientific and Industrial Research. Food Investigation. Special Report No. 54. The Condensation of Water on Refrigerated Surfaces.* By J. K. HARDY, K. C. HALES, and G. MANN. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 1s. 6d. net.]
- The Treagh Bequest. Kenwood. A Short Account of its History and Architecture.* By JOHN SUMMERSON. The London County Council's Information Bureau, County Hall (South Block), Westminster Bridge, London, S.E.1; and Staples Press, Limited, Mandeville-place, London, W.1. [Price 1s. net., postage 1½d.]
- The British Chamber of Commerce, France. Year Book, 1951.* Offices of the Chamber, 6, Rue Hatévy, Paris (9e), France. [Gratis.]
- United States Coast and Geodetic Survey. Special Publication No. 247. Manual of Geodetic Triangulation.* By COMMANDER F. R. GOSSETT. The Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A. [Price 1.50 dols.]
- United States National Bureau of Standards. Circular No. 505. Preservation of the Declaration of Independence and the Constitution of the United States.* The Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A. [Price 15 cents.]

TRADE PUBLICATIONS.

Automatic Emergency-Lighting Apparatus.—Chloride Batteries, Ltd., Clifton Junction, near Manchester, have issued a well-illustrated brochure containing the latest information about their Keopalite emergency-lighting system.

Buchholz Protectors for Transformers.—The construction and operation for the Buchholz transformer protectors made by them are described in a pamphlet received from the Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester, 17.

Street Lighting Control.—A pamphlet dealing with the operation of the Type 45A unit, which has been designed by them for the control of street lighting on the Rhythmic system, has been received from Automatic Telephone & Electric Co., Ltd., Strowger Works, Liverpool, 7.

Three-Phase Distribution Transformers.—The three-phase oil-immersed naturally-cooled distribution transformers manufactured by them in outputs up to 400 kVA at 11 kV are described in a leaflet received from Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester, 17.

High-Voltage Transformers.—Details of the design and construction of a 100-MVA 220/150-kV three-phase transformer group supplied by them to the Directorate of Power Supply of the Netherlands Government are given in an illustrated pamphlet received from the Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester, 17. A description of this transformer was published on page 128 of our 171st volume (1951).

Power for Industry.—A booklet entitled "Power for Industry," which we have received from Messrs. Richardson, Westgarth and Co., Ltd., Hartlepool, describes the firm's activities in manufacturing equipment for producing power on land. It contains illustrations of the turbines and condensers they have recently installed or are installing in the stations of the British Electricity Authority, and some useful data regarding the outputs and operating conditions.