THE ABBEY WORKS OF THE STEEL COMPANY OF WALES.

(*Continued from page 42.*)

ELECTRIC power for operating the plant in the Abbey Works of the Steel Company of Wales is obtained from a distribution system which also serves the Port Talbot and Margam works. This system is, in turn, supplied from two sources—the public mains and the Company's power station at Margam, the former being responsible for about 75 per cent. of the requirements.

A general view of the firing floor in this boiler house is given in Fig. 23.

These boilers supply steam primarily to one 60,000-cub. ft. and two 80,000-cub. ft. per minute turbo-blowers which deliver blast air at a pressure of 18 lb. per square inch and exhaust into an atmospheric main at a pressure of 0·5 lb. per square inch. They also supply steam to two 8-MW turbo-alternators which, like the blowers, were constructed by the General Electric Company, Limited. These sets, one of which is illustrated in Fig. 24, exhaust into Worthington-Simpson condensers with a cooling surface of 17,000 sq. ft.

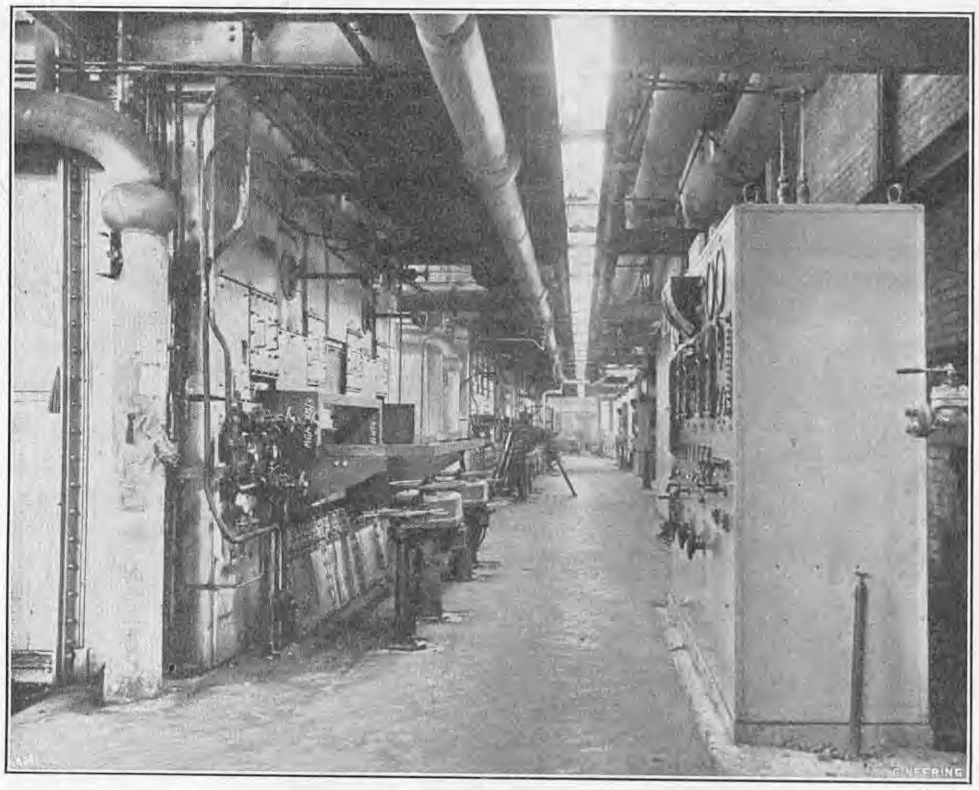


FIG. 23. GAS-FIRED BOILERS.

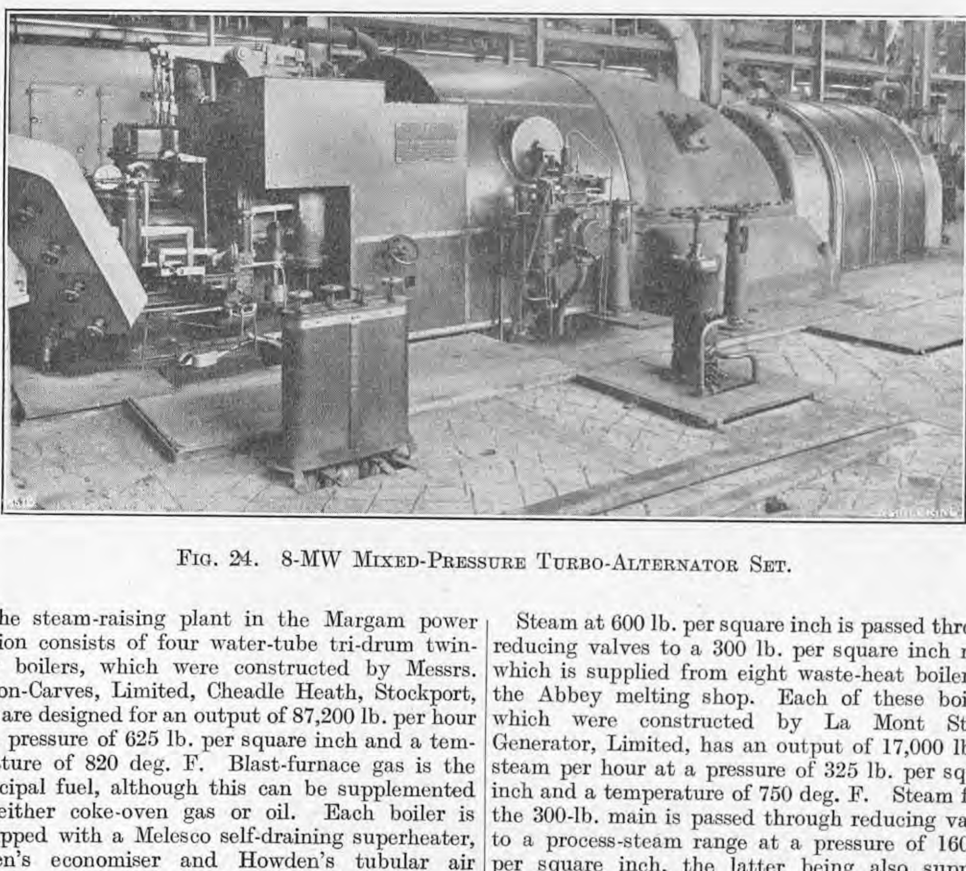


FIG. 24. 8-MW MIXED-PRESSURE TURBO-ALTERNATOR SET.

The steam-raising plant in the Margam power station consists of four water-tube tri-drum twin-flow boilers, which were constructed by Messrs. Simon-Carves, Limited, Cheadle Heath, Stockport, and are designed for an output of 87,200 lb. per hour at a pressure of 625 lb. per square inch and a temperature of 820 deg. F. Blast-furnace gas is the principal fuel, although this can be supplemented by either coke-oven gas or oil. Each boiler is equipped with a Melesco self-draining superheater, Green's economiser and Howden's tubular air heater, as well as with forced- and induced-draught fans. Automatic equipment is provided for controlling the steam temperature and to maintain correct combustion conditions for variable gas flow.

Steam at 600 lb. per square inch is passed through reducing valves to a 300 lb. per square inch main which is supplied from eight waste-heat boilers in the Abbey melting shop. Each of these boilers, which were constructed by La Mont Steam Generator, Limited, has an output of 17,000 lb. of steam per hour at a pressure of 325 lb. per square inch and a temperature of 750 deg. F. Steam from the 300-lb. main is passed through reducing valves to a process-steam range at a pressure of 160 lb. per square inch, the latter being also supplied from waste-heat boilers installed in various places in the plant as well as from a Holden and Brooke steam transformer.

The pressures in the 300 lb. and 160 lb. per square inch ranges are maintained constant by a 1,800-kW double pass-out back-pressure turbo-alternator of General Electric construction. This machine takes steam at 300 lb. per square inch and exhausts it through a primary pass-out and a de-superheater to the 160 lb. per square inch main, at the rate of 40,000 lb. per hour when the intake of the set is 73,000 lb. per hour. It also exhausts steam at a pressure of 30 lb. per square inch through a secondary pass-out to two Hick Hargreaves high-pressure feed heaters. Finally, it exhausts at just above atmospheric pressure to the atmospheric steam main which serves the low-pressure stages of the main alternators and low-pressure feed-heating system.

Steam for the works services at the Abbey plant is supplied at 175 lb. per square inch and 440 deg. F. from three Thompson-La Mont boilers which are fired with blast-furnace gas or coke breeze. Each of these boilers can deliver its maximum rated output of 38,500 lb. per hour either wholly as steam or as two-thirds steam and one-third high-pressure hot water for space heating. There are also three boilers of the same type at the slab-heating furnace. These have outputs of 10,000 lb. per hour and feed into the 175-lb. mains. Make-up water for the boilers is obtained from a Filtrator lime-soda and base-exchange water-treatment plant with a capacity of 30,000 gallons per hour.

The 8-MW alternators mentioned above generate three-phase current at 11 kV, their output being controlled by Allen West switchgear with a rupturing capacity of 250 MVA. To ensure continuity of supply to the vital services associated with the power station, each alternator is connected to a separate section of the switchboard. Normally, each machine operates under pressure control, so as to absorb all the steam made available by burning surplus gas under the boilers. If trouble occurs on the grid, the interconnection with the alternator is severed by directional over-current relays and the governor is automatically changed over to speed control. The 1,800-kW alternator mentioned above generates at 3·3 kV and is controlled by Metropolitan-Vickers switchgear with a rupturing capacity of 75 MVA. All the switchgear is operated from the power station control room which is one of three controlling supply and distribution as a whole.

The power from the South Wales Electricity Board, which, as already mentioned, provides 75 per cent. of the work's requirements, is obtained through two 40-MVA 66-kV feeders from Llynfi power station to Cefn Gwrgan substation in the Abbey Works; through one 40-MVA 66-kV feeder from the Pyle substation to Cefn Gwrgan; through one 4-MVA 11-kV standby feeder from Pyle substation to the pump-house substation in the Abbey Works; and through one 4-MVA 11-kV feeder from Bryn substation to Ffwdwyllt substation in Margam Works. The Cefn Gwrgan substation, where the principal incoming supply is controlled, is illustrated in Fig. 25, on page 130. It has a capacity of 82·5-MVA, which is made up of three 17·5-MVA 66/11-kV and three 10-MVA 66/11-kV English Electric transformers. All these transformers, one of which is illustrated in Fig. 26, on page 130, are fitted with on-load tap-changing gear and the neutral points of the 11-kV windings are earthed through liquid resistances to limit the earth-fault current to twice full-load current. The 66-kV circuits are controlled by air-blast circuit-breakers, supplied by the English Electric Company, with a rupturing capacity of 1,500 MVA, which can be operated either from the strip-mill control room, the substation relay room, or locally.

The main distribution system in the works is operated at 11 kV and is divided into two parts. The first is fed from the three 17·5-MVA transformers, mentioned above, which are connected through Reyrolle metal-clad switchgear to the group of B.T.H. rectifiers for the hot strip mill finishing stands and the three Metropolitan-Vickers synchronous motors for the roughing stands of the hot strip mill, which have been described in a previous issue. It will also be connected to two 7,500 h.p. synchronous motor-generator sets in the cold mill, which has been constructed by the English Electric Company, Limited. The second part supplies the remainder of the works load and is fed from the three 10-MVA transformers. Control of this part is effected by Reyrolle metal-clad switchgear with

THE ABBEY WORKS OF THE STEEL COMPANY OF WALES.

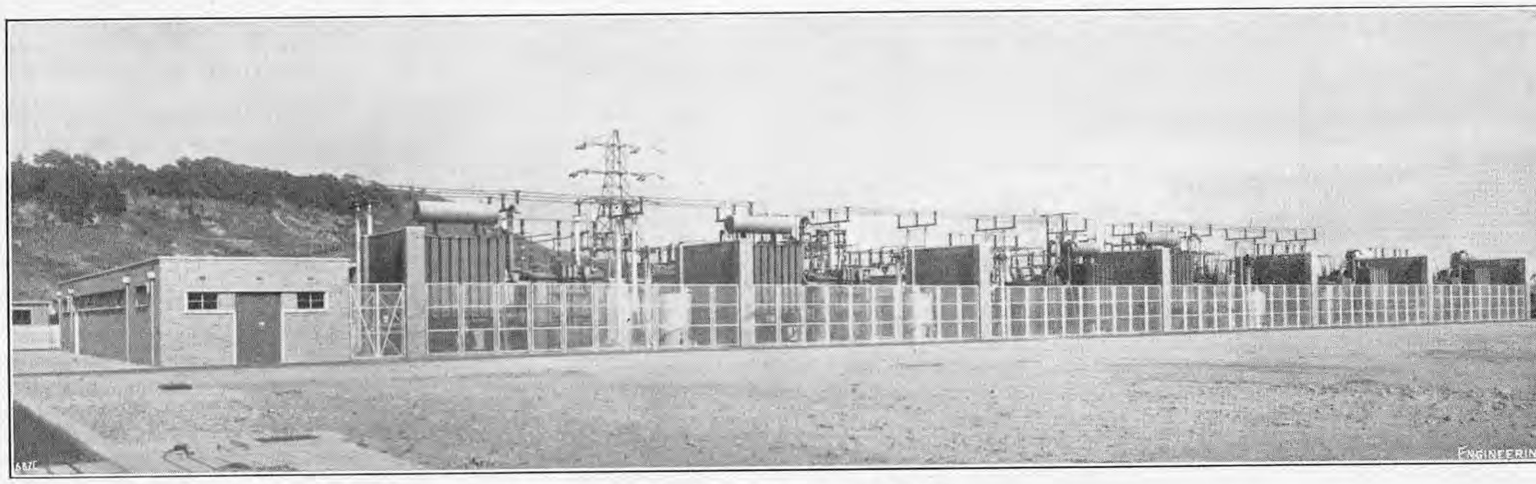


FIG. 25. CEFN GWRGAN SUBSTATION.

a rupturing capacity of 250 MVA, it being found more economical to keep down the rupturing capacity by the use of reactors than to use switches with a higher rating.

Secondary distribution throughout the works is effected thr ugh a 3·3-kV system with an unearthed neutral. This system is split into a number of sections, each of which is supplied separately from the 11-kV system through a Johnson and Phillips 3·5-MVA transformer. One section in the power house is also fed directly from the 1,800-kW alternator mentioned above. Interconnection between the sections is provided for standby purposes. This system supplies alternating-current motors having outputs ranging from 100 h.p. to 3,000 h.p. Local distribution to the ore transporters in the Margam Works is also at 3·3 kV and is obtained from the 11-kV system through two 1,500-kVA Ferranti transformers. The switchgear on the low-voltage side of these transformers is of the Reyrolle metal-clad pillar type and has a rupturing capacity of 25 MVA. The supply is taken to the transformers through flexible cables laid in an open trench. These cables are coiled on electrically-driven drums. At the Margam and Abbey Works, 800-kVA Brush and 400-kVA General Electric transformers are provided to supply a 415/240-volt system for general purposes, their primaries being connected to the 11-kV and 3·3-kV mains, respectively. Motors with outputs of less than 100 h.p. and the general works lighting are fed from this system, which is again interconnected to provide a standby. The switchgear consists either of Crompton Parkinson oil circuit-breakers or of English Electric air-break switches the rupturing capacity in each case being 25 MVA.

The 440-volt two-wire direct-current system, from which the cranes in the Abbey Works are supplied, consists of six substations, each of which is equipped with General Electric pumpless mercury-arc rectifiers. These rectifiers are, in turn, fed from the 11-kV mains through transformers, which are arranged in pairs so that they can be operated as equivalent 24-phase units. The low-tension side of each unit is connected in 12-phase quadruple zig-zag with three interphase transformers for load-sharing purposes. Each unit is fitted with anode fuses, which are designed to operate instantaneously at 15 times the full-load current.

To prevent the inherent rise in voltage at low loads, a resistance is automatically connected across the bars to provide an artificial load. Equipment is also provided in each substation so that about 50 kW of power can be regenerated for one minute with a maximum of three minutes in ten. Fault throwing devices are fitted in each substation and are arranged so that under normal conditions the mid point of the system is connected to earth through a potentiometer which can pass only a small current. Should an earth fault occur on one pole, the other pole is connected to earth through a resistance which will pass about 75 amperes. This current can be increased to about 140 amperes by operating a paralleling switch. If the fault is not cleared within 10 seconds, an alarm is sounded in the control room. To facilitate the determination of the faulty circuit, each switchboard is equipped with saturable reactor direct-current earth apparatus. This comprises a ring-type current transformer which is connected to a milliammeter, the deflection being proportional to the fault current. Places which are too remote to be fed from the main direct-current system are supplied through Nevelin glass-bulb rectifiers.

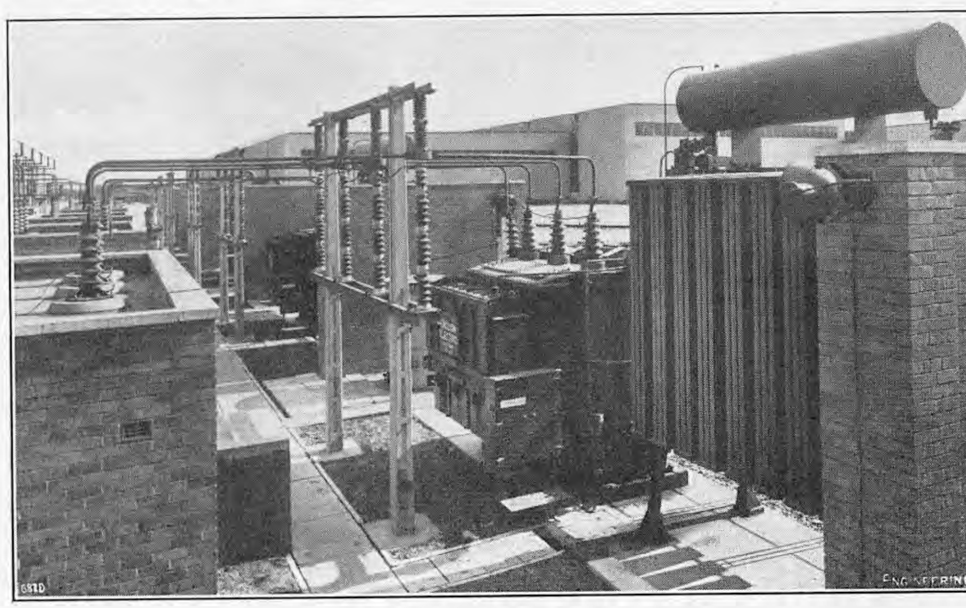


FIG. 26. 17·5-MVA 60/11-kV TRANSFORMERS.

FIG. 27. MAIN 11-kV CONTROL BOARD.

The main distribution network comprises over 350 miles of cable, which has been laid by British Insulated Callender's Cables, Limited, Norfolk-street, London, W.C.2. Some of the mains are laid directly in the ground and others are run in tunnels or basements. Cable hangers and trays of perforated steel are hung from steel inserts which have been built into the concrete of the tunnels. The 450-yard tunnel connecting the Cefn Gwrgan and strip-mill substations is equipped with Trefoil cleats of silicon-aluminium, which carry eight runs of 11-kV 0·5 sq. in. cables. These runs are divided into two sections by a wall extending for the whole length of the tunnel to reduce the risk of fire or physical damage. Most of the cables are of the paper-insulated lead-covered type, those in the basements and tunnels being braided and impregnated with fire-resisting paint. The cables laid directly in the ground are hessian served and are impregnated with compound.

The three 66-kV incoming feeders to Cefn Gwrgan substation and four of the six 11-kV outgoing circuits from the same place are controlled from a control room adjoining the main strip mill motor room. The main 11-kV control board in this room, illustrated in Fig. 27, opposite, was made by Messrs. Reyrolle, and is of "arcade" construction so that it forms three sides of a square. The positions of the substations and the associated circuits controlled are indicated on a mimic diagram. Parallel with one side of the 11-kV control board is a second Reyrolle board controlling the 3·3-kV Metropolitan-Vickers switchgear in the strip-mill substation. Opposite this is the tap-changing equipment for the transformers at Cefn Gwrgan substation, while next to this tap-changing panel is an English Electric board for controlling and indicating all the circuits in the station. The control room also contains a B.T.H. instrument board for the main finishing-mill motors, which are supplied from the rectifier installation described previously. This board includes instruments for recording the current and rolling speed schedules for each motor. In the centre of the room is a communication system and a Loudaphone installation for direct communication with selected points in the works. The room is provided with forced ventilation and is artificially lighted by General Electric cold-cathode lamps.

The total power load at the Abbey Works is approximately 175,000 h.p., which includes some 6,000 motors. In addition, the estimated lighting load is about 8,000 kW, the illumination provided varying from 6 lumens per square foot in the melting shop to 12 lumens per square foot in the rolling mills. The fittings installed to give general lighting in these departments each contain two 400-watt mercury-vapour discharge lamps and one 1,500-watt filament lamp. A feature of the outside lighting is the provision of seven 150-ft. towers upon which groups of 1,000-watt and 500-watt floodlights, supplied by the General Electric Company, Limited, are mounted.

(To be continued.)

THE ENGINEERING OUTLOOK.

V.—Coal-Mining, Steam-Raising and Heavy Electrical Plant.

The demand for coal-mining plant since the war, particularly since 1949, has been held down by the national necessity for restricting capital investment. This need is now greater than ever and some further cuts must be expected. On the other hand, re-armament and the balance of payments crisis are making greater and more urgent the need for more coal for industry at home and for export. These two conflicting needs are likely to prove difficult to reconcile, but, in view of the large sums invested in coal mining in the past few years, some retrenchment is probable.

The National Coal Board's "Plan for Coal," announced in November, 1950, was not designed for quick results. By undertaking capital expenditure of 486·6*l.* millions over the 15 years 1950 to 1965, it was hoped to raise the output of coal by 18 per cent., to 240 million tons, and to increase overall productivity from 23·9 to 31 cwt. per man-shift. The Plan makes heavy demands on the national finances and its realisation is hedged with difficulties. Mr. E. H. Brown, Director-General of Production on the National Coal Board, stated in May that mine planning had fallen behind schedule and prophesied that, unless the planning staff was strengthened, the programme could not be completed by 1965. The labour situation, as he pointed out, is also serious. If the capital investment envisaged in the Plan is carried out, only 618,000 workers will be required, 77,000 fewer than at present. It is doubtful, nevertheless, if the labour will be available in 1965. In 1949, there was a net outflow from the mines of 16,400, and 20,500 in 1950. There was a considerable improvement in the first quarter of 1951, when there was a net inflow of 14,300; but the wastage was resumed in the second and third quarters, when the mines lost 7,800.

The Plan does not, however, take into account new methods of working at the coal face, which may greatly reduce labour requirements; its authors are more concerned with what can be achieved with existing machinery and methods as a result of better mine layouts, haulage and winding systems. The rate at which mechanisation can be carried out under present mining practice has inevitably been falling over the past few years. Over 80 per cent. of the coal in the mines is already cut by machines, compared with 58 per cent. in 1939, and opportunities for the profitable employment of further machines, consequently, have been greatly reduced. Makers of mining machinery must therefore expect a continued decline in the demand for conventional types. The *Report and Accounts of the National Coal Board* for 1950 points out that, though the amount of coal cut by Meco-Moore machines increased by 800,000 tons to 4·4 million tons in 1950, and the number of machines in use had increased to 70, compared with 51 in 1949, their average output per man-shift at the face had fallen slightly.

In view of the difficulties, there can be little criticism of the rate at which mechanisation is being carried out. In 1950, there was a net addition to National Coal Board assets in plant and machinery of 69·6*l.* millions, compared with 51·5*l.* millions in 1949, and the output per man-shift worked was raised from 1·16 to 1·19 tons. By November, 1951, it had been increased further, to 1·23 tons. As will be seen from Table I, herewith, taken from the *Monthly Digest of Statistics*, deliveries of most types of coal-mining machinery in 1951 were below the 1950 level. To some extent, this was due to a fall in exports, but in many cases there was also a reduction in deliveries to the home market. Home deliveries of coal cutters in the first three quarters of 1951, for example, numbered only 473, compared with 666 in the corresponding period of 1950, and home deliveries of power loaders totalled 76, compared with 51. That some progress with the Coal Plan has been made already is evident, however, from the increased deliveries of underground conveyors and haulage gear to the Coal Board; the number of underground conveyors delivered increased from 1,632 in the first nine months of 1950 to 1,759 in the corresponding period of 1951, and the value of winder and haulage machinery delivered increased from 1·1*l.* to 1·3*l.* millions.

The drive for cleaner coal is continuing; in 1950, 4 million tons more were cleaned mechanically than in 1949, and 15 million tons more than in 1947. At the end of 1950, the Coal Board stated that plants were being designed or built with a total capacity of more than 17 million tons a year. Deliveries of coal preparation machinery to the Board in the first nine months of 1951 were valued at 2·3*l.* millions, compared with 2·2*l.* millions in the corresponding period of 1950. Considerable success has been achieved with the standard Baum washers, which can be completed in half the time (sometimes as much as four years) required for "custom-built" plant. At the end of 1950, two had been installed and three more were in course of erection.

Since nationalisation, the Board have paid considerable attention to the economies to be derived from standardisation of plant and equipment. Already, considerable results have been achieved; in the latest report it is stated that makers of coal-drilling bits have now agreed on a single standard type of bit. Agreement has also been reached on a standard detonator for mining explosives, and some progress has been made towards securing standardisation of colliery arch sections, alternating-current electric winders, mining-type transformers, winding and haulage ropes, miners' lamp bulbs, and hand tools.

Reorganisation of the mines under the "Plan for Coal" is necessary, but not spectacular; more dramatic results may follow a revolution in mining technique that is now in a very early stage. Successful experiments have been conducted recently with some new types of machines and the Board believe that only a few technical obstacles remain to be overcome before they can be adopted on a wide scale in British mines. The Board have been very cautious, however, in making predictions, since the introduction of new machinery is often beset with difficulties and organisational problems. Above all, the attitude of the miners has to be reckoned with. The new machines are said to be more efficient than anything in use and will make possible "continuous mining," which is known to make for better team work and improved morale in the mines. Reorganisation of the sequence of operations, even without the use of the new machines, has shown, in one instance at least, some of the advantages of continuous mining. The "Bolsover experiment," announced in January, 1951, showed how greater team spirit can be obtained by these methods. The men at the coal face were organised in self-contained teams; payment was on a day-wage basis of 7½ hours; jobs were made interchangeable; no overtime was paid; and men whose output was below the average became liable to disciplinary action. As a result, the output per man-shift increased by 50 per cent., to 50 cwt. The attitude of labour to new machines or new methods is not, however, always as favourable as at Bolsover. Disputes have already risen in connection with the A.B. Meco-Moore cutter-loader. In one mine, it is reported that the machine could work 120 yards successfully in a shift; in another, however, where conditions were precisely similar,

TABLE I.—United Kingdom: Deliveries of Coal Mining Machinery.

—	Coal Cutters.		Power Loaders.		Underground Conveyors.		Diesel Underground Locomotives.		Tubs and Mine Cars.*	Conveyor Belting.†
	Total.	For Export.	Total.	For Export.	Total.	For Export.	Total.	For Export.	Total.	Total.
	Number.								Thousand Tons.	
Annual totals—										
1948	1,248	315	107	25	4,031	455	93	19	60·7	26·4
1949	1,144	373	113	27	3,796	849	110	32	60·7	20·3
1950	891	321	95	30	3,024	675	65	22	58·2	23·8
Quarterly—										
1948, 3rd Qr.	257	75	44	5	922	93	26	1	15·3	6·4
4th Qr.	359	111	43	20	1,104	160	26	15	16·7	5·9
1949, 1st Qr	319	126	28	7	985	142	35	16	15·4	5·8
2nd Qr.	304	105	30	8	783	115	22	8	14·7	4·8
3rd Qr.	251	53	23	—	989	232	21	7	14·9	3·7
4th Qr.	270	89	32	12	1,039	360	32	1	15·7	6·0
1950, 1st Qr.	221	92	32	12	809	201	12	6	14·9	5·6
2nd Qr.	260	105	24	7	603	126	15	8	14·5	6·1
3rd Qr.	185	64	20	9	746	199	19	7	12·2	5·3
4th Qr.	225	60	19	2	866	149	19	1	16·6	6·8
1951, 1st Qr.	144	38	17	5	682	171	12	2	18·1	6·9
2nd Qr.	168	62	17	—	752	124	18	10	13·1	7·2
3rd Qr.	161	61	17	4	735	115	—	—	10·9	5·6

* Excluding those produced at collieries. The output is mainly for the National Coal Board. Figures refer to carrying capacity.
† Production; mainly for the National Coal Board.

it was argued that a 90-ft. face was the limit. Attitudes of this sort could easily delay the introduction of new methods or greatly reduce the benefits to be obtained from them.

Reference was made in these "Engineering Outlook" articles a year ago to some of the new machines, for example, the Samson Stripper, the Gloster Getter, the German "Coal Plough," and the Joy-Sullivan "Continuous Miner." The last-mentioned machine can have only limited application in this country, as it requires the "pillar and stall" mining method, which is used for only 13 per cent. of the output of deep-mined coal in Great Britain and cannot be expanded owing to geological conditions. It has been found, moreover, that this machine produces a large quantity of small coal and can be used only under the best working conditions. Good results have been obtained from the "Coal Plough" in the East Midlands and its more extensive use in Durham mines is planned. The German "Panzerförderer" conveyor is likely to come into prominence as continuous mining proceeds, since it can be operated close to the coal face, in front of the last row of props, and can be moved forward without being dismantled. Another Continental technique which is being tried is the use of heavy steel boxes equipped with cutting edges for mining thin seams. The boxes, spaced evenly along the face, are connected by ropes and, while forced against the face by compressed-air rams, are pulled backwards and forwards, taking off strips of coal a few inches deep.

The rate at which the new machines can come into general operation depends on important decisions of policy as well as on the ability of the manufacturers to supply them. It might be worth while to encourage the mines to install the new machinery as soon as possible, but this would invite the risk of failure in many instances and might be costly as well as discouraging. On the other hand, the more cautious policy of introducing the machines gradually, and only after thorough testing in all conditions, may lose the country coal that is urgently required. On the whole, the Coal Board are proceeding fairly rapidly; for example, 60 Samson strippers have been ordered. These will take some time to supply, however, and there is a strong case for the more rapid introduction of coal ploughs, which can b produced more quickly. The Board have been criticised for their apparent unwillingness to import German machines, but this is probably unfair; imports of mining machinery have been increasing and, in the first eleven months of 1951, were valued at 491,000*l*., compared with 351,000*l*. in the corresponding period of 1950.

Exports of mining machinery are shown in Table II, herewith, taken from the *Trade and Navigation Accounts*. It will be seen that exports of some types fell in 1951: exports of power cutters, power winders and conveyors, which together account for nearly half of the British exports of mining machinery, were all less than in 1950. That the total exports were higher than in 1950 was due to a large expansion in "miscellaneous" items. As will be seen from Table III, herewith, the fall in exports of the main categories of machinery was the result of reduced shipments to countries behind the Iron Curtain: exports to Poland and Czechoslovakia declined by half. Exports to the other main European coal-producing countries, France and the Netherlands were also considerably reduced. Exports to Commonwealth countries, mainly for metalliferrous mining, in the first eleven months of 1951, were 11 per cent. higher than in the corresponding period of 1951. The principal market continued to be South Africa, which took 21 per cent. of all British exports of mining machinery. Materials permitting, there should be no difficulty in maintaining exports in 1952; marketing is not likely to present any problem for some time to come, though the loss of the Polish and Czech markets may be a matter for concern to manufacturers specialising in coal-mining machinery. This, however, is more than offset by the expanding market at home.

The electrical supply industry, like the coal industry, is still far from meeting rising demand. Installed capacity (maximum continuous rating) in the twelve months to November, 1951, increased by 1,000 MW compared with 1,170 MW in the previous twelve months. Sir John Hacking, deputy chairman (operations) of the British Electricity Authority, pointed out in his presidential address to the Institution of Electrical Engineers that power deficits during peak loads have become worse, despite the additions of new plant. Of the plant required under the original programme for the years 1948 to 1950, only 47 per cent. had been put into service. The rate of construction of new generating plant had lagged in Britain, compared with other European countries, until about 1948, but this was partly because, unlike Britain, the latter had received considerable dollar grants under Marshall Aid for the purchase of power plant in the United States. The British Electricity Authority are now keeping abreast of anything that is being achieved elsewhere and, provided that the materials and labour can be made available, they will easily fulfil the new programme put in hand in 1950 or even larger future plans.

When the new programme was formulated, it was hoped that the increase of generating capacity would rise from the 1951 level of 1,000 MW (sent out) to 1,500 MW in 1953 and 1,800 MW from 1956 onwards. Realising from bitter experience that programmes are easily upset, the B.E.A. estimated that the amount of new generating plant commissioned each year could confidently be expected to rise at least to 1,300 MW in 1953 and 1,600 MW from 1956 onwards. If the programme of 1,500 MW in 1953 and 1,800 MW in 1956 could be carried out in full, it was considered that load shedding would be comparatively infrequent by 1954-55; if, however, it were only possible to carry out the lower estimates, it would be many years before full supplies could be given at all times. With the beginning of re-armament and the deterioration in the supply of raw materials, it became clear that there was little hope of carrying out the programme in full. Because of the need to restrict capital investment, the Government decided that it would be unwise to allow the amount of extra plant commissioned in any year up to 1955 to exceed 1,500 MW (though the report of the Minister of Fuel and Power suggested a figure of 1,550 MW in 1955). The figure of 1,500 MW coincides exactly with the B.E.A.'s lower estimate for 1955 and is 200 MW short of the planned level for 1955. It is by no means certain that the supply of materials will permit even the reduced level of commissioning, and Lord Citrine, the chairman of the British Electricity Authority, announced in October that shortages had caused work to be interrupted at eleven power stations and that boiler makers were having difficulty in obtaining steel for structural work.

The B.E.A. are seriously concerned over the need to curtail their programme and in their *Third Report and Accounts*, for 1950-51, make the point that the "limit on the amounts of new plant would not only prolong the conditions of severe plant shortage and severe load shedding, but would also

TABLE II.—UNITED KINGDOM: EXPORTS OF MINING MACHINERY OTHER THAN PORTABLE POWER TOOLS. (January to November.)

—	1949.		1950.		1951.	
	1,000 Cwt.	Value (£1,000).	1,000 Cwt.	Value (£1,000).	1,000 Cwt.	Value (£1,000).
Power-operated Coal Cutters ..	34	767	34	746	28	702
Power-operated Winders ..	56	481	61	629	55	610
Underground Conveyors ..	92	753	95	813	97	722
Others	215	2,121	175	1,992	206	2,523
Total	397	4,122	315	4,180	386	4,557

TABLE III.—UNITED KINGDOM: EXPORTS OF MINING MACHINERY OTHER THAN PORTABLE POWER TOOLS BY COUNTRIES OF DESTINATION. (January to November.)

—	1949.		1950.		1951.	
	1,000 Cwt.	Value (£1,000).	1,000 Cwt.	Value (£1,000).	1,000 Cwt.	Value (£1,000).
British West Africa	35	263	26	202	17	192
Union of South Africa	83	826	93	1,000	72	952
India	25	336	17	284	24	353
Malaya	35	216	27	210	60	441
Australia	31	279	42	420	46	516
Other Commonwealth countries and the Irish Republic ..	47	443	38	421	48	581
Poland	33	508	32	498	16	340
Netherlands	10	107	13	149	8	88
Belgium	8	105	4	78	4	94
France	21	381	11	234	5	111
Czechoslovakia	3	76	4	116	2	68
Other Foreign Countries ..	66	582	58	568	84	821
Total	397	4,122	365	4,180	386	4,557

TABLE IV.—UNITED KINGDOM: DELIVERIES OF ELECTRICITY GENERATING PLANT. (Monthly Averages or Calendar Months.)

—	Hydraulic Turbines.		Steam Turbo-alternators. 10,000 kW and Over.		Steam Turbo-alternators. Less than 10,000 kW.	
	Total.	For Export.	Total.	For Export.	Total.	For Export.
	Thousand brake horse-power.		Thousand kW.			
1948	6·4	4·2	112·0	39·0	24·8	18·1
1949	37·6	17·3	165·0	47·8	22·8	13·1
1950	49·1	36·2	202·3	73·3	17·6	9·7
1950, October	60·0	60·0	223·0	63·0		
November	56·6	56·0	205·0	160·0	22·3	10·7
December	9·1	9·1	422·5	115·0		
1951, January	95·0	95·0	135·0	30·0		
February	72·1	72·1	332·9	238·0	20·2	14·2
March	26·3	26·3	105·4	55·4		
April	14·0	14·0	80·0	—		
May	36·0	36·0	70·0	30·0	18·5	6·9
June	37·7	37·0	171·0	100·0		
July	39·0	39·0	225·0	150·0		
August	73·0	73·0	80·0	20·0	22·6	13·7
September	13·8	13·8	157·5	82·5		
October	22·0	22·0	137·0	12·0	—	—

hinder the greater mechanisation and extended use of power in industry which can make the most effective contribution to improved industrial efficiency." It may be wondered, however, whether the limitation on capital investment in electricity supply is as serious as the Authority supposes. The present programme depends largely on the construction of big thermal stations, the completion of which, in ten years' time, would nearly double the B.E.A.'s consumption of coal, which, in 1950, was nearly 33 million tons. Even if all goes well with the "Plan for Coal," it is doubtful if so much can be spared. The great cost of the expansion programme alone, apart from any question of re-armament, makes it desirable that it should be restricted if at all possible. The cost of new power stations is now 60*l*. per kW and is still rising. In 1950-51, largely because of rising costs, the B.E.A. exceeded the 102*l*. millions allotted to it for investment by 19*l*. millions. In the present year the sum allotted is 133*l*. millions, but this is likely to be even more heavily over-spent.

For some time, *The Economist* has maintained that an all-out effort to meet an exceptional peak demand was unnecessary, contending that it would be much more economical to install load-controlling devices which could, if necessary cut off supplies to less essential consumers while maintaining industrial supplies. The B.E.A. have now admitted, apparently, that there may be something in this view, for they are now conducting extensive tests of centrally-controlled load-limiting equipment in Merseyside and in South-West Scotland. Two possible methods of controlling the load, which offer some success, are discussed in the Authority's latest report. Both require the installation in consumers' premises of relays to switch off the current when demand is in excess of supply. In one instance, the relays would operate on a fall in frequency, which is always a warning of excess of load; and, in the other, on the reduction in voltage, which is always the first step in load shedding. As the report rightly points out, considerable experience of load control will be necessary before enough accurate information is obtained to influence plant programmes. An even cheaper way to control the load would be by some tariff system, but this is undoubtedly complex, and the B.E.A. dismiss it as undesirable and impracticable.

Some manufacturers insure themselves against cuts during peak periods by installing their own generating equipment and, as the Authority's hopes of carrying out their programmes have faded, their attitude has swung round from discouragement to positive encouragement of such projects. Factory generation of electricity is liable to be more costly to the individual factory than central generation, even where steam from industrial processes is available for harnessing to a turbine. Diesel generation may involve even higher first cost, but its larger development may be worth while, if only because it will reduce the demand for coal. It is now being used by the B.E.A. to give relief at peak periods; and they have undertaken to buy up any large Diesel sets not required for export or by home industrial users. This can only be interpreted as a gesture signifying their approval of the use of Diesel generation in factories, for manufacturers are unable to keep up with the demand for generating sets and cannot promise delivery against current orders in less than three years. It was announced recently that the Ministry of Fuel and Power is considering a study of the scope for Diesel generation.

TABLE V.—UNITED KINGDOM: EXPORTS OF ELECTRICAL MACHINERY. (January to November.)

—	1938.*		1949.		1950.		1951.	
	Tons.	Value (£1,000).	Tons.	Value. (£1,000).	Tons.	Value (£1,000).	Tons.	Value (£1,000).
Generators complete:								
Not exceeding 200 kW	1,980	419	15,684	7,252	20,401	9,064	13,346	5,935
Exceeding 200 kW	7,453	1,310	7,309	3,146	8,296	3,565	4,379	2,425
Parts	—	—	3,610	1,242	5,235	2,093	9,213	4,809
Total	9,433	1,729	26,603	11,640	33,932	14,722	27,138	13,169
Transformers	9,619	1,114	20,246	5,463	23,697	6,662	25,411	7,961
Rectifiers for power-house use ..	207	38	649	319	927	544	1,061	623
Switchgear and switchboards ..	8,929	2,030	16,130	8,480	18,212	9,873	22,471	11,506
Steam turbines	1,256	420	4,524	2,176	4,762	2,850	5,753	3,519
Grand Total	29,444	5,331	68,152	28,078	81,530	34,651	81,833	36,778

* Eleven-twelfths of year.

TABLE VI.—UNITED KINGDOM: DELIVERIES OF BOILERS AND STEAM-RAISING PLANT ACCESSORIES. (Monthly Averages or Calendar Months; Value in £1,000.)

—	Shell Boilers.		Steam-raising Plant Accessories.			
			Fuel-Oil Burners.	Other.	Fuel-Oil Burners.	Other.
	Total.	For Export.	Total.		For Export.	
1948	576	200	214	576	45	129
1949	643	190	147	669	31	136
1950	730	142	166	709	42	122
1950, October	779	133	151	689	20	102
November..	713	129	194	810	49	136
December	744	130	183	888	37	149
1, January	683	191	143	730	40	91
February	731	195	193	710	43	89
March	744	154	175	827	38	192
April	829	163	190	838	36	186
May	790	155	180	825	44	161
June	822	144	181	846	36	143
July	742	154	278	954	63	142
August	684	167	199	929	52	150
September	724	158	217	785	53	152
October	754	159	227	873	54	156

TABLE VII.—UNITED KINGDOM: EXPORTS OF BOILERS AND BOILER-HOUSE PLANT. (January to November.)

—	1938.		1949.		1950.		1951.	
	1,000 Cwt.	Value (£1,000).	1,000 Cwt.	Value (£1,000).	1,000 Cwt.	Value (£1,000).	1,000 Cwt.	Value (£1,000).
Water-tube boilers	602	2,134	660	4,657	695	5,437	744	6,127
Lancashire and Cornish boilers ..	25	57	41	215	43	254	25	169
Vertical boilers	} 77	195	{ 42	331	51	408	46	389
Other boilers			{ 136	842	144	932	128	1,133
Economisers, Feed-water Heaters and Steam Superheaters.. ..	124	342	125	853	145	860	116	958
Other Boiler-house Plant	202	760	312	2,669	293	3,182	281	3,182
Total	1,030	3,488	1,316	9,567	1,371	11,073	1,340	11,958

While the B.E.A. programmes have been held up too often by shortages of plant and equipment, there has been less difficulty over the supply of turbo-alternators; the expansion in capacity has kept pace with rising demand—with the possible exception of small sets—and, besides equipping power stations at home, makers have steadily increased their exports. Deliveries of generating plant, which are shown in Table IV, herewith, taken from the *Monthly Digest of Statistics*, were somewhat lower in 1951 than in 1950. From January to October, 1951, deliveries of steam turbo-alternators of 10 MW and above amounted to 1,493 MW, and deliveries of hydraulic turbines to 429 MW, compared with 1,800 MW and 523 MW, respectively, in the same period of 1950. No conclusions can be drawn from these figures, however, as deliveries tend to be irregular owing to the long manufacturing cycle.

From Table V, herewith, taken from the *Trade and Navigation Accounts*, it will be seen that the value of exports in the first eleven months of 1951 was about 6 per cent. higher than in the corresponding period of 1950. This, however, understates the increase in exports of heavy electrical plant, for the figures include exports of small generating sets to the Soviet Union, which fell from 2*l*. millions in the first eleven months of 1950 to 776,000*l*. in the corresponding period of 1951. The principal export markets for heavy electrical plant continue to be the Commonwealth countries, mainly India and Australia; but exports to other countries have also been maintained at a high level, and export orders on hand at present represent five years' work. They include important contracts in connection with electrification schemes in Spain and Portugal. A contract valued at 1*l*. million for the electrical equipment for a power station on the River Zezere, 120 miles north-east of Lisbon, was negotiated last autumn by the English Electric Export and Trading Company and the Metropolitan-Vickers Electrical Export Corporation, in the face of stiff foreign competition. Other important orders which the English Electric Company have on hand include seven 30-MW generating sets for the Viervontein power station in South Africa, a 60/66 MW set for Ontario, and a 25 MW set for Sydney.

The shortage of boiler-making capacity has been responsible for many delays in the provision of generating capacity in the United Kingdom. There is now, however, considerable promise that the difficulty has been circumvented. Hitherto, very little of this sort of plant has come from abroad, imports in the first eleven months of 1951 totalling only 162,000*l*. The British Electricity Authority has now, however, placed orders for some types of scarce equipment overseas, although an application to purchase two boilers in the United States was turned down by the Treasury on the ground that the necessary dollars could not be made available. A complete high-pressure steam pipework installation is to be imported from Germany. Coal-pulverising mills have also been purchased in that country, as well as several thousand tons of tubes, the shortage of which has been holding up production of boilers in the United Kingdom. Meanwhile, additional capacity for boiler manufacture has been brought into use. The B.E.A. report that nine firms will be supplying the boilers which come into commission during the six years 1951 to 1956, compared with five for the period 1945 to 1950. For example, John Brown and Company, Limited, who have hitherto made only marine boilers, are now constructing power-station boilers on a large scale, in conjunction with Mitchell Engineering, Limited, and C. A. Parsons and Company are now producing high-pressure piping. The Boiler Makers' Associa-

SOIL FAILURE DURING OVERTURNING OF PILES.

FIG. 1. MODELS NOS. 1 AND 2, SECTION PLANES.

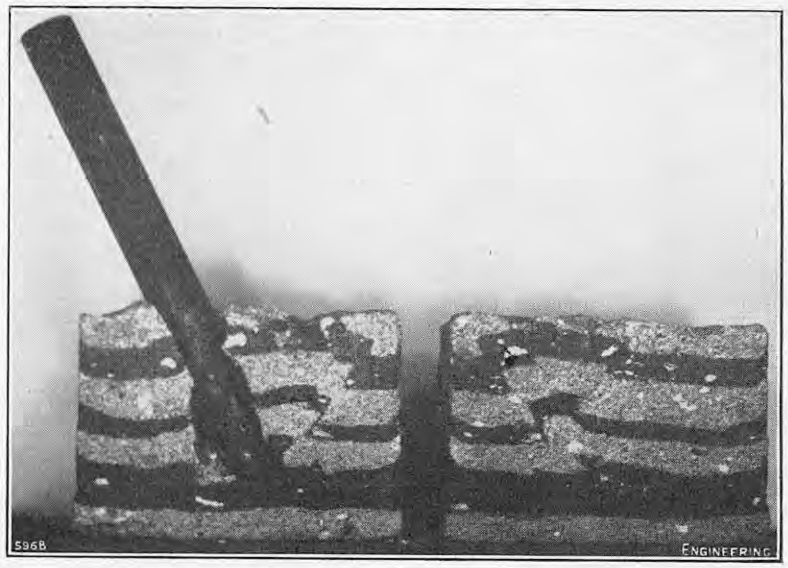


FIG. 2. MODEL NO. 1, LONGITUDINAL SECTION.

tion now believe that they have caught up with the demand and have expressed some anxiety that there may be, in fact, some surplus capacity in 1956 and 1957, particularly if the Government policy of limiting the B.E.A. programmes is carried out.

Output figures for water-tube boilers are no longer published; official statistics give only shell boilers, which may not be representative of the trend. The output of these (see Table VI, herewith, taken from the *Monthly Digest of Statistics*) increased from 7·0*l*. millions in the period January to October, 1950, to 7·5*l*. millions in the corresponding period of 1951. It does not appear, however, that boiler makers will be able to fulfil their delivery programmes in 1951. Of the 57 boilers required, only 25 had been installed at the beginning of September; nevertheless, the makers estimated, with some confidence, that the programme would be carried out to within 10 per cent. The programme for 1952 involves the installation of 69 boilers and, in view of the shortage of materials, will be even more difficult to fulfil.

It seems anomalous, in view of the shortage at home, that large exports of boiler-house plant should continue. As will be seen from Table VII, on page 133, taken from the *Trade and Navigation Accounts*, exports in the first 11 months of 1951, at 11·9*l*. millions, were 900,000*l*. higher than in the corresponding period of 1950. Lord Citrine, who has frequently questioned the wisdom of exporting boilers, pointed out in June that over 40 per cent. of the output of the leading boiler makers is being sent overseas and that a further 15 per cent. goes to home users other than the B.E.A. As a result, only 40 per cent. at the maximum is being devoted to the urgent orders of the B.E.A. Despite statements that boiler makers are urged to give priority to B.E.A., the position has not improved. The boiler makers have emphasised that the bulk of the boilers exported are of small capacity and unsuitable for the B.E.A.; naturally, they are concerned to maintain goodwill in the overseas markets, upon which they must rely when eventually B.E.A. requirements fall off. The principal markets, moreover, are Commonwealth countries, whose prosperity and industrial efficiency are of no small importance to the United Kingdom. The Union of South Africa and Australia alone accounted for nearly 40 per cent. of British exports of boiler-house plants in 1951, taking equipment valued at 2·8*l*. millions and 1·8*l*. millions, respectively, in the eleven months of the year. It may be true that much of the capacity at present being devoted to small boilers for export could be turned over to larger boilers for the B.E.A., but, before they do so, the makers are perhaps entitled to some Government assurance about the long-term B.E.A. demand.

Manufacturers of capital equipment for the mines and the electricity supply industry must look forward to a year of difficulty. Makers of heavy electrical plant, for example, are estimated to be dependent upon more than 70 key materials, all of which are more or less scarce. Faced with a demand of increasing urgency, they are not likely to be able to maintain the 1951 level of output, even if awarded high priority for supplies of steel and raw materials. Industrial productivity, however, depends to no small extent on the adequacy of fuel and power, and the inability of the supply industries to obtain vital equipment must endanger Britain's industrial future.

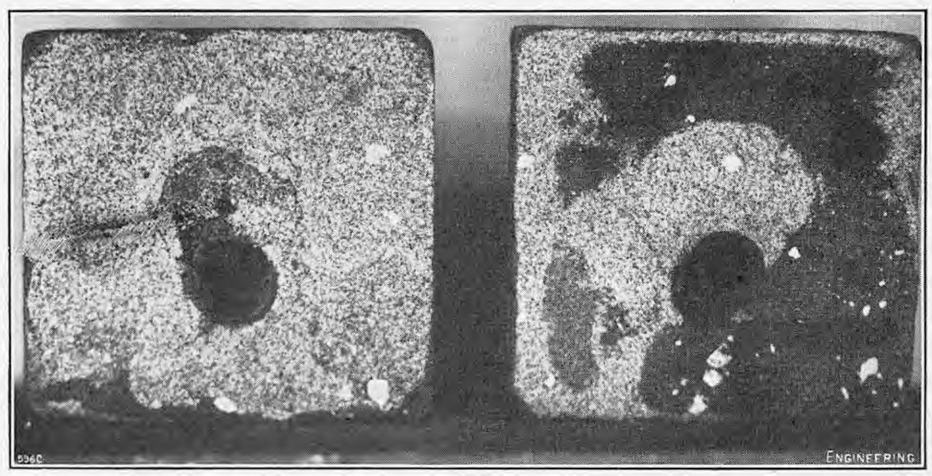


FIG. 3. MODEL NO. 3, HORIZONTAL SECTION.

OVERHAUL LIFE OF BRISTOL HERCULES 634 ENGINES.—Following successful 1,200-hour runs on four of Airwork Limited's Bristol Hercules 634 engines, the Air Registration Board has approved the extension of the period between overhauls of the Hercules 634 engines, fitted in the Vickers-Armstrongs Vikings in service with Airwork Limited, from 1,000 to 1,200 hours. It is expected that a 1,200-hour overhaul period will also be approved for Hercules 634 engines in Viking aircraft operated by British European Airways; twelve of their engines are undergoing 1,200-hour trial runs. The Hercules 634 engines are manufactured by the Bristol Aeroplane Co. Ltd., Filton House, Bristol, who have recently conducted a "repeat" type test of a Hercules 634 engine made up from major components which had already completed more than 3,000 hours of airline service; some had exceeded 4,000 hours. The Bristol company considered that the satisfactory completion of a test on such an engine would give evidence of the ability of the engine components to give satisfactory performance for at least another 1,000 hours. Excepting that the oil pump was removed at one stage, the whole test was carried out without any work other than routine servicing being done on the engine. The powers developed and the fuel and oil consumptions were found to be within the limits laid down for a new engine. When the engine was stripped for examination after the test, one cylinder-head ring was found to be in its groove and one master-rod gudgeon pin bush had moved slightly; all other components were in excellent condition.

SOIL FAILURE DURING THE OVERTURNING OF PILES.

By T. E. H. WILLIAMS, M.Sc.

MOST investigators on this subject have recognised that, before the collapse of a pile, a body of sand of definite geometrical pattern is displaced by the embedded length. No general agreement has, however, been reached on the shape of this displaced wedge. It is now generally agreed that when a vertically-embedded pole or pile is subjected to a horizontal force applied above ground level it begins to rotate at a point below the mid-penetration depth. This centre of rotation soon rises to the surface level of the ground as the magnitude of the applied force is increased. The existing methods for determining the resistance to overturning of piles are mainly based on the assumption that the centre of rotation is initially below mid-penetration depth. They also call for a series of overturning tests on trial piles in typical soils along the route of a proposed line in order to determine values for coefficients introduced into formulæ.

The investigation which resulted in the production of this article was carried out with the object of solving three problems: (1) The determination of the position of the centre of rotation when the maximum overturning moment was effective. (2) The development of a method for determining the accurate form of the displaced body of sand. (3) The derivation of a formula for the maximum resistance to overturning without the introduction of coefficients. The existing methods for determining the resistance of piles to overturning are based on the criterion of negligible movement. The passive pressure developed in the soil immediately surrounding the pile is assumed to be represented by parabolic or triangular diagrams.

SOIL FAILURE DURING OVERTURNING OF PILES.

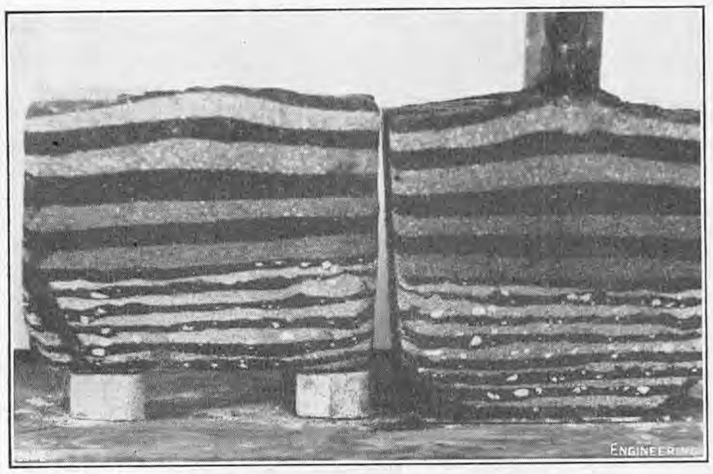


FIG. 4. MODEL NO. 3, REAR CROSS-SECTION.

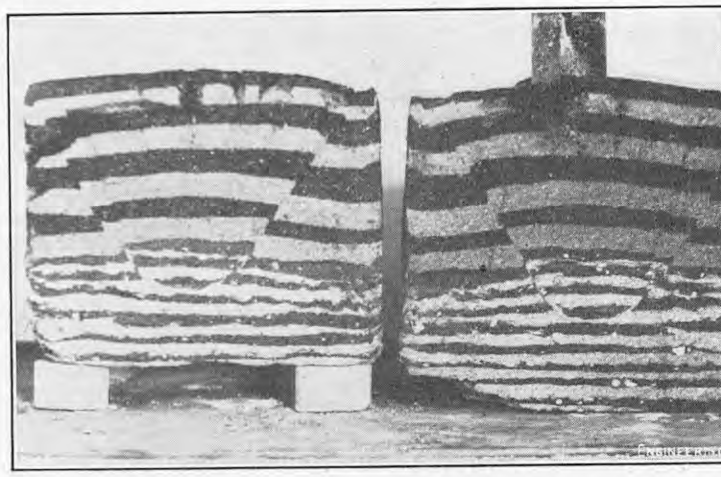


FIG. 5. MODEL NO. 3, FRONT CROSS-SECTION.

FIG. 6. MODEL NO. 3, SECTION PLANES SHOWN IN FIGS. 4 AND 5.

FIG. 7. MODEL NO. 3, CENTRAL LONGITUDINAL SECTION.

Existing theories cannot be applied to determine the maximum resistance to overturning offered by piles for the following two reasons: the theories do not cater for a change in the position of the centre of rotation; and the triangular distribution of passive pressure is truly effective only for translatory motion. It has been recognised by previous investigators that the centre of rotation of a pile moves to the surface. Tests described below proved that the centre of rotation was at surface level when the maximum resistance was encountered. There is some justification for considering a triangular pressure distribution when the amount of rotation is negligible, but when visible rotation occurs, as is always the case before the maximum resistance is encountered, mass movement of soil follows and the triangular distribution no longer applies.

Most investigators on this subject have found that a body of soil of definite geometrical form is displaced before a pile collapses. A wedge, fan-shaped in plan, or an inverted cone, was the assumed form. The production of sand-casts enabled the author to determine the accurate form of the displaced soil, as detailed later. The experimental programme consisted of three test series. The first and second series were carried out with the object of noting the mechanism of soil failure; the third series produced numerical data on overturning moments.

In the first of the test series use was made of an open box which had one longitudinal side of glass. Dry sand and powdered chalk were compacted in alternate layers around a model pile placed vertically against the plate glass. A horizontal load applied through a spring balance to the top of the pile was gradually increased and the deformation of the strata noted. The phenomena noted during this series showed that overturning of piles takes place in three stages. First, slight rotation occurs about a point below mid-penetration depth, when a localised disturbance of the sand is observed at the foot of the pile. The pile then produces a heaving of the surface material on one side by "punching" its way through the sand. On the opposite side a body of sand of regular pattern is gradually mobilised and ultimately displaced. The maximum resistance to overturning is effective at the instant when the body of sand is fully developed; the centre of rotation is at surface level when this occurs. Finally comes breakdown of the displaced sand body and collapse of the pile.

The second test series was carried out to determine the form of the displaced body of sand at various depths below surface level. A series of sand-casts was prepared by compacting alternate layers of dry sand and powdered coal around model piles in separate wooden moulds. Both sand and coal had been mixed with dry anhydrous gypsum plaster. The model piles in the form of tubes were subjected to horizontal loading from above surface level until tension cracks appeared on the top surface of the material. Water, to which had been added a detergent, was then gently poured on the material. The addition of a detergent ensured maximum speed of penetration and minimum disturbance to loose grains in the neighbourhood of the slip-surfaces. The casts were allowed to solidify for 24 hours and then sawn horizontally and vertically. Figs. 1, 2 and 3, opposite, show horizontal and vertical sections, with indications of the position of the pile. The slip-plane, shown in Fig. 2, was found to be approximately parabolic; it is eccentric with respect to the tube. Fig. 3 shows the plan of the displaced body of material to be approximately a portion of a sector of a circle with the bounding radii tangential to the pile's circumference and enclosing an angle of 60 degrees; this was typical of a number of casts.

Figs. 4, 5 and 6 show a cast sawn along transverse planes. The section on the side of the pile where the overturning pull was applied (Fig. 4) showed only slight deformation of the strata, whereas the section on the other side (Fig. 5) showed the slip-planes clearly. Fig. 7 shows a cast which was sawn along the central longitudinal plane after the pile had been withdrawn and the form of the central slip-plane is seen to be a straight line. The discontinuity of the slip plane was caused by an inclusion. From measurement on these and other sections, the author concluded that the form of the displaced wedge of sand can be reproduced by drawing an inverted oblique cone with base of diameter equal to the depth of penetration of the pile. The tangents common to the cone and pile form the side planes of the completed wedge.

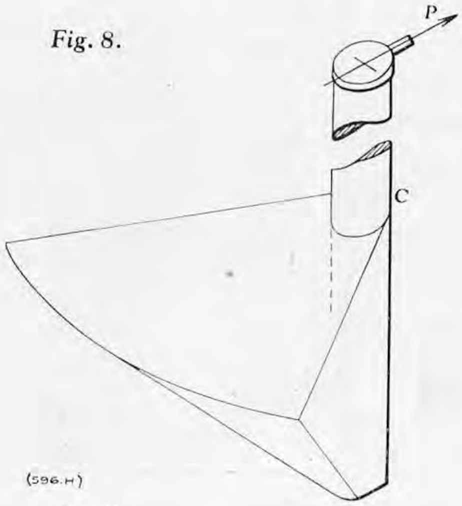
In the third series of tests, model piles were driven to predetermined depths in compacted dry sand which was contained in a large brick bin. Loading was applied to the free end of the piles through a horizontal cable and a spring balance which was pulled by hand. It was found impossible to utilise a vertically adjusted pulley and dead loading because of the danger of immediate collapse occurring after the critical maximum resistance had been overcome. The application of load by hand made possible the feeling of the sudden decrease of tension in the spring, and the lever-arm (i.e., the height of the loading cable above the undisturbed surface level) could then be accurately measured at that critical stage. For any defined depth of penetration the magnitude of the overturning moment recorded is the mean of ten results. The angle of internal friction ϕ of the sand was determined by means of the shear box. The bulk density of the compacted sand was also determined.

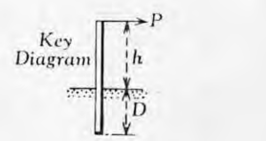
The simplified form of displaced wedge on which the proposed theory is based is constructed as shown in Fig. 8, on page 136. For the sectional elevation: commencing at the foot of the pile, draw a line at 45 deg. to the vertical to meet the plane of the free surface of sand on one side of the pile; for the plan: rotate the triangular section thus obtained through 60 deg. about the vertical axis situated on the opposite side of the pile at a distance equal to the pile diameter from its centre. Fig. 8 shows the isometric projection of the theoretical wedge form.

The two factors which provide resistance to the displacement of this conical wedge of sand are its weight and the shear strength of the conical slip surface. No frictional resistance is afforded by the

SOIL FAILURE DURING OVERTURNING OF PILES.

Fig. 8.





Site Material: Dry Sand
Bulk Density: 100 Lb. per Cub. Ft.
$\mu = \tan\phi = 0{\cdot}65$

Pile Section: Circular

Fig. 10.

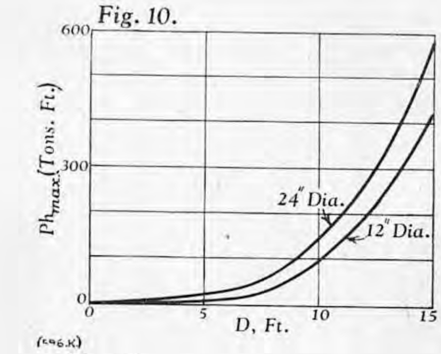


Fig. 11.

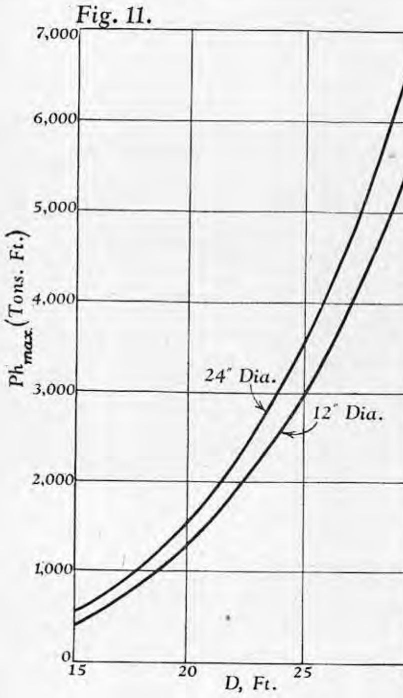


Fig. 9.

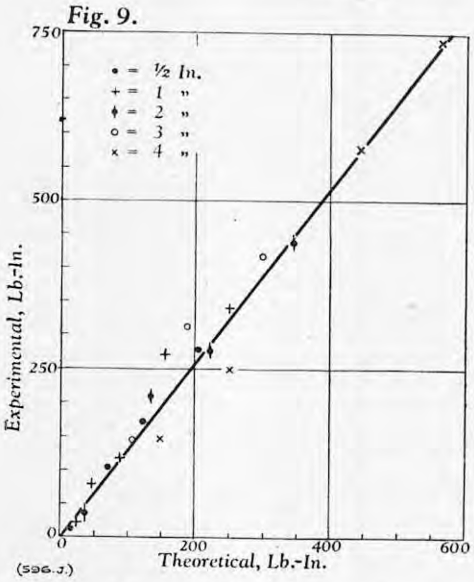


Fig. 12.

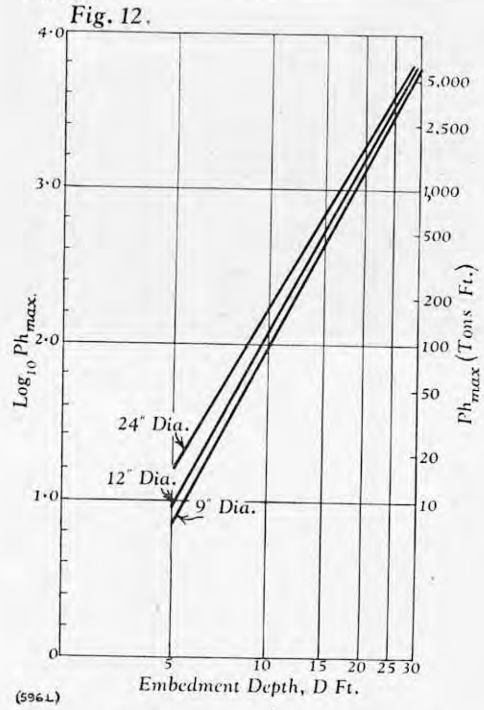
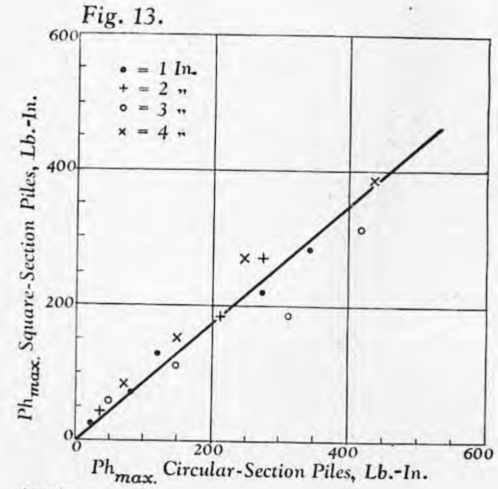


Fig. 13.



plane sides of the conical wedge since they are not parallel and the wedge movement is along an inclined plane; the compacted sand on each side of the wedge does not collapse. The moment of resistance of the above two values about the point C (Fig. 8) on the "punching side" of the pile at surface level is given by the following expressions.

Maximum resistance of overturning $Ph_{max.}$,

$$= \left[\frac{\text{Weight}}{\text{Moment}}\right] + \left[\frac{\text{Friction}}{\text{Moment}}\right]$$

Weight moment

$$= \frac{w}{72}[6\,D^4 + (36 - 2\pi)B\,D^3 + (81 - 9\pi)\,B^2\,D^2]$$

$$= w\,[0{\cdot}0833\,D^4 + 0{\cdot}413\,B\,D^3 + 0{\cdot}733\,B^2\,D^2]$$

Friction moment

$$= \mu\,w\,\frac{\pi}{72}\,[2\,D^4 + 11\,B\,D^3 + 9\,B^2\,D^2]$$

$$= \mu\,w\,[0{\cdot}0872\,D^4 + 0{\cdot}48\,B\,D^3 + 0{\cdot}393\,B^2\,D^2]$$

where w = bulk density of sand (lb. per cubic foot).
ϕ = angle of internal friction of sand,
$\mu = \tan\phi$,
B = diameter of pile (ft.),
D = depth of pile penetration (ft.).

These formulæ are confined in application to round-section piles embedded in dry granular material. Fig. 9 shows the relationship between experimental and theoretical overturning moments for the model circular piles used. The slope of the graph proves the consistency of the derived formulæ for the stated soil conditions. These formulæ have eliminated the necessity for introducing arbitrary coefficients.

The assumption that the centre of rotation is behind the pile in its undisturbed position is an error on the safe side, since when maximum resistance is encountered the pile has been tilted away from the displaced soil wedge and the friction and weight moments will have longer lever-arms. Further research is being conducted to determine the amount of pile movement before maximum resistance is reached, in order that the true horizontal position of the centre of rotation may be determined. The derived formulæ make it possible to draw curves from which the maximum overturning moment can be obtained for a round-section pile of any diameter in a granular material of known frictional properties. Figs. 10 and 11 give typical curves for 12-in. and 24-in. diameter circular piles plotted to natural scales. Fig. 12 shows the same curves plotted to logarithmic scales together with the values for a 9-in. diameter pile.

The three series of tests were repeated for square-section piles of face dimensions equal to the diameter of the circular-section piles. The form of the displaced soil wedge was similar to that for the circular piles and the centre of rotation was found to be at surface level when the maximum resistance was effective. These tests proved that circular-section piles develop greater resistance than square-section piles. This verifies the findings of a previous investigator* in this subject. This difference in resistance could be credited to the effect of the curved periphery of the circular piles producing a consolidated arching of the sand, whereas the square-section pile tends to force its way through the sand. Fig. 13 shows the relationship between the maximum resistance to overturning with round-section and square-section model piles. The maximum size of pile used was 4 in. and the maximum depth to width ratio was 25·0. The straight line drawn through the plotted points has a slope of 0·88, so that it is a close approximation to assume that the square-section piles can withstand only 90 per cent. of the overturning moment withstood by circular-section piles. Figs. 10, 11 and 12 can therefore be used for square-section piles by multiplying plotted values by 0·90.

The formulæ are based on a horizontally maintained pull as found in an anchorage pile attached to a long cable, where the angle of inclination to the horizontal is negligible. The theory is particularly applicable to a telegraph pole subject to unbalanced wire tension when the cables on one side are cut. When the length of cable is small the possibility has to be borne in mind of the pile being withdrawn from the sand before the instant of maximum soil-moment of resistance. The introduction of an adequate factor of safety, at least no less than 2, is necessary to prevent premature extraction.

The investigation, which was started at the University College of Swansea, is being continued at King's College, University of Durham, to determine the effect of cohesion in moist material on the shape and proportions of the displaced soil wedge. The results, so far, suggest that there is no critical variation in either property.

* M. A. Drucker, *Civil Engineering* (U.S.A.), September, 1935, page 589.

LOADMETER FOR INDUSTRIAL MILLS.

By R. B. SIMS, J. A. PLACE and A. D. MORLEY.

(*Concluded from page 119.*)

THE loadmeters are usually calibrated in a testing machine, but the relationship between load and current (or potential difference) may be derived for the simple case of uniaxial compression. The load applied to the loadmeter is assumed to be parallel to the axis and the cylinder rests on a flat rigid support. The strain gauges attached to the cylinder are matched in resistance before bonding, so that they may be assumed to have equal resistances denoted by R′. Let V, I and R denote potential difference, current and resistance respectively, and suffixes AB, BC, CD and DA denote values between the terminals A, B, C and D of the network in Fig. 7, page 116, *ante*; the suffix *n* will indicate input and *m*, output values.

Then $R_{AB} = R_{BC} = R_{CD} = R_{DA} = 2\,R'$ and, when the load is applied, the resistances of the gauges will change so that R_{AB} becomes $R_{AB} + \Delta R_{AB}$; R_{BC} becomes $R_{BC} + \Delta R_{BC}$ and so on. If the indicating meter is removed from the circuit, then

$$V_{AB} = V_n \left\{ \frac{R_{AB} + \Delta R_{AB}}{R_{AB} + \Delta R_{AB} + R_{BC} + \Delta R_{BC}} \right\}, \quad (1)$$

and

$$V_{AD} = V_n \left\{ \frac{R_{AD} + \Delta R_{AD}}{R_{AD} + \Delta R_{AD} + R_{CD} + \Delta R_{CD}} \right\}, \quad (2)$$

where V_n is the voltage applied to the network.

If ϵ_x is the natural strain along the axis of an electrical resistance strain gauge, and ϵ_y the strain across the gauge, then Baumberger and Hines* show that

$$\frac{\Delta R'}{R'} = l\,\epsilon_x + k\,\epsilon_y, \quad . \quad . \quad (3)$$

where *l* and *k* are constants for small strains when Nichrome or ferro alloys are used for the gauge wire. The value of the constant *k* depends largely on the gauge construction, but it is usually very small. In uniaxial tension or compression

$$\frac{\Delta R'}{R'} = \nu\,\epsilon, \quad . \quad . \quad . \quad . \quad (4)$$

where ϵ is the tensile or compressive strain, positive for the former and negative for the latter; ν is a constant, termed the gauge factor, and depends upon strain-resistance characteristics of the metal and on Poisson's ratio for the steel cylinder to which the gauges are bonded.

From a stress analysis of the loaded cylinder, the output of the Wheatstone network may be calculated from the appropriate values of the modulus of elasticity, E, Poisson's ratio λ of the steel of the loadmeter, and experimental values of *l* and *k*. In practice, the calculation is very lengthy, and too uncertain for a reliable relationship to be obtained for any but the simplest stress distribution.

If the cylinder is compressed homogeneously between two perfectly lubricated plates larger than the cylinder, then, from equation (4),

$$\left.\begin{aligned} &\Delta R_{AB} = \Delta R_{CD} = -\,2\,R'\,\nu\,\epsilon \\ \text{and}\quad &\Delta R_{BC} = \Delta R_{DA} = +\,2\,R'\,\nu\,\lambda\,\epsilon \\ &\text{if the constant } k \ll l \end{aligned}\right\} \quad . \quad . \quad (5)$$

Substituting from equation (5) into equations (1) and (2), we have

$$V_{AB} = \frac{V_n\,(1 - \nu\,\epsilon)}{2 - \nu\,\epsilon\,(1 - \lambda)} \quad \text{and} \quad V_{AD} = \frac{V_n\,(1 + \lambda\,\nu\,\epsilon)}{2 - \nu\,\epsilon\,(1 - \lambda)}, \quad . \quad . \quad . \quad (6)$$

and the effective resistance of the network is

$$R_n = R'\,[2 - \nu\,\epsilon\,(1 - \lambda)]. \quad . \quad . \quad (7)$$

These values have been derived on the assumption that the loadmeter output is on open circuit. If an ammeter of resistance R_m, or any other resistive load of this value, is connected across the output terminals, then, from Thévenin's theorem, the current in the load is

$$I_m = \frac{V_{AD} - V_{AB}}{R_m + R_n} \quad . \quad . \quad . \quad (8)$$

Combining equations (6), (7) and (8), we have for the meter current

$$I_m = \frac{V_n\,\nu\,\epsilon\,(1 + \lambda)}{\left\{2 - \nu\,\epsilon\,(1 - \lambda)\right\}\left[R'\left\{2 - \nu\,\epsilon\,(1 - \lambda)\right\} + R_m\right]}. \quad . \quad . \quad . \quad (9)$$

The strain $\epsilon = \frac{F}{\pi\,r^2\,E}$, where F is the load and *r* the radius of the cylinder, and since $\nu\,\epsilon\,(1 - \lambda) < 0{\cdot}0025$ at maximum load, equation (9) may be written, to a close approximation,

$$I_m = \frac{V_n\,\nu\,F\,(1 + \lambda)}{2\,\pi\,r^2\,E\,(2\,R' + R_m)}. \quad . \quad . \quad (10)$$

The voltage across the output terminals on open circuit is, to a close approximation,

$$V_m = V_{AD} - V_{AB} = \frac{V_n\,\nu\,F\,(1 + \lambda)}{2\,\pi\,r^2\,E}. \quad . \quad (11)$$

The output current given in equation (10) will represent closely the calibration curve of the direct-current set. The voltage on open circuit of equation (11) will represent the calibration of a balanced recording potentiometer and will agree with the calibration of the alternating-current set, since the gauges are almost entirely resistive. Equations (10) and (11) are both linear relationships with load. In addition, the voltage relationship of equation (11) is independent of the strain-gauge resistance and thus has the advantage in being completely temperature-independent, a point which is discussed in detail below.

Direct calibrations between smooth lubricated platens up to the maximum load on the 20, 50, 300 and 600-ton cylinders confirm these linear relationships, and, in Table I, details are given of a calibration of the loadmeter of 300-tons capacity made in a 50-ton universal testing machine. The bridge voltage was $100 \pm 0{\cdot}2$ volts and the circuit shown in Fig. 7 was used. Here the potentiometer is used to obtain, accurately, the current in the ammeter, and does not measure the open-circuit voltage.

TABLE I.—*Calibration of 300-ton Loadmeter in Terms of Load* v. *Output Current.* ($V_n = 100 \pm 0{\cdot}2$ volts.)

Load, Tons.	V_{BD}, Volts.	Reading of Galvanometer, Arbitrary Units.	$\frac{V_{BD}}{\text{Load}}$, Volts Per Ton.
0	0	0	—
10	140×10^{-5}	5·12	$14{\cdot}0 \times 10^{-5}$
20	282	10·34	14·1
30	423	15·58	14·1
40	564	20·74	14·1
50	702	25·92	14·05

The mean value of the ratio $\frac{V_{BD}}{\text{Load}}$ in volts per ton over a number of runs was $14{\cdot}06 \times 10^{-5}$, the small random variations being well within the known experimental error, and due, probably, to small changes in the applied bridge volts. The effective galvanometer resistance was 967·0 ohms, so that, experimentally, $I_m = 0{\cdot}1454$ microamperes per ton. The calculated value, using the experimental value of $\nu = 2{\cdot}22$, $r = 2$ in., $R' = 2435 \pm 2$ ohms, $\lambda = 0{\cdot}285$ and $E = 30 \times 10^6$ lb. per square inch, is $I_m = 0{\cdot}145$ microamperes per ton.

These equations to the output of a loadmeter in a mill have been derived on the assumption that the diameter of the screw is greater than that of the steel cylinder. This is usual in industrial practice. If, however, the screw is smaller, there is no longer uniaxial compression in the cylinder, and equations (10) and (11) do not apply. The theoretical solution is extremely complex, so that the two cases which arise when the load is applied eccentrically or symmetrically, have been examined experimentally. The cylinder was loaded through a short column to which were attached flat-ended tools of 1·0-in., 1·5-in. and 2·0-in. diameter. The column was held vertically in a bearing and located accurately on a diameter of the cylinder by means of a jig. The diameters connecting gauges 1 and 5 (axially parallel) and 2 and 6 (axially normal) were selected for experiment. Changes in the out-of-balance current and voltage were measured by a vernier potentiometer, using the circuit shown in Fig. 7.

If the cylinder is made long in comparison with its diameter, the output would, from St. Venant's principle, be independent of the form of loading. Since it is not possible to design a loadmeter on these lines, the ratio of the effective height to the diameter of the cylinder is important in the calibration. Tables II and III, page 138, show calibrations made with and without the covers on the loadmeter, giving $\frac{L}{2\,r} = 1{\cdot}095$ in the former case and 0·906 in the latter i.e., approximately 10 per cent. variation in $\frac{L}{2\,r}$.

The effect of the 10 per cent. change in the ratio $\frac{L}{2\,r}$ on the calibration in uniaxial compression is large, the error with the 1·5-in. diameter tool being 10·7 per cent. Moreover, the calibration of current *v.* load with the small tools is no longer linear, this being due to the large hoop strains developed, which make the approximations of equations (10) and (11) no longer valid. The behaviour under eccentric loading is complex, but it is clear that the greatest error is to be expected when the loadmeter is symmetrically loaded with a small tool, and the greatest variation from the calibration in uniaxial compression is to be found with the smaller value of $\frac{L}{2\,r}$. No measurable differences were found in the output of the loadmeter when the eccentric loading was made on diameters connecting gauges 1 and 5 and also 2 and 6.

When the total load in the mill is required, it is often inconvenient for the operator to sum the readings of the two load indicators. The total load may be obtained electrically on one meter, either by having the meter wound with a double moving coil and connecting a loadmeter to each one, or by making a double parallel connection between the loadmeters and presenting the output on a single meter. The former requires a specially made meter, but is the simpler and more convenient method; the second is the only method possible when the output is in microamperes, and when the total load is required as a single electrical signal, as, for instance, for gauge control.

Fig. 9, on page 117, *ante*, shows the connections of the two loadmeters. It may be shown by an extension of the analysis given for equations (1) to (11) that

$$I_T = \frac{V_n}{2\,(2\,q\,R'_y + R_{m_T})} \left\{ \frac{p\,\nu_x\,(1 + \lambda_x)\,F_x}{\pi\,r_x^2\,E_x} + \frac{q\,\nu_y\,(1 + \lambda_y)\,F_y}{\pi\,r_y^2\,E_y} \right\}, \quad (12)$$

where *p* and *q* are constants of the networks, and suffixes *x*, *y* and T denote values for the separate circuits and the combined circuit, respectively; I_T is the meter current for the combined load $F_x + F_y$.

The values of gauge factor, Poisson's ratio and modulus of elasticity do not vary appreciably, so that, for two geometrically similar cylinders, equation (12) becomes

$$I_T = \frac{V_n\,\nu\,(p\,F_n + q\,F_y)\,(1 + \lambda)}{2\,\pi\,r^2\,E\,(2\,q\,R'_y + R_{m_T})}, \quad . \quad (13)$$

and on substituting for F_x and F_y from equation (10)

$$I_T = \frac{p\,(2\,R'_x + R_{mx})}{2\,q\,R'_y + R_{m_T}}\,I_x + \frac{q\,(2\,R'_y + R_{my})}{2\,q\,R'_y + R_{m_T}}\,I_y. \quad (14)$$

These expressions have been verified experimentally, using two similar loadmeters of 50 tons capacity, which were loaded unequally, the individual and total load indications being measured. Table IV, page 138, gives a comparison of the experimental and theoretical results, and shows the linearity of the load/current calibration.

The total-load meter may therefore be calibrated from the circuit constants and the load-current calibration of the individual meters. A simpler approach, however, is to calibrate for total load during the calibration by compressing the two loadmeters in a press, one mounted above the other.

The resistance of the strain gauges may vary with temperature, due to changes in the specific resistivity of the gauge wire and differences in the coefficient of linear expansion between the gauge

* R. Baumberger and F. Hines. *Experimental Stress Analysis*, vol. 2, page 116 (1944).

wire and the steel cylinder. If the strain gauges composing the network are not all at the same temperature, the zero of the loadmeter will be altered and the circuit will need adjustment before an accurate indication of the load is given. If all the gauges are at the same temperature, but one which is different from the calibration temperature, the effective resistance R_n of the network is changed; and, if the load indication is in terms of current, the calibration will vary inversely with R_n. If a potentiometric method is employed, the calibration will be independent of temperature.

The correction for the first of these two effects, the variation of temperature between the gauges, has been made negligible by mounting all eight strain gauges on the same cylinder. Changes in temperature will affect them equally, since the thermal capacity of the cylinder is large and the gauges are shielded from draughts by the massive cover. The variation in the resistance of the gauges with temperature will then be very nearly equal, since the gauges are matched in resistance to 0·1 per cent. at least.

Equation (8) shows that I_m is inversely proportional to the effective network resistance R_n, and, within the limits of the approximation used, equation (10) shows it to be inversely proportional to the gauge resistance R′ and directly proportional to the gauge factor. The change in resistance with temperature of a strain gauge formed of Nichrome wire attached to a steel block may be taken*† as $\beta = 0{\cdot}97 \times 10^{-4}$ ohm per ohm per degree C. If the proportional change in the gauge factor is written as α per degree C., then

$$I^*_m \simeq I_m\left\{1 + (\alpha - \beta)\,t\right\}. \quad . \quad . \ (15)$$

where I^*_m is the current at temperature t deg. C. above the calibration temperature for a load equivalent to I_m at the calibration temperature. From Jones's experimental work $\alpha \simeq 0$ between 15 deg. C. and 44 deg. C. and $\alpha \simeq -4{\cdot}9 \times 10^{-4}$ per degree C. between 46 deg. C. and 73 deg. C. An experimental determination of the change of current calibration with temperature was made with a loadmeter of 300 tons capacity at 50 tons loading. Table V gives the results.

The experimental temperature coefficients, $1{\cdot}4 \times 10^{-4}$ and $4{\cdot}2 \times 10^{-4}$ are to be compared with the values of $1{\cdot}0 \times 10^{-4}$ and $3{\cdot}9 \times 10^{-4}$ obtained from Jones's experiments.

The final level of accuracy attained by the loadmeter depends almost entirely upon the quality of its components and the care with which it is calibrated and installed. The following gives an estimation of the errors which may be expected.

Errors of Calibration.—Although the output for a given load may be calculated when the cylinder is compressed homogeneously, the gauge factor and the appropriate value of Poisson's ratio are difficult to measure, so that a direct calibration is almost always required. Unless deadweight loading is used, all the errors of the testing machine will be reproduced in the final calibration. A small "hysteresis" is frequently found between calibrations with the load increasing and decreasing. Experiments have shown that this is due either to the testing machine or to the indicating instrument, and is not inherent in the loadmeter. Since the output of a loadmeter is very closely linear with load, it is not absolutely necessary to reach maximum values during calibration. A load of about a sixth to a quarter of the maximum is sufficient usually to determine the relationship between I_m and F. It should always be close to the calculated value.

Temperature Changes.—The loadmeters built for research should have a thermocouple peened to the surface of the cylinder, so that compensation may be made for temperature changes. Generally, where precision measurements are to be made, the loadmeter may be kept to within 10 deg. C. of the calibration temperature and the correction is negligible. If the effect of temperature changes is uncorrected, the maximum error for a 50-deg. C. difference between the working temperature and the calibration temperature is unlikely to exceed 2 per cent., if an adhesive with adequate strength and insulating properties is used.

Variation of Bridge Current.—The correct bridge current is established during calibration. If a current of 100 volts is used and indicated on a first-grade 3½-in. knife-edge pointer and mirror scale type of voltmeter, the bridge voltage will be repeatable to within 1 per cent., and this gives the order of error due to this cause. For more accurate work a substandard voltmeter or potentiometer should be employed to monitor the voltage continuously, or a highly-stabilised power pack should be used to supply the gauges.

Errors Due to Loading Method.—The calibration will be carried out between parallel platens in nearly every case, so that the loadmeter in the mill will indicate true load if the end of the screw is flat, has a greater diameter than the cylinder, and is properly centred. The maximum error will occur when the end of the screw is a part of the sphere. At loads greater than about a ton, applied through a screw end of radius 6 in., the top of the loadmeter will become plastic and the diameter of the impression* will be approximately $a = 0{\cdot}058\sqrt{F}$. If F = 150 tons, then $a = 0{\cdot}71$ in., so that, from Table II, the error will be approximately 2 per cent. Whenever it is practicable, a properly-fitted adaptor should be attached to the screw end to make it plane and parallel with the top of the loadmeter. Apart from the greater accuracy in load indication, it prevents the plastic deformation from spreading through the bearing disc into the cylinder and producing a permanent strain in the section carrying the gauges.

Errors in the Electrical Circuit.—The output of the loadmeter may change slowly over the first few days, due to creep in the gauges and the adhesive, particularly if Durofix is used. After this period of ageing, changes in the calibration with time should be negligible. If reasonable accuracy is to be achieved in a calibration of load against current, the microammeter (or milliammeter, with alternating-current circuits) should be to B.S. No. 89, F.G. Instruments of inferior quality are liable to give very large errors indeed in the first 5 per cent. of full-scale deflection, and friction in their movements contributes substantially to hysteresis in the calibration when the loading is reversed. For the highest accuracy, a direct-current supply from a stabilised source should be used, and these may be built to give less than 0·02 per cent. variation from their rated voltage. With care, therefore, and using a vernier potentiometer, it should be possible to measure loads to an accuracy of better than ± 0·1 per cent. with this design of loadmeter. This accuracy, however, is far in excess of the requirements of industry, and

TABLE II.—CALIBRATION IN VOLTS PER TON, DEVELOPED ACROSS THE TERMINALS OF A MICROAMMETER. (R_m = 967·0 ohms.)
Bridge Volts = 100 ± 0·2. Load applied symmetrically along axis of the cylinder.

Load,	Diameter of Loading Tool.				
	4 In.	2 In.		1·5 In.	
	$\frac{L}{2r} = 1{\cdot}095.$	$\frac{L}{2r} = 1{\cdot}095.$	$\frac{L}{2r} = 0{\cdot}906.$	$\frac{L}{2r} = 1{\cdot}095.$	$\frac{L}{2r} = 0{\cdot}906.$
Tons.	Volts Per Ton.	Volts Per Ton.	Volts Per Ton.	Volts Per Ton.	Volts Per ton.
0	—	—	—	—	—
10	$14{\cdot}0 \times 10^{-5}$	$14{\cdot}0 \times 10^{-5}$	$13{\cdot}6 \times 10^{-5}$	$13{\cdot}8 \times 10^{-5}$	$13{\cdot}1 \times 10^{-5}$
20	14·1	13·9	13·3	13·9	12·8
30	14·1	14·0	13·1	13·8	12·6
40	14·1	14·0	13·0	13·8	12·5
50	14·0	13·9	12·9	13·6	12·5

TABLE III.—CALIBRATION IN VOLTS PER TON, DEVELOPED ACROSS THE TERMINALS OF THE MICROAMMETER. (R_m = 967·0 ohms.)
Bridge Volts = 100 ± 0·2, Load = 50 tons. Load applied eccentrically to the cylinder.

Distance Between Axes of Tool and Cylinder,	Diameter of Loading Tool.					
	2 In.		1·5 In.		1 In.	
	$\frac{L}{2r} = 1{\cdot}095.$	$\frac{L}{2r} = 0{\cdot}906.$	$\frac{L}{2r} = 1{\cdot}095.$	$\frac{L}{2r} = 0{\cdot}906.$	$\frac{L}{2r} = 1{\cdot}095.$	$\frac{L}{2r} = 0{\cdot}906.$
In.	Volts Per Ton.	Volts Per Ton.	Volts Per Ton.	Volts Per Ton.	Volts Per Ton.	Volts Per Ton.
0	$13{\cdot}9 \times 10^{-5}$	$12{\cdot}9 \times 10^{-5}$	$13{\cdot}6 \times 10^{-5}$	$12{\cdot}5 \times 10^{-5}$	$13{\cdot}6 \times 10^{-5}$	$12{\cdot}5 \times 10^{-5}$
0·25	—	13·0	—	12·5	—	12·5
0·50	—	13·1	—	12·9	—	12·9
0·75	—	13·5	—	13·3	—	13·3
1·00	14·0	13·9	13·8	13·8	13·8	13·9

TABLE IV.—INDICATION OF TOTAL LOAD ON ONE METER FROM PARALLELED OUTPUTS OF TWO 50-TON LOAD CYLINDERS. (Gauge supply 100 ± 0·2 Volts, Direct Current.)

Load.		Current in Microammeter.				$\frac{F_x + F_y}{I_T}$.
		Measured Values.			Calculated.	
F_x.	F_y.	I_x.	I_y.	I_T.	I_T.	
Tons.	Tons.	μA.	μA.	μA.	μA.	Tons per μA.
0	12·3	0	9·4	9·7	9·6	1·27
0	26·4	0	20·1	20·3	20·5	1·30
12·4	0	9·9	0	9·6	9·5	1·28
27·25	0	21·8	0	20·9	20·9	1·30
11·5	9·45	9·2	7·2	15·7	16·1	1·33
9·4	26·6	7·5	20·3	27·9	27·9	1·29
12·75	32·25	10·2	24·65	35·5	34·9	1·27
24·6	33·7	19·65	25·7	45·2	45·1	1·29
31·75	31·2	25·4	23·75	48·5	48·6	1·30
31·7	18·9	25·35	14·4	39·4	39·0	1·28
31·4	14·3	25·1	10·9	35·8	35·2	1·28
19·0	8·3	15·2	6·3	21·7	21·0	1·26
18·75	18·9	15·0	14·4	29·3	29·1	1·28

TABLE V.—*Change of Current with Temperature.* (Bridge Volts = 100 ± 0·2.)

Temperature, Deg. C.	Potential Difference Across Galvo Terminals, Volts. (R_m = 967·0 ohms.)	Temperature Coefficient, Microamps Per Deg. C.
15	708×10^{-5}	
44	705	$1{\cdot}4 \times 10^{-4}$
73	696	$4{\cdot}2 \times 10^{-4}$

* *Electric Resistance Strain Gauges*, by W. B. Dobie and P. C. G. Isaacs, page 27. English Universities Press (1948).

† *The Measurement of Stress and Strain in Solids*, by E. Jones, page 20. Institute of Physics (1948).

* Using Hencky's equation $p = cY$, where Y = yield strength and p = average pressure; c = constant, 2·8.

TIDAL MODEL OF RIVER THAMES.

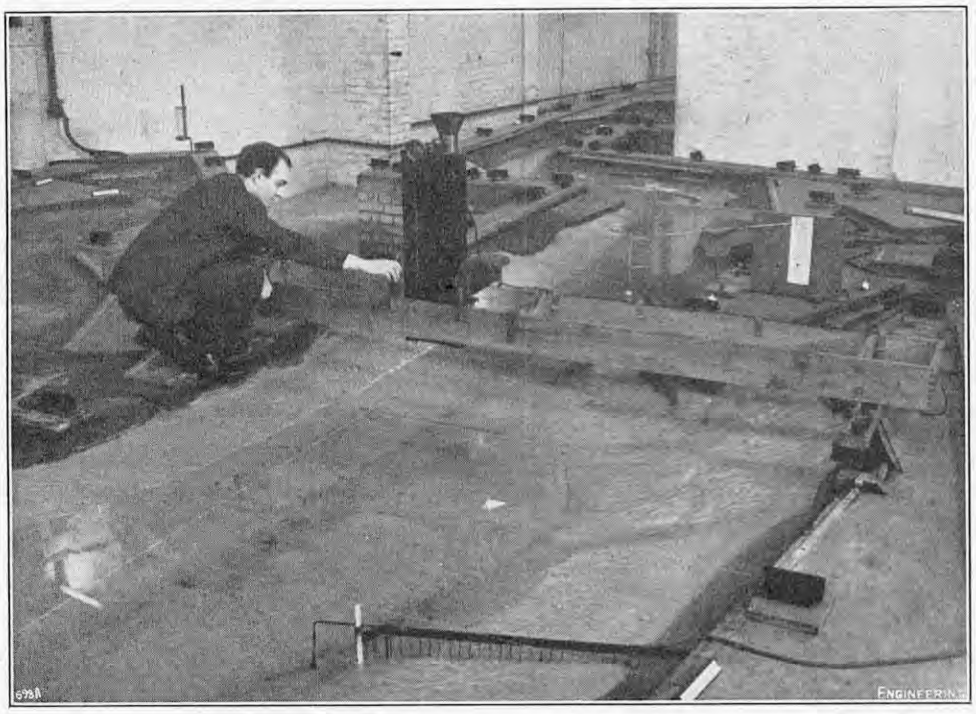


FIG. 1. VELOCITY METER ON PILOT MODEL.

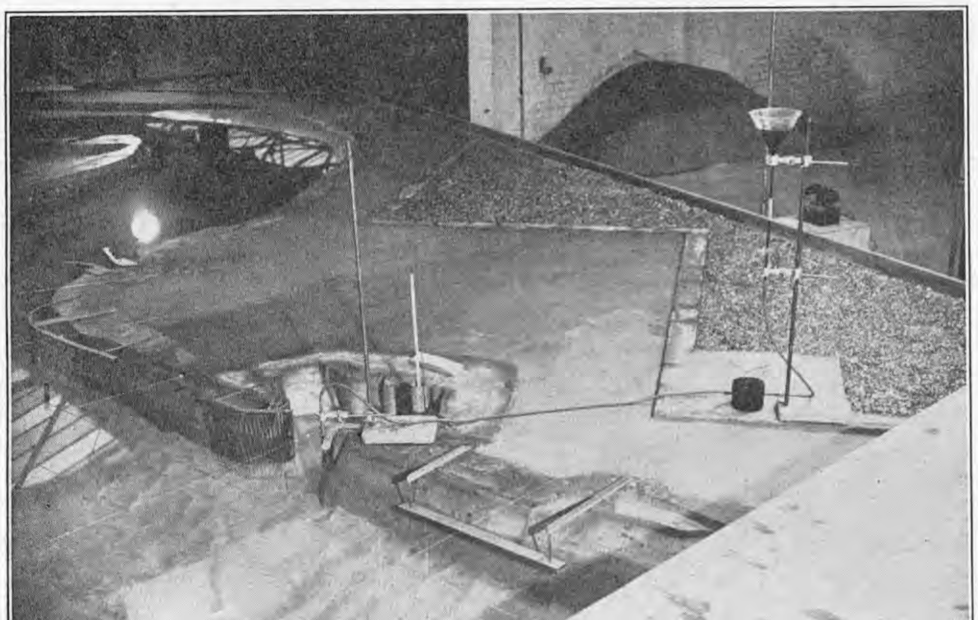


FIG. 2. CURRENT INDICATORS ON PILOT MODEL.

± 1 to 2 per cent. may be obtained with the alternating-current equipment described above, which is sufficiently accurate for normal requirements.

It must be emphasised that this loadmeter and its electronics have been designed primarily for research in industrial mills and are capable of very high accuracy. They are neither delicate structurally nor electrically, and will withstand normal usage by mill maintenance personnel. A pair of 300 tons capacity have been installed, for instance, for four months in a production hot mill, and, though they had no maintenance, were indicating satisfactorily when they were removed.

The calculated natural frequency of the 300-ton loadmeter is $2 \cdot 5 \times 10^4$ c.p.s. Frequencies of this order are measurable by electrical resistance strain gauges. The record may be obtained by using a circuit similar to that shown in Fig. 11, page 118, *ante*, for the alternating-current indicating set, and recording directly on a suitable oscilloscope. The carrier frequency, of course, must be adjusted to be at least three times greater than the frequency to be recorded. The 300-ton loadmeter has been used successfully to measure loads at frequencies of 2,000 c.p.s.

TIDAL INVESTIGATIONS ON THE RIVER THAMES.

As part of an investigation into the deposition and removal of silt in the tidal waters of the River Thames, in order to reduce pollution and minimise the present heavy cost of dredging, the Port of London Authority have constructed, at the Royal Victoria Dock, two models of the river, by means of which its flow can be studied. The work has been carried out under the direction of Sir Claude Inglis, C.I.E., M.I.C.E., Director of Hydraulic Research in the Department of Scientific and Industrial Research, and comprises a pilot model, constructed primarily to decide the most suitable location of the seaward limit and the tide generator, and the main model, which is about 400 ft. long. The illustrations, Figs. 1 and 2, herewith, and Fig. 3, on page 144, show the pilot model, and about half of the length of the main model is shown in Fig. 4, on page 144. It is not practicable to photograph the whole of either model in one exposure, as the shed that houses them is divided by a brick wall.

The pilot model is made to a horizontal linear scale of 1 : 3,000 and a vertical scale of 1 : 120. The time scale is 1 : 273·8, so that the normal tidal cycle of 12 hours 25 minutes is reproduced in 2 minutes 43 seconds. The discharge scale is 1 : 3,943,000. Initially, this model was moulded in accordance with a survey of the river made in 1830-34, but has now been remoulded to surveys made by the Port of London Authority between 1939 and 1949. It represents to scale the river bed between Blackfriars Bridge and the seaward limit of the Authority's jurisdiction, i.e., a line from Havengore Point, Essex, through the Great Nore Towers to Hens Brook, near Eastchurch, Kent. The "tidal prism" of water contained between Blackfriars and Teddington Weir is accommodated in a labyrinth. Similarly, at the seaward end, the River Medway is moulded to scale as far upstream as Rochester, and the scale volume of water from that point to the tidal limit at Allington Lock is also contained in a labyrinth, to reduce the overall dimensions that would be necessary otherwise. Where the slopes of the banks are of 40 deg. or less, the moulding of the Thames is in washed quartz sand with a mean diameter of 0·17 mm. Where the slopes exceed 40 deg., and throughout the Medway section, which has changed little in recent years, cement mortar was used. Fig. 1 shows the portion of the model from about Leigh-on-Sea to the Isle of Grain, with a velocity meter mounted to span the waterway; Fig. 2 shows the current indicators injecting dye into the tidal stream in the Tilbury section; and Fig. 3 is a general view of the pilot model, from the Medway up to Westminster.

The main model is made to a horizontal scale of 1 : 600 and a vertical scale of 1 : 60, giving a vertical exaggeration of ten times, compared with the 25 times of the pilot model. The time scale of the main model is 1 : 77·46, so that the tidal period is reproduced in 9 minutes 36·3 seconds; and the discharge scale is 1 : 278,850. The portion of the river represented to scale in plan and elevation is from a line 600 ft. east of Southend pier on a bearing N. 12½ deg. E., where the estuary is about 4½ miles wide, to Westminster Bridge, and a labyrinth contains the tidal prism between Westminster and Teddington. The form of the bed is that shown by the P.L.A. surveys of 1939-49, and the slopes, where of 40 deg. or less, are moulded in a natural silica sand with a mean diameter of 0·20 mm. The labyrinths, and slopes of more than 40 deg., are in cement mortar. Measured along the river bed, the distance from Southend to Westminster (45·17 miles in fact) is 397·8 ft. in the model; and the 16·72 miles from Westminster Bridge to Teddington Weir is represented by 148·4 ft. along the labyrinth.

In both models, the tides are generated by the variation of air pressure in a pneumatic displacer, to which is connected a turbo-exhauster. The tides to be reproduced are drawn as a graph on a roll of paper, mounted on a uniformly rotating drum. A spot of light is concentrated on the graph, which is scanned by an electronic follower, actuated by the reflection from the paper. Through an amplifier and relays this controls the air pressure in the displacer and hence the flow of water to the model. This apparatus was designed and made at the Hydraulic Research Station of the Department of Scientific and Industrial Research.

As stated, one of the principal purposes of the models is to reduce the silting and consequent dredging in the lower part of the river, particularly at Tilbury tidal basin, in the Royal Docks, and in the reaches immediately below those docks. In all, the P.L.A. dredges annually about 3,000,000 cub. yards of mud, of which two-thirds comes from these three areas, and spends each year on dredging nearly 500,000*l*. Pollution of the river is also a serious problem, which is being accentuated by the effect of the warm water discharged from the condensers of the many power stations. A separate investigation is being made into the pollution of the river by the Water Pollution Research Laboratory of the D.S.I.R., who have established a laboratory for this purpose at Tilbury. The experiments with the pilot model in its original form—i.e., to the 1830-34 survey, before the channel was dredged—provided a useful basis of comparison with the present flow, and this model will continue to be used for comparative and sectional investigations. The main model will be used to study currents, the retention of liquids discharged at various states of the tide, and the places where the least silt is held in suspension, so that the least-polluted water may be impounded to maintain the level in the docks.

"LITERATURE": ERRATA.—Two errors occurred in our review of *Practical Mathematics*, by Louis Toft and A. D. D. McKay, on page 68, *ante*. In the third paragraph of this review, the reference to "conies" should, of course, read "conics"; and in the fourth paragraph, the name "Jacobs" should read "Jacobi."

COMET AIR LINER CERTIFICATE OF AIRWORTHINESS.—On Tuesday, January 22, the Minister of Civil Aviation, the Hon. J. S. Maclay, C.M.G., M.P., signed and delivered to the de Havilland Aircraft Co., Ltd., at Hatfield, Hertfordshire, the Certificate of Airworthiness for the Comet air liner. The Comet thus becomes the first jet-propelled air liner in the world to be officially approved for carrying passengers on commercial services.

FLUE-GAS WASHING PLANT AT BIRMINGHAM GASWORKS.

Fig. 1.

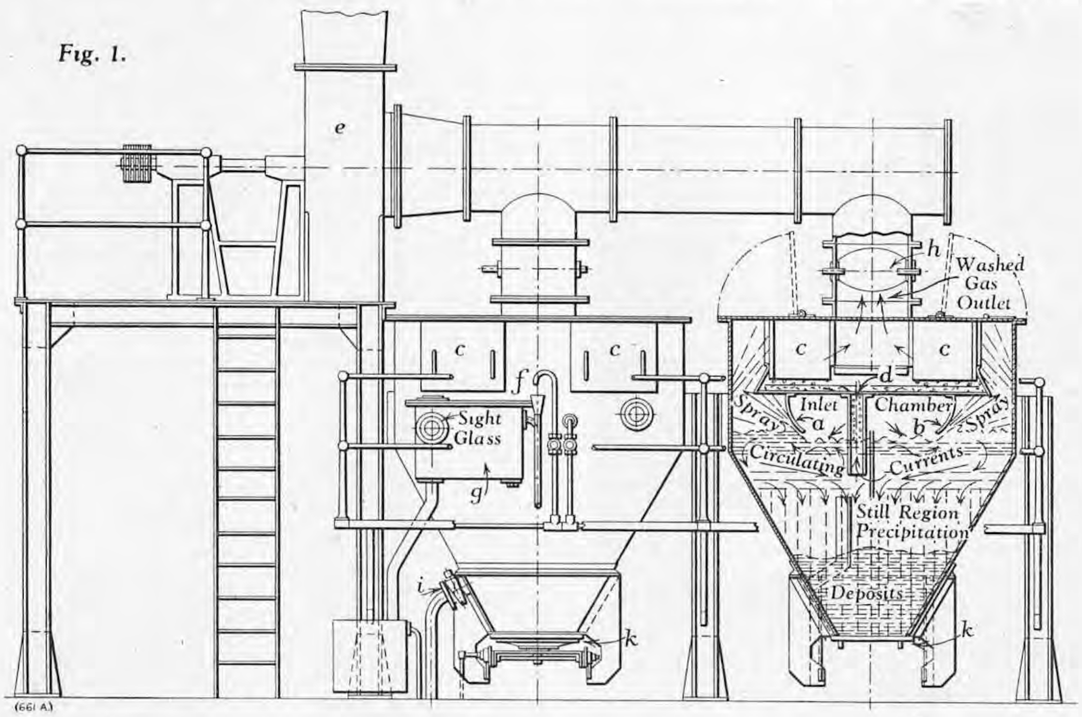
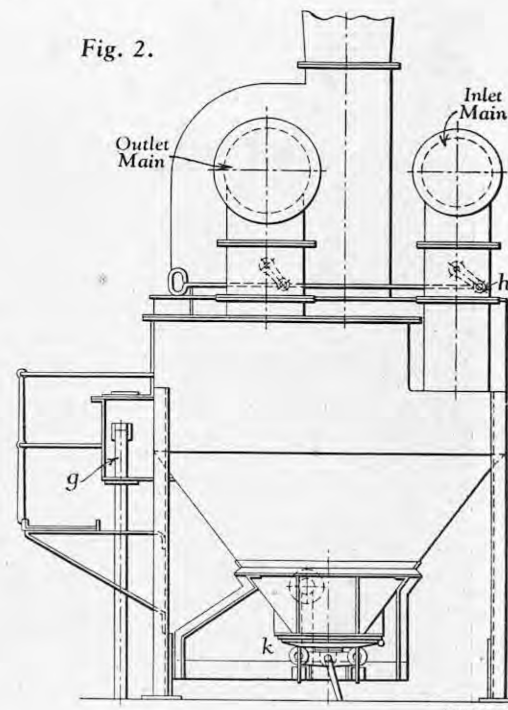


Fig. 2.



DRUMMOND FLUE-GAS WASHING PLANT, BIRMINGHAM GASWORKS.

Of late years the development of specially-designed boilers and other furnaces for the utilisation of low-grade and often finely-divided solid fuels has intensified the problem of the flue-gas dust and grit produced, as these, unless collected, become an intolerable nuisance when discharged into the atmosphere. Some two or three years ago a boiler plant utilising coke breeze as fuel was installed in the Windsor Street Works of the West Midlands Gas Board, at Birmingham, for the production of process steam and the generation of electricity for general works use. The plant consists of three water-tube boilers, two being normally at work while the third is receiving maintenance attention. Each boiler has an evaporative capacity of 17,000 lb. of steam per hour, at a pressure of 150 lb. per square inch, and a temperature of 450 deg. F., but the plant is frequently called upon to work at an overload of 40 per cent. The coke breeze for which the chain-grate stokers and the boiler furnaces were designed is fine material below $\frac{3}{8}$ in. in size, some 60 to 66 per cent. of it being below $\frac{1}{8}$ in., and 30 per cent. below $\frac{1}{32}$ in., while the ash content is about 13 per cent., but it was anticipated that the normal grit arresters would be adequate. This fuel, when first used in the plant, however, gave rise to such a great dust nuisance in the neighbourhood of the gasworks that a much higher grade of coke had to be substituted, and, as the fuel consumption of the plant is of the order of 65 tons a day or 440 tons a week, the increase in running cost was appreciable. The question of returning to the original fuel and of installing more efficient flue-dust extraction equipment was, therefore, considered. After investigating the possibilities of a number of methods, the West Midlands Gas Board decided to adopt the Drummond system of dust extraction, which they have used for some years at various points in their retort houses and coke-screening plants. The installation of this system solved the problem of the dust nuisance, and the original coke breeze, the price of which is about one-sixth of that of high-grade coke, is the fuel once again employed.

The flue-gas cleaning plant, which has been supplied and installed by Drummond Patents (Holdings) Limited, 5, Great Winchester-street, London Wall, London, E.C.2, consists of five hopper-shaped washer filters arranged to work in parallel. Any number can be run at a time, according to the boiler loading and hence the volume of flue gas produced. In practice, however, three of the washer filters are usually in service, while the remaining two are being cleaned out and refilled. A general view of the battery of washer filters is shown in Fig. 3, on this page, and their method of operation is indicated diagrammatically in Figs. 1 and 2 above. Fig. 1 shows the front elevation and section, and Fig. 2 the end elevation of the washer filters.

The washer chamber of each filter is fitted internally with two curved baffles (*a* and *b* in Fig. 1). These extend down to a pre-determined water level in the washer chamber and the vacuum created by the steel-cased paddle-blade fan (*e*, Fig. 1), fitted at the outlet of the flue-gas washing plant, causes the water level on the outlet side of the baffles to rise and that on the inlet side to fall. The conditions are such that the flue-gas sweeps round the under edge of the baffles at high velocity, creating a wave at that point. The crest of this wave continues to press upwards against the back of the curved baffle and this causes the water to break up into a dense spray. The sudden change of direction imposed upon the gas stream induces the dust particles contained within it to be impinged upon the hollow back of the wave, where the surface tension of the liquid is comparatively low. The grit particles are retained in this region and are then drawn down by circulating currents set up in the water, as shown in Fig. 1. On reaching the still-water region, the grit particles are precipitated and they accumulate in the base of the filter chamber. The spray is separated from the outgoing gas by arrester plates and moisture eliminators (*c*, Fig. 1) which consist essentially of bent plates arranged in echelon so as to deflect the gas while the inertia of the water drops causes them to strike the plates. The water from the moisture eliminators drains back into the water filter, at *d*, while the cleaned gas is drawn forward through the fan *e* to the atmosphere. The fan, therefore, operates in clean dry conditions, free from abrasive dust. As will be seen in Fig. 3, two fans are provided and these can be run separately or together, according to the prevailing load.

A constant working level is maintained within each filter by a sealed overflow pipe and trickle feed, *f* (Fig. 1). The level control is in an outside chamber, *g* (Figs. 1 and 2), which is easily accessible and connected with the main chamber in such a manner as to work under identical pressure conditions. The trickle feed is supplied by a pump from one of a pair of tanks alternately. These tanks are supplied with slightly-alkaline diluted water-softening-plant sludge, delivered at a fixed pressure which is maintained by an overflow relief valve. After emptying and cleaning out, each washer filter is refilled from the same source, and by this means the sulphurous acid, formed by the solution of the sulphur dioxide from the flue gas in the washing liquid, is neutralised and the corrosion of the mild-steel plates of which the washer filter is built up is minimised. Some 6 tons of wet dust, consisting of approximately half water and half dust, are collected in the battery of washers in a day of 24 hours. This deposit is removed in the following manner. Each of the five filters is fitted with valves in the inlet and outlet

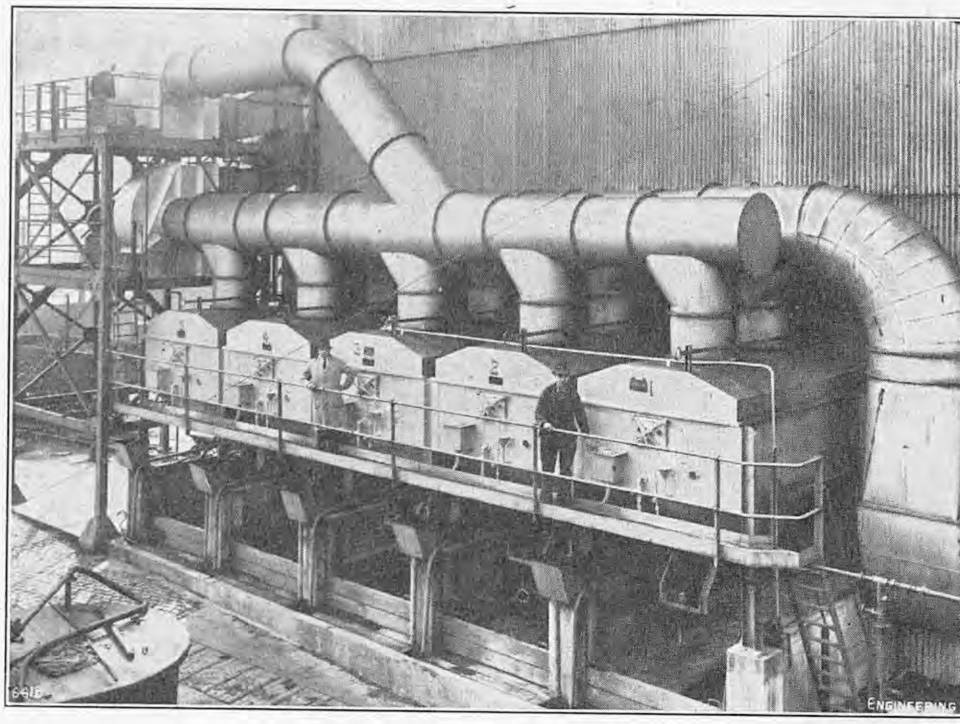


Fig. 3. Battery of Washer Filters.

DUAL-PURPOSE TRACTOR.

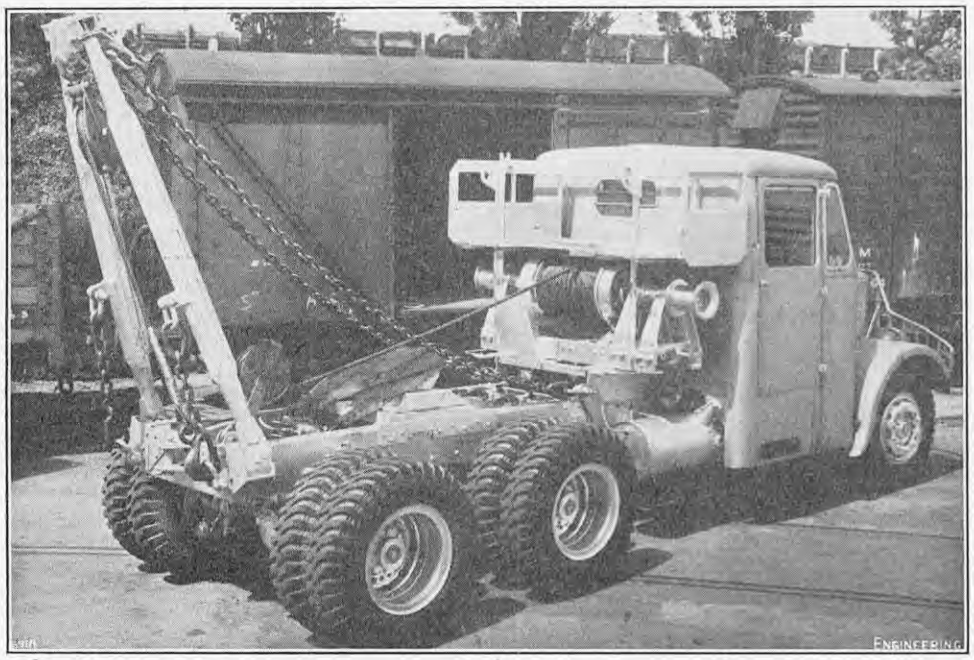


FIG. 1. VEHICLE PREPARED FOR RECOVERY WORK.

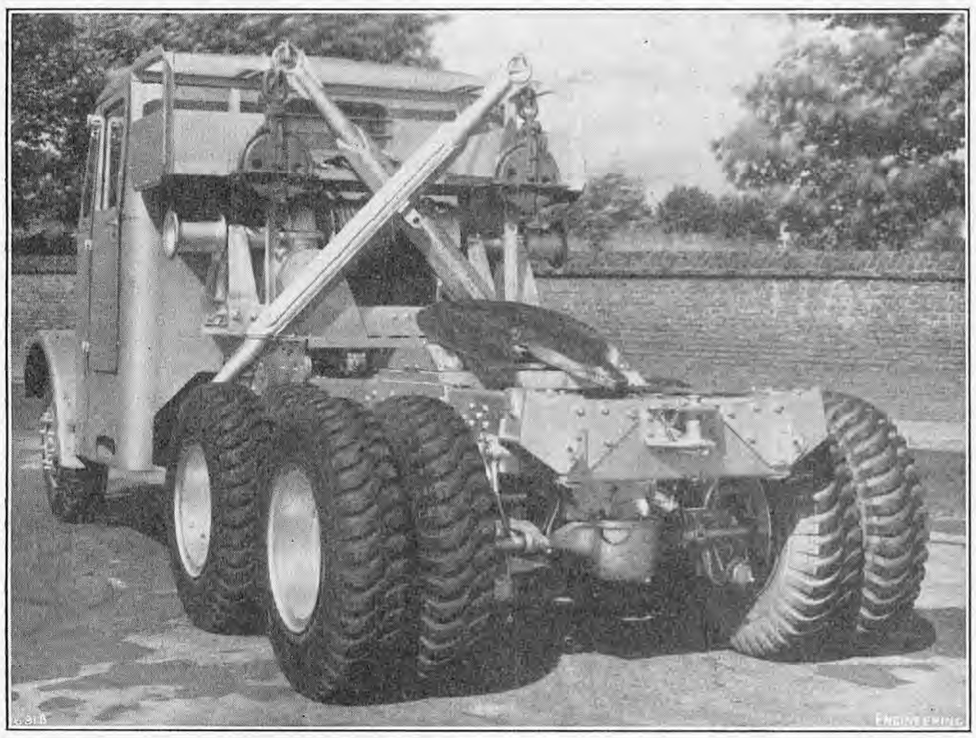


FIG. 2. VEHICLE ARRANGED FOR HAULING A SEMI-TRAILER.

mains, *h* (Figs. 1 and 2), linked together by a lever which, when thrown over, completely seals off the unit from the battery. A drain cock (*i*, Fig. 1), connected internally with a deposit-excluding device, is then opened for a period of from 10 to 20 minutes and the liquid in the filter chamber drained off. A quick-opening bottom-discharge door (*k*, Figs. 1 and 2), mounted on suspended runners, is dropped and drawn back by a lever movement at the side and the deposits fall out into a pen incorporated in the base of the filter. The deposits are then shovelled into lorries and taken away to the refuse tip. A great advantage of the Drummond system is that the dust is thoroughly wetted and that, accordingly, there is no secondary problem in disposing of it. It need hardly be emphasised that fine, dry dust can be as great a nuisance in quantity as it undoubtedly is in the uncollected state.

VEHICLE REAR LIGHTS.—To meet the need for better lighting on commercial vehicles, C.A.V. Ltd., Acton, London, W.3, have introduced a new combined tail and stop lamp which is suitable for use either singly or in pairs. The new lamp is considerably larger than usual, having a 3⅝-in. aperture, thus ensuring adequate visibility. It is strongly built to withstand road shocks and, to give additional safety, incorporates twin tail-light bulbs connected in parallel. The lamp is encased in a thick rubber moulding to render it weatherproof, the rubber being cut away to provide suitable illumination of the rear number plate.

AERONAUTICAL INFORMATION.—A joint meeting of the Aslib Aeronautical Information Group and the Royal Aeronautical Society is to be held at 6 p.m. on Thursday, February 7, at the Institution of Civil Engineers, Great George-street, London, S.W.1. Professor A. A. Hall will open a discussion on "The Availability and Use of Aeronautical Information"; he will be followed by Mr. C. W. Cleverdon, the Group secretary, who will describe the activities of the Aslib Aeronautical Information Group, which was formed in September, 1951, with the object of improving information services to the aeronautical sciences and industries. The Group have already issued to their members an interim list of aeronautical and technical periodicals available in this country.

DUAL-PURPOSE HEAVY TRACTOR.

THE tractor illustrated in Figs. 1 and 2, on this page, is of more than usual interest in that it has been designed to carry out the dual role of haulage of semi-trailers and recovery. It was manufactured by Messrs. A.E.C., Limited, Southall, Middlesex, and was shipped recently to their agents in Rio de Janiero, Messrs. Wilson, Sons and Company, Limited, for delivery to a Brazilian operator who already has in service some 30 A.E.C. vehicles. The design is based on the manufacturers' Mammoth Major, a six-wheeled bonneted chassis having a wheelbase of 14 ft. 6½ in. and fitted with an A.E.C. 11·3 litre oil engine developing 150 h.p. The transmission assembly comprises a single dry-plate clutch, and a five-speed and reverse gearbox arranged to drive the rear bogie through an open propeller shaft.

As will be seen from Fig. 1, the recovery equipment consists of a pair of gin poles situated at the rear of the chassis and a winch located behind the driver's cab. The gin poles, which were supplied by Messrs. M. O. Harper, Limited, Guildford, are circular in cross-section with tapered ends and are strengthened by angle irons welded to their parallel lengths. When erected, the lower ends fit into substantial brackets bolted to the rear of the chassis frame and the upper ends are joined by a common bracket called a crown piece, which also serves as an anchorage for the pulley block and tie chains. Two sets of tie chains are used, one of which extends forward from the crown block to shackles installed on the main frame just behind the winch, and the other rearwards from lugs welded to the gin poles to shackles fitted to the rear cross-member. The winch was supplied by the Darlington Engineering Company (Gateshead), Limited, and is capable of exerting a pull of 25,000 lb.; it is fitted with an automatic brake and is driven from the tractor power take-off through a reversing auxiliary gearbox, which, like the gin poles, was supplied by Messrs. M. O. Harper, Limited. As will be seen from Fig. 1, the winch rope is led round a free snatch block anchored to the rear part of the chassis to a further snatch block suspended from the crown piece. When the gin poles and ancillary gear are not required for use, they are dismantled and stored in special racks fitted behind the driver's cab, as shown in Fig. 2, which shows the tractor prepared for hauling semi-trailers.

Apart from its dual role, the most interesting feature of the tractor is the rear-bogie assembly, which has been designed to withstand exceptionally severe operating conditions. All four bogie wheels are driven and to ensure that traction is available when the wheels of one axle are slipping, no third, or inter-axle, differential is fitted. It is suitable for a maximum input torque of 3,300 lb.-ft. and gross loads up to 19 tons measured at the ground. A double-reduction drive is employed, primary reduction for each axle being obtained by means of spiral-bevel gearing and secondary reduction by a double-helical pinion integral with the crown-wheel shaft, which meshes with a spur wheel designed to accommodate the differential, an extension of the pinion shaft for the leading axle transmitting the drive to the trailing axle. Fully-floating axle shafts are fitted; these are machined from a nickel-chrome-molybdenum steel and each has 20 splines at the inner end with a 48-tooth involute spline formed on the flanged outer end. Single-piece alloy-steel forgings are used for the axle casings, the tube holes being bored from the solid. The hubs are mounted on taper-roller bearings and a 15½-in. diameter brake drum is bolted to each unit.

The suspension, which is designed to permit maximum articulation of the rear wheels, employs two heavy leaf-type springs. These pivot about a transverse tube held to the chassis frame through cast-steel brackets and the ends are joined to brackets on the axle casings by forks designed so that they are free to rotate about the longitudinal axis, thus permitting articulation of the bogie without imposing torsional strains on the springs. Any wheel can be raised 14 in. without the others leaving the ground. Torque reaction is taken by ball-jointed rods which extend between the top of the reduction-gear casing and a circular cross-member joining the top ends of the spring pivot-tube brackets. The brakes are applied by means of compressed air, two separate cylinders being employed for this purpose, which, as a protection against accidental damage, are mounted on the chassis side-members. Spherically-seated joints are fitted throughout the brake linkage, the design of which is such that articulation of the axles does not affect brake adjustment.

RESEARCH ON TIMBER.—The director of the Forest Products Research Laboratory, Dr. F. Y. Henderson, is to give a lecture on the work of the laboratory to the Royal Society, Burlington House, Piccadilly, London, W.1, on Thursday, February 7, at 4.30 p.m. He will give a short account of the technical work of the various specialist sections of the laboratory, with some reference to the more fundamental fields of research.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

TURBINE S.S. "KING EDWARD."—The Clyde pleasure steamer King Edward (502 tons gross) is to be withdrawn from service. Built at Dumbarton in 1901, she was the first commercial vessel to be propelled by steam turbines. Last year she completed a half-century of service with the original engines and boilers still in operation. On trials the vessel attained a speed of 20·49 knots, and her success led to the rapid development of turbine machinery, and ultimately, to its installation in the largest liners. The decision to withdraw the King Edward from service on the Clyde was announced on January 21 by Mr. Thomas Johnston, chairman of the Scottish Tourist Board, who presided at a meeting, in Glasgow, of the Consultative Sub-Committee on Clyde Steamer Services.

AYR-KILMARNOCK ROAD AT PRESTWICK.—As a temporary measure to overcome the present difficulties speedily, the stretch of the Ayr-Kilmarnock road which cuts the 1,000 ft. overshoot of the main Prestwick Airport runway is to be taken out of commission and a loop road made level with the overshoot. This proposal by the Minister of Civil Aviation, Mr. John S. Maclay, has been unanimously accepted by the Scottish Advisory Council for Commercial Aviation in Edinburgh. It will allow Prestwick to be used by every present type of air-liner. The measure does not prejudice the ultimate decision regarding the alternatives to overcome the overshoot difficulty, namely, a permanent road detour and a tunnel.

DIFFICULTIES OF RE-ROLLERS.—An acute shortage of billets, slabs, and sheet bars is causing anxiety to re-rolling firms. Steelmakers have been making an equitable distribution of available supplies, but the level of ingot production, reduced by the scarcity of scrap, limits the quantities to individual re-rollers. In addition to the overall shortage of scrap, the position has been aggravated, this week, by frost and snow, which has increased merchants' difficulties in regard to collection, segregation and dispatch.

ELECTRICITY SUPPLY IMPROVING.—As a result of an improvement in the electricity supply position, Scottish industrial firms will be required, as from February 4, to make only a 10 per cent. reduction in consumption instead of the 20 per cent. now in force. This was announced by Mr. C. Murdoch, chairman of the Scottish Board for Industry, at a Press conference in Glasgow on January 23. Simultaneously, the staggering of working hours will end.

SALE OF CLYDE TUG.—The Clyde tug Flying Foam, belonging to the Clyde Shipping Company, has been bought by a firm of Spanish owners in Ceuta, Morocco. Built by Ferguson Brothers, Port Glasgow, the vessel went into commission in 1918. A sister ship, the Flying Serpent, was sold to the same firm in April, 1947.

CLOSING OF KILMARNOCK LOCOMOTIVE REPAIR SHOPS.—British Railways are to close the 100-year-old locomotive repair workshops in Kilmarnock "in the interests of the economic position of the railways," it was stated in a notice issued to the employees on January 22. The surplus labour will be transferred elsewhere.

CLEVELAND AND THE NORTHERN COUNTIES.

THE IRON AND STEEL SITUATION.—There is no abatement of the severe pressure for a much increased delivery of iron and steel during the next month or two, but the outlook encourages the hope of appreciable improvement in the statistical situation over periods further ahead. Some expansion of work is expected and imports promise to be on a considerably increased scale. Supplies from Continental iron and steel centres and from Japan promise to be considerable and substantial arrivals, especially of steel from America, are assured. A more hopeful view is taken of the pig-iron position. There is still a grave scarcity of iron and steel scrap but personal visits by high executives of the steel industry to home sources of supply promise to result in an expansion of the tonnage distributable to foundries and steelworks.

STORMS DELAY ORE SHIPS TO CUMBERLAND.—The recent storms have delayed the arrival of ships conveying iron ore from the North African mines to the Workington Iron and Steel Co., with the result that stocks have fallen to a low level. To conserve supplies the air blast in several of the firm's blast furnaces has been reduced and home-coming ore ships have been diverted to Jarrow, Glasgow and Ardrossan. The ore is being brought by rail to Workington.

RURAL ELECTRIFICATION IN THE NORTH EAST.—In the course of a report, made in Newcastle-upon-Tyne on January 21 to the North-Eastern Electricity Consultative Council, it was announced that, during 1951, 106 farms and 10 industrial and commercial installations in the area had been connected with the electricity mains, and that, during September, October and November, 110 new substations had been put into service.

LANCASHIRE AND SOUTH YORKSHIRE.

THE SHEFFIELD STEEL OUTPUT.—Sheffield's production of steel last year fell short by 83,200 tons of the 1950 total. For some months, four, and sometimes five, furnaces have been out of production owing to lack of melting materials. The average weekly production of steel ingots and castings during 1951 was 41,100 tons, compared with 42,700 tons in 1950.

RISE IN PRICE OF GAS.—Sheffield and district gas users are to pay more for the gas they consume because costs have risen by nearly 1,000,000*l*. a year. Dearer coal and increased railway-freight charges account for an extra yearly cost of 466,000*l*. and 118,000*l*., respectively, wages are to cost 217,000*l*. more, and petrol, oil and coke-oven gas an additional 173,000*l*. The total of 974,000*l*., however, is offset by the receipt of 200,000*l*. more a year from coke sales and 142,000*l*. already provided in the estimates in anticipation of coal price increases. The amount of the increase in the price of gas is to be announced later.

IMPROVISATION IN MANUFACTURE OF WHEELS.—When Mr. G. Baker, managing director of John Baker and Bessemer, Ltd., was installed as President of the Sheffield Society of Engineers and Metallurgists on January 21, he described a number of difficulties met in making steel wheels in the past 50 years and how they had been overcome by improvisation. One improvisation, during the war, he said, had given great economies in the production of track wheels for Churchill tanks.

PROBABLE END OF LOAD-SPREADING.—The probability that load-spreading may end sooner than March 31 is welcomed by industrialists in Sheffield and district. Mr. W. H. Higginbotham, President of the Sheffield Chamber of Commerce, has stated that the decision would be a great relief to those who had had to arrange, or work on, staggered-hours schemes. It would be better for production and would mean that costs would be reduced.

THE RECOVERY OF OLD TRAMWAY RAILS FOR SCRAP.—Sheffield steelmakers are in urgent need of scrap for re-melting, yet there is a quantity of potential melting material in the rails not being used on one section of a City tramways route, now being served by motor omnibuses. If the rails were taken up, however, it would mean heavy expenditure in the re-laying of the roads, a charge much greater than the value of the scrap. The course to be taken is being debated.

WINDING ENGINE FOR YORK RAILWAY MUSEUM.—The winding engine built in 1833 by Robert Stephenson for the 1 in 17 Swannington incline on the Leicester and Swannington Railway has been sent by British Railways (London Midland Region) to the Railway Museum at York for preservation. The engine has a single cylinder 18¼ in. in diameter and 3 ft. 6 in. stroke, filled with a piston valve and gab eccentric. The working pressure was 80 lb. per square inch.

THE MIDLANDS.

BRITISH INDUSTRIES FAIR ADMISSION CHARGES.—Some of the charges for admission to the British Industries Fair, which will open on May 5, are to be increased. The cost of season tickets for home buyers will be raised from 2*s*. 6*d*. to 5*s*. for all three sections of the Fair, but tickets of admission for one day only to the Birmingham section will remain at the old figure of 2*s*. 6*d*. The price of catalogues is also to be raised from 2*s*. 6*d*. to 3*s*. Overseas buyers, as in the past, will be admitted, and provided with catalogues, without charge.

BUSINESS EFFICIENCY EXHIBITION.—The 38th Business Efficiency Exhibition is to be held at Bingley Hall, Birmingham, from February 19 to 29. A number of machines made in the Midlands will be exhibited, including what is claimed to be the lightest portable typewriter in the world, and an electric typewriter capable of producing up to 15 carbon copies at a time. An area of 33,000 sq. ft. will be devoted to the exhibits.

BIRMINGHAM CITY ARCHITECT.—Birmingham City Council have appointed Mr. A. G. Sheppard Fidler, M.A., F.R.I.B.A., to the newly created post of city architect. Mr. Sheppard Fidler was previously chief architect to the Crawley (Sussex) Development Corporation. In his new post he will be concerned primarily with implementing the Birmingham development plan.

ITALIAN MINERS IN THE WEST MIDLANDS.—The employment of Italian miners in the pits of the National Coal Board's West Midlands Division, which met with considerable opposition at first, is now proceeding smoothly. The decision to accept Italians is a matter for the individual lodges of the trade unions at each pit. So far, 21 out of 58 pits in the Division have agreed to take the Italian miners, of whom 316 are now at work. A further 104 are being trained in North Staffordshire.

OUTPUT AT BILSTON STEELWORKS.—The Bilston steelworks of Stewarts and Lloyds, Ltd., again had a record output last year. The blast furnaces produced 216,975 tons of iron, and 248,747 tons of steel came from the open-hearth melting shops.

SOUTH-WEST ENGLAND AND SOUTH WALES.

BUTANE IN RURAL WORKS.—The supply of butane gas to Whitland, which began during the past week, has been declared an unqualified success by Mr. T. Mervyn Jones, chairman of the Welsh Gas Board at a Press conference at Cardiff. The scheme is the first in the country, and the cost of installing the plant was less than it would have been to install a coal-gas plant, Mr. Jones stated. If the use of the new gas were extended, the undertakings affected would be the smaller ones of less than 3,000 consumers, which would include nearly all the undertakings in West Wales, Mid-Wales, and parts of North Wales. The highly industrialised areas would be least affected.

FIRE-FIGHTING TUGS.—A fire-fighting tug has been acquired by National Oil Refineries, Ltd., as an added precaution against fire during the loading and discharging of oil tankers at the Queen's Dock, Swansea. This vessel, the Nirumand, is a steam-driven ocean-going tug of 1,000 h.p. and 307 tons gross register, equipped with Diesel pumps capable of pumping 4,000 gallons of water or foam a minute. The Nirumand's sister ship, the Zurmand, formerly at Abadan, will be stationed for a similar purpose off the Isle of Grain, where the Anglo-Iranian Oil Company's new Kent refinery is being built.

CARDIFF WATER RESERVOIR.—Cardiff Corporation Waterworks Committee have approved a recommendation to construct a new reservoir at a cost of 185,000*l*. at Ty-Glas-road, Cardiff. It will replace a 68-years' old reservoir and filter plant.

WATER FOR THE TROSTRE WORKS.—The Steel Company of Wales have asked the Llanelly Borough Council to lay a duplicate water pipeline from the Council's reservoir in Swiss Valley to the Company's Trostre works. It is understood that the company will require 20,000,000 gallons of water a week for the works.

COASTAL OIL POLLUTION.—Suggestions at a Cardiff conference that oil tankers, especially those serving Llandarcy Refinery, have played a large part in oil pollution of the South Wales coastline have evoked a strong protest from National Oil Refineries, Ltd., who operate the Anglo-Iranian Oil Company's plant at Llandarcy. The conference was attended by representatives of local authorities, the Nature Conservancy, the Wales Tourist Board, the Council for the Preservation of Rural Wales, the South Wales Sea Fisheries District Committee, and the Ministry of Transport. In a Press statement, National Oil Refineries, Ltd., have pointed out that the companies had not been informed beforehand officially that such a conference was to take place, nor had there been any opportunity for their representation. "It is felt," the statement continues, "that the linking of the companies' names adversely with the matter of oil pollution is unfair and disregards such matters of fact as that Swansea is not the only oil port in the Bristol Channel, that not all tankers using the Bristol Channel are connected with Llandarcy operations, and that the tankers themselves are not the only ships that carry oil. It does not follow either that all the oil found on the South Wales coast has come from vessels using the Bristol Channel. It may have been discharged from vessels on other shipping routes and carried into this area." A spokesman for the company also stated that separators are provided at Queen's Dock, Swansea, the terminal for tankers calling at Llandarcy, and that tankers are instructed not to discharge oil into the sea.

PROFESSOR H. C. H. GURNEY.—The recently appointed Head of the Department of Engineering at the University College of South Wales and Monmouthshire, Professor H. C. H. Gurney, M.A., D.Sc., delivered his inaugural lecture at the South Wales Institute of Engineers, Cardiff, on January 25. Professor Gurney described representative examples of research, invention, design and management in the field of engineering, illustrating his remarks with demonstrations and slides.

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 MECHANICAL ENGINEERS.—*North-Eastern Branch:* Monday, February 4, 6 p.m., Neville Hall, Newcastle-upon-Tyne. Thomas Lowe Gray Lecture on "Ship Research," by Dr. S. Livingston Smith. Also at the *Scottish Branch:* Wednesday, February 6, 7.30 p.m., University College, Dundee; and Thursday, February 7, 7.30 p.m., 39, Elmbank-crescent, Glasgow. *London Graduates' Section:* Tuesday, February 5, 6.30 p.m., Storey's-gate, St. James's Park, S.W.1. "Performance Testing of Agricultural Tractors and Interpretation of Results," by Mr. P. H. Southwell. *East Midlands Branch:* Thursday, February 7, 6.15 p.m., Rolls-Royce Welfare Hall, Derby. Thomas Hawksley Lecture on "Some Fuel and Power Projects," by Dr. H. Roxbee Cox. *Western Branch:* Friday, February 8, 7 p.m., Technical College, Brunswick-road, Gloucester. "Industrial Design and Its Relation to Machine Design," by Mr. H. G. Conway. AUTOMOBILE DIVISION.—*Coventry Centre:* Tuesday, February 5, 7.15 p.m., Craven Arms Hotel, High-street, Coventry. Informal Discussion Meeting.

INSTITUTION OF ELECTRICAL ENGINEERS.—*Mersey and North Wales Centre:* Monday, February 4, 6.30 p.m., Town Hall, Chester. "Economics of Low-Voltage Electricity Supplies to New Housing Estates," by Mr. F. G. Copland. *London Students' Section:* Monday, February 4, 7 p.m., Savoy-place, Victoria-embankment, W.C.2. "Electromagnetism and Engineering Research," by Dr. K. J. R. Wilkinson. *North-Western Centre:* Tuesday, February 5, 6.15 p.m., Engineers' Club, Manchester. "Economic Plant Sizes and Boiler Set Groupings on the British Grid," by Mr. B. Donkin and Mr. P. H. Margen. *North Midland Centre:* Tuesday, February 5, 6.30 p.m., 1, Whitehall-road, Leeds. "Protection of Electrical Power Systems," by Mr. H. Leyburn and Mr. C. H. W. Lackey. *Southern Centre:* Wednesday, February 6, 6.30 p.m., Royal Beach Hotel, Portsmouth. Joint meeting with the *Southern Branch* of the INSTITUTION OF MECHANICAL ENGINEERS. "A New Power Stroboscope for High-Speed Flash Photography," by Mr. W. D. Chesterman and others. *Institution:* Thursday, February 7, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. "Economics of Low-Voltage Electricity Supplies to New Housing Estates," by Mr. F. G. Copland.

INSTITUTE OF ROAD TRANSPORT ENGINEERS.—*Scottish Centre:* Monday, February 4, 7.30 p.m., 39, Elmbank-crescent, Glasgow. "Rear Axles," by Mr. R. H. Wilson. *Eastern Group:* Tuesday, February 5, 7 p.m., Marshalls Airport, Cambridge. "Factors Influencing the Choice of a Crankcase Lubricating Oil," by Mr. A. Towle. *South Wales Group:* Friday, February 8, 7 p.m., South Wales Institute of Engineers, Park-place, Cardiff. Informal Discussion Meeting.

JUNIOR INSTITUTION OF ENGINEERS.—*North-Western Section:* Monday, February 4, 7.30 p.m., 16, St. Mary's Parsonage, Manchester. "Impressions of America," by Mr. Frank Burgess. *Midland Section:* Wednesday, February 6, 7 p.m., James Watt Memorial Institute, Birmingham. "Amateur Telescope Making," by Dr. R. D. Gifford. *Institution:* Friday, February 8, 6.30 p.m., 39, Victoria-street, S.W.1. "Modern Submarine Cables," with film, by Mr. E. A. Applebee.

INSTITUTION OF ENGINEERING INSPECTION.—*Coventry Branch:* Monday, February 4, 7.30 p.m., Technical College, Coventry. "Industrial Lighting," by Mr. E. F. G. Beeson. *South-Western Branch:* Tuesday, February 5, 7.30 p.m., Bristol Tramways Hall, Brislington. "Surface Finishing," by Mr. J. Reason. *Birmingham Branch:* Wednesday, February 6, 7.30 p.m., 95, New-street, Birmingham. "Control of Quality on Medium and Large Quantity Engineering Production," by Mr. J. Loxham.

ROYAL INSTITUTION.—Tuesday, February 5, 5.15 p.m., 21, Albemarle-street, W.1. "Physical Methods in Meteorology."—II. "The Study of Clouds and Rain," by Mr. P. A. Sheppard.

INSTITUTION OF CIVIL ENGINEERS.—*Structural and Building Engineering Division:* Tuesday, February 5, 5.30 p.m., Great George-street, S.W.1. "Recent Experience in Composite Pre-Cast and *In-Situ* Concrete Construction, with Special Reference to Prestressing," by Mr. F. J. Samuely.

ASLIB.—Tuesday, February 5, 5.30 p.m., Chaucer House, Malet-place, W.C.1. "Patents as a Source of Information," by Mr. H. R. Mathys.

INSTITUTION OF SANITARY ENGINEERS.—Tuesday, February 5, 6 p.m., Caxton Hall, Victoria-street, S.W.1. "Sanitation in the British West Indies," by Mr. C. L. Langshaw.

INSTITUTION OF STRUCTURAL ENGINEERS.—*Northern Counties Branch:* Tuesday, February 5, 6.30 p.m., Cleveland Scientific and Technical Institution, Middlesbrough; and Wednesday, February 6, 6.30 p.m., Neville Hall, Newcastle-upon-Tyne. "The Moving of King Henry VIII's Wine Cellar, Whitehall Gardens," by Mr. L. Scott White.

INSTITUTE OF METALS.—*Sheffield Section:* Tuesday, February 5, 7 p.m., Grand Hotel, Sheffield. Joint Meeting with SHEFFIELD METALLURGICAL ASSOCIATION. "Casting of Billets," by Dr. E. Scheuer. *London Section:* Thursday, February 7, 7 p.m., 4, Grosvenor-gardens, S.W.1. "Chromium and Chromium-Rich Alloys," by Dr. A. H. Sully.

INCORPORATED PLANT ENGINEERS.—*London Branch:* Tuesday, February 5, 7 p.m., Royal Society of Arts, John Adam-street, Adelphi, W.C.2. "Use of Low-Grade Fuels in Shell Boilers," by Dr. E. G. Ritchie. *Edinburgh Branch:* Tuesday, February 5, 7 p.m., 25, Charlotte-square, Edinburgh. "Boilers for Industrial Plant," by Mr. H. E. Partridge. *Southampton Branch:* Wednesday, February 6, 7.30 p.m., Polygon Hotel, Southampton. "Design and Construction of Foundations," by Mr. A. Glover. *Peterborough Branch:* Thursday, February 7, 7.30 p.m., Eastern Gas Board's Offices, Church-street, Peterborough. "Working of a Locomotive Running Shed," by Mr. J. Blundell.

INSTITUTION OF CHEMICAL ENGINEERS.—*Graduates' and Students' Section:* Tuesday, February 5, 7 p.m., University College, Cathays Park, Cardiff. "Chemical Engineering Problems in the Paper-Manufacturing Industry," by Mr. B. Bienkiewitcz and Mr. J. Mardon.

INSTITUTION OF PRODUCTION ENGINEERS.—*Halifax Section:* Tuesday, February 5, 7.15 p.m., White Swan Hotel, Halifax. "Machine Tool Industry," by Mr. W. J. Morgan. *Reading Section:* Tuesday, February 5, 7.15 p.m., Canteen, Messrs. Transport Equipment (Thornycroft), Ltd., Basingstoke. "Production of a High-Performance Sports Car," by Mr. J. Silver. *Nottingham Section:* Wednesday, February 6, 7 p.m., Victoria Station Hotel, Nottingham. Discussion on "Economic Use of Materials in Production Engineering." *Wolverhampton Section:* Wednesday, February 6, 7 p.m., Anchor Hotel, Wednesbury. "Abrasives," by Mr. J. G. Cowan. *London Section:* Thursday, February 7, 7 p.m., Royal Empire Society, Northumberland-avenue, W.C.2. "Modern Mechanisation of Jobbing and Repetition Foundries," by Mr. A. F. Beech.

INSTITUTION OF WORKS MANAGERS.—*Sheffield Branch:* Tuesday, February 5, 7 p.m., Grand Hotel, Sheffield. Discussion on "Services Provided by the Cost Accountant to Production Management." *Leicester Branch:* Tuesday, February 5, 7 p.m., College of Technology, The Newarke, Leicester. Discussion on "Foremen and Managements." *Tees-Side Branch:* Thursday, February 7, 7.30 p.m., Vane Arms Hotel, Stockton. "Current Aspects of American Management," by Mr. J. C. W. Stead.

INSTITUTION OF LOCOMOTIVE ENGINEERS.—Wednesday, February 6, 5.30 p.m., Institution of Mechanical Engineers, Storey's-gate, St. James's Park, S.W.1. Informal Discussion on "Passenger Comfort on Modern Coaching Stock."

INSTITUTION OF HEATING AND VENTILATING ENGINEERS.—*East Midlands Branch:* Wednesday, February 6, 6.30 p.m., School of Technology, Leicester. "District Heating Scheme at Pimlico, Westminster," by Dipl. Ing. A. E. Margolis.

INSTITUTE OF MARINE ENGINEERS.—Wednesday, February 6, 7 p.m., Woolwich Polytechnic, S.E.18. "Boiler Water Treatment," by Mr. C. J. Hasler.

ILLUMINATING ENGINEERING SOCIETY.—*Nottingham Centre:* Thursday, February 7, 5.30 p.m., Offices of the East Midlands Electricity Board, Nottingham. "Illumination of a Medium Size Factory," by Mr. W. K. Martin. *Birmingham Centre:* Friday, February 8, 6 p.m., Imperial Hotel, Temple-street, Birmingham. "Industrial Lighting," by Mr. E. H. Norgrove.

ROYAL AERONAUTICAL SOCIETY.—Thursday, February 7, 6 p.m., Institution of Civil Engineers, Great George-street, S.W.1. Discussion on "The Availability and Use of Aeronautical Information."

INSTITUTE OF PACKAGING.—*Southern Area:* Thursday, February 7, 6 p.m., Waldorf Hotel, Aldwych, W.C.2. "Palletisation," by Mr. R. H. Boyce Cam.

BRITISH INSTITUTION OF RADIO ENGINEERS.—*Scottish Section:* Thursday, February 7, 7 p.m., Royal Technical College, Glasgow. "Some Special Oscillograph Techniques," by Professor F. M. Bruce.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Friday, February 8, 6.15 p.m., Mining Institute, Neville Hall, Newcastle-upon-Tyne. "Fuel-Injection Systems for Large Marine Oil Engines," by Mr. P. Jackson. *Student Section:* Saturday, February 9, 2.30 p.m., Bolbec Hall, Newcastle-upon-Tyne. Address by Mr. P. L. Jones.

MANCHESTER ASSOCIATION OF ENGINEERS.—Friday, February 8, 6.45 p.m., College of Technology, Manchester. Annual Lecture, by Professor F. C. Williams.

INSTITUTE OF ECONOMIC ENGINEERING.—*London Branch:* Friday, February 8, 7 p.m., George Hotel, Kingsbury, N.W.9. Open Discussion Meeting.

PERSONAL.

VISCOUNT RUNCIMAN, O.B.E., A.F.C., President of the Institution of Naval Architects, has been nominated as President of the Chamber of Shipping of the United Kingdom, 3-6, Bury-court, St. Mary Axe, London, E.C.3, for the current year. MR. D. F. ANDERSON, M.A. (Oxon), has been nominated vice-president.

SIR ANDREW MCCANCE, D.Sc., M.I.Mech.E., F.R.S., has accepted the position of chairman of the Mechanical Engineering Research Board of the Department of Scientific and Industrial Research in succession to the retiring chairman, SIR HENRY GUY, C.B.E., D.Sc., M.I.C.E., M.I.Mech.E., F.R.S.

MR. H. F. H. JONES, M.B.E., J.P., M.Inst.Gas E., A.M.I.C.E., has been appointed deputy chairman of the Gas Council, 1, Grosvenor-place, London, S.W.1, in succession to COLONEL H. C. SMITH, C.B.E., D.L., M.I.C.E., who, as stated on page 783 of our issue of December 21, 1951, is now chairman of the Council.

MR. K. S. DAVIES, B.Sc., A.M.I.E.E., has been elected chairman, and MR. C. G. WHITE, vice-chairman, of the Radio Communication and Electronic Engineering Association, for the ensuing year.

MR. R. F. W. GUY, B.Sc., M.I.Mech.E., M.Inst.F., late chief engineer, James Hodgkinson (Salford) Ltd., has joined the consulting staff of Powell Duffryn Technical Services Ltd., 19, Berkeley-street, London, W.1, as a senior engineer. He will be attached to the firm's Manchester office, Lord's Chambers, 26, Corporation-street, Manchester, 4.

MR. J. V. DANIEL has been elected to the board of Crompton Parkinson Ltd., Crompton House, Aldwych, London, W.C.2, as from January 25.

MR. G. R. BALL has been elected a director of the International Nickel Co. of Canada Ltd.

MR. A. E. WATKINS, M.Inst.F., and MR. S. W. SPURR, M.Inst.F., have been elected directors of Spencer-Bonecourt Ltd., 14, Fetter-lane, London, E.C.4. Mr. Watkins, previously general manager, has been appointed also managing director. CAPTAIN (E) W. GREGSON, R.N.R., M.Sc.(Eng.), M.I.C.E., M.I.Mech.E., M.Inst.N.A., continues as chairman and technical director.

MR. E. LE Q. HERBERT, B.Sc. (Edin.), F.R.I.C., has been appointed general manager of the "Shell" Refining and Marketing Co. Ltd., following the retirement of MR. J. A. ORIEL, C.B.E., M.C., B.Sc., M.A., F.R.I.C., M.I.Chem.E.

The services of MR. P. G. MOTT, B.A., A.M.I.C.E., F.R.I.C.S., survey manager to Hunting Aero Surveys Ltd., 29, Old Bond-street, London, W.1, have been lent to the Ceylon Government under the Colombo Plan Technical Assistance Programme. He is to act as a consultant on aerial surveying for the next few months.

The United Steel Companies, Ltd., 17, Westbourne-road, Sheffield, 10, announce that MR. E. E. INGLETON has been appointed works manager of the Yorkshire Engine Co., Ltd., Sheffield.

MR. R. WALKER, secretary, and MR. B. P. HUTTON, sales manager, have been appointed directors of Marryat and Scott Ltd., Wellington Works, Wellington-road South, Hounslow, Middlesex.

MR. J. D. SINCLAIR, tyre technical representative, Dunlop Rubber Co. (Scotland) Ltd., in Glasgow, has been made deputy district manager there, in succession to MR. J. W. R. WHITE, who, as stated on page 111, *ante*, is the firm's new district manager in Edinburgh.

MR. MATTHEW WALLACE, solicitor to the British Transport Commission in Scotland, is retiring on March 28. His successor is to be MR. A. CAMERON MILLER, M.A., LL.B., at present Sheriff-substitute at Fort William.

As from to-day, February 1, the address of BROWN, O'SULLIVAN AND PARTNERS, consulting engineers, is 123, Victoria-street, London, S.W.1. (Telephone: TATe Gallery 0266.)

THE GLASGOW ENGINEERING CENTRE have arranged accommodation for agents or representatives at their headquarters, 351, Sauchiehall-street, Glasgow. Telephone facilities, postal arrangements, and secretarial services are provided.

A new company, TIMBER PRESERVATION (ABERDEEN) LTD., Aberdeen, has set up modern pressure creosoting plant for the treatment of both imported and home-grown timber. It is planned to commence operations in a few months' time.

As from to-day, February 1, the address of the AIRCRAFT SECTION of ALAN MUNTZ & CO., LTD., is Langley Aerodrome, Buckinghamshire. (Telephone: Slough 23861.)

C. M. HILL & CO. (ENGINEERS) LTD., 44-5, Tower Hill, London, E.C.3, have been appointed agents in this country for the Belgian firm, Société Anonyme Trains de Roues du Centre, manufacturers of light railway wagons.

On and after February 4, the telephone number of INTERNATIONAL REFRIGERATOR CO. LTD., and THE HOTPOINT ELECTRIC APPLIANCE CO., LTD., Fletton, Peterborough (both members of the A.E.I. Group of Companies) will be changed to Peterborough 5351.

TIDAL MODELS OF RIVER THAMES: PORT OF LONDON AUTHORITY.

(For Description, see Page 139.)

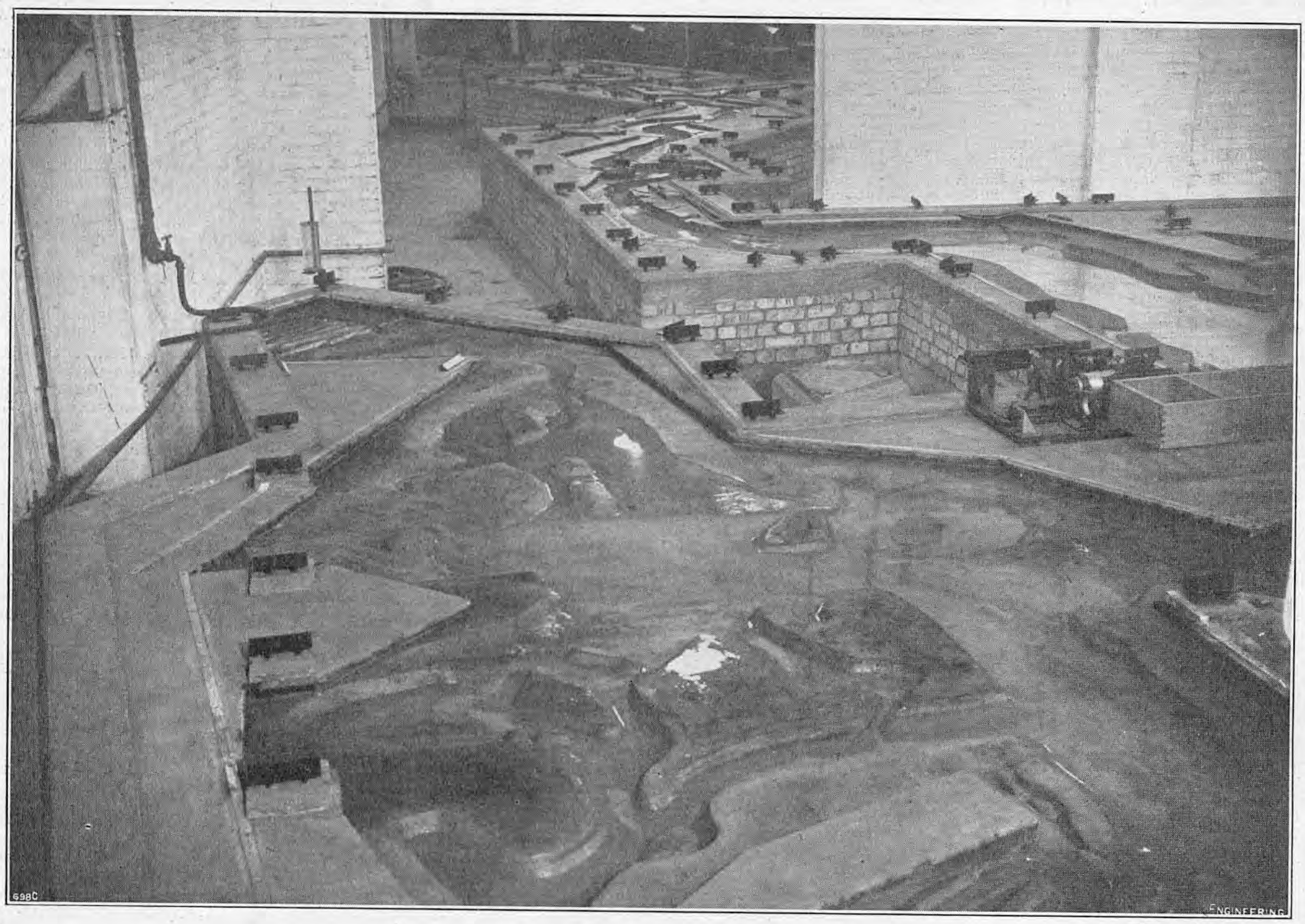


FIG. 3. MEDWAY AREA ON PILOT MODEL.

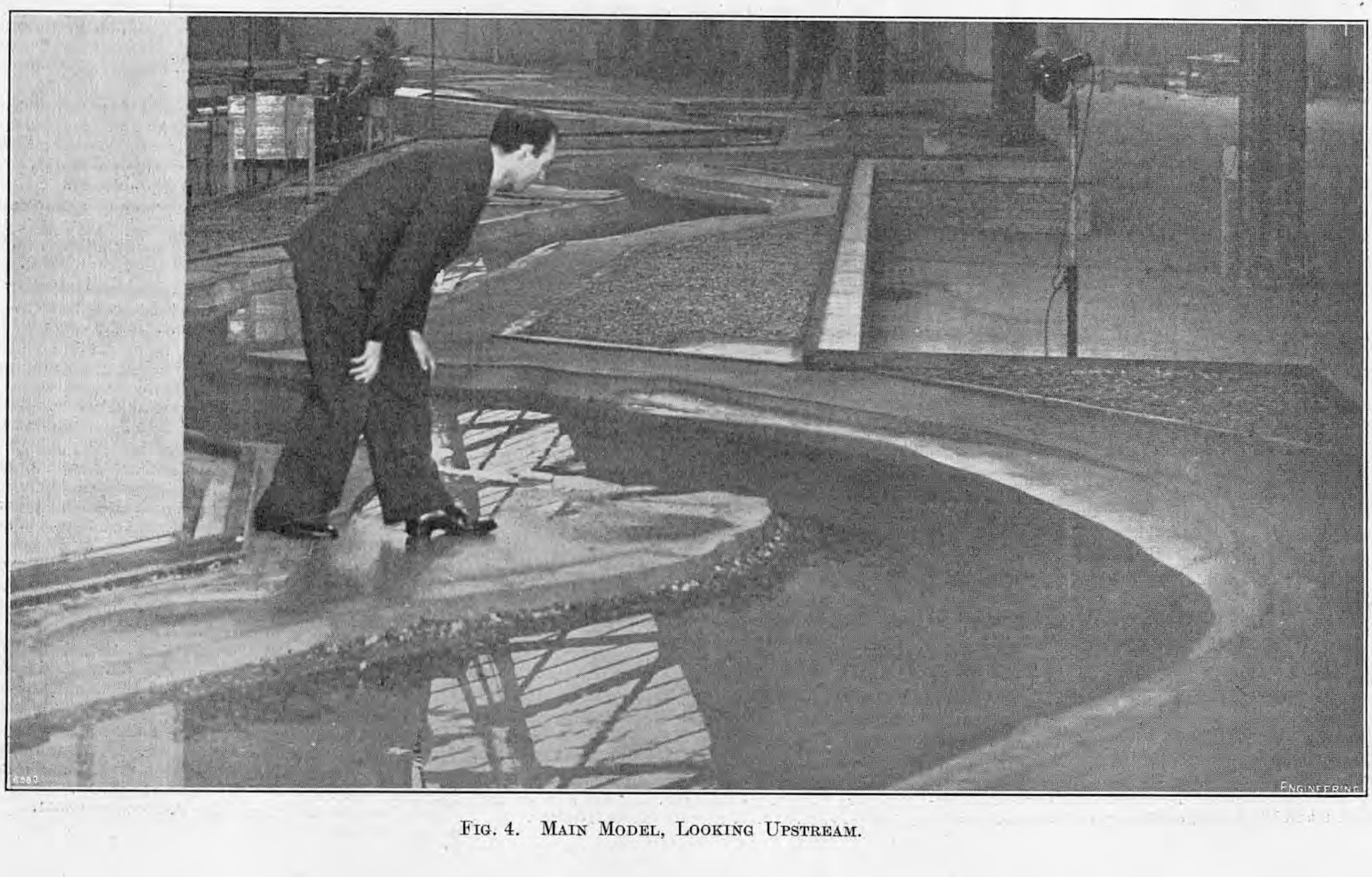


FIG. 4. MAIN MODEL, LOOKING UPSTREAM.

ENGINEERING

35, & 36, BEDFORD STREET, STRAND, LONDON, W.C.2.

Registered at the General Post Office as a Newspaper.

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.

Telegraphic Address :

ENGINEERING, LESQUARE, LONDON.

Telephone Numbers :

TEMPLE BAR 3663 and 3664.

All editorial correspondence should be addressed to the Editor and all other correspondence to the Manager.

Accounts are payable to ENGINEERING Ltd. Cheques should be crossed "The National Provincial Bank, Limited, Charing Cross Branch." Post Office Orders should be made payable at Bedford Street, Strand, W.C.2.

SUBSCRIPTIONS.

ENGINEERING may be ordered from any newsagent in town or country and from railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months, payable in advance :—

For the United Kingdom and all places abroad, with the exception of Canada	£5 10 0
For Canada	£5 5 0

Subscriptions for periods less than twelve months are based on the price of a single copy, namely, 2s. 3d. post free.

CONTENTS.

ENGINEERING

FRIDAY, FEBRUARY 1, 1952.

VOL. 173. No. 4488.

A TRACT FOR THE TIMES.

PRIOR to 1893, no specialised American periodicals existed, comparable with the *Astrophysical Journal* and the *Physical Review.* Going back a little earlier, Dr. Robert A. Millikan records that, in 1888, "the only two physics texts used at all extensively in American colleges were both translations from the French, namely, Ganot's *Physics* and Dechanelles' *Physics.*" These two statements indicate the status of the science of physics in America at the dates to which they refer. In contrasted with them it may be recorded that it was in 1867 that "James Clerk Maxwell, perhaps the greatest analytical mind of the Nineteenth Century, communicated to the Royal Society of London his epoch-making paper on the theory of electromagnetism, a theory which first appeared in fully developed form in 1873 in his great treatise on electricity and magnetism—a treatise which perhaps more than any other one influence has created our modern age of electricity."

This quotation is taken from the account* of his life's work which has been written by Dr. Millikan, who is described by Sir George Thomson, in a foreword to the book, as "the acknowledged doyen of American physicists." This autobiography is in part an answer to the question why and how American physics have developed in a lifetime from "being a poor relation" to "a position in which, by its sheer size it makes the efforts of the rest of the world seem almost puny." Robert Millikan has played a major part in that development and his book, being an autobiography, naturally is mainly concerned with his own work; but he pays many tributes to the work of others, and from his pages something may be learned of the activities of practically every leading physicist of the world during his professional life.

It is not only because Dr. Millikan's book gives some account of the rise of American physics that this review has been given the title which it carries. His record and his opinions point lessons which have close bearings on our present discontents. Many times, in these columns and elsewhere, it has been pointed out that the economic and material salvation of this country—possibly its spiritual salvation, too—can only come if the majority of its inhabitants cease, as the chairman of Martin's Bank put it, to "expect to receive 1*l.* for 10*s.* worth of work." In other words, if they are prepared to give of their best in the station to which they are called. Dr. Millikan does not preach this doctrine; his whole life illustrates it. It is necessary to read his book to realise the single-minded devotion with which he pursued his chosen career, but a few incidents may be recorded as typical examples of this devotion.

In August, 1896, after he had been studying at the University of Berlin and Göttingen, he accepted a post as "assistant in physics" at the University of Chicago, although at the time he was offered a post at twice the salary at Oberlin College, Ohio, where he had graduated; the Chicago appointment offered better opportunities for research. Many years later, when he held a professorship at Chicago, unsuccessful efforts were made to induce him to accept what were largely administrative posts, such as "the presidency of one of our foremost universities or the directorship of one of our greatest industrial laboratories . . . at four times the salary of a college professorship, and also in industrial directorships at ten times such compensation." A further quotation, bearing on the same matter, may be given. "It was arranged that I was to be free to spend at least half of my working time, i.e., not less than six hours of a twelve-hour working day, on my own researches. That left another ample twelve hours free for sleep, meals, general reading and recreation—a schedule which, as far as the division between work and other activities is concerned, I . . . am still following."

Another problem of the present time on which this book has a claim on the attention of the thoughtful is the tendency towards centralised control and the setting up of governmental or semi-governmental bodies to regulate the activities of unofficial organisations and individuals. The extent to which this procedure has been carried in some countries, not only in the political but also in the scientific sphere, need not be dwelt on here. Something might be said about the wide-embracing nature of many Government controls in Great Britain, but in the sphere of science workers have been left in comparative freedom, although the recent suggestion that a Government-sponsored body should critically review important scientific papers is a straw in the wind. Dr. Millikan's attitude towards centralised control is shown by his statement that "I see one of the biggest dangers which confronts America to-day in the effort to solve all our ills by an appeal to Washington . . . not because the end sought is not good, but because the direction in which such action tends is extremely dangerous, leading directly through our vicious federal patronage system . . . to totalitarianism, the road already travelled by many States in which freedom has disappeared." As will be obvious, this expression of opinion has direct reference to American conditions, but the importance that it ascribes to intellectual freedom is unmistakable.

It was not only to Government control that Dr. Millikan objected; he thought too much centralisation was, in itself, undesirable. In 1918, it was suggested that John D. Rockefeller might be favourably disposed to establish a central institute of physics and chemistry. This idea Dr. Millikan opposed; he thought the United States, "a very widely flung country," could not "become a highly centralised state, culturally, economically, socially or

* *The Autobiography of Robert A. Millikan.* Macdonald and Company (Publishers), Limited, 16, Maddox-street, London, W.1. [Price 21s. net.]

politically, without losing its very soul. Too much centralisation, even in the pursuit of science . . . is a dangerous tendency." The proposed Rockefeller Institute was not set up, but a group of National Research Fellowships was established, under the administration of the National Research Council. The fellowships were restricted to candidates who had already taken a doctor's degree. The fellowships were held in universities of standing throughout the country and in Dr. Millikan's opinion have been "the most vital influence in the development of the United States into a country whose scientific output is now comparable to that of the other leading scientific countries."

The National Research Council was brought into existence by the National Academy of Sciences in 1916. It may be surmised, without offence, that this latter body was not of great influence in its earlier years, as in 1914, when Dr. Millikan was elected as a member of it, at the age of 46, he knew little about its purposes and functions. The National Research Council, however, to which it gave rise and in the formation of which the Engineering Foundation and many other scientific bodies co-operated, was destined to play a major part in the first World War. Chapters of great interest, and of historic importance, in this book give some account of its work on the development of methods of submarine detection, on meteorology and other war problems. Dr. Millikan played a leading part in these matters and, in the words of Sir George Thomson, "in World War I, Millikan and George Hale . . . were the leaders in organising American science in the Allied cause." This book leaves no doubt about where Dr. Millikan's sympathies lay in that war, and it contains decidedly unfavourable comments on the attitude adopted by President Woodrow Wilson during the early days.

In 1921, Dr. Millikan, clearly not without some regret, left the University of Chicago and became Director of the Norman Bridge Laboratory of the California Institute of Technology. In his new post, he was guaranteed "an annual income for the development of the strongest possible department of physics of not less than 90,000 dollars per annum," which it was anticipated "would rise in a year or two to 130,000 dollars." There are other great research and educational institutions in the United States, the status of which in relation to the California Institute of Technology, at Pasadena, it would be out of place to discuss, but Dr. Millikan records that "at Pasadena science and engineering were merged in same proportions." He adds, "That situation attracted me greatly." This remark bears on a matter which has been the subject of much controversy in this country of recent years. Explaining the nature of the California Institute of Technology, Dr. Millikan states that it is neither an orthodox university nor simply a technical school. It is striving to build up "a great centre of creative activity in both pure and applied science, and to turn out engineers with such a cultural background as engineering schools have in general never been able to impart." Discussion about engineering education in this country has been concerned not only with the relation between pure and applied science, but also with the broad cultural attainments of the products of British engineering schools. Something may possibly be learned from the California Institute of Technology, "the only institution of any sort in the world," as far as Dr. Millikan knows, "from which no man can graduate without having had four consecutive years in the humanities," which, he adds, include, at the California Institute, English, history, economics, philosophy and ethics. There was a time when engineering was taught as a branch of "Natural Philosophy." It is an interesting reflection that philosophy should now be regarded as a branch of science; a step nearer to acceptance of the principle that all knowledge is one.

THE RETURN TO AUSTERITY.

THE statement on this country's economic situation that was made by the Rt. Hon. R. A. Butler, Chancellor of the Exchequer, when he addressed the House of Commons on January 29, provided a broad outline of the measures that the Government propose to take to balance the national books, but it left many questions unanswered, even in outline. Dollar expenditure is to be reduced; allowances of currency for foreign travel are to be cut to a mere 25*l.* for the year to November, 1952; less coal is to be bought from America; some restrictions are to be imposed on hire-purchase transactions; capital expenditure on buildings is to be pruned with more or less rigour; economies are to be made in the vast expenditure on education; charges for health services are to be imposed or increased in various circumstances; and there is to be a modest saving on the Government's information services, about half of it by abolishing the Crown Film Unit. Most of these cuts were to be expected. Others, which were expected generally enough to induce anticipatory protests, were not mentioned or, in a few cases, such as the re-imposition of petrol rationing, were dismissed as being economically not worth while. On paper, the measures proposed are estimated to check the national overspending, previously at the rate of more than 500*l.* millions per annum, and to achieve a balance by the end of the year—always provided that world costs (and, presumably, domestic costs also, of goods and services) do not upset the calculation by continuing to rise.

Assuming that costs do not rise unduly, and that the value of British currency does not depreciate still more, it does appear that the Chancellor's hopes may be fulfilled in this respect; and, if they are, it may be that the much-quoted pendulum will begin to swing the other way. The new austerity that the nation is promised, however—and which, it is painfully evident, could not be avoided now, whatever political party or coalition were in power—is rather a possible means to escape complete insolvency than a clearly defined assurance of the something more than solvency that the country really requires. That can only come from a greater productivity allied with an expansion of overseas trade; for many of the things that are necessary to the existence of 50 million people in this small and congested land, and many more of the things that are merely desirable, can only come from overseas and they must be paid for in export goods. Associated with the Government's programme of "doing without," therefore, is a campaign for increased exports; all to be achieved concurrently with the diversion (but not "direction") of half a million persons into the production of munitions of one sort or another.

To this end, the Minister of Labour and National Service has made an Order, designated the Notification of Vacancies Order, 1952, which is to become effective on February 25; apparently under the impression that it may succeed where the former Control of Engagements Order rather conspicuously failed. Its purpose (to quote the official statement) is to "ensure that all those who want to change their employment and all those who are looking for work are guided into jobs which are not only suitable for them but are also of importance to the nation." They are to be under no obligation to take the jobs that are offered; "all that will happen will be that they will be told of the important vacancies and asked to take them willingly," and, "if they do not want those jobs they will be offered vacancies in the kind of work they desire." The Order applies to men between 18 and 65, and to women between 18 and 60, except in certain specified categories of employment; and it imposes on both employer and employee the obligation to effect engagements through an Employment Exchange or a "Scheduled Employment Agency."

The categories of employment to which the Order does not apply comprise agriculture, coal-mining, registered dock work, merchant shipping, sea fishing, part-time or unpaid work, casual work "not for the employer's trade or business" (which seems slightly ambiguous), the police and fire services, "employment in a managerial capacity" and "employment in a professional, administrative or executive capacity." It is explained that "'managerial capacity' does not mean every job which carries the title 'manager,'" and some indication is given of what is intended by "professional, administrative or executive"; though this latter indication is open to criticism in that, while specifying accountants, architects, solicitors, doctors, dentists, surveyors and clerks of works, it makes no reference whatever to professionally qualified engineers, who are presumably classed among "a number of other non-manual occupations."

An employer can still advertise any vacancies in trades covered by the Order, but the advertisement must make it clear that applicants for them must apply to an Employment Exchange, etc., before they can be engaged. Where vacancies occur in categories not covered by the Order, the employer is free to take any steps he may choose to fill them. Special provision is made to meet the cases of men leaving the Forces with rights of reinstatement in their pre-Service employment, and, in certain circumstances, for those whose employment has been temporarily interrupted—for example, by illness, or by a trade dispute. Moreover, exemption certificates may be given to employers in "suitable cases"; and, in "special and exceptional cases," an Employment Exchange or agency may authorise an employer to advertise a vacancy without having to require reference to the Exchange or agency.

It will be seen, therefore, that this new Order, so gentle and persuasive in purpose, is fairly liberally provided with opportunities to escape its restrictive clauses; but to take advantage of them is going to mean as much form-filling and letter-writing as to submit to the Order as it stands, and there does not seem to be much likelihood that the staff of the Ministry of Labour is going to be reduced materially, whatever may happen in other Government departments. A further hampering circumstance is that one of the main restrictions on the mobility of labour—the housing shortage—persists almost unabated, though this handicap may be somewhat alleviated in the next year or two, if the Government's housing plans come to fruition; but any such alleviation must itself make heavy calls on the available labour reserves, and possibly may run counter to the Chancellor's plans to reduce imports.

In thus expressing some doubt about the efficacy of the new Order, we are not being unmindful of, or in the least doubtful about, the urgency of the problems that it is designed to solve; but all past experience indicates that it may not only fail to provide a solution, but may easily lead to extravagances of other kinds, such as the long-distance transport of men to and from their work, in "working" time, or sudden decisions to build and maintain expensive hostels to accommodate employees at works which some Ministry has thought fit to construct in spots remote from any natural reserve of labour. The economic history of this country during the past 30 or 35 years is full of such examples of wasteful improvisation. What is needed now is not merely employment in some officially approved category, but productive work, carried out with the minimum of overhead charges and special allowances which, in fact, are no more than additional payment with no compensating output. The Chancellor has announced his intention to be firm, but his firmness should not be directed only against the employer.

EXHIBITION OF MULTI-GAUGING EQUIPMENT.

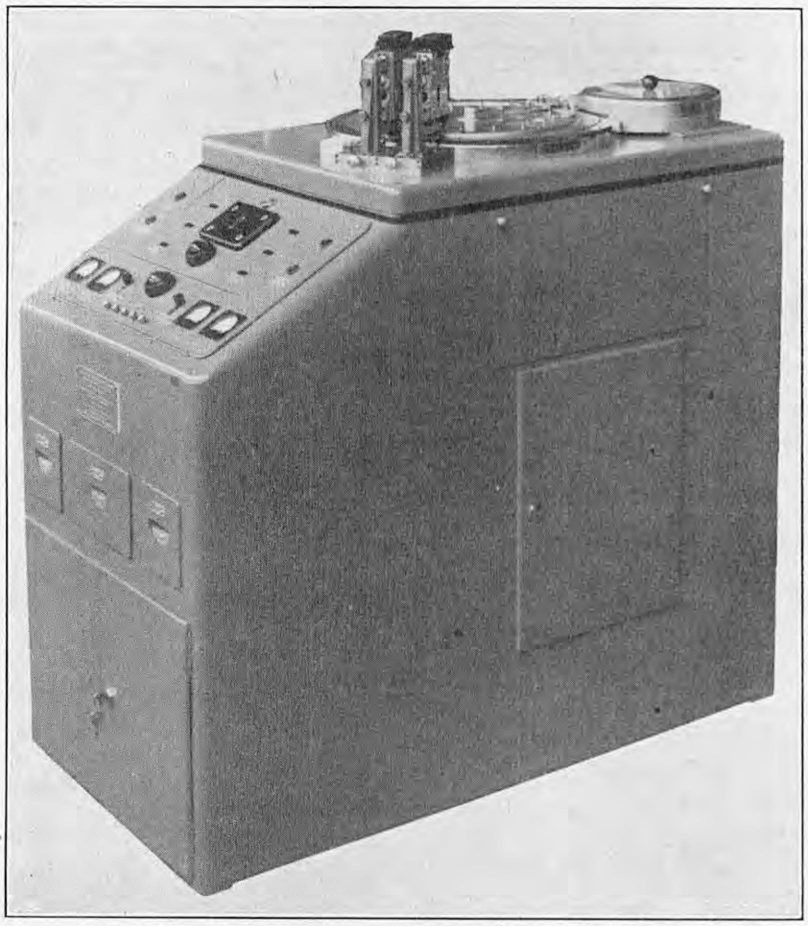


FIG. 1. HIGH-SPEED MACHINE FOR SORTING BY SIZE.

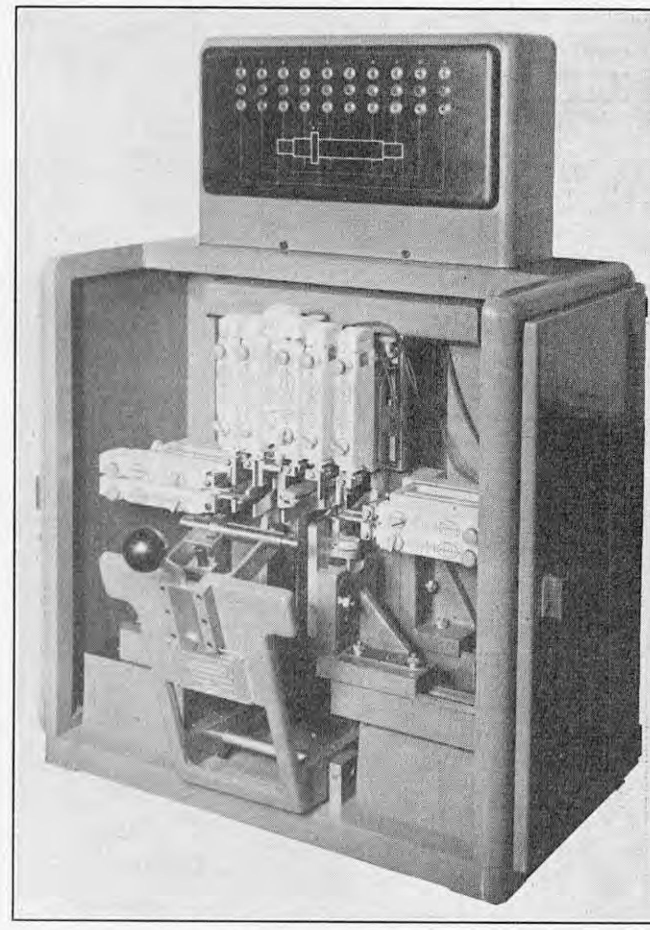


FIG. 2. HAND-OPERATED INSPECTION MACHINE.

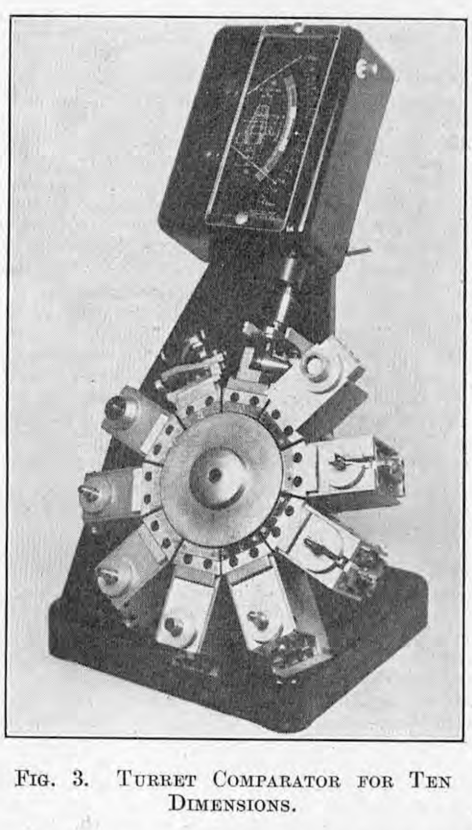


FIG. 3. TURRET COMPARATOR FOR TEN DIMENSIONS.

FIG. 4. SEMI-AUTOMATIC INSPECTION MACHINE.

EXHIBITION OF MULTI-GAUGING EQUIPMENT.

To demonstrate the contribution which multi-gauging equipments and techniques can make towards the re-armament programme, the Directorate of Engineers' Cutting Tools and Gauges, Ministry of Supply, staged an exhibition at the Institution of Mechanical Engineers, Storey's-gate, London, S.W.1, on Tuesday and Wednesday of this week. Approximately 20 multi-gauging machines were displayed at the exhibition, which was designed to illustrate how multi-gauging can save time and labour compared with orthodox manual gauging systems and to demonstrate recent advances in this technique. The value of the exhibition was enhanced by a lecture given each day by Mr. J. Loxham entitled "Multi-Gauging and its Contribution to the Re-armament Programme."

Most of the machines and equipments exhibited were manufactured by the Sigma Instrument Company, Letchworth, Hertfordshire, who, of course, have done much towards the development of multi-gauging techniques. One of the most interesting exhibits on view was the Sigma high-speed electronic sorting machine illustrated in Fig. 1 on this page. This machine has been designed for the rapid inspection up to a high degree of accuracy of parts of relatively simple form made in very large quantities. The standard rate of inspection is 10,000 parts an hour and the accuracy of inspection is claimed by the manufacturers to be in the region of six millionths of an inch. It can be arranged so that each dimension is checked individually at separate stations situated round a horizontal table, and plus and minus rejects from each station deflected into separate containers, the correct parts moving forward for further inspection. The machine can also be used for grading, the maximum number of outlets in this case being one each for over-size and undersize parts and eight for the groups into which the correct parts can be graded.

Multi-dimensional inspection and grading can be combined on the same machine. That demonstrated at the exhibition, for example, was set up for examining the cylindrical rollers used in connection with roller bearings and checked the length, taper and diameter of each roller. The parts were fed by a hopper to slots formed in a horizontal rotating circular table which carried them through the various gauging stations. Those that passed all tests were then segregated into six grades of diameter by a special gauge which, on determining the actual diameter, operated through relays a rotary selector which diverted the roller to the correct bin. Each bin was provided with a micro-switch arranged so that, when full, the weight of the parts operated the switch to shut down the machine.

Another interesting item of equipment on view was the Sigma turret-type comparator illustrated in Fig. 3, on page 149. This has a standard Sigma measuring head mounted in an inclined position on a pedestal, to the lower end of which is fitted a ten-station indexing turret. Each station is provided with a fixture to deal with one of ten dimensions of the component, the fixtures being built up from four standard types evolved by the manufacturers which, experience has shown, cater for about 95 per cent. of all requirements. The contact tip of each fixture is adjustable and is set so that when a master component is in position, the pointer registers zero. On the base of each fixture is a coloured strip marked with a number. The number refers to a specific dimension on a drawing of the component reproduced on the scale panel and the colour indicates the tolerance zone for the particular dimension, similarly coloured arcs on the scale panel showing the various zones. As already mentioned, the fixtures are of four standard types. They have been designed to deal with internal and external diameters, external lengths and internal depths, and if production of the component for which the fixtures have been adapted is stopped, it is a simple matter to convert them to suit other components. Similarly, the plate which carries

ELECTRICITY IN NEWSPAPER PRINTING.

Fig. 7. SERVO-CONTROLLED MERCURY-ARC RECTIFIER WITH DIRECT-CURRENT SINGLE-MOTOR DRIVE

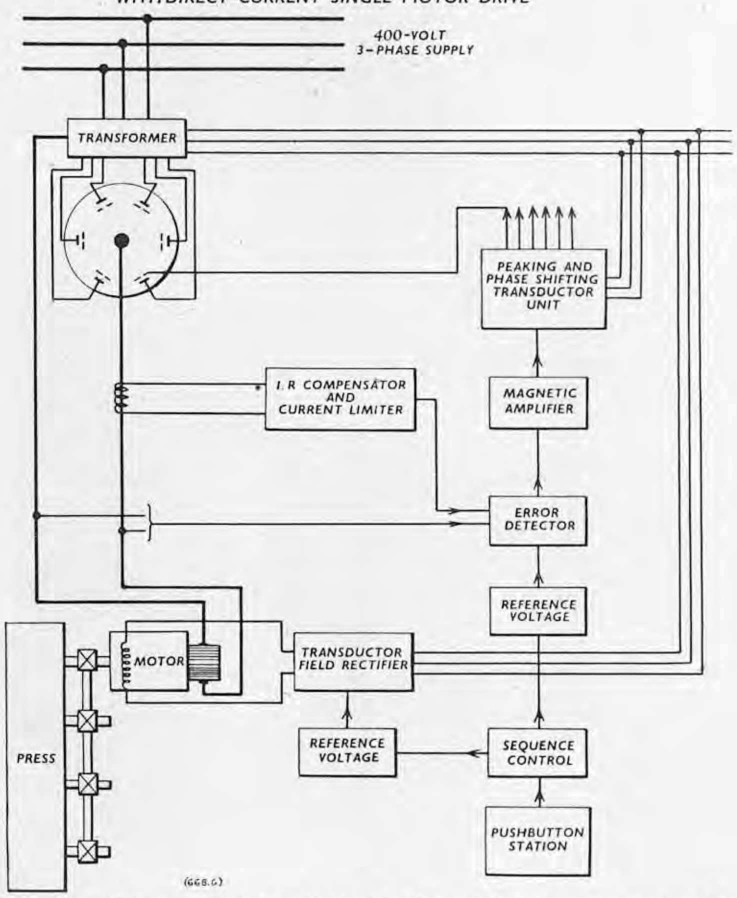
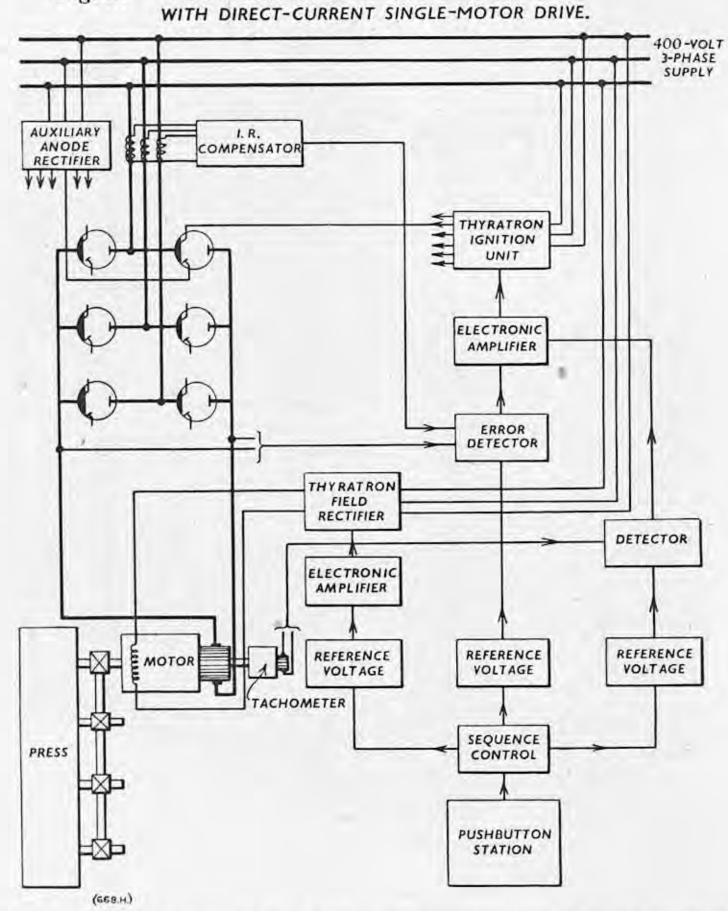


Fig. 8. SERVO-CONTROLLED IGNITRON RECTIFIER WITH DIRECT-CURRENT SINGLE-MOTOR DRIVE.



the diagrams of the component is attached to the scale by two screws so that it can be removed easily when it is required to change the role of the instrument.

This system of gauging possesses several advantages. The limits of the different tolerances, for example, are clearly defined and the whole tolerance is available to the operator; furthermore, no consideration need be given to gauge-manufacturing tolerance, wear allowance or error of "feel." Another advantage is that the cutting tools can be set to the limit of the tolerance so that maximum production is obtained before tool wear necessitates adjustment of the machine. Its use also enables the operator to determine the "drift," a factor influenced mainly by tool wear. If a check is taken at regular intervals, it is possible to assess the time when the machine will be producing work outside the prescribed tolerance and the necessary action can be taken to correct matters before scrap components are produced, not an easy matter when plain "go" and "not-go" gauges are used. Machine variability can also be assessed by checking a number of components and thereby ascertaining the suitability of any machine for a particular purpose.

Other equipments on view included a selection of standard Sigma multi-dimension measuring machines These machines are made for hand operation, semi-automatic operation and fully-automatic operation, representative hand-operated and semi-automatic machines being shown in Figs. 2 and 4, on page 149. Standard Sigma electro-mechanical gauges are used in all three types and it is claimed that these give results within 0·00005 in. Hand-operated machines. of this type are intended for checking components made in quantities not sufficiently large to warrant the use of semi-automatic or fully automatic machines. Semi-automatic machines, on the other hand, are particularly suitable for use in those cases where the component is not easily fed into the gauging position by mechanical means, the cylinder liner shown in Fig. 4 being a good example of such a component. In this case, the work is loaded into the machine by hand and, on operating a foot control, banks of electric gauges close into the measuring position, the gauges being retracted when the pedal is released. A panel installed above the measuring station shows, by means of coloured lights, whether the component is satisfactory or, if unsatisfactory, the dimension at fault. Fully-automatic machines can, if required, be equipped with indicators showing the total number of parts measured and the numbers rejected by each gauge, a most useful feature, as it enables early action to be taken to correct the fault. A semi-automatic machine has been used with comp'ete success for checking turbine blades, 28 gauges being used for this particular application.

ELECTRICITY IN NEWSPAPER PRINTING.*

By A. T. Robertson.

(*Concluded from page* 127.)

As previously mentioned, developments in the servo control of rectifiers have made it possible to obtain really satisfactory inching and crawling with single-motor drives, and Fig. 7 shows a multi-anode mercury-arc-rectifier scheme for such a drive with a servo mechanism incorporating a magnetic amplifier, with a transductor for the grid control of the armature-voltage and a transductor field-rectifier. An armature voltage, compensated for current, provides the signal for the servo control instead of a tachometer as in Fig. 5, page 126, *ante*. Fig. 8 shows a somewhat similar scheme using ignitrons in place of the multi-anode rectifier, with thyratron ignition and electronic amplifiers for the control of the armature voltage and a thyratron field-rectifier. In this scheme, a signal from the tachometer is balanced against a reference voltage as a protection against any fault that would result in overspeeding, such as the loss of the motor field. The auxiliary anodes and rectifier are required to ensure satisfactory firing of the ignitrons at very small currents. The armature-voltage signal is current-compensated from the alternating-current side of the rectifiers instead of from the direct-current side, as in Fig. 7.

Control panels are usually situated some distance from the press and are under the supervision of an electrician. Presses are invariably controlled by the manual operation of push buttons on or around the press. In addition to a main control station near the folder, with buttons for inching, crawling, speeding up, slowing down, stopping and locking, it is usual to mount control boxes on the reel stands and both sides of all printing units, to enable operators to control the press from wherever they may be working. As an alternative to all these, an emergency box is mounted at the main control stations. The control panels should be so arranged that it is possible to group together all the driving motors and control boxes required for the production of papers with any number of pages.

During the periods of making-ready for printing, including plating-up and leading-in of the webs, there may be a number of operators working on different parts of the press. These operators may be on different floor-levels and at widely separated positions, where it is impossible for one to see or know what others are doing. In view of this, special precautions must be taken to protect operators from injury, and to prevent wrong operation and possible damage of the equipment. Paper has to be threaded through a press while it is crawling, and this can be done without danger to the operators; but it is the starting-up of the press while operators are working on it that is a real danger. One way of safeguarding against this is to place within easy reach of all operators a means by which the press can be prevented from starting, combined with a light which the operator can keep in view, to indicate that the press is so locked. The lock usually takes the form of a push button in all boxes, which, when depressed to lock, requires a further operation to release it. Any push button so depressed must prevent power from being applied to the portion of the press associated with it. Only after the relay preventing the power from being applied has operated should the lights change to indicate that the press is safe to work on, and the lights which change should be limited to those at the box in which the button has been depressed and those at the main control station. With this arrangement of lights, the operator can see at a glance by which box the press is locked, and before placing himself in a dangerous position can lock the press from a nearby box under his own control; it is only at this box that the lock can be released.

As an additional measure of safety, some offices have an audible warning which is automatically sounded for a short period before the press can be moved. This is, however, a thoroughly bad practice likely to defeat the object of the safety lock by encouraging operators to rely upon getting clear before the press starts after the warning has sounded, instead of using the lock and releasing it only when they are clear. Another obvious objection is that the warning may not be heard by an operator, or he may confuse the note with that of the warning for other presses in the same room. With an automatic warning, the delay in starting makes it impossible for an operator to move the press a small fraction of an inch by the momentary depression of the button, and time is wasted in waiting for the warning every time the press is inched in a succession of operations.

Interlock switches operated by the clutches are sometimes provided to prevent the press from being started unless the electrical grouping of the motors corresponds to the mechanical clutches on the press. Protection is often provided against leaving the supply on the motors and against allowing the controller to move from the starting position if the press should fail to start because of some mechanical obstruction. If this protection is not provided, removal of an obstruction may allow the press to start unexpectedly with, possible injury to operators.

* Paper read before the Institution of Electrical Engineers on Thursday, January 10, 1952. Abridged.

"Stop" push buttons should be provided at all boxes, so that there is always one within easy reach of an operator. Depression of any one of these push buttons should disconnect the driving motors from the supply and apply the brakes to bring the press to rest quickly. A device is often provided to stop a press automatically if a web breaks, and to sever the web in such a way that it prevents the supply of paper to the cylinders while the press is coming to rest. This is necessary on high-speed presses to avoid the piling-up of additional layers of paper between the plate and impression cylinders, which might damage the press itself. Reliability and safety of operation are of prime importance in all controls and drives, and control circuits should always be designed so that if a relay coil should fail a dangerous situation cannot arise; for instance, failure of a stop-relay coil should shut down the press.

Most high-speed newspaper presses incorporate below each printing-unit a magazine reel-stand to take two or three rolls of paper arranged so that as one roll is used up another can be brought into use quickly, without threading the new web through the press, by pasting the start of the new roll to a tail-end of the old one. Push-button control of a reversible stand-rotation motor is required for loading the stand and for changing rolls. A similar control of another reversing motor is required for adjusting the rolls endways in the stand, and thus the side margins of the newspaper; this side-lay control for all the stands is duplicated at the main control station for the convenience of the printer. The web is tensioned by putting some form of brake on the rotation of the roll, and when remote manual adjustment from the main control station is required the brakes are electrically operated. Reel stands are often made with high-speed paster equipments which enable the change from an expiring roll to a new one to be made while the press is printing at full speed. The operation consists essentially of bringing the periphery of the incoming roll up to the web speed, pasting its leading edge on to the running web, and severing the tail of the used-up roll.

Stereo plates are cast from a pot of molten metal, which is an integral part of the casting machine. As soon as a plate has been cast, the header portion, or "tail," is cut off and returned to the pot. The level of molten metal is maintained by feeding back used plates at about the same rate as castings are made. When the metal is heated electrically, immersion units inside the pot take the place of gas or oil burners underneath it and enable the pot to be lagged. The maximum casting speed of a fully automatic machine is four plates per minute. Each plate requires up to 100 lb. of metal, depending on the size of the newspaper page, and for this rate of casting to continue indefinitely the heater capacity must be sufficient to maintain the temperature. To melt 400 lb. of metal a minute and raise its temperature to 600 deg. F. requires about 275 kW, to which must be added a constant radiation loss of 15 kW during casting, making a total heater capacity of 290 kW. In practice, it is generally unnecessary to continue the casting rate at its maximum for more than a short period, and it is possible to maintain the temperature with a heater smaller than that indicated above. If the heater is insufficient to maintain the temperature over an abnormally long period of maximum casting rate, it is possible to extend the period until the metal level in the pot has reached its lower limit by reducing the rate at which the metal is replaced.

In addition to the usual controls with fault protection and indicating instruments, both the standby and the casting temperature can be automatically maintained within close limits by pyrometers, backed up with an audible alarm which is sounded if the control should fail and the temperature limits be exceeded. The supply should be switched off automatically if the level of metal is allowed to fall too far, and an automatic warning of this and of over-filling is advisable. Electrically-heated pots make working conditions in the foundry very much better than when gas or oil are used, with their attendant fumes, flues and possible dangers. Any difference in capital and running costs are of little moment if production can be made more consistent and if the metal can be maintained in better condition by the larger heating surfaces, giving more even heating, and by the accurate temperature control.

Cables in the foundry, the press room and the reel floor, and also to some extent in the compositors' rooms, are subject to mechanical damage and damage caused by oil and heat. For mechanical protection, cables may be either flexible and wire-armoured or run in conduit. Oil and ink must be excluded from rubber-insulated cables by lead covering and oil-tight glands, but these are unnecessary for polyvinyl-chloride or cambric-insulated cables. Because of its resistance to oil, ink, heat and mechanical damage, mineral-insulated cable with a metallic sheath is now being increasingly used in newspaper offices and works, particularly on presses and in foundries. When this cable is used for control circuits, either the voltage should be limited to a maximum of 250 volts or surge suppressors should be fitted. Multicore control cables are used in preference to single-core cables in conduit for runs on the press to push-button boxes and to other control gear. It is hoped that provision will some day be made in the press structure to house these cables. Where conduit is used on a press, it should be of the seamless type and the joints should be covered with aluminium paint, in order to exclude oil.

TRADE PUBLICATIONS.

Fluorescent-Lighting Fittings.—Details of the single and twin lamp fittings for use with their "Instant-Self-Start" fluorescent-lighting system are given in leaflets issued by Philips Electrical Ltd., Century House, Shaftesbury-avenue, London, W.C.2.

Direct-Current Motor-Control Panels.—Details of direct-current motor-control panels with face-plate starters, for capacities up to 35 h.p. at 550 volts, are given in a pamphlet recently published by Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester, 17.

Electric Suds Pumps.—The centrifugal suds pumps described in a leaflet received from Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester, 17, are intended for use with machine tools and are designed for operation by either alternating- or direct-current motors.

Low-Voltage Equipment for Trolley 'Buses.—The low-voltage equipment designed by them for use in connection with the main, auxiliary and emergency lighting, both interior and exterior, of trolley 'buses is fully described in a pamphlet received from C.A.V. Ltd., Acton, London, W.3.

Pneumatic Chain Saw.—An illustrated leaflet issued by Holman Brothers Ltd., Camborne, Cornwall, describes briefly a general-purpose pneumatic chain saw for cutting timber. Designed for operation by one man, it weighs 39 lb. and gives a cut 20 in. long and $\frac{7}{16}$ in. wide.

Metalclad Switchgear.—Details of the metalclad switchgear constructed by them with rupturing capacities up to 2,500 MVA and for use on 66-kV circuits, are contained in a pamphlet received from Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester, 17. Another leaflet issued by the same firm contains a description of their 250-MVA 11-kV metalclad equipment.

Electric Motors.—Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester, 17, have sent us particulars of the direct-current motors they construct for short-time rated applications and for machine-tool drives at constant or variable speeds, the capacities ranging from 40 h.p. to 800 h.p. Particulars of polyphase commutator and fractional horse-power motors are also given.

Terminal Link Blocks.—A pamphlet received from Standard Telephones and Cables Ltd., Connaught House, Aldwych, London, W.C.2, deals with the terminal link blocks which they have designed for connecting stranded vulcanised indiarubber cable to single-core telephone wires. The blocks carry both studs and soldering tags, thus providing a connection which is both reliable and neat.

Economisers.—Senior Economisers Ltd., 11, Southampton-row, London, W.C.1, have issued a catalogue describing the construction of their three main types of economiser—the welded economiser, the twin-tube economiser, and the H-tube economiser. The book is fully illustrated with excellent reproductions of drawings and photographs of some 50 installations, of which the performance-test results are also given. The catalogue also includes nine pages of useful general technical data.

Cement Manufacture.—The Cement and Concrete Association, 52, Grosvenor Gardens, London, S.W.1, have sent us a copy of their latest publication, entitled "Cement in the Making." It explains the whole process of manufacturing Portland cement by a series of excellent half-tone illustrations with captions and brief descriptive notes. Short of being shown round a modern cement works by a well-informed and patient guide, we can think of no better method of acquiring a superficial knowledge of Portland-cement manufacture than by studying this publication; the latter method would certainly save time and energy, and would be almost as effective as the former.

Fans, Air-Conditioning, Dust Control and Drying Plant.—Air Control Installations Ltd., Ruislip, Middlesex, have issued two catalogues, one of which, entitled "What We Make," illustrates their general range of products, which includes centrifugal and axial fans, heating, cooling and air-conditioning plant, industrial driers, air filters, plant for dust and fume control, humidifying plant, grain transporters and grass driers, climatic test cabinets, etc. The other catalogue describes briefly their range of Rotoclone combined fan and dust collectors for use in machine shops, boiler houses and kilns, chemical and food-processing plants, etc.

ANNUALS AND REFERENCE BOOKS.

The African Press and Advertising Annual, 1951.

Edited by C. R. PASK and BARON V. M. FREDERICKSZ, 604, Boston House, Strand-street, Cape Town, South Africa. United Kingdom agents: The African and Colonial Press Agency Ltd., 8, Red Lion-square, London, W.C.1. [Price 1*l*., post free.]

THE second edition of this annual publication has now appeared. It is a development of *The South African Advertising Annual and Press Guide*, which it incorporates, and it aims at giving its readers information concerning the Press, peoples, economic progress, and market potentialities of the whole of the African Continent. The book deals with 38 territories and islands off the African coast, and the general method of treatment is to give a brief account of the political and geographical features of each territory, then to consider the advertising media and publicity methods employed, and finally to give an alphabetical list of the daily and weekly newspapers, the technical, industrial and professional publications and journals, and the various annuals issued in the territory. In each case, the nature of the publication is described in a few words; then follow the publisher's office address, the language used in the publication and the name of the advertising manager. Many photographs of African scenes are reproduced and the book closes with a "Who's Who" of Press and publicity personalities.

Whitaker's Almanack, 1952.

84th annual volume. J. Whitaker and Sons, Limited, 13, Bedford Square, London, W.C.1. Complete edition. [Price 15*s*. net.]

THE 1952 Whitaker, with its 32-page General Election supplement appearing in all editions, is the largest yet issued. All the usual features have been brought up to date, while some have been re-arranged to facilitate reference and a few new sections have been introduced. In connection with world trade, some new tables have been inserted to indicate the production, by countries, of some of the most important food crops and metals and other raw materials, and statistics are given of their consumption in the United Kingdom and the United States. Other new tables refer to such matters as the dollar value of the import and export trades of the countries of the world and the production and export of newsprint by the principal producing countries. Increased space has been devoted to figures relating to the world's merchant shipping and to statistics concerning fuel and power in the United Kingdom. Results of the census of population of 1951 from the preliminary reports of the Registrars-General, and up-to-date statistics of housing progress in the United Kingdom, are also included. The usual review of events for the year September 1, 1950, to August 31, 1951, contains, in outline form, outstanding occurrences in various fields in this country, the British Commonwealth, Europe and elsewhere. The high standard of "Whitaker" is maintained in this edition.

Oxford Junior Encyclopaedia. Volume VII. *Industry and Commerce.*

Edited by LAURA E. SALT and ROBERT SINCLAIR. Oxford University Press (Geoffrey Cumberlege), Amen House, London, E.C.4. [Price 30*s*. net.]

MANY boys and girls, approaching school-leaving age, have hankered after a book which would satisfy their hunger for the realities of the adult world in engineering, science, industry, the arts, or whatever branch of affairs they were bent on pursuing. Nearly as many have been frustrated by a well-intentioned but inappropriate book prize or present. Here, in the *Oxford Junior Encyclopaedia*, is the answer to that problem. The volume on engineering has still to appear, but, in addition to the volume under review, five have already been published, on mankind, natural history, the universe, communications, and recreations. There will be twelve altogether, and a general index volume. This division into subject-groups is convenient for an encyclopaedia of this type, since the reader will normally have a limited range of interests, which he will be able to indulge in perhaps three or four of the volumes. Within each volume the arrangement is alphabetical, with a tendency to amass information on related topics under one heading, to which the reader is led by cross-references, so that each article is an entity, interesting and informative to an intelligent boy or girl, or, indeed, an adult. Wherever possible, the treatment is partly historical, which lessens, to some extent, the danger of the encyclopaedia becoming out of date, as well as implanting in the mind of the youthful reader the enlightening concept that he is joining a historical stream of thought and work where he must give and take. A sense of history also prevails in the illustrations, which occupy about a third of the space and are enjoyable for the reader rather than necessary adjuncts to the text.

NOTES ON NEW BOOKS.

The Manufacture of Iron and Steel. Vol. II. *Steel Production.*

By G. R. BASHFORTH. Chapman and Hall, Limited, 37, Essex-street, London, W.C2. [Price 45s. net.]

SOME 20 months ago, the first volume of Mr. Bashforth's book, which dealt with iron production, appeared and was reviewed in our columns. His second volume has now been published and, like the first, it is intended to be a text-book for the general student of metallurgy and a handy reference book for the busy industrialist. Volume II contains 16 chapters, commencing with one concerned with the Bessemer process and ending with a chapter on steelworks refractory materials; in the intervening chapters, such subjects as open-hearth processes and fuels, electric-furnace practice, ingots and ingot production, special steels, and steelworks instruments are dealt with. The historical introductions in the various chapters are of the briefest, the author's aim being to describe techniques and processes as they now exist and not to dwell too much on the uphill task of creation and development. The proceedings of the Iron and Steel Institute and other metallurgical societies and the files of some of the leading metallurgical journals have been closely scrutinised for recent data, and a fair proportion of the illustrations have been borrowed from these sources. The various processes, pieces of equipment and methods used in steel production are described in detail and the language employed is generally lucid and pleasant to read; the author believes in the general use of short sentences in technical writing. Among other good features of the book are the numerous illustrations, there being 219 for 453 pages of text. Moreover, many of these, although given one figure number, are, in reality, several separate illustrations. As is now customary, the author gives references at the end of each chapter, so that readers interested in a particular subject or subjects may know where to obtain additional data.

Introduction to Heat Transfer.

By PROFESSOR AUBREY I. BROWN and PROFESSOR SALVATORE M. MARCO. Second edition. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York, 18, U.S.A. [Price 4·50 dols.]; and McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 30s. net.]

THE aim of the authors of this book, who are both professors of mechanical engineering in the Ohio State University, has been to provide a simple text-book for engineering students, containing the minimum of mathematics requisite for the subject. After an introductory chapter on heat transference in general, conduction, radiation and convection are discussed in the order given. Subsequent chapters are allotted to the transfer of heat to boiling liquids, the condensation of vapours, and the overall transmission of heat through a variety of constructional materials, without consideration of the detailed processes by which it is effected. Methods of calculation employed in the design of feed-water heaters, condensers, finned-tube apparatus and dehumidifying coils are then exemplified, and the final chapter deals with the heat flow when the temperature differences vary with time. In connection with heat conduction under steady conditions, the graphic method of computing the heat-flow through walls of irregular thickness, by dividing the section into numerous equal-sided curvilinear "squares" by isothermal lines crossed at right angles by lines of constant flow, is clearly described; but no mention is made of the modern method of "relaxation," devised by Sir Richard Southwell for the solution of similar problems. As is usual in other treatises on heat transmission, the subject of convection is preceded by an explanation of dimensional analysis. This may well be found difficult to understand by students having no previous knowledge of the matter. Otherwise, the work is admirable for its lucidity, interest, and practical nature. The outlook throughout is that of the designer rather than that of the mathematician, and a large number of typical problems are fully worked out to show the application of the principles involved. Numerous other problems, for which the student is left to find his own solutions, are to be found at the end of the various chapters, and there is an appendix containing useful diagrams and tables.

"REINFORCED-CONCRETE CONSTRUCTION AT ACTON LANE "B" POWER STATION": ERRATUM.—Our attention has been drawn to an error, which we regret, in the above article, on page 77, *ante*, in our issue of January 18. The weight of the main columns, given as 3 tons each, should be 30 tons. It should be pointed out, also, that Messrs. Brian Colquhoun and Partners were acting as consulting engineers for the contractors, Messrs. Sir Robert McAlpine and Sons, Ltd., and not directly for the British Electricity Authority, as might be inferred from our reference.

LABOUR NOTES.

HIGH rates of tax on the individual are criticised by the Federation of British Industries in a statement of its views on taxation problems, which was submitted to Mr. R. A. Butler, the Chancellor of the Exchequer, on Monday last. The Federation claims that taxation at this level is weakening the spirit of enterprise and the will to work. It states that there are cases where manual employees are not willing to take advantage of the opportunities for greater output which capital expenditure on new mechanical devices makes possible, for this reason. At the other end of the income scale, the extremely high rates of income tax and surtax on the salaries of executives in industry reduce their standards of living below that of persons holding comparable positions in practically every country in the world. As a result of this state of affairs, there is a tendency for those who can command high salaries to leave this country for employment overseas, and the Federation records that there is little or no sign of foreigners of similar standing being willing to accept employment in Britain.

It is the view of the Federation that the major cuts in the allocation of the nation's financial resources should be made in the expenditure of the Government, both on short-time requirements and on capital account, and on current private consumption. Only in that way would it be possible to reintroduce that degree of flexibility into Britain's national economy which was essential if the rearmament programme was to be completed without causing severe dislocation and hardship. The Federation welcomes the return to a more realistic monetary policy, but feels that the Government's endeavours will be frustrated if they are accompanied by taxation on industrial profits and capital. Such taxation removed the reward of savings at the source and ate into the capital invested in industry.

The country's economic problems, internal and external alike, would not be solved unless there was a really drastic and fearless cut in Government expenditure, accompanied, as early as possible, by a reduction in the general burden of taxation. In the absence of such action, industry in Britain would be faced with increasing difficulty in securing adequate capital resources and in maintaining productivity. The Federation considers that there are two matters which should be the subject of immediate legislation. One of these is the calculation of taxable business profits in the teeth of rising prices. It urges that there is a distinction between business profits and the majority of other sorts of income. As a result of price increases, allowances for stock replacements and depreciation are insufficient to provide the funds necessary to maintain physical capital and, under the existing law the whole of the surplus after maintaining money capital, as distinct from physical capital, is treated as profit. The second matter is the profits tax, in regard to which the Federation calls attention to a number of substantial anomalies.

Women employees in the engineering industry are to receive increases in their wages under an award made by the Industrial Disputes Tribunal, the terms of which were published on Monday last. The higher rates of pay will be back-dated to the first pay week after November 23, 1951, the date when male engineering employees received an advance of 11s. a week. The award provides that women aged 18 and over shall receive an extra 10s. 1d. per week of 44 hours, and that juveniles under 18 shall get proportionate advances. The five unions concerned originally sought to obtain an increase of 20s. a week for their women members, and, when an award of 11s. a week was granted in respect of men engineering operatives, they endeavoured to secure similar concessions for the women.

The award of the Tribunal is largely the same as the final offer made by the employers, with the exception that the award concedes the full increase of 10s. 1d. a week to women aged between 18 and 21, whereas the employers restricted this increase to those aged over 21. Women's weekly time rates are now 4*l*. 5*s*. 1*d*. at 21 years old and over, 4*l*. 3*s*. 1*d*. at the age of 20 years, 4*l*. 1*s*. 1*d*. at 19, and 3*l*. 19*s*. 1*d*. at 18. Rather more than 400,000 women are affected by these increases and the majority of them are engaged on piecework production. It may be mentioned that the employers had previously agreed, through the Engineering and Allied Employers' National Federation, to increase the women's annual paid holiday from one week to two, thereby bringing it into line with the amount of holiday received by men employees.

The new Order, which is designed to guide the distribution of employees throughout British industry was signed by the Minister of Labour, Sir Walter Monckton, on Tuesday last, and will come into force on February 25. The Government anticipate that this Order, accompanied by certain financial and economic measures, will substantially increase the man-power resources of trades engaged on the rearmament programme and in export. An additional half-million workpeople are stated to be required by firms engaged on rearmament contracts during the coming twelve months or so, and it is hoped, by the provisions of this Order, to secure that persons seeking work will be placed not only in employment suited to them, but in such occupations as will benefit the national effort. The new measure will be known as the Notification of Vacancies Order, 1952. It is the result of consultation with both sides of industry, and, in its final form, has been approved by the employer and trade-union sections of the National Joint Advisory Council.

The Order provides that no employer may engage workpeople affected by its provisions except through an employment exchange or an agency recognised by the Ministry of Labour for the purposes of the Order. Employers will be required to inform the local exchange, or a registered employment agency, of their vacancies, but they will be permitted to advertise their needs for new staff, provided that it is made clear in the advertisements that applicants must go to the exchange. The Order applies to men aged between 18 and 65, and to women aged between 18 and 60, and it is of interest to recall that the upper age limits in the war-time Control of Engagement Order were 51 for men and 41 for women. The Government intend, by including in the new Order men between the ages of 51 and 65, and women between the ages of 41 and 60, to encourage employers engaged in the less essential industries to accept persons of pensionable age when recruiting newcomers to their staffs.

Part-time employment is outside the scope of the Order and some other classes of employees, as well as certain services and industries, are also exempted from its requirements. Excepted services and industries, in which vacancies may be filled in the normal way, include agriculture, coalmining, dock work, fire services, fishing, merchant shipping, and the police. Employment in a managerial, professional, administrative or executive capacity is not included, provided that the managerial employee concerned is engaged on a salaried basis in charge of a department, works or office. Professional, administrative and executive employment comprises a large variety of non-manual occupations, including accountants, architects, journalists, company secretaries, surveyors and clerks of works. The Order does apply, however, to foremen, chargehands, and to persons employed on an hourly or piecework basis.

Disabled persons will be subject to the Order, but may be granted exemption permits. Men and women leaving the Forces with reinstatement rights may return to their former employers without reference to an employment exchange. Workpeople whose employment has been interrupted can be re-engaged without the intervention of an exchange, provided that the gap is not of a longer duration than 14 days. Persons losing their jobs owing to sickness may resume work with the same employer as soon as they are fit to do so. Similarly, employees displaced owing to trade disputes can be re-employed immediately work is resumed. Should an exchange be unable to provide an applicant with a suitable job within a reasonable time, a permit may be issued enabling the person concerned to seek work direct. Similarly, exemption certificates may be granted to employers in special circumstances.

Contrary to the former Control of Engagement Order, there is no provision for the compulsory direction of labour. Workpeople will be at liberty to decline situations offered to them if they consider the jobs to be unsuitable, but officials at the exchanges will endeavour to persuade applicants to take work in the defence and export trades. The Ministry will not be empowered to require any employer to dismiss members of his staff who are under-employed. In such circumstances, it will be permissible for exchange officials to put forward suggestions for a more economical use of a firm's labour force and to check further additions to it. The Order provides no penalties upon employees, but, in some cases, there may be a loss of the right to unemployment benefit. Employers disobeying its provisions are liable to both fines and imprisonment.

A strike of over 500 woodworkers employed at six of the principal shipbuilding yards at Southampton commenced on January 24. The dispute started when joiners belonging to the Amalgamated Society of Woodworkers complained that work, which should have been done by them on an Admiralty ship, had been given to shipwrights. The work is of a confidential nature.

ELECTRICAL PLANT SIZES AND BOILER GROUPINGS.

Fig. 1. RELATIONS BETWEEN FIRST COST AND UNIT SIZES.

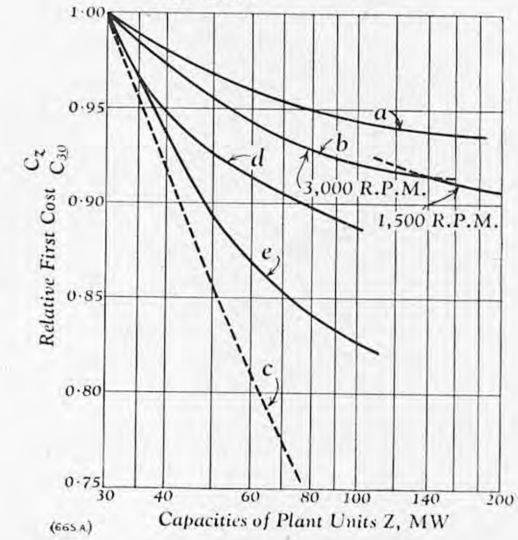


Fig. 2. DIFFERENTIAL COEFFICIENTS OF ASSUMED CAPITAL-OUTLAY/SIZE CURVES.

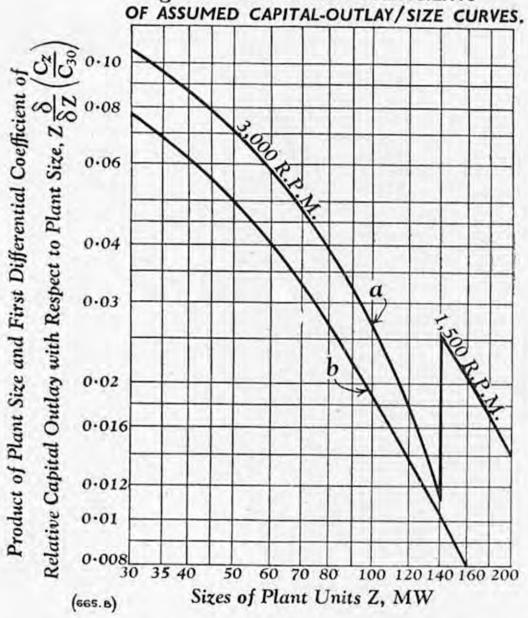


Fig. 3. FORCED-OUTAGE AND DEMAND DEVIATION/DURATION CURVES.

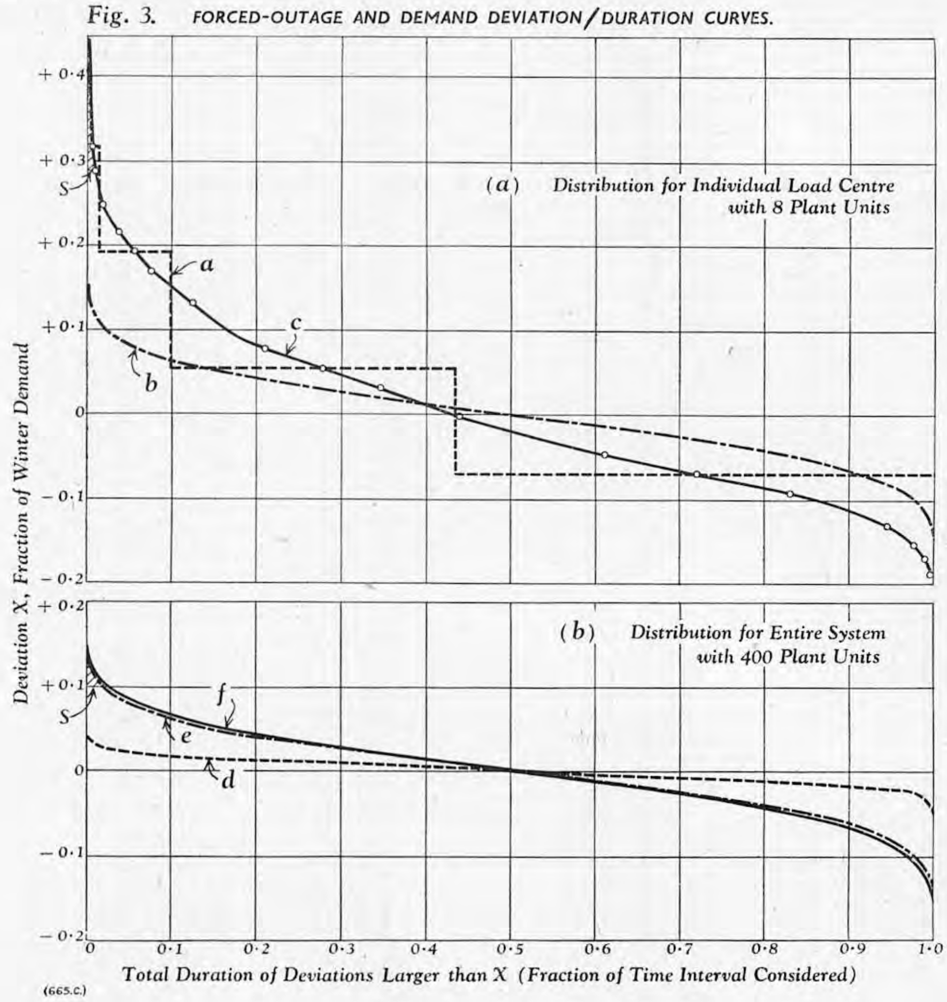
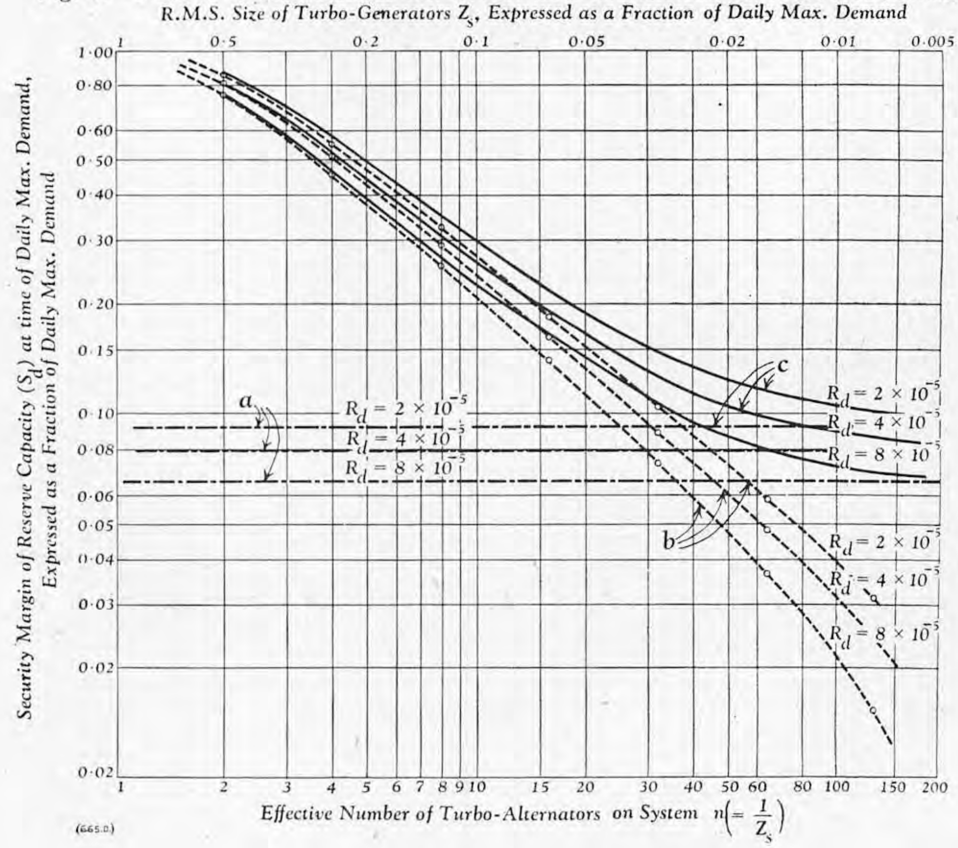


Fig. 4. SECURITY MARGIN REQUIRED FOR VARIOUS RISKS AND NUMBERS OF TURBO-ALTERNATORS.
R.M.S. Size of Turbo-Generators Z_s, Expressed as a Fraction of Daily Max. Demand



ECONOMIC PLANT SIZES AND BOILER-SET GROUPINGS ON THE BRITISH GRID.*

By BRYAN DONKIN, B.A., and P. H. MARGEN, B.Sc.(Eng.).

A MAJOR advantage of increasing the size of boilers and turbo-alternators in power stations is the reduced capital and working cost per kilowatt, while the chief disadvantage is the need for large reserve capacities and stronger electrical interconnections for a given degree of security of supply. Recently, attempts have been made to put these relations into mathematical form, and to develop in this way analytical methods of determining the economic plant size for any particular condition.† Attempts have also been made to evolve methods of determining, by calculation, the optimum number of boilers associated with one turbine, the best degree of steam interconnection, and the desirability and amount of spare boiler capacity. As none of the published methods is strictly applicable to a large interconnected system such as the British grid, the paper has been written to serve this need.

The capital cost of generating stations may be divided into three components which are, respectively, functions of the unit sizes of the boilers, of the unit sizes of the turbo-alternators, and of the capacities of the stations. An increase in unit size reduces the cost per kilowatt of the first two of these components, but these reductions tend to diminish when the sizes become relatively large for the given design. At some size a different design usually becomes more economic; for instance, pulverised-fuel firing instead of stoker firing for large boilers, or 1,500-r.p.m. machines as opposed to 3,000-r.p.m. machines for the largest turbo-alternators. The actual relations between costs per kilowatt and unit size are somewhat uncertain, because of varying prices and operating conditions. Curves *a* and *b* in Fig. 1, herewith, show the relations between first cost and unit sizes used in the sample calculations for the paper, C_z being the capital outlay in £ per kilowatt on a plant of unit size Z. These were chosen as conservative estimates of the reductions in costs obtained with increasing sizes of units when compared with the cost/plant size relation assumed by Ricard (curve *c*), the relation of station costs to mean size of boilers and turbo-alternators suggested by

* Paper read before the Supply Section of the Institution of Electrical Engineers on Wednesday, January 30, 1952. Abridged.

† J. Ricard: "Concentrations des Puissances dans la Production d'Energie Thermique." Fourth World Power Conference, 1950. Paper E1, No. 3.

ELECTRICAL PLANT SIZES AND BOILER GROUPINGS.

Fig. 5. SECURITY MARGIN OF RESERVE CAPACITY REQUIRED FOR A RISK OF 4×10^{-5} WITH VARIOUS PLANT GROUPINGS.

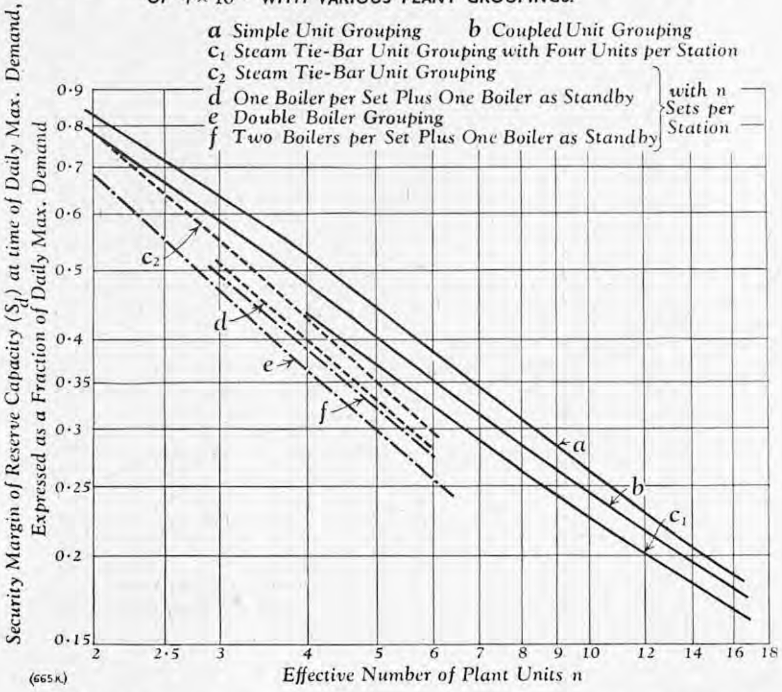


Fig. 6. OPTIMUM SIZES OF TURBO-ALTERNATORS.

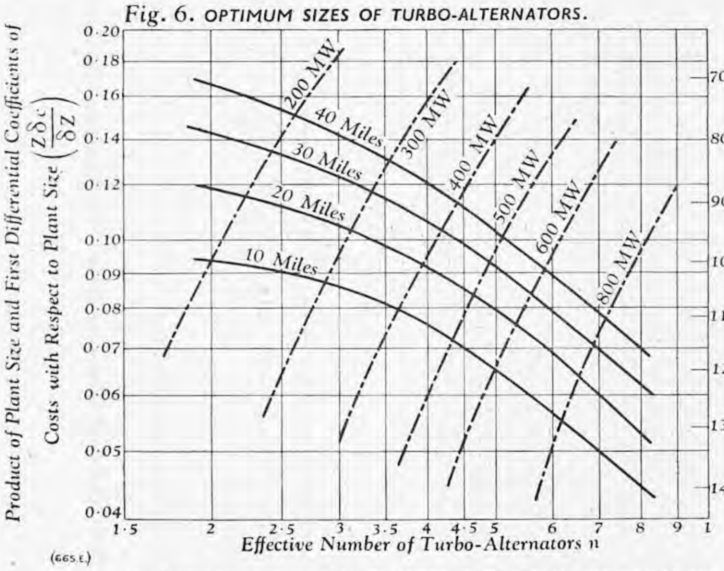


Fig. 7. ECONOMIC SIZES OF TURBO-ALTERNATORS FOR UNIT GROUPING.

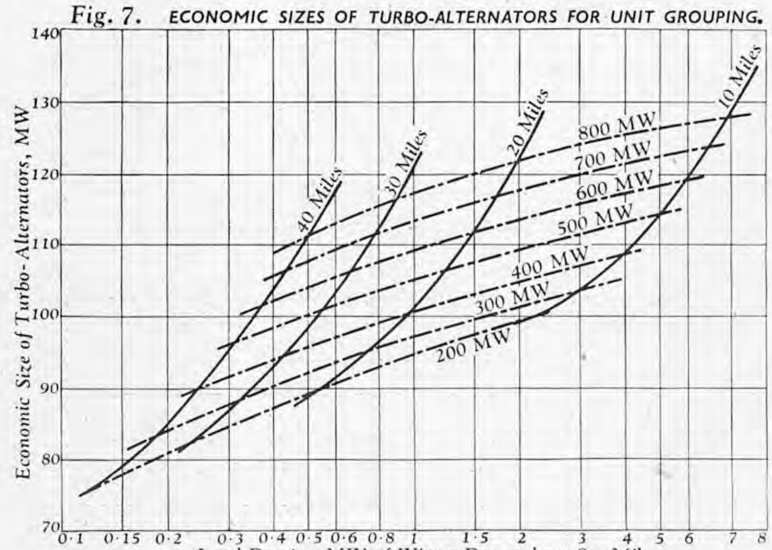
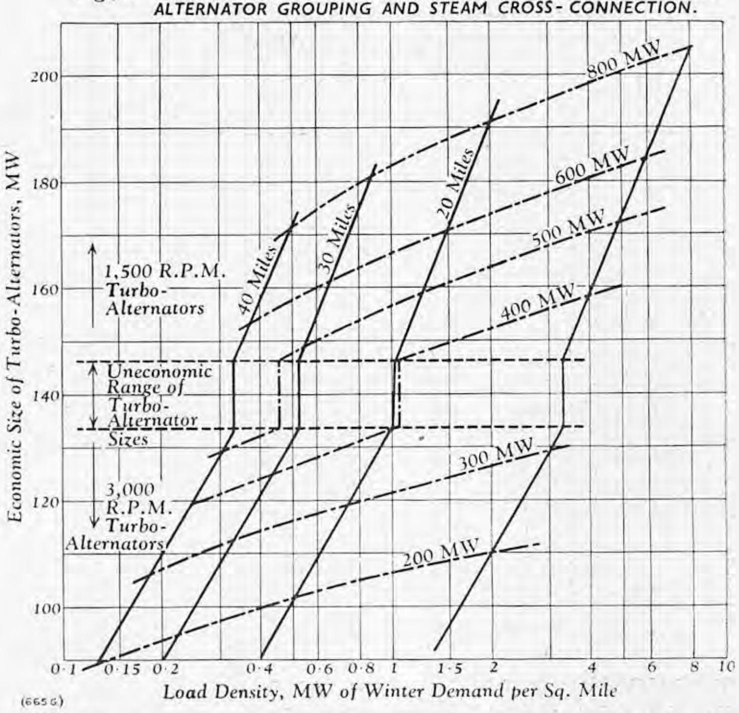


Fig. 8 ECONOMIC TURBO-ALTERNATOR SIZES WITH TWO-BOILER-PER-ALTERNATOR GROUPING AND STEAM CROSS-CONNECTION.



Forth and Jackson* (curve *d*) and turbo-alternator costs drawn from American data (curve *e*).

Since only a small proportion of the plant remains on base-load duty throughout its life, large units only become an important part of generation economics if they are suitable for regular shift operation. This involves some technical difficulties in view of the large masses and high temperatures involved, but recent experience in the United States suggests that the difficulties have been overcome in a number of cases. To obtain the desired flexibility for shift operation of large plant units, it is in general necessary to incur some sacrifices, such as the small loss in efficiency resulting from the larger turbine clearances, and the inconvenience and expense of alternator-rotor and turbine-casing pre-heating. These sacrifices must be taken into account in the cost/size relations of all plant units which are expected to operate on shift duty at some stage of their life.

The total generation costs affected directly by the size of the plant units for given steam conditions are the capital charges, the station running and maintenance costs, and a small component of the fuel costs—in so far as the larger units have more efficient blade heights at high steam pressures and lower radiation losses. The sum total of these costs affected by unit sizes have been termed the "total charges," and have been taken as 10 per cent. of the capital outlay for the purpose of the sample calculations. Fig. 2, on page 153, shows the first differential coefficient of these total charges with respect to plant size. Curves *a* and *b* are derived from curves *a* and *b* in Fig. 1, curve *a* referring to the turbo-alternators and curve *b* to the boilers. The differential coefficients of the total charges in the sample calculations have been obtained by multiplying curves *a* and *b* by $0 \cdot 1 \times 19l.$ and by $0 \cdot 1 \times 22 \cdot 8l.$, respectively.

The difference between the maximum demand on the grid and the plant allocated to meet it affords a security margin of reserve capacity to provide for deviations in demand or in outage capacity from the expected values. With a given security margin* some supply curtailments may occur. The probability of this occurrence is called "risk" and is defined as the ratio of the average number of kilowatt-hours lost, owing to supply curtailments over a given time interval, to the average number of kilowatt-hours required during this interval.

To determine the required security margin of reserve capacity for a particular risk on an interconnected system, it is necessary to examine the combined effect of chance fluctuations in load and chance variations in the forced-outage capacity. For this purpose, "deviation/duration" curves may be drawn, such as those in Figs. 3a and 3b, where the deviation in load or forced outage capacity from the expected value is plotted as the ordinate X, and the total duration of deviations larger than X is plotted as the abscissa. If sufficient plant to give a security margin S is provided on the system, the area below the deviation/duration curve and above the ordinate S represents the average number of kilowatt-hours which have to be shed at the time of the daily peaks, and it is thus proportional to the risk of supply curtailment during peak hours. The daily or annual risks can be obtained by integrating the average number of kilowatt-hours lost at various periods.

Fig. 3b, curve *e*, shows the chance deviations in load for the whole grid, while curve *d* indicates the calculated chance deviations in forced-outage capacity and curve *f* the distribution of total deviations. The deviations (curve *d*) are small, owing to the large number of plant units on the system, and have a negligible influence on the total security margin required. Fig. 3a shows the conditions for an individual load centre on the grid supplied by eight plant units of equal capacity. The curves *a*, *b* and *c* have the same meaning as *d*, *e* and *f* in Fig. 3b, but in this case the chance deviations in the forced outage capacity are larger than those of the load, with the result that the individual load centre needs a much larger security margin of reserve capacity than the grid as a whole. The shaded areas in these diagrams represent the loads which have to be shed at peak periods if the load system security margin is $0 \cdot 29$ of the winter demand in Fig. 3a and $0 \cdot 1$ in Fig. 3b. The difference between the requirements of individual load centres and those of the entire grid can be provided by means of electrical interconnection between the load centre and other points on the system.

Fig. 4 shows typical results obtained by calculation for several different risks and different numbers of

* E. Forth and J. B. Jackson: "*The Trend of Power Station Design.*" Journal of the Institute of Fuel, Vol. 22, page 127 (1949).

* The "security margin" of reserve capacity as defined above is required only to guard against chance happenings occurring at short notice, such as cold weather spells or forced plant outages. Long-term chance events, such as forecasting errors in load development or plant commissioning dates, can in normal times be offset by readjusting the retirement programme of old plant without incurring significant additional cost of generation. It is only in special emergencies, such as the present period of plant shortage, that the above adjustments become impracticable, and that the security margin therefore has to cope also with forecasting errors.

plant units, assuming a one-boiler-per-turbo-alternator grouping without steam cross-connections. In this diagram, Rd indicates the daily risk, while curves *a* show the security margin ($\sigma = 0 \cdot 05$) required to guard against chance demand variations only; curves *b* the security margin required to guard against chance variations of forced-outage capacity only ($q = 0 \cdot 0688$) and curves *c* the total security margin required to guard against both types of chance variation. Fig. 5 shows similar curves for a particular risk and several different plant groupings. The figure is based on a 5 per cent. standard deviation in the loads from the expected seasonal values in accordance with the demand variations on the British grid in 1947-48, and on average forced-outage capacities of 3 per cent. and 4 per cent. of the daily maximum demand for turbo-alternators and boilers, respectively.

To obtain the saving in reserve generation capacity effected by interconnection of load centres containing, say, *n* plant units each, the security margin S required by the load centres may be read off at the ordinate *n* on Fig. 4, and the security margin required by the entire system subtracted—it has an effective number of about 400 plant units in the case of the grid. This difference in security margins also gives the minimum capacity of the interconnectors which must enter the load centre to achieve the full saving in reserve generation capacity. It is sensitive to changes in the number of plant units per load centre and consequently to the size of these units, whereas the value of the reserve generation capacity for the entire grid is almost independent of the size of the units, being decided mainly by chance load fluctuations. Even on a "basic" system in which each load centre is normally supplied by its own generating plant, and the interconnectors are for emergency power transfer only, the capacities of the latter are larger than the ideal value obtained from Fig. 4 because they are limited to multiples of the capacities of a standard line. The interconnectors may also have to serve for emergency inter-area power important for reserve capacity calculations. The effective mean loads on which plant designed now should be based are estimated at about twice 1949 loading conditions. On this basis the optimum plant sizes for four selected areas on the grid would be those shown by item 4 in Table I, i.e., from about 80 MW to 160 MW.

With the gradual retirement of the old pre-grid stations the pattern of the generating stations and functions of the high-voltage network are changing in several ways which will modify the basic solutions for the economic unit sizes derived in the previous paragraph. The most important changes are: an increasing number of stations will have to transmit their output to the load centres by high-voltage lines. These lines, if economically loaded, will have spare capacity available for emergency power transfers and will thus reduce the capital expenditure on security interconnectors. In some areas, such as parts of Southern England, there are no towns capable of absorbing individually the entire load of generating stations of economic sizes. Each new station will, therefore, supply several towns and rural substations directly through a 132-kV network. This network, though designed primarily for distribution, will inevitably have spare line capacities which will contribute to the security interconnections between different stations and districts. There is an increasing tendency to allow entire stations to perform particular duties at a given stage of their life in accordance with their thermal efficiency. This tendency will result in heavier power interchanges between load centres served by base-load stations, and those served by peak-load stations. These power interchanges would bear a portion of the costs of interconnection. All the above factors tend to reduce the costs chargeable to security interconnections, thereby reducing the positive differential coefficients in Fig. 6 (i.e., the family of curves with the negative gradient). This lowers the points of intersection of the two families of curves and thus increases the

TABLE I.—ECONOMIC PLANT SIZES FOR VARIOUS REGIONS ASSUMING BASIC NETWORK.

Item.	Loading Conditions of Region.			
	Very Dense.	Dense.	Medium.	Light.
1. Assumed mean load density—MW of winter demand per square mile	1·25	1·00	0·445	0·188
2. Assumed winter demand supplied per station, MW ..	500	400	400	300
3. Mean spacing of stations— $\{= \sqrt{[(2)/(1)]}\}$, miles	20	20	30	40
4. Economic plant sizes, MW—				
(*a*) With one boiler per turbine	106	100	94·5	83
(*b*) With two boilers per turbine				
(i) Turbo-alternator size	158*	133·3	125	106·5
(ii) Boiler size	79	66·7	62·5	53·3

* 1,500-r.p.m. turbo-alternators.

flows; and there is an additional risk introduced by line failures. To allow for these factors in the following calculations for optimum plant sizes, the ideal capacities of the interconnectors have been multiplied by 1·3 in the case of the lines and by 1·1 in the case of the terminal transformers.

The economic plant sizes are obtained by summing all the relevant costs of generation, differentiating with respect to plant size and equating to zero. Fig. 6 illustrates a graphical process of obtaining these solutions for the basic system where each load centre is provided with its own generating station, and where the electrical interconnectors are for emergency use only. All the positive differential coefficients which arise from the costs of interconnection are grouped together (full lines) and their sum is plotted against the number of plant units per load centre for load centres of various capacities. Similarly, all the negative differential coefficients which arise from the "total charges" on the generating plant are grouped together and their sum is plotted with a reversal of sign for various spacings of the load centres (dotted line). The points of intersection of the two families of curves then provide solutions of the optimum number and sizes of the plant units over a large range of conditions. The results are also replotted against load density in Fig. 7 for lines of constant spacings between concentrated load-centres (shown by full-line curves) and constant load-centre demands (shown by dotted-line curves). While Figs. 6 and 7 refer to the one boiler per turbo-alternator grouping, Fig. 8 provides similar results for a two-boiler-per-turbine arrangement. The full lines in Fig. 8 are lines of constant spacing between concentrated load-centres, and the chain-dotted lines are lines of constant load-centre demand. The loading conditions on these diagrams refer to the effective mean values over the life of the plant item, and should be calculated by giving a greater weight to the first part of the life (when the plant item is large in relation to the area demand) than to the latter part, when the plant item is relatively small, and, therefore, less optimum size of units. It is a tendency which will be particularly pronounced in the lightly loaded areas, where there will be 132-kV distribution and where the sizes of units might otherwise be relatively small, i.e., below 100 MW.

From the above discussion it may be concluded that turbo-alternators designed for the British grid during the next few years will, in nearly all cases, have economic sizes larger than those derived in Figs. 7 and 8 and Table I, i.e., 100 MW or more if one boiler is associated with each turbo-alternator, and 130 MW or more if there are two boilers per turbo-alternator. In view of the conservative assumptions made regarding the cost/size relations used in the calculations for the paper, actual economic unit sizes may turn out to be even larger as soon as adequate design and operating experience is obtained with the new large units.

(*To be continued.*)

AIRCRAFT RESEARCH ASSOCIATION, LTD.—A group of companies in the aircraft industry have formed a new organisation, the Aircraft Research Association, Limited, with registered offices at 32, Savile-row, London, W.1, to design, build and operate a 35,000-h.p. wind tunnel for testing aircraft scale models at transonic and supersonic speeds; when constructed, it will be the largest sonic-speed wind tunnel in the United Kingdom. The project was initiated by the Technical Board of the Society of British Aircraft Constructors; the companies taking part are Blackburn and General Aircraft, Ltd., Boulton Paul Aircraft Ltd., The Bristol Aeroplane Co., Ltd., The Fairey Aviation Co., Ltd., Folland Aircraft Ltd., Handley Page Ltd., the Hawker Siddeley Group Ltd., Rolls-Royce Ltd., Vickers-Armstrongs Ltd., and Westland Aircraft Ltd. The siting of the wind tunnel and the supply of power and other services are at present under discussion with the Ministry of Supply and other authorities.

BRITISH STANDARD SPECIFICATIONS.

THE following publications of engineering interest have been issued by the British Standards Institution. Copies are available from the Sales Department of the Institution, 24, Victoria-street, London, S.W.1, at the price quoted at the end of each paragraph.

Hydro-Extractors and Centrifugal Machines.—A revision of B.S. No. 767, originally issued in 1938, to cover hydro-extractors, has now been published under the title "Hydro-Extractors and Centrifugal Machines," an alteration of title made in order to avoid confusion. In its revised form the specification covers machines having vertical, horizontal or inclined shafts, running at speeds of from 400 to 3,000 r.p.m., for use in laundries and in the textile and other trades. It sets down certain principles governing the design, construction and operation of hydro-extractors and centrifugal machines used for the extraction of liquids from solids, but it does not apply to high-speed centrifuges or separators employed, for example, in oil or cream-separation plant. The specification covers such matters as details of the rotating-basket construction, the quality of the materials used, safety designs, tests, and the marking of the finished machines. Information on the operation of the machine and its maintenance, and the data to be supplied with inquiries or orders, are included in appendices. [Price 2*s.* 6*d.*, postage included.]

Steel Spring Washers.—A new specification, B.S. No. 1802, covers steel spring washers for general and automobile-engineering, but not aircraft, use. The term "lock washer" has been omitted from the title and text of the specification as it has been agreed that a "spring washer" is not necessarily a "lock washer." Certain types of spring washer, to which the term lock washer does apply, are available, and, since details of them are not included in the specification, it is considered that the use of the term would be misleading. The specification is concerned primarily with dimensions, and an endeavour has been made to include a range of sizes which will suffice for general industrial use and cover most ordinary requirements, while at the same time limiting the number of different sectional sizes which manufacturers will require to stock. Clauses relating to material, heat treatment, hardness and certain other test requirements, are also included. [Price 2*s.*, postage included.]

Electric Passenger and Goods Lifts.—The Council for Codes of Practice for Buildings, Construction and Engineering Services, Lambeth Bridge House, London, S.E.1, have now issued, in final form, Code No. 407.101, dealing with "Electric Lifts for Passengers, Goods and Service." It has been drawn up by a committee convened by the Institution of Mechanical Engineers and covers installations in flats, shops and departmental stores, hospitals and industrial premises. General guidance is given on the conditions governing the choice of equipment, the location of lifts and machine room and other matters, while the structural requirements are also dealt with. [Price 4*s.*, postage included.]

Calcium Carbide.—Originally issued in 1935, B.S. No. 642, covering graded sizes of calcium carbide, has now been published in revised form. Test requirements for dust, gas yield and impurities are given and methods of sampling and testing are specified. The main alterations in the revised edition are concerned with new apparatus and improved methods for the determination of gas yield and impurities. It is now stipulated that the gas produced by the carbide shall contain not less than 99 per cent., by volume, of acetylene, instead of 96 per cent., as in the original edition. Limits for arsenic and nitrogen compounds have been added to those for sulphur and phosphorus. Eight graded sizes are specified ranging from a first grade in which the pieces are within the limits of 1 mm. to 2 mm., to an eighth grade, in which the pieces may vary in size from 80 mm. to 120 mm. [Price 4*s.*, postage included.]

Rubber Conveyor and Elevator Belting.—A revision of B.S. No. 490 covering rubber conveyor and elevator belting has now been issued. This specification was originally published in 1933 and a revised, war-emergency, edition was issued in 1943. The new edition reverts, to a great extent, to the original specification of 1933, but five weights of fabric are now specified as well as three grades of rubber cover. The specification also gives details regarding the construction of the belting and limits for defects, tolerance on width, strength of the fabric, and adhesion are stipulated. Methods of test are given in the appendices, where information regarding the selection of belting and recommendations on service conditions are also to be found. In view of the present shortage of cotton, an amendment slip (reference PD1297) is included with the specification, temporarily relaxing the strength of the fabric by 5 per cent. [Price 3*s.*, postage included.]

SHIP RESEARCH.

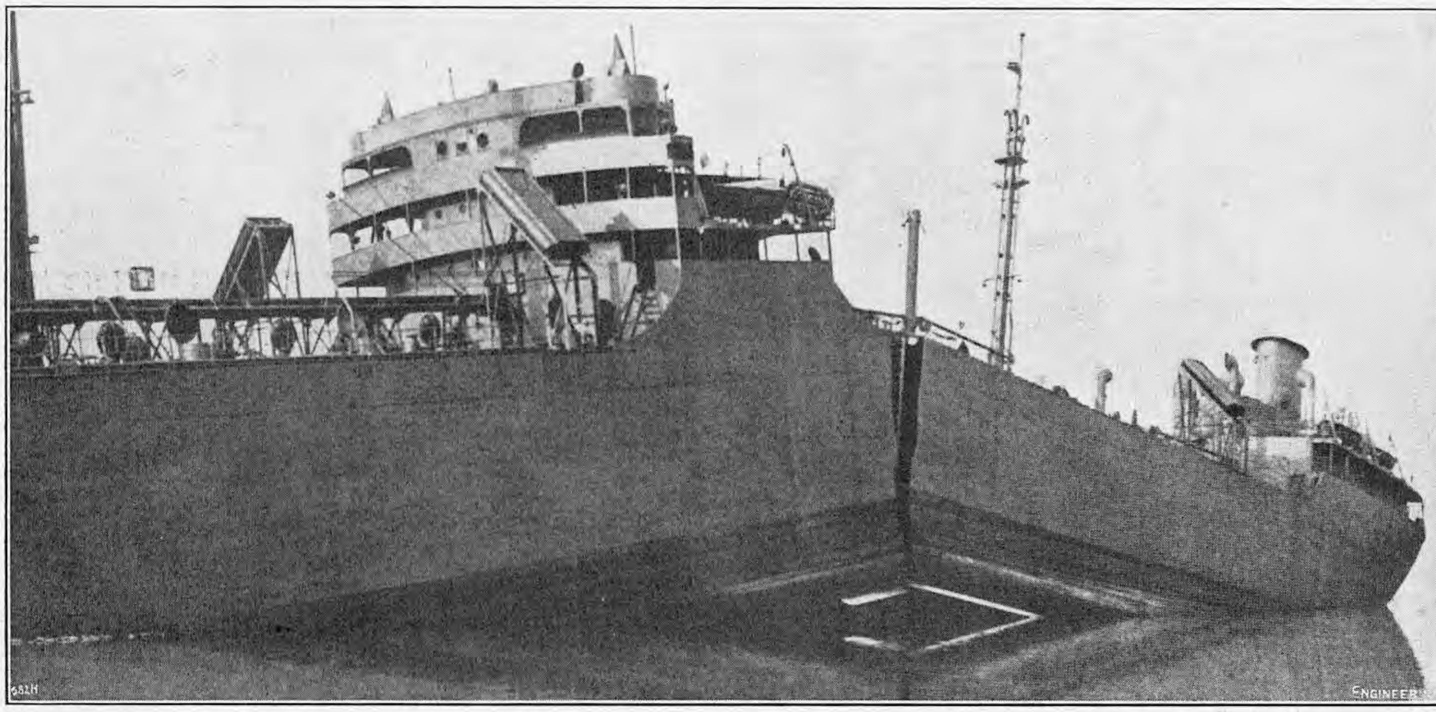


FIG. 7. HULL FAILURE OF S.S. "SCHENECTADY."

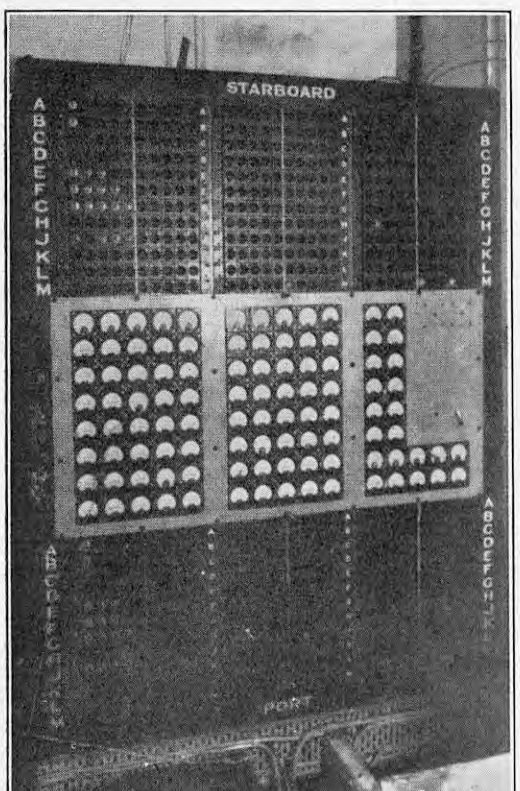


FIG. 8. RECORDING PANEL IN S.S. "OCEAN VULCAN."

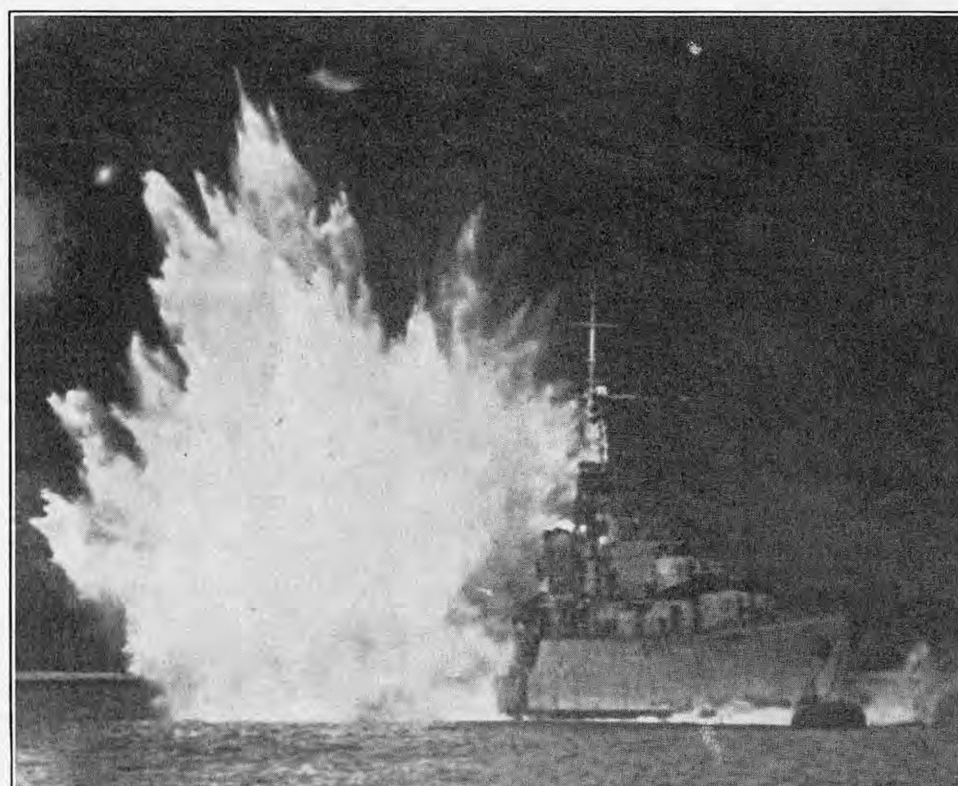


FIG. 9. UNDERWATER EXPLOSION TRIAL OF WARSHIP HULL.

SHIP RESEARCH.*

By DR. S. LIVINGSTON SMITH, C.B.E., M.I.Mech.E.

(*Continued from page 106.*)

SOME important problems of ship research arose from an outbreak of serious structural failures in welded ships during the 1939-45 war. In the early part of 1943, some disturbing reports came in of ships breaking in two suddenly, and often without apparent reason. Fig. 7, herewith, shows one case of an American tanker that broke in two while lying alongside the builder's outfitting quay after undergoing successful trials. These reports were of serious concern in Great Britain because of the Admiralty drive to promote welding in British shipyards.

* The 24th Thomas Lowe Gray Lecture, delivered to the Institution of Mechanical Engineers at a meeting held in London on Friday, January 18, 1952. Abridged.

Immediately, intensive investigations were started on both sides of the Atlantic, those in Britain being under the Admiralty Ship Welding Committee, which was set up for the purpose. The detailed reports of some 1,400 casualties were carefully analysed. Most of these concerned American ships, and the majority were of a minor character, but included 11 ships broken in two. In proportion to the large number of ships built under the emergency programme, the number of serious failures was small, but they all showed some important features in common. Practically all the fractures originated at notch effects, occurred suddenly, and were definitely brittle in character. They tended to be more frequent at low temperatures, and, though some originated in defective welds, they travelled mainly through the plating, disregarding the welds.

At first, there was a strong impression that "locked-up stresses" due to welding were to blame, and a great deal of investigation was devoted to this aspect. This work showed that, whatever effect such stresses might have on a brittle material, they could not by themselves account for brittle fracture in a ductile material. A theory that the trouble was due to the "rigidity" of welded ships led to extensive full-scale experiments on riveted and welded ships (Table I) in which bending stresses were induced by changes in loading, and measured by a large number of strain gauges. Within the limits of the bending moment applied to the two types of ship, these experiments failed to show any significant difference in overall structural stiffness between the two types of construction. It was found, however, that the conventional methods for estimating the stresses in ships give reliable results, provided that stress concentrations and local bending effects are taken into consideration.

These experiments were done in still water, and the question now was whether different results would be

SHIP RESEARCH.

Fig. 10. VIBRATION TESTS ON 10,000-TON DRY CARGO SHIP, S.S. "OCEAN VULCAN"

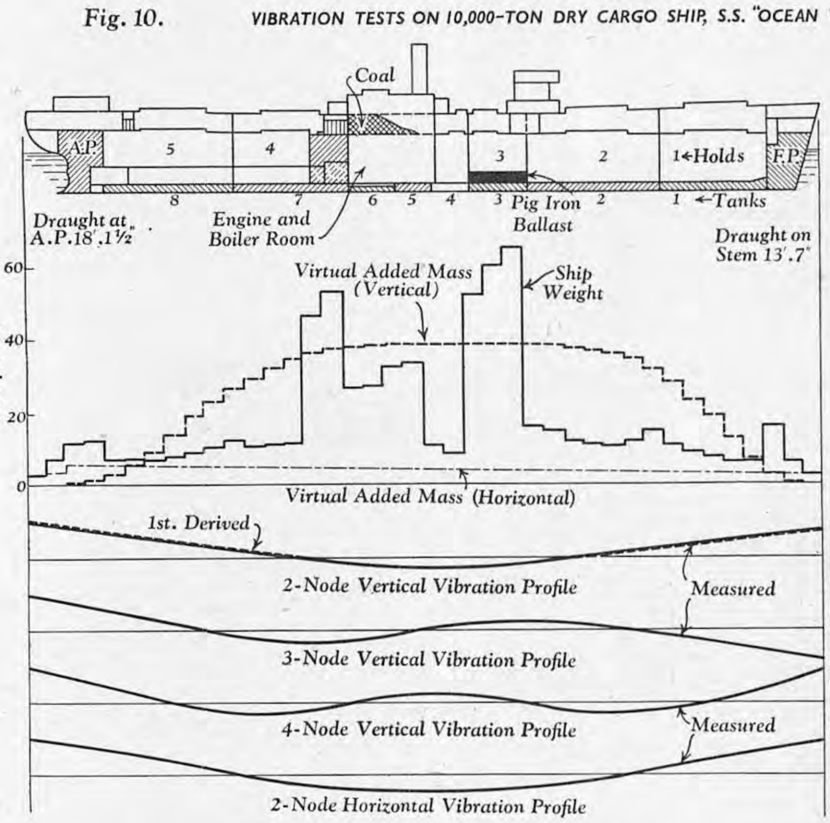


Fig. 11.

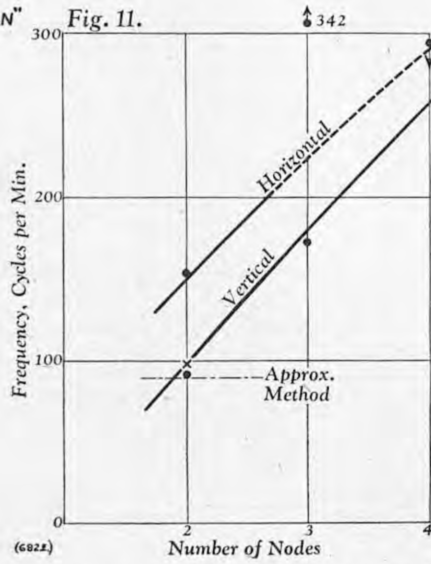


Fig. 12. STRAINS MEASURED AT LAUNCH OF TANKER.

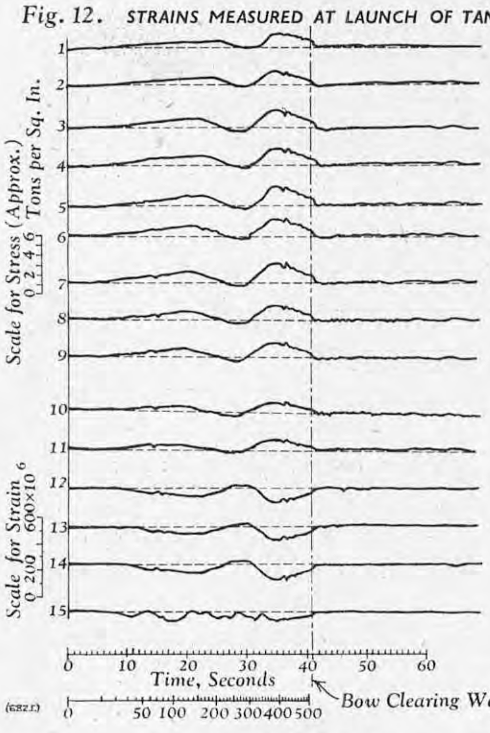


Fig. 13.

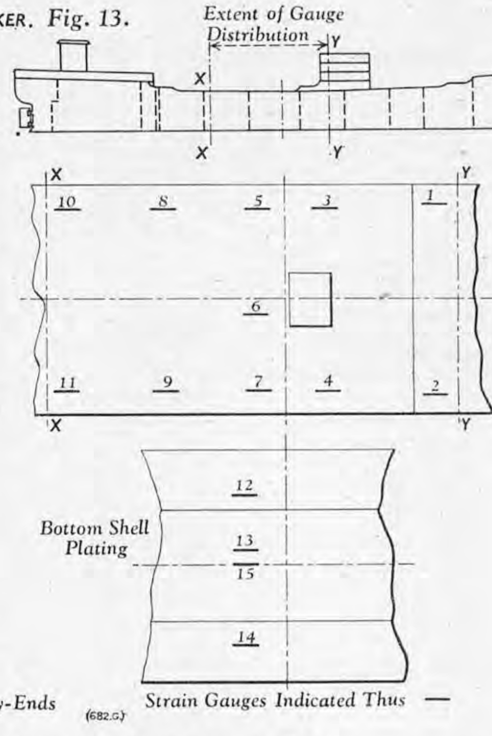


TABLE I.—SUMMARY OF STRUCTURAL INVESTIGATIONS ON SHIPS.

Type of Experiment.		Type of Ship.	Riveted ships.	Welded Ships.
Preliminary hogging and sagging	Still water	10,000-ton dw. tramp	Empire Duke	—
Full-scale hogging and sagging ..	Still water	10,000-ton dw. tramps	Clan Alpine	Ocean Vulcan.
Full-scale hogging and sagging ..	Still water	12,000-ton dw. tankers	Newcombia (Shepheard and Bull, *Trans. N.E. Coast Inst.*, vol. 63, page 237, 1946-47)	Neverita (Admiralty Ship Welding Committee, 1946, Report R1).
Stresses during launching ..	Launching	12,500-ton dw. cargo dw.	Empire Haig (Pascoe, *Trans. I.E.S. Scot.*, vol. 90, page 126, 1946-47)	Empire Allenby (Pascoe, *loc. cit.*, 1946-47).
Preliminary experimental voyage	At sea	12,000-ton dw. tanker	Niso (Boyd, Bull and Pascoe, *Trans. I.E.S. Scot.*, vol. 91, page 178 1947-48)	—
Full-scale sea-force investigations	At sea	10,000-ton dw. tramp	—	Ocean Vulcan.

obtained under the "dynamic" conditions imposed by a seaway. A comprehensive investigation on the welded ship Ocean Vulcan was therefore undertaken, directed towards the determination of the forces imposed on a ship at sea. This has always been a great unknown in ship design, and generations of naval architects have dreamed of elucidating it. An attempt was made by Schnadel in 1936, but modern developments in instruments, combined with strong government backing, enabled this new endeavour to be made on a grander scale. The ship was fitted with a multiplicity of instruments to measure the distribution of water pressure on the hull, the wave profiles, and the accelerations, as well as the rolling, pitching, heaving and yawning movements, wind forces, ship's speed, shaft torque, etc., and the stresses at a few important positions in the structure. All the instruments were wired to a central recording panel, which was photographed automatically at half-second intervals. The front of this panel is shown in Fig. 8, opposite.

With these instruments and a team of observers on board, the ship plied on normal North Atlantic trading routes for over 17 months, during which time hundreds of thousands of readings were recorded. Important conclusions have emerged. After this work of the Admiralty Ship Welding Committee, the Admiralty subjected H.M.S. Albuera, an uncompleted "Battle" Class destroyer, to bending moments. A large number of strain gauges of several types were used to determine the distributions of longitudinal and transverse stresses at a test section in the forward boiler-room and in way of the break of the forecastle. Preliminary hogging and sagging cycles afloat were followed by a hogging test to destruction in dry dock. In this test, the ship was supported from the dock bottom at two sections approximately 60 ft. apart on four specially constructed pillars, the hull being locally stiffened at these points. The water in the dock was then pumped out to apply the initial hogging moments, and this was followed by progressively filling the end compartments of the ship with water until the hull girder failed. Strain and breakage readings are now being analysed in detail, and appear on the whole to confirm the classical beam theory.

Explosion trials (Fig. 9, opposite) against a considerable number of warships prior to their being scrapped have also been carried out by the Admiralty, and attention paid not only to the causes and nature of hull damage, but also to the effect of shock on the machinery and equipment. Arising from this, information assisting industrial designers of equipment to provide adequate shock resistance is being made available by the Admiralty.

The main material used in hull construction is mild steel, and there is a strong probability that light alloys will be increasingly used in the near future. It is interesting that a material so well known and so widely used in all branches of engineering as mild steel should display an unexpected behaviour in shipbuilding, owing to the property known as notch-brittleness. If notched specimens of mild steel are broken at various temperatures, it is found generally that, below a certain temperature, the fractures are almost entirely crystalline (brittle) with low energy absorption, and above another temperature they are entirely fibrous (ductile) with high energy absorption. The range between these two temperatures is known as the "transition range," and it varies considerably between different steels, and even between steels of similar compositions. The transition range depends also upon the type of test by which it is determined.

The appearance of this phenomenon in shipbuilding coincided roughly with the introduction of welding on a large scale in ship construction, and a considerable amount of research on it has been carried out and is still in progress in Great Britain, in the United States, and on the Continent. The full-scale investigations on ships' structures revealed the important role played by notch-brittleness in the behaviour of steel in ships' hulls. It was found that the steel involved in the casualties was notch-brittle at the temperatures at which the fractures occurred, and this led to a great deal of research into the mechanical and metallurgical

SHIP RESEARCH.

Fig. 14. GENERAL ARRANGEMENT OF MACHINERY INSTALLATION IN THE "LUCY ASHTON."

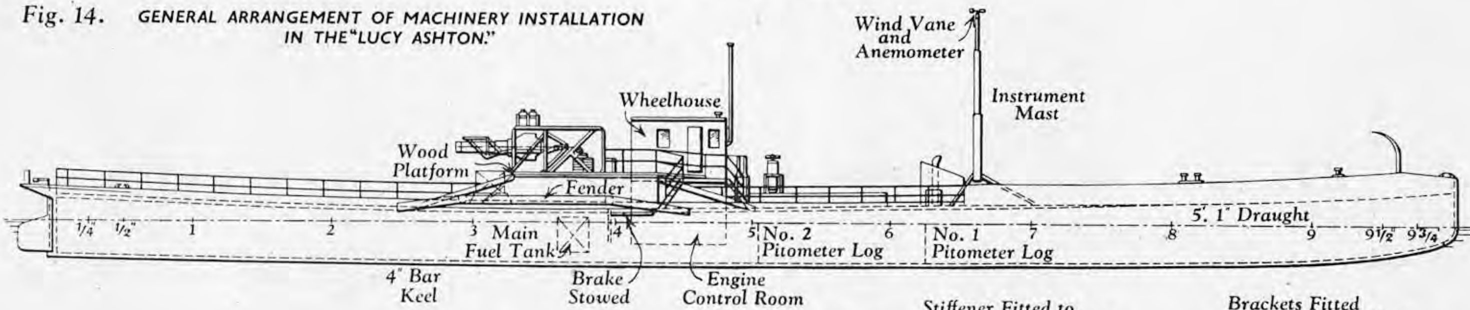


Fig. 16. SECTION AT STATION 3 LOOKING FORWARD.

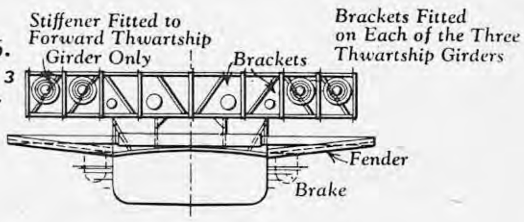
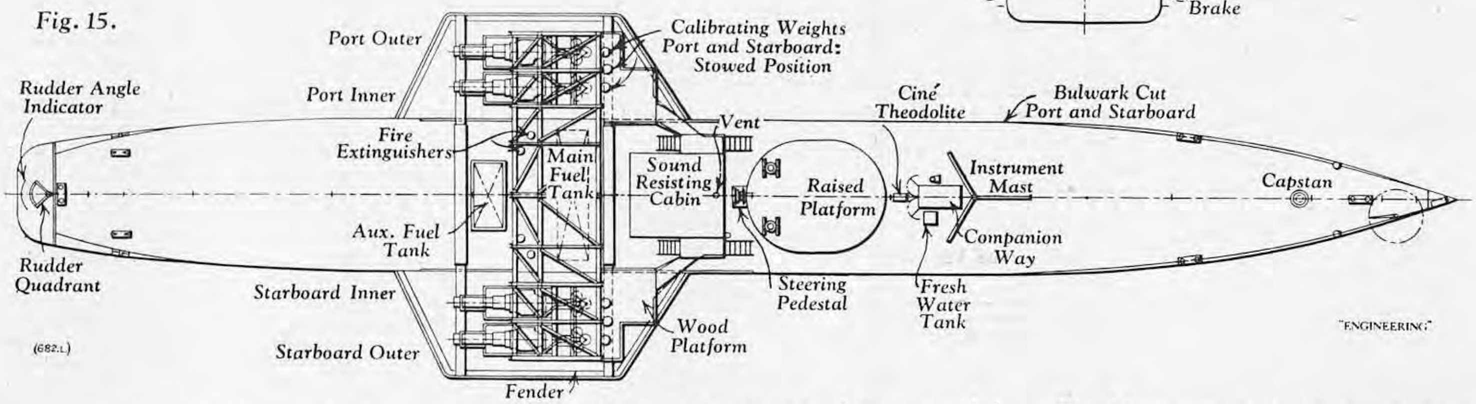


Fig. 15.



ENGINE MOUNTINGS IN THE "LUCY ASHTON."

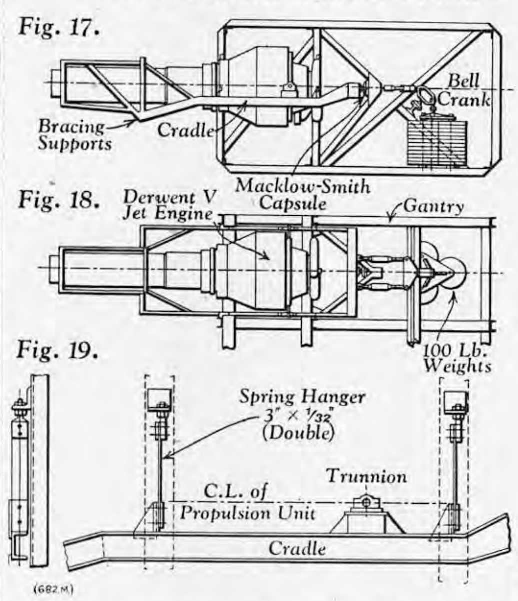
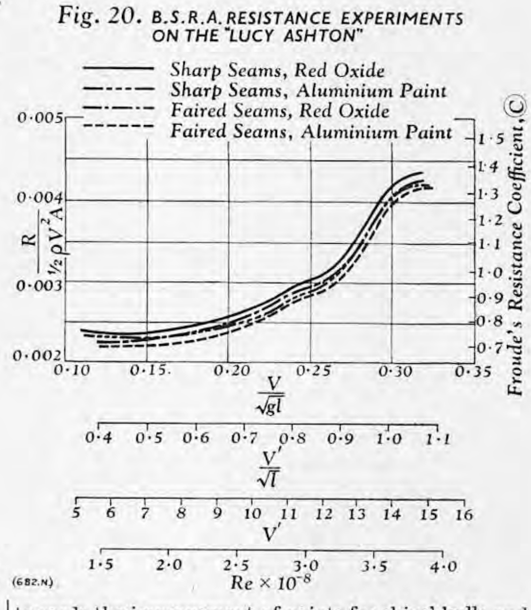


Fig. 20. B.S.R.A. RESISTANCE EXPERIMENTS ON THE "LUCY ASHTON"



factors controlling notch-brittleness. It also became necessary to find means of assessing the property, which is not revealed by the normal specification tests. This problem is complex and difficult. The research is being actively pursued in collaboration by the many interests concerned, and considerable progress is being made. Very little trouble has been experienced with British shipbuilding steel on this score, but until the phenomenon is fully understood the margin of safety is unknown. An excellent introduction to the problem is afforded by the report of a conference held at Cambridge in October, 1945,* and a report by the Admiralty Ship Welding Committee (1948 Report R3).

Considerable research is also being carried out by the Admiralty into the steels used in warship construction, with special reference to notch-toughness and to their behaviour under very high rates of loading, such as are produced by explosions and at temperatures possibly lower than those to which ships are normally subjected. A programme of welding development is also in hand, again with special reference to the needs of warship construction and to the ability of the welded joints to withstand explosive loading.

The use of light alloys in ships offers attractive possibilities. The medium-strength alloys, the mechanical properties of which can be increased by cold working and which contain $3\frac{1}{2}$ to 5 per cent. of magnesium, have ultimate tensile strengths of about 14 to 20 tons per square inch, and possess high resistance to corrosion. These materials have already found application in the construction of deckhouses, wheelhouses, etc., and their application to more extensive superstructures is often advocated. Until it is possible to weld this material satisfactorily, riveting must be adopted, and much experimental work is being done to determine the optimum diameter and spacing of rivets in this material. Many difficulties in the use of light alloys remain to be investigated, notably the effect of differential expansion between steel and light alloy arising from temperature changes, and the effect on the structural characteristics of still higher temperatures, arising from fires.

The introduction of welding in ship construction represents a major change, the importance of which may be regarded as comparable to the change from iron to steel in shipbuilding. It has made possible improved production techniques, but has created certain new structural problems which are being investigated by the appropriate organisations. The welding industry in Great Britain has formed its own research organisation—the British Welding Research Association (B.W.R.A.)—which has on its programme several items of special interest to the shipbuilding industry. Among these are the effects of flame-cutting on the quality of welds, the welding of high-tensile or other high-quality steels and of light alloys, and the effect of fatigue on welded joints. Another problem which has been studied by the B.W.R.A. is that of the all-welded pipe line. The replacement of flanged and bolted joints by welds offers a number of important advantages in addition to the saving of metal, but introduces certain new problems with high-pressure high-temperature pipe lines.

In addition to the work of B.W.R.A., efforts to improve the quality of welds have been and are being made by all shipbuilders, both individually and collectively. It has been found that the welding operators must be well and thoroughly trained, and that tests of the quality of their work, either by X-rays or other means, have a very good effect on their skill and efficiency.

Corrosion is naturally a matter of great concern to the shipbuilder, and, unless proper preventive precautions are taken, it can be the cause of very serious wastage of material. The subject has been studied intensively for many years, and the fundamental causes of corrosion are fairly well established. Most of the research at present in progress in Great Britain, mainly under the supervision of the British Iron and Steel Research Association (B.I.S.R.A.), is directed towards the improvement of paints for ships' hulls and fittings. Tests of paints for the outside of hulls are mainly conducted by means of small metal panels exposed on rafts to the action of sea water, under conditions similar to those experienced in ships. These panels are painted with the various paints under test, and from their behaviour over a period of time the best paints can be selected. In addition, the paints are tried out by applying them to "patches" of the hulls of ships actually in service.

The extent of protection against corrosion is largely a matter of the money the shipbuilder and shipowner are prepared to spend on suitable methods. Proper protection is, of course, expensive, but must be balanced against the cost of replacing material which has deteriorated badly owing to excessive corrosion. A recent development indicates that protection can be obtained with magnesium blocks instead of the zinc blocks often fitted to parts of hulls subject to corrosion. Although this work, done mainly in Canada, is not yet complete, it shows that magnesium is likely to be more effective than zinc. Fouling by marine organisms also concerns the shipowner, since even a small amount causes a serious increase in resistance and hence of the power necessary to achieve a given speed. Much effort has been devoted to the development of antifouling paints by the Admiralty, the Association of Ships' Composition Manufacturers, and by B.I.S.R.A.

Marked vibration in ships is to be avoided at all

* See ENGINEERING, vol. 164, page 532, *et seq.* (1947); and vol. 165, page 16, *et seq.* (1948).

SHIP RESEARCH.

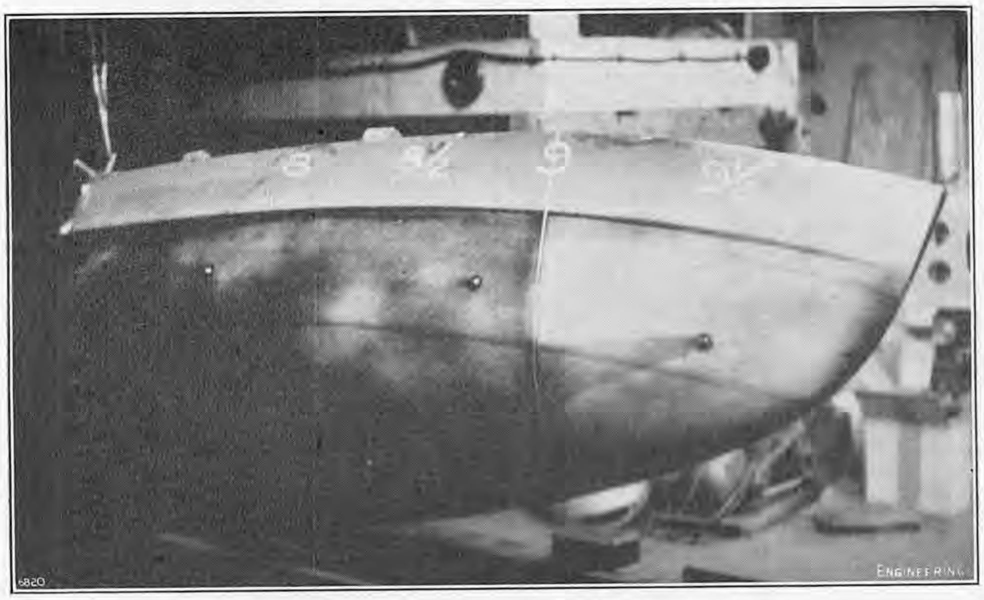


FIG. 21. DETECTION OF LAMINAR FLOW ON SHIP MODELS.

costs. Only in rare cases do the resultant stresses reach significant magnitudes, but considerations of comfort and nuisance make vibration most undesirable. The designer's problem is to determine the critical hull frequencies in the design stage when decisions are being made regarding the choice of propeller speed, number of blades, etc. Great efforts have therefore been made to improve the available methods of estimating ship vibration frequencies for all fundamental and higher modes. Such theoretical work is unacceptable to designers until its validity has been established by experiment. For this and other reasons, the British Shipbuilding Research Association have found it necessary to utilise a vibration exciter. Such a machine, capable of exerting pulsating forces of various controlled magnitudes and frequencies, was designed and constructed by Lloyd's Register of Shipping. When this apparatus is mounted, generally at the bow or the stern, the investigators can determine the complete ranges of vertical and horizontal frequencies, obtaining simultaneous records of frequency, amplitude, and strain in the hull by apparatus specially developed for this purpose. Figs. 10 and 11, on page 157, show typical records obtained in this way with a cargo vessel.

Vibration characteristics are affected by the depth of water in which the ship is floating and by the virtual mass effect of the entrained water vibrating with the ship. Model investigations of both these aspects are being pursued in parallel with work on the full scale. The vibration of ships' masts is a matter of some concern to the Admiralty, who investigate it both in actual ships and by means of half-scale or quarter-scale models. This study is becoming increasingly necessary as the number and weight of specialised aerials attached to the mast increase.

The launching of a ship might be regarded as a crude and risky process, but experience has built up a store of information relating to the desirable declivities, launching lubricants, drag weights, etc., for specified conditions. The production of mineral oil greases has led to renewed interest in the performance of the old launching greases, and both large-scale model and laboratory experiments have shown that the loads on the launching triggers immediately before the launching operation are much higher than was originally thought. Figs. 12 and 13, on page 157, show some results obtained during the launching of an oil tanker, when the opportunity was taken to obtain strain measurements in addition to the usual launching data.

The qualities of an efficient hull-propeller combination may be stated briefly as low resistance combined with high propulsive efficiency, minimum loss of speed at any given shaft horse-power in rough water as compared with smooth, and good steering and manœuvring qualities. The components of ship resistance are generally considered as being the friction of the water on the hull surface, or "skin-friction"; the "wave-making" resistance caused by normal pressures on the hull, arising from the inevitable generation of surface waves; the energy losses arising from the formation of eddies shed from bluff endings of appendages, such as shaft bossings and brackets; and resistance due to wind acting upon the above-water portion of the hull. The difference between the total water resistance and that from skin friction is termed the "residuary resistance," and its principal component is the resistance due to wave making.

Our detailed knowledge of the factors that enter into the resistance and propulsion of ships has been derived mainly from model tests in experiment tanks—the form of apparatus introduced by William Froude. This experimental equipment is extremely useful, not only for routine tests of ship types, but also for investigating the effect of systematic changes in hull form. The naked hull is towed through the water by a carriage, which usually spans the tank and is equipped with balances that enable all the necessary forces arising from the motion of the hull through the water to be measured. The two main components of resistance are the friction and the wave-making resistance. As these two vary in a different manner with scale, the main difficulty is to predict the full-scale resistance from model tests. The skin friction varies with Reynolds number and the wave-making resistance with the Froude number,* and the procedure is therefore as follows.

From the total resistance of the model measured at a number of speeds, the skin friction (as calculated from known empirical data) is subtracted at the appropriate Reynolds number. Neglecting wind resistance on the above-water portion of the hull, which is very small in tank tests, the resistance obtained after subtracting the skin friction in this way is the residuary resistance, which can then be plotted on a basis of the Froude number and extrapolated to values for the full-scale ship by the appropriate law of dynamical similarity. To this is then added the skin friction, calculated as before from empirical data, at the appropriate Reynolds number, and the result gives the calculated value of the total resistance (neglecting wind resistance) of the full-scale hull.

It will be clear that the main uncertainty in this method of predicting the hull resistance lies in the estimation of the full-scale skin friction. Froude assumed that this was the same as the skin friction on a flat surface of the same wetted area as the hull and moving at the same speed. He measured experimentally the resistance of a number of flat planks towed at various speeds, and used the results to draw up a method of extrapolation to predict the full-scale skin-friction of ships' hulls. Although this method of prediction has been used in almost all experimental tanks ever since, it is obvious that a full-scale check on the resistance of a ship's hull is very desirable. Simple as this problem sounds, it is extremely difficult in practice. Froude, in his famous Greyhound experiments, tried to obtain full-scale information by towing one ship behind another, but, although he achieved some success, the results of his trials were not entirely conclusive. The measurement of thrust in the actual ship is a useful, but not entirely satisfactory, guide to the resistance of the hull, because the thrust of the propeller is equal to the hull resistance together with the increase of resistance caused by propeller action.

* Reynolds number $= \frac{V l}{\nu}$ and the Froude number $= \frac{V}{\sqrt{g l}}$, where V = velocity, l = length, ν = coefficient of kinematic viscosity, and g = acceleration due to gravity.

This can be determined on the model scale by suitable tests in the experiment tank, but it is clearly still desirable that some full-scale check should be obtained of hull resistance.

This problem was considered by the British Shipbuilding Research Association, and active work on the subject was begun early in 1950. An ex-Clyde paddle steamer, the Lucy Ashton, was purchased from the shipbreakers. Examination of the hull showed that its proportions, fineness, etc., were suitable for the purpose, and it was estimated that, at a speed of 15 knots, the resistance would be of the order of 5½ tons. The corresponding Reynolds number was reasonably high, $3 \cdot 75 \times 10^8$, which would enable a most valuable comparison to be made between full-scale resistance measurements and the resistance predicted from model tests.

There are many possible methods of measuring the resistance of a towed hull. The provision of craft capable of heavy tows at high speeds raises difficulties, and the dynamometer required on board the towed vessel calls for onerous and conflicting requirements of robustness, accuracy, and sensitivity. Owing to the slipstream shed from a towing vessel, this craft must not be directly ahead of the towed craft, thus demanding an outrigger, which presents formidable design problems. Propulsion by airscrews is possible, but the highly periodic thrust developed by an airscrew is difficult to record accurately. Interference effects between airscrews and hull, caused by induced and slipstream velocities, appear to be unavoidable and are impossible to allow for accurately. Propulsion by jet engines was adopted because they give steady thrusts which are easily and rapidly altered by comparatively simple means. When they are mounted on a gantry extending beyond the vessel's sides, the discharge from jet engines is clear of the hull and does not affect the water in the immediate vicinity. Further, the thrust recorded can be measured very accurately and therefore gives a close assessment of the hull resistance. These are important advantages and the main disadvantages are solely high fuel consumption and the noise emission.

It should be clearly understood that measurements of the hull resistance of the Lucy Ashton over a wide range of speed were attempted with the fundamental aim of securing information for the comparison of ship resistance and model prediction. Other tests, such as the deduction of virtual-mass factors from acceleration and retardation experiments, appendage resistance tests, the effect of seam fairings, etc., were subsidiary aims. Considerable alterations were made to the hull, the shell plating being cleaned and smoothed. Machinery, sponsons, paddle wheels and deckhouses were removed, sand ballast was loaded, and a gantry for carrying jet engines was installed, together with the necessary fuel tank. A sound-resisting cabin was fitted to protect the observers from the high-frequency noise.

The main dimensions of the Lucy Ashton are: length between perpendiculars, 190 ft. 6 in.; breadth moulded, 21 ft.; and depth moulded, 7 ft. 3 in. Most of the experiments were made at a draught of 5 ft. 2 in., corresponding to a displacement in salt water of 390 tons at level trim. The coefficients of form in this condition were: block coefficient, 0·685; prismatic coefficient, 0·705; and midship area coefficient, 0·972.

Four Derwent V jet engines were fitted, and proved entirely satisfactory. Each engine delivered a thrust of about 3,600 lb. at a speed of 14,500 r.p.m. The general arrangement of the machinery installation is shown in Figs. 14 to 16, on the opposite page, and the mountings of all four engines, which were identical, are shown in Figs. 17 to 19. Thrust measurement was, of course, of fundamental importance. The device deemed most suitable for this purpose was the Macklow-Smith hydraulic capsule,* and the recorded pressures were read on 10-in. Bourdon gauges. Each of the four thrust-measuring units was calibrated in the dead-load calibrating machine at the N.P.L. and *in situ* during the trials by means of special gear.

Records were taken of the ship's speed, the wind speed and direction, the rudder angles, etc., by the most accurate means available, and the experiments were run over the measured mile course in the Gareloch. Roughness measurements were made over representative areas of the hull surface. Sample results obtained are shown in Fig. 20, opposite, where ship results (corrected for wind and to a standard temperature of 59 deg. F.) are given. In this diagram, Re = Reynolds number, R = resistance, ρ = density, A = wetted surface area, V = velocity (general), V′ = speed in knots, g = acceleration due to gravity, and l = length of ship. Froude's resistance coefficient $= \frac{2{,}938 R'}{\Delta^{\frac{2}{3}} V'^2}$, where V′ is as above, R′ is resistance in tons, and Δ is the displacement of the ship in tons.

* The Macklow-Smith capsule, as fitted in the Lucy Ashton, was described and illustrated in ENGINEERING of December 29, 1950 (vol. 170, page 573).

Skin friction is associated with the type of flow in the boundary layer; whereas, at low Reynolds numbers, the boundary layer is laminar, at high Reynolds numbers it is almost entirely turbulent and the skin friction is much higher than it would be if the layer were laminar at these high Reynolds numbers. On models of the size commonly used in experiment tanks, the boundary layer may be partly laminar and partly turbulent, whereas on full-scale ships only a negligibly small portion of the boundary layer is laminar, the greater part of it being turbulent. Therefore, unless we know how much of the boundary layer is laminar in the model test, we shall be in error in predicting the full-scale skin friction resistance from that measured in the tank. It has recently become standard practice to ensure that the boundary layer is turbulent in the tank tests by introducing a small trip wire near the bow of the model. This is simply a wire of 0·036 in. diameter, fixed to the surface at a standard distance from the bow, and experiments show that the boundary layer behind this wire is fully turbulent. Concurrently with the development of this technique, an experimental method of examining the type of flow on ship models has been developed. A sprayed paint of special composition is used; it is slowly soluble in water and dissolves more quickly when the boundary layer is turbulent. A model, of which the surface has been covered with this paint, is removed from the tank after a run and examined. There is a distinct difference in appearance between the regions in which the boundary layer is laminar and turbulent. Fig. 21, on page 159, shows the laminar area, light in colour forward of the trip wire, and abaft is the dark-coloured area of turbulent flow.

(*To be continued.*)

REPORT ON TRAIN DERAILMENT AT DONCASTER.

A RAILWAY accident report* published last week reveals the fact that drivers frequently fail to adhere to low speed restrictions, of the order of 10 or 20 miles an hour, and recommends that speed indicators should therefore form part of the equipment of the new standard locomotives. The report also contains a suggestion that the behaviour of bolts in crossings should be investigated to ascertain whether they should be renewed periodically, or whether, given good maintenance in other respects, they can safely be left in position until the crossing is due for renewal.

The accident occurred in March last year at Bridge Junction, Doncaster. A passenger train comprising 14 coaches and a horse box, hauled by a class A2/2 Pacific engine, "Cock o' the North," was negotiating a scissors crossover, leading from the slow line to the main line 600 yards after leaving the station. The engine and the first two coaches passed through safely, but the rear bogie of the third coach, or the leading bogie of the fourth coach, was derailed to the left just as it cleared the trailing V crossing of the up main connection; the bogies of the next six vehicles were also derailed to the left at the same place. The rear of the third coach and the front of the fourth coach were diverted more and more to the left by the rails of a long crossover 50 yards beyond, while the front of the train continued along the main line. The third coach was thus tilted and carried forward broadside until the middle of its body struck the pier of Balby bridge. At this moment the engine was pulling the leading end of the coach to the right of the pier while the thrust from the rear of the train carried the trailing end to the left until the coach was virtually wrapped round the pier. The body was crushed against the brickwork and demolished, and the underframe was bent into a U-shape; so far as could be ascertained, all the fatalities, numbering 14, were in this coach. The snatch was so great that the vertical pin of the Buckeye coupling between the second and third coaches—all the coaches had Buckeye couplings—failed in double shear (equivalent to 100 tons).

At the site of the accident the up main line is on a left-hand curve of 48½ chains radius with a designed cant of 4 in., which is suitable for speeds up to 70 miles an hour, though the maximum permissible at the present time is 60 miles an hour. This cant, however, could not be applied to the slow line through the scissors and the line therefore had to be run up steeply through the lead between the 1 in 9 trailing V crossing (in the low rail of the main line) and the switches. A speed limit of 10 miles an hour applied, mainly because of the sharp rise in cant. One of the oak packing pieces that the layout necessitated was split and decayed; a transverse bolt connecting two chairs in the crossing was missing, and the other two had fatigue flaws.

Examination of bolts from other crossings showed that cracks and fatigue flaws were not uncommon. Tests were carried out to assist in deciding at what speed the train had been travelling, and tests were also conducted with two coach underframes on a special crossover to study the sequence of derailment. The inspectors concluded that the disaster was initiated by the bursting of the crossing. The train was travelling at 20 to 25 miles an hour and the crossing was not adequately maintained. The inspectors suggest that layouts with steep cant gradients should be investigated to see whether they can be remodelled.

* *Report on the Derailment which occurred on March* 16, 1951, *at Bridge Junction, Doncaster, in the Eastern Region, British Railways.* H.M. Stationery Office. [Price 3*s*. net.]

SAFETY ELECTRODE HOLDER FOR ALTERNATING-CURRENT WELDING.

ONE of the disadvantages of alternating-current arc welding is the risk of serious shock when the work is being carried out in confined spaces, such as boilers, or at heights above the floor. This risk can be overcome by using an insulated holder and isolating the electrode from the supply when it is not in use, but even then it is necessary to guard against the mistakes that may arise from mishandling. The safety electrode holder which is now being produced by the General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2, and is illustrated in Fig. 1, has been designed to fulfil these conditions. It embodies a

FIG. 1.

FIG. 2.

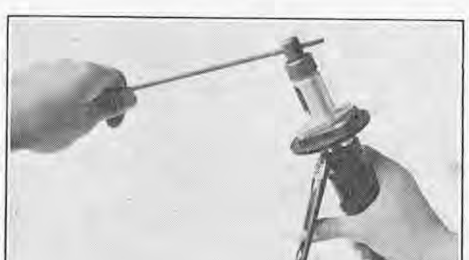


FIG. 3.

switch in the handle which automatically isolates all the exposed metal surfaces in the holder, as well as the electrode itself, from the supply as soon as the operator releases his grip upon it.

The holder is capable of continuous duty with alternating currents up to 300 amperes and will accommodate electrodes up to No. 4 s.w.g. The isolating contacts are housed in the handle and are operated by depressing a lightly-loaded spring lever, which is located along the body of the holder, as shown in Fig. 2. Although the welding current is usually broken at the arc, the switch may have to perform this duty and it has therefore been designed so as to be capable of rupturing the full reactive welding current without damaging the contacts. To prevent this safety feature from being deliberately put out of action by tying the operating lever in the "on" position, a central plunger is used to hold the electrode in position. This plunger must be retracted by an outward movement of the switch lever, as shown in Fig. 3, when it is desired to replace an electrode, an operation which ensures the separation of the contacts and the isolation of the holder and electrode. Other advantages claimed for this holder are coolness in operation, even when working at maximum current, long life, and simplicity of dismantling without special tools. The weight is only 24 oz., owing to the use of a nose-piece made of a light alloy.

BOOKS RECEIVED.

American Society for Testing Materials. Special Technical Publication No. 106. *Triaxial Testing of Soils and Bituminous Mixtures. A Compilation of Papers Presented at the First Pacific Area National Meeting at San Francisco, California, October* 10, 1949, *and the Fifty-Third Annual Meeting at Atlantic City, New Jersey, June* 28, 1950. Offices of the Society, 1916, Race-street, Philadelphia 3, Pennsylvania. [Price 3.50 dols.]

Annuaire pour l'An 1952. Published for the BUREAU DES LONGITUDES. Gauthier-Villars, 55, Quai des Grands-Augustins, Paris (6e). [Price 750 francs in paper covers, and 1,100 francs cloth bound.]

The British Electrical and Allied Industries Research Association. Technical Report. No. G/XT 137. *Series Breaks in Circuit-Breakers: Some Factors Affecting Accuracy in Recording the Distribution of Restriking Voltage.* By F. O. MASON. [Price 7*s*. 6*d*. net.] No. G/T 259. *Intrinsic Safety of Electrical Circuits in Relation to the Explosion Hazard in Industry and Relative Ease of Ignition by Weak Sparks of Various Gases and Vapours.* By J. A. B. HORSLEY. [Price 7*s*. 6*d*. net.] No. L/T 248. *The Zeeman Effect in Astrophysical Spectra.* III. *Bright-Line Stellar Spectra.* By C. E. R. BRUCE. [Price 15*s*. net.] No. L/T 250. *The Static and Dynamic Rheological Properties of Dielectrics.* By W. LETHERSICH. [Price 9*s*. net.] No. L/T 264. *Some Aspects of the Relation Between the Relaxation Spectrum and the Creep Spectrum. A New Mathematical Relation Concerning the Delta Function.* By R. GROSS and H. PELZER. [Price 7*s*. 6*d*. net.] No. W/T 20. *Differential Effects in High-Frequency Dielectric Heating.* By A. MORRIS THOMAS. [Price 6*s*. net.] No. W/T 22. *A Problem in Radial Heat Flow.* By H. GOLDENBERG. [Price 7*s*. 6*d*. net.] Offices of the Association, Thorncroft Manor, Dorking-road, Leatherhead, Surrey.

Earth Retaining Structures. Civil Engineering Code of Practice No. 2 (1951). The Institution of Structural Engineers, 11, Upper Belgrave-street, London, S.W.1. [Price 15*s*. post free.]

Ministry of Transport. Railway Accidents. Report on the Collision which Occurred on 5th August, 1951, *at Ford Station in the Southern Region British Railways.* [Price 6*d*. net.] *Report on the Derailment which Occurred on 16th March,* 1951, *at Bridge Junction, Doncaster, in the Eastern Region British Railways.* [Price 3*s*. net.] H.M. Stationery Office, Kingsway, London, W.C.2.

Production of Heavy Equipment for Power Stations in the O.E.E.C. Countries. Third survey. The Organisation for European Economic Co-operation, Paris.

Colombo Plan Exhibition 1952. Examples of British Consulting Engineering Work in Asia, Australasia and Africa. Published by Princes Press Limited, 147, Victoria-street, London, S.W.1, in collaboration with the Association of Consulting Engineers, 36, Victoria-street, London, S.W.1. [Price 10*s*. 6*d*.]

Structural Adhesives. The Theory and Practice of Gluing with Synthetic Resins. Lectures given in Cambridge at the Summer School held by Aero Research Limited, Duxford, Cambridge, from September 23 to 29, 1951. Lange, Maxwell and Springer, Limited, 41-45, Neal-street, London, W.C.2. [Price 21*s*.]

LAUNCHES AND TRIAL TRIPS.

S.S. "CAIRNGOWAN."—Single-screw cargo vessel with accommodation for twelve passengers, built by William Gray & Co., Ltd., West Hartlepool, for the Cairn Line of Steamships, Ltd., Newcastle-upon-Tyne. First vessel of an order for two. Main dimensions: 419 ft. between perpendiculars by 60 ft. by 37 ft.; deadweight capacity, about 9,400 tons on a draught of 27 ft. Double-reduction steam turbines developing 4,650 s.h.p., constructed by Parsons Marine Steam Turbine Co., Ltd., Wallsend-on-Tyne; and two Babcock and Wilcox oil-fired water-tube boilers, constructed by the shipbuilders. Service speed, 13 knots. Launch, December 14.

M.S. "ANNO."—Single-screw cargo vessel, built by Hall, Russell & Co., Ltd., Aberdeen, for Mitchell and Rae, Ltd., Newburgh, Aberdeenshire, for service in the coal, grain and potato trade. Main dimensions: 120 ft. between perpendiculars by 24 ft. by 9 ft. 6 in. to upper deck; deadweight capacity, 326 tons. British Polar two-stroke direct-reversible Diesel engine, constructed by British Polar Engines, Ltd., Glasgow. Trial trip, January 9.

M.S. "CALTEX DELHI."—Single-screw oil tanker, built and engined by William Doxford and Sons, Ltd., Sunderland, for the Overseas Tankship (U.K.), Ltd., London, W.1. Third vessel of a series of four for these owners. Main dimensions: 490 ft. overall by 61 ft. 9 in. by 36 ft. 3 in.; deadweight capacity, about 12,000 tons on a draught of 28 ft. 2½ in. Doxford five-cylinder opposed-piston balanced oil engine, developing 5,150 b.h.p. at 108 r.p.m., giving a service speed of 13¾ knots. Launch, January 10.