THE ENGINEER

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A BY-WAY IN ENGINEERING DESIGN

Engineering development has by-ways as well as highways of advance. Most of the products of engineers have been made and have been continuously improved over so many years that the problems set in design and manufacture are clear-cut, the advantages and disadvantages of differing arrangements are well-established and there is little room for innovation except in, often rather abstruse, detail. Those working upon such products are driving along the highways of engineering. The line of further advance is clearly established. Achievement waits only upon the coming of improved materials, upon the completion of detailed researches which will make possible greater precision in design, or upon the growth of demand for bigger machines or machines designed to meet more onerous conditions. The sight lines are long, the way relatively smooth, and there are no cross-roads or sudden partings of the ways. By contrast, the by-ways of engineering design are far less important. The economy of the country as a whole would not be noticeably affected were many of them never explored. But, like an English country lane, they are full of surprises and unpredictable hazards. The object to be achieved may be distinct enough ; but none of the signposts mark at all clearly the right direction of travel. There come frequent and confusing partings of the way. What seems the more attractive road leads only to a dead end ; whereas what seems a side-alley turns out to be the straighter route. Like Alice in the garden, an explorer may find the quickest way to reach a given spot is to start off in precisely the opposite direction!

The work of engineers in just such a fascinating by-way is recorded in the Annual Report of the Institute of Seaweed Research for 1955, which in a valedictory way, reviews the work done over the past ten years. Seaweed can be used for the production of animal feeding stuffs and fertilisers, has medical uses and contains certain raw materials for the chemical industry. A great deal of work has had to be done upon the investigation of its qualities and of methods of processing it and in discovering where and in what quantity it grows. Those have been by-ways for chemists, biologists and botanists. The engineering by-way has lain in the devising of means of harvesting the weed in quantity and at economic cost. The problem was to design a mechanism which could cut or pull the weed from the bottom at depths down to five fathoms from a rough sea-bed and deliver it into a boat at an economical expenditure of power ; and the mechanism had to be so sturdy and reliable that it would require little maintenance and be operable by ordinary fisher-folk. It is difficult enough, as agricultural engineers well know, to devise harvesting machinery that will operate satisfactorily on land. But the Seaweed Research team had to devise machinery that could operate reliably from a boat small enough to run close inshore in seas off the Scottish coasts which are seldom smooth. It had to start from scratch with no history of previous development to act as a guide. The progress made has been recorded from time to time in our pages in articles contributed by the men actually doing the work. Primarily, development has proceeded along the classic lines of trial and error. But once the dimensions of the problem had been determined in this way the resources of more academic research were drawn upon to investigate more exactly how grapnels or cutters operated or how cut weed was entrained into a suction pipe. It has been a fascinating story and a further article will shortly be published in our pages, bringing it right up to date.

So successful has the research team proved itself that it has "worked itself out of its job." On the advice of the Advisory Council on Scientific Policy, the Government has now decided that further technological studies "would more properly be undertaken by industrial concerns." Since June of this year the work of the Institute has been restricted to the support of algal studies at universities, the provision of information, and the fostering of seaweed utilisation by crofting communities. So has ended an exploration of a by-way of engineering design ; hence the valedictory nature of the year's report on the work of the Institute. But now the sign-posts have been erected, now that the pioneering work has been done, it is very much to be hoped that one or more commercial firms will step in to carry on the work and pursue development further. For though the demand for equipment may not be high—the sales value of the whole output of seaweed products does not much exceed £1,000,000 per year and the cost of harvesting must be only a small fraction of that figure—the lines upon which immediate further advances could be made have been already established by the Institute. Moreover, as other countries also are interested in the harvesting of seaweed, there may be opportunities for export.

MOTIVE POWER FOR BRITISH RAILWAYS

The publication by the Diesel Engineers and Users Association of the text of the address delivered by Mr. R. C. Bond at its recent annual luncheon makes available a point of view which will receive the attention appropriate to any considered utterance by the Chief Mechanical Engineer, British Railways. At the outset, Mr. Bond paid just tribute to the service given by the steam locomotive during the past century and a quarter. Indeed, we are all likely to feel something of a pang when, passing a pitiful assortment of old locomotives resting and rusting alongside the track, the steam engine hauling our train emits what might be mistaken for a valedictory whistle, after the example of the Roman soldier who, saluting Claudius, cried: "*Ave, Imperator, morituri te salutant*!" We have not yet, however, come quite to the end of the steam locomotive era and readers of Mr. Bond's address will note his remarks as to the cost of a diesel locomotive having capacity equivalent to that of the largest express passenger steam locomotives now operating in Great Britain. After quoting the figures (£95,000 for the diesel and £35,000 for the steam locomotive) Mr. Bond goes on to observe that "the limiting conditions, where overall costs break even between diesel and steam power, are determined by the relation between fixed annual charges for interest and depreciation, on the one hand, and operating and maintenance costs, on the other hand. The thermal efficiency of diesel traction is about three times that of steam, operating wages may be less and maintenance costs are so far not very different. The interplay of all these factors boils down to one vital result—that to pay their way at the annual mileages which can be got out of locomotives in this country, appreciably fewer diesels must be enabled to do the work of a given number of steam locomotives. And thus the vital factor is that the potentially greater availability of the diesel must be turned into reality—the locomotives must keep going all the time, they must be reliable and free from trouble, they must be as simple as possible to maintain." This seems to us to be manifestly and irreversibly true and the words will surely be pondered by the manufacturers entrusted with the supply of the pilot orders for 174 diesel locomotives referred to by Mr. Bond. He added that "We are interested in these diesel engines and transmissions simply and solely from the point of view of their capabilities in traction service as component parts of a locomotive."

There is already a great accumulation of experience relating to diesel locomotives. For example, it was as long ago as 1912 that the first diesel main line locomotive was tested. Twenty-four years earlier (in 1888) Sir William Thomson (afterwards Lord Kelvin) reported on his examination of a two-cylinder vertical Priestman oil engine "mounted upon a truck which is worked on a temporary line of rails to show the adaptation of a petroleum engine for locomotive purposes." As for railcars, it is as many as forty-three years since what may have been the first diesel-electric railcar went into service. It was still at work when reported on in 1933. Diesel locomotives were thus in use for traction before most of us were old enough to distinguish a locomotive from a perambulator. Nevertheless, it appears to remain difficult—as Mr. Bond remarked—"to define exactly the rating which should be assigned to diesel engines under traction conditions to ensure reliable service at reasonable maintenance cost. And thus we must exercise caution in assigning the loads to be hauled by our diesel locomotives." This is no new theme and it certainly augurs well for the future of motive power on British railways that so cautious and practical an approach is being made. It was pointed out some years ago by an American locomotive engineer that "the maintenance cost of any type of locomotive increases as the working-load factor increases. Proper design of a motive-power unit should provide some reserve power for emergency use, but not such an excess as to result in uneconomically high cost of construction." At the time those words were written the approximate cost of diesel-electric express locomotives was 87.50 dollars per horsepower, corresponding steam locomotives costing 35.00 dollars per horsepower. This compares fairly closely with the ratio to-day.

It has long been recognised that the electrification of our railways must be widely extended and Mr. Bond expressed this in the following plain words:—"Where traffic density is sufficient to justify the inevitable heavy cost of providing the fixed equipment needed for transmission and distribution of the electric power to the railway routes, electric traction is superior, from all points of view, to the alternative of diesel or steam. It provides, too, the most practicable, if not the only means, whereby the possibilities of nuclear energy can be exploited for rail traction." Since the date upon which the above words were uttered, events in the Middle East have reminded everybody of certain hazards which need to be noticed in connection with any project for establishing a public traction system based on fuel oil. The hazards apply not only to supply but to cost and quality as well. Much can happen in the life span of a locomotive, and we do well to regard all-round security as the primary objective of the railway engineer. This is not conservatism, but practical wisdom. Experience has certainly shown that as against a steam locomotive of equal horsepower "the diesel has the advantage of greater power for accelerating at low speeds and greater sustained horsepower at very high speeds." But experience also warns that overloading must be avoided not only in order to ensure the requisite high degree of reliability, but with a view to preventing excessive maintenance cost. In this connection the report made by Coverdale and Colpitts in 1938 showed how the maintenance costs of diesels are higher than for steam locomotives when the total load is much above 450 lb per horsepower. We do not doubt that in the forthcoming re-equipment of the British Railways, every effort will be made to reduce, within limits determined by safety, the weight to be hauled per passenger seat.

CENTENARIANS

In our Centenary Number, published on January 4, 1956, we printed a list of firms, Institutions and Journals which had celebrated their centenaries prior to that day, and expressed our congratulations to them. We realised that, in spite of our endeavours to make the list as complete as possible, there were likely to be omissions. Our apologies are due to several firms and one society for the omission of their names from our original list. Their names are printed below.

1660 (*circa*)	Henry Beakbane (Fortox), Ltd.
1790	Plenty and Son, Ltd.
1790	Whessoe, Ltd.
1805	Rylands Brothers, Ltd.
1815	Hayward Tyler and Co., Ltd.
1816	G. N. Haden and Sons, Ltd.
1820	Dawson and Usher, Ltd.
1825	W. J. Fraser and Co., Ltd.
1833	John Oakey and Sons, Ltd.
1834	Gibbons Brothers, Ltd.
1837	Richardsons Westgarth (Hartlepool), Ltd.
1840	John Thompson, Ltd.
1842	Wilson's Forge, Ltd.
1848	William E. Cary, Ltd.
1848	George Clark and North Eastern Marine (Sunderland), Ltd.
1852	William Boulton, Ltd.
1852	Sir James Farmer Norton and Co., Ltd.
1853	Royal Photographic Society of Great Britain
1854	Thomas Hunt and Sons, Ltd.
1855	J. Blakeborough and Sons, Ltd.
1855	Penney and Porter, Ltd.
1855	George Wailes and Co., Ltd.
1855	Samuel Williams and Sons, Ltd.

A Seven Day Journal

Fenchurch Street–Southend Electrification

THE work which has now been started on the rearrangement of the rail approaches to Barking station forms one of the most important parts of the electrification scheme of the London, Tilbury and Southend line. This work, which will cost some £1,750,000, includes the removal of Barking goods depot to a site close to Ripple Lane, a new marshalling yard. A new double-track bridge is to be built over the River Roding and a main flyover west of Barking station to carry traffic to and from Woodgrange Park over the main Fenchurch Street–Southend and London Transport District lines. A second flyover west of the station will carry the westbound London Transport District line over the Fenchurch Street–Southend lines and a burrowing junction east of the station will enable westbound London Transport trains to pass under the Fenchurch Street–Southend line. Rearrangement of running lines and platforms will allow cross platform exchange between the District line and the London, Tilbury and Southend service in both directions. All Eastern Region trains will be able to use the up and down Tilbury line platforms and a subway will connect all platforms at Barking station. A new stabling depot for London Transport trains is to be provided to the east of Barking station—about mid-way between Barking and Upney stations. Buildings at Barking station, both on street level and on the platforms, are to be reconstructed and a complete resignalling scheme includes the construction of a new signalbox which will initially replace two existing signalboxes (Barking West and East) and will eventually control all train movements as far west as Plaistow. The new box will also provide for London Transport District line signalling.

The Radio Show

THREE interesting trends can be discerned at the Radio Show, which was opened at Earl's Court on Wednesday, August 22nd, by the Rt. Hon. Reginald Maudling, the Minister of Supply. The first is the introduction of transistors in radio receivers. In some portable sets in the show, transistors are used throughout instead of valves, resulting in reduced size and battery consumption, with some increase in cost; in other sets a compromise between these qualities is reached by using both transistors and valves. The second trend is towards the use of printed circuits to reduce the amount of wiring and soldered joints and, therefore, production costs. Printed circuits are incorporated in about six different makes of radio receiver, compared with only one at last year's Radio Show. The third major development is that an increasing number of radio receivers and radiograms, about 200 in all, are designed to accept the v.h.f. waveband as well as the normal wavebands. It is expected that, by the end of this year, the B.B.C. Home, Light and Third programmes will be available by the v.h.f. frequency modulation system, to give interference-free reception to more than 84 per cent of the population of the United Kingdom. Exhibits concerned with guided missiles and radar are prominent among the displays arranged by the three armed Services. The G.P.O. is showing improved electronic equipment for letter sorting and the new Electronic Random Number Indicator which is to be used for drawing the prize-winning Government premium bonds. Another interesting exhibit is the electronic timing apparatus that was used for the record-breaking flight of the Fairey "Delta II" aircraft, as described in our issue of March 23, 1956. The Radio Show remains open from 11 a.m. to 10 p.m. daily until Saturday, September 1st.

"Model Engineer" Exhibition

THE thirty-first "Model Engineer" Exhibition which is being held at the New Horticultural Hall, Westminster, was opened on Wednesday last and will continue until Saturday, September 1st. For the first time the exhibition includes a display of Russian models, consisting of six large ships and three miniatures. As in previous years, the models on show cover practically every aspect of engineering, and the exhibitors include manufacturers of model-making equipment and tools. The majority of the exhibits in the general mechanical section are working models, but the section is subdivided into different classes, including non-working scale models, tools and equipment, and examples of general craftsmanship. Locomotives and ships, as in other years, seem to retain their popularity with modellers of all ages. The locomotives range from 0-4-0 shunters to the more elaborate "Pacifics" and "Mallet" compounds. To the intracacies of modelling ships, in recent years has been added the problem of radio control. In addition to steering the boat, enthusiasts can now control many other shipboard functions, such as dropping the anchor or raising a flag while the boat pursues its course many yards away. There are demonstrations in the marine tank of powered models and radio controlled models. Other exhibits range from a model of a Percival P67 "Provost" R.A.F. trainer, costing five shillings, to a John Fowler road locomotive valued at £3000. This year, for the first time, there is the possibility that some of the prizes and trophies may go out of Britain, as the Russian models are eligible to be awarded prizes in any of the appropriate sections.

The Engineer

100 Years Ago

(AUGUST 22, 1856)

"SHIPBUILDING ON THE TYNE"

"Some months ago, upon the proclamation of peace with Russia, it was anticipated that iron shipbuilding, which had been carried on with great vigour upon the Tyne to meet the requirements of the transport service, would undergo a sudden collapse. This has not been verified, and large iron vessels are built and launched with wonderful rapidity from the building yards upon this river. There is no doubt that the great expedition with which immense quantities of material were removed to the seat of war by screw vessels has given merchants and maritime companies on the Continent an idea of their real value, and since the peace there have been numerous inquiries for screw steamers by merchants and companies belonging to the Baltic, the Elbe and Levant; one firm on the Tyne alone has launched 3500 tons of iron shipping since the commencement of the year. . . .

"On Monday afternoon a large East Indiaman, timber-built, and named the 'Gosforth,' was launched from Messrs. T. and W. Smith's building-yard at North Shields. This fine vessel was built under a capacious glass shed, and her launch, from an accident that occurred, might have been of a fearfully tragical character. When she moved away, from some cause or other, she left a considerable portion of the front part of her cradle standing on the starboard side, which to a considerable extent changed the centre of gravity, and, as sailors termed it, made the vessel run 'like a dog upon three legs.' The run to the river was but short, fortunately, and the 'ways' stood firm, though she tore away a large post next to the river. If she had lurched over she would have killed hundreds of people, as she would have smashed down the shed. This occurrence caused great excitement; the vessel is not in the least injured."

Mr. John Wilfred Rodger, M.I.E.E.

MR. JOHN WILFRED RODGER, who was managing director of Bruce Peebles and Co., Ltd., died in Edinburgh on August 16th. He had been with the company thirty-two years. John Rodger was born at Warrenpoint, Co. Down, in 1887, and was educated in Northern Ireland. On leaving school he went to study mechanical and electrical engineering at Bolton Technical School, Manchester School of Technology, Woolwich Polytechnic and Goldsmith's College. He served an engineering apprenticeship with Paterson Cooper and Co., and then continued his practical training with Royce, Ltd., Manchester. His experience was broadened by his subsequent work with Johnson and Phillips, Ltd., in various capacities in the testing, design and sales departments. Specialisation in transformers came with his appointment as chief transformer designer with Ferranti, Ltd., and later with the Hackbridge Electric Construction Company, Ltd. In 1924 Mr. Rodger joined Bruce Peebles and Co., Ltd., to start and develop the manufacture of transformers, for the first time in Scotland. There he was responsible for equipping and managing the transformer factory, which has been extended six times since it was first established. When he became works manager and chief engineer of the company in 1933 he assumed administrative and technical responsibility for the design and manufacturing departments for all the company's products. In 1941 he was elected to the board of directors and was appointed general manager of the company in 1943 and managing director in 1946. Export markets became his particular interest and his knowledge of overseas requirements was obtained at first hand by extensive tours abroad. Mr. Rodger was a member of the Institution of Electrical Engineers, a past president of the Scottish Engineering Employers' Association, vice-president of the Edinburgh Chamber of Commerce, and a member of council of the British Electrical and Allied Manufacturers' Association. Educational matters claimed much of his attention and he was a member of the I.E.E. joint committee for National Certificates and Diplomas in Electrical Engineering (Scotland) and a governor of Heriot-Watt College.

Further French Locomotive Experiences

By EDWARD H. LIVESAY

(Continued from page 223, August 17th)

No. III—PARIS-CHERBOURG EXPRESSES

THE profile (Fig. 1) of the line from Paris to Cherbourg shows very clearly the severity of the route ; I do not remember ever travelling over such a succession of heavy gradients in a like distance. One would expect it to be worked by the latest types of engines, such, for instance, as are found on the Nord, or perhaps by eight-coupled engines, similar to those running to Nancy over the Est, or taking the " Mistral " from Lyons to Marseilles. On the contrary, old rebuilt " Pacifics " are employed, taking 600/800-ton trains over it at high speed, engines with only 56 tons of adhesion weight, and a total weight of under 100 tons. As was mentioned in the last article, they are modelled on the Paris-Orleans engines (Fig. 2), which are now working the Nord Region trains, such as the " Golden Arrow," and were reconstructed twenty years ago on the same Chapelon lines which have enabled both types to achieve such fine results. I remember saying once, perhaps more than once, that the work done by Chapelon-improved engines often verges on the incredible, and the following example is given to justify this panegyric ; others could be adduced almost *ad infinitum*. It shows what these old Paris-Orleans engines were doing seventeen years ago, and are no doubt still capable of doing over the Nord line where they are now found. The details of this remarkable run were recorded at the time by Baron Vuillet, who has made such a study of French locomotive work and whom I had the pleasure of meeting in Paris. It took place in 1937. The engine No. 231/725 was a rebuilt Chapelon " Pacific " hauling a Special bringing members of the International Railway Union back to Paris, and the train consisted of eight vehicles weighing approximately 400 tons, booked non-stop from Bordeaux to St. Pierre-des-Corps. It was deliberately started 25 min late to allow ample scope for a time-recovery demonstration on the working schedule, and a permanent way slowing to 6 m.p.h., which occurred immediately after getting away, caused a further loss of 3 min. Yet the 28 min were entirely regained in the 216·7 miles to St. Pierre-des-Corps, which were covered non-stop 183 min, or 180 min net, at an average speed start to stop of 72·2 m.p.h. The extraordinary merit of this performance, however, is brought out by the Flaman recording (Fig. 3), which shows the remarkable regularity of the running, inasmuch as the legal 74½ m.p.h. limitation was never exceeded, nor did the speed fall below 68 m.p.h., save when starting and stopping, and at the three slowings, gradients having no effect, though the profile shows that these were far from negligible. From the speed line on the graph it is impossible to detect rising or falling gradients, where they begin or end ; in fact, it is impossible to show the majority in a small scale reproduction, and I have not attempted to indicate more than a mere tithe of them ; if the original graph is held a couple of feet from one's eyes the speed line looks absolutely level. Yet the track was far from level, as the profile shows. Charmant, for instance, is near the summit of a 23½-mile climb, much of it 1 in 200, on which the speed never fell below 68 m.p.h.; the worst part of it, 5 miles also 1 in 200, was surmounted at 71. Up the long rise through St. Maire, again on the same gradient, the speed remained between 68½ and 71. The graph shows three service slacks, down to 50 m.p.h. at Libourne, and to 15 m.p.h. through Poitiers and Angouleme. As a demonstration of perfect driving, scarcely any variation of speed being permitted up, down, over summits or on the level, nothing could well be finer, yet the engine was by no means big, the load substantial, strong wind and rain making things more difficult throughout the run. This was done, be it remembered, seventeen years ago, by an engine even then not in its first youth, but rejuvenated by the application of advanced principles to a basically good design. I do not think the description " incredible " is too adulatory of this performance. Such work has not, to my knowledge, been done outside France ; I wish it had been done in Britain, and was still being done there—but it certainly isn't !

These fine engines thrive on conversion, some having become 4-8-0's, one of which performed the following " incredible " run with a load of no less than 1000 tons. Leaving Bordeaux, the speed rose to 60½ in the first 3·7 miles, after having been restricted through the freight yards ; the drawbar horsepower reached 2200 at the first kilometre, increasing then to 2300. Out of Libourne, the only intermediate stop short of Angouleme, speed rose to 59 in 3½ miles, the train resistance being low, 1750 h.p., kept the train moving at 60-65 m.p.h. on the level, and at about 45 m.p.h. on 1 in 200 gradients. The average speed from Bordeaux to Angouleme was over 55 m.p.h., though at least half the distance tends steadily upward —with 1000 tons ! Again the word " incredible " is fully justified.*

The chief dimensions of the prototype " Pacifics " are given with Fig. 2.

Coming to my recent Paris-Cherbourg runs, train No. 301 left the Gare St. Lazare at 9.10 a.m., handled by a rebuilt " Pacific," No. 231-D645, built in Glasgow during the first war, and approximately forty years old. In addition to Mecanicien Lanquier and Chauffeur Mallnoe, Monsieur Devaud, Superintendent of the Cherbourg Depot, and Monsieur Faure, Chief Mecanicien of the same shed, came with me, the former acting as courier and interpreter. The train, loaded to 600 tons, left punctually, the engine showing no trace of slip, though adhesion weight is only 56 tons, and acceleration was rapid, past the large Batignolles Locomotive Depot between Pont Cardinet and Clichy-Levallois, to which the engine belonged, reaching 60 m.p.h. by the time the Seine was crossed at Asnières, my *pied-à-terre* in Paris. An interesting and busy piece of line this, with at least half a dozen tracks over which a great variety of traffic shuttles between Paris, Dieppe, Havre and Cherbourg, in addition to local trains to St. Germain, Argenteuil, Poissy and other suburbs. Every kind of motive power is to be seen—steam, diesel, electric, on expresses, autorails, push-and-pull, double-deck and at night, freight. The electrics are only local ; they leave from the west side of the Gare St. Lazare, crossing under the main lines just beyond Asnières by " burrowing " tracks so common round Paris. These services are frequent, but are not so fast as the corresponding London electrics, nor is their acceleration so rapid, due, I believe, to lower voltage. I had so often watched all this kaleidoscopic traffic from a lineside vantage point near Asnières, le Rue Henri Barbusse, that it was pleasant to be taking a more active and intimate part in it from behind the scenes, as it were; or rather, on the stage.

Round sweeping curves, up 1 in 200 through Sartrouville and Maisons-Lafitte, down through Achères—the name struck a chord of memory connected with the early days of the automobile.† Nothing serious in the way of gradients was met until 2 miles

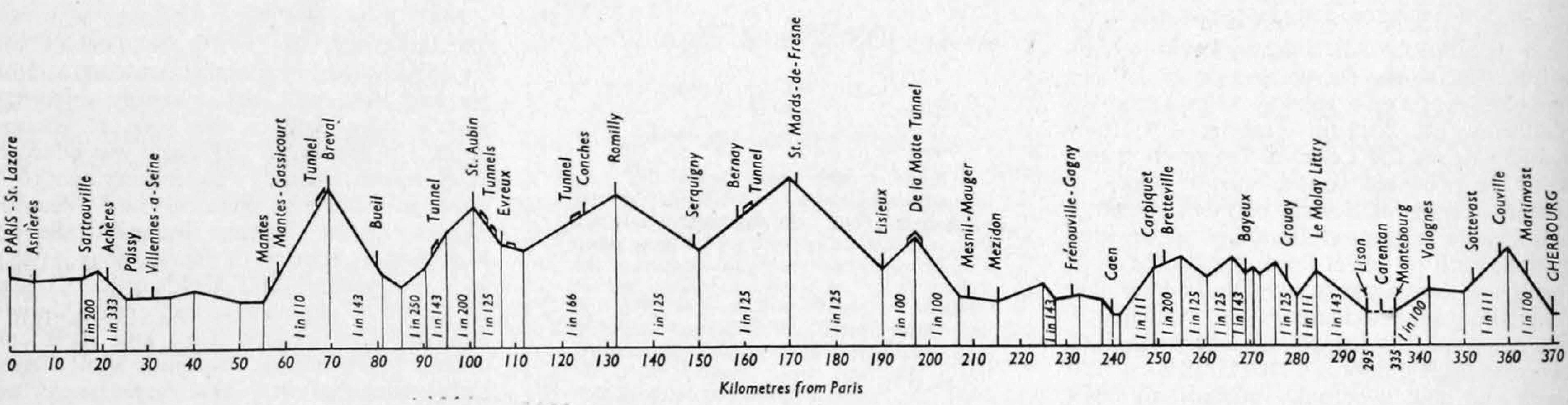
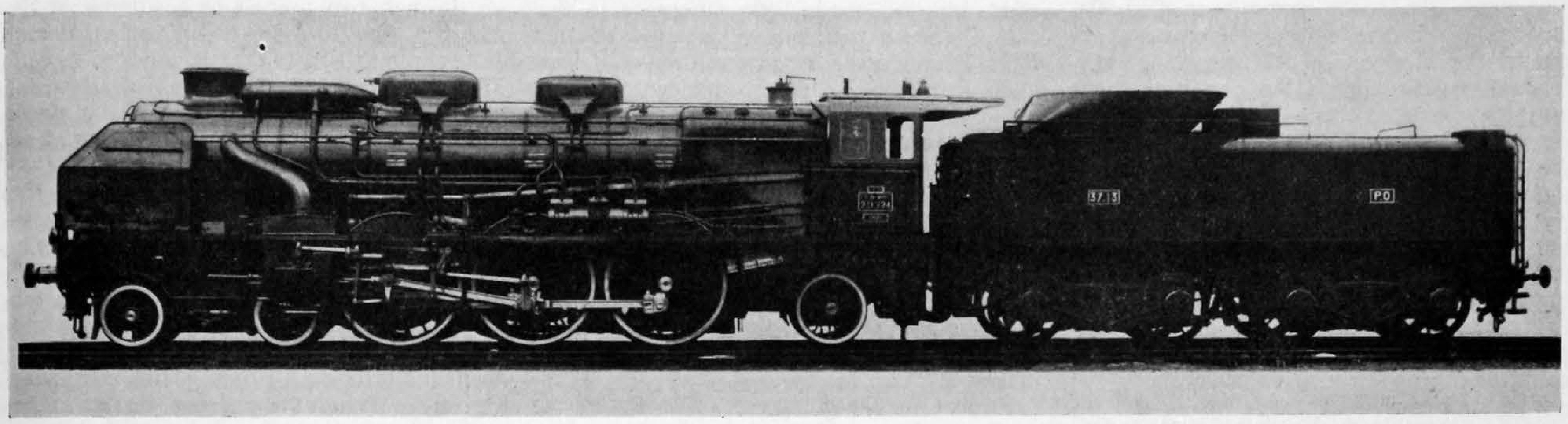


Fig. 1—Condensed profile, Paris-Cherbourg, ruling gradients

* The recordings of these runs were done by Baron Vuillet and published in various journals, including the *Railway Magazine*, from which they are taken.

† In the Forest of St. Germain, in the direction of Achères, April, 1899, for the first time a speed of 60 m.p.h. was reached and exceeded by a motor vehicle on the common road. Camille Jenatzy, driving a torpedo-shaped electric car designed by himself, covered 2km, the first from a standing start, in 47⁴/₅ sec, and the second in 34 sec, 105·882km, or 65 miles 1404 yards per hour.



Cylinders (two), h.p.:	
Diameter	16½in
Stroke	25½in
Cylinders (two), l.p.:	
Diameter	25½in
Stroke	25½in
Ratio h.p. to l.p.	1/2·32
Receiver volume, cubic feet	10·9

Heating surface:	
Tubes and flues (inside area), square feet	1797
Firebox, square feet	164
Siphon, square feet	27
Superheater, square feet	784
Total, square feet	2772
Firebox, Belpaire, one siphon, grate area, square feet	46·5

Boiler: 19ft 4in between tube-plates, 5ft 6in diameter.	
Steam pressure	246 lb
Driving wheels, diameter	6ft 5in
Weight:	
On driving wheels, tons	56·25
Of engine, tons	100·15
Tender, tons	70
Coal, tons	9
Water, gallons	7700

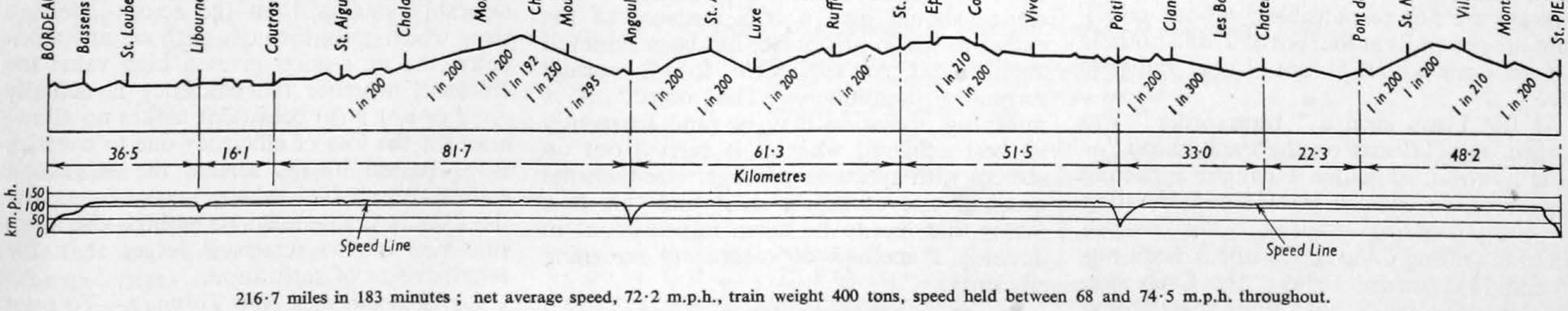
Fig. 2—Four-cylinder compound "Pacific," Paris-Orleans Railway

of 1 in 200 began nearing Mantes, passed at 9.50, at 60-plus, 39 miles in 40 min; this was succeeded a mile or so farther on at Mantes-Gassicourt, by a tremendous climb of 8 miles at 1 in 110, to the peak at Breval, at which the speed had fallen to 45 m.p.h.; the h.p. and l.p. cut-offs were 45 per cent and 65 per cent, respectively, with pressure slightly down, notwithstanding Mallnoe's best efforts; a good man, this, doing his utmost. The load, it will be remembered, was 600 tons. Thence, without even the briefest "rest-and-be-thankful," the line dropped for 10 miles, mostly at 1 in 143, followed by another great climb of 11 miles, the gradient varying from 1 in 143 to 200, reaching the summit at St. Aubin, after which it fell at 1 in 125 through two tunnels to Evreux. It had been heavy going nearly the whole way from Paris, yet 71 miles had been covered in 76 min by this forty-year-old engine hauling 600 tons, fettered by an overall limitation of 75 m.p.h., strictly observed, not merely because there were officials in the cab, but because the Flaman recorder kept accurate tab on whatever happened. If British engines were fitted with recorders it is very improbable that accidents of a kind that have occurred recently would have done so; still less likely were audible signalling the rule, as it is in France. The presence of both these devices in French cabs gives me, at any rate, a feeling of security and confidence not always experienced elsewhere.

Water was picked up a little beyond Evreux, the apparatus in the cab including a long lever calling for two men to operate it when withdrawing the scoop, though the speed was reduced to about 40 m.p.h. over the trough. Monsieur Faure now took over the firing for a while, to "spell" Mallnoe, who had been going hard for some time, and had earned a stand-easy. Monsieur Faure was clearly an expert with the shovel, whom it was a pleasure to watch, and a 13 mile pull up to Romilly gave him a good chance to demonstrate finesse. Another sharp drop followed Romilly, several miles of 1 in 125, then a brief level stretch and up again for a further 13 miles, much of it 1 in 125 *en route* and nearing the summit at St. Marde-de-Fresne; a similar descent right into Lisieux. Certainly this was a very heavy route, the hardest I came across in France or, in fact, that I can remember anywhere else either. Down these descents an injector was invariably put on, the regulator being shut, and under such circumstances the A.C.F.I. feed-water pump was out of action; this normally takes care of boiler supply.

A very heavy 1 in 100 climb succeeds Lisieux into the de la Motte tunnel; then 7 miles down at the same steep inclination to Mesnil-Mauger, after which things moderated into Caen, though there was still considerable curvature and not much really level going. There was plenty of war-damage to be seen too, but also an immense amount of reconstruction—white-walled, red-roofed houses, stone bridges, practically all replacing those damaged or destroyed in the invasion, or by the preliminary Allied bombing. There did not seem to be as much traffic over this line as one would expect, passing trains being few, and certainly there was far less movement on the roads than in England. The train came to a stand in Caen at 12.05, having made 155 miles over a very difficult line in 175 min, an average of 54·5 m.p.h., a fine performance by an old engine showing no signs whatever of senility, which had more than once induced an entry, "riding at speed *admirable*." It came off here, and I was quite sorry to see it go away to the shed.

Another "Pacific" of the same type, No. 231-D561, took the train out of Caen at 12.16, the load having been reduced to ten coaches, say, 475 tons. Almost at once a heavy climb began, 5 miles in length, most being 1 in 111, ending at Bretteville, followed by a succession of saw-tooth variations for 40 miles through Bayeux to Lison, many at 1 in 111 to 150, with not half a dozen miles of level in the whole distance. Yet the speed remained high; up, down, anywhere, seldom below 60 and often up to the 75 limit. A stop was made at Bayeux; this was very evidently the invasion zone; Arromanches was only a few miles away to the north, with the sea so close that Caen suffered naval bombardment from the 15in guns of British battleships. Lison, and another stop, and at Carentan; gradient fluctuations were incessant—Fig. 1 only shows ruling figures on the different sections, the most important—the changes taking place so often that there was seldom a mile without an alteration. Though the terrain looked fairly level, the track showed an upward inclination through Valognes (stop) to the foot of a steep climb of several miles through Sottevast to the peak at Couville, after which it dropped immediately down a severe declivity of 7 miles at 1 in 100 right into the terminus at Cherbourg, arrival time being 2.12 O.T. The approach to Cherbourg was impressive, after catching sight of the



216·7 miles in 183 minutes; net average speed, 72·2 m.p.h., train weight 400 tons, speed held between 68 and 74·5 m.p.h. throughout.

Fig. 3—Flaman record of run from Bordeaux to St. Pierre des Carps, by rebuilt "Pacific" No. 231-725, Paris-Orleans Railway, showing remarkable uniformity of speed under all conditions of gradient

port from the rocky summit at Couville, through which the defensive German lines ran in the final phase of their occupancy. It was easy to picture the conditions that must have existed then—the holding of the ridge by the enemy, their dislodgment by the Americans and withdrawal down the rock-bound clefts through which the train swept at high speed, nearing 70 m.p.h., into the station. The riding was not quite as good as it had been earlier in the day, but one could safely put much of this down to track conditions, all the lines in this part of the country having been badly damaged during the invasion period.

The return run to Paris was made on another rebuilt "Pacific," No. 231-D750, the train consisting of ten cars, say, 475 tons gross. Messieurs Devaud and Faure again accompanied me, the enginemen being Messieurs Hainville and Zoonekyndt. Leaving at 4.58, the great 7-mile 1 in 100 climb, beginning almost at the end of the platform, immediately called for everything the engine had, with full regulator and both valve gears 65 per cent, but it was tackled without any trouble, the speed never falling below 45 m.p.h. right to the summit. The profile shows the incessant and heavy gradients facing the engine over the whole stretch from Cherbourg to Caen ; stops were made at Valognes and Carentan, only a couple of minutes being allowed at each. As I had taken plentiful notes on the outward journey from Paris, it did not seem necessary to do much returning over the same route, but merely to jot down any odd item of interest. For instance, the Flaman recorder, with which every French locomotive is fitted, irrespective of class or work on which it is engaged, has two hands, one registering the actual speed, the other remaining set at the line limit. The first must not be allowed to pass the second ; if it does, the fact appears on the graph—and the driver appears on the carpet in due course. Another entry concerns something I have mentioned again and again in these French articles—the riding of the engine. Quoting it verbatim, without subsequent colouring : "The same *perfect* riding, even better than this morning—100 per cent—a joy to be on this engine." A little later, still evidently enthusiastic, I find : "Why don't British (railwaymen) come over and try for themselves ? Thousands of miles on the footplate gives me the ability to judge and the right to say what I think." Yet this engine was probably thirty-five to forty years old. I daresay some readers may have thought my eulogies on the fine riding—which *ipso facto* indicate condition and good shop work of the average French locomotive—as exaggerated. I can only assure these doubting Thomases that it is not. I have never once ridden in France on any engine that even approached "bad" conditions ; most were "good" to "perfect." The running condition of French engines is undoubtedly much higher than British ; but, having made that assertion, in justice to B.R., I admit that for this state of things the railways are not responsible ; labour conditions are generally at the root of it, and nothing can be done about it until these radically alter.

At the Lison stop a "train order" was handed up—"Beasts on the track ahead"—actually cows, of which I caught a fleeting glimpse as we slowed out of consideration for them nearing Bayeux. On longish straights nearing Caen the 75 m.p.h. limit was hit and held several times ; the Caen stop was longer than usual, three cars being added, bringing the load up to nearly 600 tons. We left at 7.08, darkness falling soon after, but this made little difference in the cab, filled as it was with soft, mellow electric light, punctuated by intermittent blinding glare from the fire door ; incidentally, the coal was better than average, less dusty. Another entry : "The charm of electric light—controls, gauges, &c., as easy to read as in daylight—why do we still run in darkness (in Britain) ?" Surely it is time we did better ; an oil lamp cuddling up against the water gauge is *infra dig*. on a modern locomotive. Again : "Engine keeping up easy, springy motion—cannot help being enthusiastic at beautiful running of French machines."

From Caen the going was somewhat easier as far as Mesnil-Mauger, at the foot of a severe 7-mile 1 in 100 climb up to the de la Motte tunnel, which the engine made light of, but the fireman could not—his shovel was seldom at rest. The peak passed in the roaring blackness of the tunnel, the speed rising rapidly down a similar steep drop into Lisieux, where a stop was made at 7.51 ; 33 miles of very heavy going had been covered in 43 min. Away after a very brief stop, typical of French station work. Zoonekyndt had every reason to get busy with his shovel again, a 14-mile ascent, mostly 1 in 125, beginning at once, and continuing to St. Marde-de-Fresne, followed by switchback swoops, up and down, over Romilly peak, then falling steeply down to Evreux, which was reached at 9.10, 55 miles in 77 min. This may not sound very impressive, but it was a good performance for that old engine to take a 600-ton train over a succession of heavy inclines, while limited to 75 m.p.h. Leaving Evreux after another short stop, 3 miles of 1 in 125 lead up through two tunnels to a summit at St. Aubin ; then 10 miles down and an immediate climb at 1 in 143 for 10 miles to Breval. Then another 10 miles' descent, a clean sweep, into Mantes, where all the heavy work ended, as from there to Paris there were no more gradients in any way comparable to the succession already mastered, and the train was well up to time. Nearing Paris, the engine and route limitation of 75 m.p.h. was touched several times ; in fact, the speed seldom was less. The blackness outside the cab only brought the brightly lit interior into sharper contrast, and though I do not care much for after-dark running, this particular trip was as pleasant as possible, thanks to the proper illumination on and about the engine ; a seat would have made things even better, as by this time over 400 miles had been covered. The final arrival at the Gare St. Lazare was clocked as 10.29, one minute early ; are French trains ever late ? The last 72 miles had been covered in 77 min, 56·1 m.p.h., the only sign of stress given by this sterling veteran being one box of the second axle of the leading bogie, which had shown a slight tendency to heat ; not enough to cause serious concern, and at the finish the report was still "just warm."

So ended this very interesting day, with the carrying out of the ritual to which I became habituated in France on these runs, and quite approved of, the quintette adjourning to a nearby hostelry, appropriately the "Britannia," where the *entente cordiale* was cemented, and Zoonekyndt, friendly soul, presented me with a pair of *à la mode* goggles, in a gesture of fellowship, and as a memento of a fine run made in good company. Not that I should be likely to forget it.

(To be continued)

Efficiency of Screening Operations for Roadmaking Aggregates

By F. A. SHERGOLD and J. R. HOSKING*

The suitability of a roadmaking aggregate for a particular purpose depends to a considerable extent on its grading. Different gradings are required for different purposes, and present-day practice tends increasingly towards the production of "single-sized" aggregates of various sizes,[1, 2] which are used singly or mixed in appropriate proportions to produce the gradings required. The production of single-sized aggregates calls for efficient screening, but no generally satisfactory formula exists for expressing the efficiency of screening operations. This article paper describes the work undertaken at the Road Research Laboratory to develop a method for measuring efficiency in the screening of roadmaking aggregates.

Definition of Screening Efficiency

Object of Screening Operations.—Machinery for commercial screening is available in a variety of forms, but the object of the operation is the same in all cases—to separate at each screening surface a mixture of particles of different sizes into two fractions respectively larger or smaller than a given size (the "nominal size of separation"). An acceptable formula for efficiency should give a true measure of the extent to which this object has been achieved and should be applicable to all normal screening conditions. The object of a screening operation may be (and frequently is) best achieved when it is carried out on screens with apertures of larger size than the nominal size of separation,† and this is a factor that has to be taken into account in devising a method of measuring screening efficiency.

Objections to the Existing Formula.—Screening efficiency is most commonly expressed as the percentage of the true undersize that is correctly classified, that is, the weight of the material actually passed by the screen expressed as a percentage of the weight that would have passed had the separation been 100 per cent complete. There are two objections to this expression : (*a*) if the feed contains a high proportion of material considerably smaller than the screen aperture size, which falls through without any difficulty, the expression gives a high value for efficiency whether the efficiency is actually good or not ; (*b*) because it makes no allowance for the loss of efficiency due to oversize being passed by the screen, the expression cannot be applied where—as is frequently the case in commercial screening—the aperture size of the screen is larger than the required size of separation.

Development of a New Formula.—To meet the objections to the existing formula it is necessary to neglect the small undersize and

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† For example, in the screening of roadmaking aggregates, where a small proportion of oversize is always tolerated.

consider only the "near-mesh" or "difficult" particles, that is, the particles that will not easily fall through the screen, and to refer efficiency to the required size of separation independently of the aperture size of the screen used. It is proposed to define the difficult particles as those found by accurate laboratory sieving to lie between the sizes immediately above and below the required (or nominal) size of separation in the British Standard series: 3in, 2in, 1½in, 1in, ¾in, ½in, ⅜in, ¼in, $\frac{3}{16}$in, and ⅛in, which is the series normally used in defining single-sized road-making aggregates.[1, 2] Thus for separation at ⅜in, the difficult particles are those found by laboratory sieving to lie between the ½in and ¼in B.S. square-holed test sieves, and they are further classified into "difficult oversize" (½in to ⅜in) and "difficult under-size" (⅜in to ¼in.).

The proposed expression for the efficiency of a screening operation then contains two terms; the first is the percentage of difficult undersize correctly classified (i.e. the weight of difficult undersize passed by the screen, expressed as a percentage of the total weight of difficult undersize in the feed); the second, which must be subtracted from the first as a correction for oversize passed by the screen, is the percentage of difficult oversize incorrectly classified (i.e. passed by the screen).

In a normal continuous screening operation it is not possible to determine the weights directly, but they can be calculated as relative values from the results of sieve analysis of samples taken from the feed and from the material passed by the screen. The full development of the formula is given as an appendix to this paper, where it is shown that if

A=The percentage of difficult oversize in the material fed to the screen.
B=The percentage of difficult undersize in the material fed to the screen.
C=The percentage of difficult oversize in the material passed by the screen.
D=The percentage of difficult undersize in the material passed by the screen.
E=Efficiency, and
F‡=The percentage of the total feed passed by the screen, the percentage of difficult undersize correctly classified is given by the term DF/B and the percentage of difficult oversize incorrectly classified by the term CF/A, so that the efficiency= $DF/B-CF/A$, which simplifies to :—

$$E=F\left(\frac{D}{B}-\frac{C}{A}\right).$$

The expression cannot give a negative value in practice, since the second term could be greater than the first only if it were possible for the oversize to pass more easily than the undersize.

‡ The value of F can be determined by simultaneously but separately collecting the whole of the materials rejected and passed by the screen over a relatively short period of time.

Application to Theoretical Cases

The formula was first studied by applying it to a number of theoretical cases of extreme efficiency or inefficiency. The details of these examples are given in Table I; each is a case that gives an absurd value for efficiency with other formulæ that have been used or suggested.

Example 1 in Table I is a case where all the difficult particles are correctly classified; the proposed formula gives an efficiency of 100, because in all such cases $DF/B=100$ and $CF/A=0$.

Examples 2–6 are cases where no separation of sizes is achieved because all the material is retained (example 2) or passed (example 3), or because the grading of the materials passed and retained is the same as that of the feed (examples 4, 5 and 6, having respectively 10, 50 and 90 per cent passing the screen). In all such cases the formula gives an efficiency of 0.

In example 7 only a fifth of the difficult undersize passes through the screen, the remainder, together with all the oversize, being retained; an efficiency of 20 per cent seems reasonable in this case. Example 8 refers to a feed containing 60 per cent of difficult undersize, the whole of which is passed, and 20 per cent of difficult oversize, half of which is passed; in this case the object of the screening operation would be to remove the oversize; as only half has been removed, a value of 50 for efficiency seems reasonable despite the facts that the small amount of material retained is 100 per cent single-sized, and the material passed is within B.S. limits.[1]

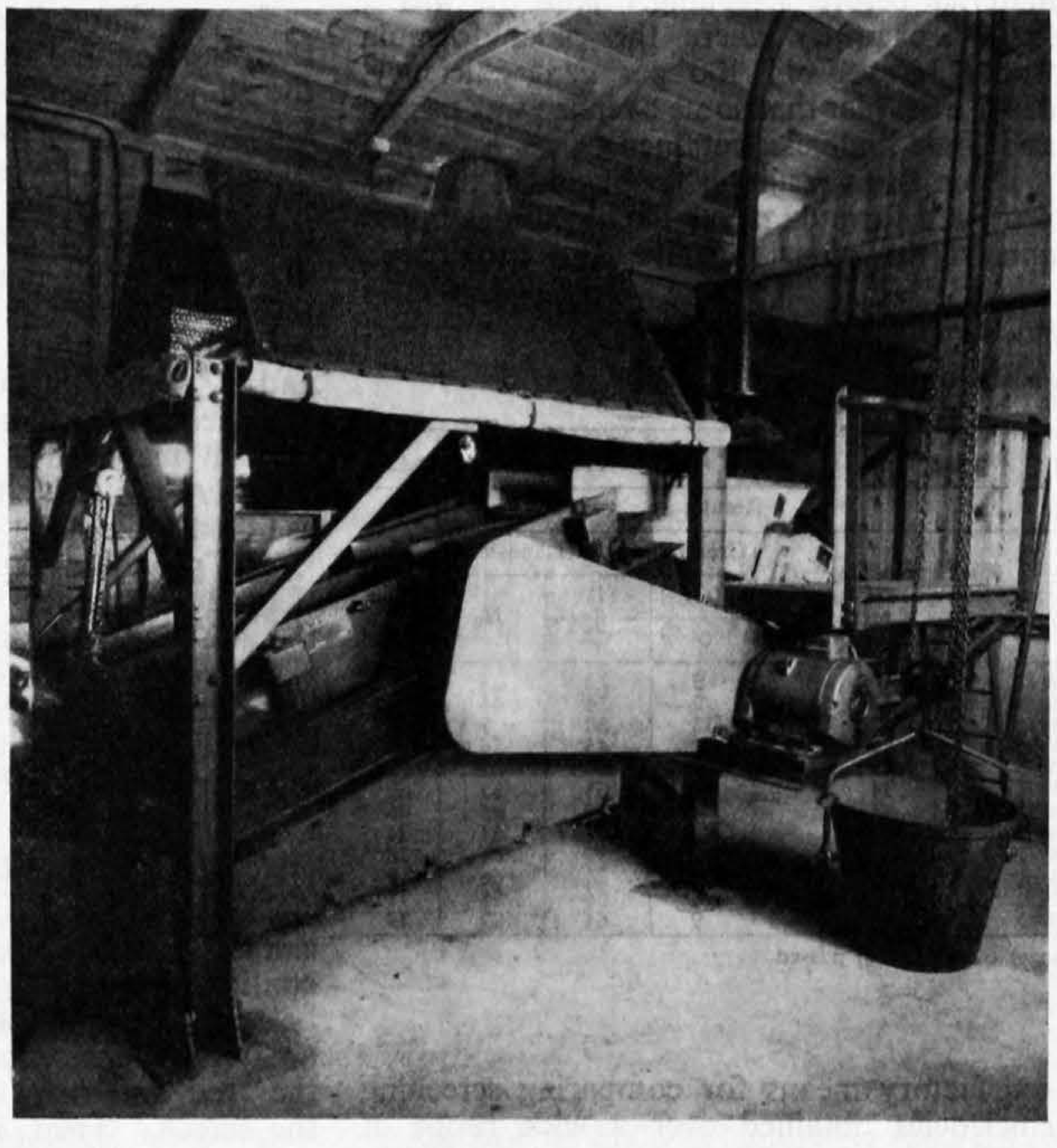

Fig. 1—Experimental screening plant

As the proposed formula gave reasonable values in all these theoretical cases, it was applied to the results of a series of tests made on the Laboratory's experimental screening plant, in which the operating conditions were varied over a range such as might be expected to occur in commercial screening.

Practical Work

Description of Plant.—The experimental screening plant used is shown in Fig. 1. The screen is of the single-deck vibratory type, driven by an eccentric shaft mounted above the screening surface and running at a speed of 950–1000 r.p.m. with a throw of 0·256in. The normal angle of slope of the screen for dry materials is 20 deg., the flow of the feed is downhill and the throw of the eccentric is uphill. The maximum free screening area is 5ft by 2ft, but for most of the work described in this note the width of the screen was reduced to 1ft by means of angle plates bolted to the surface. The aggregate is fed to the screen from a 10 cubic foot hopper (top right of Fig. 1) by means of an electric vibratory feeder, which can be controlled to give rates of feed ranging to over 40 tons per hour; the hopper is filled by means of the bucket and hoisting gear seen on the right. The slope of the screen can be altered by raising or lowering the lower end with the lifting tackle on the left. The material rejected by the screen is discharged into the wheeled bin on the left, whilst that passing falls into a bin divided into four compartments of equal length, to permit studies of the material passed through each quarter of the screen.

Test Procedure.—The feed hopper was loaded with aggregate and the electric control of the vibratory feeder was set to give the rate of feed required. The screen was then switched on and allowed to reach its full speed; the feeder was switched on and a clock was started. Screening was continued until the receiving hopper for the rejected material was nearly full, after which the feeder was switched off and the clock was stopped. The length of the runs varied from twenty seconds to five minutes; for the majority it was between one and one-and-a half minutes and about 2 cwt of aggregate was screened. The materials retained and passed by the screen were then weighed and reduced on a sample splitter to give samples of a size suitable for sieve analysis.§ From the results of the sieve analyses the efficiency of the screen under the given conditions of feed and operation was calculated by the formula given above.

Experimental Work.—The required size of separation was ⅜in for all the tests and a Thames Valley gravel was used throughout.

§ The results of the sieve analysis of the material retained are not given in the present article, since they are not required for the proposed formula for efficiency.

TABLE I—*Application of Proposed Formula to Theoretical Cases*

The grading figures are percentages by weight.
N_o and N_u=non-difficult oversize and undersize respectively.
O and U=difficult oversize and undersize respectively.
Symbols $A-F$ as defined in text.

Example No.	Grading of feed				Total percentage passed (F)	Grading of material passed				Efficiency $E=F\left(\frac{D}{B}-\frac{C}{A}\right)$
	N_o	(A) O	(B) U	N_u		N_o	(C) O	(D) U	N_u	
1	10	40	40	10	50	0	0	80	20	100
2	10	40	40	10	0	0	0	0	0	0
3	10	40	40	10	100	10	40	40	10	0
4	10	40	40	10	10	10	40	40	10	0
5	10	40	40	10	50	10	40	40	10	0
6	10	40	40	10	90	10	40	40	10	0
7	20	10	50	20	30	0	0	33·3	66·7	20
8	0	20	60	20	90	0	11·1	66·7	22·2	50

To prepare different gradings for the feed the gravel was first separated on a laboratory sieving machine into large oversize (retained on ½in), difficult oversize (½in to ⅜in), difficult undersize (⅜in to ¼in) and small undersize (passing ¼in), after which these fractions were remixed in different proportions to give feeds with a variety of gradings. Wire screening cloths were used, different aperture sizes being obtained by using cloths with the same number of meshes per inch but with different thicknesses of wire. Runs were made with a variety of gradings, at three different angles of slope of the screen, with four different lengths of screen and with screens of three different aperture sizes. The rate of feed was kept within the limits 70–85 cwt/h/ft width of screen. The object of varying the conditions of screening was merely to obtain a range of efficiencies: no attempt was made to study systematically the factors varied, and the results should not be taken as comprising a study of the effect of these factors on the efficiency of screening operations. The conditions of test on each run are given in the first eight columns of Table II, the ninth column gives the total percentage of the feed passed by the screen, columns 10, 11 and 12 give the grading of the material passed, and column 13 gives the value of efficiency calculated from the proposed formula.

Discussion of Results.—On runs 1–4, where the grading of the feed was varied over a wide range, the other conditions being kept constant, the values obtained for efficiency fell within a relatively narrow range. Therefore, the proposed formula gives values that are relatively insensitive to differences in the grading of the feed, which meets the first of the objections raised to the formula at present in use.

Run 3 provides an example of the disadvantage of the older formula when applied to screens with apertures larger than the required size of separation.¶ On this run the feed contained 17 per cent of material smaller than the required size of separation, and 17 per cent was actually passed by the screen. The efficiency by the older formula would, therefore, be 100 per cent, but this would not be correct because some undersize was retained and an equal weight of oversize was passed (column 10 of Table II). The value of 80 per cent given by the proposed formula appears to meet the case better.

Runs 7–10 were made with the whole length, three-quarter length, half length and quarter length screen, respectively, and the results reflect clearly the fall in efficiency as the length of the screen was reduced ; on run 10 the grading of the material retained on the screen differed little from that of the material before screening. Run 12 was a further example where the older formula would have given 100 per cent efficiency, despite the fact that some oversize was passed and some undersize retained.

From these results it is concluded that the proposed formula meets the objections raised against the older formula, and provides a satisfactory means for comparing screening efficiencies obtained over a wide range of conditions.

TABLE II—*Test Conditions and Results*

The grading figures are percentages by weight.
Nominal size of separation — ⅜in. Notation as in Table I.

1	2	3	4	5	6	7	8	9	10	11	12	13
	Conditions of test							Results				
Run No.	Slope of screen (deg.)	Length of screen (ft)	Aperture size (in)	Grading of feed N_0	Grading of feed (A) O	Grading of feed (B) U	Grading of feed N_u	Total percentage of feed passed by the screen (F)	Grading of material passed* (C) O	Grading of material passed* (D) U	Grading of material passed* N_u	E†
1	20	5	0·375	13	44	34	9	40	5	72	23	80
2	20	5	0·375	42	22	21	15	32	2	54	44	79
3	20	5	0·375	39	44	16	1	17	13	80	7	80
4	20	5	0·375	0	15	41	44	81	1	45	54	84
5	16	5	0·375	13	46	31	10	35	3	66	31	72
6	24	5	0·375	12	45	32	11	31	2	63	35	60
7	20	5	0·375	9	40	37	14	31	—	55	45	46
8	20	3¾	0·375	9	40	37	14	26	—	49	51	34
9	20	2½	0·375	9	40	37	14	19	—	39	61	20
10	20	1¼	0·375	9	40	37	14	12	—	34	66	11
11	20	5	0·408	8	47	33	12	41	6	66	28	77
12	20	5	0·436	10	43	34	13	47	9	64	27	79

* In no case was any non-difficult (large) oversize (N_0) passed.

† E=efficiency$=F\left(\frac{D}{B}-\frac{C}{A}\right)$.

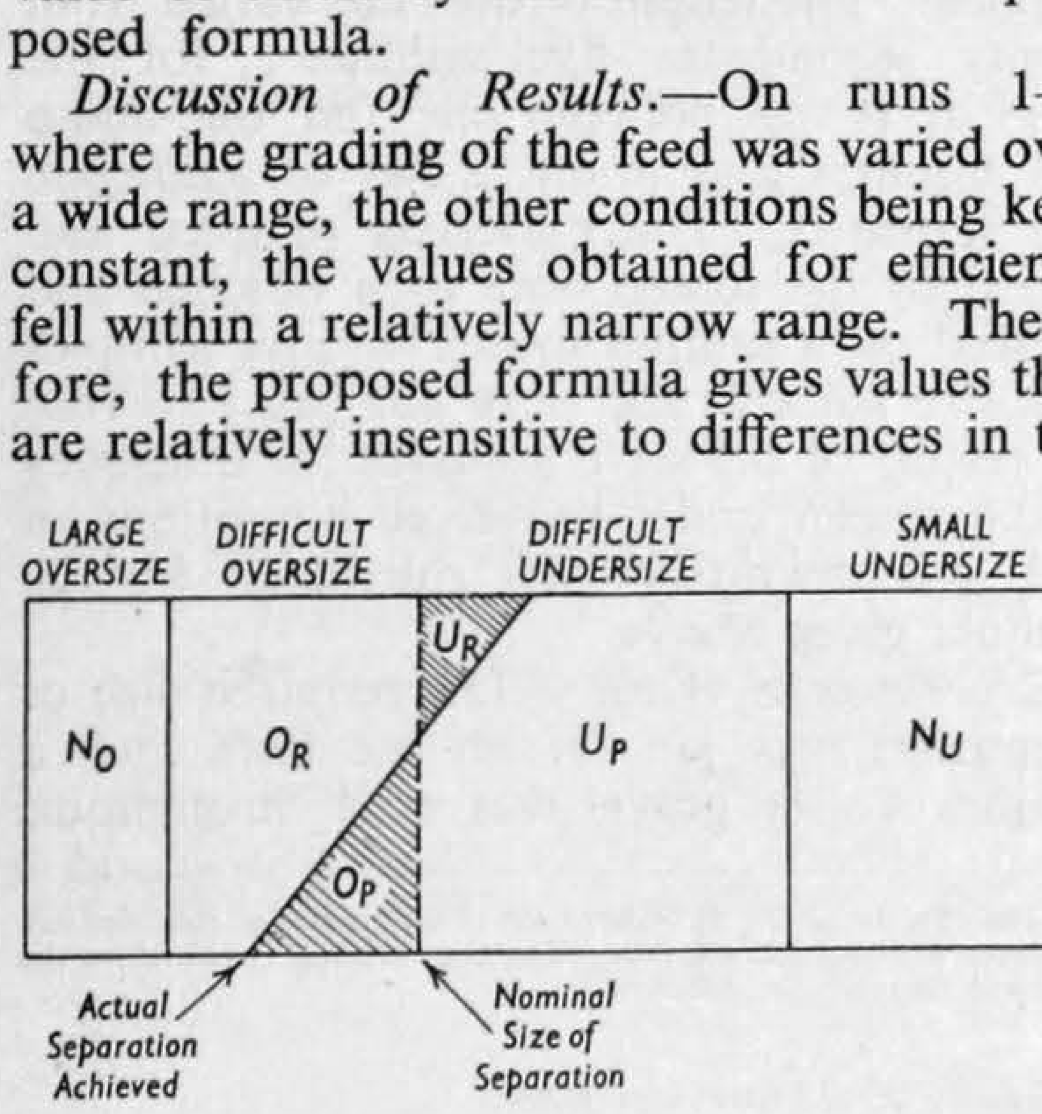

Fig. 2—Diagrammatic representation of the symbols used in the development of the formula for efficiency

¶ This may occur by deliberate choice (as on run 12), through wear, or (as in the present case) through the slight inaccuracy inherent in weaving wire screens.

REPORTING THE RESULTS OF TESTS FOR SCREENING EFFICIENCY

The efficiency of a screening operation depends on a number of factors apart from the machine itself. In quoting the value of efficiency for a particular machine, therefore, the conditions under which the value was obtained should be stated, and in particular :

(*a*) The grading of the feed.

(*b*) The particle shape of the feed (this may be descriptive, e.g. angular and flaky, angular and cubical, semi-rounded or rounded, but preferably should be stated as the flakiness, elongation and angularity indices determined by laboratory tests).

(*c*) The surface texture of the feed (smooth or rough).

(*d*) Condition of feed (surface dry, containing *x* per cent surface moisture, or flooded (wet screening)).

(*e*) Rate of feed and dimensions of screening surface.

(*f*) Nominal size of separation (B.S. test sieve).

(*g*) Details of screening surface : (i) aperture size, shape and condition ; (ii) whether punched plate or woven wire.

(*h*) Slope of screen and any other operational characteristics that are variable on the machine.

In comparing the performance of different machines, these factors should be kept within as close limits as possible.

FORMULA FOR EFFICIENCY

The weights of material passed and retained in a screening operation can be represented by areas in a diagram of the form shown in Fig. 2. The total area represents the total weight of material fed to the screen. This material is composed of :

N_0=Non-difficult (large) oversize.
O=Difficult oversize.
U=Difficult undersize.
N_u=Non-difficult (small) undersize.

The vertical broken line represents the nominal size of separation : if the screening is perfect, the area to the left of this line will represent the material retained by the screen and that to the right the material passed.

When using a screen with apertures larger than the nominal size of separation, some of the difficult oversize will be passed (represented by the shaded area O_P) and some of the difficult undersize will be retained (represented by the shaded area U_R) : the line of separation can then be represented by the oblique full line. The unshaded areas O_R and U_P represent the difficult material correctly classified, the shaded areas O_P and U_R the difficult material incorrectly classified. It is assumed that all the non-difficult material is correctly classified ; if any were not, the efficiency would be so low as to make the slight error involved negligible.

The proposed expression for efficiency is the value obtained when the percentage of the difficult oversize that is incorrectly classified (passed) is subtracted from the percentage of the difficult undersize that is correctly classified (passed). If E=efficiency, in the terms of Fig. 2 :

$$E=100\frac{U_P}{U_R+U_P}-100\frac{O_P}{O_R+O_P} \quad . \quad (1)$$

The terms U_P, O_P, &c., are weights, which cannot be directly determined in a normal continuous screening operation, but have to be calculated from the results of sieve analysis of representative samples taken from the feed and from the material passed by the screen. Then, if the total area of the rectangle in Fig. 2, that is, the total weight of material fed to the screen be represented by S ($S=N_0+O_R+O_P+U_R+U_P+N_u$), and the values determined by sieve analysis are :

A=The percentage of difficult oversize in the material fed to the screen$=100(O_R+O_P)/S$

B=The percentage of difficult undersize in the material fed to the screen$=100(U_R+U_P)/S$

C=The percentage of difficult oversize in the material passed by the screen $=100\,O_P/(O_P+U_P+N_u)$

D=The percentage of difficult undersize in the material passed by the screen $=100\,U_P/(O_P+U_P+N_u)$

E=Efficiency, and

F=The percentage of the total feed passed by the screen$=100(O_P+U_P+N_u)/S$

equation (1) above can be rewritten :—

$$E=\frac{DF}{B}-\frac{CF}{A} \quad . \quad . \quad . \quad . \quad (2)$$

or

$$E=F\left(\frac{D}{B}-\frac{C}{A}\right).$$

ACKNOWLEDGMENT

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Combined Stress Creep Fracture of a Commercial Copper at 250 Deg. Cent

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No. I

The tertiary creep and fracture characteristics of a commercially pure copper at 250 deg. Cent. are examined. Some fifteen combined tension and torsion, pure tension, pure torsion and pure compression creep tests have been made on the copper at 250 deg. Cent. and the results analysed. The conclusions reached are that in the case of the commercially pure copper at 250 deg. Cent. all fractures under complex stress creep conditions, including pure tension and pure torsion, are overwhelmingly intercrystalline in nature. Satisfactory evidence was obtained to indicate that the Siegfried hypothesis that intercrystalline fracture is due to hydrostatic stress is incorrect for this material. It would appear that the period to creep fracture is purely a function of the maximum tensile principal stress. No other reasonably possible stress criterion is in accord with the results. A continuous relation between octahedral stress and average octahedral strain rate over the whole period of the test to fracture, as suggested by Kochendorfer, does not exist for this material. It was indicated that for the great majority of tests an equation of type $\varepsilon_0 = At^n + Be^{Kt}$ represents the complete creep curve, At^n corresponding to primary creep and Be^{Kt} to tertiary creep. In the tests at particularly low stress levels and long fracture periods, however, the equation does not adequately represent the whole creep curve although the tertiary creep when fully established follows a relation of type $\varepsilon_{0t} = Be^{Kt}$. No evidence was obtained of stress dependence in the case of the characteristic B.

THE relation of the long period fracture of metals under creep conditions at high temperatures to the imposed general stress system is one which is of much practical importance in relation to power plant, and until recently very little information concerning this matter has been available. Obviously, it would appear to be a difficult matter to relate fracture period and physical nature of fracture to the imposed stress system. Creep fractures in general will be of a complex nature, partly transcrystalline and partly intercrystalline, and the degree of transcrystalline and of intercrystalline detail changes (as is well known) with temperature, and presumably at a specific temperature there is no reason why these degrees should not change with the nature of the imposed stress system. In systems composed of tension and torsion stresses any such change would be expected to be most marked between pure tension and pure torsion tests. Two items of much use to a practising engineer would comprise information as to (*a*) what function of the imposed stress system at a given temperature determines the degree of creep strain in the tertiary regions of creep approaching fracture, and (*b*) what function determines the actual time at which fracture could be expected.

While, as already mentioned, in general creep fractures will be of a mixed nature, consideration may be given to the possible functions of the stress systems which would influence purely transcrystalline or purely intercrystalline fracture. Since the stress deviators are defined as causing actual crystal distortion, they might (particularly the maximum stress deviator) be expected to have some relation to the period of purely transcrystalline fracture as was suggested by Siegfried. However, analysis of primary complex stress creep strain indicates that the strains are dependent upon a function of the stress system more complex than the simple stress deviators, and since it cannot necessarily be expected that the stress dependence of tertiary creep towards transcrystalline failure becomes more simple than primary creep, it does not seem likely that the stress dependence of the features of transcrystalline fracture can be simple.

KEY TO SYMBOLS USED ON GRAPHS.

- ● Pure torsion 2 tons per sq. in. ○ Pure tension 3 or 3·5 tons per sq. in.
- + Tension 2 tons per sq. in. ------- Torsion 2 tons per sq. in.
- □ do. 3 do. ------- do. 1 do.
- × do. 2 do. ------- do. 1 do.
- ◊ do. 0·9 do. ------- do. 2·25 do.
- ♦ do. 3 do. ------- do. 1·5 do.
- △ do. 2·3 do. ------- do. 2·3 do.
- ■ Solid specimen: Tension 4, 3 and 2 tons per sq. in.

In the case of intercrystalline fracture two factors may well contribute to failure, these being first the aggregation of lattice vacancies at boundaries to cause cracks; and secondly, stress concentrations arising at boundaries due to relative motion of the crystals. It seems quite likely that in the general case both factors would be operative, but while in the case of the first factor any function of the shear stresses, say, maximum shear stress, maximum stress deviator or octahedral stress might be some measure of the propagation of vacancy aggregation, in the case of the second factor the greatest single stress present in the system (the maximum tensile principal stress) appears likely to be the propagating agent. Where the nature of the fracture changes with temperature the mechanism of failure and its stress dependence might be expected to change. Thus Siegfried[1] suggested that at temperatures producing intercrystalline fracture the hydrostatic stress might govern failure, while at temperatures at which purely transcrystalline failure occurred the maximum stress deviator was responsible.

In a paper published in THE ENGINEER[2] one of the present authors showed that for a 0·5 per cent molybdenum steel at 550 deg. Cent. the Siegfried hypothesis certainly did not hold at the temperature in question according to the stress system involved, all variations of fracture occurred from purely transcrystalline to purely intercrystalline. The results appeared to indicate that whatever the type of fracture the time of failure was simply dependent upon the maximum tensile principal stress (see Fig. 17). This suggests that it is possible that a variety of mechanisms may be responsible for the initiation of cracks, but that once incipient cracks exist, the propagation of such features to eventual failure may be largely dependent upon the maximum tensile stress of the system, i.e. the maximum tensile principal stress. From this point of view primary creep may be regarded as leading up to a point where, whether as a result of internal strain of the grains themselves or weakening of grain boundaries by any one of several possible mechanisms, the stage is prepared for tertiary or accelerating creep to take place due to propagation of weaknesses formed in the primary stage of creep. Their propagation would then be governed by the maximum tensile principal stress irrespective of the mechanism of formation of the weaknesses. It was with such ideas in mind that the present work on copper at 250 deg. Cent. was commenced, it being hoped that evidence of the criteria, not only of time to fracture but of the tertiary strain in the stages approaching fracture, might be obtained.

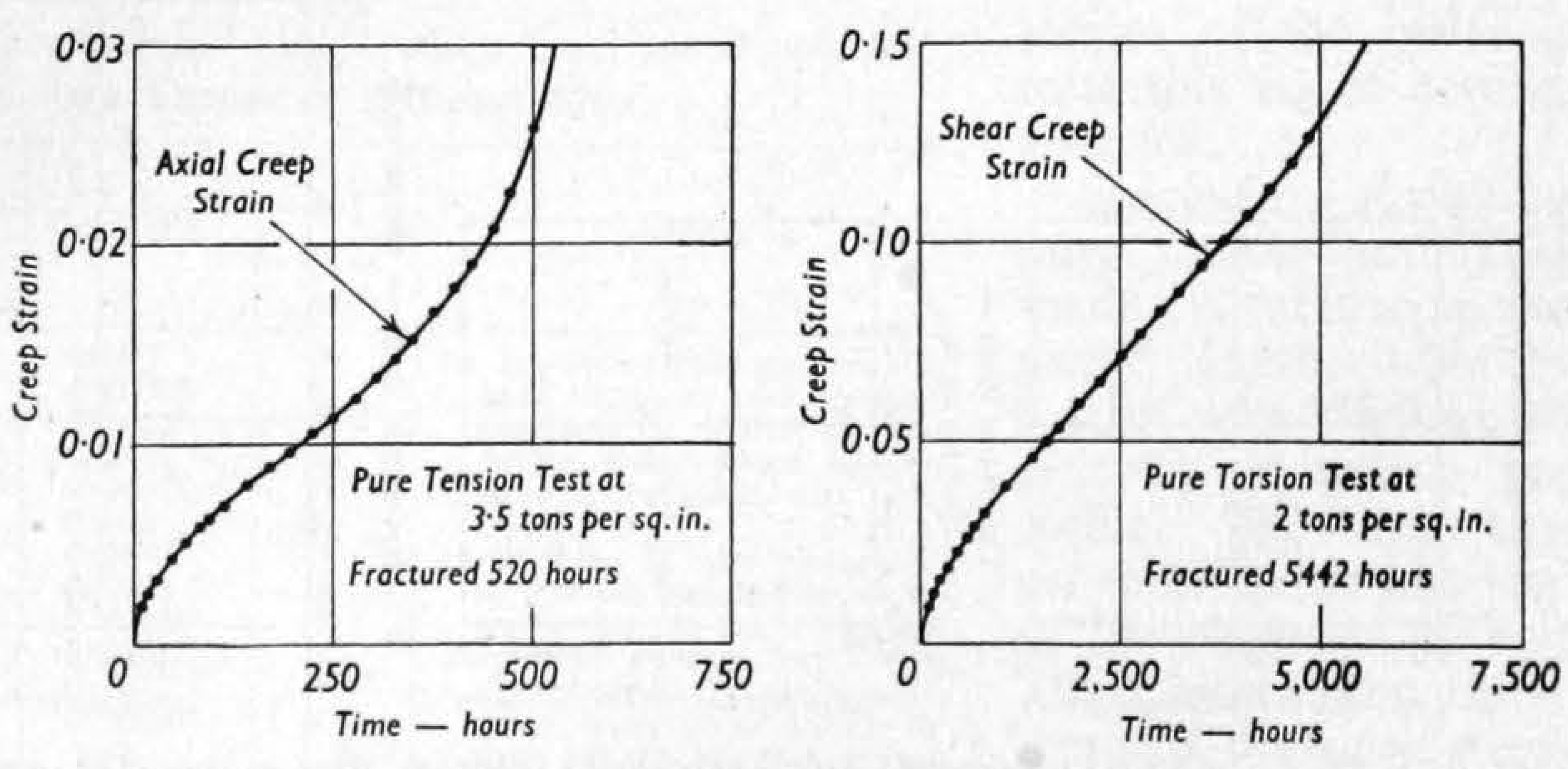
Before passing on to consideration of the experimental work on copper, mention should be made of a suggestion by Professor A. Kochendorfer, of Stuttgart, in regard to the results of tests by one of the authors on 0·5 per cent molybdenum steel at 550 deg. Cent., which have been mentioned in previous paragraphs. On the basis of experience in the analysis of short-time yielding and fracture tests on ductile materials under complex stress at several temperatures, he suggested that a continuous relation between stress and strain quantities proportional to octahedral stress and strain might exist at the point of fracture. He called these quantities the reference stress and strain.

$$\sigma_r = \frac{1}{\sqrt{2}}\sqrt{\Sigma(\sigma_1-\sigma_2)^2} \text{ and } \varepsilon_r = \sqrt{\tfrac{2}{3}}\sqrt{\Sigma\varepsilon_1{}^2}.$$

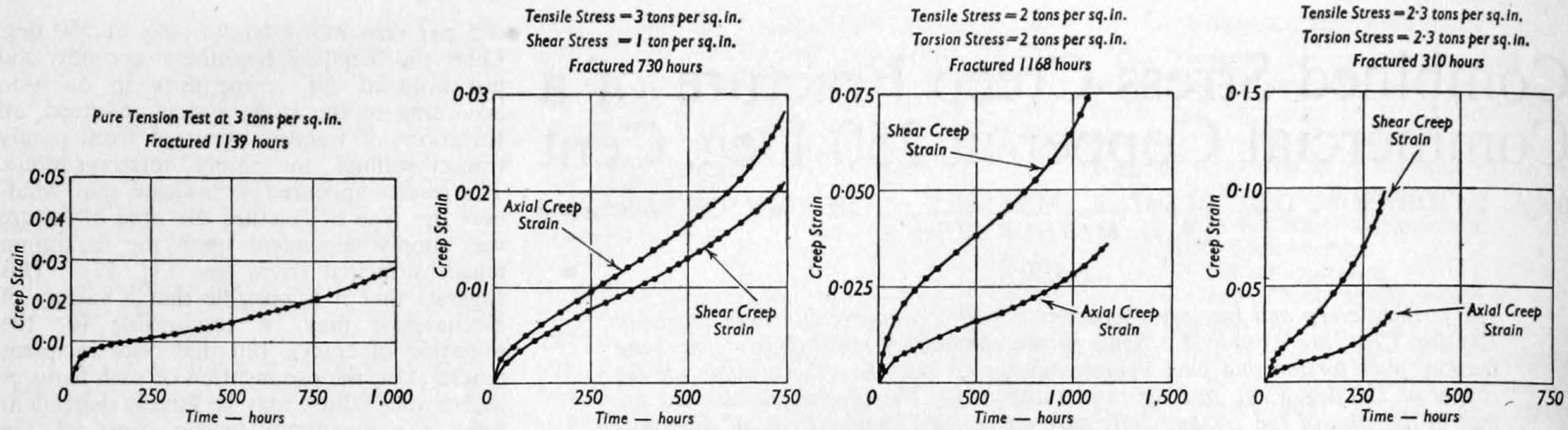
However, considering the set of results upon the 0·5 per cent molybdenum steel, he concluded that in regard to the combined stress creep problem the comparison should be made, not between σ_r and ε_r, but between $\dot{\sigma}_r$ and $\dot{\varepsilon}_r$, where $\dot{\varepsilon}_r$ is equal to

$$\frac{\varepsilon_r}{\text{Total time to fracture}}.$$

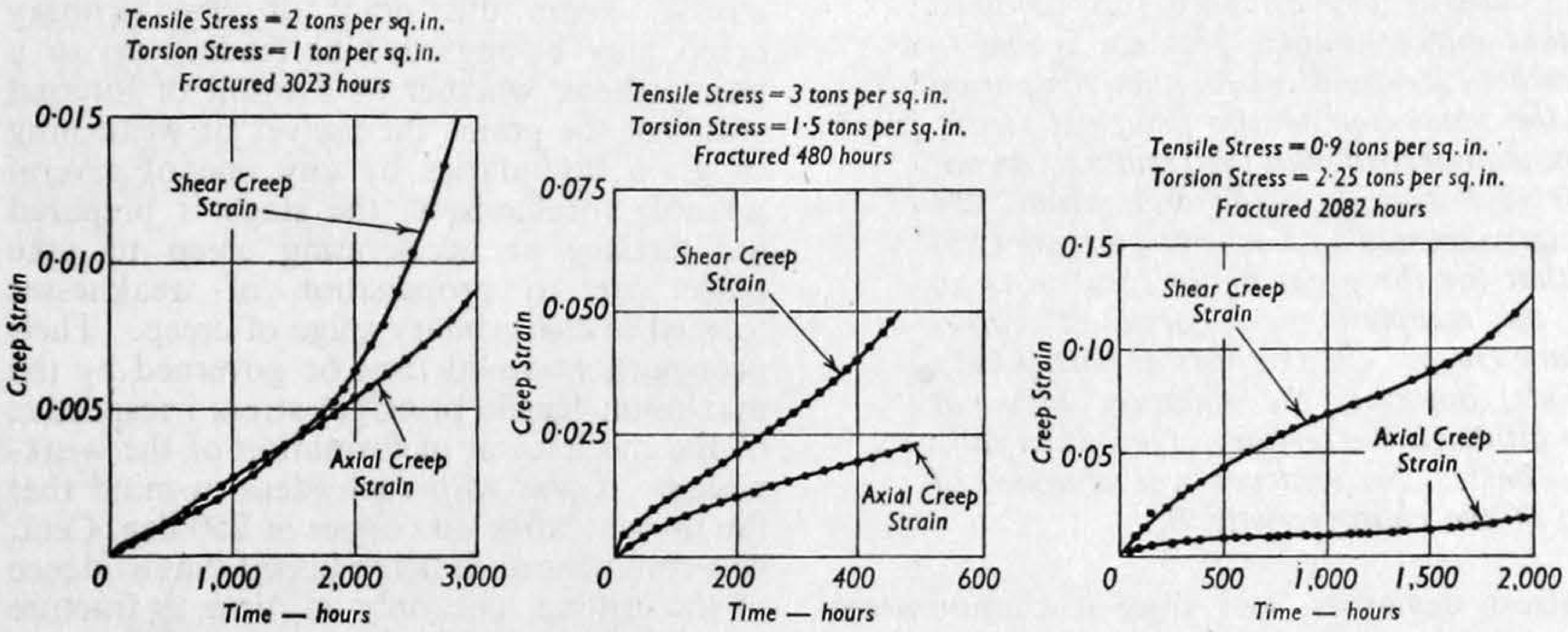
He appeared to regard the data available from the 0·5 per cent molybdenum steel tests as inadequate to check his ideas, but suggested that they should be borne in mind in the course of analysing the results of further sets of tests which, he understood, the authors were about to undertake. (This the authors undertook to do.) It is to be noted that Professor Kochendorfer did not advance any physical explanation of his suggestion that the octahedral stress strain relation could be extended to fracture times.



Figs. 1 and 2—Creep strain-time curves for pure tension test (left) and pure torsion (right) on thin-walled tubular specimen of commercially pure copper at 250 deg. Cent.



Figs. 3, 4, 5 and 6—Creep strain-time curves for combined stress creep tests on thin-walled tubular specimens of commercially pure copper at 250 deg. Cent.



Figs. 7, 8 and 9—Creep strain-time curves for combined stress creep tests on thin-walled tubular specimens of commercially pure copper at 250 deg. Cent.

Outline of Investigation

In the work previously referred to on 0·5 per cent molybdenum steel at 550 deg. Cent. the main object was to examine the features of the Siegfried hypothesis, and a relatively small but adequate number of tests was performed for this purpose (which was adequately fulfilled). However, at the conclusion of this work it was felt that a more comprehensive examination of a number of materials at suitable working temperatures was necessary since the implication of the results of the work on 0·5 per cent molybdenum steel was that the Siegfried view was incorrect and that a quite different state of affairs (outlined in the introduction) existed ; these views required examination and confirmation in detail for various materials and temperatures to examine their generality or otherwise.

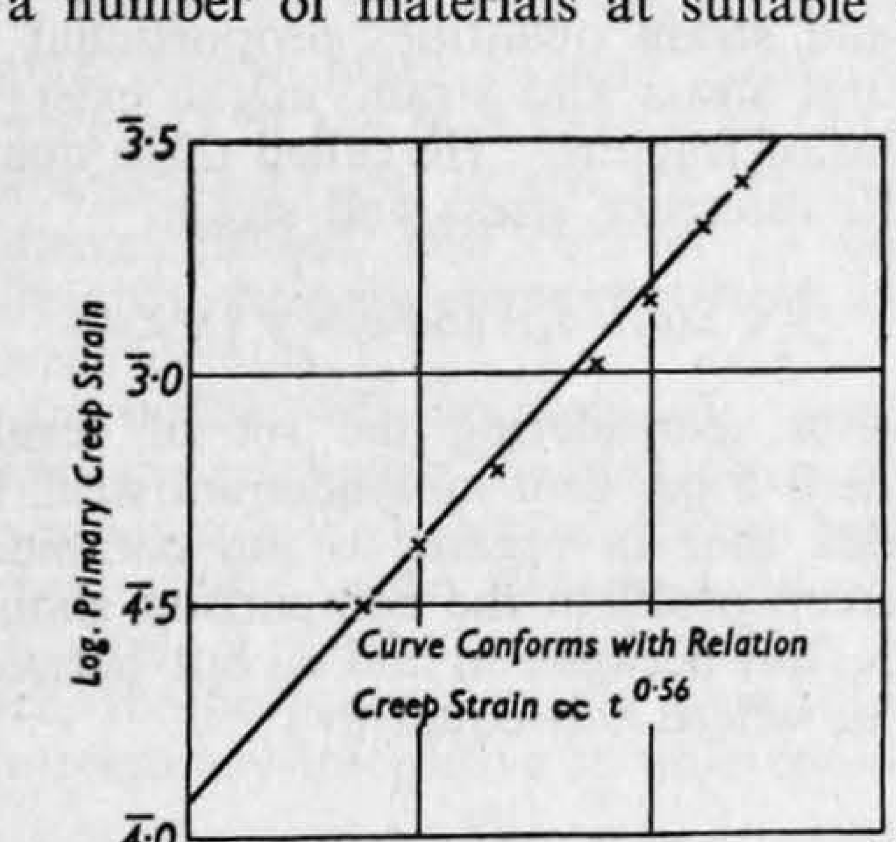


Fig. 10—Composite primary creep curve form for thin-walled tubular specimens of commercially pure copper at 250 deg. Cent.

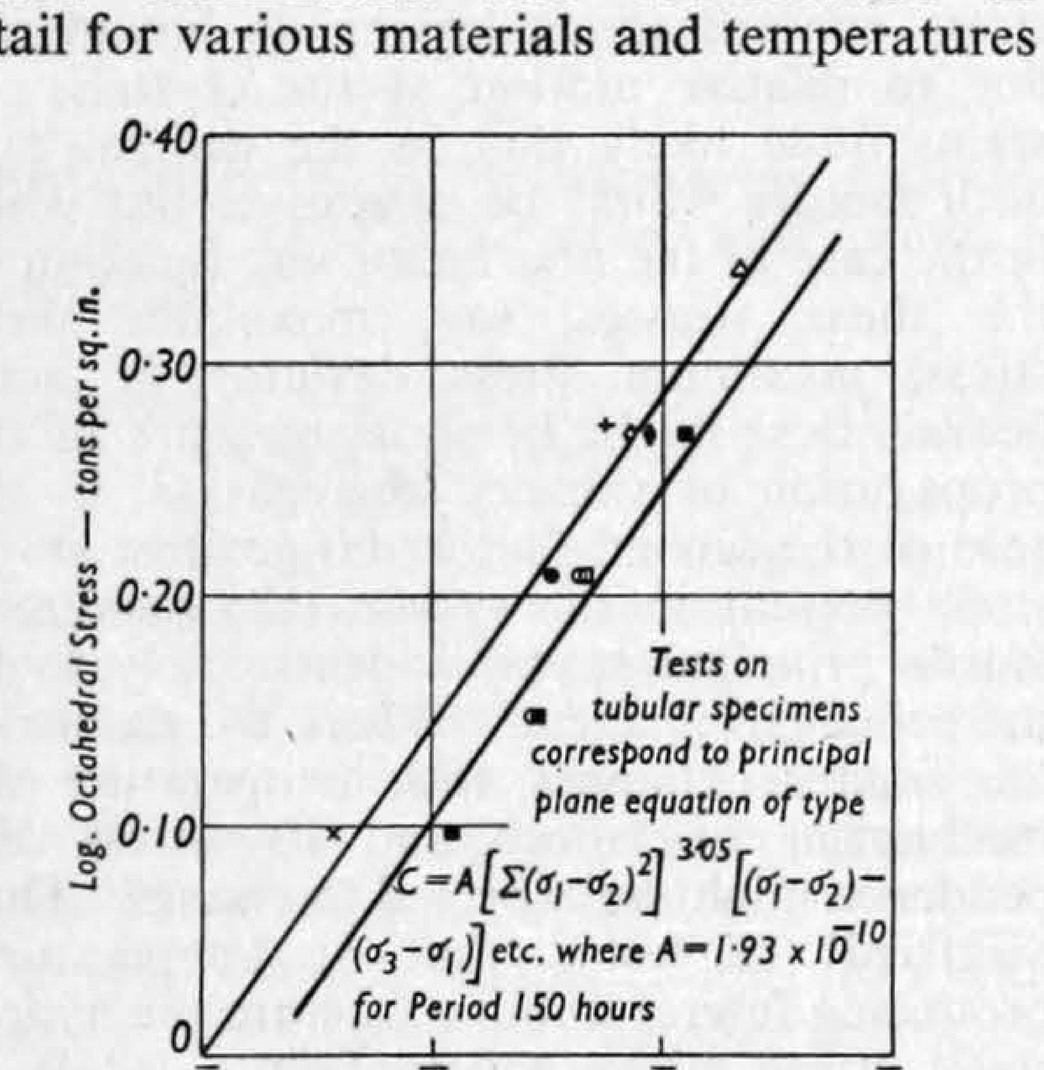
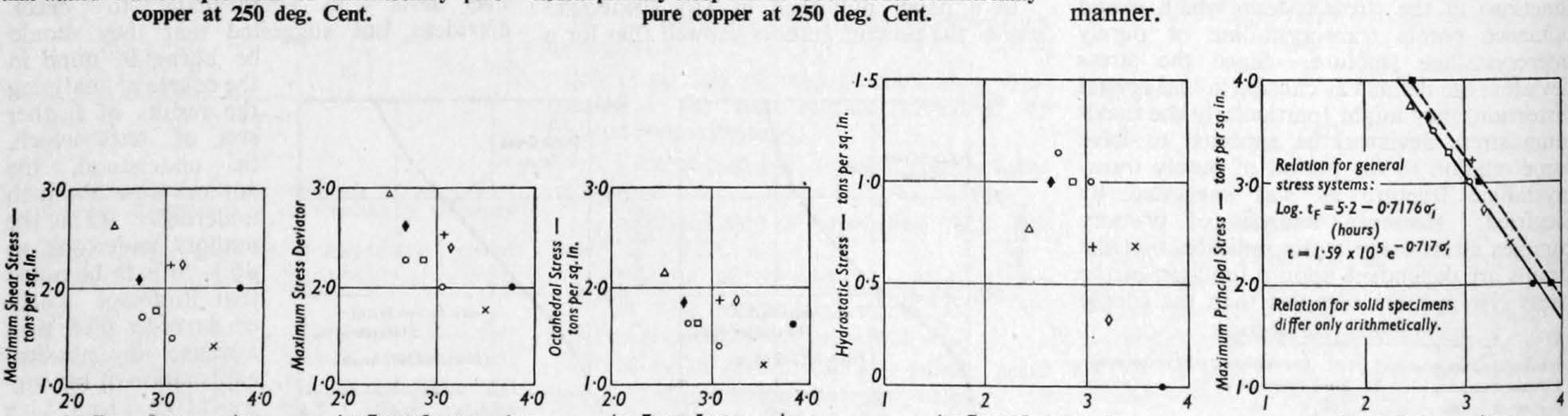


Fig. 11—Relation log. octahedral stress-log. octahedral primary creep rate at 150 hours for commercially pure copper at 250 deg. Cent.

Accordingly, as a first step, an examination has been made of the combined stress creep tertiary strain and fracture characteristics of the copper at 250 deg. Cent., comprising some nine tests including various combinations of tension and torsion, pure tension and pure torsion on tubular specimens, and three tensile creep tests on solid specimens. The results of these latter tests actually existed before the tubular specimen tests commenced, and were incorporated for comparison with the results of compression creep tests at similar stresses on solid specimens. This step had the object of checking the hypothesis that the maximum tensile principal stress was the propagating agent of tertiary creep, since, of course, an equal compressive maximum principal stress would accordingly not be expected to give rise to tertiary creep and fracture (at all).

It was considered that no test below 200 hours was of practical use and that most certainly some tests approaching a length of 5000 to 10,000 hours must be incorporated. For the rest the majority of the tests were of a length between 500 and 2000 hours and corresponded to a range of creep rates of the order 10^{-6} to 10^{-4} per hour at 150 hours. Owing to the fact that, under a combination of tension and torsion stresses on a thin-walled tube, the section of the test piece at fracture was of a ragged nature and could not reasonably be pieced together, the values of axial and shear strain taken in the following paragraphs as corresponding to fracture were in fact values measured immediately before fracture. There was some virtue in this, since it was evident that under the combined pull and twist the actual final operation of fracture of the specimen distorted the local cross-section at fracture in a manner which was not likely to be characteristic of the progress of strain immediately preceding fracture. In the case of tensile creep tests on solid specimens, of course, the elongation to fracture could be measured in the normal manner.



Figs. 12, 13, 14, 15 and 16 (left to right)—Relation maximum shear stress-log. fracture time curves for commercially pure copper at 250 deg. Cent. Relation maximum stress deviator-log. fracture time curves for commercially pure copper at 250 deg. Cent. Relation octahedral stress-log. fracture time curves for commercially pure copper at 250 deg. Cent. Relation hydrostatic stress-log. fracture time curves for commercially pure copper at 250 deg. Cent. Relation of maximum principal stress-log. fracture time curves for commercially pure copper at 250 deg. Cent.

TABLE I—*Period to Fracture of Tubular and Solid Specimens of Commercially Pure Copper at 250 deg. Cent.*

Nature of specimens	Tensile stress, tons/in² t	Torsion stress, tons/in² s	Ratio, t/s	Principal stresses ($\sigma_3=0$) tons/in² σ_1	σ_2	Maximum stress deviator $\frac{1}{3}(2\sigma_1-\sigma_2)$	Hydrostatic stress $\Sigma\left(\frac{\sigma_1}{3}\right)=t/3$	Maximum shear stress $(\sigma_1-\sigma_2)/2$	Octahedral stress $=\frac{\sqrt{2}}{3}\sqrt{t^2+3s^2}$	Time to fracture hours	Nature of fracture
Tubular	3	0	00	3	0	2	1	1·5	1·41	1139	Fully intercrystalline
Tubular	3·5	0	00	3·5	0	2·3	1·16	1·75	1·64	520	Fully intercrystalline
Tubular	3	1	3	3·3	−0·3	2·3	1·0	1·8	1·64	730	Virtually all intercrystalline
Tubular	2	1	2	2·41	−0·46	1·75	0·67	1·41	1·25	3023	Fully intercrystalline
Tubular	3	1·5	2	3·62	−0·62	2·62	1·0	2·12	1·87	480	Virtually all intercrystalline. Two transcrystalline cracks visible
Tubular	2	2	1	3·24	−1·24	2·57	0·66	2·24	1·89	1168	Virtually all intercrystalline
Tubular	2·3	2·3	1	3·73	−1·43	2·96	0·77	2·58	2·17	310	Virtually all intercrystalline. One or two transcrystalline cracks visible
Tubular	0·9	2·25	0·4	2·74	−1·84	2·44	0·3	2·29	1·88	2082	Fully intercrystalline
Tubular	0	2	0	2	−2	2	0	2·0	1·63	5442	Fully intercrystalline
Solid tensile	4	0	00	4	0	2·66	1·33	2·0	1·88	280	Not examined
Solid tensile	3	0	00	3	0	2	1	1·5	1·41	1374	
Solid tensile	2	0	00	2	0	1·33	0·67	1·0	0·94	7965	
Solid compression...	−4	0	00	−4	0	−2·66	−1·33	−2·0	−1·88	453 Unbroken	No cracks in either transverse or longitudinal sections
Solid compression...	−3	0	00	−3	0	−2	−1	−1·5	−1·41	1250 Unbroken	No cracks in either. transverse or longitudinal sections
Solid compression...	−2·6	0	00	−2·6	0	−1·73	−0·87	−1·3	−1·22	2578 Unbroken	No cracks in either transverse or longitudinal sections

TABLE II—*Creep Characteristics of Tubular Specimens of Commercially Pure Copper in the Range of Primary Creep*

Tensile stress, tons/in²	Shear stress, tons/in²	Axial creep rate $Ca\times10^{-5}$ per hour	Shear creep rate $Cc\times10^{-5}$ per hour	Ratio Ca/Cc	Ratio Ca/Cc according to isotropic Mises criterion	Octahedral creep rate 150 hours $Co\times10^{-5}$ per hour	Principal creep rates at 150 hours: C_1 $\times10^{-5}$ per hour	C_2 $\times10^{-5}$ per hour	C_3 $\times10^{-5}$ per hour
3	0	2·1	—	—	—	3	2·1	−1·05	−1·05
3·5	0	3·4	—	—	—	4·8	3·4	−1·7	−1·7
3	1	3·0	2·3	1·3	1·0	5·0	3·35	−0·85	−2·5
2	1	0·2	0·17	1·17	0·67	0·38	0·235	−0·005	−0·23
3	1·5	4·65	7·3	0·64	0·67	8·9	6·15	−4·15	−2·0
2	2	2·0	5·2	0·39	0·33	5·1	3·6	−2·2	−1·4
2·3	2·3	5·7	22	0·26	0·33	20·1	12·5	−12·1	−0·4
0·9	2·25	1·3	9·1	0·15	0·135	7·72	5·05	−4·25	−0·8
0	2	—	4·1	—	—	3·35	2·05	−2·05	0

TABLE III—*Strain and Strain Rate to Fracture of Tubular and Solid Specimens of Commercially Pure Copper at 250 deg. Cent. (application of Kochendorfer criterion)*

Nature of specimen	Tensile stress tons/in² t	Shear stress tons/in² s	Reference stress tons/in² σ_r	Time of fracture hours	Total axial creep strain to fracture $\times10^{-4}$	Total shear creep strain to fracture $\times10^{-4}$	Total creep reference strain to fracture $\times10^{-4}$ ε_r	Total creep reference strain rate to fracture $\times10^{-4}$ per hour $\dot{\varepsilon}_r$	Remarks
Tubular ...	3	0	3	1139	400	—	400	$3\cdot5\times10^{-5}$	Except in the case of solid tensile creep test pieces, the fracture strains were measured immediately preceding fracture
Tubular ...	3·5	0	3·5	520	300	—	310	6×10^{-5}	
Tubular ...	3	1	3·48	730	280	210	330	$4\cdot5\times10^{-5}$	
Tubular ...	2	1	2·65	3023	94	189	155	5×10^{-6}	
Tubular ...	3	1·5	3·96	480	230	510	419	$8\cdot7\times10^{-5}$	The reference stress $\sigma_r=\frac{1}{\sqrt{2}}\sqrt{\Sigma(\sigma_1-\sigma_2)^2}$
Tubular ...	2	2	4·01	1168	360	830	620	$5\cdot5\times10^{-5}$	
Tubular ...	2·3	2·3	4·6	310	345	1000	680	$2\cdot2\times10^{-4}$	$=2\cdot12\times$ octahedral stress
Tubular ...	0·9	2·25	4·0	2082	220	1330	800	$3\cdot85\times10^{-5}$	The reference strain $\varepsilon_r=\sqrt{\frac{2}{3}}\sqrt{\Sigma\xi_1^2}$
Tubular ...	0	3	3·46	5442	—	1440	1440	$2\cdot65\times10^{-5}$	$=0\cdot71\times$ octahedral strain
Solid	4	0	4·0	280	750	—	750	$2\cdot67\times10^{-4}$	
Solid	3	0	3·0	1374	650	—	650	$4\cdot73\times10^{-5}$	The reference strain rate $\dot{\varepsilon}_r=\frac{\varepsilon_r}{\text{Time to fracture}}$
Solid	2	0	2·0	7965	450	—	447	$5\cdot6\times10^{-6}$	

TABLE IV—*Application of Kochendorfer Criterion to Test on Copper at 250 deg. Cent. (Tubular Specimens)*

Tensile stress tons/in²	Torsion stress tons/in²	σ_r tons/in²	σ_1 tons/in²	$\frac{\sigma_r}{\sigma_1}$	$\left[\frac{\sigma_r}{\sigma_1}\right]\times[\sigma_1]=K$	$\frac{\dot{\varepsilon}_r}{\text{Time to fracture per hour}}$
3·0	0	3·0	3·0	1·0	—	$3\cdot5\times10^{-5}$
0·9	2·25	4·0	2·74	1·46	4·0	$3\cdot8_5\times10^{-5}$
2·0	2·0	4·01	3·24	1·24	4·0	$5\cdot5\times10^{-5}$
3·5	0	3·5	3·5	1·0	—	6×10^{-5}

TABLE V—*Values of Characteristics in the Form of Equation $\xi o=At^n+Be^{Kt}$ where ξo is the Octahedral Strain at Time t in Hours for Commercially Pure Copper at 250 deg. Cent.*

Nature of specimen	Tensile stress, tons/in² t	Shear stress, tons/in² s	Value of A	Value of n	Value of B	Value of K		Remarks
Tubular ...	3	0	$3\cdot5\times10^{-4}$	0·57	$8\cdot2\times10^{-4}$	0·003	F	In the case of tests marked F a fit of the order of 5 per cent accuracy or better of the whole creep curve by the general equation was obtained.
Tubular ...	3·5	0	$7\cdot1\times10^{-4}$	0·54	$1\cdot6\times10^{-4}$	0·00925	F	
Tubular ...	3	1	$6\cdot7\times10^{-4}$	0·56	$2\cdot7\times10^{-4}$	0·0055	F	
Tubular ...	2	1	$0\cdot56\times10^{-4}$	0·56	$6\cdot9\times10^{-4}$	0·0011	X	
Tubular ...	3	1·5	$1\cdot2\times10^{-3}$	0·56	$3\cdot2\times10^{-4}$	0·0092	F	
Tubular ...	2	2	3×10^{-3}	0·38*	$1\cdot3\times10^{-3}$	0·003	F	
Tubular ...	2·3	2·3	$2\cdot4\times10^{-3}$	0·54	$4\cdot9\times10^{-4}$	0·0142	F	In the case of tests marked X it proved impossible to fit the complete curve by an equation of this type. The characteristics shown correspond, however, separately to the purely primary and established tertiary portions of the creep curve
Tubular ...	0·9	2·25	$1\cdot15\times10^{-3}$	0·56	$3\cdot8\times10^{-4}$	0·0021	F	
Tubular ...	0	2	$5\cdot05\times10^{-4}$	0·56	$7\cdot1\times10^{-3}$	0·00038	X	
Solid ...	4	0	$4\cdot3\times10^{-3}$	0·31†	$7\cdot2\times10^{-4}$	0·0137	F	
Solid ...	3	0	$2\cdot5\times10^{-3}$	0·34	$5\cdot3\times10^{-4}$	0·0029	F	
Solid ...	2	0	$1\cdot4\times10^{-3}$	0·30	$1\cdot7\times10^{-3}$	0·00037	X	

* This exponent differed from those of the other tubular specimens. No reason was apparent.
† It is to be noted that the value of n for tubular and solid specimens differed.

DETAILS OF MATERIAL, SPECIMENS AND TESTING TECHNIQUES

Material.—The copper used in the tests was in the form of 1½in diameter rolled bar of normal commercial standards of purity. The material before use was heat treated for one hour at 400 deg. Cent. and furnace cooled, and in this condition an average grain size of 0·09mm was obtained, this

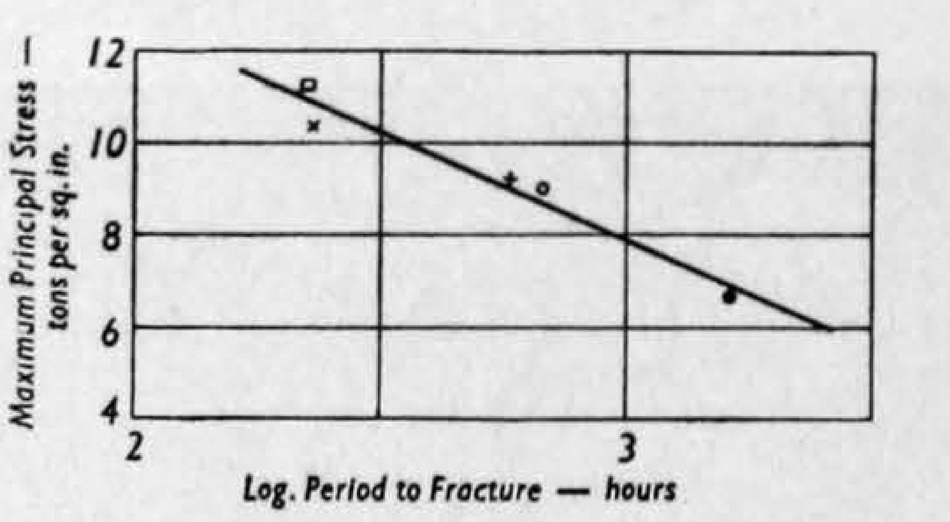


Fig. 17—Relation between maximum principal stress and log. period to fracture for 0·5 per cent Mo steel at 550 deg. Cent.

giving, for the tubular specimen used in the tests (see later) an average of ten to fifteen grains across the wall thickness, which was, in the light of previous creep work using tubular test pieces, a sufficient number of grains to establish reasonably uniform and characteristic behaviour throughout the test piece cross-section and length.

A check upon the initial isotropy of the material was made by means of creep tests at 3 tons per square inch and 250 deg. Cent. on specimens cut in three rectangular directions from the bar, and indicated a close degree of isotropy as regards creep properties. The subsequent combined stress tests indicated that in the region of primary creep this isotropy was well preserved. In the region of tertiary creep a change in ratio of axial to shear strain took place, but since, as will be shown later, the stress criterion governing creep also changed, the change of strain ratio did not necessarily mean that anisotropy developed, although for strains of the order concerned in fracture tests this is, of course, likely upon general grounds.

Specimens.—Combined stress creep tests, pure tensile and pure torsion tests were made on tubular specimens 2·3in equivalent gauge length, 0·5in internal diameter, and 0·03in wall thickness. Loss of wall thickness by oxidation proved to be inappreciable. The three tensile creep tests made on solid specimens were made on specimens of 2in gauge length and of diameter 0·357in. The compression tests were made on specimens of the same diameter, but of 1in gauge length.

Testing Technique.—The tensile and compression creep tests on solid specimens were

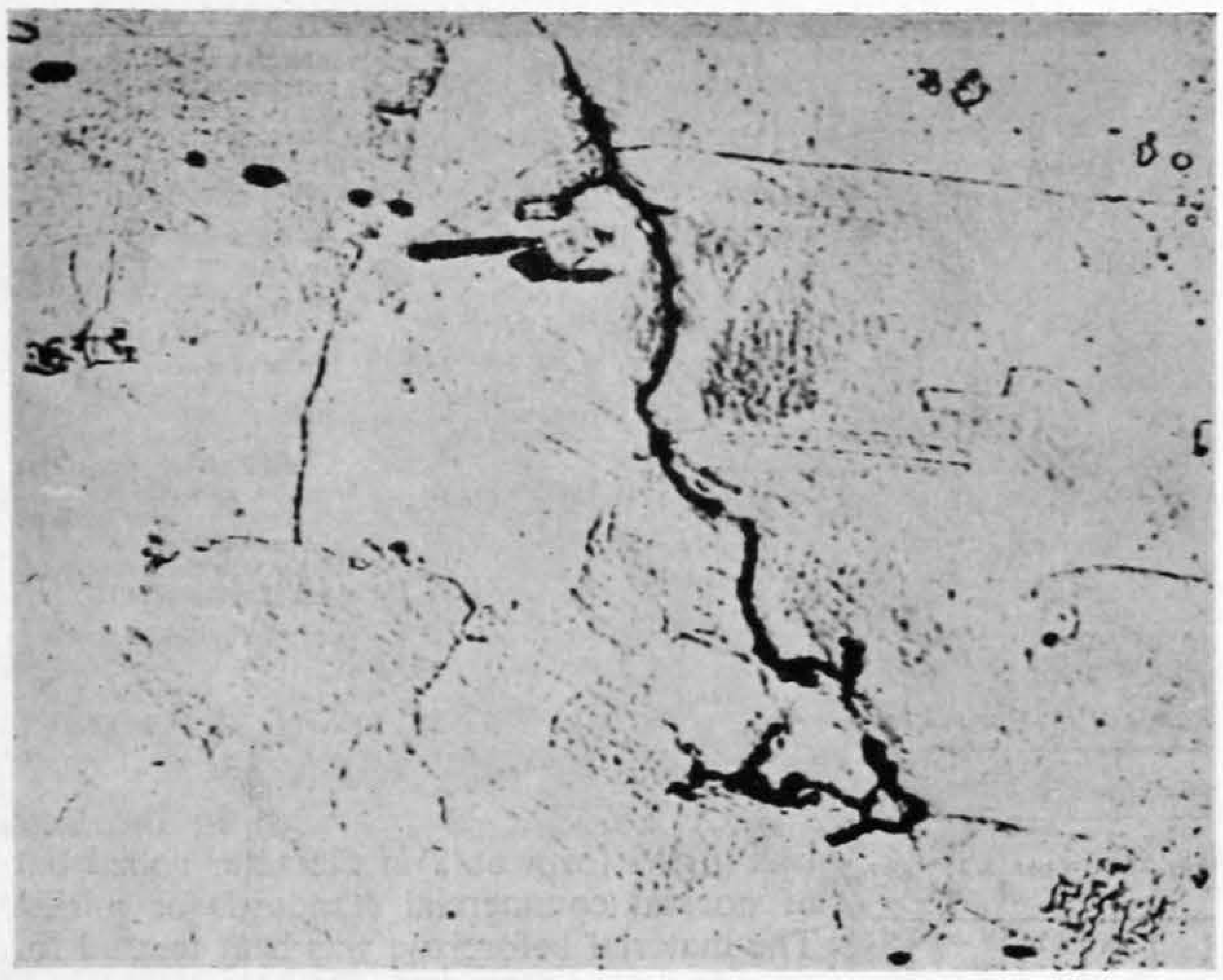


Fig. 18—Pure torsion stress 2 tons per square inch ; fractured, 5442 hours ; magnification ×500

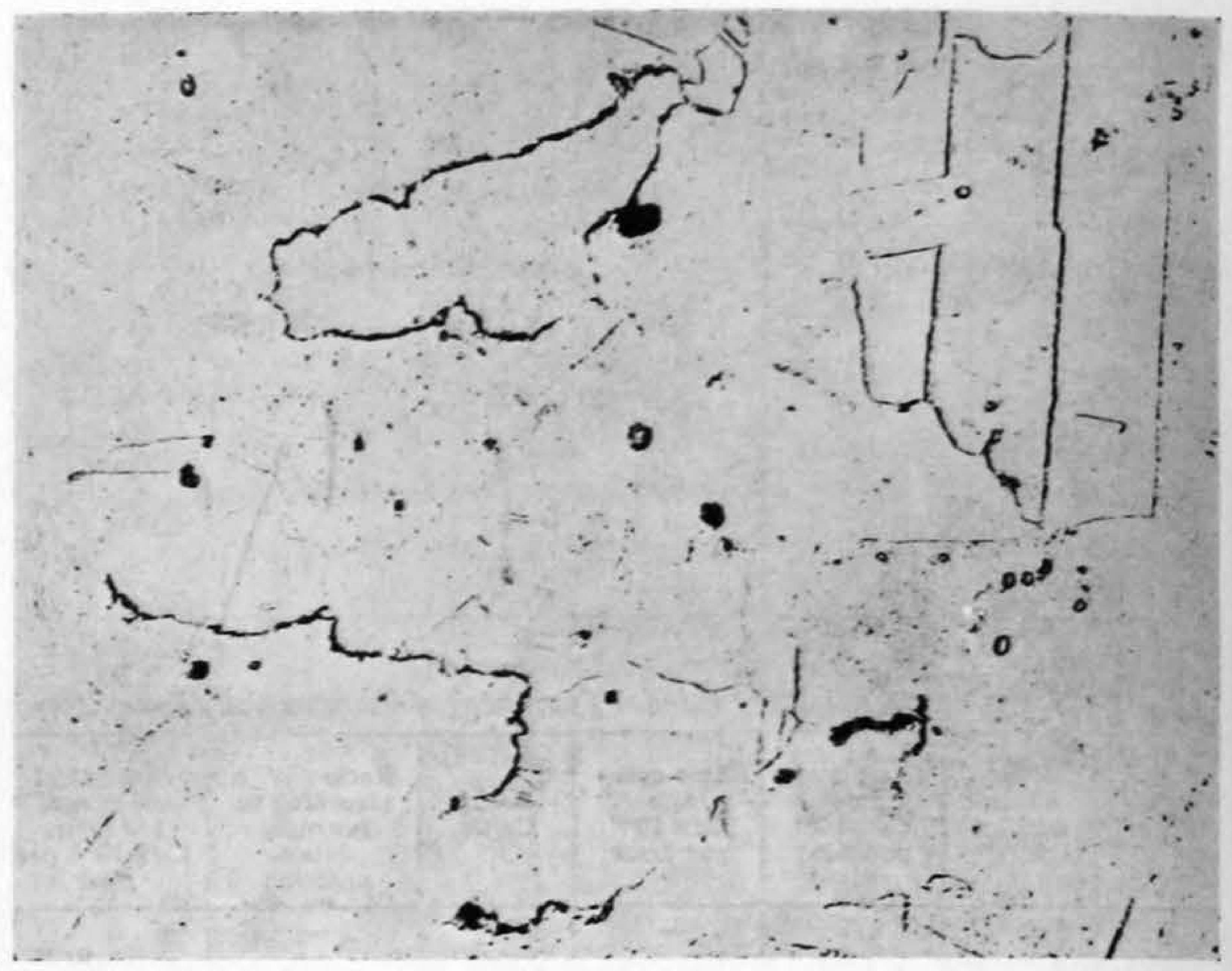


Fig. 19—Pure tension stress, 3 tons per square inch ; fractured, 1139 hours ; magnification ×500

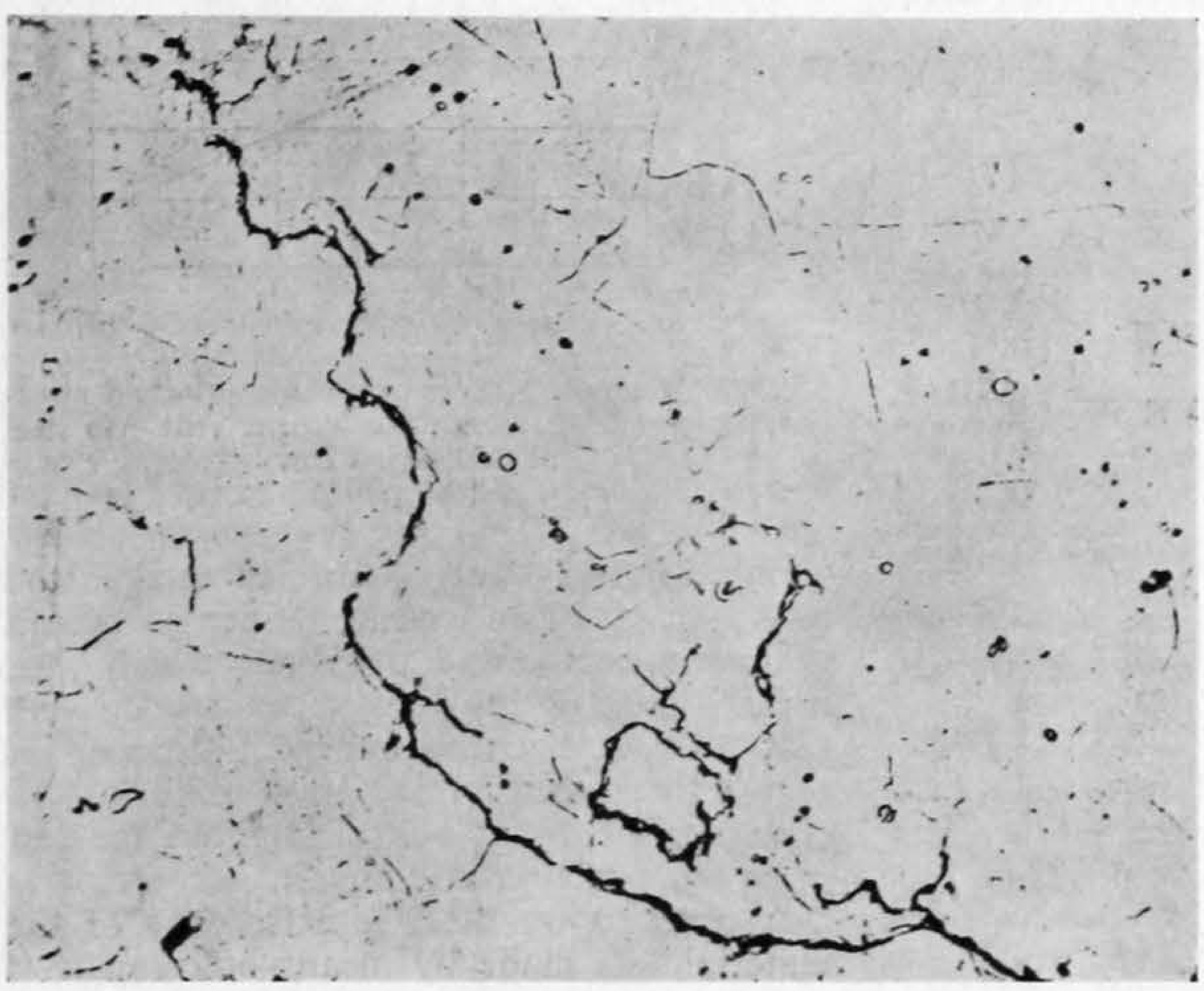


Fig. 20—Tension stress, 2·3 tons per square inch ; torsion stress, 2·3 tons per square inch ; fractured, 310 hours ; magnification ×500

Fig. 21—Tension stress, 0·9 ton per square inch ; torsion stress, 2·25 tons per square inch ; fractured, 2082 hours ; magnification ×500

Fig. 22—Compression stress, 3 tons per square inch ; unbroken, 1250 hours ; magnification ×500

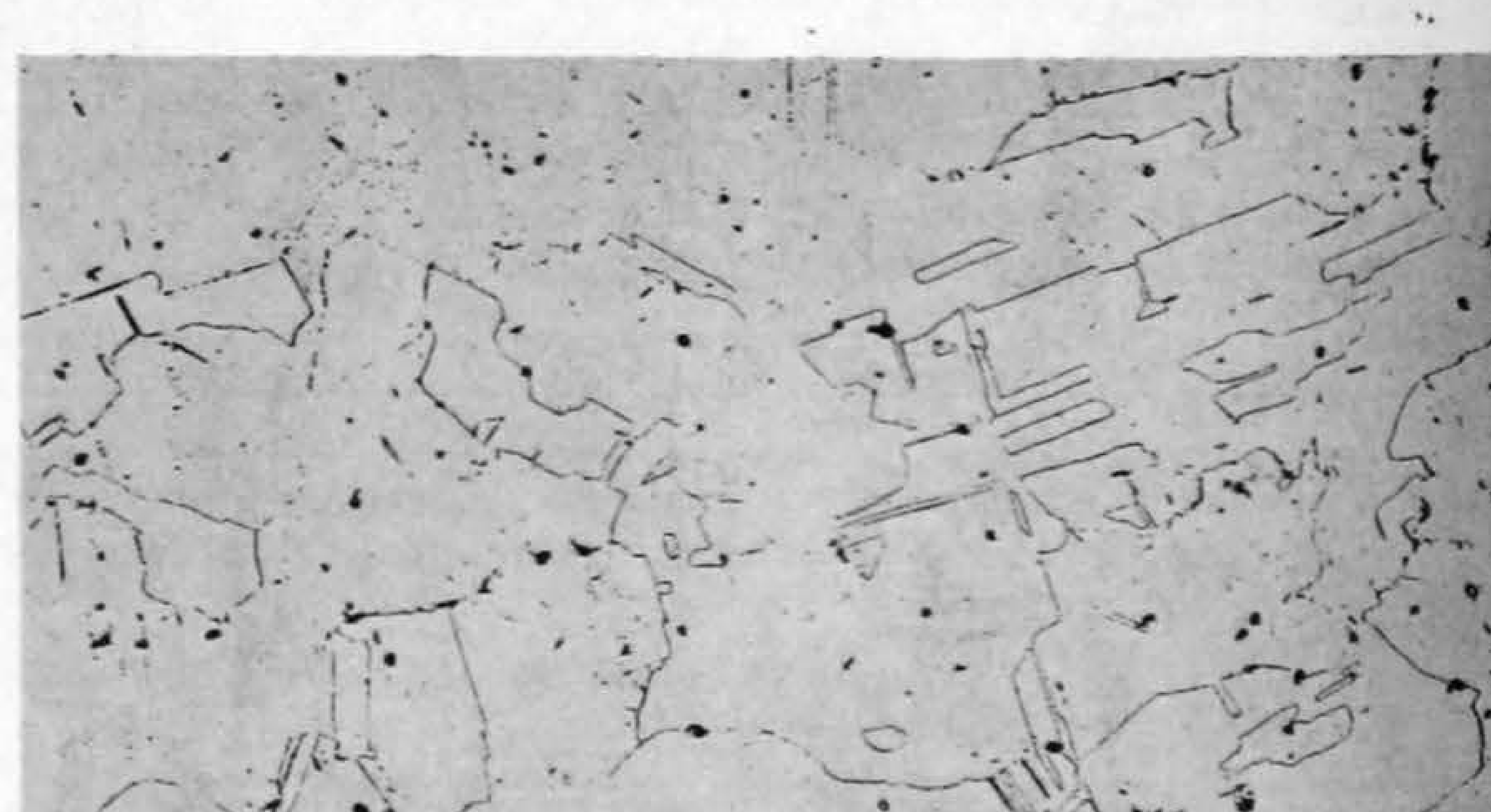


Fig. 23—Compression stress, 3 tons per square inch ; unbroken, 1250 hours ; magnification ×200

made in a 5-ton creep machine ; for the compression tests use was made of conversion equipment designed some years ago by one of the authors. The tension torsion and combined stress creep tests on tubular specimens were made in a M.E.R.L. type combined stress creep machine.

Results of Creep Tests

The creep curves to fracture for tubular specimens are given in Figs. 1–9, and the test results including those on solid specimens in Tables I–V, Table II being, however, specifically concerned with the primary creep behaviour of the material. Table I gives an indication of the relation of various possible stress criteria to the time of fracture. Tables III–V are largely concerned with the tertiary creep and fracture characteristics of the tests, including the relation of the test results to the Kochendorfer proposition. Figs. 10 and 11 indicate the geometrical characteristics of the primary creep curves, and the remainder of the figures deal either with the applicability of various criteria to the creep results or with the nature of the tertiary creep of the material.

Discussion of Results

(*a*) *The Characteristics of Primary Creep in the Material.*—In view of developments in the argument arising in subsequent paragraphs, this section of the paper commences with some discussion of the primary creep region of the various creep curves. Data concerning this region of the creep curves is given in Figs. 10 and 11, and in Table II. All the primary creep portions of the curves appeared to show quite closely the same geometrical creep-time curve form, and it was possible to construct from the family of curves a composite curve form. To the scale of one of the tests chosen this curve is given plotted by strain log. time in Fig. 10. On a log.-log. basis the curve is linear throughout and corresponds with a relation of the type : creep strain $\doteq At^{0\cdot 56}$ where A depends on the stress system applied. The solid specimen exhibits a curve of the same general nature (a power function of time), but the power exponent differs.

In Table II the values of observed axial and shear creep rate and of the other computed rates correspond to the composite curve form. In this table the ratio of the experimentally measured axial and shear creep rates is given for each combined stress system, and is compared with the theoretical value corresponding with an isotropic Mises criterion of creep strain. With one exception the agreement is good, and indicates that principal primary creep rate relations of the type

$$C_1=A_1F[\Sigma(\sigma_1-\sigma_2)^2][(\sigma_1-\sigma_2)-(\sigma_3-\sigma_1)]t^{0\cdot 56}$$

hold.

Fig. 11 shows a plot of the octahedral stress versus octahedral creep rate, and here, with the exception of one point, all points are well disposed round a straight line. This confirms that a principal rate relation of the type indicated above is valid, and further that F is a power function. From Fig. 11 it appears that at a specific time the principal creep rates for primary creep are well given by relations

$$C_1=A[\Sigma(\sigma_1-\sigma_2)^2]^{3\cdot 05}[(\sigma_1-\sigma_2)-(\sigma_3-\sigma_1)], \text{ \&c., or } C_0=A_0\sigma_0^{7\cdot 1}.$$

In later paragraphs the need arises to compute the element of total strain occurring which is of the nature of primary as opposed to tertiary strain, and to do this use is made of the relations discussed above.

(*b*) *The Nature of Creep Fracture in the Material.*—In the last column of Table I remarks are made on the nature of the fractures in the various tests on the tubular specimens. It will be seen that it is true to say that all fractures are completely intercrystalline. This is fortunate in the sense that it provides that one of the group of materials to be ultimately examined fulfils the part of yielding fractures of one definite unmixed type, but is unfortunate in the sense that by the nature of this result a check in the most general sense cannot be provided of the results of the work previously performed on the 0·5 per cent molybdenum steel at 550 deg. Cent. On the other hand, an explicit check is provided of Siegfried's proposition that the criterion of intercrystalline cracking is the hydrostatic stress.

(*c*) *The Criterion of the Time to Creep Fracture.*—Since no appreciable element of transcrystalline cracking occurs in the fractures, the results present a clear cut check of the applicability of Siegfried's hydrostatic stress criterion of intercrystalline fracture. In this group of tests there are three, namely, the test at 3 tons per square inch tension, and 1 ton per square inch torsion, and finally the test at 3 tons per square inch tension and 1·5 tons per square inch torsion, in each of which the hydrostatic stress is the same. The times to fracture are, however, respectively 1139, 730 and 489 hours ; this result is completely out of line with Siegfried's proposition. Again the test at 2 tons per square inch tension with 2 tons per square inch torsion has a hydrostatic stress of 0·66, compared with 1·0 in the pure tension test at 3 tons per square inch, yet the periods to fracture are virtually the same. Finally, a general plot of the hydrostatic stress against log. time to fracture in Fig. 15 shows no continuous relation at all. Accordingly it appears that the Siegfried criterion may be dismissed as inapplicable to this material.

In Figs. 12–16 the various possible stress criteria, the maximum stress deviator octahedral stress, maximum shear stress, and maximum principal stress are plotted against log. time to fracture. It will be noted that none of these stress functions gives a continuous relation except the maximum principal stress, which gives a linear relation over the whole stress range for the tubular specimens and a linear log.-log. relation for the solid specimens.

$$\log. t=5\cdot 2-0\cdot 717\sigma, \text{ or}$$
$$t=1\cdot 59\times 10^5 e^{0\cdot 717\sigma_1} \text{ where } t \text{ is in hours.}$$

This confirms the results of the tests on 0·5 per cent molybdenum steel at 550 deg. Cent., although, as noted in a previous paragraph, the copper fractures are purely intercrystalline.

Before leaving this topic a glance at the comparison of tensile and compression creep test results on solid specimens given in Table I is interesting. Three tensile creep tests on solid specimens at respectively 4 tons, 3 tons and 2 tons per square inch were made, and these fractured in 280, 1374 and 7965 hours, showing normal tertiary creep. For comparison three compression creep tests at 4 tons, 3 tons and 2·6 tons per square inch were made on specimens of similar diameter, and in the case of the tests at 4 tons and 3 tons per square inch were also carried to the periods of 280 hours and 1374 hours. The stress of 2·6 tons per square inch was chosen for the third test, since insufficient time was available for prolonging a test at 2 tons per square inch to the fracture period in tension (7965 hours), and accordingly the test at 2·6 tons per square inch was continued to 2500 hours, at which period fracture would have been expected to occur in a test at 2·6 tons per square inch in pure tensile creep on a solid test piece. In all three cases the compression creep tests on solid specimens exhibited neither tertiary creep nor cracking (see, e.g. Figs. 22 and 23) at periods at which fracture would have occurred under pure tensile stresses of the same denomination. This is in agreement with the suggestion that the maximum tensile principal stress is the criterion of creep fracture.

In Figs. 18–23 a selection of photographs of various fractured specimens is given.

References

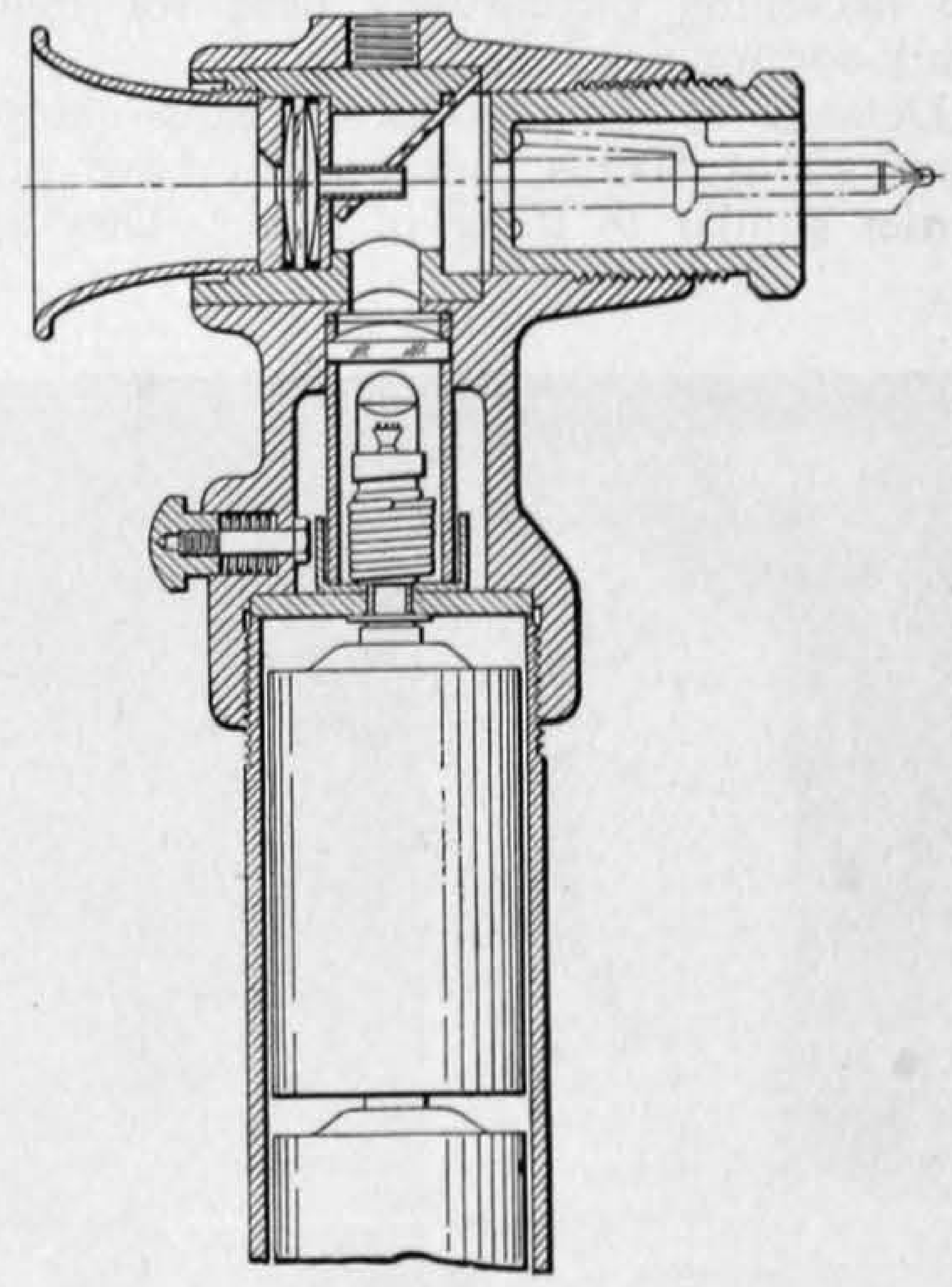
[1] " Failure from Creep as Influenced by the State of Stress," by W. Siegfried, *Journal of Applied Mechanics*, December, 1943, page A202.

[2] " Fracture Under Combined Stress Creep Conditions of a 0·5 per cent Molybdenum Steel," by A. E. Johnson and N. E. Frost, The Engineer, Vol. 191, 1951, pages 434 and 437.

(*To be continued*)

Injector Inspection

For the inspection of the nozzles and needles of small diesel injectors, Simms Motor Units, Ltd., East Finchley, London, N.2, have produced an optical device styled a " Nozzlescope." In the accompanying drawing it is seen adapted for the examination of the needle seat in a nozzle ; illumination is by means of an electric bulb, the light passing through a condenser and being turned on to the axis of the nozzle by a



" Nozzlescope " assembled for nozzle inspection

metal mirror. An unobstructed view of the interior of the nozzle is obtained through a small hole in the centre of the reflector ; to prevent light being diffracted from the edges of the hole a short tube passes through the mirror. The shadow cast by this cannot be perceived in use, the magnification of 3½× giving a good view of the needle seat, albeit very close to the eye.

For the inspection of needles a different optical system is used. The needle points towards the light source and is viewed transversely with a magnification of 10× ; this renders oxidation, erosion or burrs clearly visible.

Adaptors are also provided for the inspection of nozzle and needle laps. As an alternative to the casing holding three U2 dry cells, a small mains transformer can be screwed into the head of the " Nozzlescope." A bench stand can be supplied, if desired.

Mining for Nickel.—A sound colour film, " Mining for Nickel," was recently shown in London for the first time by the Mond Nickel Company, Ltd. This film, the first of a series of four dealing with different aspects of nickel, was made by the International Nickel Company of Canada, Ltd. It opens with a brief description of the first discovery of the vast nickel copper sulphide deposits in the Sudbury District of Ontario, Canada, in 1856, followed by detailed descriptions of the exploration methods and mining techniques now used for the production of nickel ore from the company's mines, in which the underground workings total some 400 miles. The film describes graphically shaft sinking and drifting operations ; square set, blast hole and open pit operations ; shrinkage and cut and fill practice ; and caving operations at the various mines of the company.

Use of Wind Tunnel Techniques in Radio Engineering

By J. M. FALCONER, A.INST.P.*

The aerial arrays for microwave radio systems generally consist of large parabolic reflectors carried on towers tall enough to be clear of the surrounding terrain. The towers and the mounting of the reflectors must be sufficiently stable to keep the displacement or vibration of the reflectors within narrow limits under all weather conditions. Wind tunnel tests are carried out on scale-model towers and aerial arrays to provide the required information about the structural stiffness of the proposed system. An outline of the method is given here.

THE demand for communication systems of all kinds (whether telephone, telegraph, facsimile or television) is continually growing. Owing to the scarcity of many of the raw materials used in cable manufacture, radio systems are now more and more used for such applications. Problems are then raised by the congestion among the wavelengths used for business, television and sound broadcasting purposes, so that microwaves are becoming increasingly used for much trunk communications traffic.

Defined as having wavelengths shorter than about 50cms, microwaves have properties similar to those of light. They are propagated along paths that are substantially straight lines, and are progressively attenuated beyond the optical horizon. Their similarity to light also enables them to be focused into narrow beams, the " mirror " being a parabolic reflector or a similar device.

In order to provide a reliable communication service over a distance greater than the eye can see, the microwaves have to be relayed between stations. In each pair the transmitting and receiving aerials have to face each other along a " line-of-sight " path and, to cut down the number of stations necessary, the aerials should be mounted as high above the surrounding terrain as possible. The final system then consists of a series of towers, all (except the two terminals) bearing at least two aerial systems, one to receive and the other to transmit the radio signal to the next station.

The required narrow microwave beam is produced by placing the aerial at the focus of a parabolic reflector which is several wavelengths in diameter. For any given wavelength, the reflector becomes larger, the beam narrower, and the gain greater. The gain is here defined as the ratio of the signal received using a reflector to that received by the same aerial without a reflector. For a system using a wavelength of 15cms (corresponding to a frequency of 2000 Mc/s) and a reflector diameter of 12ft, the power gain is some 900. The width of the beam, defined as the angle subtended at the aerial by two directions in which the gain is half the maximum value, is about 4 deg. of arc. It, therefore, becomes clear that the reflectors must be so rigidly mounted that they face each other accurately throughout the entire life of the system. This in turn places emphasis on the design of the towers which carry the aerial arrays. They must be carefully designed to retain their stability under all conditions, particularly those of weather.

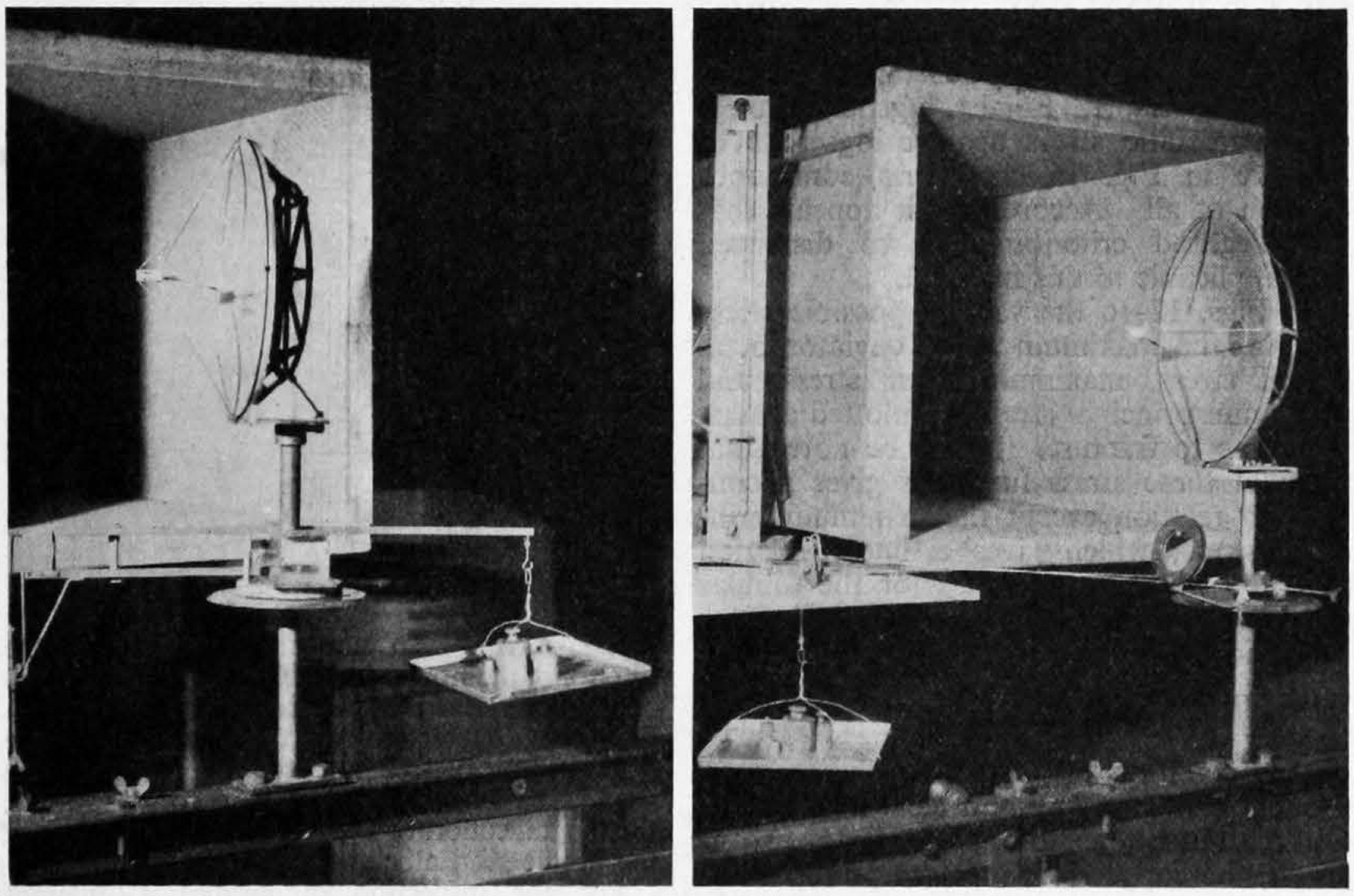


Fig. 1—Measuring direct thrust (left) and measuring turning moment (right)

Owing to the parabolic nature of the reflector, the effect of wind forces on the system is greater than if the reflectors were planar. The curved surfaces act as an aerofoil, in a manner similar to the wing of an aircraft, and produce lift and drag forces whose magnitudes depend upon the wind direction. (The wind lift is here used in the aerodynamic sense as denoting a force, not necessarily vertical, which acts at right angles to the wind direction. A drag force acts in the same direction as the wind.) While it is possible to calculate these forces for simple parabolic sheets, the supporting structures (needed to maintain the shape of the reflector) modify the wind flow to such an extent that the calculated results are not valid for practical aerial systems. This disadvantage of the purely theoretical treatment has, therefore, led to a more experimental approach. By making scale models of the aerial systems, and using a wind tunnel to simulate the conditions likely to be encountered in practice, the forces acting on the system have been measured.

The design of a tower that will be sufficiently strong to withstand a high direct wind loading is a comparatively simple matter. Such a structure may, however, not easily resist the torsional forces acting upon it. For this reason, the tangential forces tending to twist the reflector system are of greater interest to the designer than the direct thrusts acting along the axis. The information required from the scale-model experiments is, therefore, the variation in magnitude of the torsional forces with wind direction, at the maximum wind velocity likely to be encountered in any particular location. The strengths of the tower members to which the aerial system is attached may then be estimated, and the remaining parts of the structure calculated.

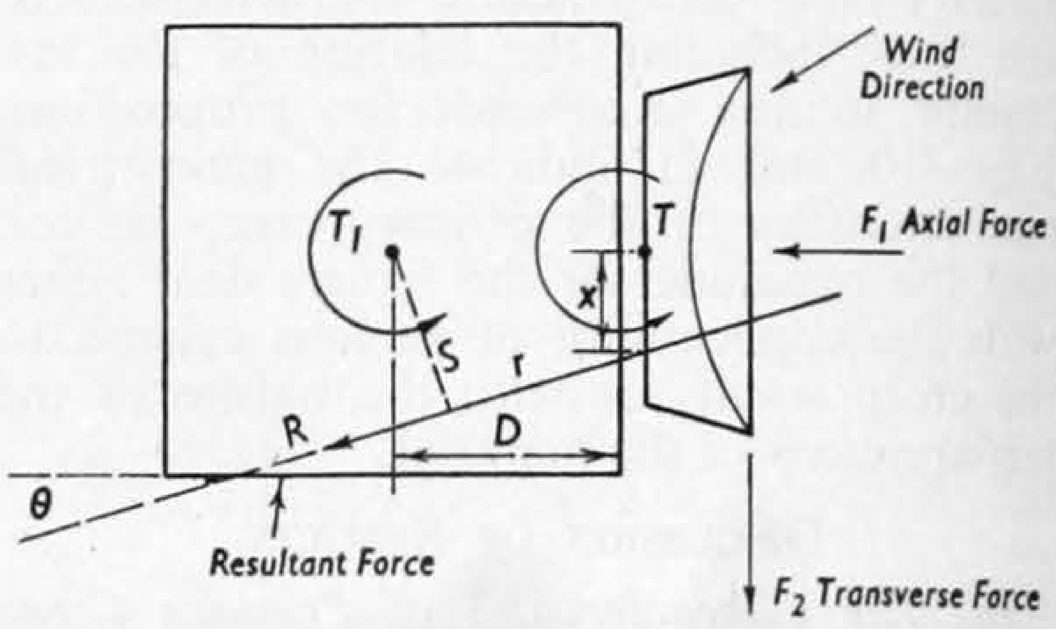


Fig. 2—The forces on the aerial system and tower

To measure the desired quantities a scale model of the system is set up in the air stream at the mouth of the wind tunnel. Fig. 1 shows the arrangement for measuring the axial force, i.e. the component of the force in the direction of the mirror axis. The whole system is on a vertical pivot so that the aerial can be set to face at any desired angle to the wind direction. A simple balance arrangement is used with which one force component at a time can be measured, and three series of measurements are made for axial force, transverse force and (with a modified arrangement) torque about a vertical axis.

To be of value to the design engineer, the data obtained from these tests must be corrected for the scale of the model, and the wind speed. Provided the flow pattern round the model and full-scale system are the same, forces are proportional to the area of the surface under test and to the square of the wind speed. The conditions that the pattern shall be the same in the two cases are known, but to meet them would entail, in effect, doing full-scale tests. However, from general experience in this type of work it is known that it is unlikely that there will be any large changes in flow pattern in the range involved : and tests which have been carried out, using one-twelfth and one-quarter scale models, and comparing the results with those on a full-sized version of a small aerial system (4ft in diameter) in a large wind tunnel have shown that the simple corrections given above are valid over a large part of the range. Hence the model data can be used with confidence to predict the forces on the full-scale system.

From the results of the tests mentioned above it has also been shown that the addition of a " wind-spoiler " ring to the

* Research Laboratories of The General Electric Company, Ltd., Wembley, England.

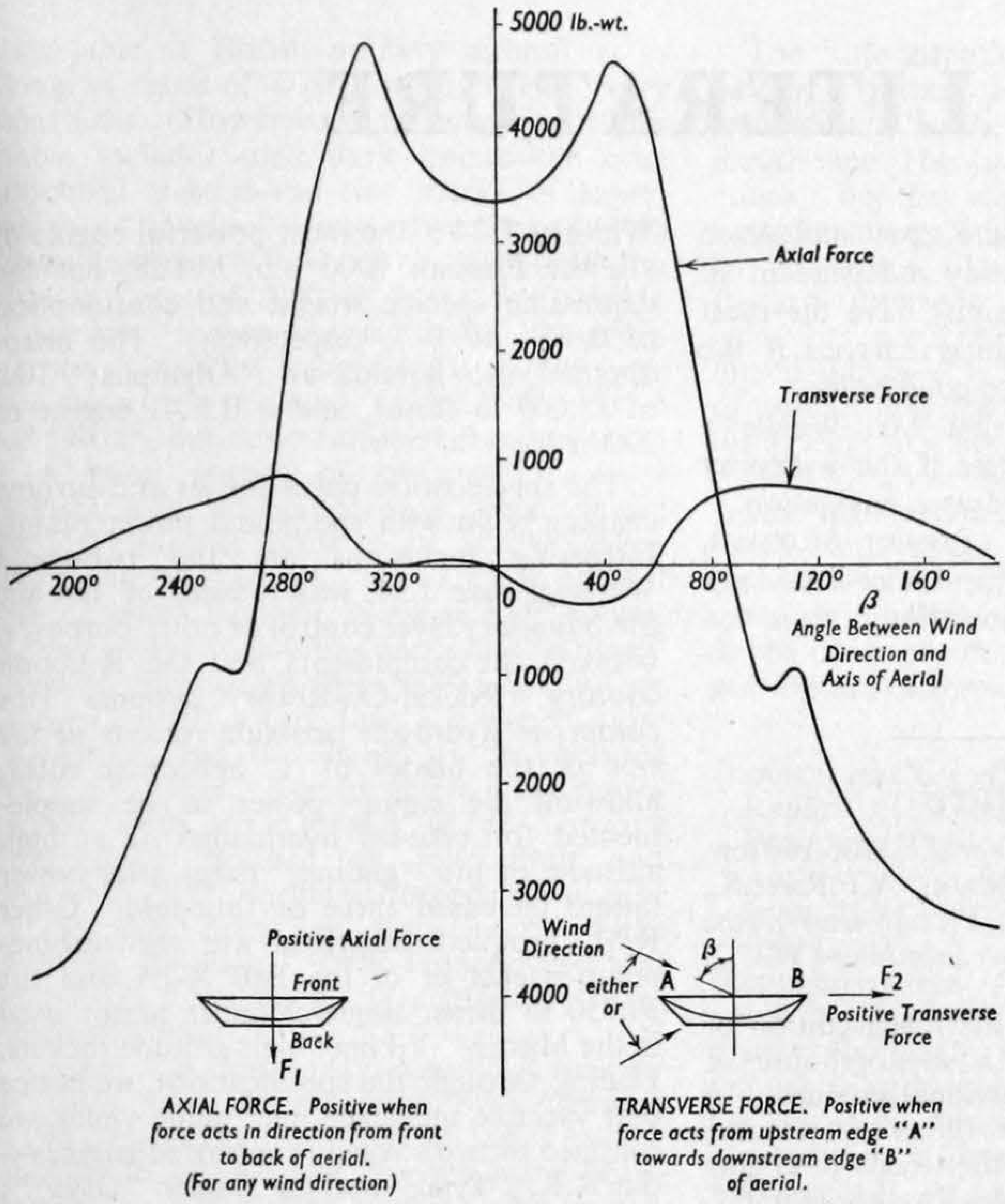


Fig. 3—Axial and transverse forces on 12ft diameter aerial. Wind velocity 100 m.p.h.

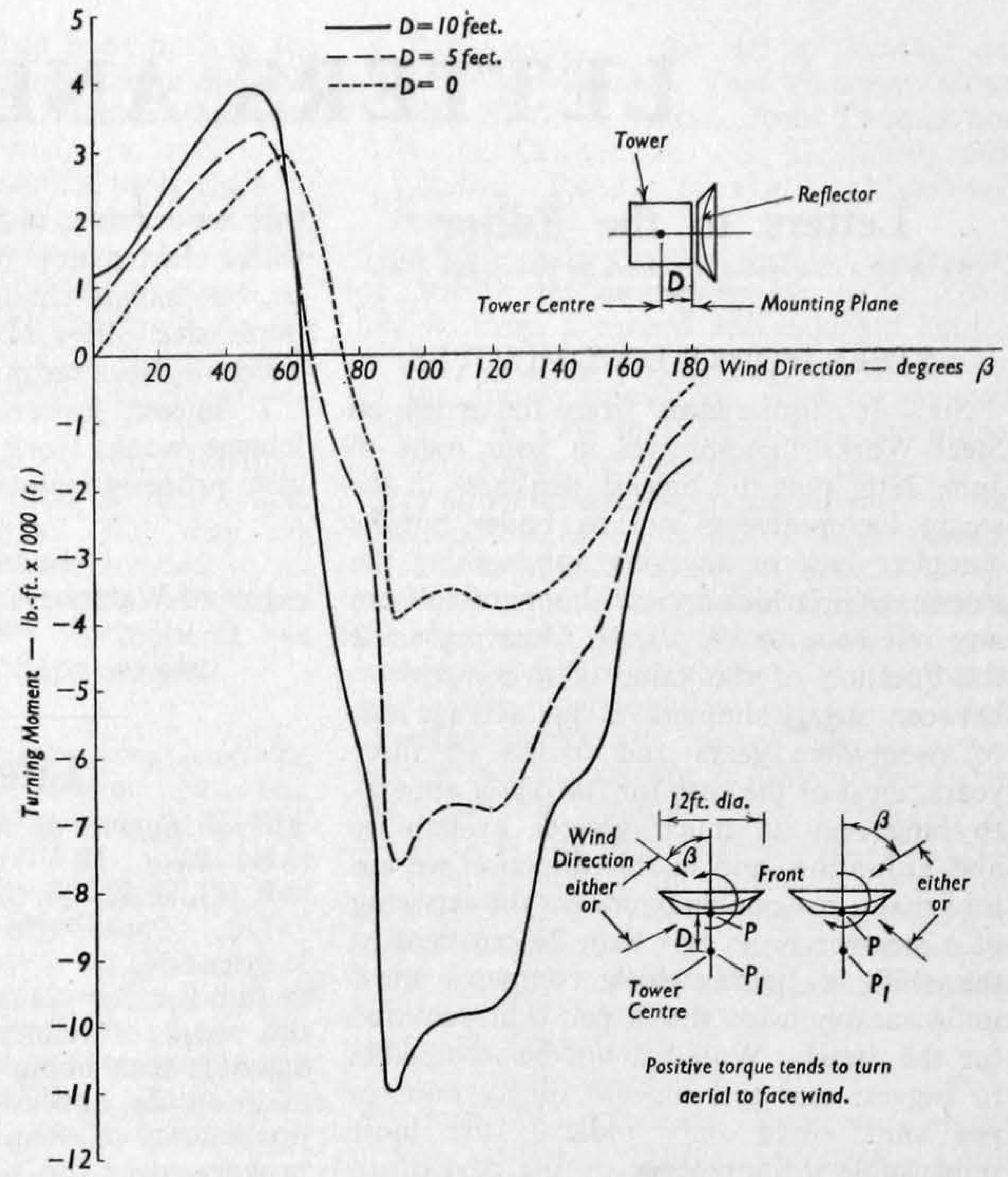


Fig. 4—Variation of turning moment about tower centre with wind direction. Wind velocity 100 m.p.h., reflector diameter 12ft

edge of the reflector can reduce the torque by an appreciable amount, without seriously increasing the direct thrust with the wind head-on.

The results of the tests are generally expressed in terms of the forces shown in Fig. 2. These are two perpendicular forces (F_1 acting along the axis of the reflector and F_2 acting in the plane of the aperture) and a torque T about some arbitrarily fixed vertical axis (generally in the plane of the fixing bolts). A plot of forces F_1 and F_2 against wind direction is given in Fig. 3.

From these data we may readily calculate the torque T_1 about the tower centre, since $T_1 = T - DF_2$, provided the sign conventions adopted are correctly observed. These are as follows: for any wind direction relative to the system, a positive axial force acts in

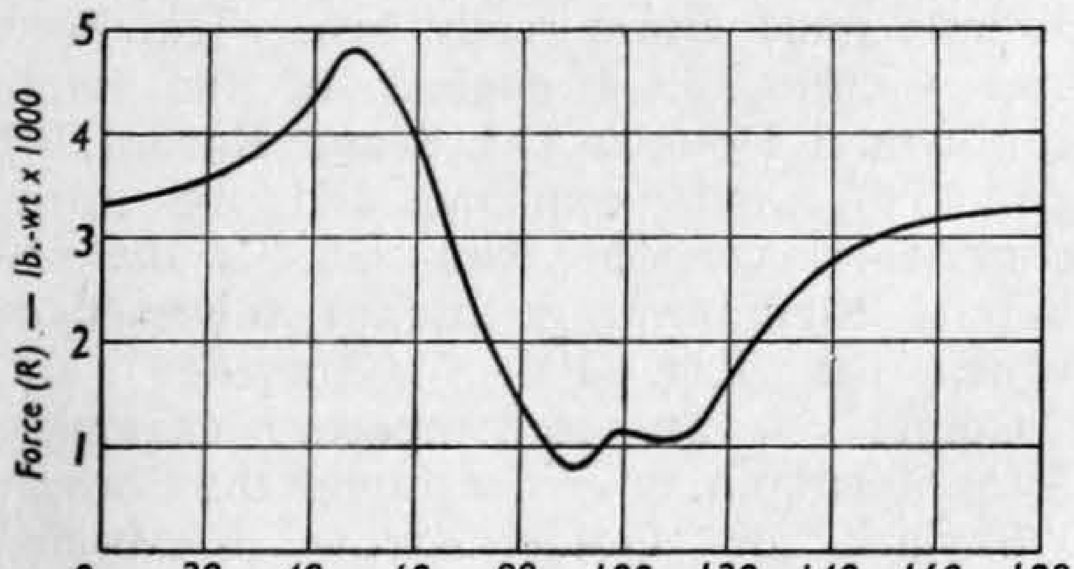


Fig. 5—Force on tower due to wind pressure on 12ft reflector. Wind speed 100 m.p.h.

the direction from front to back of the reflector. For any wind direction, a positive transverse force tends to move the aerial down-wind, and a positive torque tends to turn the aerial so that its concave face is towards the wind. Fig. 4 shows T_1 plotted against the wind direction for three different widths of tower. It is clearly shown that the turning moment increases considerably with the distance (D) between the tower centre and the reflector. The irregularities in the curves are due to the disturbance of the wind flow over the surface of the reflector.

The direct load on the tower, tending to overturn it, is the resultant, R, of the two measured forces: $R^2 = F_1^2 + F_2^2$, and if its point of application on the tower is required, this may be determined as follows:

$$\tan\theta = F_2/F_1$$
$$\text{and } X = T/R \sec\theta.$$

The force R is plotted against wind direction in Fig. 5. This direct load is such that a tower whose torsional rigidity is sufficient to meet the requirements of a radio system will easily remain upright.

Tests of the kind described have been carried out on scale models (1in to 1ft) of both 8ft and 12ft diameter aerial systems of 60 deg. angular aperture. The results have always been in reasonable agreement with the calculated values for a paraboloidal sheet. In the curves shown, the figures are all scaled to a wind speed of 100 m.p.h., since this represents the generally accepted maximum wind force with which towers would have to contend when erected in tropical or temperate areas, unless in very exposed sites. The 12ft reflectors were made for a 2000 Mc/s trunk radio system developed by The General Electric Company, Ltd., for multi-channel telephony and television relay purposes. Other kinds of reflector tested include a scale model of the 14ft cage-type paraboloid used for the London-Birmingham Radio Relay Link.

Gas Turbines for Australia

The new weapons testing range in Australia, Maralinga, is remote from communication and draws water only from bore-holes, which yield water more salty than that in the sea. To circumvent these difficulties, gas turbine-driven alternators have been installed, they being relatively light and compact, needing no cooling water, and providing waste heat to evaporate local water for household purposes.

The two main generators are Ruston and Hornsby "TA" sets, running on distillate oil, which is also used for the 500kW Ruston-Paxman vee-eight emergency diesel alternator. "Ozonair" filters precede the normal Vokes "Micro-Vee" air cleaners as an additional precaution against dust entering the compressor. The alternators are 1250kVA Bruce Peebles machines, giving 6·6kV on three phases.

Each turbine exhausts to a Davey, Paxman double-pass tubular boiler working at 100 lb per square inch. At a turbine power of 750kW they raise 8500 lb saturated steam per hour; the maximum output of 15,000 lb per hour can be realised by using auxiliary oil-firing equipment. Sturtevant forced draught fans allow the boilers to be steamed when the turbines are not running, as may be the case in between tests on the ranges. An economiser gives a feed temperature of 146 deg. Cent.; make-up water is taken from the main Aiton triple-effect evaporators and treated for correct alkalinity.

Automatic "Argonarc" Welding Equipment

An electronically controlled automatic "Argonarc" welding equipment has been developed by British Oxygen Company, Ltd., Cricklewood, London, N.W.2, for welding jigged components, cylindrical sections and similar work involving the welding of a contour. The machine is fitted with a welding head with a vertical travel of 16in, and under an automatic arc length control system it follows contours on a workpiece, a precise distance between the arc and the joint being maintained to ensure a uniform weld deposit with controlled penetration. The head is fitted with a water-cooled welding torch having a maximum current capacity of 400A d.c. For adjustment the head holder can be tilted up to 6 deg. to the right or left of the centre line, and a micro-positioner facilitates close setting of electrode alignment.

The water, gas, current and other controls are operated from a remote push button panel and once the welding conditions are set on the machine the welding sequence is automatic. The control unit fitted to the equipment acts as an "electronic balance." The desired arc voltage is set on one side of the scales provided and a signal circuit across the arc provides the comparison on the opposite side. Any discrepancy in the balance is then automatically calculated, amplified and transmitted to the head unit, in which a motor comes into operation to move the torch up or down, according to the balancing signal received, and reset the arc gap to the the desired length and voltage.

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

STEEL WORKS LOCOMOTIVES

SIR,—It is quite clear from the article on Steel Works Locomotives in your issue of June 29th, that the biggest weakness in the steam locomotive is not its boiler but its complete lack of anything approaching the salesmanship which appears inseparable from any reference to the diesel. Leaving aside the question of the value of a comparison between steam shunters of an average age of twenty-five years and diesels of three years, most of the case for the diesel appears to hinge on its much greater availability and utilisation, and in this direction we are told that a reasonable figure for the servicing of a steamer is no less than 20 per cent of the shift, a figure which compares most unfavourably with the 2 per cent required for the diesel. Would it not be reasonable to suggest that this time of ninety minutes per shift could only indicate the most remarkable incompetence on the part of all concerned and that it should be quite a simple matter to do all that is required in fifteen or twenty minutes, assuming that the machine is designed with this in view? Similarly with washouts, minor repairs and major overhauls.

Surely it is not necessary, merely because certain methods were acceptable in an age of cheap machines, cheap fuel and relatively cheap labour, to regard such methods as the only ones possible under present-day conditions?

L. IRVINE-BROWN

Singapore, August 15th.

LONDON'S WATER SUPPLY

SIR,—We are a little concerned by the suggestion in the otherwise interesting letter by Mr. Whalley in your issue of August 10th that the lock gates on the Kennet and Avon should be replaced by fixed dams, and by Mr. Whalley's evident conviction that the waterway may be finally written off as a navigation. This is so far from the case that it is difficult to know where to begin in refuting the idea. I shall only mention that in ten weeks last winter more than 22,000 persons signed a petition to the Queen calling for the reopening of the canal to traffic; that this was the culmination of what may be fairly described as a nation-wide campaign on the subject, assisted by Privy Councillors and others of equal eminence, and, finally, that on March 13th this year the House of Commons unanimously rejected the British Transport Commission's proposal that the existing statutory right of navigation be extinguished.

The semi-derelict condition of the waterway follows its acquisition by the former Great Western Railway Company, who did everything possible to discourage traffic which would compete with its own main line. Unfortunately, the British Transport Commission has, since nationalisation, taken the same destructive policy even further. But this Association, and the Kennet and Avon Canal Association (a body independent of us, but having similar aims) have the most impressive offers of regular cargoes if the waterway were restored to good order.

I suggest, however, that Mr. Whalley's scheme would work better if the waterway were properly maintained as a navigation.

ROBERT AICKMAN,
Founder and Vice-President.

Inland Waterways Association,
London,
August 18th.

Literature

Aircraft Engines of the World. 1956 edition. By PAUL H. WILKINSON, A.F.R.Ae.S., A.F.I.Ae.S. Sir Isaac Pitman and Sons, Ltd., Parker Street, London, W.C.2. Price 55s.

IT is taken for granted that each edition of this work of reference is a storehouse of valuable data about individual engines. In addition its appearance offers a welcome opportunity to examine the trends of engine progress over the world. In this country, advance has been confined largely to turbine engines, though the author in his introduction to the reciprocating engine section draws attention to the output of 4500 e.s.h.p. achieved by the Napier "Nomad" N.Nm.8, with aftercooler and reheat: this is handsomely the highest power of any piston engine. We also notice that the Cirrus "Bombardier" is no longer our sole exponent of direct fuel injection.

But interest attaches mainly to the turbine to-day, and twenty-three new engines appear this year in the pages. One trend is immediately evident: larger and larger engines are being built. While there are, under development, 25,000 lb Allison and 18,000 lb Orenda engines, the most thrustful engine in the world to-day is the Russian MIK-209, of 17,500 lb thrust. This is indeed a remarkable engine; it cannot be denied that it is very large, since it has a frontal area of 12·3 square feet against the 11·7 square feet of the D.H. "Gyron." The by-pass ratio is presumably small, since the specific consumption of 0·75 lb per pound thrust per hour is much nearer the 0·76 of "Avon" and "Olympus" jets than the 0·7 of the English by-pass engine, the "Conway." The commercial version of this engine, with 15,000 lb thrust, is used in the T.U.104; the reduced acoustic energy level of the diluted jet explains the use of wing root engine mountings as seen on pioneer jet airliners such as the "Comet" and the "Jetliner." In the tabulated turbo-jet information, another superlative that stands out is the 35,000 r.p.m. maximum speed of the Blackburn "Palas" 600. Among the after-burning engines, the Allison J.71-A-2 is unbeaten both for thrust and efficiency, 14,000 lb at a specific consumption of 1·8 lb per pound thrust per hour. British engines are more prominent in the turbo-prop table, the 5050 h.p. Bristol B.E.25 being unchallenged in its specific consumption of 0·38 lb per horsepower hour; next comes the Rolls-Royce "Tyne," at 0·41 lb, which has the advantage in specific weight at 0·43 lb per horsepower against the bigger engine's 0·6 lb. Only one other engine equals this power-weight ratio, the much bigger Pratt and Whitney T.34: the most powerful engine of all, the Russian 8000 h.p. M-028, has the depressing specific weight and consumption of 0·83 and 0·7, respectively. The introduction also heralds an "Olympus" 106, of 15,000 lb thrust, and a B.E.41 engine of 2000 s.h.p.

The specification pages for jet and turbine engines begin with specialised power plants. Intriguing inclusions are the two-spool Westinghouse J.54, with a bleed of hot air, for boundary layer control or other purposes, between the compressors, and the Reaction Motors "Rocket-On-Rotor" system. This comprises hydrogen peroxide rockets at the tips of the blades of a helicopter rotor, allowing the engine power to be supplemented for take-off overloaded or at high altitude, or the "gliding" range after power failure increased three or four-fold. Other R.M. products described are the turbine-pump rocket-jet of the Bell X-1A and the 20,750 lb thrust single-chamber motor used in the Martin "Viking" high-altitude rockets. Leafing through the specifications, we notice that variable incidence inlet guide vanes are confined to two strongly contrasted engines—the R.R. "Tyne" and the Napier "Oryx"; it is believed that the General Electric J.79, mentioned in the introduction, will have the stator blades of more than one stage adjustable. The "Orion" is unique in carrying only one of four stages of turbine blades on the h.p. wheel. The Fiat 4002 is a remarkable revival of early Whittle ideas, with a single-stage centrifugal compressor, single reverse flow combustion chamber, and single-stage turbine, a specific consumption close to that of the lightweight "Soar," 1·25 lb per pound thrust per hour, suggests that the theoretical disadvantages have yet to be overcome. Prominent on the engines from the U.S.S.R. are hollow air-cooled turbine blades, although Western engines confine themselves to air-cooled nozzles.

After a few pages devoted to British and United States components manufacturers, there comes a fascinating section linking the engines with their aircraft. The introduction concentrates on the airliners, and emphasises that once the jet is adopted, the long range aircraft must cruise really fast. The Pratt and Whitney JT-4 engines of the inter-continental Douglas D.C.8 and Boeing 707 give 590 m.p.h. cruising, and the trans-continental versions with J.T.-3's do 550 m.p.h. Medium-range aircraft, however, of which the T.U. 104, "Caravelle" and "Comet" 4 are contemporary examples, fly at 500 m.p.h. or less, although the Convair "Skylark" or "Golden Arrow" is expected to rival the bigger machines at its, later, introduction. The short range aircraft vary about and below the 400 m.p.h. of the best propeller-driven craft. More exotic performance figures appear in the tables of military aircraft: 2400 m.p.h. is credited to the Bell X-2, with its Curtiss-Wright rocket, while a really ambitious turn of speed is expected from the North American X-15 on the 20,000 lb of rocket thrust available. The reference to the Republic XF-103 is almost the only mention of ram-jet engines in the volume. One notes with interest that the Ryan vertical take-off project, with a reheat R.R. "Avon" credited, like that of the Fairey F.D.2., with 14,000 lb thrust, is expected to achieve 1000 m.p.h.

It comes as a pleasant surprise to find that the table of British military aircraft is as long as those of U.S. Air Force and Navy machines. However, it transpires that this table includes such dark horses—or even doubtful starters—as two marks of supersonic "Javelin" interceptors and the Saunders-Roe S.R.53, with two "Gyron Junior" jets of 8000 lb thrust each and a "Spectre" rocket to total 21,000 lb thrust. Bristol Simplified Reheat is invoked to give the supersonic Folland "Gnat" II a thrust of 5800 lb, but not mentioned elsewhere.

A good muster of supersonic aircraft appear in the French division, including one with the highest thrust of all, 100,000 lb on the Leduc 022 ram-jet. The U.S.S.R. aircraft are specified by their Western code names, the original designations appearing in parentheses: throughout these tables, the author shows himself aware that a name is more significant and less liable to be confused than a number. The freighters range downwards from the Douglas C.132, carrying 100,000 lb payload on four Pratt and Whitney T.57 turbines, expected to give 15,000 h.p. each, but stops short of the Scottish Aviation "Twin Pioneer," so that the Alvis "Leonides" is attributed in the text to no aircraft.

There is a brief index, mainly of makers' names. Such minute mistakes as crediting eight combustion chambers to the "Avon" R.A.29 in a table can be overlooked in an annual as up to date as this. We would, however, be pleased if it was easier to discover, on the specification pages, how the two, three or four turbine stages quoted were coupled together; in the case of the Napier "Gazelle" the two turbines have separate paragraphs, as have the compressors of some of the two-spool engines, and this practice should be made uniform. A generous degree of cross-reference where related engines appear under different names would also be valuable; when reading of the Ford J.57 one is given no indication that two other J.57's appear fifteen pages further on.

Dynamique Générale des Vibrations. Second edition. *L'Instabilité en Mécanique*. By Y. ROCARD. Masson et Cie, Editeurs, 120, Boulevard Saint-Germain, Paris VIe. Price 51s. 6d. and 27s.

THOSE with a knowledge of French and who have used Rocard's book *Dynamique Générale des Vibrations* will welcome this new and enlarged edition. To those vibration engineers who are not acquainted with this work, it can be strongly recommended. The book is a long one and is divided into two parts, each containing a mass of information which is lucidly presented and very well organised. The first eighteen chapters constitute part I and deal with vibrating systems. Perhaps the most striking feature of this portion is the way it differs from the majority of textbooks on vibration that are available at the moment in English. This part of the book gives, so to speak, the full treatment. In addition to the body of introductory theory, it deals with electrical (as well as mechanical) vibration, gyroscopic coupling, transients, filters, instability, self-excited oscillation, non-linear effects, and so on and on. The author's purpose, when dealing with each of these topics, is to explain the physics and mechanics of the problem rather than to explain practical techniques of calculation. Part II of this book is concerned with acoustic waves. It comprises nine chapters and gives an excellent introduction to the subject of wave propagation in a gas. Perhaps the author will, one day, be persuaded to write an equally lucid account of acoustic waves in elastic media.

Too little attention has been paid in the past by engineers to the problem of dynamic instability. To be sure, the methods of Routh and Hurwitz provide a method of attack; but they are analytical tools which do not demand scrutiny of the causes of stability. In his book *L'Instabilité en Mécanique*, Rocard discusses in detail problems of instability with particular reference to the directional stability of cars, the flutter speeds of aircraft and the instability of suspension bridges in the wind.

Both of these books are, unfortunately, rather high-priced in view of their paper covers and uncut pages. But they are excellent value and are commended to all vibration analysts. Indeed, there appears to be a good case for investigating the possibilities of translation into English.

Drainage and Use of Methane from Coalfields. Report of O.E.E.C. Mission No. 163. European Productivity Agency, 2, Rue André-Pascal, Paris (16e). Obtainable from H.M. Stationery Office. P.O. Box 569, London, S.E.1. Price 10s.

THE primary aim of improving the safety of mines by removing methane (firedamp) is greatly assisted by the recovery of this gas for use in industry and as town gas, states the report of a recent O.E.E.C. mission on the drainage and use of methane from coalfields.

After reviewing the history of the subject, the report discusses the methods applied in various collieries, and concludes provisionally that for seams yielding less than 100 cubic metres of methane per ton of coal produced, it will in most cases be sufficient to drill boreholes upwards from the seam in order to obtain enough degasification. In particularly fiery pits, other methods may be required in addition. While it was not possible to put a money value on the increased safety obtained, says the report, there were found several instances where a considerable increase in output had resulted, not to mention the value of the recovered methane as a fuel. The report concludes with a very full discussion on the technical and economic aspects of recovery and utilisation.

Design and Construction of Engineering Foundations. By F. D. C. HENRY. E. and F. N. Spon, Ltd., 15, Bedford Street, Strand, W.C.2. Price 63s.

THE aim of the treatment expounded in this book is to link the theory of soil mechanics with actual foundation design and methods used in structural analysis. Thus, emphasis is placed on outlining existing solutions of foundation problems of various kinds, and the book, as a whole, contains a comprehensive treatise of both the theoretical background and the constructional procedures commonly encountered in foundation engineering.

There is, first of all, a chapter on the application of geological knowledge to the subject; then a chapter on the principles of soil mechanics, and, thirdly, a chapter linking structural theory and soil mechanics in foundation design, giving information on permissible bearing pressures, concrete stresses and so forth.

These three chapters form an introduction to a more detailed study of foundation design, which gradually progresses from the simplest to the more complex designs. The subjects dealt with are: individual footings; continuous footings and rafts; retaining walls and culverts; cofferdams and caissons; bearing piles and piling; mining subsidence; bridge abutments piers and underpinning.

A Bibliography of the Art of Turning and Lathe and Machine Tool History. Compiled by S. G. ABELL, JOHN LEGGAT and W. G. OGDEN, Jr. S. G. Abell, 568, London Road, Isleworth, Middlesex. Price 10s. 6d.

THIS bibliography is published for the Society of Ornamental Turners by Mr. S. G. Abell, and it forms a revised and enlarged edition of that first produced in 1950 as a supplement to the society's bulletin. The society was founded in 1948 in London with the object of fostering and developing the art and craft of ornamental turning as exemplified in the fifth volume of Holtzapffel's work *Turning and Mechanical Manipulation*, and the bibliography is intended as a work of reference for members and others interested in the historical aspect of the subject. It is probably one of the most complete works of its kind, covering books and periodicals on ornamental turning and the history of the lathe, both in this country and abroad. A majority of the references are accompanied by brief details of the particular aspect of turning covered by the book or article. A useful chronological index of the basic works on ornamental turning and a comprehensive subject index add to the interest and the usefulness of the book.

A Handbook on Belt Conveyor Design. The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2. Price 30s.

THIS latest addition to the series of technical handbooks published by The General Electric Company, Ltd., has been compiled by the staff of the materials handling department of the Fraser and Chalmers Engineering Works, in association with Hewitt-Robins, Inc., of New York. Its object is to give complete details of basic design which will be of service to engineers concerned with the design and application of conveyor systems. It opens with a comprehensive section on the information which is required to design a belt conveyor and goes on to deal in graphic detail with idler diameter and spacing; take-up design and location; driving equipment; feeders; trippers; cleaners; holdbacks and brakes, and weighing in transit of material. An interesting fundamental analysis of conveyors is given, and a large number of relevant tables and charts, which add to the value of the book, provide ready reference to the essential data required for conveyor calculations.

Books Received

Legal Problems in Engineering. By Melvin Nord. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 60s.

Solution of Problems in Aerodynamics. By S. A. Urry. Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2. Price 32s. 6d.

Aberrations of Thin Lenses: An Elementary Treatment for Technicians and Students. By H. H. Emsley, Constable and Co., Ltd., 10, Orange Street, London, W.C.2. Price 50s.

Progress in Nuclear Energy, Series IV. Vol. I, *Technology and Engineering*. Edited by R. Hurst and S. McLain. Pergamon Press, Ltd., 4 and 5, Fitzroy Square, London, W.1. Price 84s.

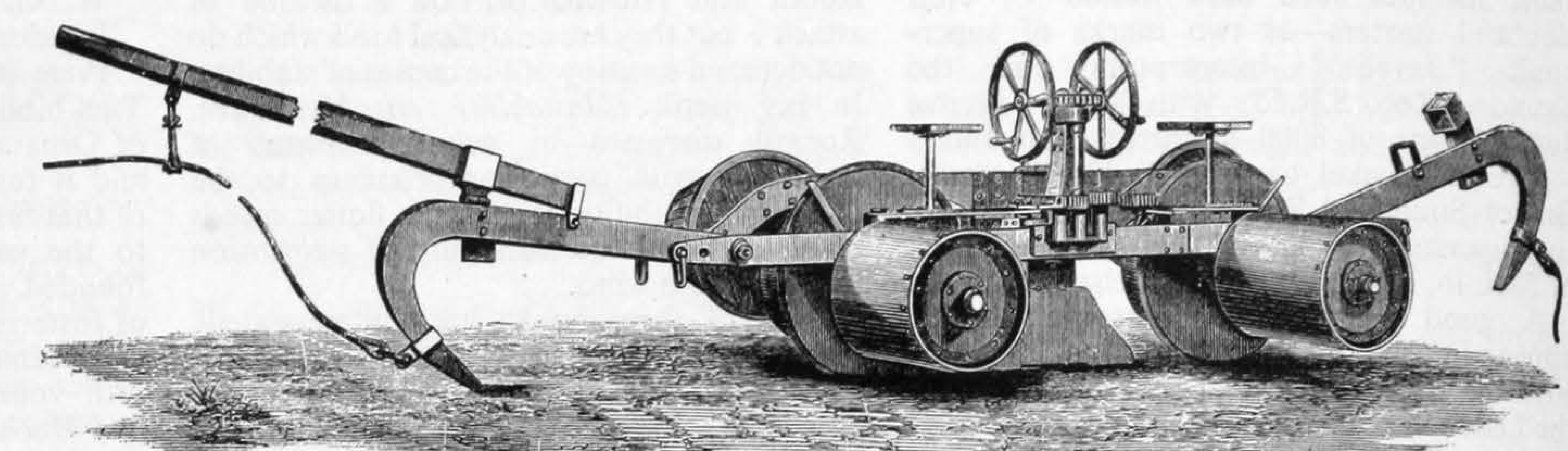
Streamlined Specifications Standards. Vol. II, *Mechanical and Electrical*. By L. Axelbank and B. J. Small. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 80s.

Electronics and Electron Devices. Third edition, *Fundamental Electronics and Vacuum Tubes*. By A. L. Albert. The Macmillan Company, New York, 10, South Audley Street, London, W.1. Price 44s.

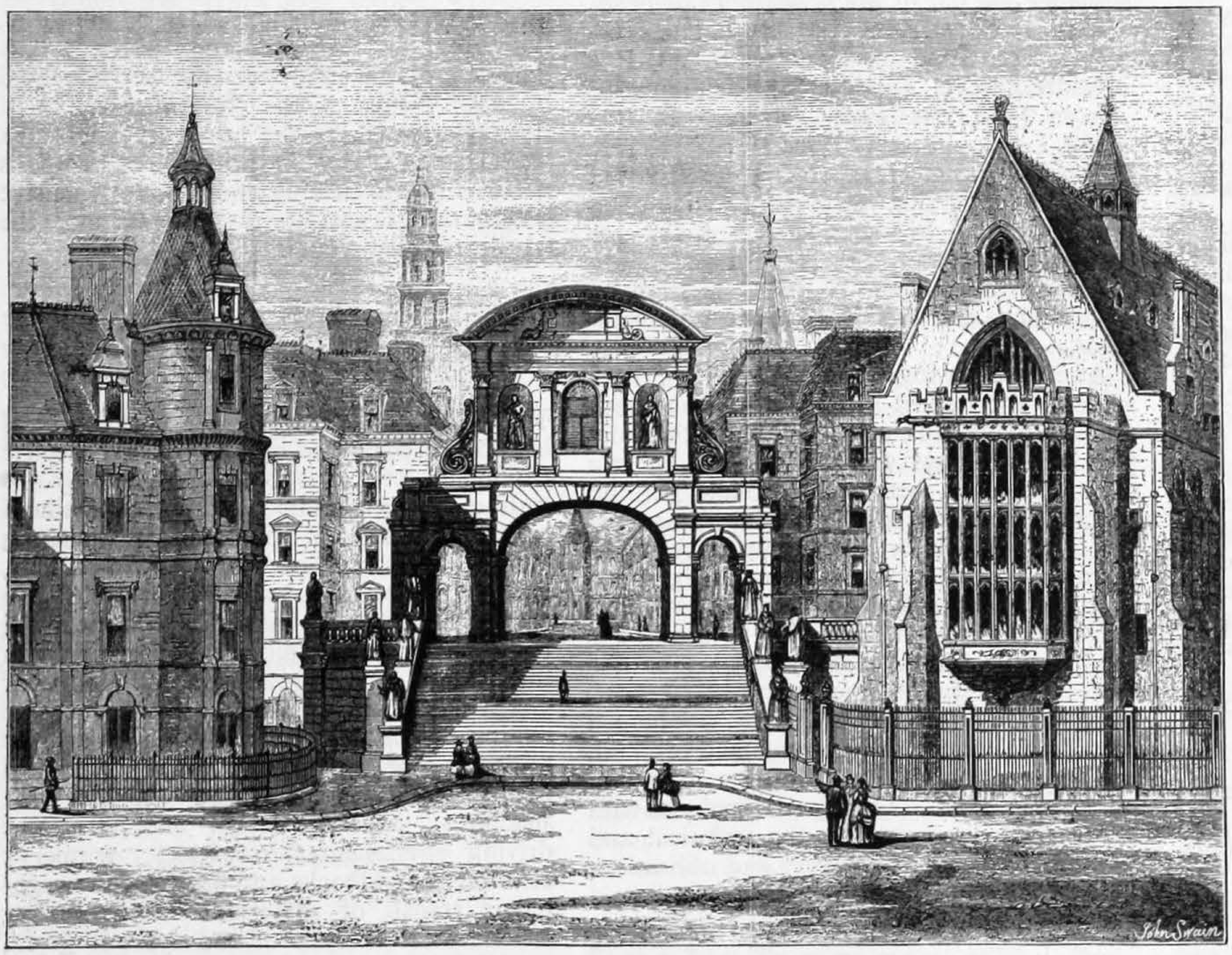
Television Engineering: Principles and Practice. Vol. II, Video-Frequency Amplification. By S. W. Amos and D. C. Birkinshaw. Iliffe and Sons, Ltd., Dorset House, Stamford Street, London, S.E.1. Price 35s.

ENGRAVINGS OF 1874

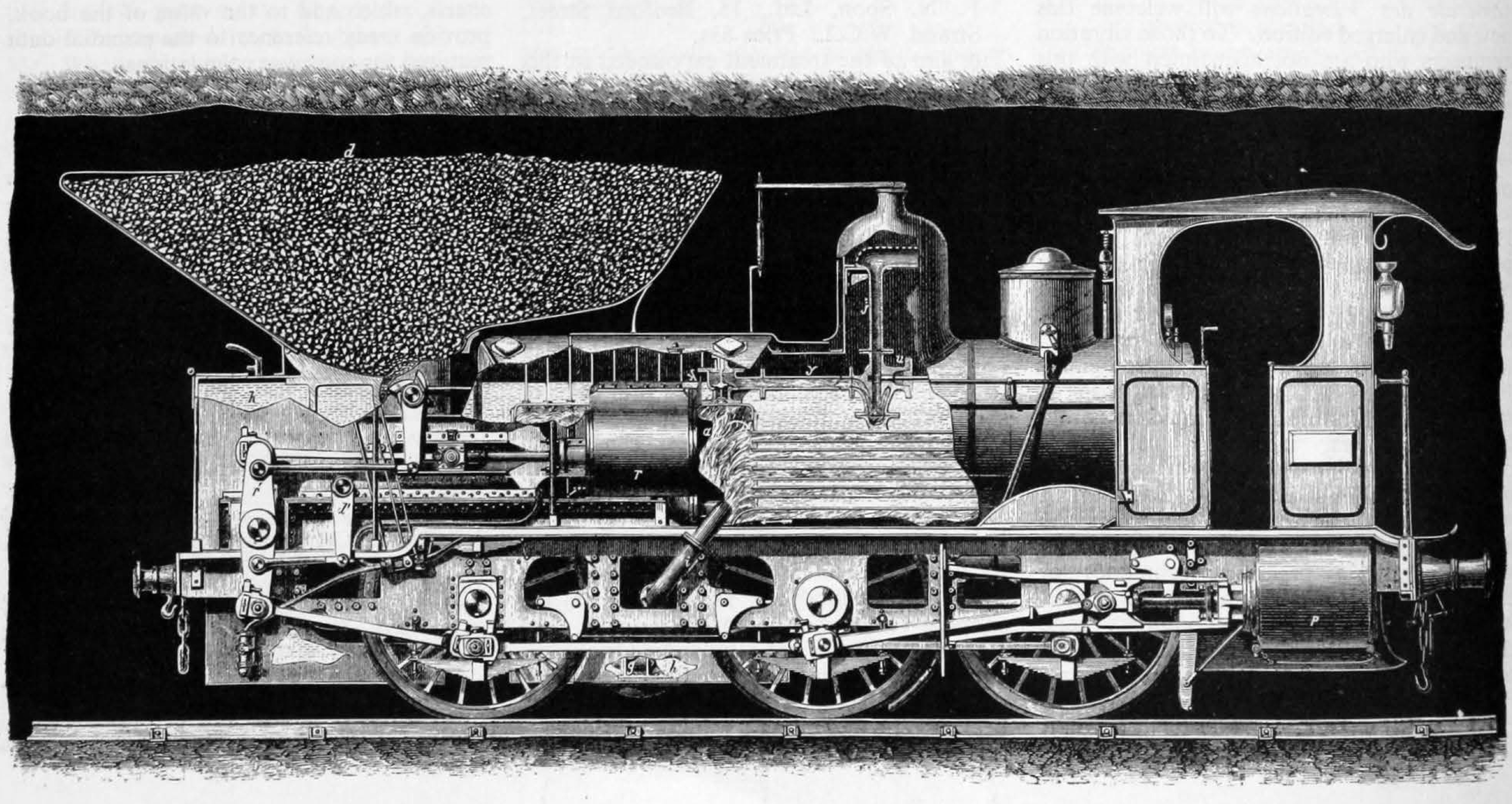
The "Sutherland" plough, shown in the right-hand engraving, was one of those produced by John Fowler and Co., Ltd., for operation by a pair of 16 h.p. steam traction engines. A brief description in our issue of July 24, 1874, explains that "behind and before the plough is a tine centred on a stud, and of the shape of a one-pronged anchor. To these tines the rope-ends are attached."



In our issue of December 4, 1874, we put forward a suggestion "for the re-erection of Temple Bar when removed from its present position at the west end of Fleet Street." The Law Courts were then being built, and when they were completed, we argued, "Essex Street, leading from the Strand to the Victoria Embankment, would of necessity become an extremely important thoroughfare." Our proposal was to "remove the buildings at the bottom of Essex Street, and in their place, and on the site of the present steps, throw out a platform from which a bold flight of steps would lead to the Embankment, and place the Bar in the centre of this platform, so as to form at once a finish to the street end as seen from the Strand, and an ornament to the platform and steps viewed from the Embankment." The engraving on the left illustrates the scheme we had in mind.



The engraving below, taken from our issue of August 21, 1874, shows "a very singular locomotive engine intended for working underground, and patented by Hurd and Simpson, of Wakefield." Our description says that "the products of combustion from the fire receptacle are returned to the same by means of an injector actuated by compressed air or other equivalent agent."



An Industrial Establishment for Nuclear Power Development

An industrial establishment for the development of nuclear power has been set up by the General Electric Company, Ltd., and Simon Carves, Ltd. It is one of the four industrial atomic energy groups which have been formed by the four major electrical plant manufacturing companies in Great Britain in response to the Government's invitation to participate in the White Paper programme for the building of nuclear power stations. The G.E.C. Simon-Carves Atomic Energy Group is based on the Fraser and Chalmers Engineering Works at Erith, where a self-contained department has been established, with its own research and development laboratories and drawing-office. The laboratories, which are briefly described here, are staffed and equipped mainly for metallurgical and heat transfer work in nuclear engineering. An analogue computer designed to serve as a nuclear power station simulator is one of the interesting pieces of equipment in use in these laboratories.

LAST week we visited the G.E.C. Simon-Carves Atomic Energy Group at Erith to see the progress that has been made by this establishment in equipping itself to contribute towards the development of nuclear power. It will be recalled that when the British Government was contemplating a programme for the development of nuclear power stations in Great Britain, it was appreciated that private industry would have to play a prominent part. Accordingly, steps were taken to enlist the help of the industry even before the publication of the White Paper on Nuclear Power early in 1955. In the second half of 1955 the four leading electrical engineering manufacturers in the country were invited to undertake a study of the gas-cooled, graphite-moderated reactor as a means of generating heat for thermal power stations. It was suggested that each of the four electrical manufacturers should, for this purpose, enter into association with a leading boiler manufacturer and it was as a result of this suggestion that the G.E.C. Simon-Carves Atomic Energy Group was formed.

Because the problems to be tackled in reactor design are mainly mechanical it was decided to establish a centre for the group at Fraser and Chalmers Engineering Works at Erith, Kent, where the heavy mechanical plant of the G.E.C. is manufactured. From September, 1954, the senior members of the group began to undergo training in the United Kingdom Atomic Energy Authority's establishment.

When the White Paper was published it became apparent that a very rapid expansion in highly trained technical staff was required if the group was to be able to submit a competitive tender to the Central Electricity Authority for a complete nuclear power station by the specified date, October 1, 1956. Since the requirements for a reactor " optimised " to produce economical power differed somewhat from those at Calder Hall, where plutonium production was the primary aim, it was clear that a very considerable research effort would also be needed.

Because of the short time available it was felt that the desired results could be obtained only through very close collaboration between design and research staffs. It was therefore decided to build new laboratories at Erith combining all the facilities for the research and design work necessary for complete nuclear power projects.

In association with the G.E.C. and Simon-Carves are the Motherwell Bridge and Engineering Company, who will fabricate the pressure vessels, and John Mowlem and Co., who will be the civil engineering contractor in any work that may be undertaken.

The present laboratory staff of the group at Erith totals about 300, approximately 75 per cent of whom have been seconded to the group from the G.E.C. and the remainder from the Simon-Carves organisation. About half are of graduate status, roughly 5 per cent of the total staff being physicists, 10 per cent metallurgists, and the remainder mechanical, electrical and civil engineers. At present the expenditure of the Erith group on nuclear power development is at an annual rate of more than £500,000.

In general terms the main problems engaging the attention of the Erith laboratories are concerned, first, with heat transfer from the fuel element to the can, to the coolant and to the heat exchanger, and, secondly, with metallurgy, particularly under reactor conditions. The immediate task is to produce a competitive design of gas-cooled, graphite-moderated reactor, " optimised " for power production, complying with the C.E.A. requirements for power stations at Bradwell-on-Sea and Berkeley.

Nuclear Power Station Simulator

One of the first essentials is to be able to study transient phenomena in a reactor and other components of a nuclear power station, and to analyse automatic control systems. For this class of work an analogue computer specially designed as a nuclear power station simulator has been built and installed in the group laboratories at Erith.

With the help of this simulator the performance of a particular unit or group of units (for example, the variation in reactor power with the movement of the reactor control rods) can be predicted without long and laborious calculations.

By setting the appropriate voltages on one section of the computer, the electrical circuits can be made to simulate the behaviour of the actual equipment and the results obtained as graphs on the recording instrument, saving days of manual computation. More complex problems, involving the interdependence of several sections of the plant, can be dealt with equally well, and in these cases the saving of time and effort is even greater.

The computer is designed to be equally useful in the investigation of more advanced forms of reactor than the gas-cooled, graphite-moderated type now under development.

A unique characteristic of the new simulator is that it has been designed to operate either as one large computer or as two completely independent smaller computers. It is thus possible to examine simultaneously two separate problems, with a considerable saving in time in cases where neither problem requires the use of the complete machine.

In many of the problems the time scale may vary from a fraction of a second to several hours. The computer normally operates in terms of real time, and the performance of any section of the power station can be examined from the traces of two continuous high-speed pen recorders which allow four variables to be recorded simultaneously. Alternative indication of each section is provided by a cathode-ray oscilloscope. An additional advantage of real-time working is that actual units of control systems can be coupled into the simulator circuit and their behaviour analysed. For longer-term problems such as the effects of xenon poisoning of the fuel, the rate of working can be accelerated.

A typical problem which was solved with the help of the simulator was that of predicting (in connection with the tender to the C.E.A.) the behaviour of the gas-cooled reactor in the event of loss of coolant circulation. Curves were produced on the pen recorders to show the reactor fuel element temperature rise that would result from coolant failure, first, if no remedial action were taken and, secondly, if shut-down were initiated at various rates by controlled operation of the boron control rods. These curves suggested that, for the reactor design here involved, the maximum temperature rise would be within the prescribed limits for the worst case considered—that is, coolant failure without remedial action.

The computer (Fig. 1) comprises a total of eight panels, arranged in " L " formation, with the control panel at the junction. One special panel, to the right of the control section, is permanently connected to simulate the nuclear reactor itself, and the remaining six (five of which can be seen in Fig. 1) are identical general-purpose cabinets which can be set up to simulate the performance of heat exchangers, control rods, blowers, turbo-alternators or other components of the power station plant.

Provision is made for the incorporation of 100 drift-connected amplifiers and twenty servo-multiplier units. At present eighty-four amplifiers are available, any one of which can be used as a summing amplifier, integrator or servo-amplifier. Two transit time units are provided for the simulation of time delays, the output signal of each unit being the input signal delayed in time.

The simulator was manufactured by the nuclear division of Elliott Brothers (London), Ltd., who collaborated with the G.E.C. in the design of the machine.

The computer is housed in its own room, the air in which is maintained at slightly above atmospheric pressure by fans above the false ceiling. This precaution ensures that all leaks are outward and tends to keep out dust. A workshop, for the routine servicing and testing of computer units, adjoins the computer room.

Materials Research

There are two materials research laboratories in the group establishment at Erith. Their functions are to assess the suitability of materials for use in the present design and to study new and modified materials for future designs. These laboratories are specially equipped for research and development work needed for nuclear power station design, bearing in mind three important considerations not normally involved in engineering design.

First, many of the well-tried materials in common use must be excluded because of their high neutron absorption cross-sections. Secondly, despite elaborate remote handling devices, there are still many components within the reactor, essential for its operation, which cannot be inspected, maintained or replaced after the reactor has started operation. Thirdly, irradiation alters the properties of metals, causes profound changes within the fuel, damages most organic materials to an extent which precludes their use, and alters the fundamental characteristics of many chemical and physical processes.

Within these limitations, materials must be found which will have adequate strengths at high temperatures and under high pressures, which can be fabricated into the desired form and in the required quantities, and which are economically acceptable.

Much experimental work has been done to determine the oxidation and corrosion resistances of materials in the reactor circuit in the presence of the small amounts of carbon monoxide (produced by interaction with the graphite moderator) and water vapour in the carbon dioxide coolant. The main interest so far has been in magnesium alloys used for the fuel element cans and in various steels used for the reactor pressure vessels, heat exchanger shells, gas ducting and other components.

A special " thermobalance " designed and built for the rapid measurement of magnesium oxidation rates in carbon dioxide is in use in the Erith laboratories. It consists of an electrically heated pressure vessel containing a spiral quartz spring supporting the specimen. The specimen is heated in an atmosphere of carbon dioxide under pressure, and as oxidation takes place weight changes are indicated by the vertical movement of the quartz spring.

These movements are observed through a pressure-tight window by a travelling microscope, and the progress of oxidation process can thus be followed continuously without having to dismantle the apparatus and weigh the sample at intervals. By using a number of these vessels

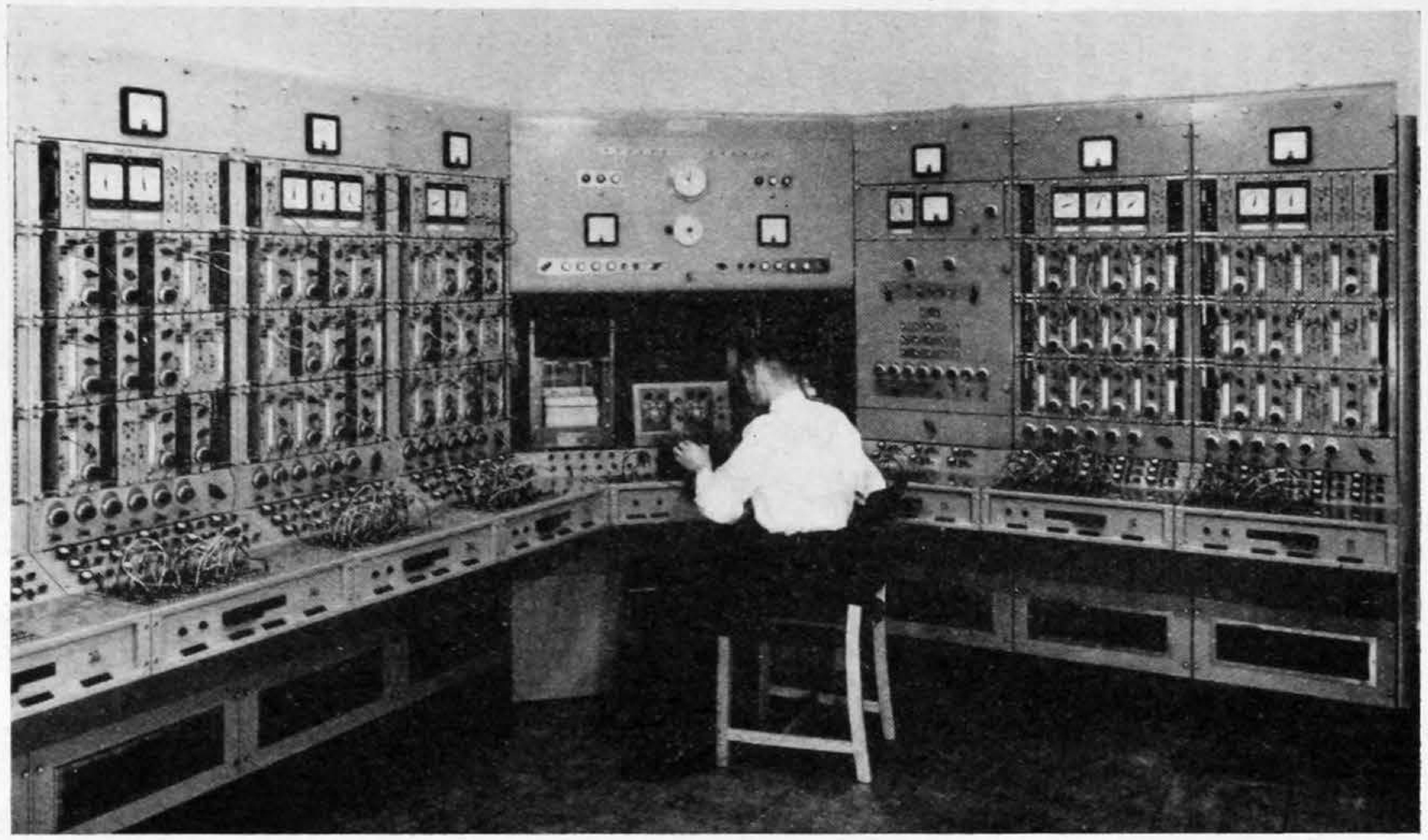


Fig. 1—Analogue computer for estimating nuclear power station performance. It has a panel to simulate the reactor and six other panels to simulate heat exchangers, control rods, turbo-alternators, &c.

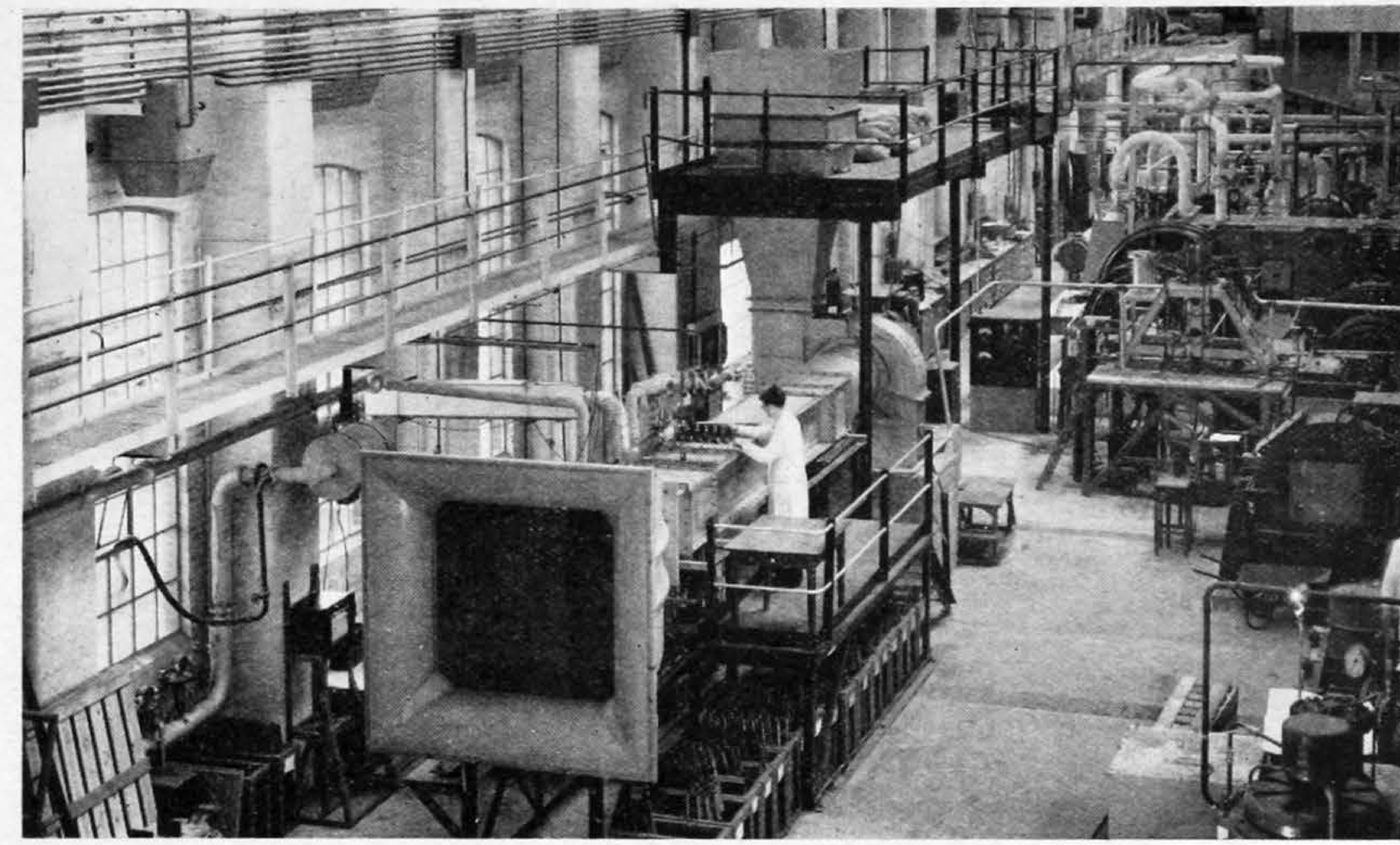


Fig. 2—Experimental heat laboratory of G.E.C. Simon-Carves Atomic Energy Group. The equipment seen here includes a heat transfer test rig for heat exchanger tubes (Fig. 3) and a gas seal test rig (Fig. 5)

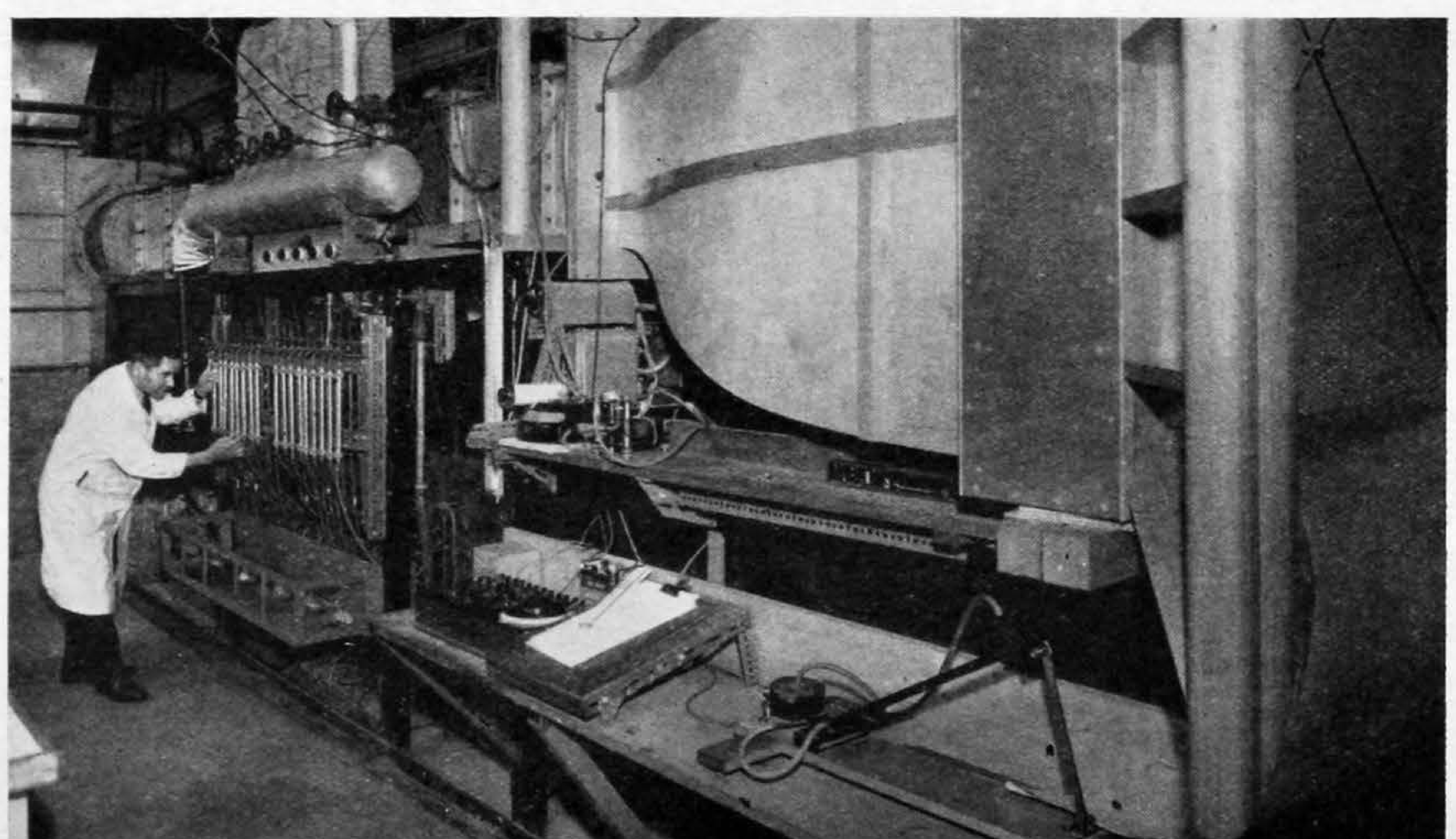


Fig. 3—Rig for experimental work on the heat transfer characteristics of heat exchanger tubes. Tubes with various forms of finning, including cylindrical and aerofoil studs and helices have been compared here

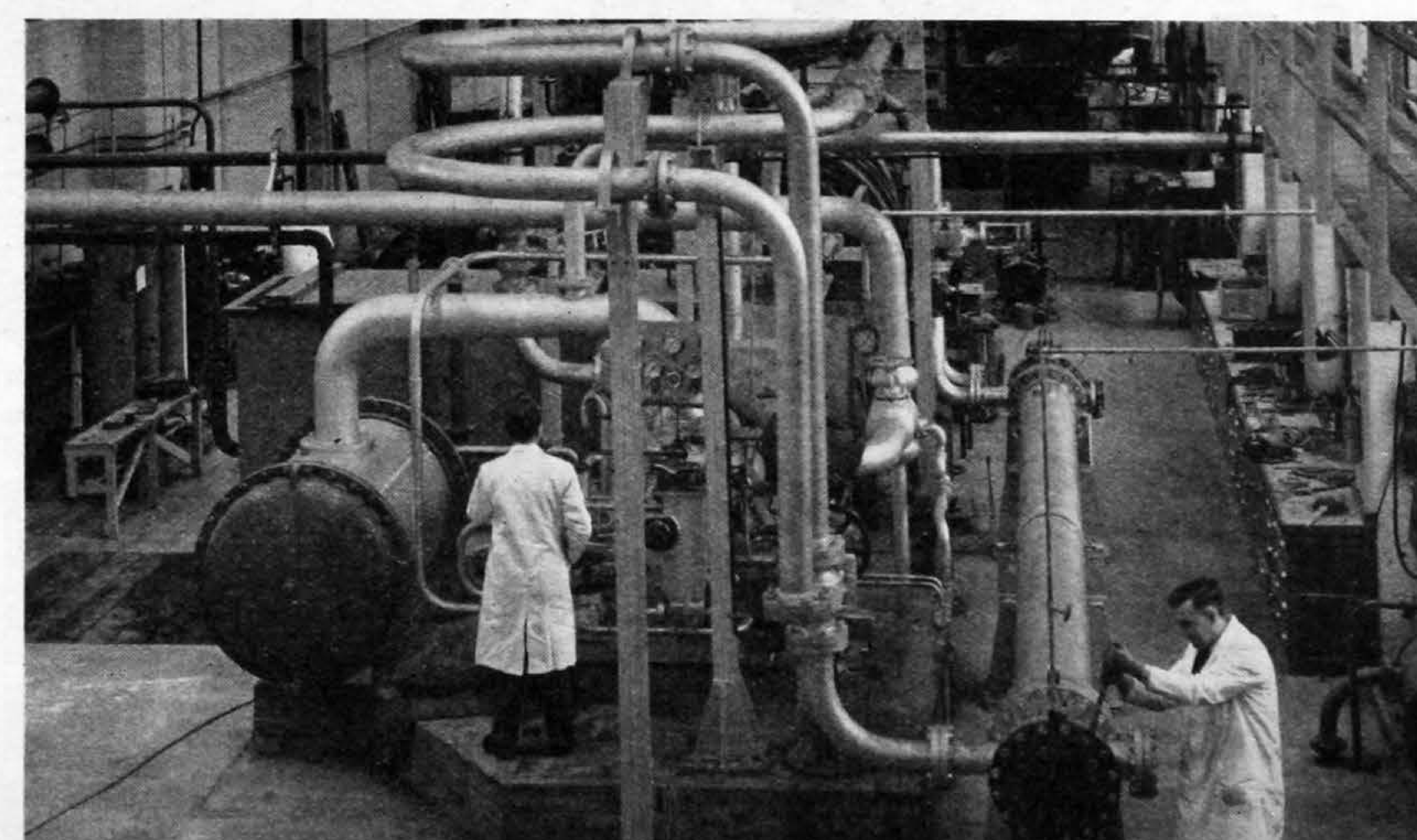


Fig. 4—Pressurised CO_2 rig for work on heat transfer characteristics of fuel cans at pressures up to 200 lb per sq. in. Heat is applied electrically to the inside of the cans in the cylindrical test chamber on the right

simultaneously, operating at different pressures or temperatures, graphs of oxidation with time can quickly be obtained. The apparatus can be used for metals other than magnesium.

For corrosion tests on steels and other alloys a battery of twenty-three G.E.C. vertical, heat-treatment furnaces are installed in the two laboratories, one of which is illustrated in Fig. 6. Each furnace is fitted with a removable pressure-tight stainless steel autoclave in which specimens are placed. Tests have been carried out in various mixtures of carbon dioxide and carbon monoxide, with and without additions of water vapour, and over a range of gas pressures up to 200 lb per square inch and temperatures up to 550 deg Cent.

The cooling fins on the fuel element cans are subjected to bending stresses caused by the high-pressure coolant gas flowing over them. The fins may therefore creep during operation, and a test rig has been devised to examine this effect. Part of the rig can be seen on the extreme right of Fig. 6.

A battery of stress corrosion machines is at present being installed so that the corrosion resistance of metals and alloys under load can be measured. Work initially will again be on magnesium in carbon dioxide atmospheres, but the equipment can readily be converted for future work to deal with other materials and other corrosive media.

The machines are designed to accommodate both the test specimen and the weights which impose the load, thus giving better accuracy and avoiding sealing difficulties.

A method of improving the corrosion resistance of magnesium alloys by treatment in an anodising bath has been developed in the laboratories. The bath consists of a fluorite solution with other elements, and the surface coating produced thereby has proved to be strongly resistant to corrosion even in the presence of lead and tin.

The laboratory is also equipped with a 25kW, G.E.C. high-frequency furnace which is useful for the induction melting of small amounts of experimental metals and alloys (including those with very high melting points) and for work on powder metallurgy and brazing.

The development of welding techniques for magnesium alloys and other materials, such as stainless steel, is an important part of the design programme. A 300A argon arc welding set is therefore installed in one of the metallurgical laboratories, and can be operated with either manual or automatic control. In particular, a technique has been developed for welding the ends to the cylindrical body of the fuel element cans which are of magnesium alloy.

Fig. 6—Materials research laboratory for nuclear power development. The work done with the furnaces shown here includes compatibility, creep and corrosion tests in various atmospheres, including pure CO_2 and CO_2 contaminated with CO and moisture

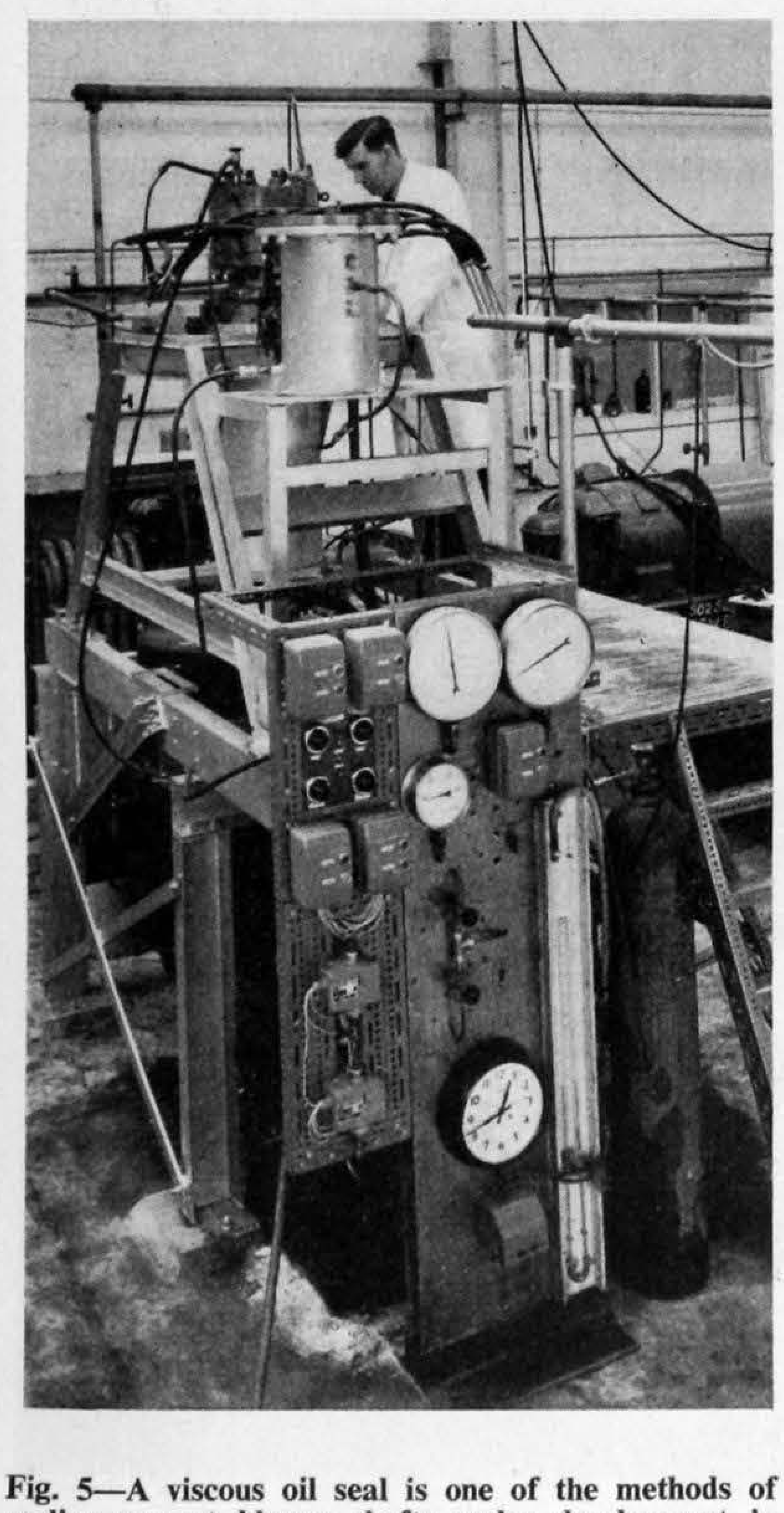


Fig. 5—A viscous oil seal is one of the methods of sealing gas at blower shafts under development in the heat laboratory of G.E.C. Simon-Carves Group

Heat Transfer

The investigation of heat transfer characteristics is an important part of the experimental work in the Erith laboratories. For the performance of a nuclear power station depends largely on the effectiveness of heat transfer from the fuel element to the can in which it is contained, and thence to the coolant gas and to the heat exchanger. In particular, the amount of heat which can be extracted from a fuel can is one of the controlling factors in reactor design.

In the main heat transfer installation (Fig. 3) the measurement of heat transfer coefficients and friction factors is carried out under conditions of temperature and pressure resembling those in a reactor. The fissile fuel is replaced by a stainless steel heating element inside the fuel can, the heater power being supplied by two d.c. generators. The can is supported within a copper tube which is lagged to prevent heat losses. Carbon dioxide from " Cardice " generators is circulated under pressure throughout the system by a steam-turbine-driven blower ; provision is made for supplying the gas with extra heat and also for making-up the small losses of gas that occur during circulation.

During tests, measurements are made of gas and fuel-can temperatures and of gas flows and pressure drops so that a heat balance can be obtained. A complete fuel channel can be accommodated and tested in the cylindrical jacket, on the right of Fig. 3.

For preliminary experimental work there is also a heat transfer rig in which experiments are carried out in air at atmospheric pressure instead of under pressurised carbon dioxide. This equipment is basically similar to the carbon dioxide rig, but is very much simpler and quicker to operate. In this case air is drawn over the electrically heated cans by a blower which is driven by a constant speed motor through a fluid drive. The apparatus provides useful data on the maximum heat output that can be obtained from a given design of fuel can at a particular temperature.

Studies are also being made of heat transfer from the centre of the uranium fuel rod, to the outside, and from the surface of the fuel to the walls of the can. The effect of surface roughness on the inside of the can and of oxide films on the uranium are additional factors influencing the effectiveness of heat transfer.

In the steam-raising part of the system, because of the relatively low temperature difference compared with fuel-fired plant of the same output, great attention is paid to the problem of obtaining the most compact arrangement of heat exchange surface, the aim being to keep to a minimum the size of the pressurised vessel required. The solution adopted is to use large numbers of small diameter steel tubes with an extended surface in the form of fins. The use of extended surfaces under such conditions has entailed investigations into heat transfer and pressure drop, backed up by a major development programme on the metallurgical and manufacturing aspects of such a heat exchanger.

Equipment constructed for the experimental work is shown in Figs. 2 and 3. In practice, the hot gas will pass downwards through the heat exchangers over the banks of tubing through which water and steam are flowing. Heat transfer is, therefore, inwards through the heat exchanger tubes to the water. In the experimental apparatus this procedure is reversed ; that is, dry superheated steam is passed through the heat exchanger tubes and heat is extracted from them by a current of cooling air. An assessment of the effectiveness of a particular design of tube is then easily obtained by measuring the amount of steam condensed in a given time, a method which has facilitated the rapid testing of numerous alternative designs of extended surface tubes under varying conditions of temperature and pressure drop.

Prototype testing constitutes the last stage in the development programme and a number of prototype equipments are undergoing tests in the Erith laboratories. These units include parts of the charge and discharge equipment, control rod operating mechanisms, gas selection valves, special gas seals (Fig. 5) for carbon dioxide blowers, mechanical and electrical drive units operating in hot carbon dioxide, and bearings which will have to be run in hot gas without conventional lubrication. The special gas seals include a viscous oil/gas seal in which the oil pressure required to maintain the gas seal is produced by double helical grooves in the rotating shaft. A carbon seal has also been studied.

Tests are also being carried out on pneumatic motors, driven from a compressed air supply, running in a furnace with pressurised carbon dioxide atmosphere.

12 Cubic Yard Walking Dragline

The first walking dragline of a new design introduced by Ransomes and Rapier, Ltd., was recently put into service by the United Steel Companies, Ltd., at Scunthorpe. It has a maximum capacity reach of 12 cubic yards at 165ft radius with alternative capacities of 8 cubic yards at 201ft and 10 cubic yards at 184ft. The heaviest member of the machine weighs 24 tons, and it is assembled with fitted bolts throughout so that it can be dismantled when its work is completed at one site and transported and re-erected on a new site.

THE range of walking draglines made by Ransomes and Rapier, Ltd., of Ipswich, has been extended by the recent introduction of a new machine with a maximum capacity of 12 cubic yards, which is believed to be the only mobile dragline of its size made outside the United States. This machine incorporates a number of interesting points in design, and by changing the head end of the boom assembly it can be adapted for the following capacities—8 cubic yards at 201ft ; 10 cubic yards at 184ft ; and 12 cubic yards at 165ft. Provision is also made for easy setting of the boom to three different angles to vary the working radius and capacity of the machine to suit particular requirements in the field. Fitted bolts and cover plates are used for coupling its main assemblies together, and the heaviest individual member weighs only 24 tons. This method of assembly and the relatively small weight of the heaviest member makes it possible to dismantle the machine on a site where it is no longer required, and facilitates transport and re-erection on another working site. This is a point of particular economic importance in overseas countries where a machine of large capacity is required, but where the full life of a machine will not have expired before the site is worked out. In such cases the relative ease with which the new machine can be dismantled, without detriment to main structural members, will enable its transfer to distant sites to complete its full effective working life.

The first dragline to this new design known as the "Rapier W600," has been built for the United Steel Companies, Ltd., and is in service removing overburden at the Scunthorpe opencast iron ore mines. As can be seen from the illustrations and drawings we reproduce, the machine is similar in many respects to the 20 cubic yard walking dragline supplied to Stewarts and Lloyds, Ltd., some four years ago. The main particulars of the new dragline with its three boom lengths, are given in the table above and its working ranges as a 10 yard machine are shown in one of the drawings facing page 276.

W.600 Walking Dragline Capacities

Length of boom	204ft 9in	186ft 0in	165ft 0in
Capacity of bucket	8 cubic yards	10 cubic yards	12 cubic yards
Angle of boom to horizontal	25 deg., 30 deg., 35 deg.	25 deg., 30 deg., 35 deg.	25 deg., 30 deg., 35 deg.
Radius of discharge, vertical	201ft, 192ft, 183ft	184ft, 176ft, 169ft	165ft, 158ft, 150ft
Maximum allowable working load at maximum radius	19.3 tons	23·3 tons	29·8 tons
Dump height at maximum radius, approximately	72ft, 88ft, 103ft	65ft, 79ft, 92ft	55ft, 68ft, 80ft
Clearance radius of house		50ft	
Centre of shoes		46ft	
Width of house		35ft	
Diameter of roller circle		34ft	
Diameter of base structure		35ft	
Area of base		962 sq ft	
Effective bearing area of shoes		238 sq ft	
Average bearing pressure of base	13 lb per sq in	12·8 lb per sq in	13 lb per sq in
Maximum bearing pressure at front of base	24·8 lb per sq in	23 lb per sq in	26 lb per sq in
Bearing pressure of shoes (at start of stride)	14·3 lb per sq in	15·1 lb per sq in	14·5 lb per sq in
Drag motors, two		225 h.p.	
Hoist motors, two		225 h.p.	
Walk motors, two		225 h.p.	
Rotate motors, two		187·5 h.p.	
Motor generator set, driving motor		1500 h.p.	
Drag rope single part	$6\frac{1}{4}$in circumference	$6\frac{1}{4}$in circumference	7in circumference
Hoist rope single part	$6\frac{1}{4}$in circumference	$6\frac{1}{4}$in circumference	7in circumference
Boom hoist rope, eight parts	$5\frac{1}{2}$in circumference	$5\frac{1}{2}$in circumference	$5\frac{1}{2}$in circumference
Working weight (with ballast)	792 tons	777 tons	776 tons
Ballast	20 tons	10 tons	10 tons

The dragline is electrically operated throughout with Ward-Leonard amplidyne control, and is designed to take current at 6600V from a mains supply through trailing cables. The driver has full control of the machine from a cabin which projects some distance out from one side at the foot of the boom to give an unobstructed view of the bucket. Under normal conditions, working with readily handled material, the machine is designed to complete the following cycle in 61 seconds—drag and hoist bucket, slew through 90 deg., discharge bucket and return for the next cut.

The 35ft diameter base structure of the machine is built up from heavy rolled steel plates, well braced and supported by sections. It comprises a number of welded assemblies coupled together by fitted bolts and cover plates to form a rigid structure of ample strength to support the machine in its digging and walking duties. The roller path round the upper circumference of the base is built up of twenty-four segments of bridge rails made from cast nickel-chrome-molybdenum steel and securely attached to the base frame. These rails are machined on both faces and provide a path with a mean diameter of 34ft and a face width of 5in. The path carries a live ring of seventy-two alloy-steel taper rollers 10in mean diameter. These rings are mounted in a frame with heavy inner and outer channel

Walking dragline fitted with a 10 cubic yard bucket and arranged for a 184ft working radius

Interior of machinery house. The drag gear unit can be seen on the right of the deck and the walking drive in the left foreground

members in which are bolted cast iron distance pieces. The 24·35ft diameter rack for the superstructure rotating gear also mounted on the base structure comprises a ring of heat treated cast steel segments, with machined teeth. The centre post about which the superstructure rotates consists of steel forging welded into a heavy frame which is rigidly connected to the radial girders and forms an integral part of the main base structure. The head of the post projecting above the surface of the base is 1ft 9in diameter and 2ft high.

The rotating superstructure of the machine is designed as a cantilever unit supported at one end on the 34ft diameter live ring of rollers. It has an overall length of 65ft, a width of 45ft and is 9ft deep. This superstructure is built up of welded assemblies of rolled steel plates and sections rigidly coupled together by cover plates and fitted bolts. It has four main longitudinal girders running its full length and into these girders at the forward end are built the girders carrying the upper roller path. The structure is completed by transverse girders and continuous end girder members. It is plated over top and bottom to form a rigid support for the heavy dragline machinery and resist any tendency to deflection resulting from external loading when the machine is in operation. At the point where the centre post passes through the frame, heavy fabricated reinforcing pieces are introduced to provide effective distribution of the walking, dragging and rotating loads through the structure.

Unlike other designs of the maker's walking draglines a single heavy transverse bridge girder is not built into the superstructure frame for carrying the walking legs and shoes. Instead, the legs are supported by two separate girders coupled together and built into and forming an integral part of the superstructure frame, a form of construction which, whilst providing adequate support for the legs, avoids the use of a single large and heavy bridge member. The largest girder sections used in the superstructure assembly are 23ft long, 11ft wide and 9ft deep, and with their weight of 24 tons they are the heaviest individual members of the whole machine.

Welded bracket assemblies built into the heavily reinforced forward end of the superstructure frame are designed to locate and support the main *A* frame legs and boom feet through pins.

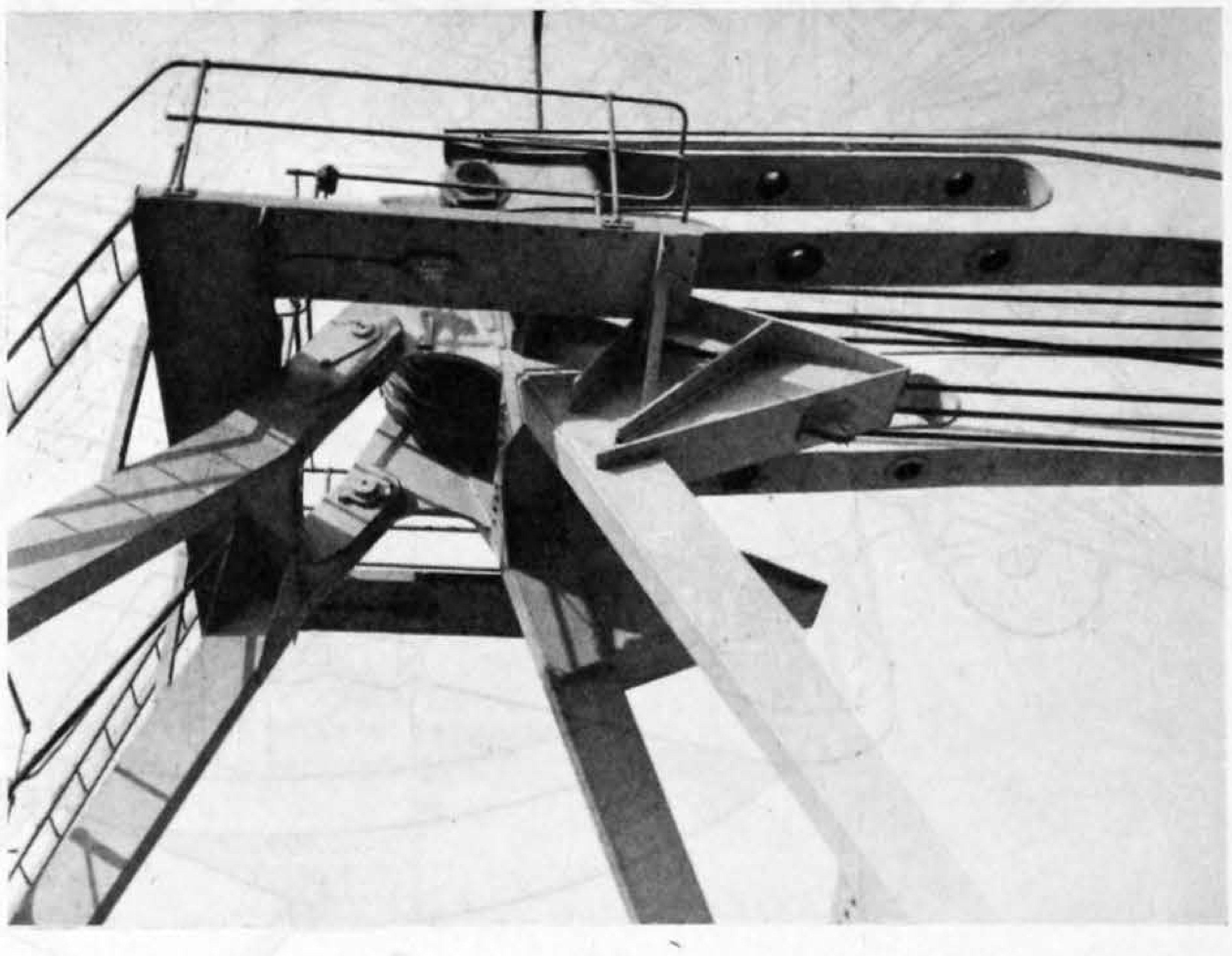
As in all "Rapier" walking draglines, this machine has Cameron and Heath design walking gear, in which large shoes fitted to legs on each side are actuated by eccentric-operated jacking mechanisms which serve and raise and tilt the machine and slide it over the ground in a continuous series of steps. Each eccentric of the walking gear is an alloy steel casting with an offset bore fitted on the inner side with a bronze bearing, on which it turns on a large-diameter fixed axle forming part of the main support girder. The outer end of the eccentric bore is of square section to accommodate the squared end of the walking axle drive shaft. This method of supporting each eccentric and jacking leg assembly on a separate fixed axle relieves the walking shafts of any bending moments.

Each of the fabricated steel jacking legs has a machined bore, through which it is supported on the eccentric by means of five spherical machined steel rollers. These rollers rotate on pins with offset bearing ends supported by bushes in the main eccentric casting. A locking lever attached to the squared outer end of each roller pin has teeth machined on its end, and these teeth register with corresponding teeth in a quadrant rack plate screwed on the body of the eccentric. When a leg has been placed on its eccentric the pins are turned to register the spherical rollers in their working positions in the leg bore, and the pin levers are locked in position by the quadrant plates.

Each leg has an extension to its upper part, through which it is pivotally attached to a link fixed at the opposite end to the main structure. These leg links constrain the upper ends of the legs to move in an arc as the eccentrics turn, so that a longitudinal motion is imparted to the lower ends of the jacking legs for traversing the dragline.

The legs are fitted with walking shoes, 35ft long by 7ft wide. These shoes are box form welded assemblies of steel plates and sections, well reinforced by diaphragm plates and having tee sections welded to the undersides to assist gripping the surface of the ground. Rigid fabricated brackets in the webs of the shoe girders carry the pins of the ball and socket ankle connections to the walking legs, which allow the shoes to adjust themselves to irregular ground contours in all planes. At one end each shoe is coupled to a spring strut righting device. Should a shoe rotate about its axis in the walking operation, this righting device automatically returns it into parallel relationship with the centre line of the superstructure when it is lifted.

Each of the two walking shafts is a nickel-chrome-molybdenum steel forging, 16in diameter and 23ft 9in long and weighing $7\frac{1}{2}$ tons. These shafts are only used for transmitting torque, any loads imparting bending stresses being taken by the



(Left) Foot of boom with drag gear. The driver's cab projecting beyond the machinery house at the side gives a clear view of all operations (Right) Head of boom suspension "A" frame. The legs of the boom suspension member have three sets of holes by the use of which the angle of the boom can be set at 25 deg., 30 deg. or 35 deg., to vary the capacity of the machine bridge girder and by a balanced driving gear. At their inner ends, the shafts are supported by heavy bearings rigidly mounted in the longitudinal members of the superstructure frame. The parts of the shafts extending beyond the bearing are of square section and on these sections are keyed the main driving gear wheels. The walking drive mounted on the top deck of the rotating frame consists of two separate motor-driven units, providing a common drive to the two shafts. In each unit a 225 h.p. motor drives a double helical gear through a pinion, and from the helical gear the drive is taken through straight spur reduction gears to the walking shafts. The final drive pinions are arranged on each side of the walking shaft gears to provide a balanced drive, and this arrangement ensures that no bending movement is imparted to the shafts as a result of tooth bending. The length of each walking stride is 6ft, and with the motors running at 600 r.p.m. the walking speed is 0·109 m.p.h.

The hoist and the drag equipment consists of two self-contained, motor-driven winch units of similar design, except for the drum grooving. The drag equipment, which can be seen in one of our illustrations, is mounted towards the front of the rotate frame deck and the hoist unit at the rear. In each unit a balanced drive is provided by two continuously rated 225 b.h.p. motors driving a central shaft through helical reduction gears, and a spur pinion on the shaft transmits final reduction drive to the drum gear. No operating brakes are required, but each motor is provided with a holding brake. The total gear ratio is 37 to 1 and the capacities of the units with different drum diameters are :—

Drum diameter ...	6ft 6in ...	5ft 9in ...	5ft
Maximum pull off drum	46 tons (stalled) ...	52 tons (stalled) ...	60 tons (stalled)
Rope speed at 650 r.p.m. of motor	357ft per min. ...	316ft per min. ...	276ft per min.
Rope speed at no load	424ft per min. ...	487ft per min. ...	550ft per min.
Drag rope...	$6\frac{1}{4}$ circ. ...	$6\frac{1}{2}$ circ. ...	7in circ.
Hoist rope	$6\frac{1}{4}$ circ. ...	$6\frac{1}{2}$ circ. ...	7in circ.

The superstructure is rotated on the base by two vertical motor-driven units, one on each side at the front end of the rotating frame deck. In each of these units a 187·5 b.h.p. motor drives, through a reduction gearbox, a vertical shaft with an integrally forged rack pinion 21·5in diameter. The gear ratio is 444 to 1 and at no load the rotational speed of the superstructure is 2·225 r.p.m., which is equivalent to 2580ft per minute at the head of a 186ft boom. When the superstructure is rotating the maximum torque at the centre post is 2,340,000 lb-ft.

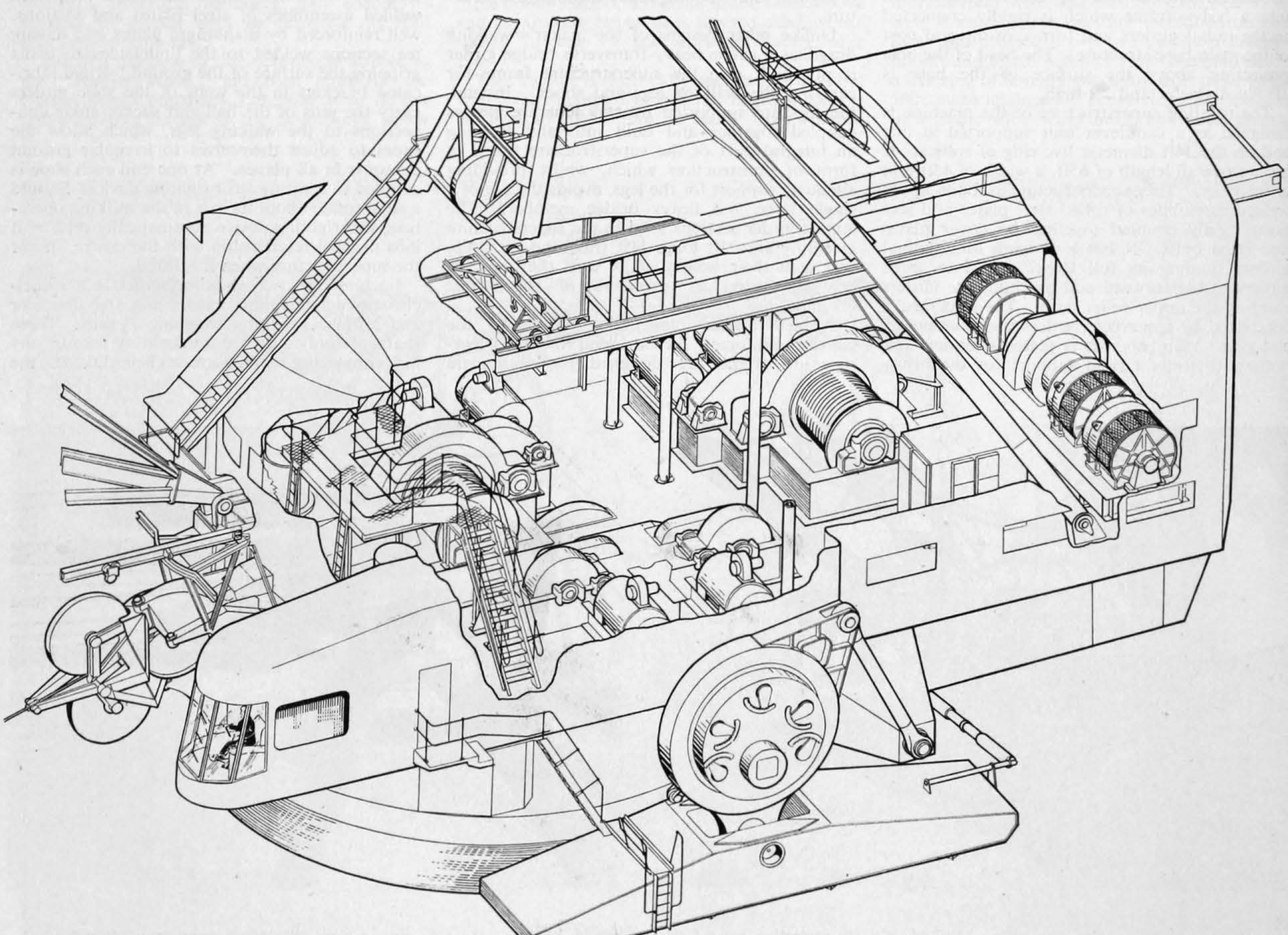
For adjusting the boom to different angles to the horizontal, a boom hoist unit is installed at the rear of the hoist drum assembly. This boom hoist has a 30 h.p. motor driving the rope drum through double helical reduction and spur gears, and with it the boom can, when required, be lowered to a horizontal position, using eight parts of rope.

The triangular section boom is built up of fabricated steel sections, rigidly braced and jointed, and it has two double-section compression members and one quadruple-section tension member. The basic boom, to which the required nose extension piece of similar design is rigidly connected by pin joints, is 141ft 2in long between centres. When the boom is fitted with its nose-piece the two main compression members form a continuous beam from the heel-pieces, where it is pinned to the superstructure, to the head. The main tension member extends from the head to the apex where it opens out into a " fish-tail " structure extending rearwards down to the heel-pieces.

The boom is suspended by a fabricated structural steel member connected by pin-jointed links to the apex and at the far end to the " A " frame built into the superstructure. At the " A " frame end the sides of the suspension member are spaced apart to accommodate the mounting for the sheaves of the boom hoist rope, and, as can be seen in one of the photographs we reproduce, three sets of pin-joint holes are provided in the legs, extending rearwards from the sheave mounting. By pinning the suspension member legs to the " A " frame at an appropriate set of holes the angle of the boom can be set to either 25 deg., 30 deg. or 35 deg. For this boom setting operation the boom is fully supported by its own hoist gear. The pins used in the link at the " A " frame weigh some 200 lb, and to facilitate their removal and manipulation when resetting the boom a davit with a chain hoist has been installed over the joint.

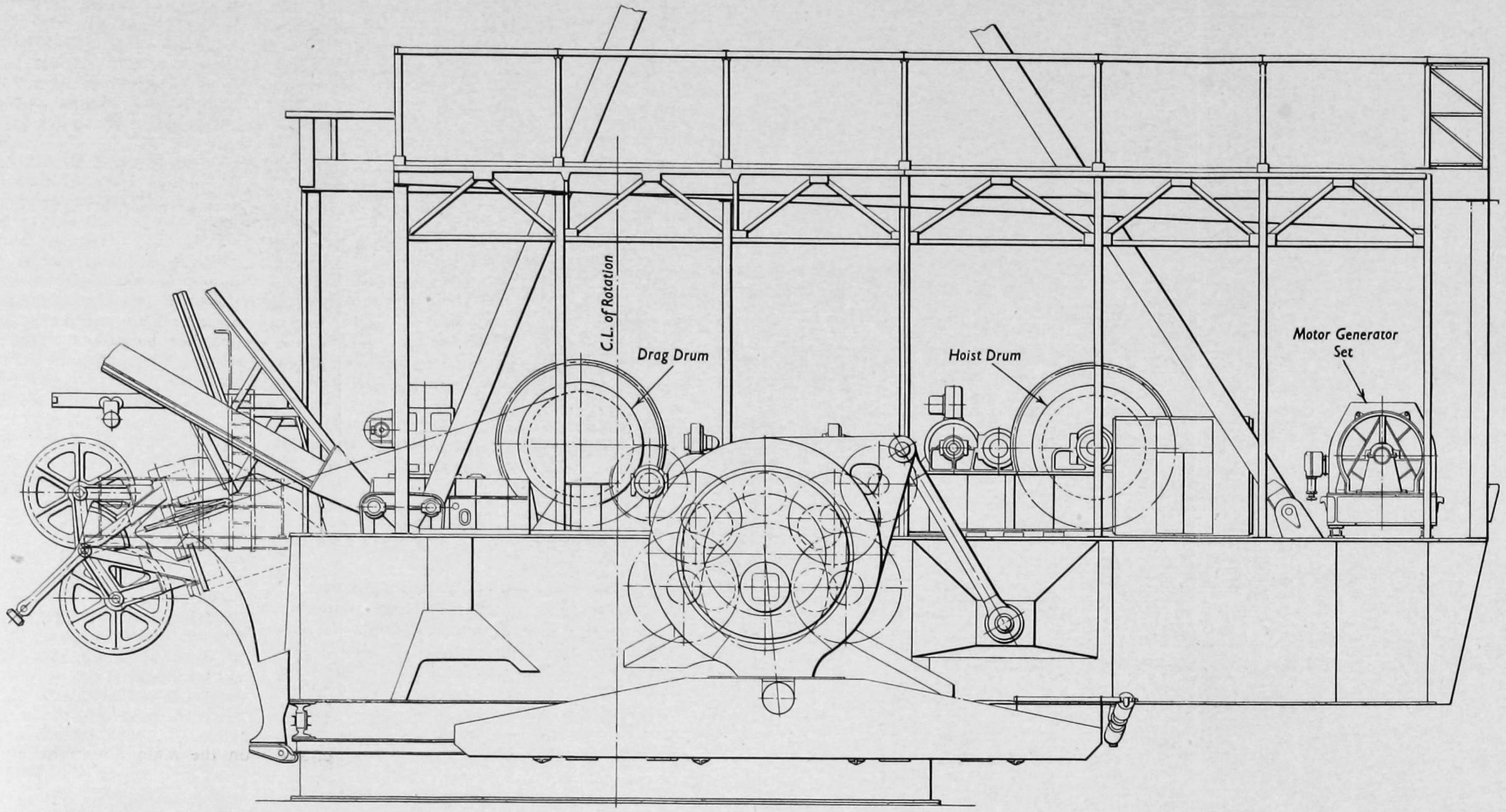
When the dragline was being erected on site the boom was assembled in front of the machine on a series of concrete packing blocks which raised it about 1ft 9in above the levelled erection area. The nose section was assembled in line with, but a short distance in front of, the main boom. When it was required to mount the boom on the machine its outer end was first raised and supported on a wheeled bogie carried on a short length of concrete runway laid between the packing blocks. The boom was then drawn back and its foot lifted and pressed into its socket on the dragline. As the rear end of the boom was raised its outer end pivoted on the bogie and clearance for the overhanging portion was provided by the excavation of a short trench in the ground in front of the bogie runway. Ropes from the main suspension member on the " A " frame were then coupled to the apex of the boom and the front end of the boom raised a short distance to enable the removal of the bogie.

The head or the nose section of the boom was fitted with a temporary trunnion pulley for erection purposes. With its head supported through this pulley on a steel plate path, the inner end of the nose section was raised and pulled back after the main boom had been raised a short distance. When the top pin-holes of the nose section were in line with those on the main boom the pins were fitted. The

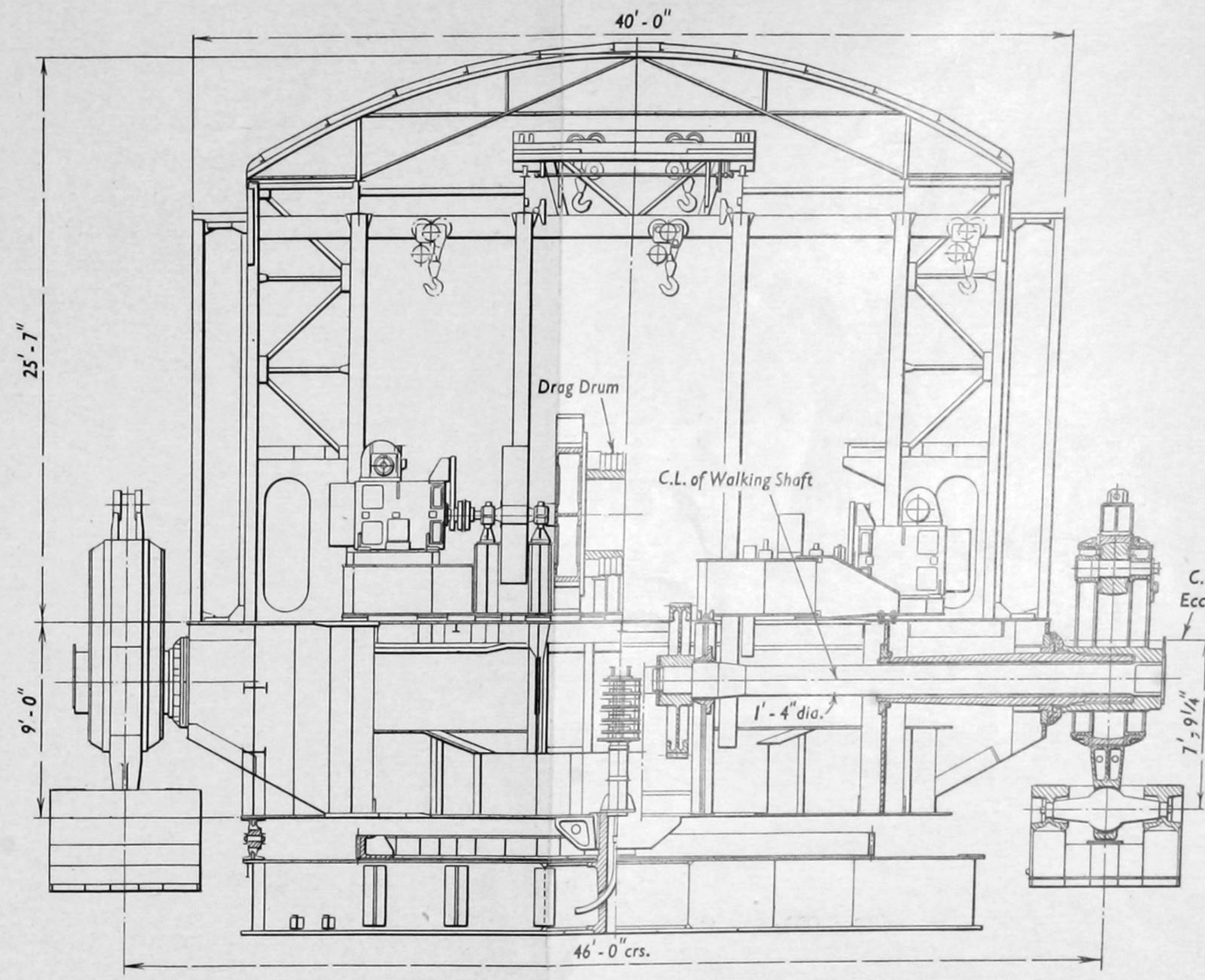


General arrangement of 12 cubic yard walking dragline

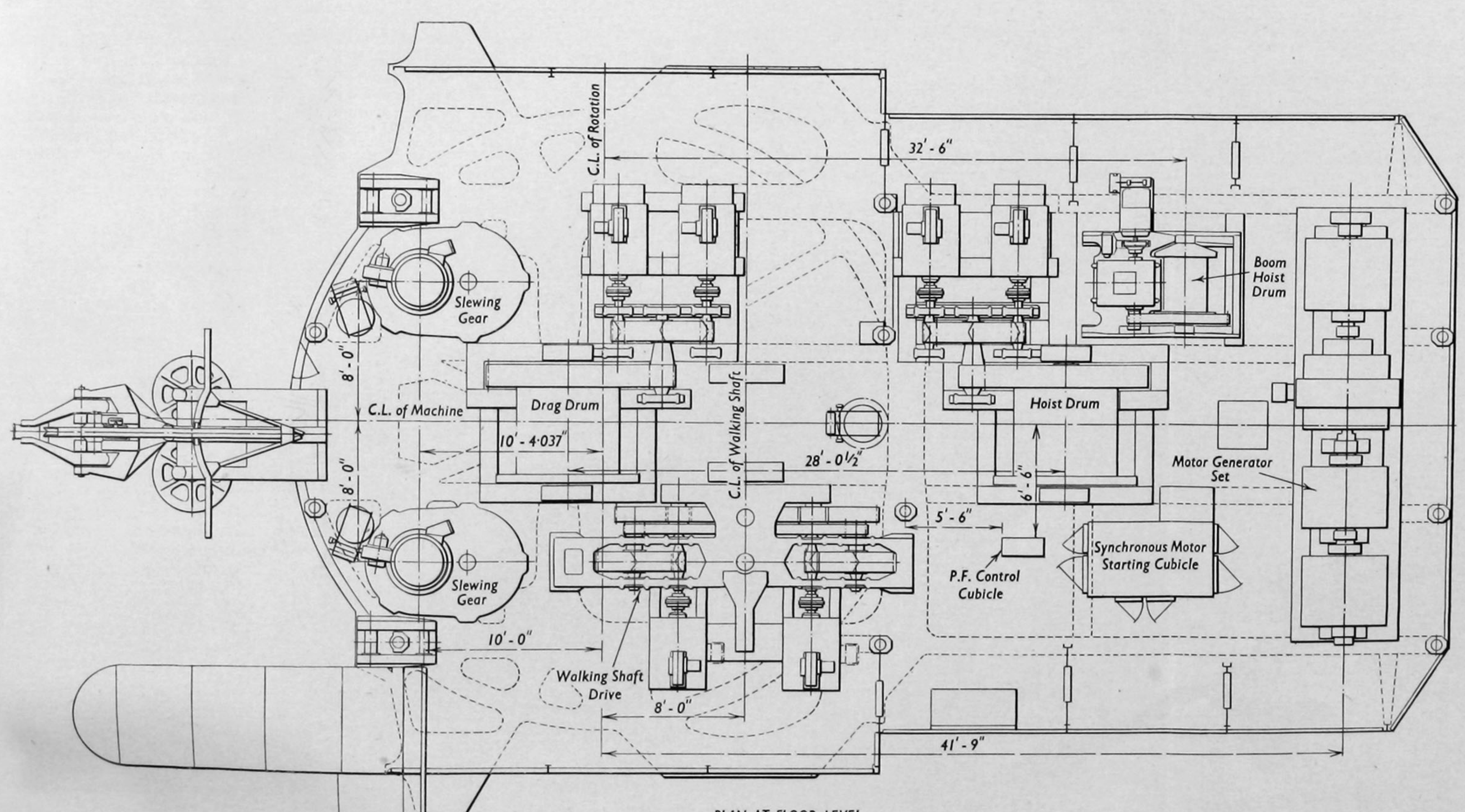
12 CUBIC YARD WALKING DRAGLINE



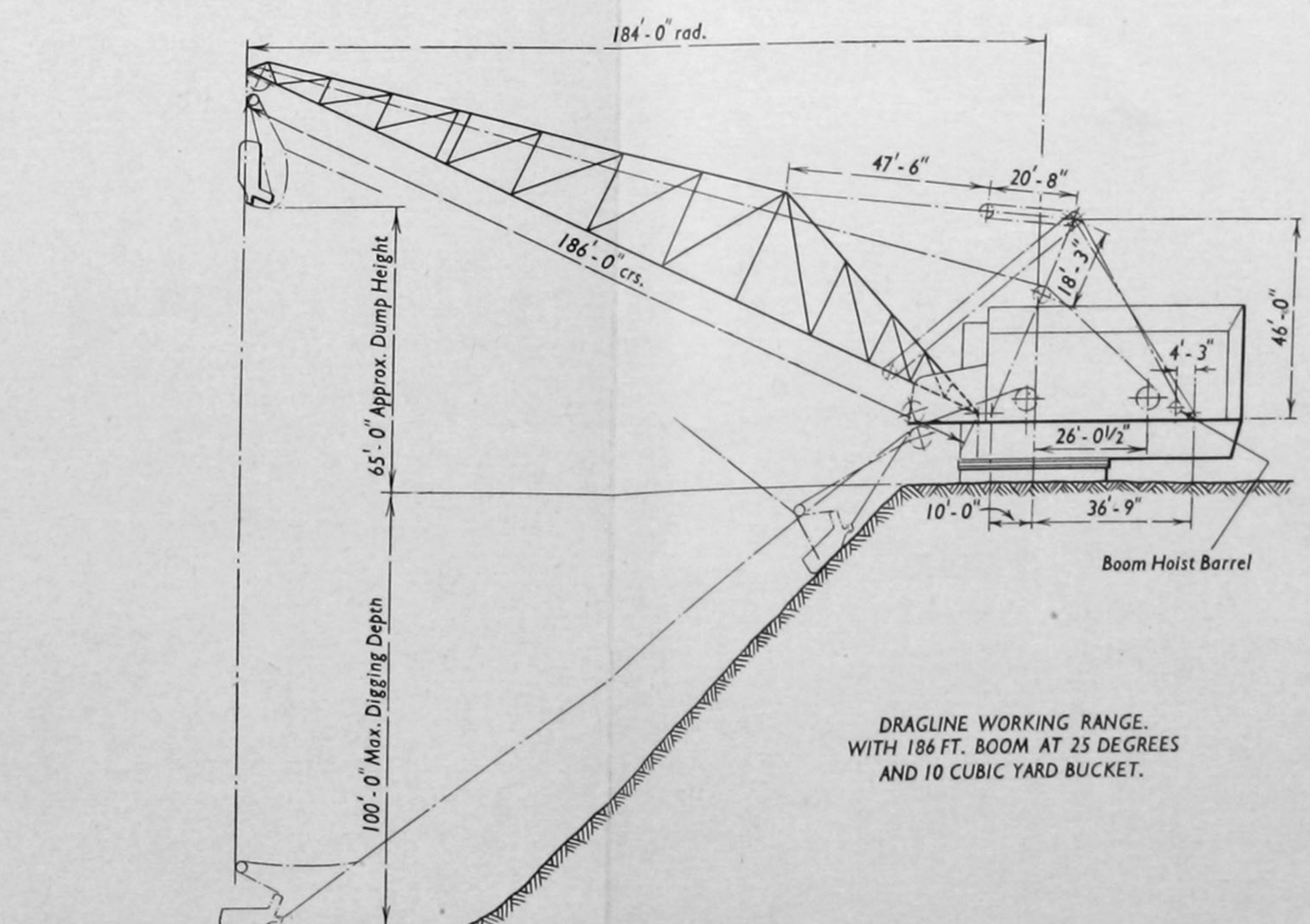
SIDE ELEVATION.



HALF SECTION ON C.L. OF ROTATION. HALF SECTION THROUGH WALKING SHAFT.



PLAN AT FLOOR LEVEL.



DRAGLINE WORKING RANGE.
WITH 186 FT. BOOM AT 25 DEGREES
AND 10 CUBIC YARD BUCKET.

boom was then raised until the nose section pivoted down sufficiently for the bottom pins to be inserted. With the boom thus assembled, it was hoisted up and the suspension member pins inserted at the apex.

A trunnion-mounted hoist sheave is fitted at the head of the boom, and the hoist rope is supported and guided by pulleys set at intervals down the length of the boom. The drag rope fairlead of orthodox design is mounted in a frame on the main deck, and its two vertical and two horizontal pulleys are carried on phosphor bronze bushes.

The machinery house has an angle framework with sheet metal-clad walls in which large windows are fitted to give good natural lighting over the whole interior. A gallery situated along the sides of the house, well above the level of the machinery, provides accommodation for the electrical switchgear and other control equipment. To facilitate maintenance and, if necessary, the removal of any machinery for replacement, a system of overhead crane rails is provided in the house. Two overhead rails at 10ft centres and running the full length down the centre of the house, carry a travelling cross carriage on which two 8-ton hoist blocks are mounted on runners. A series of transverse girder hoist-block rails set at a lower level extend out to the sides of the house above the main machinery installations. These transverse girders are designed to carry 5-ton hand-operated blocks. When it is required to move a piece of heavy equipment an extension beam is raised and fixed to the end of the appropriate transverse girder, using the blocks of the longitudinal crane. This beam is located in line and locked in place by means of pivoted latches, and it enables equipment lifted by the 5-ton block to be run out and deposited on the central gangway of the machinery deck, whence it can be transferred out of the house by the main overhead crane.

Electrical Plant

Power is supplied to the machine at 6·6kV through one four-core, pliable-armoured flexible trailing cable of 3·7in overall diameter, and is taken through Ransomes and Rapier air-insulated slipring collector gear to a main cubicle in the revolving superstructure. In this cubicle it is divided through three independent isolating switches ; thence the cubicle supplies a 1200kVA synchronous motor driving the main motor generator set, and a 150kVA, three-phase, 6600/440V auxiliary transformer, and a 30kVA, three-phase, 6600/110V lighting transformer.

The main motor generator set is mounted across the tail end of the main structure, and supported on six resilient pads. It is driven by the 1200kVA unity power factor, 1000 r.p.m. synchronous motor mentioned above, and consists of a 400kW, 550V hoist generator, a 400kW, 550V drag/walk generator, and a 270kW, 550V swing generator. The four machines, comprising the generating set, are solidly coupled and run in five oil-ring lubricated pedestal bearings ; a Michell bearing is incorporated at one end to take thrust.

An auto-transformer with a single hand-operated oil circuit breaker is used for starting the set and the changeover from tap to line is done through an air-break rotary switch operated from the circuit breaker handle while the circuit breaker is momentarily open. The synchronous motor field is supplied from a 9kW, 45V exciter, forming part of an independent exciter set, which includes an amplidyne. The amplidyne supplies the exciter field and a small control panel provides for either hand or automatic control. The synchronous motor is started with the amplidyne under hand control and then the control is switched over to " automatic," whereupon the amplidyne adjusts the excitation to maintain the power factor at any desired value from unity to 0·8 leading—irrespective of load variations on the synchronous motor. Alternatively, provision is made to maintain constant any value of reactive kVA from 0 to 1200 either leading or lagging.

The hoist, drag and walk motions are each driven by two 225 h.p., 230V, 450 r.p.m., separately excited, shunt-wound, heavy-duty motors with ball and roller bearings. They operate in tandem and are individually blown by a fan from the 440V a.c. supply. The motors are connected in series across the hoist or drag/walk and swing generators. The drives, controls and electrical characteristics of the hoist, drag and walk motions of the dragline are generally similar to those on the 20 cubic yard machine, built by the firm for Stewarts and Lloyds, Ltd., and described in our issue of November 9, 1951, except that each motion is driven by two instead of four motors.

All the motions are controlled by the driver from the glass-fronted control cabin, to be seen, on the left side of the superstructure at the front and on a level with the bottom of the boom, in one of our illustrations. The cabin contains a control console built round the driver's seat. Three cam-operated master controllers, situated behind the driver's seat, are operated by a link mechanism from two vertical levers for the hoist and drag/walk motions, and from pedals for the swing motion. These pedals are spring biased to the " off " position. Along the right-hand arm of the console are three pistol-grip, two-position switches for the brakes, and a fourth similar switch for changing over from drag to walk. Indicator lamps, suitably inscribed, show when the motor-operated changeover switch has actually completed its travel. Tumbler switches are also incorporated to control the various flood-lighting circuits, through contactors where necessary, to enable the machine to work at night. A central-zero meter, situated at the front of this arm, is scaled in feet per minute and is coupled to a tacho-generator; it serves to give the driver an indication of the speed of the hoisting line. A lamp indicator shows the driver when the walking shoes are fully raised into the normal working position. The left-hand arm of the console has an exciter voltmeter, emergency stop and reset buttons at the front, followed by a meter showing how many of the four aircraft warning lights at the boom head are actually alight, together with the switch controlling these lights.

An automatic metering system of lubrication is employed to feed all the journal bearings throughout the machine, and two separate oil spray equipments are provided for lubricating all the totally enclosed gears in the main rotating units. The interior lighting of the house over the machine consists of ten 300W wall lanterns and four 300W concentrating reflectors in the roof. The dragline will be in operation both day and night, and for working during hours of darkness the boom is fitted with a floodlighting system with nine 1000W and three 500W projectors.

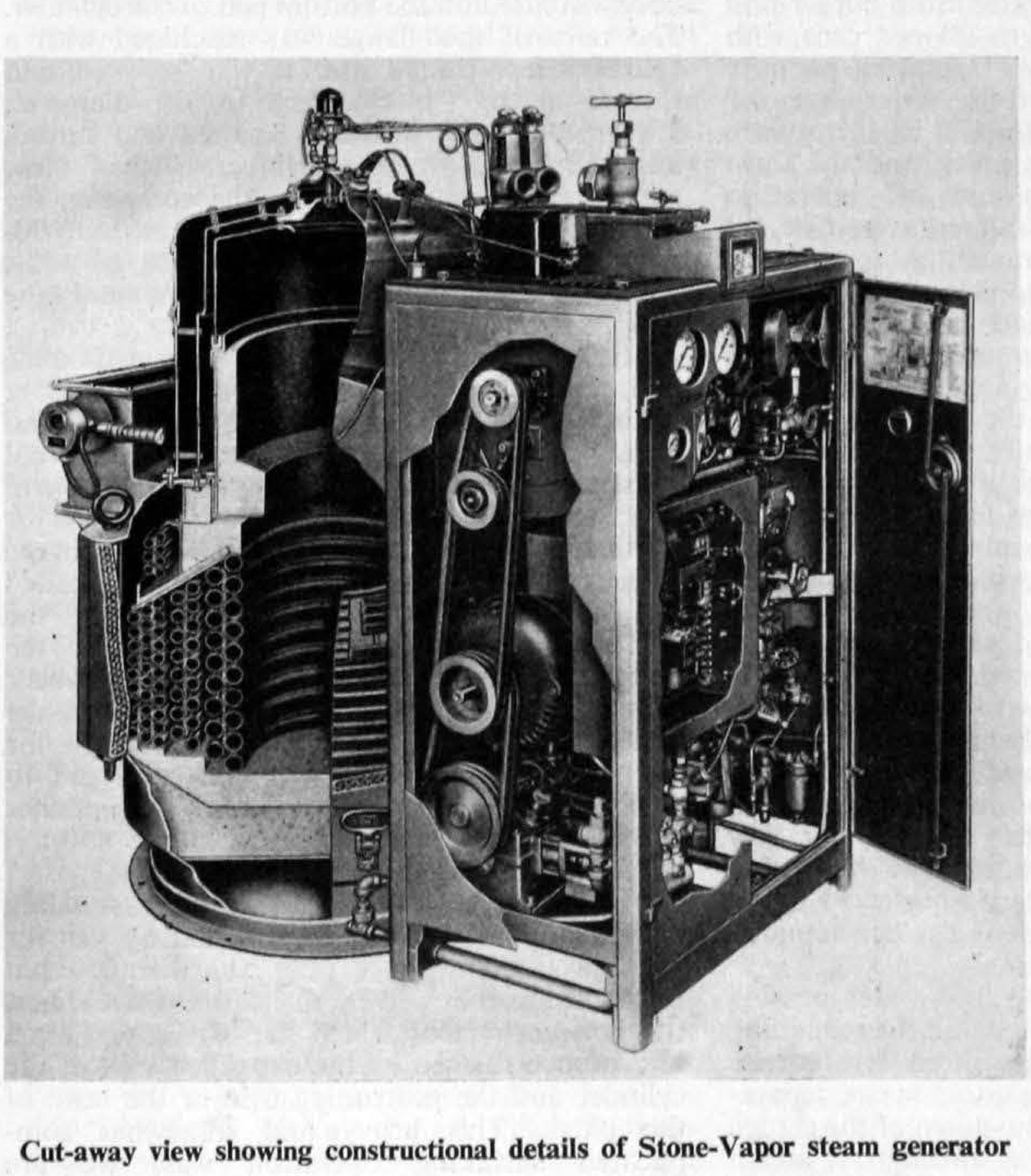
Small Packaged Steam Generators

A RECENT addition to the range of products manufactured by J. Stone and Co. (Deptford), Ltd., is a steam generator for which the company has concluded arrangements with the Vapor International Corporation, Ltd., of Chicago, to build under licence. Known as the Stone-Vapor packaged steam generator, this compact power unit is available in four sizes, of which the main particulars regarding performance are given in the table above.

Model number	H.p.	Minimum rating, lb of steam per hour	Thermal output, B.Th.U. per hour, thousands	Fuel consumption, imperial gallons per hour	Heating surface, square feet	Electric motor, h.p.	Overall dimensions			Approximate net weight, lb
							Length, in	Width, in	Height, in	
OK 4610... ...	35	1000	1163	8·75	87	3·0	68	41	60	2700
OK 4616... ...	65	2000	2275	16·6	105	3·0	66	46	65	2750
OK 4625... ...	100	2750	3450	25·0	171	5·0	68	43	73	3520
OK 4740... ...	160	4500	5356	39·5	245	7·5	73	73	80	5680

All models have a design pressure of 300 lb per square inch or 600 lb per square inch as a high pressure unit, while all have constant electric spark ignition except the largest, which is equipped with constant oil pilot ignition, having push-button electric ignition of the pilot burner. The table indicates that the sizes of the units range from 1000 lb to 4500 lb of steam per hour and that the related weight ratios are 2·7 lb to 1·25 lb per pound per hour of steam raised.

The generator, owing to its compactness, can be installed close to where steam is required, so that piping costs and heat losses are kept to a minimum, while the low weight also means that the unit floor load is small. After installation of the unit, which is already completely assembled and tested, only the service connections have to be made and a large natural draught chimney is not required. Other points to be noted about the steam generator is that steam can be raised within two minutes from a cold start so that burner heat is almost instantaneously converted to the production of steam. This rapid availability of steam means a saving in fuel and water, since the generator need only operate when steam is required. This form of steam generator is used extensively in a large number of industries, manufacturing a wide variety of products, and elsewhere where steam is in demand, and particularly on railways for heating and other purposes. For marine use the automatic functioning of the generator means that it requires



Cut-away view showing constructional details of Stone-Vapor steam generator

no watch-keeping attention apart from the need to start up and shut down.

The boiler, of which we show a cut-away view, showing the constructional details, contains nested coils, connected in series to form a single coil of steel tubing, which are arranged so that the combustion gases flow across them and split and envelop all coil surfaces. A positive displacement reciprocating pump passes feed water once through the tubes ; there is no recirculation so that no drums or headers are necessary, a factor that has been largely responsible for the reduction in the size of the boiler. It is claimed that the comparatively small amount of water in the coils at any moment makes a steam explosion impossible. Diesel or gas oil is supplied to the single down-firing compressed air atomised or steam atomised burner, sited in line with the axis of the coil, and the amount of fuel is automatically regulated by servo control to that required to heat the water and generate steam to meet demands.

In the pressurised combustion chamber heat is released at rates up to twenty times that of ordinary boiler practice and a high degree of turbulence ensures that the hot gases scrub all the surface of the coils and remove any insulating film of cool gas. A centrifugal blower delivers the combustion air, which is preheated in the air jacket surrounding the upper part of the fire pot, to the burner. The products of combustion flow downwards and outwards over the staggered arrangement of coils.

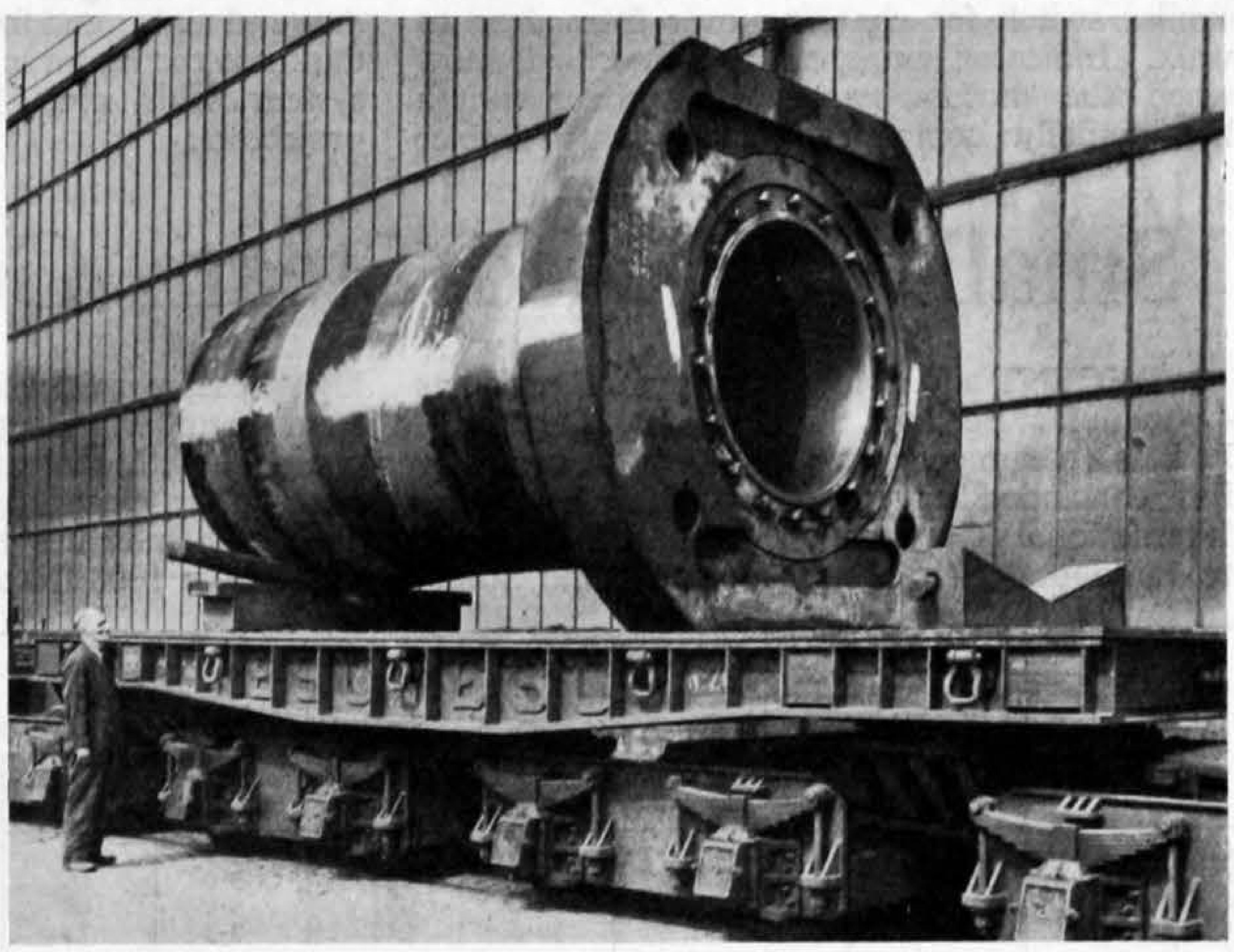
To drive the feed pump, fuel pump and the forced draught fan, there is a single electric, 220V d.c. or 440V, three-phase a.c., motor or a petrol or diesel engine. After starting up, the operation of the generator is automatic and some units cycle on and off under control of a steam pressure switch. Modulating units automatically adjust output from 100 per cent down to 30 per cent with an air atomising burner and from 100 per cent down to 20 per cent with a steam atomising burner. Operating pressure ranges from 15 lb to 275 lb per square inch for standard generators and to 575 lb per square inch for the high pressure units, and the form of ignition allows for on and off operation without supervision, should the steam demand fall below the modulation range.

Water, fuel and air supplies are regulated, according to the steam load, by proportioning flow controls, and the steam pressure is set by a water by-pass regulator, actuated by steam pressure, which controls the amount of feed water admitted to the coils by returning varying amounts of feed water back to the supply tank. In turn, the rate of flow of feed water governs the supply of oil fuel and combustion air through the servo-fuel control which automatically adjusts fuel and combustion air in direct proportion to the flow of feed water. Should the flow of water fall below a predetermined amount the servo control shuts down the unit. In addition to this safety device there is a temperature limit control which operates should the coils be subjected to an abnormally high steam temperature caused by either a low water flow or maladjusted flame. Should the flame fail through any cause the boiler is protected by an electric eye, a chimney switch or a switch actuated by the drop in steam pressure.

About 90 per cent of the feed water passing through the coils is evaporated and the remaining 10 per cent travels at high speed and carries with it scale forming sludge into a steam separator. There is a periodic blow-down of the sludge and the condensate returns through a steam trap either to the make-up tank or to drain. The thermal efficiency claimed for the Stone-Vapor Steam Generator is between 73 to 83 per cent over the operating range. This is an important factor in calculating the cost of steam, which is also influenced by starting and stopping operations, both of which have a considerable bearing upon overall efficiency. Other characteristics affecting operating costs are the automatic controls, rapid raising of steam, and short cooling period.

Stainless Linered Press Cylinder

THE English Steel Corporation, Ltd., recently overhauled a 7000-ton forging press installed in one of its shops. This press, said to be the largest of its kind in the British Commonwealth, has been fitted with a cylinder having a stainless steel liner in order to prevent wear, due to cylinder corrosion, of the main hydraulic packings and ram head.



Cylinder for heavy forging press fitted with stainless steel liner. This 7ft 2in outside diameter 15ft long cylinder weighing 65 tons, has shrunk on it a 12ft 6in long, 5ft diameter steel liner with a 2in wall thickness

Before the liner was inserted a flange 18¼in thick by 12ft diameter and with a 7ft 4in bore was fitted on the bottom end of the cylinder. The bore of this flange was machined with a 1¼in buttress thread and it was screwed and shrunk on to the cylinder. A 5ft diameter, 3ft 4in long plug was also inserted and shrunk into the top end of the cylinder. All of these parts were forgings made by the company, the cylinder and the liner being forged on the 7000-ton press itself. The cylinder weighs 65 tons, the liner 7 tons, the flange 18 tons and the plug 10 tons.

The machining of the liner presented some difficulty because of its relatively thin wall section. It had a tendency to sag during machining and during each stage of turning and boring internal support rings held by adjustable split spiders were fitted, and plugs were also inserted in both ends for the turning operations. The actual assembly of the various components on the cylinder also called for careful organisation and planning on the part of the firm. This was partly due to the necessity of heating the flange in a plate treatment furnace situated ½ mile away by rail from the assembly point. Further, even after a pit for the shrinking operation had been enlarged to receive the cylinder, there was only a few inches of clearance left for the hook of the 150-ton overhead crane used in the operation.

In the assembly sequence the cylinder, standing upright in the pit, was first heated by gas for four days. The flange plug was then lowered into position followed by the stainless steel liner, the bottom 6¼in of which had to be registered in a groove formed by the expanded wall of the cylinder and the protruding 6¼in of the head of the plug. This heavy and somewhat complicated shrinking operation was, we are informed, completed in twenty minutes, with entirely successful results.

Australian Aeronautical Research

A WIDE variety of investigations, many of great general interest, are described in the Annual Report for 1954–1955 of the Commonwealth of Australia Department of Supply Aeronautical Research Laboratories. The High Speed Aerodynamics Laboratory having become part of the Weapons Research Establishment, the Laboratories are at Melbourne. The Aerodynamics Division is proposing to proceed with its tests of a five-seat tandem rotor helicopter by " flying " a model in a wind tunnel ; tunnel tests have been done to check the design of power station smokestacks and the Olympic swimming pool structure. Prolonged outages were suffered by the high-speed tunnel due to its " Merlin " engine drive, but by applying suction to the slotted working section the pressure distribution and drag measurements on the " Jindivik " Mk. II aerofoil were extended to M 1·05. The work on hot wire anemometry is proceeding and, whereas last year King's law was suspect for Reynolds numbers between 0·5 and 5, it is now rejected below Re 40.

The Structures Division continue to concentrate on fatigue problems. No mention is made of the projected tests of discarded D.H. " Dove" centre section spar tension booms, but it was shown that the redesigned steel boom has a satisfactory life. Full-scale tests on ninety-one N.A. " Mustang " wings were completed, and among the conclusions were those that the life can be considerably extended by application of a high pre-load, and that for a large part of the life the rate of crack propagation is fairly constant. Progressive repair techniques investigated included the use of resin impregnated glass fibre patches. Fundamental work by the Materials Division showed that, while surface finish had the expected influence on the S-N curve, this improvement was less marked than that due to surface deformation, so that a specimen with a coarse finish could be made superior to one with a fine finish. The theoretical work of the Laboratories had previously shown that fatigue cracks might form within the first 10 per cent of the fatigue life, and one has now been observed at only 25 per cent.

The joint programme with the Defence Standards Laboratory on chromium-base alloys for turbine blades intended to realise maximum gas temperatures of 2200 deg. Fah. is being prosecuted strenuously. The best alloy to date, containing 36 per cent tungsten, performs as well under creep compression tests at 950 deg. Fah. as the best commercial materials at 750 deg. Fah. Hot working processes for the alloys show promise, but an experimental casting contained excessive nitrogen, an established cause of embrittlement of chromium, tungsten and molybdenum. The static rig being designed by the Mechanical Engineering Division to test typical turbine blades of the chromium-based alloys under tension, gas loading, and thermal shock is awaiting the evolution of a suitable blade root.

Other interesting features of the work of this department concern combustion. It has been shown that the flame in an aero-engine combustion chamber can be stabilised effectively at low fuel rates by injecting oxygen through the shroud of the fuel nozzle. Since the need to avoid flame extinction at low temperatures and pressures governs the volume of the combustion chamber, a substantial reduction in engine frontal area can be expected with this technique, and even a small reduction in weight despite the need to carry the oxygen and its storage and control equipment. The problems of burning dried pulverised brown coal in industrial gas turbines are considered to have been overcome, but no progress has been made with the acquisition of a full-scale turbine. It has been demonstrated on a small turbine that control of ash deposition is readily obtained by the injection of water or sand in practicable quantities. Ram-jet studies have included flow instability in intakes ranging from 50 lb per square inch impulses at 300 c/s to " buzz " at 1000 c/s. A photographic technique of fuel droplet sizing has been perfected to cover distributions down to 5μ in a 350ft/sec air stream.

Industrial and Labour Notes

The T.U.C. Report

This week, the Trades Union Congress has published the annual report of its general council. This report, which will be presented at the eighty-eighth congress, to be held at Brighton at the beginning of next month, summarises the manifold activities of the general council during the past twelve months. In that period, the report explains, "economic affairs have had high priority," and the general council says that it has "left the Government in no doubt that it would prefer to see a much more positive direction of the national effort aimed at a permanent economic and financial recovery."

One of the appendices to the report deals with the general council's deliberations on the subject of automation. It urges that "automation must be neither under-estimated as an instrument of industrial change nor exaggerated into an immediate industrial revolution." The report surveys the technical aspects of automation, and comments on the "considerable differences of opinion which have been expressed by experts and specialists as well as laymen about the meaning and implications of automation." The general council then says that what is or may be new about automation is the rate of acceleration—the speed and extent to which automation is introduced into industry and commerce, and whether in each case it is a new development or the replacing of conventional production, processing or servicing methods. The "implications for trade unions" are considered in the report, under which heading it is stated that "up to the present no major difficulties have been experienced." It is added, however, that "unions are aware of the quickening pace and possible widening impact of automation, in office work particularly, and are keeping a close watch on the extent to which industrial relations problems may, as a result, be sharpened and new ones posed."

Among the conclusions set out at the end of the chapter on automation, the general council says that the major interests of workers are the continuance of full employment and improvements in working and social standards, to which increasing efficiency and productivity in industry make a substantial contribution. In the wide context of industrial efficiency and in relation to automation in particular, it is claimed, the T.U.C. and affiliated unions are playing a positive and constructive role. The increasing use of management and production techniques in industry, including work study, which, with suitable safeguards, unions are showing themselves prepared to accept, the report says, are part of the process of opening up the way to future automation. There follows the observation that "to offset the impact of industrial disturbance caused by automation, and to humanise technical innovation, trade unions are seeking all the while to improve negotiating and consultative procedures, to keep abreast of human factor research, and are providing technical training for full-time officers and workplace representatives." Finally, the T.U.C. general council asserts that, far from opposing automation, unions are helping it on, and are, at the same time, meeting successfully the challenge of change in the place of work.

The T.U.C. Agenda

The final agenda for this year's Trades Union Congress has now been published. The congress will open, at Brighton, under the presidency of Mr. W. B. Beard, on Monday, September 3rd.

The agenda contains eighty-nine notices of motion which have been submitted by affiliated unions. They are classified under eight different headings, and, as in past years, deal with a variety of matters of national and international concern. In the motions dealing with relations between trade unions, there is one, submitted by the National Union of Public Employees, which urges that the T.U.C. should exercise more effective leadership in industrial life. The resolution says that the application of automation and nuclear forces to industry will have far-reaching effects upon the working population and will present the trade union movement with complex and difficult problems. To deal with those problems effectively, and to safeguard the interests of the workers in "this new industrial age," the resolution suggests, it is imperative that the T.U.C. general council should take a more active and positive role in industrial affairs.

Under the heading "Production and Industrial Development," there are thirteen proposed resolutions, ten of them dealing with some aspect or another of automation. Most of these resolutions recognise the importance of modernising production methods by the application of new techniques. At the same time, the resolutions call for a greater degree of joint consultation on the subject, and there is one, from the National Union of Vehicle Builders, which "considers that strong and united action on the part of all organisations is necessary in order to secure equal shares for the workers in the form of increased leisure, &c., arising from increased productivity." There are thirty-four resolutions on economic policy, many of them condemning, or expressing "deep concern" about, present financial policy. Those of the resolutions in this group which deal specifically with wages declare opposition to a policy of wage restraint. There is a small group of four notices of motion entitled "Education." One of them, which has been submitted by the Engineer Surveyors' Association, welcomes recent Government statements on technical education. This resolution then draws attention to the need for the best standards of pay and prospects for salaried engineering and scientific employees in general, in order to attract sufficient candidates for the proposed educational facilities, and also to ensure the achievement of the major objective, namely, the maintenance by Great Britain of a leading position in the industrial field.

Automation and Labour Problems

Various aspects of automation are commented upon by Mr. S. R. Dennison in the August issue of the *National Provincial Bank Review*. In this survey, Mr. Dennison says that displacement of labour is caused not merely by the greater productivity of automatic machinery, but also by changes in the types of skill which are needed. As with all technical change, the *Review* continues, many of the old skills are no longer needed and new ones are required in their place. The concern expressed by the unions over the introduction of automation, Mr. Dennison adds, is, therefore, not altogether misplaced. Common humanity, as well as good industrial relations, demands that the introduction of new methods should have regard to the position of the workers who will be affected.

Mr. Dennison goes on to say that although the normal processes of movement of labour might give some opportunity to reduce the effect of a radical change in techniques, and although some firms may be large enough to make internal readjustments to obviate the need for dismissals, there remains a problem which in some cases must be of major importance. The *Review* recalls that many suggestions have been made for softening the impact of change and, in the U.S.A. in particular, the unions have given much attention to the matter. Specific proposals include the payment of compensation to the workers who are displaced, the provision of training facilities, the reduction of working hours, the reorganisation of systems of promotion, and the like. But in this country, Mr. Dennison asserts, trade union declarations have not gone much beyond broad statements of the kind that, in the words of the president of the T.U.C., the new developments must be turned "to our advantage and not our disadvantage." There, the *Review* suggests, is a major dilemma of policy. On the one hand, it can be urged that a firm should bear the "social costs" of any change which it introduces, but, on the other hand, to impose these costs on the individual firm is to increase the cost involved in making a change. Compensation pay to dismissed workers, for instance, can properly be regarded as an increase in the capital cost of new machines. The effect, Mr. Dennison observes, would be to diminish the rate at which new developments are introduced and to delay the increased productivity and rising standards of living which are expected to accrue from technical progress. There are, indeed, according to the *Review*, serious dangers in requiring individual firms to meet the social costs of change, and much to be said for spreading them, as the benefits are spread, over a larger part of the community.

Engineering Wages

In these notes in our last issue, there was a brief reference to the deliberations at the annual conference of the Confederation of Shipbuilding and Engineering Unions, which was held last week at Hastings. The debate on wages took place on Wednesday, on a composite resolution moved by Mr. R. Openshaw, the president of the Amalgamated Engineering Union.

The outcome of this debate was a direction to the executive of the Confederation to make "an immediate application for a substantial wage increase for all manual workers" in the engineering and shipbuilding industries. No figure has been specifically mentioned, though it has been suggested that the unions have in mind an increase of £1 a week. During the debate it was urged that no trade union could agree to refrain from attempts to improve the living standards of its members, when other people were improving theirs. It was also claimed that higher wages would be an incentive to greater efficiency.

Other matters decided by the conference on the same day included a restatement of the Confederation's determination to press for a forty-hour week without loss of pay. It was also agreed that claims for higher wages for apprentices and limitation of overtime should continue to be pressed.

Joint Consultation on British Railways

With the idea of increasing the effectiveness of joint consultation between the management and staff of British Railways, the British Transport Commission and the trade unions, through the medium of the British Railways Productivity Council, have been reviewing the former procedure for joint consultation in the light of experience gained since its inception in 1949. The British Transport Commission says that, as a result of this review, an amended procedure has been adopted for railway staff, and a similar procedure, adapted to meet their particular conditions, will also apply to railway workshop staff and to other grades on British Railways for whom separate agreements for machinery of negotiation and consultation exist.

The facilities for joint consultation are through local departmental committees, sectional councils and shop, works and line committees, as well as between headquarters representatives of the management and unions at regional and national levels. The local departmental committees are the recognised channels of communication between employees and local officials at stations, yards and depots, whilst the sectional councils enable the management to confer with representatives of groups of grades at regional levels. The new provisions are designed to improve the existing channels of discussion.

There is one new clause which states that the British Transport Commission and the unions have agreed that, should any difficulties arise at the appropriate level of consultation, or any question be raised as to the eligibility of a subject for discussion under the scheme, these should be referred to headquarters for assistance in the interests of smooth working of the scheme. It is pointed out that this will enable the representatives of the staff to appeal to headquarters if they feel they are not being given a fair chance to put their point of view.

Lightweight Electric Passenger Train

OUR illustration shows an electric train of four coaches, one of a number which are being delivered by Breda Elettromeccanica e Locomotive, S.p.A., of Sesto S. Giovanni, Milan, to the Indian Railways, which will use them on the suburban services of Madras. Each train consists of three carriages and a locomotive, the locomotive being placed either second or third along the train. By providing driving cabs at each end, the train can be driven in either direction. The locomotive itself has, of course, its own driving cab, in addition to the high-voltage cabin containing electrical equipment for a supply voltage of 1500V d.c., the remainder of the locomotive forming a luggage compartment.

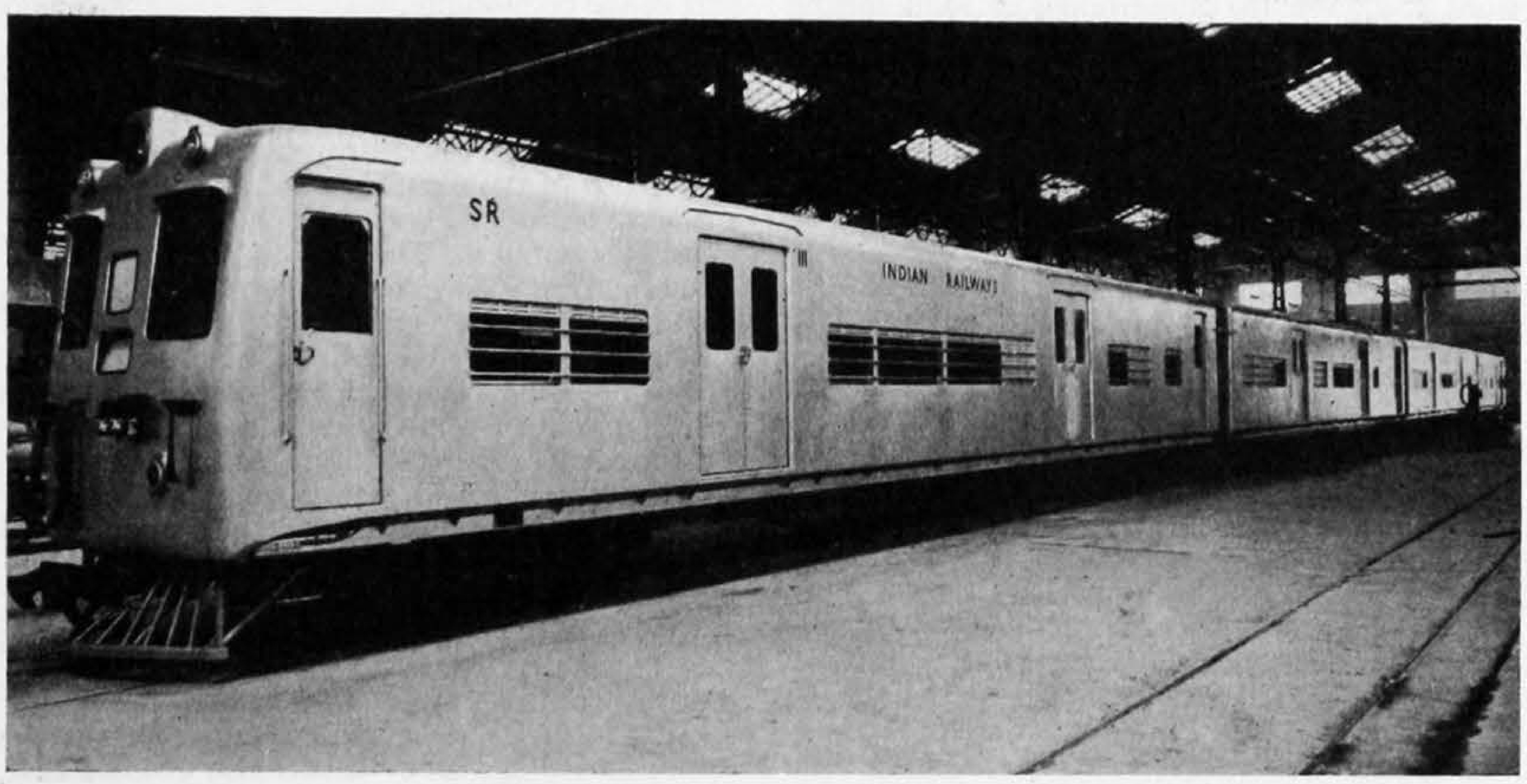


Fig. 1—Four-unit electric train for suburban passenger service in India

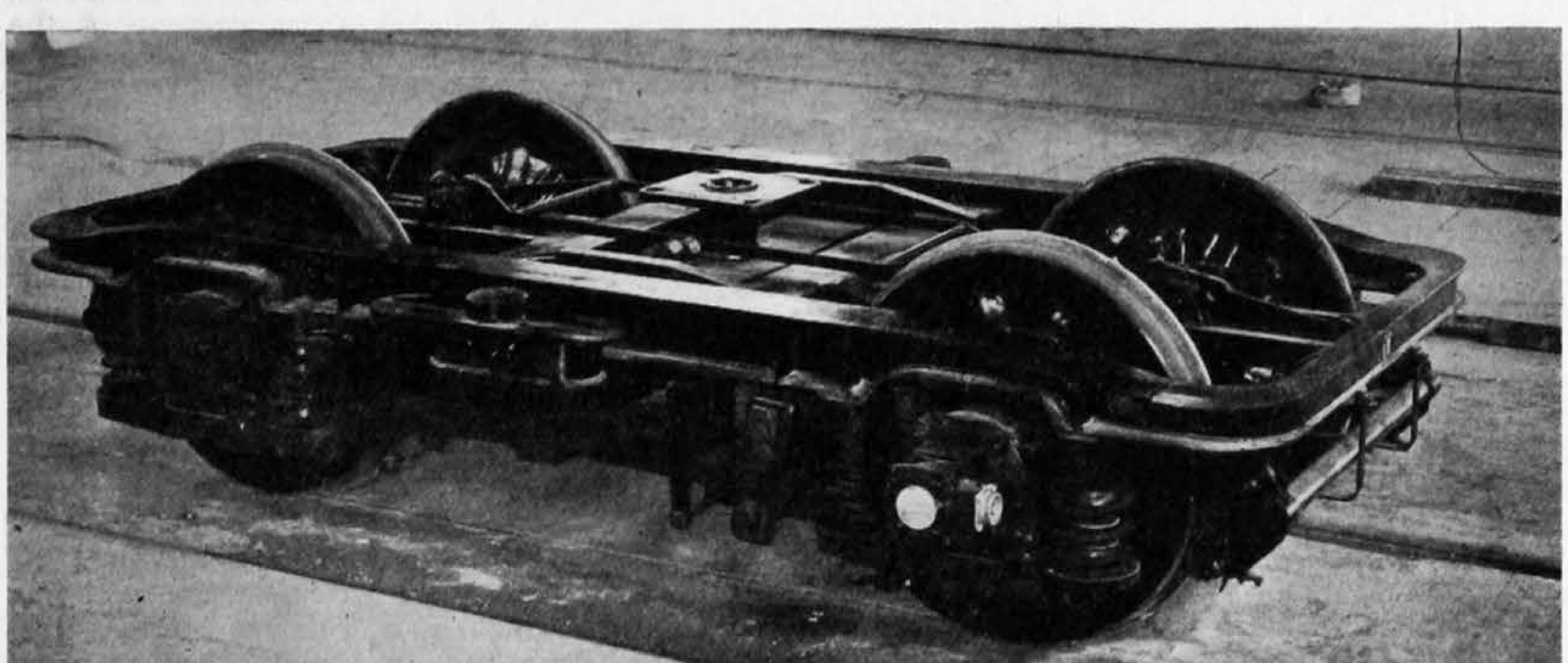


Fig. 2—One of the carriage bogies

Great emphasis was placed on reliability of the equipment, including full resistance to conditions of heavy rain, tropical temperatures and moisture, and dust and sand. As the services are to be run with train intervals which may be as low as two minutes, any fault putting a train out of commission even temporarily would be liable to cause a breakdown of schedules all along the line. The required top speed of 90km per hour is considered to be a substantial achievement in view of the narrowness of the gauge, which is 1m. High acceleration is obtained by using powerful traction motors and lightweight construction. The engine has a weight of 20 tons, while the end carriages weigh 13 tons and the remaining carriage has a weight of 10 tons. Four traction motors of 160 h.p. each are installed.

The carriages contain third-class compartments only. A large number of passenger-controlled electric fans are fitted, as is usual on Indian railways.

Wide sliding doors are used on the train. The windows, as may be seen from the illustration, are long and low, to give maximum protection from the sun. Panes of bluish glass are fitted, as well as aluminium shutters. The outside is aluminium painted.

The train has a seating capacity of 306, and a maximum capacity of over twice this number. Design and construction of the electrical equipment was undertaken by Breda Elettromeccanica e Locomotive S.p.A. The carriage project was initially studied by Breda Ferroviaria S.p.A., which handed the bodywork over to Industrie Meccaniche e Aeronautiche Meridional (IMAM), of Naples, and the construction of the undercarriages to Ansaldo Ferroviaria, of Genoa.

Breda agent in the U.K. is the Central Engineering Company, Ltd., Colquhoun House, 27–37, Broadwick Street, London, W.1.

European Road Traffic

The Brussels–Ostend autoroute, which was opened at the end of April, was begun before the last World War II. Work on it was interrupted in 1942 when only 17 miles had been completed, and was not resumed until 1949. The new road is 63 miles long, compared with 70 miles by other routes. Its cost was 2300 million Belgian francs (£16,500,000). It is estimated that even at the present traffic rate this capital expenditure should be amortised by traffic savings within ten years. The road is not quite complete and work remains to be done particularly at the junction with the " ring road " planned around Brussels.

The Italian Council of State has ratified the agreement creating the Italstrada Group which will construct and operate for thirty years a super-highway from Milan to Naples. I.R.I., the private financial agency concerned, will provide 60 per cent of the capital investment and A.N.A.S., the Italian Government Road Department, 40 per cent. The total cost is estimated at 184,000 million lire (£105 million) for the 443 miles from Milan to Naples. This autostrada will form the main arterial link of a future national network.

Work is to begin immediately on the section Milan–Bologna–Florence (167 miles), and is due to be completed in three years. Part of the Rome to Naples section, comprising the 24 miles from Capua to Naples, will also be started immediately. The 157-mile section from Florence to Rome will be completed within six years, together with the remaining section of the Rome to Naples route (95 miles).

The plans for the Rome–Naples highway were developed by S.I.S.I., a private organisation of leading Italian industrialists. The existing road totals 495 miles compared with the 443 miles proposed for the new autostrada. Driving time is now double that which will be comfortably possible on the new road.

Several other construction programmes are under construction, the most important being the extension of the Genoa–Serravalle autostrada to Milan (51 miles) at a cost of 16,800 million lire (£9,500,000). This will complete a long-needed traffic link between industrial areas of Lombardy, the Port of Genoa and the Ligurian coast. Other works include the roads Brescia–Padua, Naples–Bari, Naples–Padua and Padua–Mestre.

Apart from the agreement signed regarding Italstrada provision is made also for a total of 300,000 million lire (£171 million) of autostrada construction to be carried out over the next ten years with the aid of private finance. The Government, through A.N.A.S. will contribute up to 30 per cent of the finance required. The A.N.A.S. budget is to spend 100,000 million lire (£57,000,000) on autostrade and 20,000 million lire (£11,000,000) on State roads over the next ten years.

In Sweden, a commission, composed of members of the Royal Board of Roads and Waterways, industry representatives and road organisations, has published the preliminary plans for the modernisation of the national road system. In preparing its scheme the commission based its work on the principle that the future road system should provide a link between towns and industrial areas so as to serve most expeditiously the important local and short-distance traffic. The commission also considered the needs of long-distance traffic to ensure that these would be met. The road system will total some 7800 miles, of which some 1000 miles will be divided four-lane traffic roads, or motor roads. The total cost is estimated at 7000 million kronor (£483 million).

Technical Judges in Germany

For many years past much attention has been given by the Association of German Engineers (V.D.I.) to the question of technical judges, a matter which is clearly of great importance in many civil cases especially in connection with patents. The term " technical judge " means a person with completed technical or scientific training to degree standard and subsequent practical experience, who also has either legal experience or special knowledge of patent law. A Law redefining the German judicial system is to be ratified by the present parliament. It is claimed by the V.D.I. that the draft law on this subject, which was completed in August of last year but has not so far been published, disregards several points essential to technologists.

The reforms which are sought by the V.D.I. are the recognition of the German Patent Office as a court of law, and the recognition *de lege* of the legal and legal-technological members of the Patent Office as judges. This view, expressed in a memorandum which the V.D.I. published in 1954, is stated to have the approval of many industrial firms—some of them internationally known—universities, scientific technical associations, industrial associations, the trade unions, and many individual persons of standing.

In addition, it is sought to establish mixed panels comprising technically trained judges as well as judges with a purely legal training, to deal with patent litigation. Lastly, the V.D.I. seeks the recognition, also *de lege*, of technical judges, as professional judges with the same rights and duties as those who have been trained in law.

It appears that last year's draft law has been the subject of several discussions between the Ministry of Justice and legal circles, without the participation of engineers. The draft law would admit as judges only persons who have passed both judicial state examinations. This would eliminate from jurisdiction in patent cases the technical experts of the Patent Office, and so end a tradition of nearly eight decades, and one on which rests the international reputations of the German Patent Office. It would also eliminate the possibility of mixed panels of judges in patent cases.

The V.D.I. foresees that if such a measure were passed the probability of just decisions would be reduced, and cases would take longer and be more expensive. No direct influence could then be exerted by technology upon the basic principles of interpretation of patent law. Simplification and standardisation of the law relating to patents and similar matters would be rendered more difficult, and a need would be created for using arbitration.

The draft law leaves open the question of the status of the Patent Office, and what the procedure should be for the granting and nullification of patents. The V.D.I. stresses the significance of the proposed measure and warns against hastiness and coming to a decision without having consulted all interested parties.

Domestic Heating in Europe

A recently published report of the Economic Commission for Europe (E.C.E.)* deals with problems in domestic heating, both short and long-term. The proportion of coal consumed by the domestic sector—which is taken to include handicrafts, schools, hospitals, offices and shops, in addition to dwellings—varies widely from country to country, ranging from 6 per cent to over 40 per cent, and is on the average 23 per cent. If the coal used to generate domestic electricity is included, it is estimated that well over 25 per cent of solid fuel consumption will be in the domestic sector.

The report makes a number of recommendations with regard to fuel economy. Studies made in the United Kingdom show that in Britain, or under comparable conditions elsewhere, closed stoves are cheapest for continuous space-heating for five hours per day and over, central heating being more convenient but dearer. In Sweden, where the percentage is highest, 50 per cent of dwellings have central heating, compared with 1 per cent in Britain, and nearly all new houses, whether in town or in the country, are being equipped with it.

The swift growth of industry in many countries has increased the demand for the available hard coal, so that heating has been forced to rely more on what were previously regarded as inferior fuels, such as coke, briquettes and lignites. Increasing use is made of oil, the outstanding example being Sweden. Because of the low cost of electricity generation, Norway is foremost with electric space heating, this method being predominant there. Gas is making slow progress and the use of wood, which is still of importance in rural areas, is declining.

Among the proposals for increasing efficiency are : to reduce ash content and smoke emission in the case of solid fuels ; to improve the design of appliances and to reduce their cost by standardisation. The use of coal should be promoted. Heat measuring apparatus in flats could help to reduce wastage, as, for instance, in Denmark, where fuel consumption was reduced by as much as 35 per cent. Another system provides, by means of central heating, uniform heating to all parts of a house to 14 deg. or 15 deg. Cent., which individual tenants can supplement at extra cost.

Long-term measures include the development of more efficient appliances for burning wood and wood waste, district heating schemes, and the use of gas from the total gasification of non-coking coals.

* "Trends in Fuel Consumption for Household and Domestic Uses in Europe," Economic Commission for Europe, Geneva : Palais des Nations. Obtainable from H.M. Stationery Office, P.O. Box 569, London, S.E.1, price 3s. 6d.

The Timmelsjoch Road

An additional road connection between Austria and Italy will be available with the completion of the road over the Timmelsjoch, which is at present under construction. The Timmelsjoch is the only ice-free pass between the Brenner and the Résia (Reschen Scheideck), and provides the connection between the Inner Ötz Valley and the Passeier Valley. It is situated in a district with a very favourable climate, and has the minimum of rainfall for the Eastern Alps (about 28in per annum) and 50 per cent of the maximum possible sunshine. In consequence of the east-westerly direction of the pass, both approaches are situated on sunny slopes.

What made the construction of the road a particularly attractive proposition was the fact that most of the southern part was already in existence in the shape of a military road, so that only 2 km had to be built in order to reach the pass. Eleven out of fourteen road tunnels were already in use, and the twelfth, at a height of 2300m above sea level and 700m long, had already been pierced. On the Austrian side, only about 12km of road were required to make the connection. The Timmelsjoch road is therefore one of the most economic projects of its kind, both in terms of time and cost.

The road branches off from the Zwieselstein–Obergurgl road, just before Obergurgl (1900m). Rising from 1900m to about 2200m it reaches the Angerer Alm and then descends slightly to the Timmelstal Valley, which it crosses, before rising to the pass itself. It is thought that at some future date the construction of a summit tunnel may be undertaken, in order to enable the road to be used at times when the pass is blocked by snowdrifts.

From the highest point the road descends with a gradient of 6 to 8 per cent to Schönau (1600m) and Moos (1100m), and continues to St. Leonhard in the Passeier Valley (693m). In this manner the Timmelsjoch road constitutes the most direct connection between Füssen (Bavaria) and Merano.

The construction of the road over the Timmelsjoch goes back to a resolution in the Tyrol Land Parliament of November 17, 1954, supported by a corresponding resolution by the Regional Parliament at Bolzano on January 24, 1955. The foundation of a limited company to construct the road took place in Obergurgl on August 20th of last year ; 60 per cent of the capital of this company is owned by the Austrian Federal Government, 15 per cent by the Land of Tyrol, and the remainder by twenty-four Tyrolese parishes. Work was begun on October 30, 1955, and it is hoped will be completed next year.

German Iron and Steel

In spite of increasing production, the German steel industry is not yet in a position to meet all domestic requirements for rolled steel, so that considerable quantities are still being imported. In April, May and June of this year, rolled steel imports amounted to 213,000 tons, 173,000 tons and 238,000 tons respectively. In the whole of the first half of 1956, orders exceeded deliveries. The table shows how the position has developed since 1954 :

German Rolled Steel Production and Consumption (without semi-products and broad strip)

Millions of tons

Year	Orders received	Deliveries	Orders in hand at end of half-year
1954, first half ...	6·30	4·98	3·05
1954, second half	8·73	6·24	5·35
1955, first half ...	7·67	6·60	6·05
1955, second half	7·76	7·27	6·35
1956, first half ...	7·89	7·51	6·44

A further increase in the demand for steel is anticipated, although the rate of increase is expected to fall off progressively.

Increases in the production of iron and steel led to a higher consumption of coal and coke by the steel industry, the figure being 1·81 million tons a month during the first six months of this year, compared with 1·70 million tons a month in the first half of 1955, and 1·74 million tons during the whole of last year. Of this year's total, 1·35 million tons were blast-furnace coke (compared with 1·26 million tons and 1·30 million tons during the first half of 1955, and the whole of last year, respectively).

The consumption of coke per ton of pig iron decreased from 954kg in the first half of 1955 to 944kg in the first half of this year. Consumption of fuel oil, though still small, increased from 27,337 tons per month last year to 38,230 tons per month in the first half of this year. Fuel oil consumption per ton of steel increased from 15·4kg to 20·4kg.

Total deliveries of ore until June of this year amounted to 13·6 million tons, compared with a consumption of 13·7 million tons in the same period. Deliveries of ore from abroad were 7·8 million tons, and consumption of foreign ores was 8·9 million tons. In terms of iron content, 69 per cent of ore came from abroad during the first half of 1956.

Scrap consumption for iron and steel-making ran at 891,000 tons per month, compared with 865,000 tons per month in 1955, making a total of 5·35 million tons for the first half of 1956, compared with 5·19 million tons in the first half of last year. Of these 5·35 million tons, about 2·9 million tons could be provided by the steel works themselves, so that about 2·4 million tons had to be obtained from other sources, both domestic and foreign, the latter largely from outside the Iron and Steel Community.

Sweden's Forest Products Industries

Growing demand for Swedish pulp, both at home and abroad, is to be met by a further switch-over to continuous operation of the mills, according to Press reports. Shipments of chemical pulp are expected to reach 2,070,000 tons this year, an increase of 100,000 tons over 1955, and shipments of mechanical pulp are likely to reach 410,000 tons, as compared with 385,000 tons last year. Exports of newsprint are expected to rise by about 10 per cent to 220,000 tons, and other kinds of paper and board by 3 per cent to 650,000 tons. Total output of the paper industry is expected to be 100,000 tons more than last year, with export prices 4 per cent over 1955.

Exports of sawn and planed timber, excluding beams, spars, sleepers and boxboards, are likely to reach 85,000 standards this year, a decrease of some 150,000 standards. Since no change in domestic consumption is anticipated, output will decrease to correspond with the drop in exports, which is likely to affect mostly the small and medium-sized mills which accounted for a considerable share in output and exports last year.

The saw milling industry in Southern Sweden is greatly decentralised and there are very few large saw mills. Apart from the large number of small saws used for domestic purposes, both on farms and in towns, there are no less than 2500 saw mills in Götaland ; their density is greatest in the highlands of Småländ. Developments are now tending towards somewhat larger kinds of saw mills, the various circular saw mills being extended to form so-called complete mills, whilst gang saws are being employed where the supply of timber permits.

This is not, however, likely to take place at a quick rate, and the sawing industry in Southern Sweden can be expected to remain a small-scale industry, whilst sawing undertaken by artisans will tend to disappear more and more. Production per man per day per mill is strikingly similar for all kinds of mills. Commenced or planned extensions to the sulphate pulp and wallboard industry can be expected considerably to ease difficulties in the disposal of the South Swedish saw mill waste.

Swiss Car Imports

In the first half of this year, Switzerland imported 67,000 motor vehicles, an increase of 4200 over the corresponding period in 1955. Of the total imports, 19,983 came from Germany (an increase of nearly 2000 over last year). Imports from France increased by one-third, while slight reductions took place in the case of the U.S.A. and Italy.

Automatic Transfer Feed Press Line for Automotive Wheel Production

BY OUR AMERICAN EDITOR

The Clearing Machine Corporation, of Chicago, Illinois, recently designed and built a completely automatic transfer feed press line for the production of automotive wheels, to be installed at the Coventry works of the Dunlop Rim and Wheel Company. The line comprises one 275-ton and three 600-ton, single-action, eccentric gear drive presses equipped with feeding and transfer mechanisms which integrate them into an " automated " unit. The presses can, if desired, be operated independently of each other, and additional presses can be added to the line.

FLEXIBILITY is probably the most important aspect of the automatic transfer feed press line for the production of automotive wheels which has been designed and built for the Dunlop Rim and Wheel Company, of Coventry, by the Clearing Machine Corporation, Division of U.S. Industries, Incorporated, Chicago, Illinois. The photographs accompanying this article were taken when the line of four presses connected by an integral transfer feed mechanism was completely erected at the Clearing works, equipped with dies and thoroughly tested under actual operating conditions. This press line is the result of transfer principles applied to an unusual set of production problems which faced the Dunlop Company. That company, at one time facing a critical labour shortage, was seeking " automated " equipment in order to be able to increase its output without increasing the labour force. It came as an added advantage that production costs could be cut considerably. A second phase of Dunlop's problem involved the size of the production runs and the number of different pieces to be produced on this equipment. Extreme versatility was needed, since the firm manufactures wheels for a large number of the British motor-car manufacturers. None of the quantities approach the tremendous output of the American automotive industry. The firm wanted to be able to change dies quickly after a few days or weeks of production. It needed a transfer mechanism that could be converted quickly from handling one wheel part to handling another. It also wanted to be able to use the equipment for hand-fed operation when the production scheduling called for it. In addition, there was involved a long-range obsolescence problem. Dunlop, as a contract manufacturer, does not have control of the design of the wheels produced. At any time, automotive designs may alter production requirements so completely as to make an ordinary production line unusable. To-day it takes four operations with a reasonably consistent sequence of tonnages to produce a wheel. To-morrow the tonnages may vary or the number of operations may be increased or decreased. The engineers of the Clearing company, therefore, were faced with the problem of developing a piece of automatic equipment which would meet all of these requests for flexibility. Consequently, the Dunlop press line was designed with four individual machines rather than as a single large transfer feed press. Each machine is equipped with an independent feeding mechanism and these feeds are mechanically and hydraulically interlocked to operate as a unit. However, the presses can be operated independently of each other without using the feed. In fact, the line (Fig. 1) can be physically taken apart and put together in different combinations, such as two-press or three-press automatic units. Additional presses may be added to the line in the future, if this becomes necessary.

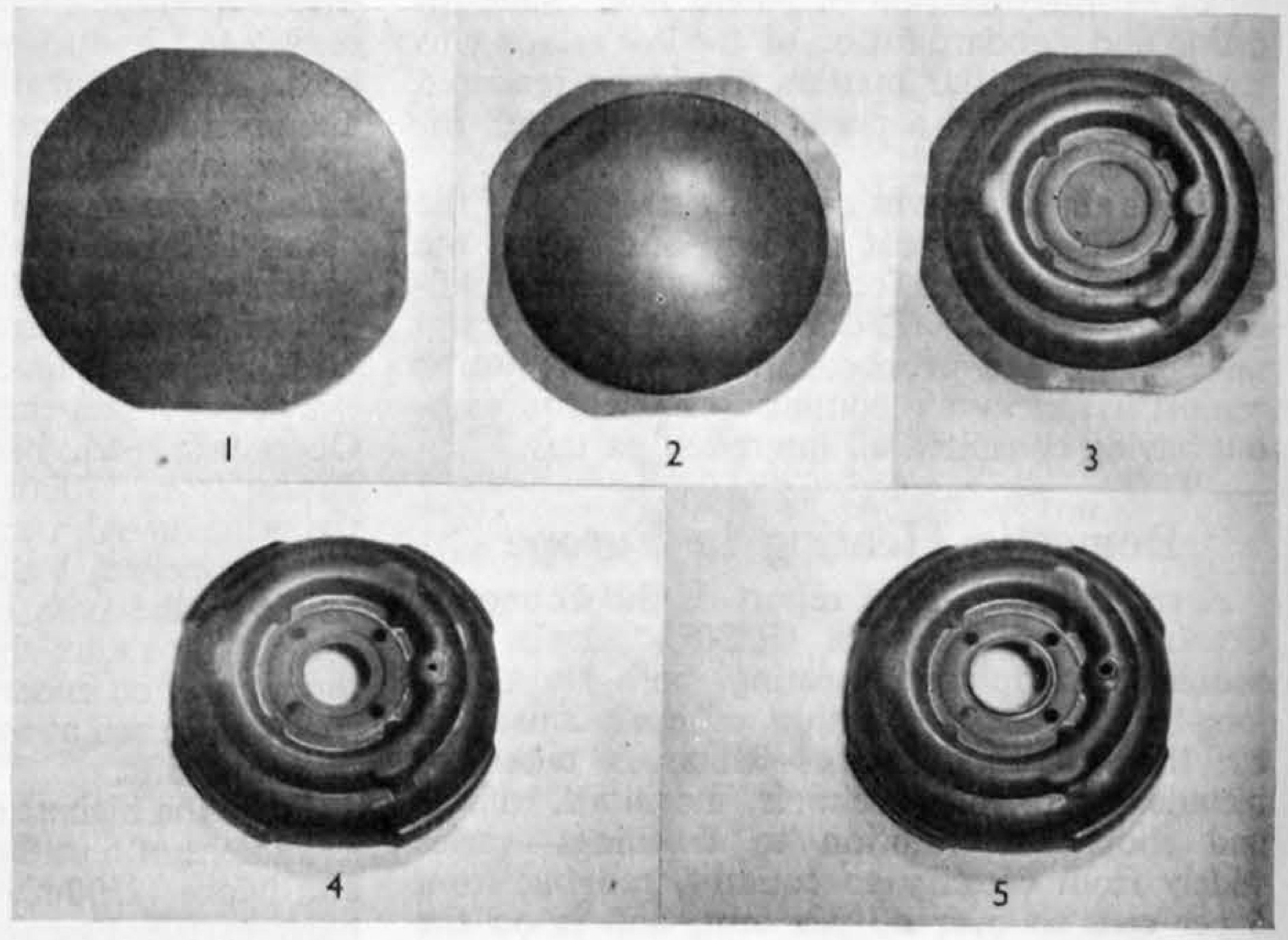


Fig. 2—Sequence of press operations involved in the production of automotive wheels

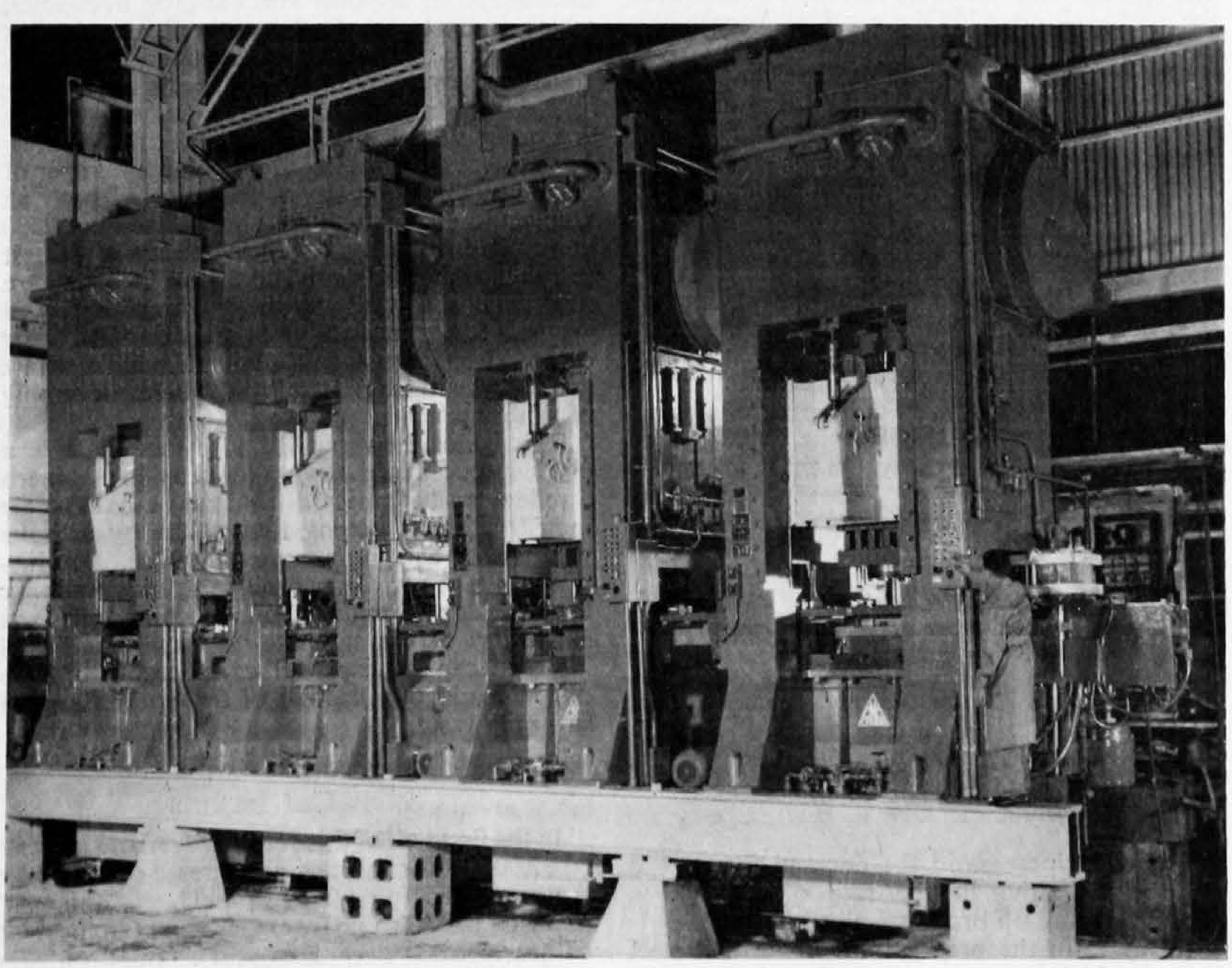


Fig. 1—Automatic transfer feed press line for the production of automotive wheels during performance tests at Chicago

SEQUENCE OF OPERATIONS

The initial design of the press line has been based on the production of wheels in accordance with the sequence illustrated in Fig. 2, except that the initial blanking of the 0·116in thick steel blank is performed in a previous operation. The initial cupping operation takes place on the first, a 275-ton, press. The cupped blank is reverse formed in the second press and is then transferred to the third press, where the edges are cupped and the centre bore and bolt holes are pierced. In the final press in the series the blank is turned upside down for sizing the holes and undercutting the bosses. The last three presses are all of 600-ton capacity with 12in strokes, and are equipped with protective devices which prevent an overload from occurring in the bottom ½in of stroke.

Fig. 3 shows a diagrammatic arrangement of the press line, and the sequence of machine operations.

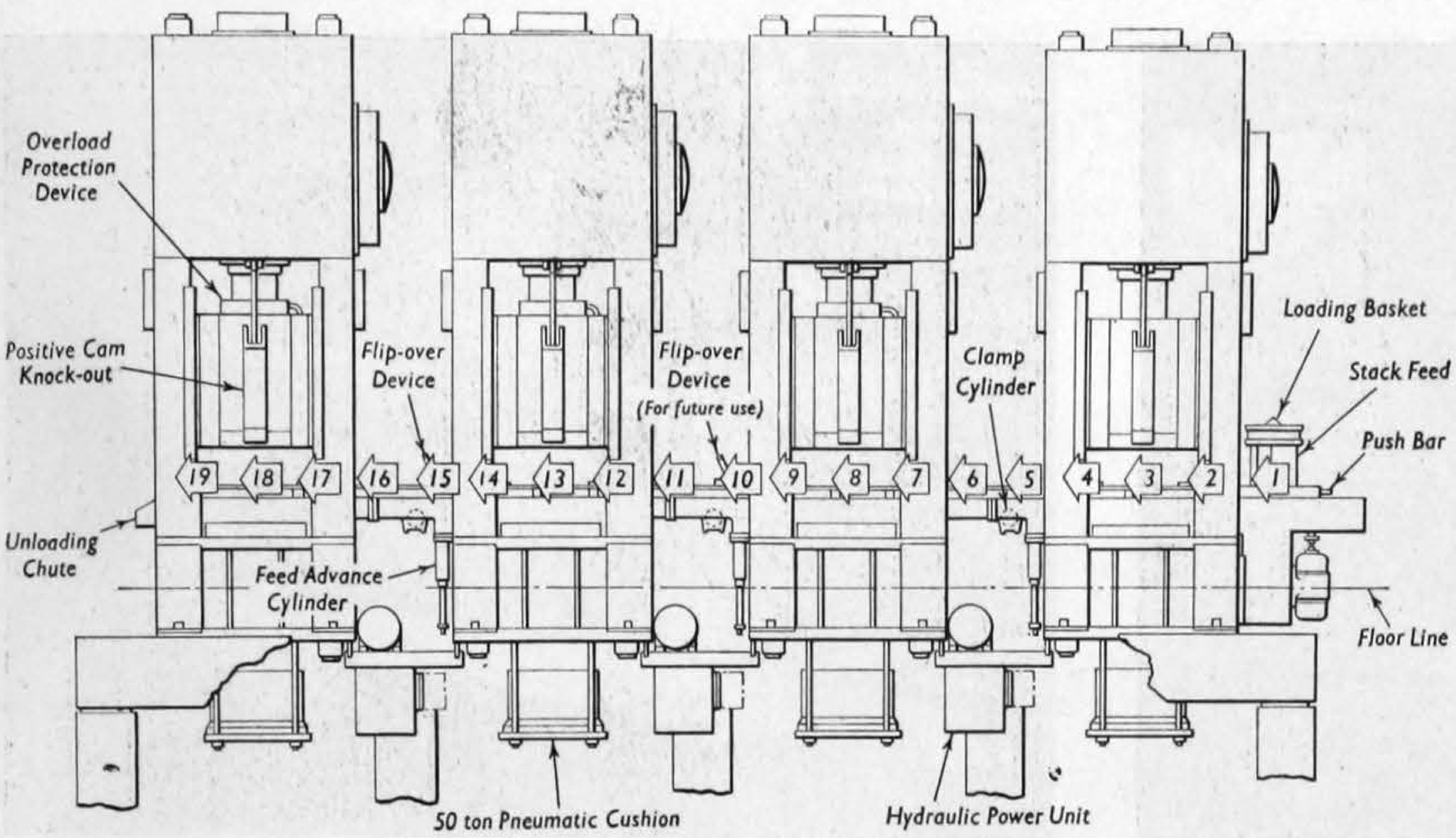
The line comprises four Clearing model " F " presses. All the machines are one-point, single-action units with eccentric gear drives and plunger guiding. They conform to the specifications listed in the Table:

Model of press	" F–1275–42 " ...	" F–1600–42 "
Capacity of press	275 U.S. tons ...	600 U.S. tons
Operating motor	40 h.p. ...	60 h.p.
Stroke of slide...	12in ...	12in
Adjustment of slide... ...	6in ...	6in
No. of strokes per minute	20 ...	20
Capacity of cushion... ...	50 tons ...	50 tons
Stroke of cushion	6in ...	6in
No. of presses in line ...	One ...	Three

Overload protection devices are installed on the three 600-ton presses, and all four presses are equipped with self-contained pneumatic die cushions. All the machines are equipped with positive cam knockouts on the slides, and spring strippers are built into the upper dies. The positive knockout bars serve as a reserve safety factor to avoid picking up a piecepart and creating an overload on the following stroke.

THE STACK FEED

A close-up view of the stack feed mounted at the entry side of the line is reproduced in Fig. 6. During the test operations at Chicago, the blanks employed were 14in square by 0·116in thick steel blanks, with corners rounded off at 14⅞in diameter. The stack feed is designed to permit reloading without interrupting the automatic operation. Special steel baskets are provided which hold an eight-minute supply of blanks, or about 100 pieces. The baskets are bottomless and the blanks rest on cams projecting from the sides. While the line is in operation, a full basket of blanks is placed in position on a pneumatically elevated platform directly above the feed stack. When the previous supply of



1—Blanks are loaded into the stack feed.
2—Double blank safety switch and positive stop.
3—Cupping operation—275 tons.
4—Idle.
5—Idle.
6—Idle.
7—Idle.
8—Reverse forming—500 tons.
9—Idle.
10—Idle (flip-over mechanism provided for future use).
11—Idle.
12—Idle.
13—Edge cupping and piercing—300 tons.
14—Idle.
15—Flip-over device inverts the stamping.
16—Idle.
17—Idle.
18—Bore sizing and undercutting—300 tons.
19—Unloading chute.

Fig. 3—Diagram of general press line arrangement indicating machine operations

blanks has been reduced to six pieces, a limit switch is tripped which lowers the basket on to the stack. The basket cams are pushed aside and the contents of the basket are deposited on top of the stack. The basket is then returned to the top, where it may be removed and replaced with another full one.

The blanks are fed into the transfer mechanism from the bottom of the stack. A push bar, which is operated by a hydraulic cylinder timed electrically with the transfer feed, slides the bottom blank forward to a positive stop at station 2. There is physically enough clearance to advance only one blank at a time from the hopper stack. A limit switch is also provided at station 2 as additional protection against feeding a double blank. Although the subsequent transfer mechanisms are also designed to make it virtually impossible to feed a double blank into a die, the overload mechanisms provide desirable protection against oversize stock or improper slide adjustments when setting up dies in the presses. In addition, protection is provided for the optional manual operation, which always offers a greater possibility of feeding double blanks or faulty placement of a blank.

The Transfer Feed

Each of the presses, except the last one in the line, has a transfer feed mechanism for advancing work in process to the next press. All of the transfer mechanisms act as a unit, yet they actually consist of three individual transfer devices, hydraulically and mechanically interlocked. It is this characteristic which makes it possible to add or take away presses from the original line. The transfer mechanism includes opposed sets of fingers that move inwardly from front and back to grasp or clamp blanks as they rest on runways between the respective presses. They advance the blanks 23in from right to left along the runways to the next station. The fingers automatically release the blanks at the next station, retract and return to their starting positions. There are four idle stations between presses, so that each blank advances through four steps along the runways before reaching the next press. Altogether, there are seventeen sets of transfer fingers which, together with the stack feed pusher rod, move the blanks through nineteen stations in the line.

The through-feeding motion of the transfer mechanism is controlled by a double-acting hydraulic cylinder which operates a gear rack to drive a pair of supporting channels in advance and return directions. A second hydraulic cylinder is suspended from the channels and operates a rack which is connected to a series of gearboxes mounted along the channels at 24in centres. The feed fingers are actuated by small racks extending from the gearboxes. The three photographs reproduced herewith show close-up views of the press operations as well as the transfer feed mechanism. Fig. 4 shows the blank being cupped in the first press. Fig. 5 illustrates edge cupping and piercing being performed in the third press, and the final

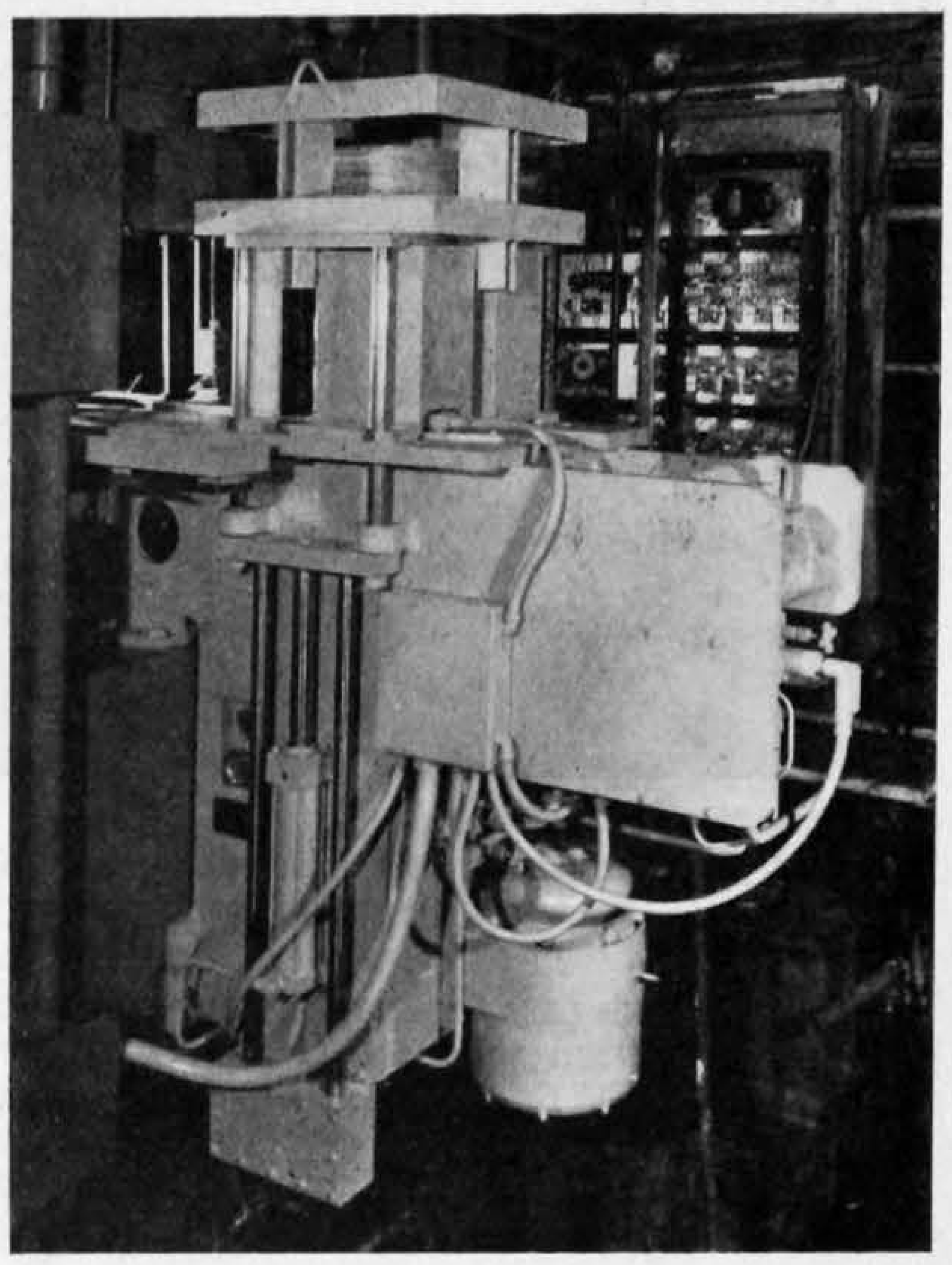


Fig. 6—Stack feed containing wheel blanks mounted at entry side of press line

operation of bore sizing and undercutting on the fourth press is shown in Fig. 7.

Flip-Over Mechanisms

Flip-over mechanisms are provided at certain idle stations between the second and third, and between the third and fourth presses, for turning the blanks upside down. In the present arrangement, the flip-over mechanism between the second and third presses functions only to advance the blanks because it is not necessary to turn the blank over for the next operation. It is provided to accommodate potential design changes in the wheels to be produced.

As illustrated in Fig. 8, each flip-over mechanism has a pair of heavy fingers which are spring-loaded so that they normally move to a vertical position. At their " start " station, the fingers are tripped into a horizontal position and lay flat on the runways ready to move inwardly to clamp blanks resting at respective stations on the runways. As the fingers advance to carry a clamped blank toward the next station they pass off the runways, into a gap, and the springs rotate the fingers 90 deg. into a vertical position.

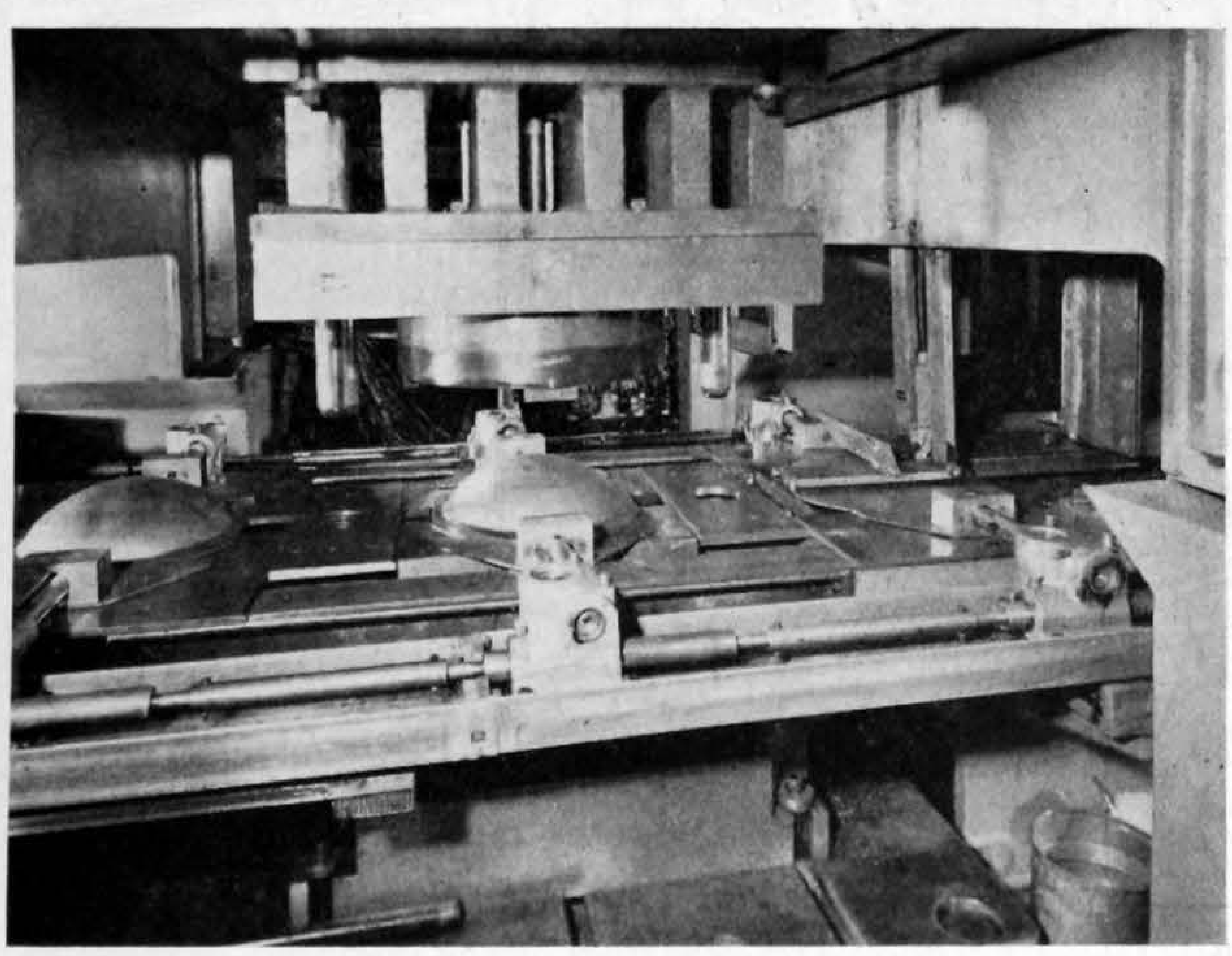


Fig. 4—Cupping of wheel blank in first press

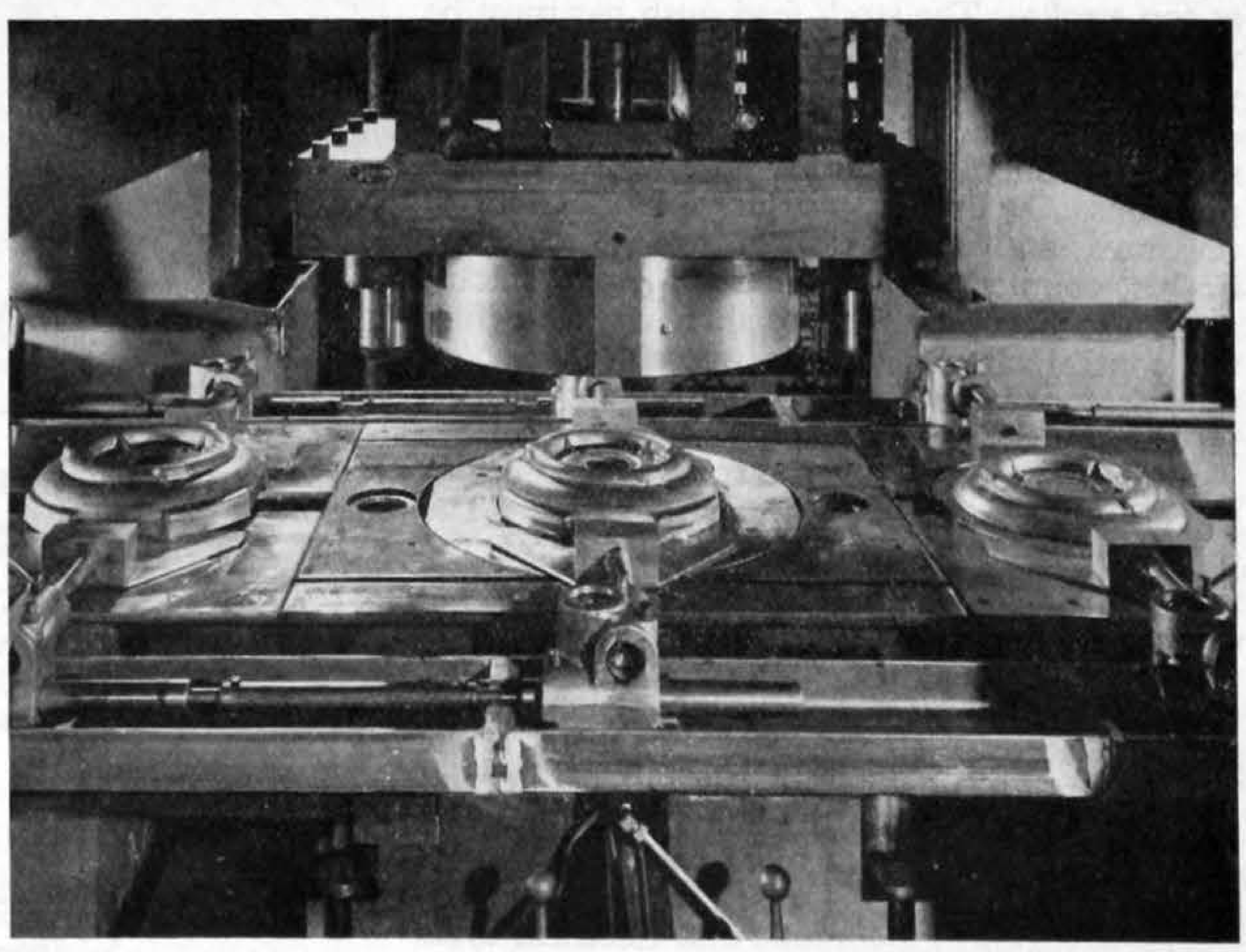


Fig. 5—Edge cupping and piercing of wheel in third press

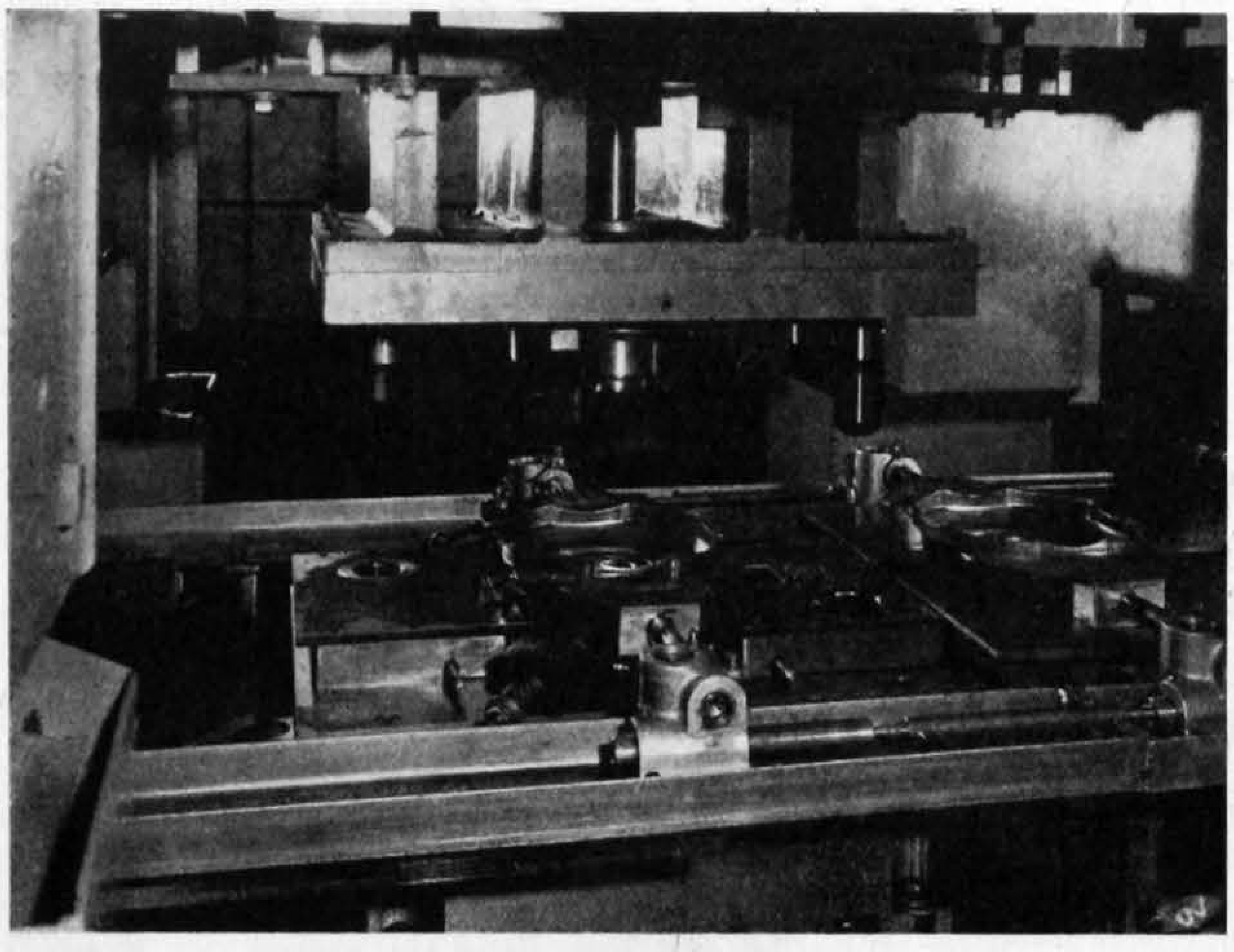


Fig. 7—Bore sizing and undercutting of wheel in reverse position in fourth press

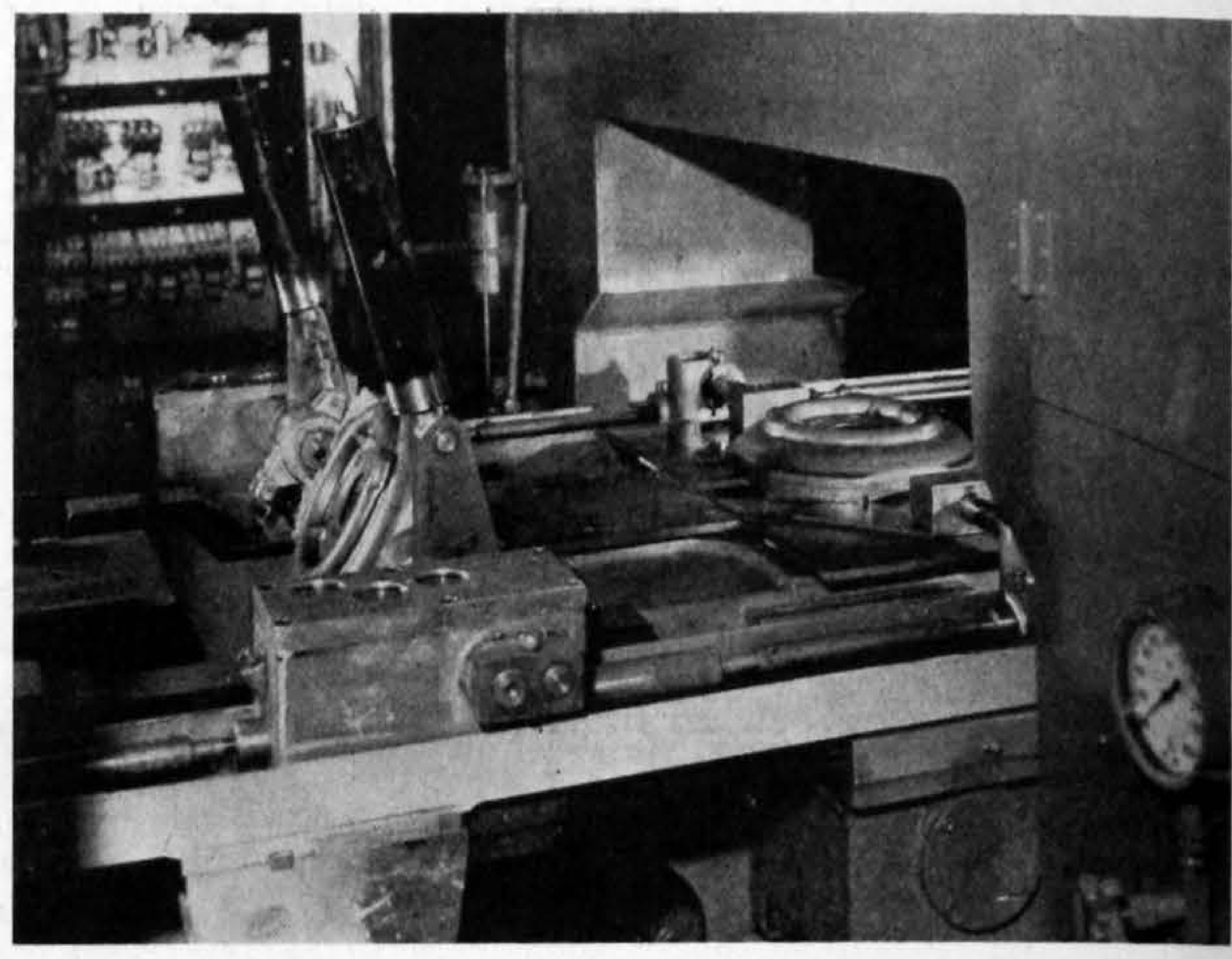


Fig. 8—Flip-over mechanism between third and fourth press shown turning over a wheel

When the fingers pass the gap, as they continue to advance toward the next station, they are tripped another 90 deg., completing the 180 deg. turnover of the blank. On the return stroke the fingers reverse the process and are ready to clamp another blank at their " start " station.

Automatic Cycle Timing

The four presses all cycle at the rate of three seconds per stroke, equivalent to a speed of twenty strokes per minute. The transfer feed mechanism requires slightly more than three

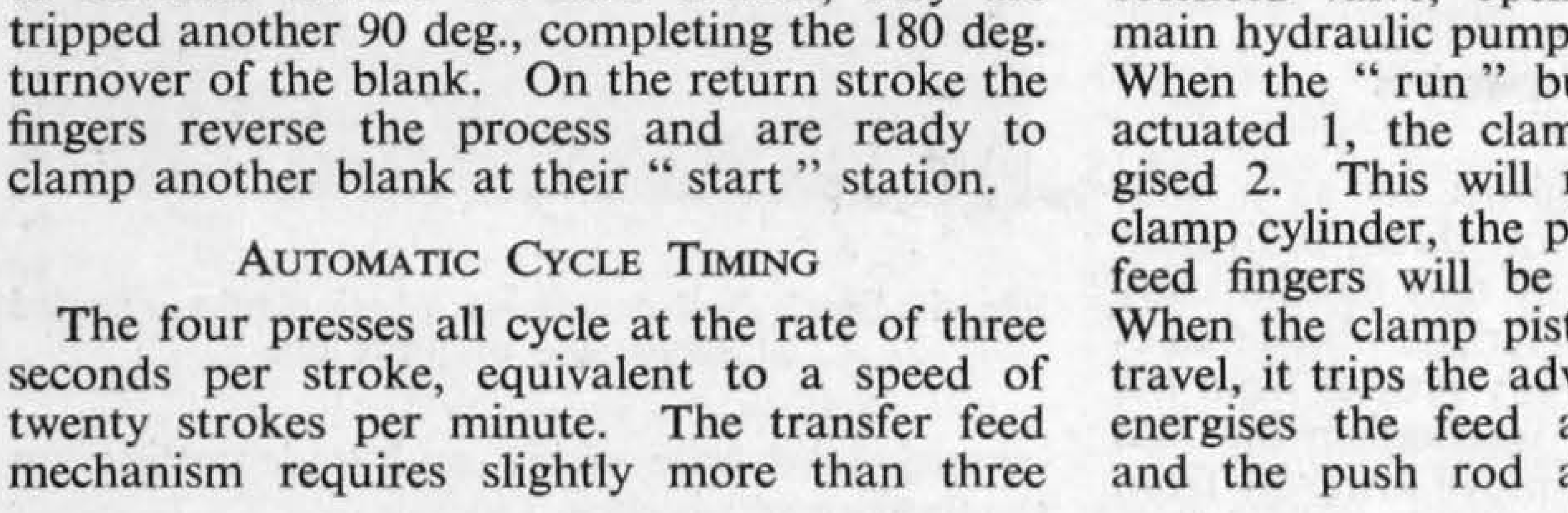


Fig. 9—Timing cycle of automatic transfer feed press line

seconds to cycle. The stack feed push bar completes its operation in about two-and-a-half seconds. These various independent mechanical and hydraulic motions are electrically co-ordinated into a composite automatic cycle which requires five seconds.

Operation must be started with all devices in their home positions. The presses must all be at top stroke. The stack feed push bar must be withdrawn. The transfer feed fingers must be unclamped and returned. If previous automatic operation was halted with the " automatic stop " button, all equipment will be in the home positions. Hydraulic pressures, lubrication oil pressures and air pressures to the clutches, brakes, counterbalance cylinders, and cushions, must also be up to their required values before the control circuits will be operable. Finally, the selector switches on the four presses must be set to automatic operation.

As indicated in Fig. 9, the transfer feed begins to clamp when the presses reach 240 deg. The punches are then high enough to allow the fingers to enter the dies. When clamping is complete, the feed advances. When fully advanced, the fingers unclamp. When fully unclamped, the presses, which have previously stopped at top stroke, start another cycle. The fingers are now completely out of the dies and the feed returns to the home position. The stack feed push bar advances with the transfer feed and immediately returns.

The mechanical, hydraulic and electrical cycle control system is shown diagrammatically in Fig. 10. Setting the selector switch to " automatic " will energise the full line pressure solenoid valve, opening the circuits from the main hydraulic pump to the operating cylinders. When the " run " button on the first press is actuated 1, the clamp solenoid valve is energised 2. This will reverse the circuits to the clamp cylinder, the piston will stroke 3 and the feed fingers will be moved inward to clamp. When the clamp piston reaches the end of its travel, it trips the advance limit switch 4, which energises the feed advance solenoid valve 5 and the push rod advance solenoid valve 6. This similarly strokes the respective cylinders 7 and 8, and both the feed fingers and the push-rod travel forward.

When the push-rod reaches its forward position it trips the push-rod return limit switch 9, which de-energises its own push-rod advance solenoid valve 10 and moves the rod back 11. When it again reaches home position it trips a clamp limit switch 12, which must be closed to permit the transfer feed to start another clamp action.

Meanwhile, when the feed advance cylinder has completed its stroke, it trips the unclamp limit switch 13, which de-energises the clamp solenoid valve 14, causing the unclamping action to occur 15. When this action is complete the press stroke and feed return limit switch 16 is tripped, which energises the four press clutches simultaneously and a stroke is begun 17. This same switch de-energises the feed advance solenoid valve 18, initiating the return stroke 19. When the feed completes its return stroke it trips another clamp limit switch 20, which must be closed to permit another clamp action. When the presses have all reached 240 deg. of cycle their rotary cam limit switches 21 close a circuit in series with the two clamp limit switches mentioned above 12, 20. This energises the clamp solenoid valve 2 and the sequence is repeated. The presses complete a cycle while the feeds are still advancing. They stop at the top stroke 22 and wait for the advance and unclamping actions to be completed.

When the supply of blanks in the hopper feed basket reaches a low level the lower basket limit switch 23 is tripped, which energises the lower basket solenoid valve 24. This exhausts the air

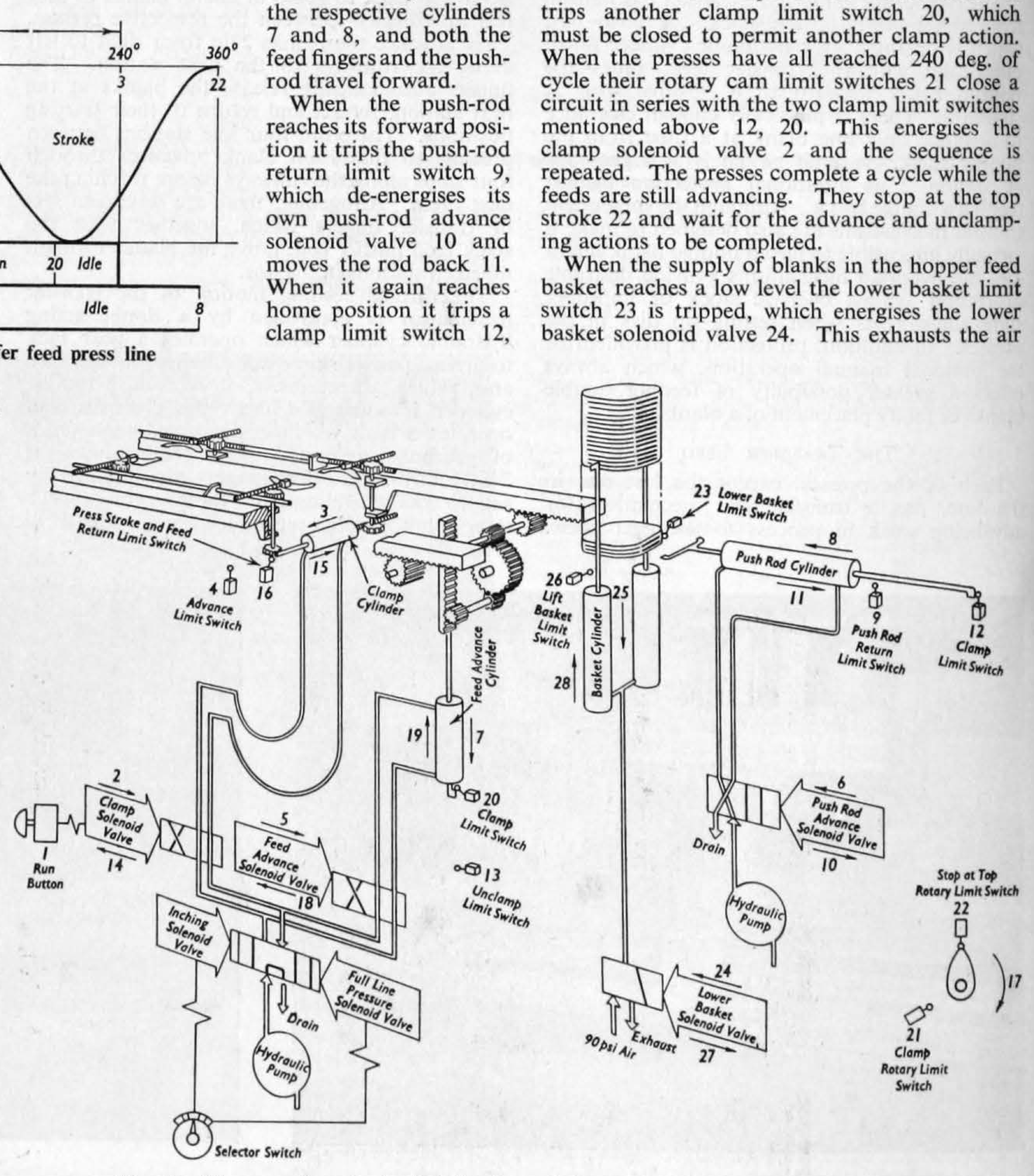


Fig. 10—Diagram of mechanical, hydraulic and electrical press cycle control system

in the basket cylinder, dropping the basket 25. When the blanks have been deposited on the stack the lift basket limit switch 26 is tripped, which de-energises the lower basket solenoid valve 27, and pneumatic pressure raises the basket 28 to the top of the feed. A safety timer is provided in the automatic circuit, and in the event that any action in the sequence should fail to occur, within fifteen seconds, all automatic circuits will be broken. Such protection will prevent an unexpected resumption of operation if the delay was due to a faulty valve or cylinder which eventually crept to its limit switch.

Manual Feeding

The control circuitry of the press installation has been designed to permit individual operation of each press, without operating the feed mechanisms. In such a case the blanks are fed by hand from the front or back of the press. One section of the feed mechanism, which comprises a bar immediately in front of the die area, can be removed easily to leave the entire area open for hand loading operations or for changing dies. With the present die design, however, the dies can be moved into or out of the presses without removing this bar. The four presses are each equipped with a 50-ton self-contained pneumatic die cushion. Limit switches are provided to stop operation of the line if a cushion should fail to rise fully.

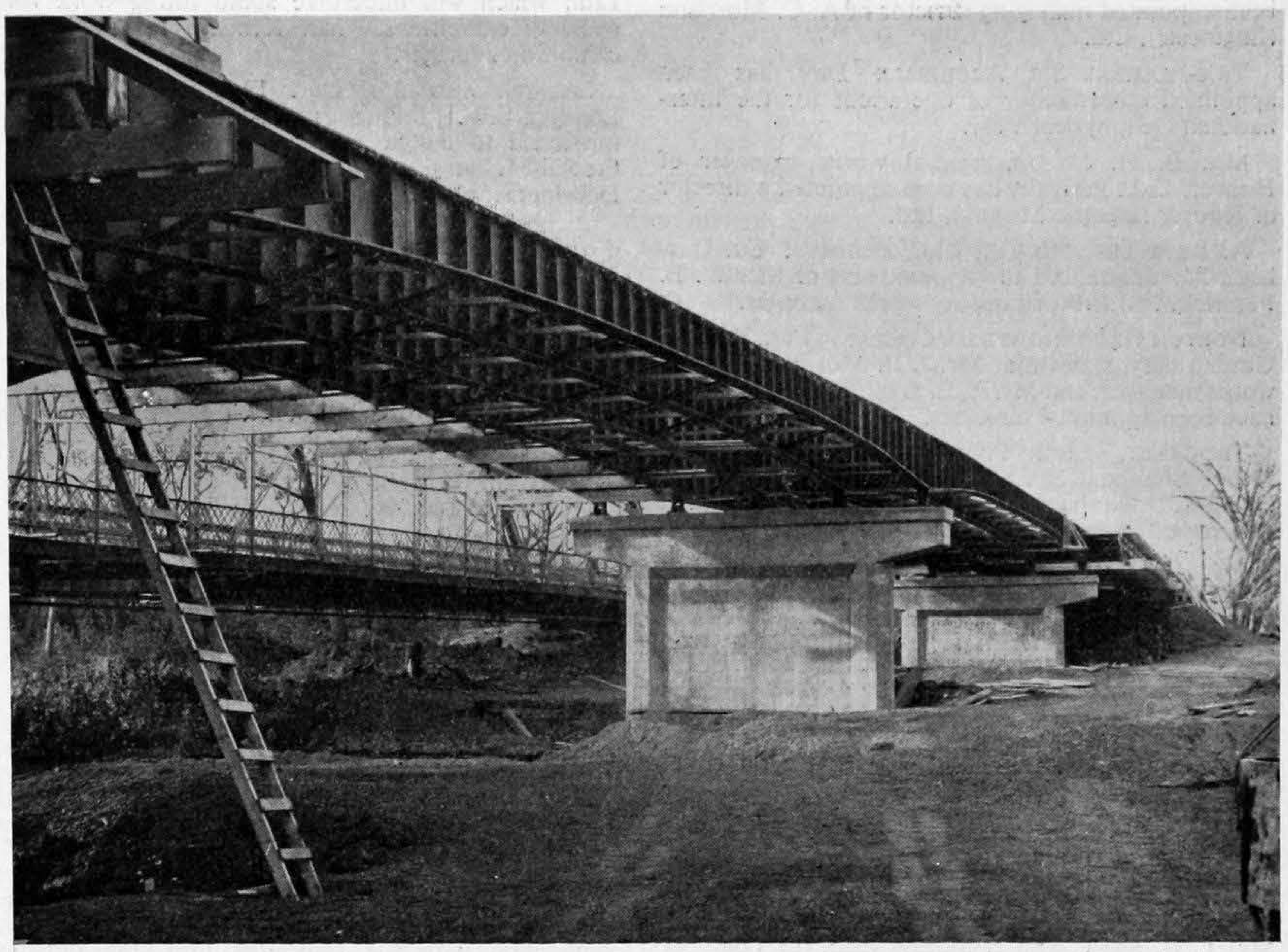
All of the presses are equipped with positive cam knockouts on the slides, and spring strippers are built into the upper dies. The positive knockout bars serve as a reserve safety measure to avoid picking up a blank on the punch and thus creating an overload on the following stroke. Each press may be individually inched without running the feed. The clamping and unclamping actions of each of the three sections of the transfer mechanism may be individually inched from the control panel of its respective press. Furthermore, all three transfer mechanisms may be inched together from the panel at the first press. The advance and return motions of the transfer fingers may also be inched from the control panel at the first press.

The British agent for the Clearing Machine Corporation is the Rockwell Machine Tool Company, Ltd., Welsh Harp, Edgware Road, London, N.W.2.

Stud Welding Application in Reinforced Concrete Construction

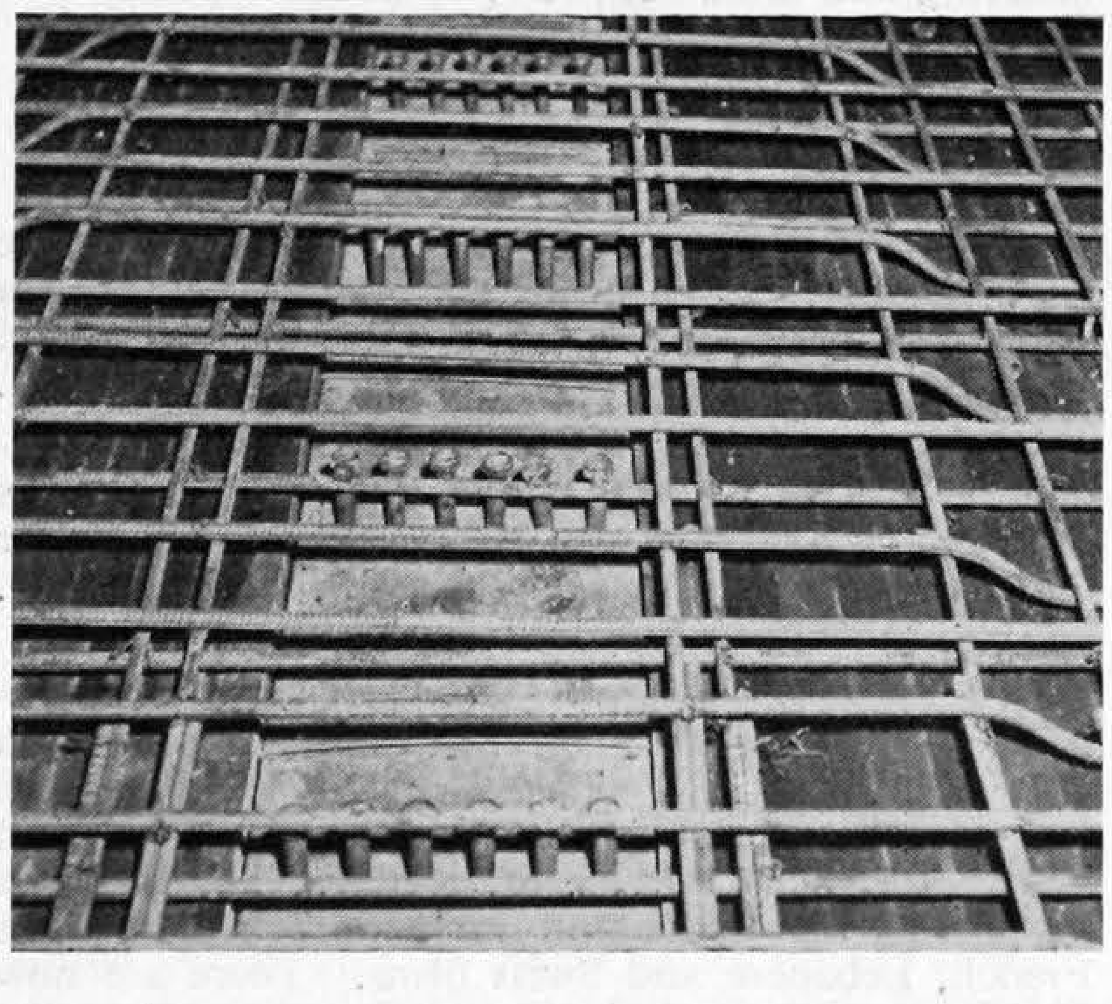
An interesting new application of stud welding in reinforced concrete construction is illustrated in the accompanying photographs, which relate to the recent building at Fort Pierre, South Dakota, of the first American composite steel and concrete bridge using end-welded studs as shear connectors. Less than two years after laboratory tests began, to obtain engineering and design data, this application of the granular flux-filled studs made by the Nelson Stud Welding Division of Gregory Industries, Lorain, Ohio, has already received considerable acceptance among designers, steel fabricators and contractors in the United States. It is being used on other bridges now under construction in South Dakota, Georgia, California and New Jersey. In many instances, the studs are being welded in fabricating shops. Because of the portability of the equipment, however, this welding method also lends itself to field installation. In addition to the bridge work, Nelson stud shear connectors were used in the structural framework of the research laboratory recently erected by the International Business Machines Corporation at Poughkeepsie, New York. Several other composite buildings under construction are employing studs as shear connectors.

The South Dakota Department of Highways designed the composite bridge erected over the Bad River at Fort Pierre, which is illustrated here. One of the main reasons for substituting studs for the steel angles originally specified as shear connectors was the fact that studs permit the concrete to be compacted more satisfactorily, so that interaction between the concrete slab and the steel beams is ensured. Furthermore, the distortion and warping caused by hand welding other shear connectors to bridge girders is eliminated with studs. According to the fabricator of the beams, the stud shear connectors were end welded to the flanges of the girders approximately four times faster than the estimated time that would have been required for hand welding other equivalent shear connectors. This work was done by the Egger-Scudder Company in Sioux Falls, South Dakota. The beams were then transported about 200 miles to the bridge site and were moved into place with only two studs being bent. The fabricator reported that shop time was further reduced because of the elimination of the preliminary tack welding, shearing, grinding and other machining work often required with shear connectors.



Continuous girder highway bridge at Fort Pierre, South Dakota

The Fort Pierre bridge is a continuous girder structure of five girders with shear connectors used in the positive moment sections of each girder. These sections are approximately 68ft long, and the width of the flanges to which the studs are welded is 14in. A total of 8300 granular flux-filled studs, ¾in in diameter and 4in long, with upset heads, were end welded to the girders in lateral rows of six.



Connection of reinforcing spacer bars to studs for support purposes

A Nelson heavy-duty "NS-9" stud welding gun was used, with a 2000A welding set as the power source. With the aid of a special wooden loading frame that minimised handling of studs, the operator welded studs at a rate of five to six a minute. The studs were placed in the loading board with six studs in a row in the frame. The operator then merely pressed the gun over a stud in the frame, placed the end of the gun through a ceramic ferrule which had been positioned on the girder, and pressed the trigger of the gun. The studs were spaced at 2in centres in the rows, and the rows were from 12in to 24in apart. After the beams were in place at the bridge site, wooden falsework was erected and corrugated steel sheets, serving as a mould for the concrete, were laid over the wood between the girders. The sheets were left in place after the concrete was poured. The contractor found that the studs were convenient as aids in spacing the mat for the reinforcing bars. He was able to tack weld the spacer bars on the studs and to fabricate his mat in place obtaining positive support for the spacer bars, as shown in the second illustration.

The engineering and design data which have led to the wide acceptance of the granular flux-filled studs as shear connectors was based upon a comprehensive test programme of stud-welded shear connectors and fatigue tests of bare studs which were carried out in 1954 and 1955. The tests, conducted under the direction of Dr. I. M. Viest, at the University of Illinois, proved that the studs were reliable shear connectors and provided the necessary design and loading data. On the basis of the tests, the stud dimensions recommended as being the most economical for shear connectors were ¾in and ⅞in diameters and a 4in length. For special requirements and where design dictates, studs of additional length up to 8in are now available.

The Biological Effects of Atomic Radiation.—The National Academy of Sciences—National Research Council, Washington, D.C., has published reports on the biological effects of atomic radiation. The main summary reports include sections dealing with the work of the committees on genetics, pathology, meteorology, oceanography and fisheries, agriculture and food supplies and disposal and dispersal of radioactive wastes. In a "popular" version of the report there is, *inter alia*, a brief digest of findings and recommendations. Here it is estimated that the U.S. population is at present exposed, in thirty years, to the following amounts of radiation: background, about four roentgens; X-rays and fluoroscopy, about three roentgens; weapon tests, if continued at the rate of the past five years, 0·1 roentgens. The genetic damage is cumulative and it is recommended that records should be kept of exposure to radiation throughout the lifetime of each individual, that individuals should not receive a total accumulated dose to the reproductive cells, of more than fifty roentgens up to thirty years of age and an additional fifty roentgens up to the age of forty.

Personal and Business

Appointments

MR. S. E. GILLIES has joined the Railway and General Engineering Company, Ltd., as director of sales.

MR. E. H. L. COOPER, M.I.Mech.E., M.I.E.E., has been appointed managing director of A. C. Morrison (Engineers), Ltd.

VICE-ADMIRAL SIR ARCHIBALD DAY has been appointed co-ordinator of operations for the International Geophysical Year.

MR. B. H. DYSON, general works manager of Hoover, Ltd., Perivale, has been appointed a director of Hoover (Electric Motors), Ltd.

A. REYROLLE AND CO., Ltd., Hebburn, Co. Durham, has announced the appointment of Mr. W. B. Fenwick, M.I.E.E., as deputy works manager.

NORTON GRINDING WHEEL COMPANY, Ltd., Welwyn Garden City, states that Mr. J. B. Morrison, general works manager, and Mr. A. E. West, chief accountant, have been appointed directors.

TECALEMIT, Ltd., Plymouth, states that Mr. J. Dee Shapland has been appointed chief chemical engineer. He has also been appointed technical director of Foamite, Ltd., a subsidiary company.

MR. H. FRANKLIN CARPENTER, chairman of the Electricity Authority of Cyprus, and a member of the South Eastern Electricity Board, has been appointed vice-president of the British Electrical Development Association.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., Trafford Park, Manchester, has announced the following appointments :—Mr. E. Tankard, comptroller ; Mr. A. Cooper, accountant ; and Mr. A. G. Evans, assistant accountant.

POWERS-SAMAS ACCOUNTING MACHINES, Ltd., states that Mr. F. W. Hutchings and Colonel F. T. Davies have been appointed to the board. Mr. Hutchings has become director of production in succession to Mr. T. R. Swift, who is retiring from the board at his own request.

MR. C. N. KINGTON, M.I.Mech.E., M.I.E.E., has been appointed chief mechanical and electrical engineer of Husband and Co., consulting engineers. Mr. Kington has been, until recently, group manager of the British Iron and Steel Research Association's laboratories at Sheffield.

THE FAIREY AVIATION COMPANY, Ltd., announces the appointment of Mr. Geoffrey W. Hall as managing director. He succeeds Sir Richard Fairey, who has relinquished that office, but continues as executive chairman. Mr. L. Massey Hilton has relinquished the office of assistant managing director, on medical advice, but remains a director of the company.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., Trafford Park, Manchester, announces the following appointments in the instrument and meter department : Mr. R. M. A. Smith, M.I.E.E., sales manager ; Mr. A. H. Gray, M.I.E.E., assistant chief engineer. Mr. Smith succeeds Mr. R. H. Knott, who will continue to serve the department as an adviser.

CABLE AND WIRLESS, Ltd., announces the appointment of Mr. C. J. V. Lawson, M.I.E.E., as deputy engineer-in-chief, in which capacity he will serve jointly with Mr. W. J. Knight until December 31st, when Mr. Knight is retiring. On April 1st next, Mr. Lawson will become engineer-in-chief in succession to Mr. J. A. Smale, M.I.E.E., who will then be retiring. Mr. Smale joined the company in 1929 and has been engineer-in-chief since 1948.

BABCOCK AND WILCOX, Ltd., Farringdon Street, London, E.C.4, is forming an atomic energy department which will operate from October 2nd. It will function under the direction of the company's chief engineer, Mr. W. F. C. Schaap. Mr. T. B. Webb has been appointed chief engineer and manager of the atomic energy department, and Mr. W. R. Wootton has been appointed assistant manager. Dr. W. B. Carlson is to succeed Mr. Webb as chief research engineer of the company.

Business Announcements

ENFIELD CABLES, Ltd., has moved its London branch to 19-21, Store Street, W.C.1.

CLARKSON (ENGINEERS), Ltd., Nuneaton, has opened a new stockroom and office at 32, Shaftesbury Square, Belfast.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., is building an extension to its works at Attercliffe Common, Sheffield.

THE BRIGHTSIDE HEATING AND ENGINEERING COMPANY, Ltd., has moved its Glasgow branch to 6, Lynedoch Crescent, Charing Cross, Glasgow, C.3 (telephone, Douglas 3971).

BECK AND POLLITZER, Ltd., announces the formation of a subsidiary, Beck and Pollitzer-Overseas Ltd., which will undertake stand fitting work for overseas exhibitions. Mr. Kenneth Priddy is the exhibition manager.

SPENCER AND PARTNERS, 19, Grosvenor Place, London, S.W.1, inform us that they have been commissioned to design and supervise installations for the Sui-Multan gas pipeline of the Pakistan Industrial Development Corporation.

J. C. NEVILLE, Ltd., 34, Priests Bridge, London, S.W.14, states that Andre Duchscher, 68, Rue Ermesinde, Luxembourg, is now responsible for the distribution, in Luxembourg, of " RG " tube cutting and screwing machines and tube bending machines.

Contracts

HEENAN AND FROUDE, Ltd., Worcester, has received an order for aircraft engine test plant amounting to £60,000, which is to be supplied to Air India International, Ltd., Bombay.

THE SHELL PETROLEUM COMPANY has ordered from Metropolitan-Vickers Electrical Company, Ltd., a 4500kW gas turbine-generator set for base load operation on natural gas. It will be installed at Seria, British North Borneo.

DUNCAN STEWART AND CO., Ltd., the Glasgow subsidiary of Davy and United Engineering Company, Ltd., has received a contract from the National Sugar Mills, Ltd., Calcutta, for the supply of a cane sugar factory for producing white sugar. The factory is to crush 600 tons of cane a day and will be erected at Ahmedpur, West Bengal. The value of the contract is over £300,000.

BRITISH INSULATED CALLENDER'S CABLES, Ltd., in conjunction with the associated firm, the Indian Cable Company, Ltd., has received an order for the supply and installation of cables on certain sections of the Eastern Railway, which are to be electrified to improve communications in the central and suburban areas of Calcutta. The contract is worth about £250,000 and it involves 33kV, 11kV and 3·3kV paper insulated power cables and 245 miles of control cable.

WOODALL-DUCKHAM CONSTRUCTION COMPANY, Ltd., 63–77, Brompton Road, London, S.W.3, states that, in connection with the coke oven development project at Corby, it has received orders from Stewarts and Lloyds, Ltd., to the value of about £4,000,000. Work on the first stage of this project will soon begin and will include the building of a complete new coke oven installation embodying about fifty ovens, coal blending and handling plant, by-product plant, and coke screening and distribution plant.

Miscellanea

MR. N. D. RIDSDALE.—We record with regret the death of Mr. N. D. Ridsdale, which occurred on July 17th. He was managing director of Ridsdale and Co., Ltd., and the Bureau of Analysed Samples, Ltd.

TRANSPORTATION CENTRE PUBLIC DAY.—The Commandant of the Transportation Centre, R.E., regrets that, owing to unforeseen circumstances, the public day arranged to be held on Saturday, September 1st, has had to be cancelled.

GOLD COAST ROAD ASSOCIATION.—The International Road Federation has announced that on July 27th the Gold Coast Road Association was formed. The president is Sir Patrick Fitz-Gerald and the secretary Mr. E. M. Ketley. The concerns supporting the association include British, Danish French, Lebanese and Swiss firms. There are now fifty-four road associations operating throughout the world.

PNEUMATIC STOP VALVE.—An electrically controlled stop valve for gas at pressures up to 4000 lb has been produced by the Hymatic Engineering Company, Ltd., Redditch, Worcs. Evolved for aircraft and missile applications, it weighs 1·8 lb and consumes 0·16A at 24V ; at the maximum working pressure it passes 76 lb per minute of air. It is pilot operated and works satisfactorily down to 100 lb per square inch.

LOW-TEMPERATURE TEST CABINET.—The Lightfoot Refrigeration Company, Ltd., announces that it has introduced a low-temperature test cabinet for operating conditions to an extreme of −85 deg. Fah. The cabinet, which can be designed to any individual size specification, has a cooling plant, compound in arrangement and automatic in operation, housed in the base and the refrigerant used is Freon 12.

GLASGOW WATER DEPARTMENT'S ANNUAL REPORT.—The annual report for the year ended May 31, 1956, of the Water Department at Glasgow records a year of some difficulty in maintaining the supply, due to low rainfall. The department's West main works were completed during the year and are due to be inaugurated this autumn. Construction of the Glen Finglas Scheme was also in progress, and most of 2¾ miles of tunnel under Ben A'an was driven.

BRITISH GERMANIUM POWER RECTIFIER INSTALLED IN FRANCE.—A large germanium power rectifier, the first equipment of its kind to be installed on the Continent of Europe (outside the U.K.), is in service at Pechiney's St. Jean-de-Maurienne factory in Savoy. It was made by the British Thomson-Houston Company, Ltd., Rugby, and consists of two 1000kW, 250V, 400A, fan-cooled germanium power rectifiers. They will work in parallel with existing motor converters, supplying direct current to a battery of electrolytic cells for the production of aluminium.

BIGGEST AIRLINER.—On July 31st the first flight took place of a Bristol " Britannia " 301, prototype of the 300 and 310 series aircraft. These aircraft have a fuselage 10ft 3in longer than that of the " Britannia " 100, and have " Proteus " 755 engines of 4120 e.h.p. The 310 long-range version will be able to carry ninety-three passengers across the Atlantic non-stop throughout the year, and the 320 variant will be economical on stages as short as 200 miles. It is expected that, when they enter service, the " Britannia " 300s will be the largest air liners in the world.

LARGE BLAST-FURNACE HEARTH.—We are informed that when its relining is completed one of the blast-furnaces at the works of Appleby-Frodingham Steel Company, Scunthorpe, will have a hearth diameter of 31ft—larger than that of any other known blast-furnace. When this furnace was first commissioned in March, 1954, its hearth diameter was 27ft, bosh diameter 30ft 3in, throat diameter 22ft, and height 100ft, giving a working volume of 42,372 cubic feet. With the enlarged hearth the bosh diameter will be 34ft 3in and the throat diameter 23ft 9in, the effective volume being 51,615 cubic feet.

TRAINING FOR SUPERVISORS.—The Ministry of Labour and National Service has just issued a new booklet entitled " Training for Supervisors," which forms the fourth publication in what is known as its " True Story " series based upon the report of the Committee of Inquiry on the Training of Supervisors. The book records verbatim the views expressed on the report and its conclusions by five people from different spheres of industrial life, under the chairmanship of an officer of the Ministry. The five people included a training officer, a general manager, a director, a production superintendent, and a shop foreman.

PLASTIC FOR ENGINEERING APPLICATIONS.—A plastic material known as " Waltolon " is being made in a number of standard grades by Thos. and John Walton, Ltd., Stoneswood, Todmorden, to cover a wide field of applications in the engineering industry. The material is stated to be impermeable to natural greases and oils, petrol, alcohol, ozone and oxygen, and it can be used in combination with metals, rubber and textile fabrics. The nine standard grades give a useful range of physical and mechanical properties to suit mining engineering requirements in gears, bearing seats, clutch laminations, jointings, friction wheels, diaphragms, bellows, shock-absorbing suspensions, &c.

HIGH-TEMPERATURE ALLOY.—Additional details of Nimonic 100, latest of the creep-resisting Wiggin nickel alloys, which was referred to on page 305 of our issue of August 26, 1955, are now available. The composition of the alloy is : Carbon, 0·3 per cent maximum ; titanium, 1 to 2 per cent ; chromium, 10 to 12 per cent ; aluminium, 4 to 6 per cent ; molybdenum, 4·5 to 5·5 per cent ; silicon, 0·5 per cent maximum ; iron, 2 per cent maximum ; cobalt, 18 to 22 per cent ; nickel to 100 per cent. The melting range is 1310 deg. to 1380 deg. Cent., and at 1000 deg. Cent. the tensile properties are ; 0·1 per cent proof stress, 5·5 tons per square inch ; maximum stress, 8 tons per square inch ; reduction of area, 42 per cent ; modulus, 18×10^6 lb per square inch. At 980 deg. Cent., creep failure takes place in fifty hours under 5·2 tons per square inch ; 100 hours under 4·2 tons per square inch ; 300 hours under 2·8 tons per square inch, and 1000 hours under 1·3 tons per square inch. Further details are available from Henry Wiggin and Co., Ltd., Wiggin Street Birmingham, 16.

British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

MINING ENGINEERING

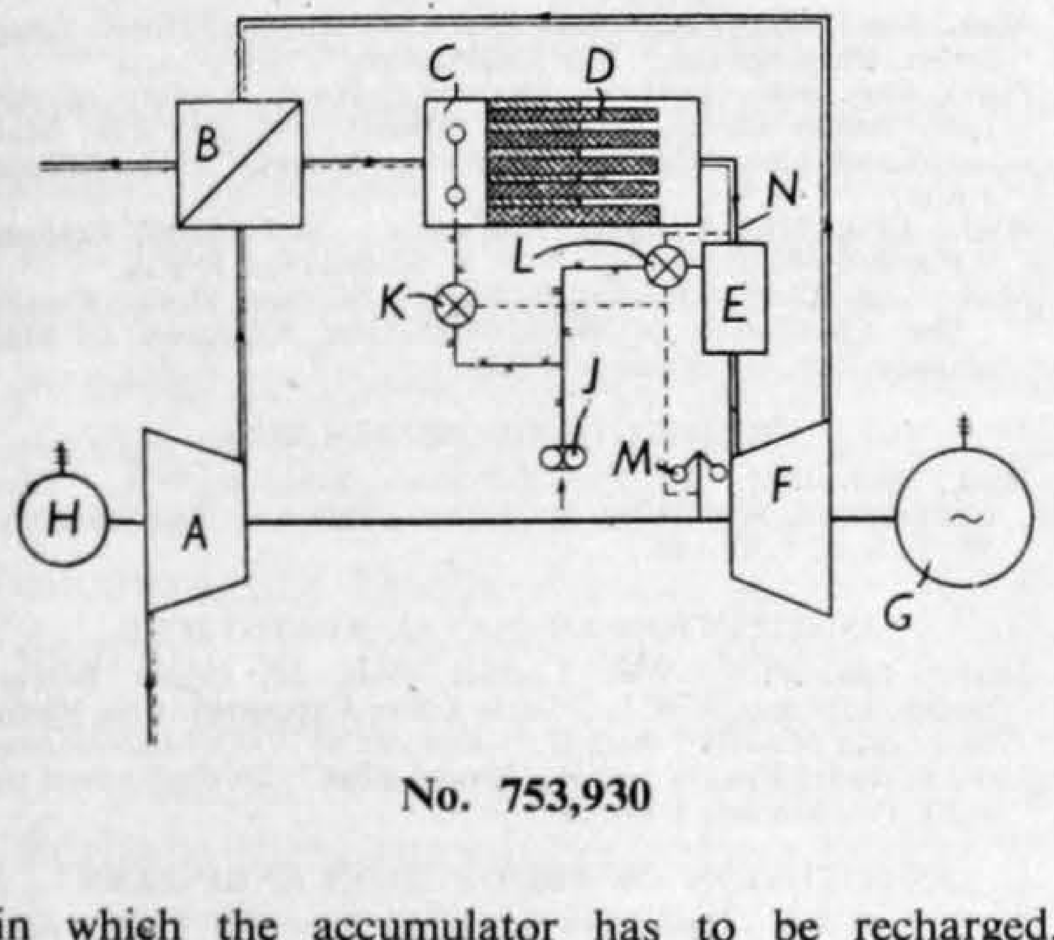
753,186. August 20, 1954.—METHOD OF SUPPRESSING EXPLOSIONS IN MINE-WORKINGS, Ernst August Christian Schlochow, Duisburgerstrasse 267, Duisburg-Hamborn, Germany, and Josef Rohe, Hofscherstrasse 260, Duisburg-Beeckerwerth, Germany.

The invention is concerned with a method of suppressing explosions caused by coal and rock dust in mine-workings, and is complementary to the method forming the subject of the co-pending application (Specification No. 713,975). That specification disclosed a method of suppressing coal and rock dust explosions in mine-workings, in which the dust is made innocuous by means of a damped salt which first causes the dust to settle and then fixes it, thereby depriving it of its explosive properties. The salt is spread in a dry state to a sufficient thickness over the floor of the mine gallery and suitably and repeatedly damped. This earlier method is suitable for use in situations where the relative humidity of the atmosphere in the mine does not exceed 75 per cent. Above this figure the salt becomes hygroscopic and no longer acts as a binder of the dust. According to the present invention—which is applicable to situations where the relative humidity exceeds 75 per cent—the periodic damping of salt is dispensed with and the salt absorbs sufficient moisture from the air. A non-ionic wetting agent is added to overcome the surface tension of the resulting liquid so that the dust can penetrate into it. Moreover, a gel is added to prevent excessive moisture running down the walls and roofs. By the term "non-ionic" is meant wetting agents which are built up organically and do not decompose when in contact with a salt solution but break up the surface tension. The proportion of the wetting agent in the salt solution is, for example, 1 per cent by weight. As an example of a proportion of suitable gel there may be added 25 per cent by weight of $Mg(OH)_2$.—*July* 18, 1956.

GAS TURBINES

753,930. May 28, 1954.—REGENERATOR ARRANGEMENTS, Siemens-Schuckertwerke Aktiengesellschaft, Berlin and Erlangen, Germany.

This invention relates to a gas turbine plant and regenerator. Referring to the drawing, the working air is compressed by a compressor *A* and, after flowing in a continuous stream through a heat exchanger *B*, reaches a heat accumulator comprising a combustion chamber *C* and the accumulator mass *D*. *E* is an additional regulating combustion chamber and *F* is the turbine which drives an electric generator *G* and which also drives the compressor *A*. Coupled to the common shaft is a starter motor *H*. Assuming that the operating state has been reached



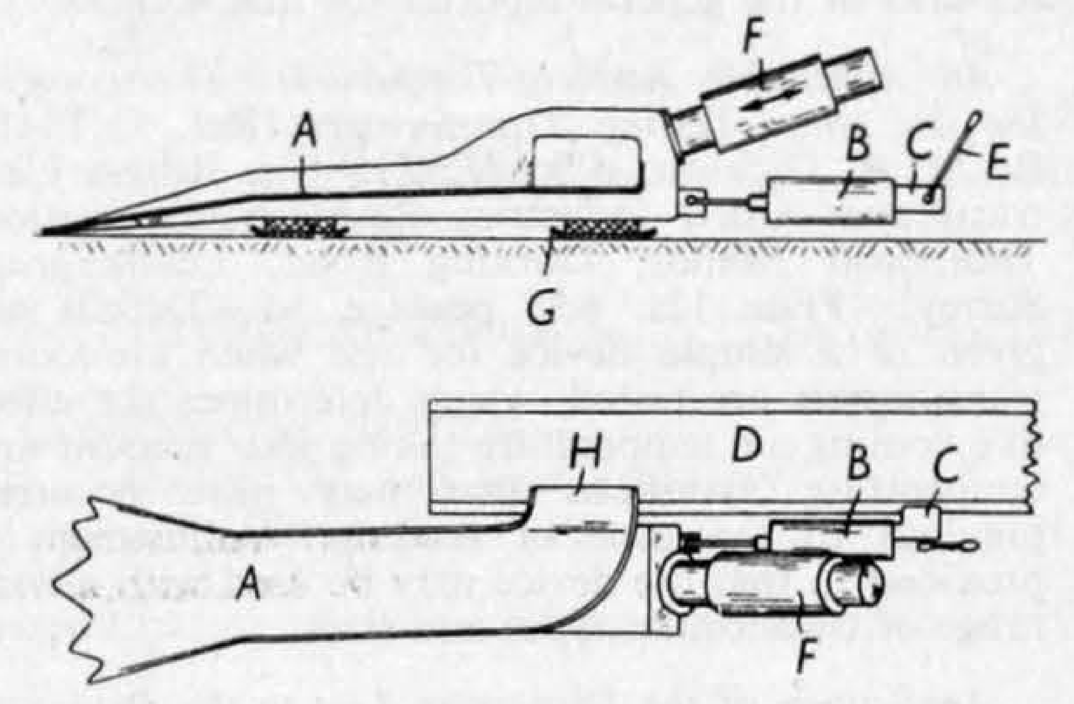
No. 753,930

in which the accumulator has to be recharged, this recharging is effected by combustion of fuel in the chamber *C*. The fuel is delivered by a pump *J* and admitted into the combustion chamber through a pilot valve *K*. As long as the pilot valve allows the fuel to pass through, the heat accumulator *D* receives a mixture of combustion gases and air. When the fuel supply is cut off, only fresh air flows through the accumulator mass. The duration of the combustion period is adjusted by the speed regulator according to the load on the turbine. The combustion chamber *E* also serves for regulating purposes, more particularly for accelerating the regulating process. The quantity of fuel to be supplied to the chamber *E* is regulated by a valve *L* controlled from the governor *M* of the turbine *F* and also by a temperature sensitive member at *N*.—*August* 1, 1956.

CONTRACTORS' MACHINERY

753,971. September 22, 1954.—RECIPROCATORY SHOVEL LOADERS,—Gewerkschaft Eisenhutte Westfalia, Wethmar, near Lünen, Westphalia, Germany.

The invention relates to shovel loaders of the reciprocatory type. The invention results from the discovery that, with a frequency of oscillation of approximately 1000 per minute and an amplitude of approximately 10mm, a movement of approximately 2mm in a direction perpendicular to the loader is quite sufficient to effect an adequately rapid conveyance of the material to be loaded. As will be seen from the drawing, the shovel *A* is forced against the won minerals by a compressed air cylinder *B*. The compressed air cylinder is provided with a clamp *C*



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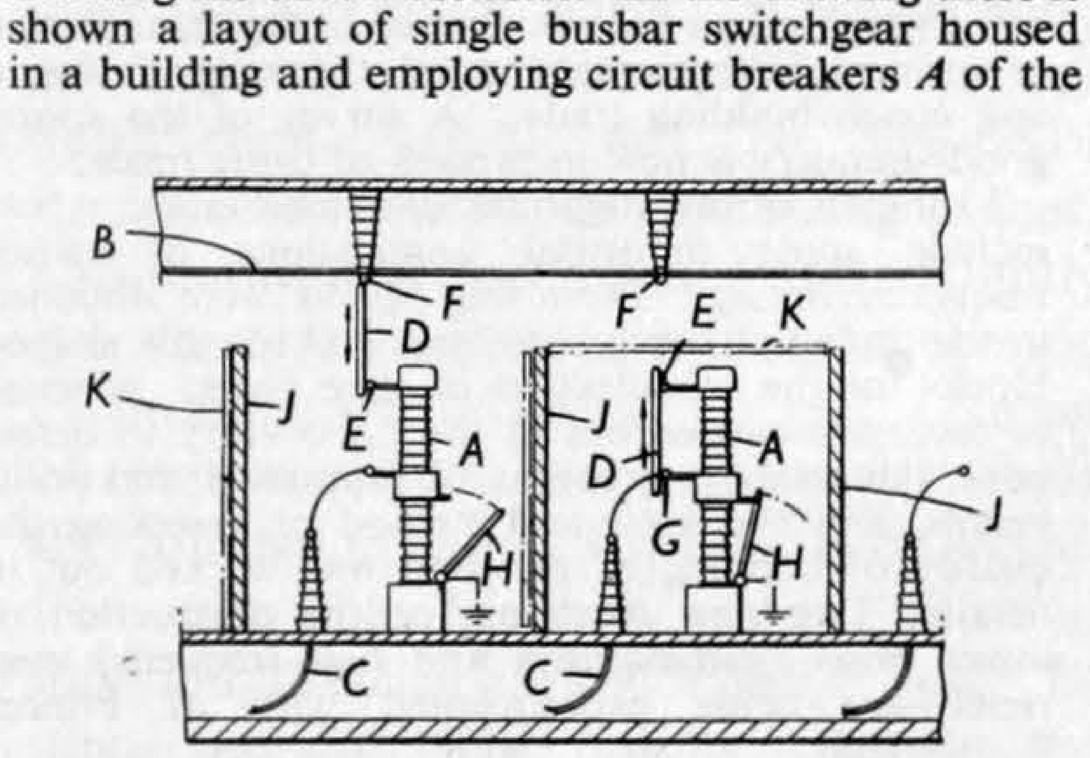
by means of which it can be clamped to a conveyor *D* by a lever *E*. The shovel *A* is connected to a generator *F* which produces rectilinear oscillations of the shovel. The generator is mounted obliquely with respect to the shovel. The oblique position of the axis of the generator is such that the direction of oscillation forms an acute angle with the gallery floor on which the shovel slides. The shovel is slidably supported on the floor by means of runners *G*. The loading shovel is pushed by the oscillatory impulses in the direction towards the minerals and by the pressure cylinder. By means of the resultant movements of the shovel out of the horizontal and vertical directions the minerals are caused to travel towards the delivery end *H* of the shovel and are supplied to the conveyor.—*August* 1, 1956.

ELECTRICAL ENGINEERING

751,851. February 25, 1953.—HIGH-VOLTAGE ELECTRIC SWITCHGEAR, A. Reyrolle and Co., Ltd., Hebburn. (*Inventor: John Christie.*)

The invention relates to high-voltage indoor switchgear employing fixed live-tank circuit breakers, and is concerned principally with the means for isolating the circuit breakers. In the drawing there is shown a layout of single busbar switchgear housed in a building and employing circuit breakers *A* of the

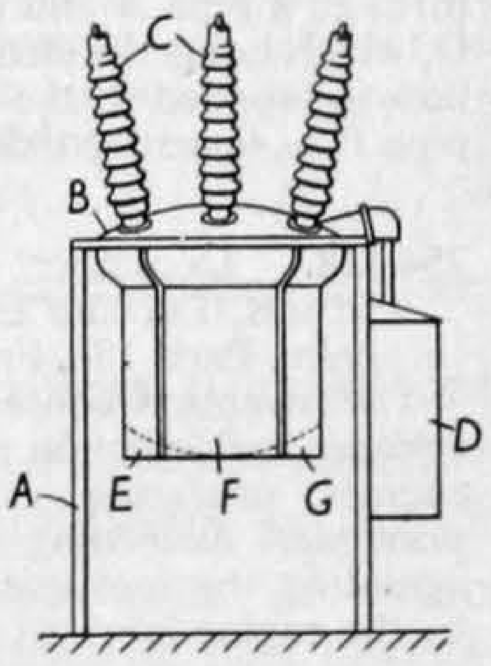


No. 751,851

air-blast or small oil volume type between the busbar *B* and the ends of the feeder cables. The feeders are brought in as cables *C* rather than as overhead lines on account of the limited space in town sites. Each circuit breaker is provided with a sequentially operated isolating switch having a vertical, vertically movable switch arm *D* which in its upper, closed position, as shown in the first bay, extends between the upper terminal *E* of the circuit breaker and the terminal *F* of the busbar, and in its lower and open position as shown in the second bay, extends across and short circuits the two terminals *E* and *G* of the circuit breaker. An earthing switch *H* is provided for each circuit breaker and when closed, as shown in the second bay, it connects to earth the lower terminal *G* of the circuit breaker. Each circuit breaker *A* is installed in its own open-topped compartment separated by permanent walls *J* from neighbouring compartments, but no permanent barrier or roof is provided between the circuit breakers and the overhead busbar *B*. Instead, a movable earthed metal screen or shutter *K* is provided for each bay, which can be closed across the top of the circuit breaker compartment between the circuit breaker and the busbar, as shown in the second bay, being interposed through the gap provided by opening the isolating switch *D*. Thus the circuit breaker can be adequately isolated for maintenance purposes within a completely closed compartment containing no live metal, the two contacts of the circuit breaker being short circuited by the switch *D* and connected to earth by the earthing switch *H*. In this way the cable is also earthed. When the circuit breaker is in normal service, the earthed metal screen *K* is disposed in its storage position alongside one of the compartment walls *J*, as shown in the first bay. Several modified designs are shown in the specification.—*July* 4, 1956.

753,034. February 26, 1954.—MULTI-POLE OIL CIRCUIT BREAKERS, The English Electric Company, Ltd., Queens House, 28, Kingsway, London, W.C.2. (*Inventor: Archibald Allan.*)

The invention is concerned with an improved form of oil circuit breaker in which the poles can be mounted on a common plate, but in which each pole has its own tank. With reference to the drawing a frame mounted oil circuit breaker comprises a frame structure *A*, a dome-shaped top plate *B*, bushings *C* mounted on the top plate, an operating mechanism *D*, and three tanks *E*, *F* and *G* containing the terminals of the three poles of the breaker. When fitted together the three tanks have a combined periphery which is circular. The bottoms of the tanks are formed from a single dishing so that the composite contour is of the curved form shown dotted. Lifting gear is provided by means of which any of the three tanks may be lifted or lowered inedependently of the other two. The tanks are earthed so that the sections of the tanks between the poles serve as interpole barriers. The top plate *B* may be fitted with earthed metal interpole barriers corresponding to and co-operating with the edges of the tank sections so that complete separation of the poles is provided within the whole interrupting enclosure.—*July* 18, 1956.



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METALLURGY

754,557. March 25, 1954.—AN IRON ALLOY AND ARTICLES FOR HIGH TEMPERATURE USES, The Timken Roller Bearing Company, Canton, Ohio. U.S.A.

The invention relates to articles operated at elevated temperatures, especially metallic parts which are highly stressed or are exposed to oxidation at high temperatures, and to steels for making such articles. The invention describes an iron alloy consisting of 10 to 20 per cent of chromium, 5 to 10 per cent of manganese, 4 to 8 per cent of molybdenum, 10 to less than 20 per cent of nickel, between 0·05 and 0·1 per cent of carbon, and the remainder iron together with impurities. As quenched, the room temperature tensile strength of the alloy was about 107,000 lb per square inch and the elongation about 45 per cent. Stretching of the bars up to 30 per cent elongation followed by tempering four hours at 1300 deg. Fah. resulted in progressive increase in tensile strength to about 135,000 lb per square inch, with the elongation decreasing to about 24 per cent; tempering fifteen hours at 1300 deg. Fah. produced approximately the same results. The yield strength (0·2 per cent offset) increased from about 57,000 lb per square inch in the as-quenched condition to 103,000 lb per square inch at 30 per cent elongation by cold stretching. The results demonstrate the good room temperature ductility of these new steels. Standard specimens for rupture strength tests were prepared also from the hot-rolled bars, solution treated at 2150 deg. Fah. and quenched. These possess good rupture strength under stress at high temperatures. Modified compositions of the alloy are also mentioned in the specification.—*August* 8, 1956.

INTERNAL COMBUSTION ENGINES

754,223. February 3, 1954.—FUEL SUPPLY MEANS FOR INJECTION PUMPS, Klockner-Humboldt-Deutz Aktiengesellschaft, Deutz-Mulheimerstrasse 149/155, Köln-Deutz, Germany.

The fuel supply element shown in the left-hand view of the drawing comprises a block *A* having an inlet opening *B* and an outlet *C* for the fuel to be delivered to the fuel injection pump. The openings *B* and *C* are connected by a bore *D* adjoining the opening *B* and a helical pipeline *E*. The overflow fuel fed by the injection pump passes through the opening *F* into the block and flows from it through a duct *G* leading obliquely into the bore *D* to the pipeline *E*. Liquid is intermittently sucked from the

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CONTENTS

A BY-WAY IN ENGINEERING DESIGN

Engineering development has by-ways as well as highways of advance. Most of the products of engineers have been made and have been continuously improved over so many years that the problems set in design and manufacture are clear-cut, the advantages and disadvantages of differing arrangements are well-established and there is little room for innovation except in, often rather abstruse, detail. Those working upon such products are driving along the highways of engineering. The line of further advance is clearly established. Achievement waits only upon the coming of improved materials, upon the completion of detailed researches which will make possible greater precision in design, or upon the growth of demand for bigger machines or machines designed to meet more onerous conditions. The sight lines are long, the way relatively smooth, and there are no cross-roads or sudden partings of the ways. By contrast, the by-ways of engineering design are far less important. The economy of the country as a whole would not be noticeably affected were many of them never explored. But, like an English country lane, they are full of surprises and unpredictable hazards. The object to be achieved may be distinct enough ; but none of the signposts mark at all clearly the right direction of travel. There come frequent and confusing partings of the way. What seems the more attractive road leads only to a dead end ; whereas what seems a side-alley turns out to be the straighter route. Like Alice in the garden, an explorer may find the quickest way to reach a given spot is to start off in precisely the opposite direction!

The work of engineers in just such a fascinating by-way is recorded in the Annual Report of the Institute of Seaweed Research for 1955, which in a valedictory way, reviews the work done over the past ten years. Seaweed can be used for the production of animal feeding stuffs and fertilisers, has medical uses and contains certain raw materials for the chemical industry. A great deal of work has had to be done upon the investigation of its qualities and of methods of processing it and in discovering where and in what quantity it grows. Those have been by-ways for chemists, biologists and botanists. The engineering by-way has lain in the devising of means of harvesting the weed in quantity and at economic cost. The problem was to design a mechanism which could cut or pull the weed from the bottom at depths down to five fathoms from a rough sea-bed and deliver it into a boat at an economical expenditure of power ; and the mechanism had to be so sturdy and reliable that it would require little maintenance and be operable by ordinary fisher-folk. It is difficult enough, as agricultural engineers well know, to devise harvesting machinery that will operate satisfactorily on land. But the Seaweed Research team had to devise machinery that could operate reliably from a boat small enough to run close inshore in seas off the Scottish coasts which are seldom smooth. It had to start from scratch with no history of previous development to act as a guide. The progress made has been recorded from time to time in our pages in articles contributed by the men actually doing the work. Primarily, development has proceeded along the classic lines of trial and error. But once the dimensions of the problem had been determined in this way the resources of more academic research were drawn upon to investigate more exactly how grapnels or cutters operated or how cut weed was entrained into a suction pipe. It has been a fascinating story and a further article will shortly be published in our pages, bringing it right up to date.

So successful has the research team proved itself that it has "worked itself out of its job." On the advice of the Advisory Council on Scientific Policy, the Government has now decided that further technological studies "would more properly be undertaken by industrial concerns." Since June of this year the work of the Institute has been restricted to the support of algal studies at universities, the provision of information, and the fostering of seaweed utilisation by crofting communities. So has ended an exploration of a by-way of engineering design ; hence the valedictory nature of the year's report on the work of the Institute. But now the sign-posts have been erected, now that the pioneering work has been done, it is very much to be hoped that one or more commercial firms will step