

THE ENGINEER

FEBRUARY 25, 1955

Iron and Steel Development Programme

THE Iron and Steel Board has presented to the Minister of Supply a special report dealing with the development of the British iron and steel industry between 1953 and 1958. The report embodies the second post-war development programme of the iron and steel industry and estimates that by 1958 the annual demand for crude steel will have reached 22,500,000 tons. The development plans of the industry, with modifications which have been introduced since 1952 when the programme was first outlined, envisage that steel production will increase by 1958 to the level of the estimated demand. Accordingly, the report says that the total cost of modernisation and expansion schemes planned by the industry and approved by the Iron and Steel Board is estimated at just over £250 million. Major schemes are already in progress at twenty-five iron and steel works in Great Britain. With further schemes which are likely to be approved in the next few years, but which will mainly affect production after 1958, capital expenditure over the five-year period 1953-1958 is likely to exceed £300 million. The report says that pig iron output is expected to increase to just over 15,000,000 tons a year by 1958. Requirements of coal, home and imported ore, shipping and internal transport have all been reviewed in relation to the increased iron and steel production foreshadowed in the report. The Iron and Steel Board says that work has now begun on estimates of steel demand in the 1960's, and in the light of these estimates, attention will be directed to the longer term problems facing the industry. These problems include the extent to which it may be desirable to expand further the home ore production, and also the further modernisation of the pig iron industry, particularly in the making of hematite and foundry iron.

Annual Report of North of Scotland Hydro-Electric Board

THE North of Scotland Hydro-Electric Board's annual report for the year 1954 has now been published by Her Majesty's Stationery Office. The report notes a continued growth of demand for electricity in the Board's area, and emphasises the saving of coal—estimated at 700,000 tons in 1954—due to hydro-electric generation of power, totalling 1183 million units. Plant totalling 32.7MW was brought into operation in 1954, bringing the Board's total installed hydro-electric capacity to 431MW in operation, 398MW under construction, and 389MW in course of promotion and survey. In all, 1566 million units were generated by the Board in 1954, the costs of hydro-electric, steam and diesel generation being given as 0.46d., 0.84d. and 1.86d. respectively. About 75 per cent was consumed in the Board's area, and 25 per cent sold to the British Electricity Authority in Central Scotland. Constructional work continued on ten hydro-electric schemes during the year, and the Breadalbane and Shin schemes were started. Thirteen miles of rock tunnels were driven during the year (85 miles have been driven since the start of the Board's schemes) and four dams were completed. The prestressed concrete dam at Allt-na-Lairige thus reached the stage when steel anchorage rods are being placed in position, and at the Lednock dam, near Comrie, the first concrete was placed in the foundations six months after work started. The intake tower of Lowers dam was built in 13½ days (it is 100ft high) with a continuously travelling shutter. The Board was compelled to authorise at short notice last summer, it is stated, the import of Continental cement, as supplies of home cement were insufficient.

Chamber of Shipping Annual Report

THE Chamber of Shipping of the United Kingdom has issued its annual report, 1954-1955, Part I of which deals with the main events of the year. The investment allowance is noted as a step to a more rational basis for the calculation of depreciation and to the recognition that linking depreciation allowances with the historic cost is a fallacy. With regard to strikes, the report points out the deplorable effect upon the national economy, quoting an increase of £82,000,000 in the adverse trade balance for one month, and emphasising that the loss of voyage time can never be made up during the life of the ship. The spread of flag discrimination is deplored and the report instances several such systems of cargo preferences, particularly the United States Cargo Preference Act, which extends the 50 per cent rate to trade cargoes. The report records that the International Chamber of Shipping emphasised that sea transport could only provide economic services under conditions of free supply and demand. Invisible exports are considered next and tables summarise the results of the industry's inquiry for the year 1952, which gave a figure of £221 million for shipping's contribution, and represented a direct saving of foreign exchange. The report contains a number of statistical tables, the total world tonnage being given as 90,924,000 tons, and the United Kingdom's as 17,286,000 tons, the respective increases over 1953 being 4,820,000 tons and 454,000 tons. There are tabular statements setting out the type, propulsion and size and also the average age of the merchant fleet, which is quoted at 11.33 years. Another table shows that, including vessels of 100 tons gross, the tonnage owned in the United Kingdom is 19.4 per cent, compared with 19.9 per cent in 1953.

Association of Consulting Engineers

AT the Association of Consulting Engineers' annual dinner, which was held in London, on Monday, February 21st, Sir Brian Robertson, chairman of the British Transport Commission, made some observations on the development plan for the railways, during his speech, in which he proposed the toast of "The Association." Sir Brian considered that the ambitious nature of the plan was a challenge to the operating staff and senior engineers of the railways. Over the years, he said, sufficient numbers of young men had not been attracted to make railway engineering their permanent profession, but he hoped the new proposals would help to change that situation. There was considerable scope for the services of consulting engineers in carrying out the plan, he affirmed, and he looked forward to the day when British Railways would again be a model, for others to admire and copy, and would have a significant effect on the export market. The chairman of the Association of Consulting Engineers, Mr. T. G. N. Haldane, responded to Sir Brian's toast, and spoke of the deep interest which consulting engineers had in the success of the railway development plan. He also referred to the effects of that work on the export trade, and of the emphasis placed on exports by another development programme recently announced in a Government White Paper—that of the development of nuclear power. Mr. Haldane quoted from the White Paper a passage referring to the fulfilment of this country's traditional role as an exporter of skill. Overseas work, for consulting engineers, he considered, was important not only because of its basic effect on the country's economy, but because it helped to raise living standards in other countries and was a factor in increasing political stability and peace. The toast of "The Guests" was proposed by Mr. V. A. M. Robertson, and Mr. A. R. W. Low, Minister of State, Board of Trade, replied.

Institution of Mechanical Engineers

AT a general meeting of the Institution of Mechanical Engineers, which was held in London last Friday evening, certificates of honorary membership were presented to Dr. Karl Baumann and Dr. J. A. Ringers. The presentations were made by the president of the Institution, Dr. R. W. Bailey. At the meeting, Mr. P. L. Jones, a vice-president, recalled that Dr. Baumann joined the staff of the British Westinghouse Company (now Metropolitan-Vickers Electrical Company, Ltd.) in 1909, as turbine engineer, became chief mechanical engineer in 1912, and was appointed a director in 1927, remaining on the board until his retirement for health reasons in 1949. During Dr. Baumann's long career, Mr. Jones said, he had been principally associated with the development of the steam cycle. The advances in power station practice over the past forty years owed much to his skill and inventive genius. Among Dr. Baumann's contributions to engineering progress, he added, there must be included his many papers which had justly earned international recognition and had enhanced the reputation of British engineering in general. A citation of the work of Dr. Ringers was made by Mr. A. Roebuck, a past-president of the Institution. He spoke of Dr. Ringer's close association with the Zuiderzee and other important public works in Holland, and recalled the long and valuable association which Dr. Ringers has had with the Royal Netherlands Institute of Engineers. Another presentation made at last Friday's meeting was that of the 1954 James Clayton prize. This was awarded to Sir Christopher Hinton, F.R.S., for his pioneer work in applying the results of nuclear research to the production of fissile material and industrial power. An account of some of that work was given in Sir Christopher's lecture to the Institution, lengthy extracts from which were printed in our issues of March 5 and 12, 1954.

Folkestone Warren Landslips

FOLKESTONE WARREN is an area of under-cliff between Folkestone and Dover, about 2 miles in length, which for centuries has been the scene of extensive landslides. Evidently believing that further slips were unlikely, the railway pioneers built a railway along this treacherous belt, running at both ends into tunnels in the chalk, which was opened in 1844. Many slips have occurred since then, and the most recent large-scale movement, which caused the line to be closed for four years, was in 1915. An account of an investigation into the causes of the landslips at Folkestone Warren, and a description of recent works carried out to obviate further trouble, were given in two papers presented on Tuesday, February 22nd, at the Institution of Civil Engineers. The papers under the general title of "Folkestone Warren Landslips," were "Investigations 1948-50," by A. M. M. Wood, and "Remedial Measures, 1948-54," by N. E. V. Viner-Brady. The investigations showed that slips were deep-seated, occurring along the base of Gault clay that underlies the chalk cliffs. The mechanism of these slips is explained in some detail in the first paper, where it is pointed out that orthodox sampling methods proved ineffectual. Stability could be improved, it was pointed out, by loading the foreshore to resist upheavals and at the same time resist encroachment by the sea, and provide a heading to drain water flowing into the Warren from the chalk cliffs. The works carried out include a drainage heading 850ft long, toe-weighting in certain areas and the construction of a stepped sea wall with a protective apron at its toe, to retain the chalk filling. Regular checks for any sign of movement have proved the effectiveness of these measures, it is pointed out.

Railway Engineering Prospects

No. II—(Concluded from page 228, February 18th)

The proposals contained in the plan for modernisation and re-equipment of British Railways open up a prospect of vast engineering activity during the next fifteen or twenty years. In the first article published last week implications of the plan so far as civil engineering and signalling are concerned were discussed; this concluding article deals with proposed changes in motive power.

THE more controversial section of the British Transport Commission plan concerns the changes to be made in motive power. That full electrification is the ultimate ideal there is no doubt, nor indeed are there any grounds for questioning it. According to present developments it is thought that atomic power for industrial uses will be made available for railway use most readily by electrical transmission, so that little change of railway rolling stock and lineside equipment is likely to be necessary as atomic power stations gradually supersede the steam ones of to-day. But progress towards full electrification must necessarily be relatively slow and costly, and it is that portion of the B.T.C. plan that sketches in proposals for the interim period that is most open to criticism. Comment may be grouped under three main headings:—

(a) The routes first chosen for full electrification.

(b) The dieselisation schemes.

(c) The part to be played by steam in the changeover period.

MAIN LINE ELECTRIFICATION

Amid the general welcome accorded to the new proposals some faintly cynical attitudes may here and there be discerned. There has been more than a suggestion, in certain quarters, that at last those responsible for managing the railways of this country have realised the advantages to be derived from electrification; at last notice has been taken of developments abroad, and so on. On the contrary, several important schemes for main line electrification in this country were being vigorously projected nearly fifty years ago and but for the violent intrusion of the 1914-18 war they would, almost certainly, have been undertaken. It is interesting to recall these proposals in the light of the present plan. First and foremost there was the Lancashire and Yorkshire Railway, of which Sir John Aspinall was then general manager. This company electrified the Liverpool-Southport line in 1904 in order to cope with the rapidly increasing residential traffic, and with the keen personal interest of Sir John Aspinall—the only chief mechanical engineer in British Railway history to become a general manager on the home railways, let alone that of the same company—the prospects of main line electrification were excellent. The lines of the Lancashire and Yorkshire did provide an almost ideal network for such a development. The main line from Liverpool to Wakefield is very heavily used; the residential traffic into Manchester is intense in the rush hours, while the heavy gradients encountered on the routes leading northward from Manchester to the large towns lying in the hill country, such as Blackburn, Accrington, Burnley and Colne, have always made the going hard and laborious with steam, whereas it would have been an ideal terrain for multiple-unit electric trains.

The 1914-18 war, however, had the effect of thrusting any such projects into the background, and after the war they never seem to have been revived. With the very

successful experience of the Southern Railway in mind, in working up a fast and punctual all-electric traffic over a wide and complex group of lines south of London one would have thought the old Lancashire and Yorkshire group of lines would have been a first priority in the British Transport Commission plan. It is the kind of area, densely populated with large towns close together, in which a fast and frequent service of electric trains invariably creates traffic. It is true that the main line offers little opportunity for really spectacular running of the 100 m.p.h. order; but service to the public is of far greater importance than the speed exploits of a relatively few "show"

fulfilled between the two wars, though after amalgamation in 1923 the single phase a.c. system of the Brighton was discarded in favour of the 600V d.c. system of the London and South-Western installed on the so-called "Riverside" electrification of 1915.

Another of the pre-grouping railways that was very much to the fore with electrification plans was the North-Eastern. The Chief Mechanical Engineer, Sir Vincent Raven, was one of its strongest advocates, and the first installation was made in most interesting circumstances. On the North-Eastern Railway congestion was arising not so much in passenger working, but on the purely mineral line from the Bishop Auckland district to Tees-side, and as a prelude to much wider application of electric traction the section between Shildon, the concentration point for the coastward-bound coal trains, and Newport yard near Middlesbrough was equipped and brought into service in July, 1915. By adoption of 1500V d.c. and overhead wires the North-Eastern Railway anticipated the recommendation of the Weir Committee in later years, while the inauguration of electric traction in 1915 came at a very opportune time, when, due



Newhaven boat train, electrically hauled, at Lewes

trains, and the population living on or near the intricate ramifications of the Lancashire and Yorkshire line presents a vast agglomerate of potential customers.

The Lancashire and Yorkshire lines electrified over fifty years ago, were equipped on the 600V d.c. system, with third-rail pick-up; but in 1909 great interest was created in the south of England when the first section of the London, Brighton and South Coast Railway to be electrified was equipped for 6600V, single phase, a.c. working with overhead wires. This system was adopted on the advice of Sir Philip Dawson (consulting electrical engineer to the company) not on the basis of a purely suburban scheme, but with the main line electrification to Brighton, Portsmouth and Hastings in prospect. The first stretch to be equipped was the South London line, over which a shuttle service is operated between Victoria and London Bridge. The introduction of electric traction brought an immediate and almost embarrassing increase in traffic. Under the auspices of the Southern Railway the wider project envisaged in 1909 was

to the war, freight traffic was rising to unparalleled heights and many heavy mineral steam locomotives could be released from the Shildon-Newport line for other duties. Experience with electric traction was so successful that after the war the North-Eastern Board decided upon the electrification of the main line between York and Newcastle. It was an unfortunate result of the legislation imposed by Parliament upon the railways of this country that this fine project was allowed to lapse. In 1923, under the grouping scheme, the North-Eastern was amalgamated with other lines to form the London and North-Eastern Railway, and the main line north of York is still steam worked to-day.

The 80-mile stretch between York and Newcastle is, at the present time, much the most intensely worked part of the line from King's Cross to Edinburgh, and one would have thought that in the B.T.C. plan this should have received preference over the former Great Northern line from Leeds and Doncaster to King's Cross. Particularly in County Durham there is a network of lines,

serving a whole collection of thriving industrial towns, which seems ideal for electrification, and where, if experience elsewhere is anything to go by, new passenger traffic could readily be created. On the other hand, the B.T.C. proposal to deal with the King's Cross-Doncaster-Leeds section would no doubt make possible some very spectacular long-distance express services, and with the fitting of continuous brakes on all goods wagons some considerable improvement is to be expected in the long hauls of coal from the Yorkshire and Nottingham collieries. A large proportion of this latter is, however, diverted to the eastern lines at Peterborough for distribution in East Anglia and the eastern suburbs of London; this latter traffic would thus require to be steam or diesel hauled for about half the total mileage run. Altogether, this King's Cross-Leeds proposal does not look so attractive as those sponsored so long ago by two out of the "biggest five" of English railways in pre-grouping days—projected in full knowledge of local needs and local possibilities. When planning on a national scale there is always the danger of providing lavish facilities where the going is already fairly good, and leaving untouched some areas of severe congestion. These latter, while relatively small in extent, have a way of spreading reaction from their worst bottlenecks far and wide.

The other two main line proposals seem to be admirably chosen; the extension of the eastern line from Chelmsford to Ipswich, including the various important branch lines to the Essex Coast, and the main line from Euston to the north. Traffic on this latter route is very heavy, and the inclusion of the Birmingham group of subsidiary lines, and extensions northward from Crewe to Liverpool, on the one hand, and Manchester, on the other, opens up the prospect of a very busy, intensively used, electrified system. The engineering work involved will be tremendous, demanding the closest co-ordination between all branches of the profession in designing the equipment, and giving the utmost assistance to the operating officers in the planning of the new train services. Fortunately, it has at last been recognised that engineers have a vital part to play in the preparation of train time schedules, and their services will be required in full measure if full advantage is to be taken of the London Midland Region electrification scheme.

DIESELS

While the shunters have amply proved their worth, and the new twin railcar units are showing every promise, British experience so far with main line diesels has been disappointing. It is true that the locomotives concerned are no more than prototypes, but while it is true that this might give rise to maintenance difficulties, due to inexperience and non-availability of spare parts, it is no less true that they have been very carefully nursed through a rather prolonged period of teething troubles. All five are now working on the Southern Region, and although each and all are capable of excellent individual performance, their overall reliability is low, and it apparently seems rare for more than two out of the five to be in service at the same time. Clearly more prototypes should be built, embodying the fruits of experience so far, and the most sustained and intensive working must be possible before any design is acceptable for building on the scale envisaged by the British Transport Commission. As THE ENGINEER has recorded, the Southern diesel-electrics have given a very satisfactory account of themselves



West of England express, diesel-electric hauled, on Southern Region

scientifically, as tested with the Swindon dynamometer car. What are now wanted are locomotives that will stand up to the rough and tumble of everyday traffic, month in, month out.

There is no doubt that running-shed maintenance is one of the greatest "headaches" on British Railways to-day. The prospect of shift working is not attractive to young men who, in many of the most important centres, can readily obtain alternative work involving regular hours and more congenial conditions. Whether a changeover to diesels with the enhanced standards of maintenance will prove an incentive to recruiting remains to be seen; but unless the locomotives receive proper maintenance failures will be widespread. Of this nothing is more certain. In America maintenance work on diesels has become very highly organised, with the most elaborate provision of spares at intermediate service stations. Such spares do not merely consist of individual items, such as pistons, connecting-rods, pins, and so on. In case of troubles it is often the practice to substitute rapidly complete sub-assemblies, even to the extent of a complete diesel engine, in order

to keep a locomotive in traffic. If such an organisation were available on the Southern to-day doubtless the five units stationed on that Region would show better availability figures, though the cost of providing such a service for only five locomotives would be altogether disproportionate.

FLUID AND MECHANICAL TRANSMISSIONS

If the main line diesel-electrics have so far given disappointing results, the Western Region experience with gas turbine propulsion has been even worse. The Metrovick locomotive has been out of service for some eighteen months undergoing extensive alterations, while during the year 1954 the companion Brown-Boveri machine was in traffic for a total of about twelve weeks in all—an availability of roughly one in four. It is understood that a high proportion of the troubles arise from the electrical gear, and nowadays strong claims are being put forward for both mechanical and fluid transmissions for diesel-powered locomotives, and gear drives for gas turbines. Now that the word has gone forth that no new steam locomotives are to be built after 1956, and presumably



Western Region, gas turbine engine on Penzance express

on this account new design work will stop forthwith, the appropriate mechanical engineering design staffs of British Railways will be available to co-operate with manufacturers in the intensive development of diesel or gas turbine locomotives in order to determine the most suitable types for quantity production under the plan. It is a big task and the need is urgent. In the meantime it should be possible to go ahead with the production of the railcar sets. The progressive introduction of these in areas hitherto worked by steam should go some way towards relieving the acute shortage of manpower that exists at many locomotive depots, since, as on a multiple-unit electric train, only one engineman or motorman is needed.

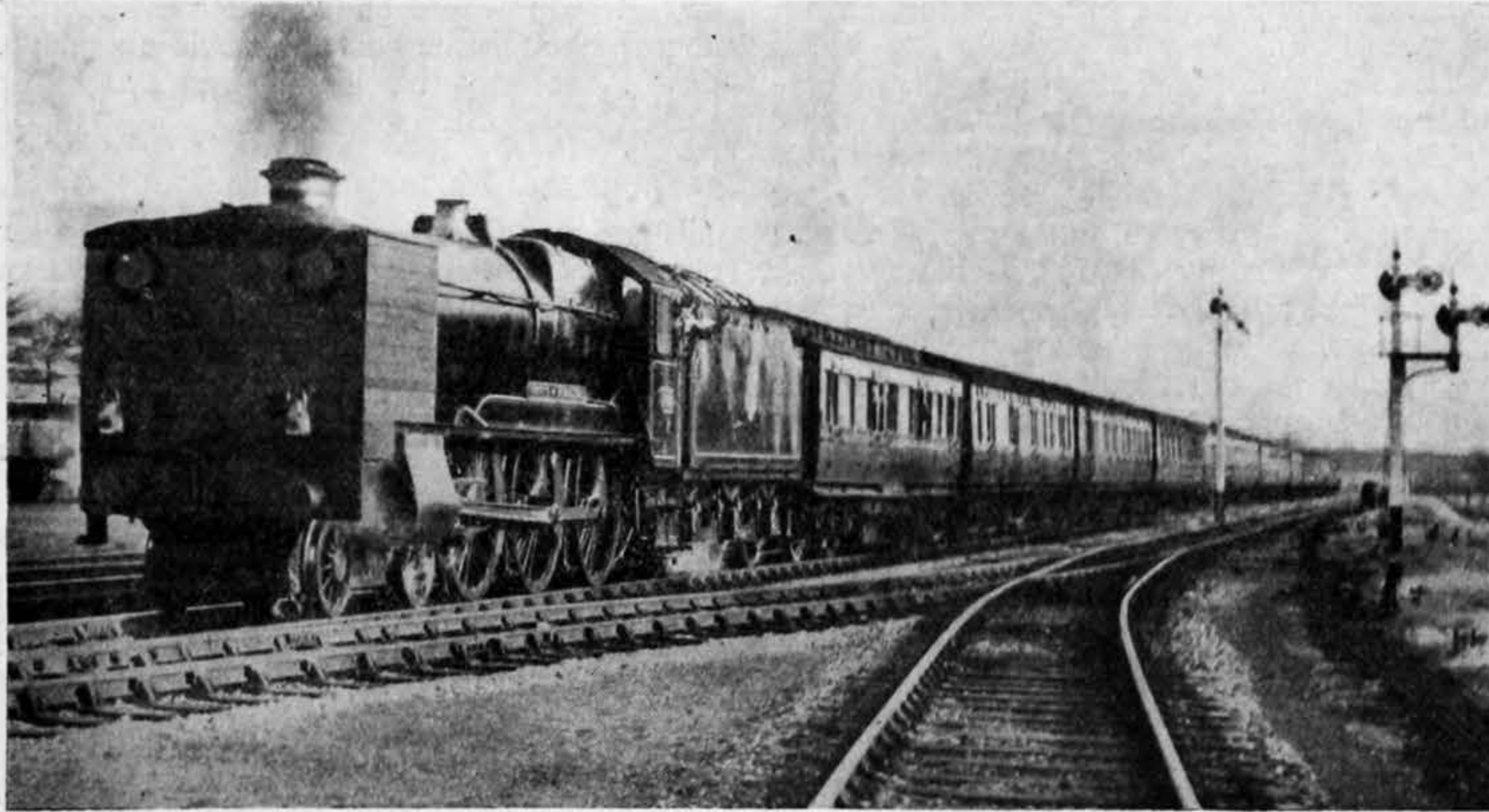
THE FUTURE ROLE OF STEAM

From now onwards it is evident that the steam locomotives of this country are in for some of the toughest assignments of all the steam era. There are some non-technical commentators who make the facile assumption that once the order to electrify and dieselise has gone forth the new machines will roll from the assembly lines, if not overnight then certainly within months. No engineer is likely to suffer any such delusions,

themselves. The delays were mostly due to signal checks, which might be attributed partly to the tardy movement of other trains and partly to the old-fashioned signalling methods. The equipment of all freight trains with continuous automatic brakes will permit of smarter movements, and lessen chances of delay to fast trains, while the advantages of power signalling with concentration of control in fewer signalboxes needs no further emphasis.

Thanks in no small measure to the development work carried out at Swindon and Rugby since nationalisation, motive power for the heaviest and fastest express passenger services in this country is in a healthy state, and well able to carry on for many years to come. Modern testing practice has also been applied to all varieties of the large stud of general utility 4-6-0 locomotives in the "class 5" power group, and detail improvements made. It is on the heavy passenger and general utility classes that the greatest burden is likely to fall in the next ten to fifteen years. Relief should be coming reasonably soon for branch line and suburban engines. When quantity production of the main line diesels begins it is hoped, according to the plan, to install two diesels for every three steam locomotives replaced. This presupposes

timetables to make better use of locomotives and coaching stock; but on the main lines and in the most favoured holiday districts the peaks will remain. To reinforce the diesels, running long mileages on regular rosters, it seems essential to have a substantial reserve, stored for some months in the year as at present on the Southern Region, and brought into service during the summer. So far as the principal main line services are concerned, as the plan gets under way much permanent way and civil engineering work will be involved, with accompanying speed restrictions, and yet the public has a reasonable right to expect as near punctuality as possible during the transition period. This will call for hard running between checks and a high standard of engine performance. At the present time both the stationary testing plants are concerned with "class 8" express passenger "Pacific" engines; Rugby has one of Sir William Stanier's "Duchess" class, while Swindon is dealing with the new Caprotti valve gear engine No. 71000, "Duke of Gloucester," completed at Crewe works last year. There is every need to continue research and development work on the steam locomotive, for a time at any rate, so that the critical period of the next ten to fifteen years may be successfully bridged.



Controlled road test with Western Region "County" class engine

but from the mere psychology of the situation the railways can expect a steadily worsening supply of locomotive coal. Not only are modern mining methods tending to produce the coal itself in smaller sizes than hitherto, but it would not be human nature if in some places at least one did not meet the attitude that locomotive coal was no longer of any consequence. "The locomotives will all be scrapped soon."

From one reason or another there are cogent reasons for keeping steam locomotive performance at concert pitch during the years of transition. Improved front-end draughting arrangements are making first-class standards of running possible with lower grades of coal; there are prospects of further substantial accelerations of service in the coming summer season, using existing motive power, demanding the highest standards of repair and maintenance. The steam locomotive, like other forms of motive power, shows up at its best when handling the cream of the traffic, and analyses taken since the introduction of greatly accelerated service on the Western Region last summer show clearly that late running, except in a negligible few instances, was not due to the locomotives working the accelerated trains

more elaborate engine diagrams, with increased daily mileages and a high standard of reliability. But the basis of replacement must essentially take into account those phenomena of present-day operating, the two heaviest months of the summer holiday season, when at week-ends in certain large districts freight is practically suspended and every passenger and mixed-traffic engine that can "turn a wheel" is in almost continuous service for a period of about eighteen hours. While 100 diesels in a certain large area might be able to do the work of 150 steam locomotives on ordinary weekdays the entire stud of 150 is needed all at once to cope with the summer Saturdays. Unless the travelling habits of the public can be guided into different channels before the plan comes into full operation the British Transport Commission might easily become the victim of its own enthusiasm for scrapping steam locomotives, as the London and North-Western Railway was fifty years ago in its over-zealous cutting up of the Webb compounds.

Traffic on British Railways is such a complex, widely fluctuating business that to plan its operation with textbook precision will always be difficult. A great deal can be done, and has already been done, to replan

Lloyd's Register of Shipping

THIS week Lloyd's Register of Shipping has published its *Annual Summary of Merchant Ships Launched in the World During 1954*. In Great Britain and Northern Ireland 253 steamships and motorships of 1,408,874 tons were launched, the highest total since 1930, representing 26.8 per cent of the world output, which compares with 25.9 per cent in 1953 and 34.5 per cent in 1938. A table gives the tonnage for the principal districts, the Clyde output being 478,091 tons, and that of the Tyne, Wear and Tees being 214,967 tons, 190,177 tons and 170,967 tons respectively. Eight ships of 20,000 tons and upwards were launched during the year, four of which are oil tankers. Oil tankers totalled 63 ships of 714,301 tons, a decrease of 48,141 tons compared with the previous year, representing 50.7 per cent of the total output for the year. Of the total, 40.6 per cent is for registration abroad. A total of 79 ships of 481,825 tons, representing 34.2 per cent of the total tonnage launched in Great Britain and Northern Ireland, are for registration abroad, compared with 27.7 per cent in 1953. Abroad, excluding China, Poland and Russia, the total tonnage launched amounted to 980 ships of 3,843,757 tons, an increase of 65,170 tons over the 1953 total, and this total is the highest since 1919.

A table gives the tonnage launched by the leading countries abroad, the returns being: Germany, 963,114 tons; Sweden, 544,311 tons; U.S.A., 476,984 tons; Japan, 413,405 tons, and the Netherlands, 410,559 tons. Twenty-three ships of over 20,000 tons were launched and all are oil tankers or ore carriers. Ships for the carriage of oil in bulk totalled 204 of 2,184,697 tons, or 56.8 per cent of the total tonnage launched abroad. Of the total tonnage, 1,598,377 tons, or 41.6 per cent, are for registration other than the country of build. Throughout the world a total of 1233 ships of 5,252,631 tons were launched in 1954, an increase of 156,581 tons over 1953 and the highest figure since 1920. Of the total, 55 per cent are motorships, as compared with 58 per cent in 1953 and 65 per cent in 1952, and of the steamships geared turbines are to be fitted in 154 ships of 2,166,110 tons. Oil tankers amounting to 267 ships of 2,898,998 tons were launched in 1954, representing 55 per cent of the world output, and of the total 25 per cent was built in Great Britain and Northern Ireland and 15 per cent by Germany. Motorships represent 44 per cent of all oil tankers launched in 1954, as compared with 53 per cent in 1953, figures which indicate the development of the large tanker.

800-Ton Plate Stretching Machine

An 800-ton hydraulic plate stretching machine recently built by Joshua Bigwood and Son, Ltd., is designed to handle sheets from 6ft to 26ft 3in long by 7ft 6in wide. It has an improved design of grip head fitted with a preflattening device for facilitating the handling of sheets with buckled ends, and all its movements are controlled by an operator at a centralised control panel.

A HYDRAULICALLY operated plate stretching machine, designed and recently completed at the Wolverhampton works of Joshua Bigwood and Son, Ltd., for a firm in Norway, is believed to be the largest machine of its kind yet made and installed in Europe, although larger equipment is in use in the United States. The new machine is designed to exert a maximum pull of 800 tons and has an effective stroke of 3ft. It is fitted with a movable grip head, the position of which can be adjusted along the machine to enable it to handle sheets from 6ft up to 26ft 3in long and 7ft 6in wide. The stretching speed is infinitely variable up to 0.39in per second, the unloaded take-up speed being 3.5in per second and the ram return speed 1.34in per second.

The machine embodies an improved design of grip head, a preflattening device to ensure easy entry of buckled plates or sheets into the grips, and centralised control. Its general construction and some details of its design can be seen in the drawings we reproduce, and the photographs of the machine when erected for tests at the maker's works.

The main frame is fabricated from heavy steel plate, the two main side frames being made in sections to facilitate construction, transport and erection on site. The side sections are bolted together at the flanges and after erection they are further secured by heavy link plates on the tension side of the neutral axis. These side frames are spaced and secured by heavy cross bridges set at intervals along their length to form a rigid frame assembly. The frame itself rests on roller supports on the foundations to permit it to deflect without restraint under load.

A series of large holes bored at 18in centres along the upper part of the side frames are used for locating the locking pins, which transfer the load from the movable grip head to the main frame members. These holes are lined with hard-chrome plated steel bushes which can be replaced in the event of wear or damage.

Mounted on the bed below the level of the locating holes and on top of the bridge pieces are two joists which are rigidly fixed to the frame members. Each of these joists carries on its upper flange a flat-bottomed rail which forms a runway for a movable grip head which can be traversed along the machine and fixed in position in accordance with the length of the plates being handled. In the spaces between the frames there are also housed the traversing drive equipment for the movable grip head, limit switches for the alignment of this grip head with locating holes, and the power supply cables and reels.

The main cylinder, which can be clearly seen in one of the photographs and in detail in one of the sectional drawings, is machined from a special steel hollow forging and it is carried in a massive steel yoke anchored to the side frames by heavy pins. The main ram is bored to take a secondary supplementary piston which is used to bring the grip head to the initial position and provide take-up at high speed. A steel cross-head on the ram is supported on rollers from the side members of the frame and takes the overhung weight of the ram and links and relieves the hydraulic packings of vertical loads. This cross-head is coupled to the stretching grip head by two heavy steel draw links which are secured at each end by large trunnion pins. A large capacity relief valve fitted to the cylinder is designed to return the oil to the tank directly in the event of a rupture of the sheet being stretched.

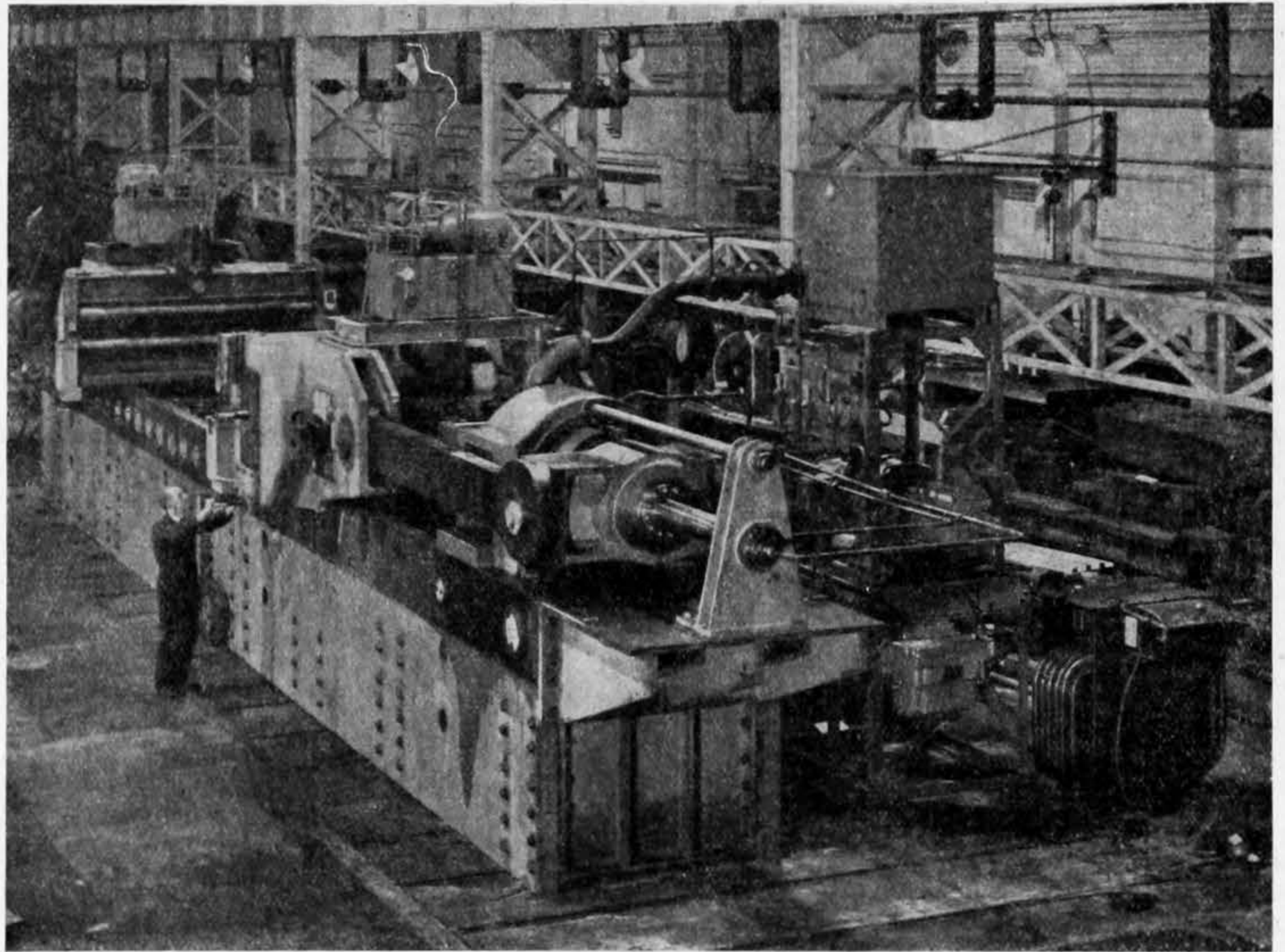
The grip heads are each fitted with the firm's own design of sectional grip assembly and one of the drawings we reproduce shows the arrangement of the head which is movable along the

machine and is generally similar to the stretching head. Each of the heads has a massive cast steel body with the grip assembly mounted in a deep recess across its front. The top and bottom grip blades are mounted on segmental blocks riding on steel rollers which bear on inclined faces. The actual blades are made in 12in long segments to facilitate their removal and replacement if different forms of blade or alternative serration patterns are called for. The two blade assemblies are operated in unison by a hydraulic cylinder at the back of the head through an equalising link system. Through this system push rods coupled to each end of each blade assembly are actuated by a cross beam pivotally connected at the centre to the piston rod of the hydraulic cylinder. In operation the blade assemblies are pushed forwards down these inclined faces until a plate is gripped firmly. During actual stretching, however, no

operated ratchet lever, the rolls are rotated to feed the flattened end of the sheet into the grip jaws. The top roll is raised clear of the sheet after it has been gripped and before the stretching operation begins.

Each grip head has a self-contained motor-driven hydraulic pumping set mounted on it and the power supply cables for these pumping sets are wound on spring-loaded reels. These pumping sets are driven by 7½ h.p. motors and supply fluid at a maximum pressure of 4000 lb per square inch. The set on the stretching grip head at the hydraulic ram end of the machine supplies fluid for operating the flattening roll and grip jaw actuating cylinder. That on the movable head also supplies pressure fluid for an anchor pin operating gear which is described below.

The moving grip head is moved along the frame of the machine to the required setting by means of heavy roller chains supported in channels on the frame bridge members. This grip head weighs some 21 tons and it is supported through disc springs on a heavy carriage mounting. Whilst it is being drawn to the required position along the bed the head is supported on its rollers clear of the bed and relatively little effort is required to draw it along. When it is locked in position and the stretching load is applied to the head there is a component of force which pulls it down on the



Stretching grip head end of machine. The main hydraulic cylinder is carried on a yoke anchored to the side frames and the grip head is coupled by draw links to a cross head on the main ram

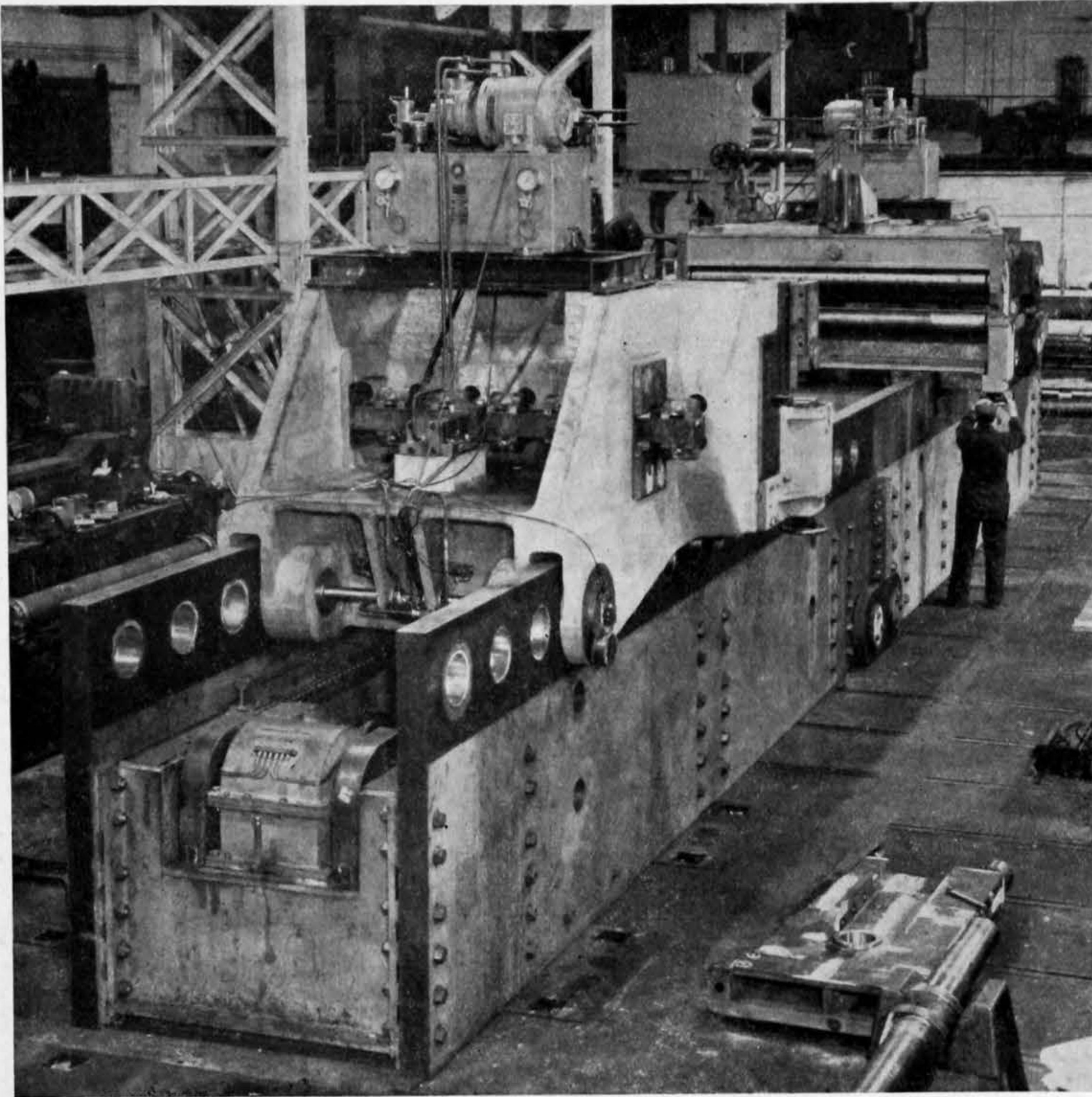
load is imparted on the blade hydraulic system as the tendency for a plate to pull out of the jaws draws the blade assemblies down the inclined faces to increase their mechanical grip in proportion to the load. With this grip design a wide range of plate thicknesses from $\frac{3}{16}$ in to 1½in, can be handled with the one set of grips.

In order to overcome the difficulty which might occasionally be encountered in introducing an excessively distorted sheet into the grip jaws hydraulically loaded preflattening roll equipment for the sheet ends has been fitted in front of each head. In this equipment the bottom roll housing can be adjusted for height by means of screw gear operated from a hand wheel at the side of the head. The top roll and housing is lifted or lowered on its guides by a hydraulic cylinder. When a sheet end requires flattening the top roll is raised to its upper limit and the sheet is placed on the bottom roll. The top roll is then lowered and the sheet end held flat on the lower roll by the load imparted by the hydraulic cylinder. Then, by means of a hand-

spring mounting so that the load is supported through its base over a large area of the side frames of the machine.

The travelling grip head chains are driven by a 10 h.p. motor and reduction gearing set between the frames at one end of the machine. The drive is transmitted from the motor through an electromagnetic clutch and sprocket drive to the final reduction gearbox, which drives the common shaft of both chain sprockets. This drive is controlled from the central control desk and the clutch disengages the drive when the head is on approximate alignment with the required anchor holes in the frame, in which position the lead on the pins ensures their alignment.

The two heavy anchor pins used to lock the grip head to the side frames of the machine are mounted on the inside arms of a rearwards extension of the head. They are moved out to the locking position and retracted for repositioning of the head by hydraulic cylinders. When extended to lock the head the pins pass through the holes in the side frames and enter holes in



Movable grip head end of plate stretching machine with head traversing drive

the outer arms of the head casting. With this arrangement the pins are in double shear when under load and are subjected to a minimum bending moment. Micro switches are fitted to prevent the machine being operated unless the anchor pins are fully engaged.

MAIN HYDRAULIC SYSTEM

A double pump unit driven by an 80 h.p. squirrel-cage motor supplies the hydraulic

system of the main and supplementary rams of the machine. Each of these five plunger pumps has a capacity sufficient for operating the rams at half speed, and a by-pass valve enables either or both pumps to be used. The circuit and components of the main hydraulic system are shown in the accompanying diagrams.

The stretching head movements operated by hydraulic pressure are initiated and stopped by push buttons on the control desk. These buttons

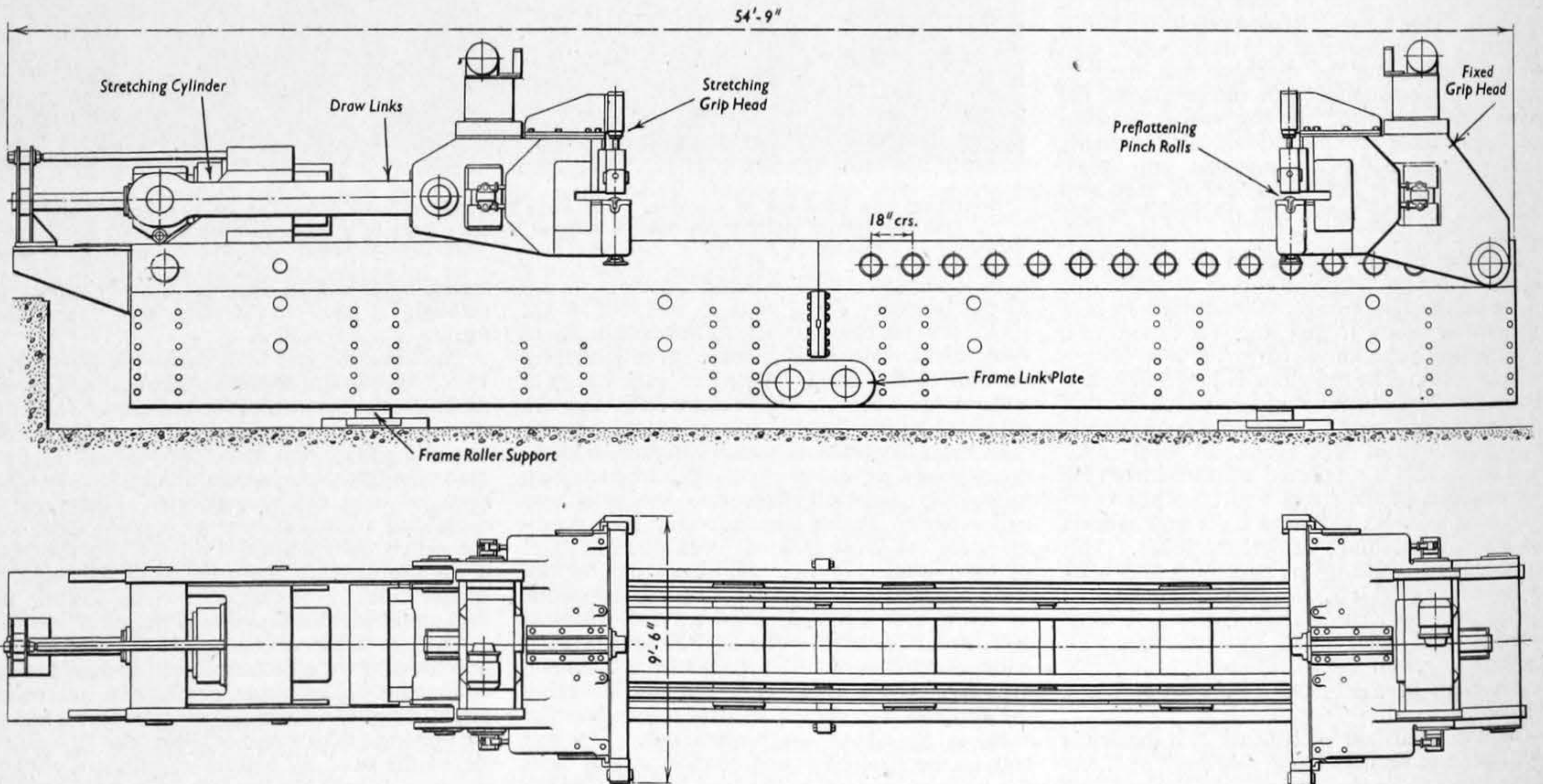
actuate a solenoid-operated pilot valve V2 which varies the setting of the control and exhaust valve V1 (see hydraulic control circuit).

The outward or stretching stroke is carried out in two stages. In the first stage fluid at a pressure of 2000 lb per square inch is admitted to the annulus behind the head of the fixed secondary ram so that the main ram is drawn back until the slack in the sheet being stretched is taken up. When this stage has been completed, an increased resistance, due to rising stress in the material, is encountered. This automatically causes a pressure of up to 5000 lb per square inch to be applied to the annulus as well as in the main ram cylinder, and the grip head continues to move outwards until the required load on the sheet—as shown on the strain indicator—has been attained. If it is desired to hold a sheet at a certain load, the pressure is locked in the hydraulic cylinders by setting the control valve in the neutral position. The inward or return stroke is effected by admitting a pressure of 500 lb per square inch to the front of the cylinder of the secondary ram and exhausting the main cylinder and annulus.

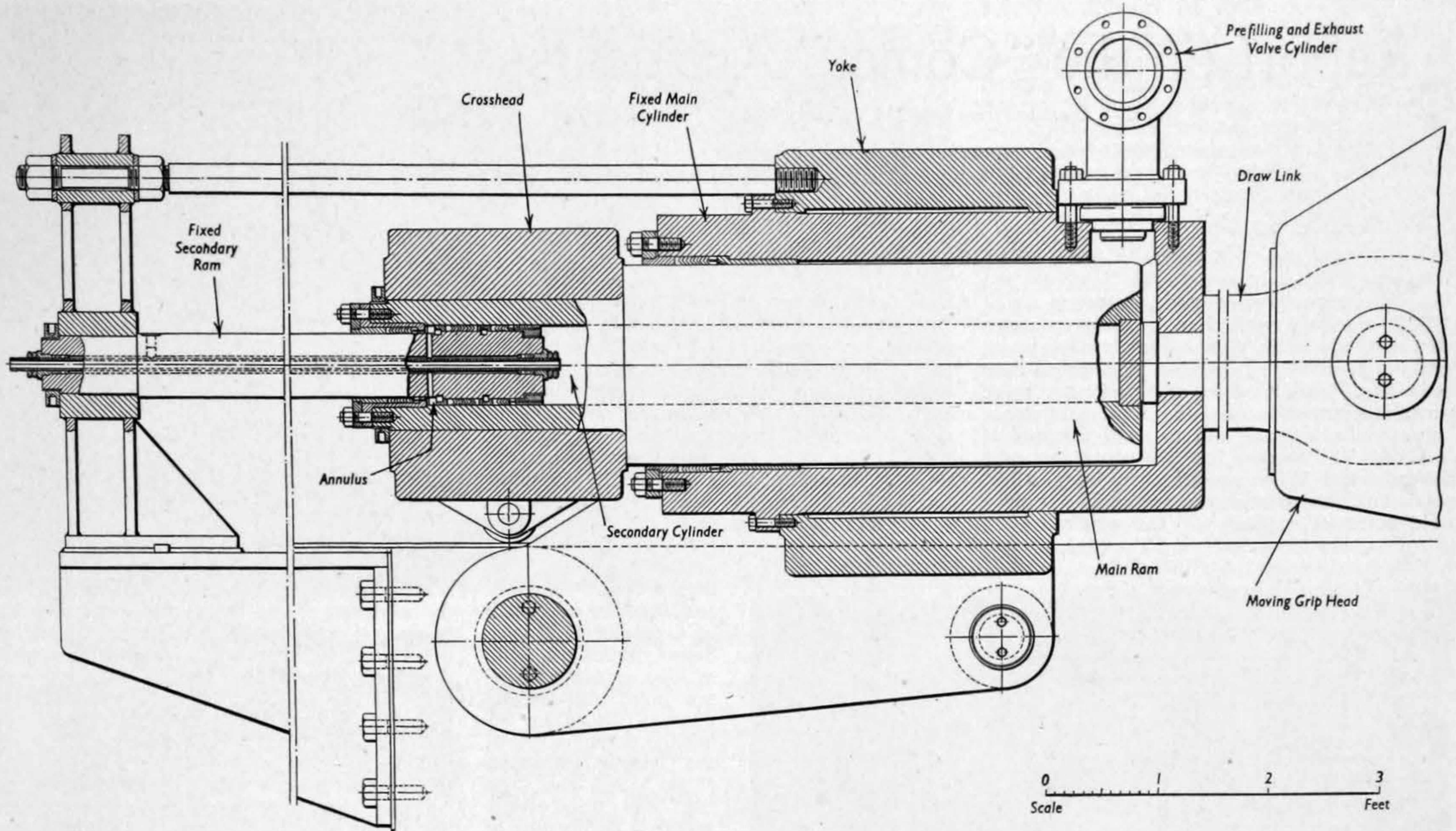
During take-up, the front section of the main pump delivers to the annulus by way of the amplifier valve V3A, the calibrated variable pressure relief valve V4A, and the control valve V1. Oil is admitted to the main ram cylinder through a pressure-operated prefiller valve and from the rear pump by way of the amplifier valve V3B. At the same time, oil is exhausted from the secondary cylinder through the fixed pressure relief valve V6. When the stretching load is reached, the prefiller valve is closed, pressure rises in the annulus and the fixed pressure auto admission valve V5 lifts to admit oil at a pressure of up to 5000 lb per square inch to the annulus and the main ram. The stretching speed is controlled between 12 in per minute to 24 in per minute from the desk by manipulating the metering valves V8A and V8B, which by-pass a proportion of the oil back to the tank. Slower speeds may be obtained, if required, by by-passing completely the volume of the rear pump through the valve V9.

To return the main ram to its inner position after stretching, the control valve admits oil at a pressure of 500 lb per square inch through the fixed pressure relief valve V6 to the secondary cylinder. The annulus exhausts by way of the control valve V1 into the secondary cylinder, whilst the main cylinder is exhausted through V1 back to the tank.

The machine is controlled completely from a



General arrangement of 800-ton hydraulic plate stretching machine



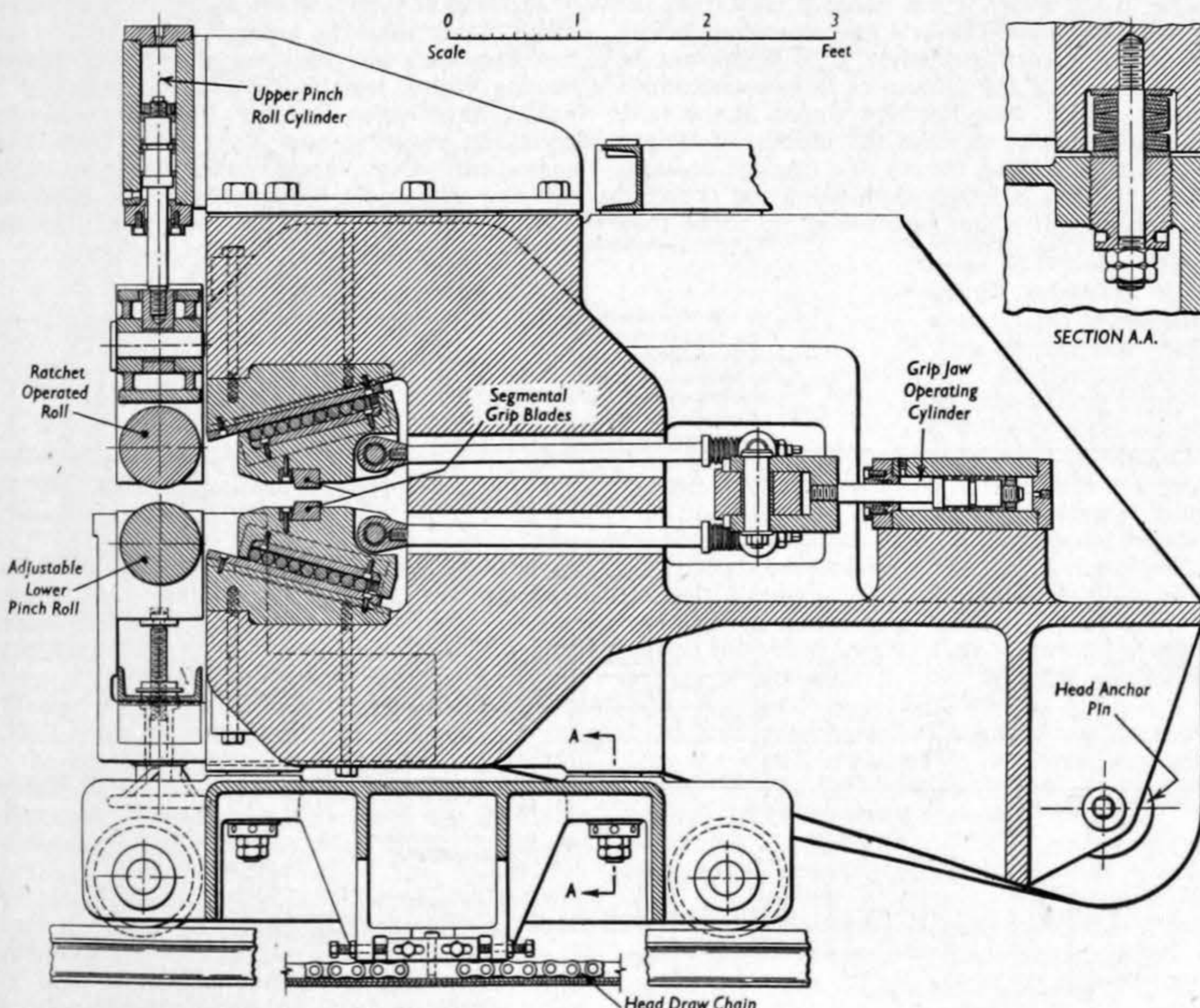
Arrangement of main hydraulic cylinder assembly

separate control desk which can be situated in any convenient position and raised to give full view of all working members of the machine. The control is by electric push-button switches which operate the solenoid valves of the hydraulic systems. The main ram is controlled by three push buttons, for loading, unloading and pressure holding conditions. Supplementary cylinder valve gear controls are incorporated for each set of grips, the locking pins and the adjustable grip head motor controls. The setting of all controls is shown by indicator lamps. An electrically-coupled pair of "Magslips" show

the position of the travelling head, whilst a second pair indicate on a calibrated dial the movement of the ram-operated grip head under load and thus the amount of elongation or extension to which a sheet has been subjected.

The controls are provided with interlocks so that the moving head grips can only be operated when the locking pins are in engagement, and the locking pins cannot be operated unless the grip head has been correctly positioned with respect to the locating holes by the adjusting motor.

The pitch of the locating holes is 1ft 6in and



Arrangement of fixed grip head

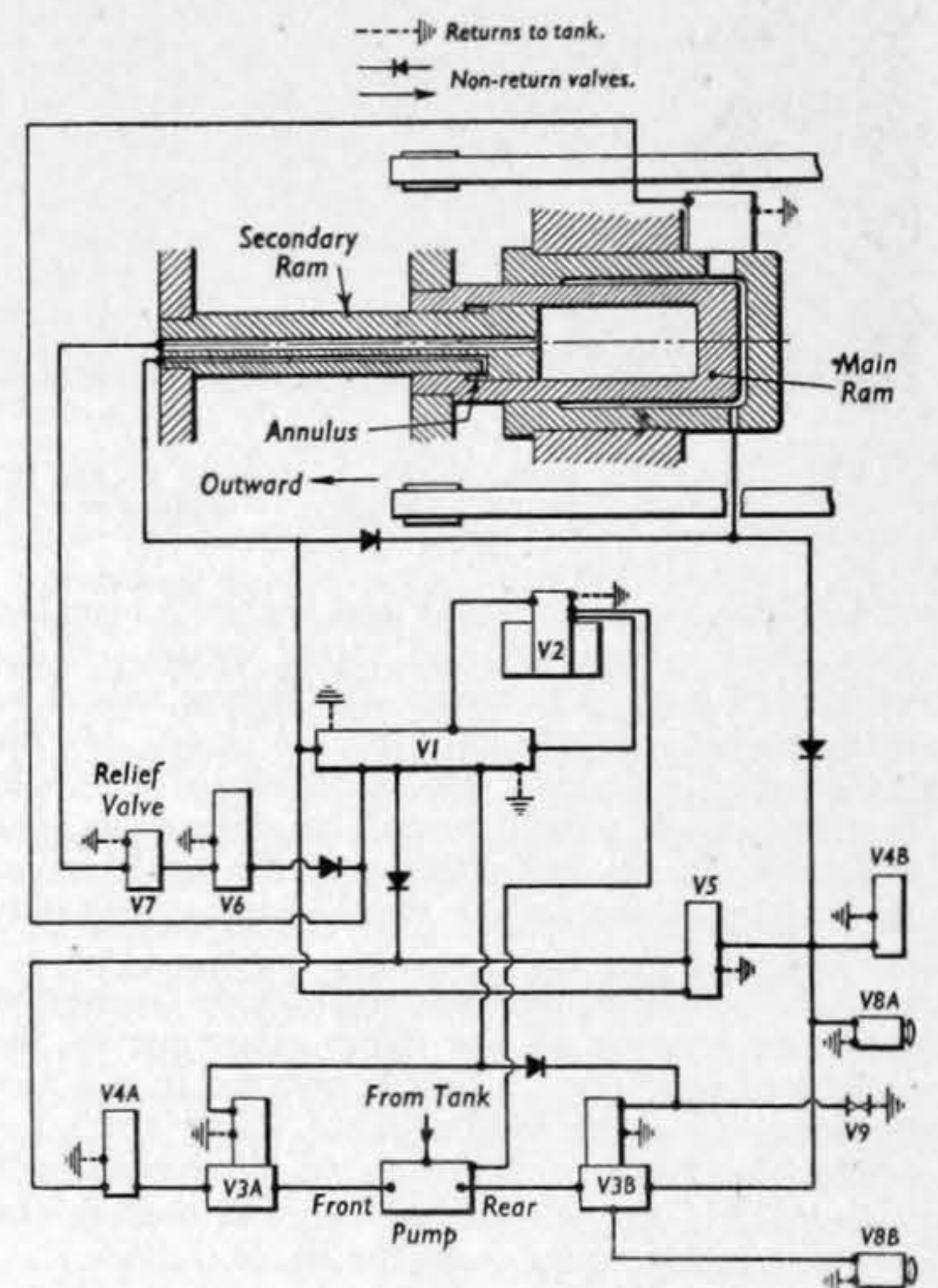


Diagram of hydraulic control circuit of stretching ram

the maximum ram travel on the fixed grip head is 3ft.; consequently, a full coverage of sheet lengths is given within the stated capacity of the machine.

MONOLITHIC REFRACTORY CONSTRUCTION. — On account of the ease with which intricate shapes can be quickly constructed, the use of cold-setting refractories in place of bricks is now a widespread practice for many applications. Refractory concrete is made from mixtures of aluminous cement and crushed well-graded firebricks or grog. Some users prefer the proprietary pre-mixes, while others make up their own concrete. To help those firms who make their own mixtures, the Lafarge Aluminous Cement Company, Ltd., 73, Brook Street, London, W.1, has produced a revolving chart which shows at a glance the various uses of refractory concrete, the most suitable aggregates, suggested mixes, and also the hot face temperatures which such mixtures should withstand. Copies of this chart will be supplied free on application.

Report on the "Comet" Accidents

No. II—(Continued from page 234, February 18th)

Abstracts from the Commissioner's report* of the Court of Inquiry into the accidents to "Comet" G-ALYP and G-ALYY which was published, with illustrations, recently are here reproduced. The Commissioner was Sir Lionel Cohen, and the assessors were Sir William Scott Farren, Professor William Jolly Duncan, and Air Commodore Allen Henry Wheeler

INVESTIGATION OF THE ACCIDENTS

THE normal method of testing pressure cabins up to the point when they fail under pressure is similar to that used for vessels such as boilers. They are filled with water and more water is pumped in until the desired difference between the internal and external pressure is reached. This method has two advantages over the use of air. Water is relatively incompressible, so that failure when it occurs produces only a mild form of explosion. The origin of the

tests included, at intervals of approximately 1000 "flights" a proving test in which the pressure was raised to $1\frac{1}{2} P$ (11 lb per square inch). It must be understood that there are other sources of fluctuating load and, therefore, of fatigue, to which no precise value can be attached. No attempt was made to represent these in the test. Examples are vibration due to irregular airflow, vibration due to the engines and the jet efflux and fluctuating loads occurring during take-off and landing.

"Yoke Uncle" had made 1230 pressurised flights before the test and after the equivalent of a further 1830 such flights, making a total of 3060, the cabin structure failed, the starting point of the failure being the corner of one of the cabin windows (Figs. 1 and 2). The fact that the failure occurred during one of the proving tests to 11 lb per square inch is not thought significant since the crack would have spread in very much the same way after a few more applications of the working pressure. Examination of the failure provided evidence of fatigue at the point where the crack would be most likely to start, namely, near the edge of the skin at the corner of the window (Fig. 3). This

was revealed by the discoloration due to algae in the water which made it clear that the crack had endured several pressurisations before it spread catastrophically. It is important to note here that the sources of fatigue mentioned above, which were not reproduced in the tank test, all tend to increase the burden of fatigue and that, therefore, the life of a fuselage deduced from the test is longer than would be expected in service. It is not possible to do more than

estimate the magnitude of this effect but it was suggested by Dr. Walker that a "life" of 3060 flights in the test might be equivalent to about 2500 in practice.

The inference suggested by the tank test, that the primary failure of "Yoke Peter" was the bursting of the pressure cabin, was confirmed by a close examination of the wreckage and by the experiments referred to in the next following paragraphs of this Report.

The character of the damage caused to the structure was such that it became possible to determine with a high degree of probability the manner in which the various fragments struck the sea, mainly because of the very high local pressures produced by the impact with the sea. Moreover, it rapidly became clear that the intense fire which had existed was confined virtually to the centre part of the wing, leaving the outer parts of the wing and the front and rear parts of the cabin untouched. These considerations led to the conclusion that it was probable that the main part of the aircraft fell into the sea in a small number of relatively large pieces, one of which was on fire (Fig. 4). Most of these pieces had fallen in a surprisingly small area. This conclusion was in agreement with the evidence of the farmer at Elba, who saw fragments, one of which was on fire, falling into the sea. This led to a line of experiment which produced remarkable results. Models were made of the "Comet" in light wood, suitably ballasted, and projected in the air at the appropriate speed. They were released from a kite balloon at a height above the ground corresponding to that at which it was believed the "Comet" structure failed, reduced in proportion to the scale of the model. The model was so constructed that it would break at the point where the failure of the cabin was suspected, namely, in the neighbourhood of the wing. The outer parts of the wing (only one of which had been recovered), were also separated from the centre part. The descent of the fragments was photographed, and it was found that they fell in a manner which agreed with the deductions which had been made from the evidence mentioned above.

Simultaneously with this work, further experiments in the water tank were made on the cabin of "Yoke Uncle," after the first failure had been repaired by de Havillands. Until then, owing to the need to discover whether the cabin had, against all previous belief, a relatively short life under repeated loading, no attempt had been made to measure the stress in the material of the skin at points where it might be expected to be higher than the average. One reason for this omission was that the number of places coming within this description is large, and it would have taken a long time to install the necessary strain gauges and other associated equipment. But it now seemed highly probable that the stress near the corners of the windows was higher than had been believed by the

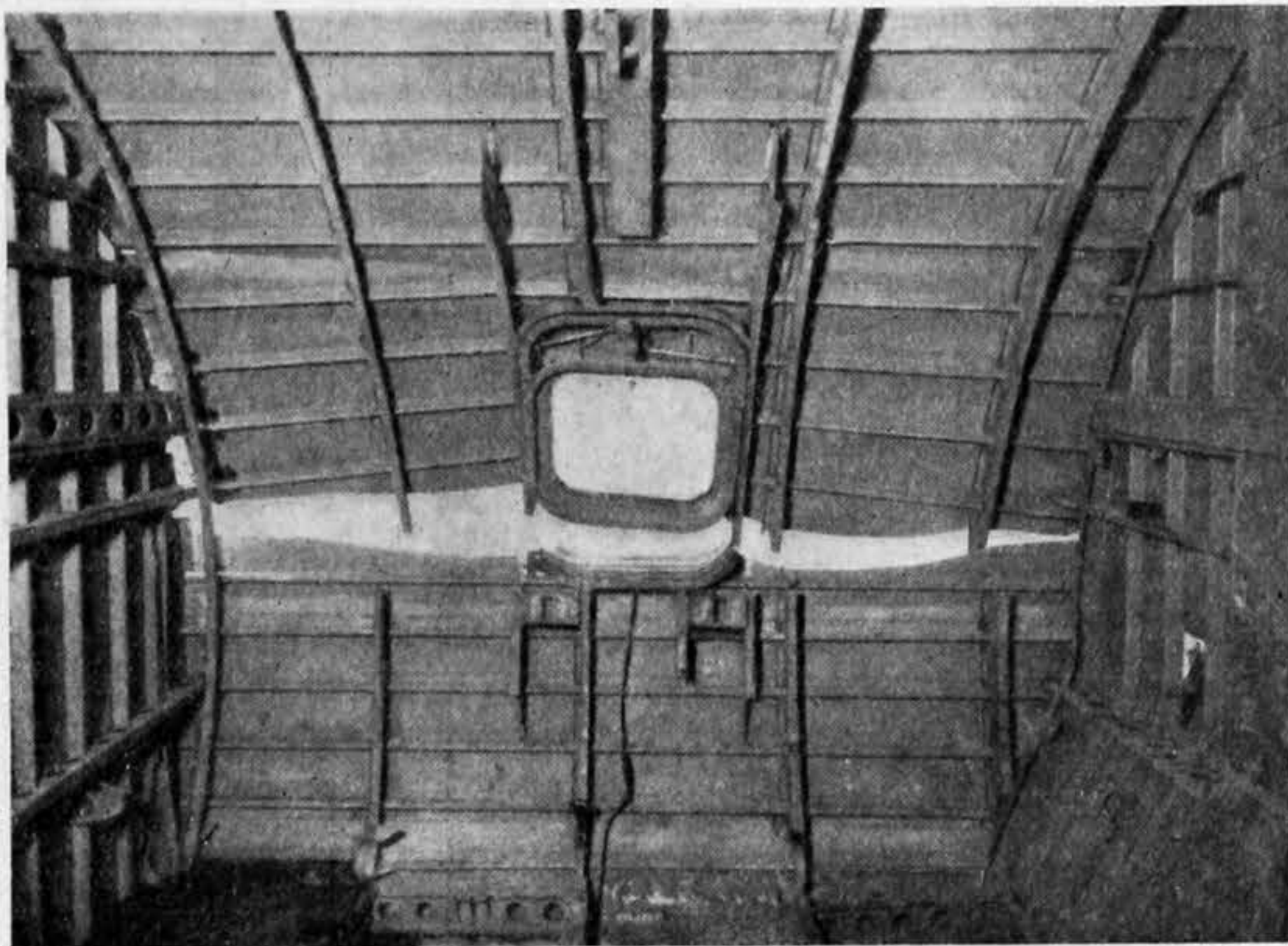


Fig. 1—View from inside, of failure at the forward escape hatch on the port side. "Comet" G-ALYU

failure can be determined and the structure can generally be repaired and tested again. If air were used instead of water, the failure would be catastrophic (equivalent in the case of the "Comet's" cabin to the explosion of a 500 lb bomb). Such a test would be dangerous, the cabin would be destroyed, and the evidence of the origin of the failure would almost certainly be lost.

It is, however, necessary to prevent unrepresentative loading of the cabin structure by the weight of the water. This is ensured in practice by immersing the whole cabin in a tank, and filling the tank and the cabin simultaneously with water. Pressure in the cabin is then raised by pumping in water from the space outside it.

Cycles of loading, to the same or different levels of pressure as desired, are applied by a suitable routine of pumping.

By a remarkable effort, to which de Havillands and the firms who built the tank contributed to the full and by the use of all the resources of R.A.E., repeated loading tests began early in June on aircraft G-ALYU ("Yoke Uncle"). The object of the tests was to simulate the conditions of a series of pressurised flights. To this end the cabin and wings were repeatedly subjected to a cycle of loading as far as possible equivalent to that to which they would be subjected in the period between take-off and landing. In addition to one application of cabin pressure, fluctuating loads were applied to the wings in bending to reproduce the effect of such gusts as might be expected in normal conditions, although the contribution of gust loads to the stresses in the cabin structure, compared with that made by the internal pressure, was in general small. Moreover, the programme of

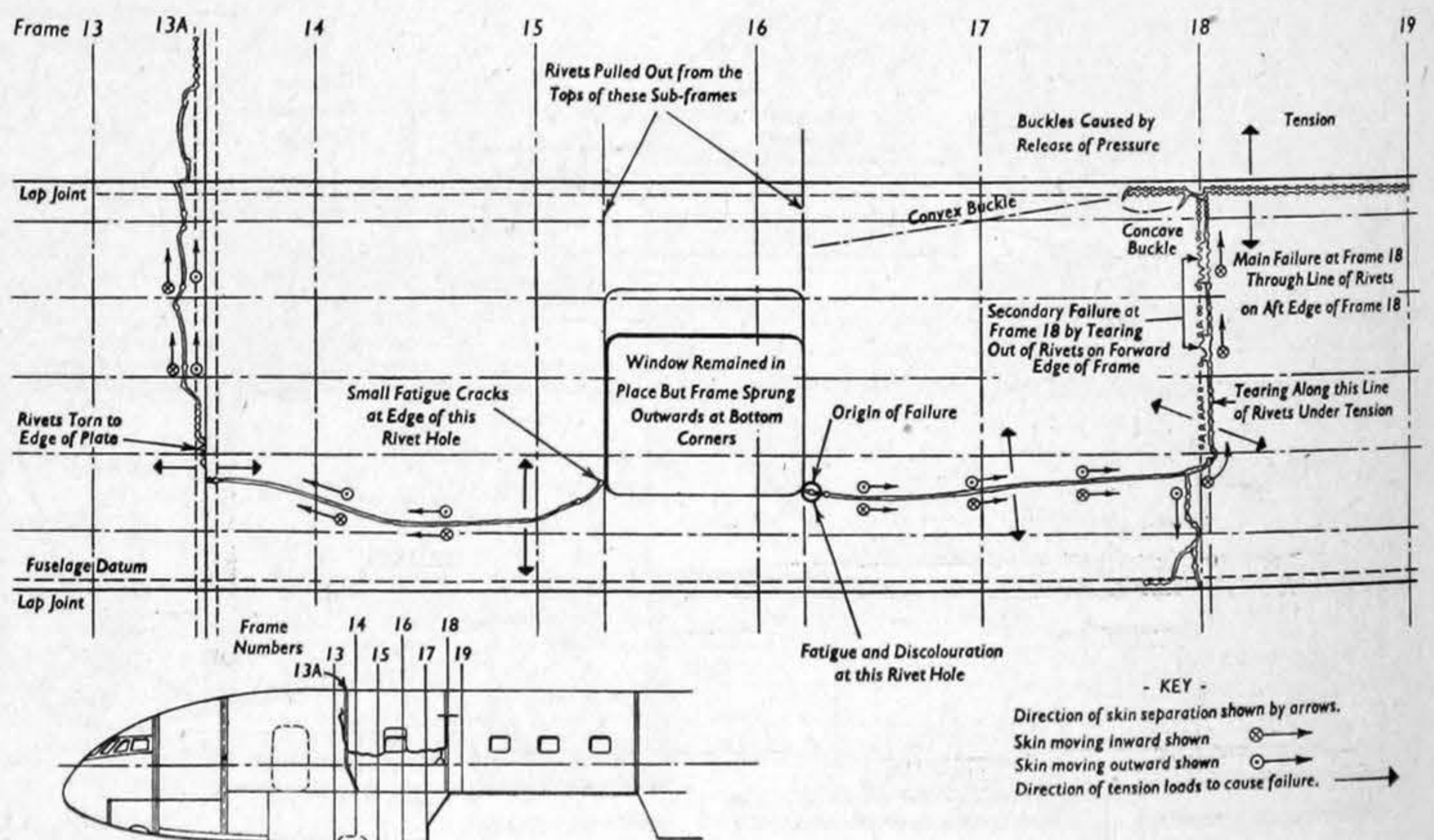


Fig. 2—The progress of the failure of the forward escape hatch on the port side. "Comet" G-ALYU

* Published C.A.P. 127, Ministry of Transport and Civil Aviation. Price 8s.

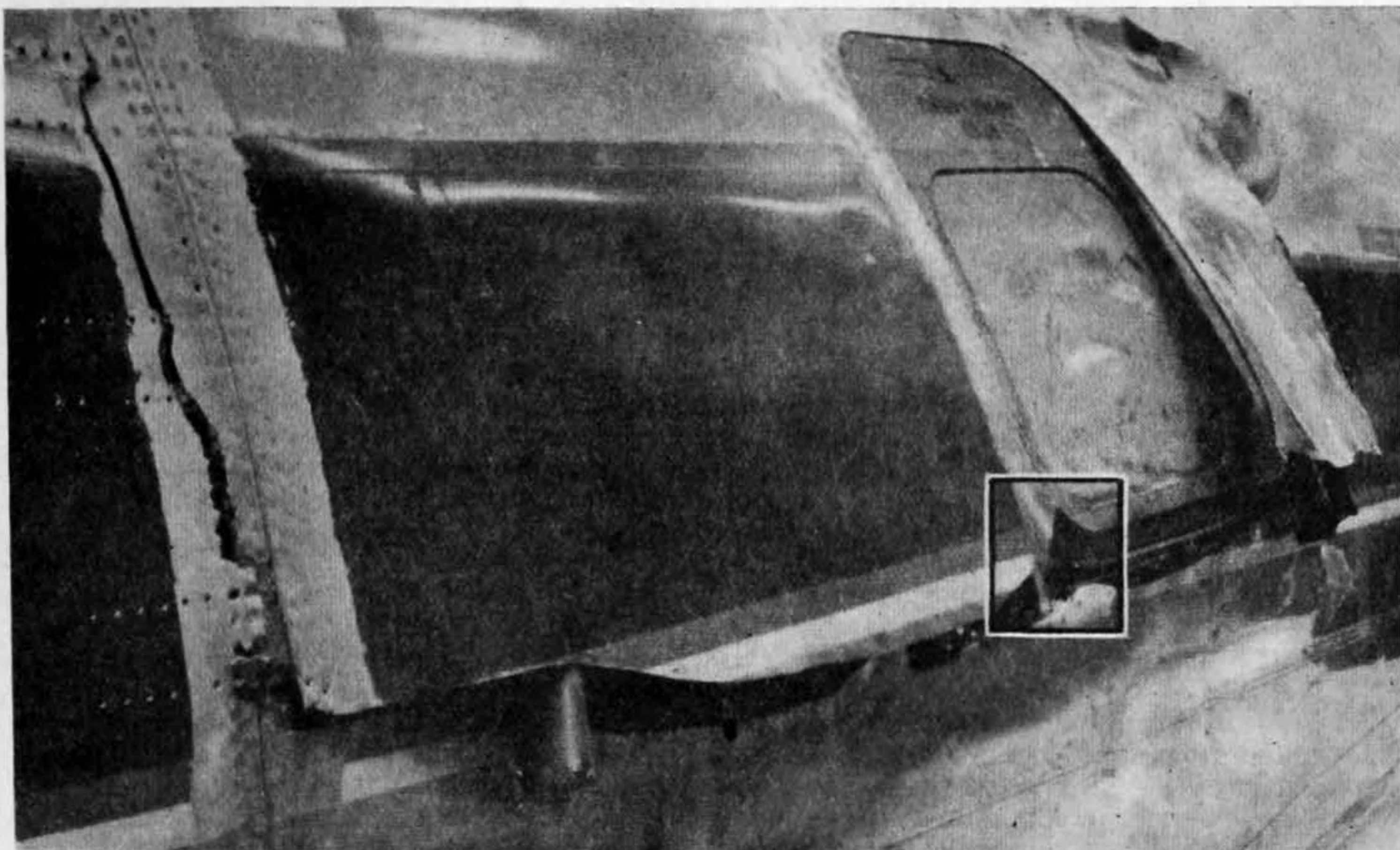


Fig. 3—Failure of front fuselage at 10.4 lb per square inch (3057 total flights). Looking aft

designers, and the strain gauges were therefore fixed to the surface of the skin, at various positions near the corners of typical windows, including the window corresponding to the one which had failed but on the other side of the cabin.

A discussion of the evidence bearing on the reliability of the estimates of the stress at the edge of the window will be found in (later) paragraphs. It is sufficient here to say that I am satisfied that the highest stress in the skin, at the edge near the corner of the window of "Yoke Uncle," was probably over 40,000 lb per square inch when the pressure difference was 8½ lb per square inch and that the general level of the stress in the skin in these regions was significantly higher than had been previously believed. In the light of known properties of the aluminium

under repeated loading, there will be appreciable differences between the number of cycles of application of given loading before failure occurs. Experience suggests that there will be a variation of at least 9 to 1 in the number of cycles necessary to produce failure when the general level of stress is high, and the number of cycles undergone before failure, therefore, low. If a large number of specimens could be tested, it would undoubtedly be found that the weak and the strong were relatively few in number, and that the majority would be more or less evenly distributed round a mean value. But it is impossible from a single test to say where, in the total range to be expected from general experience a particular specimen lies.

At the time of the Elba accident "Yoke Peter" had made 1290

pressurised flights, and at the time of the Naples accident "Yoke Yoke" had made 900 pressurised flights. Sir Arnold Hall said in evidence that in the light of the experiment on "Yoke Uncle," and of the measurements and calculation of stress referred to above, he considered that the cabin of "Yoke Peter" had reached a point in its life when it could be said to be in danger of failure from fatigue, and that the cabin of "Yoke Yoke" would similarly be in danger. Dr. Walker said that he did not regard the picture presented by the three failures (on the assumption that these were all due to the same fundamental cause) as surprising, since the three results taken

together are consistent with general experience of the strength under repeated loading of a number of nominally identical structures, in which the stress level is high. They lie within a range of just over 3 to 1, whereas experience suggests a total range of at least 9 to 1.

At this stage in R.A.E.'s attack on the problem, it seemed unlikely that any more wreckage would be recovered which would throw light on the problem which was now obviously the chief one. But after a further review R.A.E. reached the conclusion that search in a wider area was justified. Whatever the cause of the bursting, it seemed probable that the disruption of the aircraft would have resulted in some relatively large pieces of the structure being blown clear.

(To be concluded)

Ferritic Steels at Low Temperatures

IN a paper entitled "The Mechanical Properties of Ferritic Steels at Low Temperatures," recently delivered to the Institution of Refrigeration, Dr. N. P. Allen showed how heat-treatment can lower the temperature at which embrittlement of iron and steel occurs and the effect of the addition of various elements. In his discussion on the behaviour of ferritic materials at low temperatures, he paid particular attention to some features of the work carried out over the past few years at the Metallurgy Division of the National Physical Laboratory. He noted that there is much interest at the present time in the properties of ferritic steels at low temperatures or under conditions where notches are present in a structure. Mainly because of the extended use of low temperatures in chemical engineering, of the use of aeronautical and military equipment at moderately low temperatures, and of the failures of welded structures particularly in cold weather. The cheapness and availability of ferritic steels are such that these materials have to be used as extensively as possible and a knowledge of the limitations of ferritic steels and of the factors that influence their properties is therefore important to engineers who have to design equipment to withstand particular combinations of conditions of stress and low temperatures.

Dr. Allen described the properties of high-purity iron, the modifications to the behaviour of iron produced by certain impurities and alloying elements, the effects of the two elements, carbon and manganese, which are present in all steels and ended with a discussion of the properties attainable in some hardened and tempered commercial steels. The paper stated that pure polycrystalline iron shows a brittle behaviour in a notched bar test at about -15 deg. Cent. but does not become brittle in plain tension until much lower temperatures of about -150 deg. Cent. are reached, while a single crystal of iron at -196 deg. Cent. is either ductile or brittle according to the direction of the stress.

Phosphorus was stated to have a detrimental effect on the properties of iron because it raises the temperature of transition from a tough to a brittle fracture. Some detailed results were also given to show the adverse effect of phosphorus in a heat-treated 1½ per cent manganese-molybdenum steel and brought out the importance of hardening fully prior to tempering. According to the paper, the behaviour of polycrystalline material is further complicated by the fact that some elements, e.g. oxygen, nitrogen or phosphorus in iron, reduce the brittle fracture stress by weakening the grain boundaries to such an extent that brittle fractures may take place partly or wholly along the grain boundaries. The sensitivity of this effect to heat-treatment is illustrated by the remarkable grain-boundary weakness that can be developed in iron-nitrogen alloys. Steel differs from pure iron principally in containing carbon and manganese and the effects of carbon and manganese separately and together on the properties of iron at low temperatures were described. It was mentioned that the effect of carbon on iron depends upon the heat-treatment and on the quantity present and that when slowly cooled from the austenitic condition steels of all carbon contents are brittle at -196 deg. Cent., while steels of very low carbon content (below 0.05 per cent carbon) are much improved both in strength and toughness at low temperatures by being cooled rapidly. The paper stated that steels containing enough carbon to be hardened are embrittled by this treatment and that excellent properties can be obtained at -196 deg. Cent. from steels containing 1 to 2 per cent of manganese and 0.05 per cent of carbon suitably heat-treated.

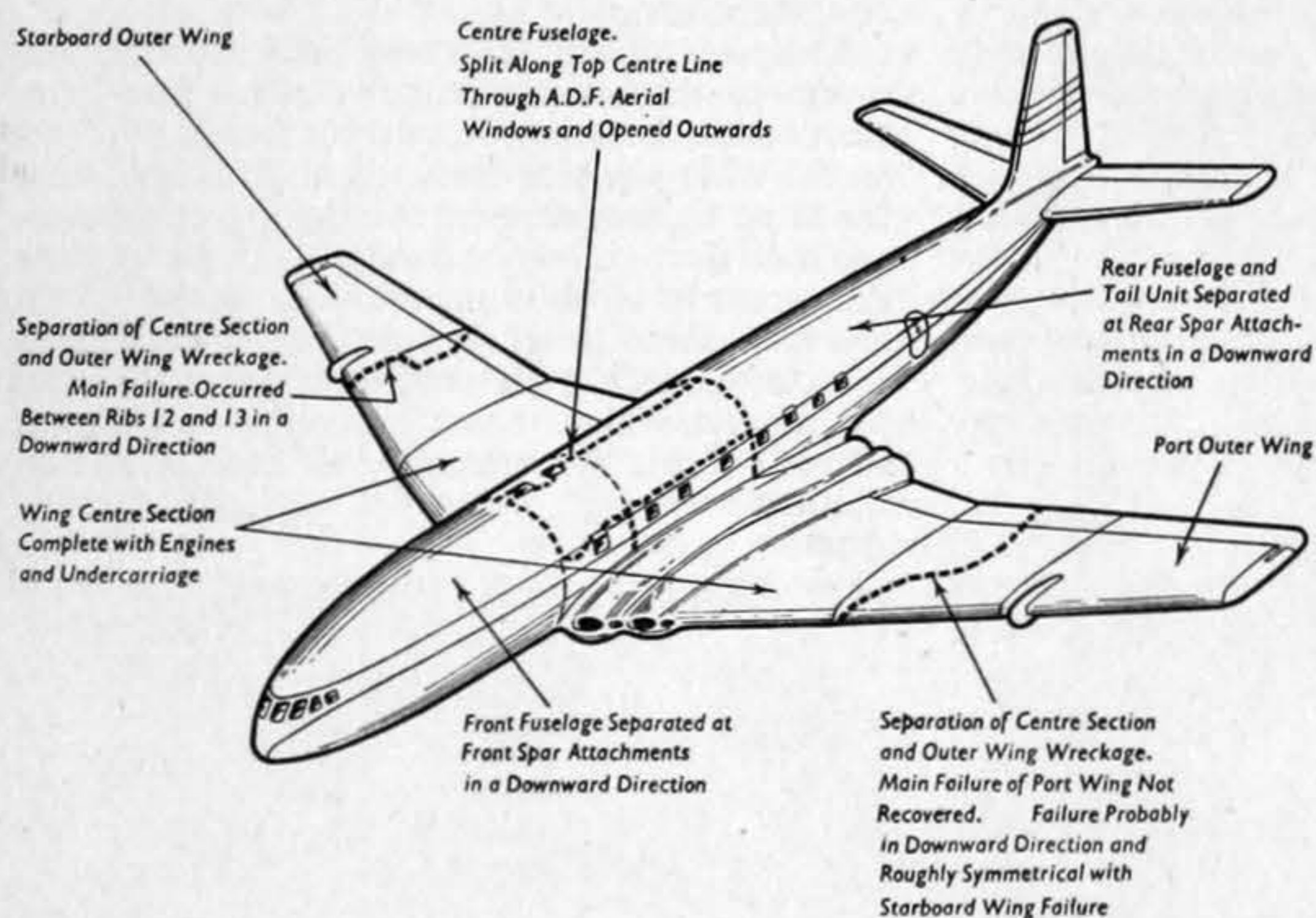


Fig. 4—Location and direction of main failures. "Comet" G-ALYP

alloy D.T.D. 546 or 746, of which the skin was made and in accordance with the advice I received from my assessors, I accept the conclusion of R.A.E. that this is a sufficient explanation of the failure of the cabin skin of "Yoke Uncle" by fatigue after a small number, namely, 3060 cycles of pressurisation.

In considering the possible bearing of this result on the accidents at Elba and Naples, it is necessary to recognise that there are inevitable differences between individual aircraft structures built to the same drawings. The nature and extent of these depend on a number of factors, such as variations in the thickness of metal sheet of nominally the same gauge, and local regions of high stress due to the methods employed in joining the various parts, such as rivets, bolts, &c. If a number of such structures are tested

INELASTIC BEHAVIOUR OF DUCTILE MATERIALS UNDER DEAD LOAD.—We have received a copy of Bulletin No. 426 of the Engineering Experiment Station of the University of Illinois, which has the above title. Experimental data for dead load tests of various ductile members are given in the bulletin, concerning tests of conventional duration, and also of tests covering longer periods; in particular the time effects of inelastic, dead loading of steel and aluminium members is considered.

Electronic Digital Computers

No. II—(Continued from page 233, February 18th)

In this country electronic digital computers are nearing a stage in their development at which they may be applied generally in industry and commerce, for various processes involving very rapid computations or analysis of statistical data. Because of their high cost these computers have, in practice, hitherto been available only to very large organisations. In this and subsequent articles we refer, briefly, to the activities in this field, of some British firms. This article deals with the "DEUCE" computer, made by The English Electric Company, Ltd., which has recently introduced a computing service in Stafford.

WE recently visited the Nelson Research Laboratories of the English Electric Company, Ltd., Stafford, to attend the first demonstration of a new electronic digital computer. This machine, which is known as the Digital Electronic Universal Calculating Engine ("DEUCE"), is the result of intensive development of ideas that were first proposed at the National Physical Laboratory, Teddington, soon after the 1939-45 war. After a logical design had been worked out on paper, Sir Charles Darwin, who was then director of the N.P.L., approached Sir George Nelson with the suggestion that the English Electric Company should assist the N.P.L. scientists with the development of an Automatic Computing Engine ("ACE"). As a result of the collaboration that sprang from this suggestion, the pilot version of "ACE" was completed and put into operation in the Mathematics Division of the N.P.L. in February, 1952.

The success with which this pilot "ACE" tackled problems presented by Government Departments and industry encouraged the English Electric Company to embark on the production of a fully-engineered version of "ACE," making use of detailed improvements suggested by the extensive operational experience obtained with the pilot model. Through this work the company has now developed a new electronic digital computer, "DEUCE" (Fig. 5), which is in commercial production.

To make the facilities of a computing service available to organisations that cannot make full-time use of such a machine, a computing centre has been set up in the Nelson Research Laboratories at Stafford, and the company is shortly to establish another centre in London. A "DEUCE" computer manned by a team of mathematicians and operators will be available at each centre. A maintenance organisation is also being set up to ensure that the machines are kept in optimum condition.

For initiating scientists, mathematicians and machine operators in the actual use of machines supplied to their organisation a training service

will be available, based on the two computing centres. A library of information is being set up in which will be recorded the programmes and sub-routines which have been worked out for the solution of problems, and this information can be made available to customers if required. Finally, a development programme is in hand to add other information-handling equipment, such as magnetic tape, to enable the machine to process different forms of mathematical and experimental data.

Like all other high-speed digital computers, "DEUCE" is designed to carry out elementary arithmetical operations, such as addition, subtraction, multiplication and division, together with some logical operations of which the most important is the ability to proceed along one of two alternative paths at specified points in the calculation, depending on the results obtained up to these points. To make effective use of the great speed available the machine must be supplied with the "programme of instructions" which it is to carry out. This is coded into numerical form and is fed (using a punched card system, as described below), together with numerical data on which it is to operate, into the machine's storage system.

All operations in the computer itself are carried out in the binary scale of arithmetic; the digit 1 is represented by an electrical pulse and the digit 0 by the absence of a pulse. Numbers and instructions are therefore represented by sequences of pulses at intervals of 1 microsecond. A train (or "word") of thirty-two such pulses is used to represent either a number (equivalent to nine decimal digits with sign) or an instruction. To handle these numbers and instructions there are two forms of storage. The first form of store is closely associated with the computing circuits and is immediately accessible; it includes twelve mercury delay lines (Fig. 7), each storing thirty-two words, together with ten shorter lines of various lengths, which are used as accumulating registers, &c. The second store, which is of large capacity (8192 words, or 262,144 digits) is provided by a

magnetic recording drum (Fig. 6), which is rotated synchronously. Information can be written on to 256 tracks on this drum by means of a set of 16in "writing" heads and can be abstracted at any time by a second set of "reading" heads and transferred thence to the computing circuits. The two sets of heads can be moved into any one of sixteen positions (sixteen heads and sixteen positions to cover 256 tracks) by a high-speed shifting mechanism, operated by a closed-loop servo-system, to give access to any track in 25 milliseconds. The fact that this access time is slow compared with the speed of operation of the computing circuits is immaterial, however, because useful work can be carried on during this transfer time and because transfer operations are required relatively infrequently.

Each "instruction word" in the input specifies some transfer within the machine, and therefore determines the source (that is, the position in storage, &c.) from which a number is to be extracted, and the destination to which it is to be sent. To achieve maximum speed optimum coding is used: each instruction specifies both the timing and duration of the current transfer as well as the position in the store from which the next instruction is to be taken. This system avoids the loss of time which must otherwise occur if instructions are placed consecutively in the store, causing the computer to halt after each operation until its next instruction is emerging from the mercury delay line in which it is stored.

Accordingly, it is possible to perform all the elementary operations (such as addition and transfers between storage positions) in 64 microseconds. The only exceptions are multiplication and division, which require 2 milliseconds. During this time, however, all other facilities in the machine are available for doing other operations simultaneously with the multiplication or division.

Normally the input of information to the computer and the output from it are produced on Hollerith eighty-column punched cards of standard form. Use of a card punch instead of a printer on the output enables the maximum speed of the computer to be utilised; subsequent sorting and printing can then be carried out on standard machinery without occupying valuable computer time.

Each input card can carry twelve instructions or up to thirty-two decimal digits. The latter can consist, for example, of three 9-digit numbers (each with sign) or several smaller numbers. Input of information in sterling or other non-decimal form is also possible. The computer can convert these numbers into binary form and send them to its storage system when cards are being read at the maximum speed of 200 per minute. The reverse process is carried out at the output, the speed in this case being 100

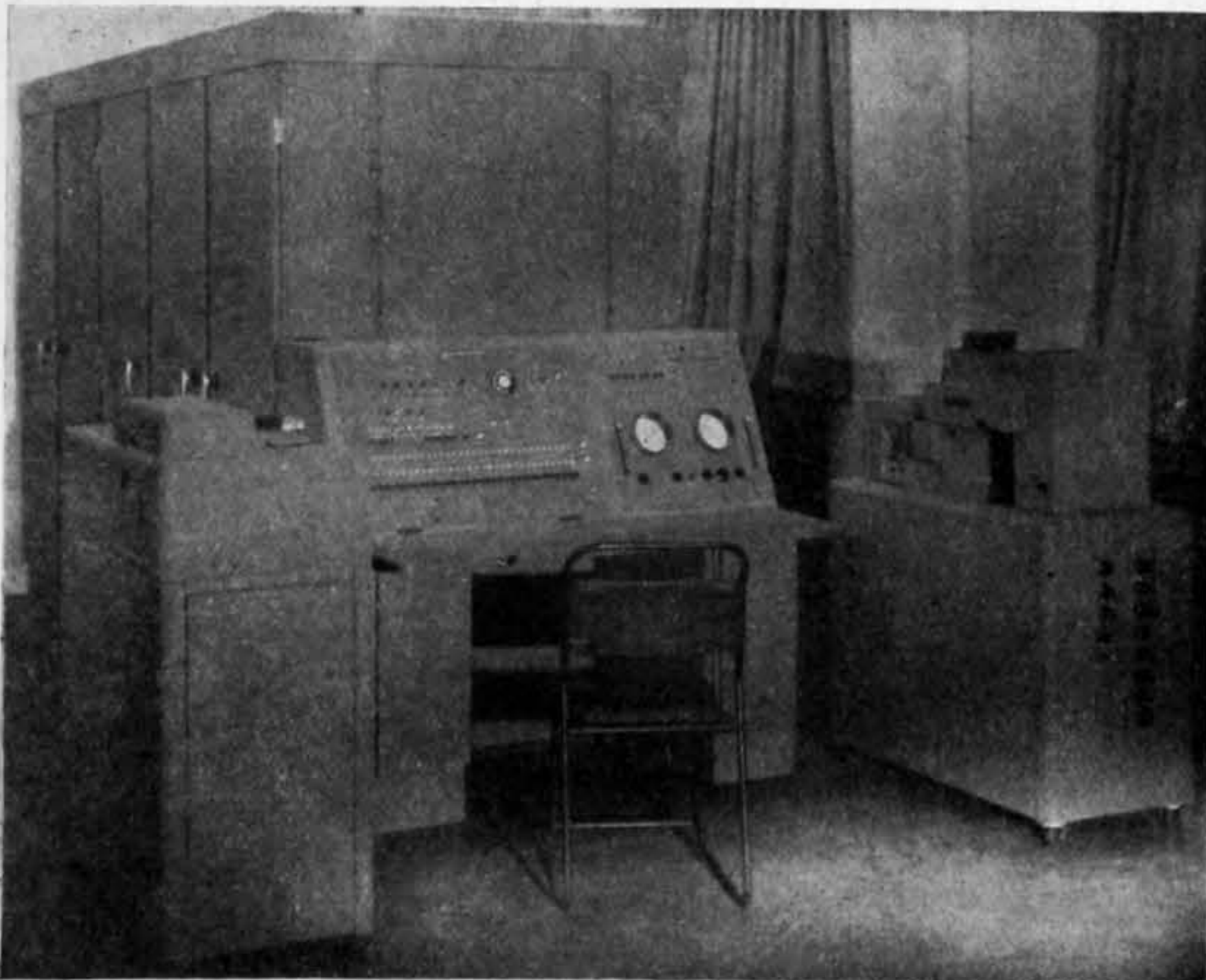


Fig. 5—Digital electronic computer known as "DEUCE." The main electronic components are housed in an assembly of vertical cabinets. In front of it is the control desk which is flanked by the input and output punched card machines

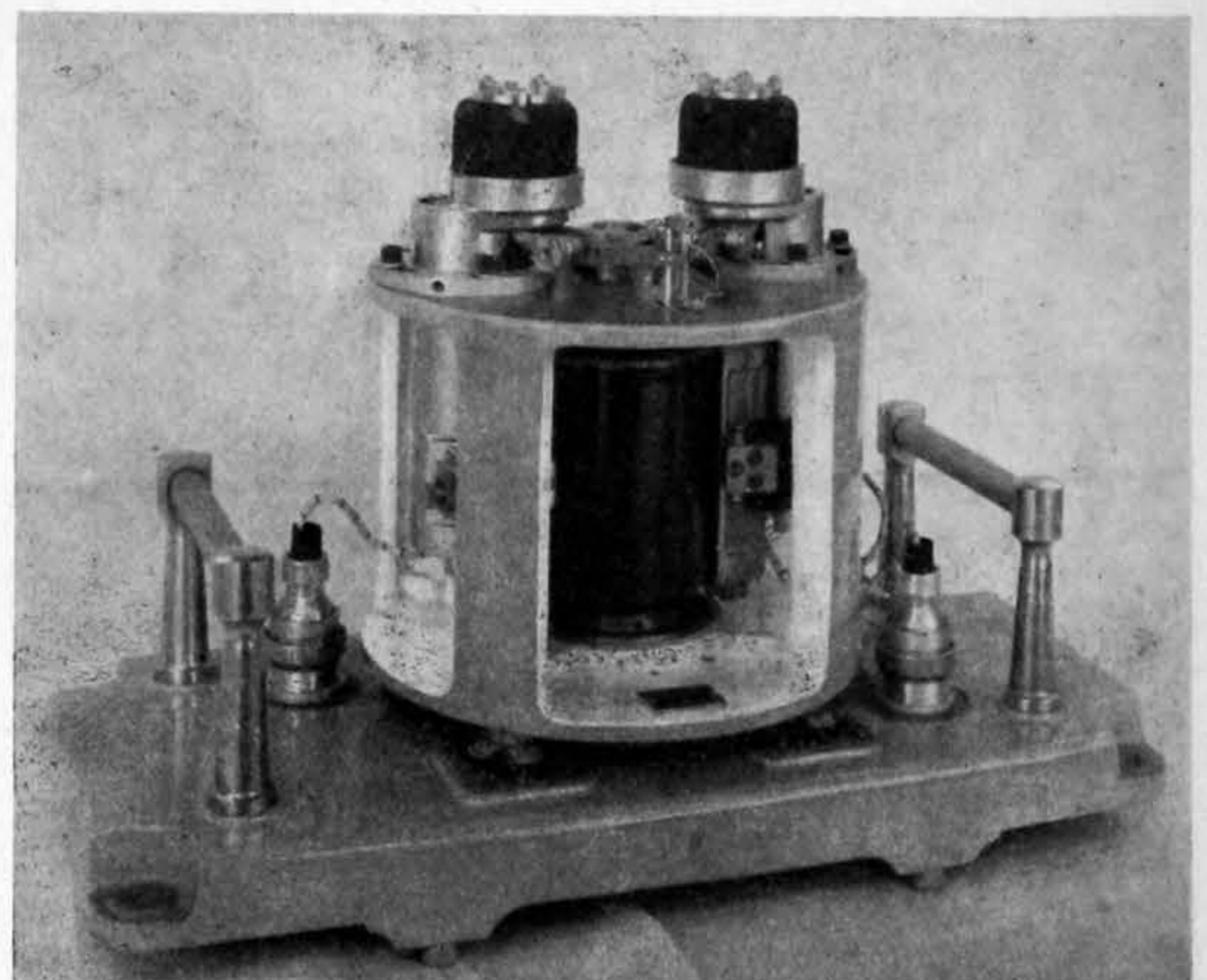


Fig. 6—The magnetic drum which can store 8192 words on 256 tracks. The two independent servo-operated drives for the writing and reading heads are mounted on top. One of the sets of heads can be seen bearing on the surface of the drum to the right

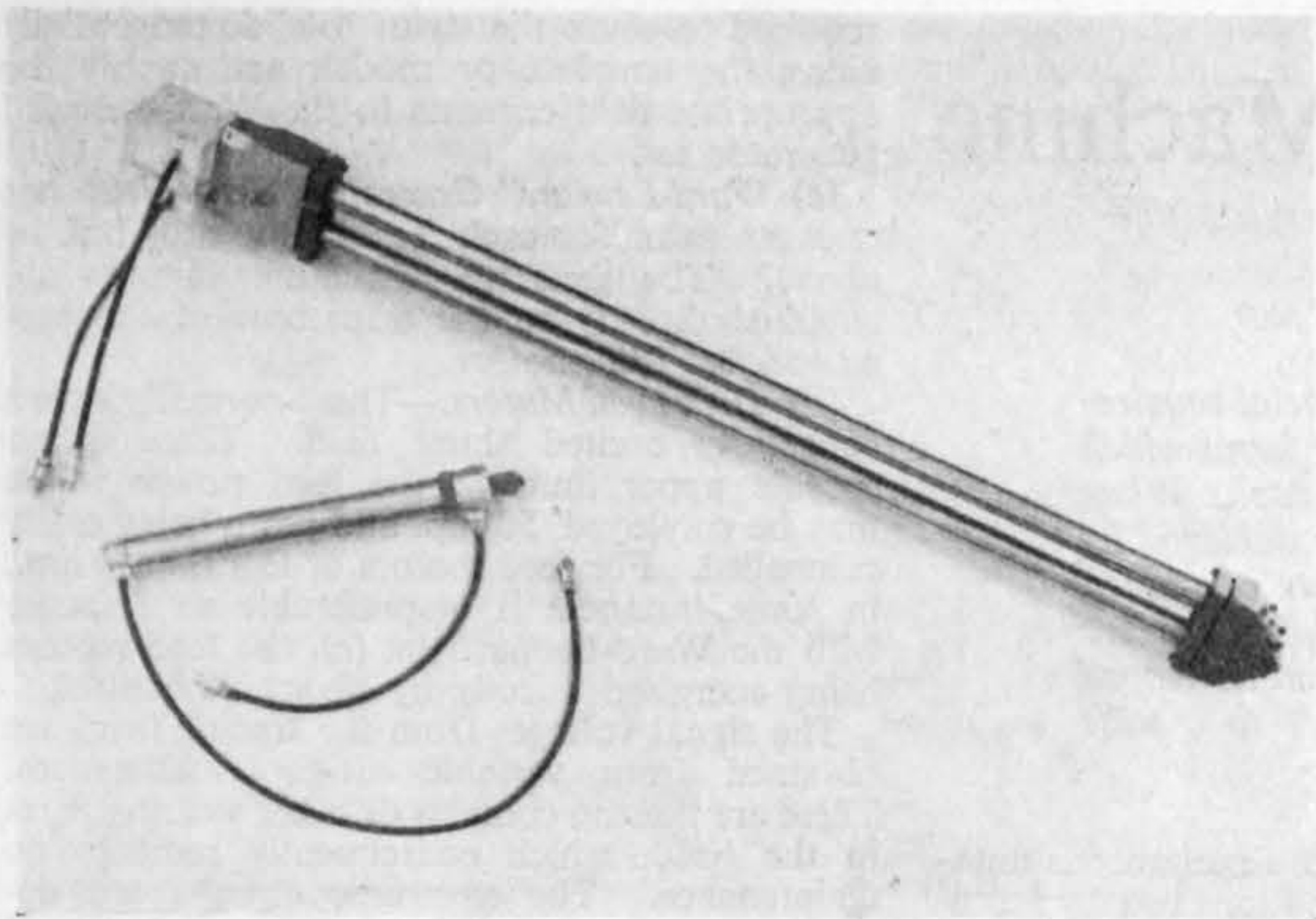


Fig. 7—Typical mercury delay lines which provide storage with immediate access to the computer circuits. There are twelve of the longer mercury delay lines, each with a storage capacity of thirty-two words, and there are ten shorter delay lines to serve as accumulators, &c.

cards per minute, corresponding to about 50 decimal digits per second. The computer is designed so that it can be used with punched paper tape or magnetic tape instead of, or in conjunction with, the standard punched card input and output machinery.

The general arrangement of the computer is shown in Fig. 5.

The main electronic units and the magnetic store are housed in an assembly of nine vertical cubicles, each containing about eight chassis (Fig. 8). Together with the control desk it occupies a floor area of 14ft by 4ft 6in. Access is by doors to the components on one side of the chassis and by a central "corridor" to the valves which are all on the inward facing side of each chassis. The total number of valves used is about 1300; they are all of standard miniature types. The mercury delay lines (Fig. 7) other than short lines of one, two or four-word lengths each, are contained in a thermostatically controlled drum 3ft in diameter and 3ft 6in high (Fig. 9), located a convenient distance away from the main electronic units. A power supply unit takes power from the standard mains and converts it into suitable supplies for the machine. Isolation from the supply mains by means of a motor alternator is not necessary. The power unit can be housed at any appropriate distance from the main machine and is remotely operated from the control desk. The input and output punched card units stand on either side of the control desk, as illustrated in Fig. 5. Because the power consumption of the computer is nearly 7kW, provision is made for connection to a forced ventilation system removing heat from the machines so that the room temperature is not unduly raised.

Safeguards against faulty operation of the computer are based on the consideration that faults are of two general kinds. The first kind is caused by sudden failure of valves or components; although such failures are unpredictable they occur more frequently on switching on or off and interruption of useful work is therefore unlikely to be caused by this kind of fault. The second and more troublesome kind of fault is that resulting from slow variation of the characteristics of components. Such changes can be detected in the "DEUCE," before their effect can cause trouble, by the use of the marginal checking facilities which are provided.

A series of test programmes is available which check the operation of each part of the machine in turn. In the event of faulty operation the result obtained indicates the nature of the fault. The fault can then be accurately located by application of the marginal checking facilities to individual elements of the suspected group of circuits. Correct performance of the test programmes under the marginal conditions, which can be applied from the control desk, ensures that the machine will operate satisfactorily during the next operating period.

As stated earlier, the solution of problems on a digital machine must be preceded by the pro-

duction of the programme of instructions for those particular problems. The "DEUCE" has been provided with programme test facilities to assist the programmer in this preparation. There is, for example, a "programme display" facility which causes the programme to be executed step by step at 20 steps per second. Instead of punching out results the output punch is used to punch out each instruction as it is obeyed. Comparison of the output cards with the intended sequence of operations will indicate the points of failure of the programme, with a considerable saving in machine time as compared with the usual method of proceeding step by step under manual control and observing the progress of the calculations on a monitor showing the contents of storage locations.



Fig. 9—Thermostatically-controlled drum container for the longer mercury delay lines. This container is positioned at any convenient distance from the main cubicle assembly and control desk

Monitoring facilities are provided, enabling the contents of any storage location to be examined, for use for some aspects of programme testing and machine testing.

Many of the problems so far solved on the pilot "ACE" and the "DEUCE" are typical of the numerous engineering problems that involve the solution of large sets of linear algebraic simultaneous equations. Whereas the solution of a set of 60 such equations would be impracticable by traditional desk computation methods, the total time required for solution on the "DEUCE," including the input of information and output of the solutions on punched cards, is eighteen minutes. The largest set of simultaneous equations so far solved by the "DEUCE"

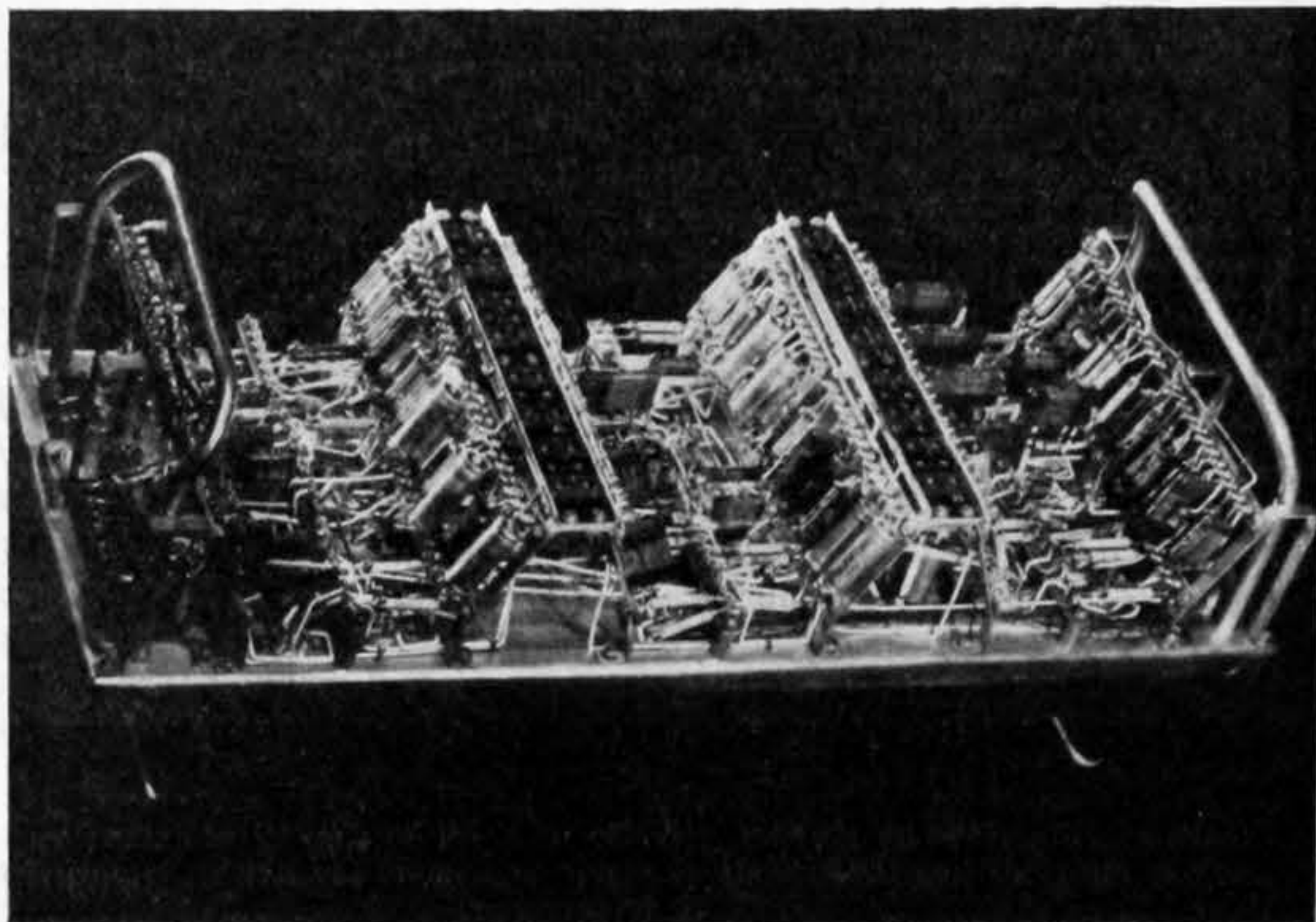


Fig. 8—Typical chassis carrying electronic equipment. Some eight chassis are contained in each of the nine cubicles, making up the main computer assembly. The total number of valves is about 1300 and the total power consumption is 7kW

was a set of 115 equations with 37 right-hand sides.

Many problems in engineering require the determination of the largest latent root of a matrix of high order. This determination is usually made by an iteration process and the length of time for obtaining the root is determined by the number of iterations required for a given accuracy dependent on the particular problem. However, for a general case the time required can be estimated from the fact that input of the coefficients for a matrix of order 60 requires six minutes and each iteration requires one minute.

Another common class of problem involves the solution of sets of linear differential equations. A set of 60 such equations requires six minutes for input of coefficients, two minutes for each step of a Runge-Kutta process and one minute for the output of results at any step. Usually results are not required after every step and in many cases are only necessary after every fifth or tenth step.

Generalised mathematical problems such as these occur in many branches of engineering. In particular, the techniques mentioned have been applied in determining the structural design and aerodynamic behaviour of the "Canberra" and the "PI" aircraft.

In heavy engineering the company has used digital computing in the calculation of surge tank oscillations in hydro-electric power stations and in the determination of the critical speeds of a multi-span shaft for what is believed to be the largest turbo-alternator built in this country. In light current engineering, the Marconi Company has been helped in electron optics and filter design.

During the demonstration that we attended recently at the Nelson Research Laboratories, we saw the computer being used to solve a number of problems. For example, an analysis was made of the allocation of overheads as between the factories in a company group and the products of those factories. A task that would have required two man-days, using desk calculators, was completed by the computer in one and a half minutes.

(To be continued)

BRUSSELS AIRPORT TRAIN SERVICE.—The C.I.C.E. information bulletin of the European Railways Administration states that in May next a new railway connection between Brussels and the Melsbroek airport will be placed in service. For this service a special platform has been reserved at Brussels central station and every half-an-hour a diesel railcar will carry air passengers from the centre of the city to the air terminal. It is planned to build a railway station a few yards from the airport entrance with two passenger and an intermediate freight platform. The Brussels-Melsbroek line will follow the Brussels-Louvain railway as far as Zaventem, from which point a single track connection 5½km in length leads to the airport. This is a temporary measure until the air station itself is moved and reconstructed, when the railway station will be permanently constructed about 1200m from the Brussels-Louvain electric line. The railway connection to the airport will then be electrified and will probably be made by an underground tunnel.

Electronic Tracer Control of Machine Tools

By J. A. STOKES, B.Sc.*

Automatic control of machining operations is now a recognised industrial requirement, especially when applied to the production of workpieces having forms which are not inherently simple to obtain by manual control of a machine tool. When such workpieces are to be produced, considerable economies may be achieved by supplying the machine with "information" in the form of a template or model, the shape of which can then be reproduced automatically as the workpiece. Here we describe several forms of tracer control equipment which have been developed by the British Thomson-Houston Company, Ltd., and are applicable to a wide range of machine tools.

TRACER control equipment may be used to control any number of feed motions on a machine tool. They may include angular motions (i.e. cutter tilt) in addition to the more normal linear feed motions. Applications involving simultaneous control of one, two and three-feed motions are described below. They are generally applicable to the following fields:—

(1) *Single Dimension*.—(i.e. automatic control

(2) *Two Dimensions*.—(i.e. simultaneous automatic control of two feed motions usually mutually at right angles—sometimes called 360 deg. tracing). For example: saddle and table feeds on vertical milling machines; ram and cross traverse on boring mills; table and headstock feeds on horizontal boring and milling machines.

(3) *Three Dimensions*.—(i.e. automatic control of three mutually perpendicular feed motions).

Vertical and horizontal boring and milling machines.

Equipment can also be supplied for machines requiring control of cutter tilt about either one or two axes. Such machines are generally designed for milling light alloy forgings for the aircraft industry.

ELECTRONIC CONTROL EQUIPMENT

The control equipment is entirely electrical in character and includes the following main units:—

(a) *Tracing Head*, the movable stylus of which contacts the master form (i.e. the template or model) causing a small deflection of the stylus. This produces in the tracing head control voltages which are supplied to the electronic control circuits and amplifying system.

(b) *Electronic Control Circuits*.—These circuits determine the feed speeds and directions

required to cause the stylus to slide tangentially along the template or model, and supply the appropriate field currents to the Ward-Leonard generator set.

(c) *Ward-Leonard Generator Set*.—This has one generator for each feed motor of $\frac{1}{2}$ h.p. or above. The generator armature outputs are supplied directly to the armatures of the corresponding feed motors.

(d) *D.C. Feed Motors*.—These normally have a constantly excited shunt field. There is no specific upper limit to the feed power which may be employed, 50 h.p. and more being easily controlled. For feed motors of less than $\frac{1}{2}$ h.p., in some instances it is preferable to dispense with the Ward-Leonard set (c), the feed motors being energised directly by electronic control.

The signal voltages from the tracing head are obtained from variable air-gap inductances. There are thus no contacts or other wearing parts in the head, which consequently requires no maintenance. The electronic circuits are designed to ensure long life of all components, all valves being appreciably under-run and arranged so that changes in valve characteristics due to ageing do not have any significant effect on the performance of the equipment.

PROTECTION

In addition to any protective features which may be embodied in the machine tool design, the tracer control system has its own means of protection against mal-operation. Should the deflection of the stylus tip increase or decrease to a value outside its normal working range, the controlled feed motions are immediately stopped, thus preventing damage to the machine and frequently preserving a workpiece against attempts to trace at an excessive speed for the shape of that workpiece. The circuits also provide protection against failure of any portion of the control system or machine tool.

All a.c. and d.c. motors and generators are fully protected against overload, and the various controls are interlocked to minimise the possibility of mal-operation.

SINGLE, TWO AND THREE-DIMENSION TRACING

A more detailed consideration of these three forms of copying is given below. It must be emphasised that two and three-dimension control cannot be obtained by mere duplication or triplication of the equipment required for single-dimension control.

SINGLE-DIMENSION CONTROL

In this case only one motion of the machine is on automatic control, for example, the cross-

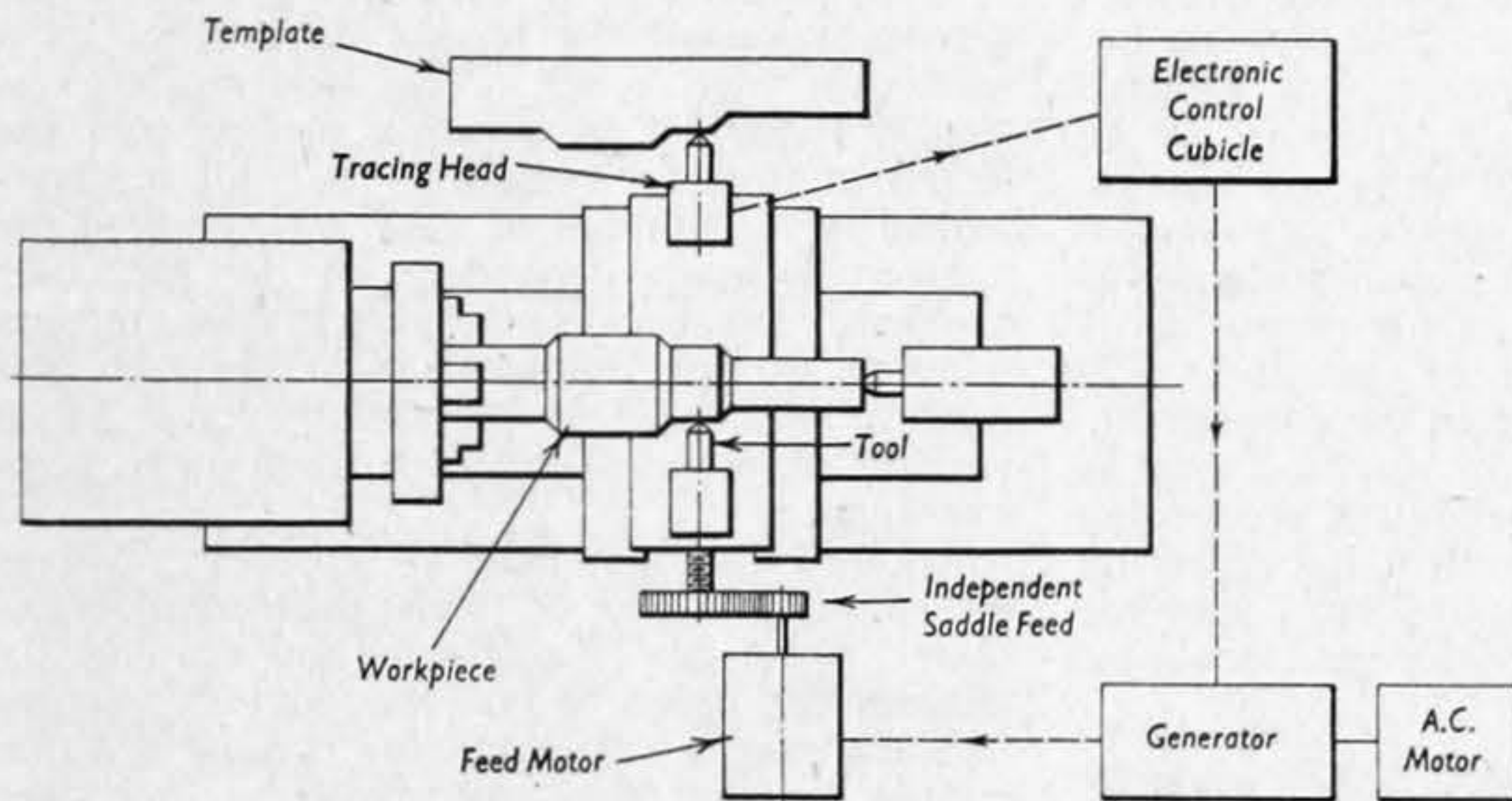


Fig. 1—Cross-slide of lathe moved by feed motor under electronic control (single dimension tracing)

of one feed motion only). For example: cross slide motion of lathes; ram feed of boring mills; spindle feed of horizontal boring and milling machines; cutter rise and fall on horizontal millers.

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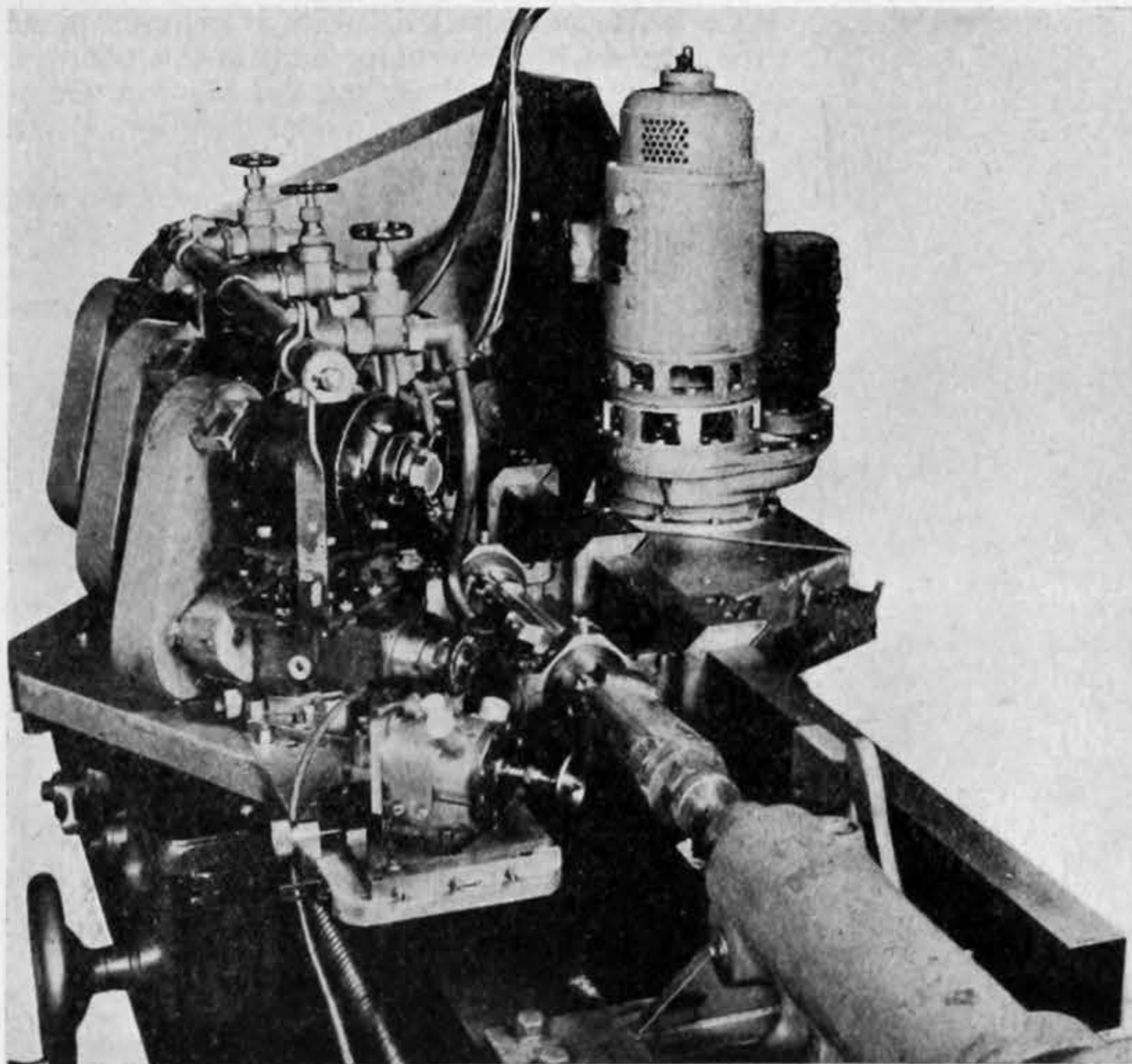


Fig. 2—Machining of eccentric workpieces. In this example, three milling cutters are machining nine blocks of high-tensile steel under the control of the tracing head in the foreground

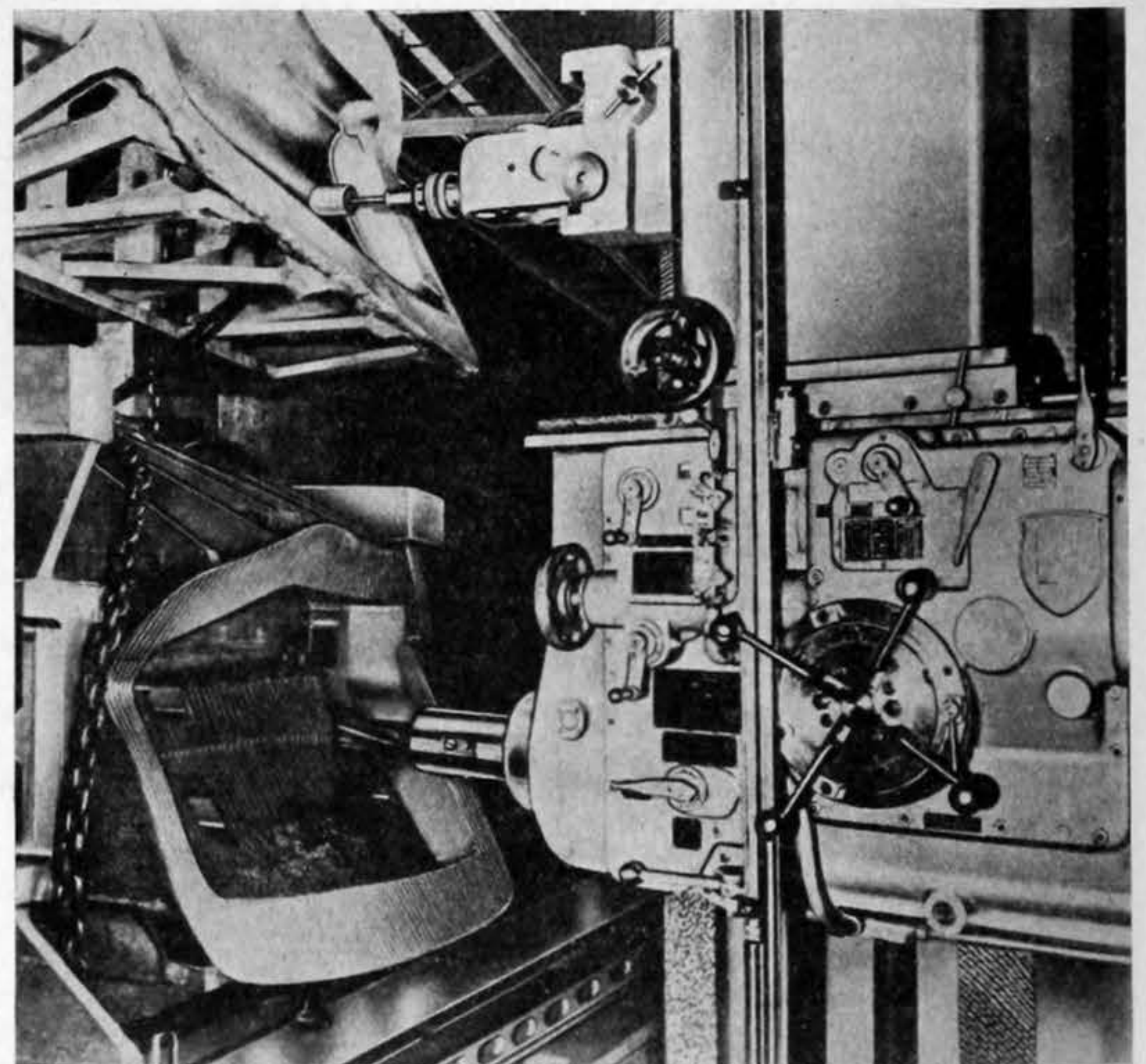


Fig. 3—Three-dimension machining of complicated workpiece on horizontal borer

slide of a lathe. A constant feed is applied to the lathe saddle, and the cross-slide is moved by the feed motor under automatic control to maintain the stylus head mounted on the cross-slide in contact with the template, which is carried from the bed of the lathe (see Fig. 1).

A limitation of many systems of this type arises if the motion under automatic control is required

motion on automatic control executes a reciprocating motion as the workpiece revolves. An example of this kind of application is shown in Fig. 2.

TWO-DIMENSION CONTROL

In a simple single-dimension copying system the direction of motion of the tool cannot lie parallel to the slideways of the tracer-controlled feed. On lathe work, the effects of this limitation can be mitigated by inclining the slide at an angle to the bed (usually 45 deg.), thus permitting the turning of square shoulders. However, if the workpiece is such that this limitation cannot be avoided, for example, if the cutter path is to describe a closed loop round the work, then a two-dimension control scheme must be employed. Two-dimension control can also be employed with advantage to maintain a constant feed speed over the surface of the work—a condition which cannot normally be achieved with a single-dimension system.

The two-dimension system employs two

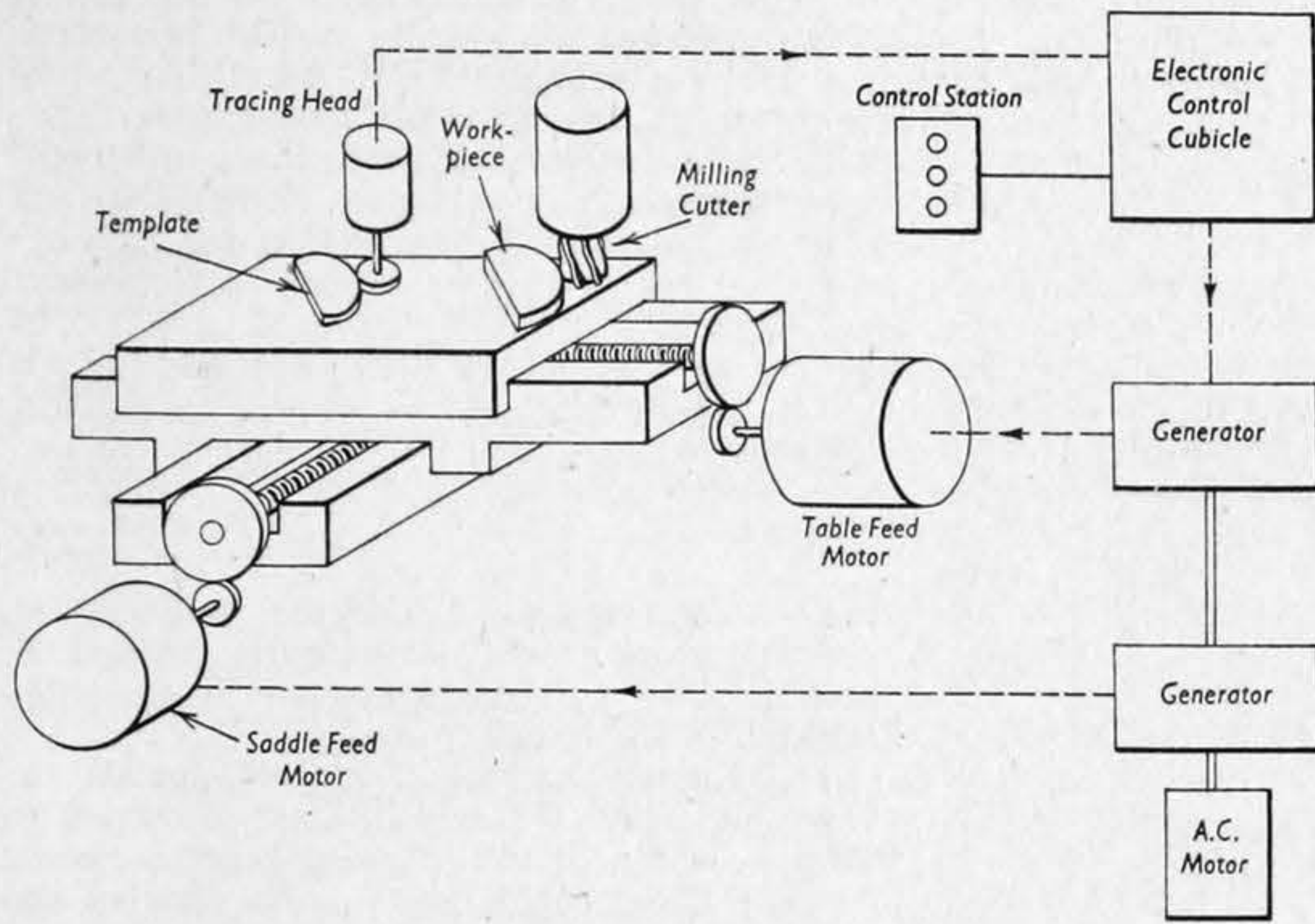


Fig. 4—Two-dimensional control of vertical milling machine

to move with appreciable velocity while cutting, say, 10in per minute or more. The stylus deflection required to produce such velocities becomes appreciable, and causes an error in the size of the workpiece.

The B.T.H. electronic system will maintain a controlled feed of 60in per minute with a change in stylus deflection of only 0.001in. This high sensitivity permits the accurate machining of rapidly changing contours, including non-circular workpieces. In the latter case, the

separate feed motors, each driving one of the two feed motions, which are normally at right angles (see Fig. 4).

The tracing head (Fig. 6) is sensitive to deflections parallel to both feed motions and gives an output signal from which both the amplitude and direction of stylus deflection can be obtained. From this signal the electronic circuits (Fig. 5) determine the correct feed speeds and directions required in the two feed motions to cause the stylus to move tangentially along the template maintaining a constant working deflection which can thus be allowed for by making the stylus tip larger in radius than the cutter by the amount of this deflection. The equipment may be set up to work with any chosen deflection from 0.005in to 0.040in depending on the application.

The feed speed is maintained at the chosen value irrespective of the direction of motion of the stylus; the feed speed can be preset or changed during cutting within a range of 10 : 1. This range can be extended by change gears.

The actual feed speeds attainable depend upon the accuracy requirements, the shape of the workpiece, and the mechanical properties of the machine tool. These are considered again later, but in a typical case, feed speeds of 2in per minute can be used with copying errors not exceeding 0.001in, up to 5in per minute for 0.002in error and 10in per minute for 0.004in. Higher speeds of 60in per minute and more can be provided, but the errors depend heavily on the shape of the workpiece. If this is of a gently curving nature, errors may be held to 0.005in or less.

The operator is usually provided with a "steering" control, which permits him to steer the tool in any desired direction when the tracing head is free of the template. This control can be used for roughing operations and for directing the stylus towards the template. When the stylus meets the template the system automatically changes over to stylus control, and will follow completely round the template in either direction as selected by a switch.

THREE-DIMENSION CONTROL

Horizontal boring and milling machines are normally used for milling large three-dimensional forms, such as dies and punches, for the manufacture of pressed steel parts. Both vertical and horizontal machines are used for smaller work. In either case it is necessary to control three motions of the machine to produce the required form.

In the majority of cases it is satisfactory to carry out the work in a series of parallel cuts across the workpiece, as shown in Fig. 3. The

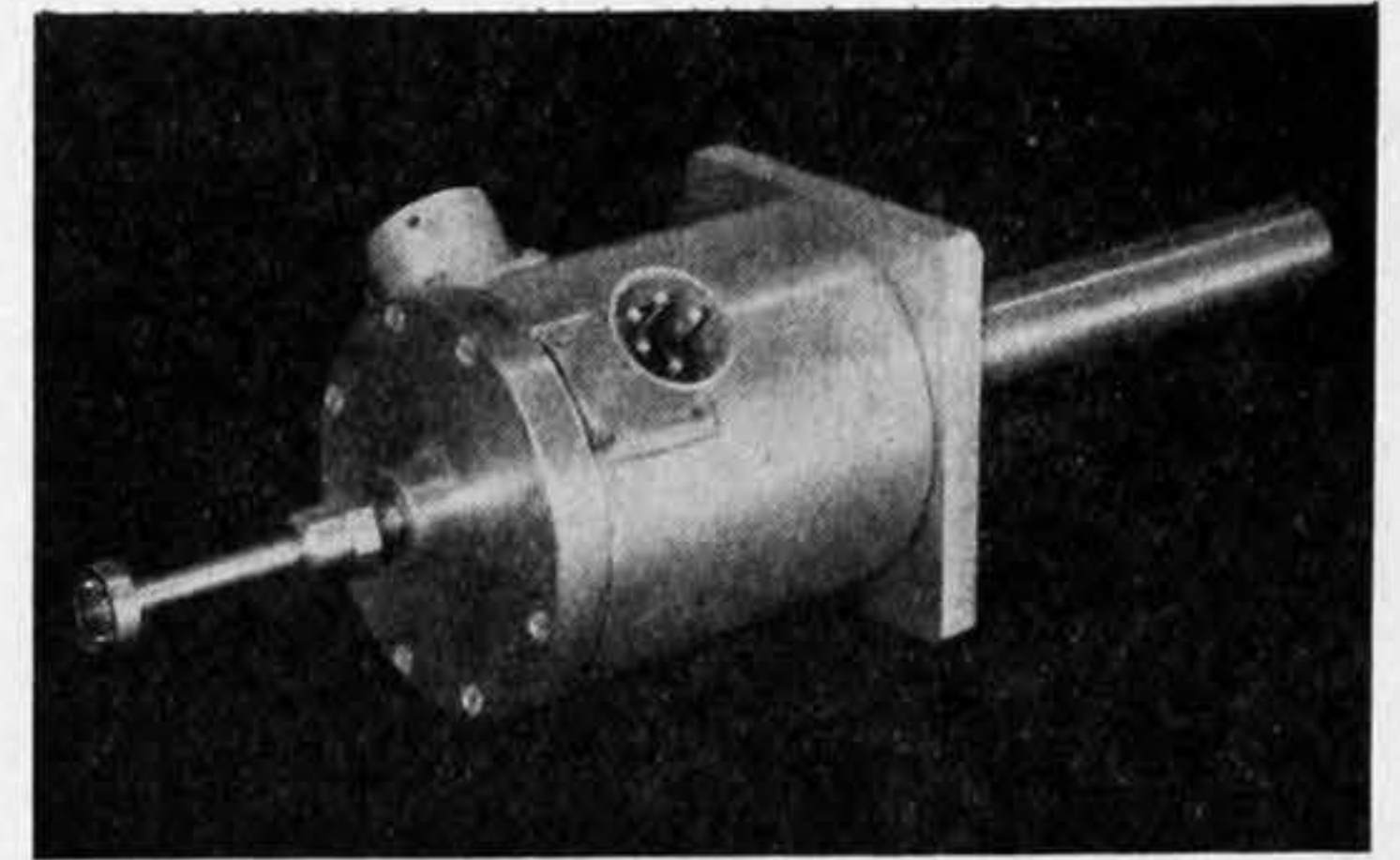


Fig. 6—Tracing head for two-dimension electronic control

cuts may extend either vertically or horizontally, hence automatic control is required on the depth motion together with either the vertical or horizontal feed. It is also convenient to operate the horizontal and vertical feeds together without depth control for cutting exterior or interior profiles.

With the B.T.H. "3D" system all these operations may be carried out at one set-up, as the tracing head (Fig. 7) is sensitive to deflections in all three directions, the system automatically selecting the required combination of signals.

A further B.T.H. development permits all three motions of the machine to be on simultaneous automatic control.

This system can be operated in either of two separate and distinct ways, which will be described as applied to a horizontal boring and milling machine used for die milling.

(a) If the workpiece is, for example, a cavity having steep sides and varying depth, then the horizontal and vertical feeds can be made to follow the profile of the sides as a two-dimension control system, while the depth motion tracks the bottom of the cavity as a separate single-dimension system. This arrangement is useful for cleaning out a small radius corner such as a bead on a car door panel.

(b) If the radius of curvature of the workpiece is greater than that of the tool, this form of control cannot be used. For use in such cases, B.T.H. is now able to offer a novel form of three-dimensional control. With this system the operator has an added control, the function of which is similar to the "steering" control mentioned in connection with two-dimensional tracing except that the new control is operative while tracing and controls the direction of motion of the tool over

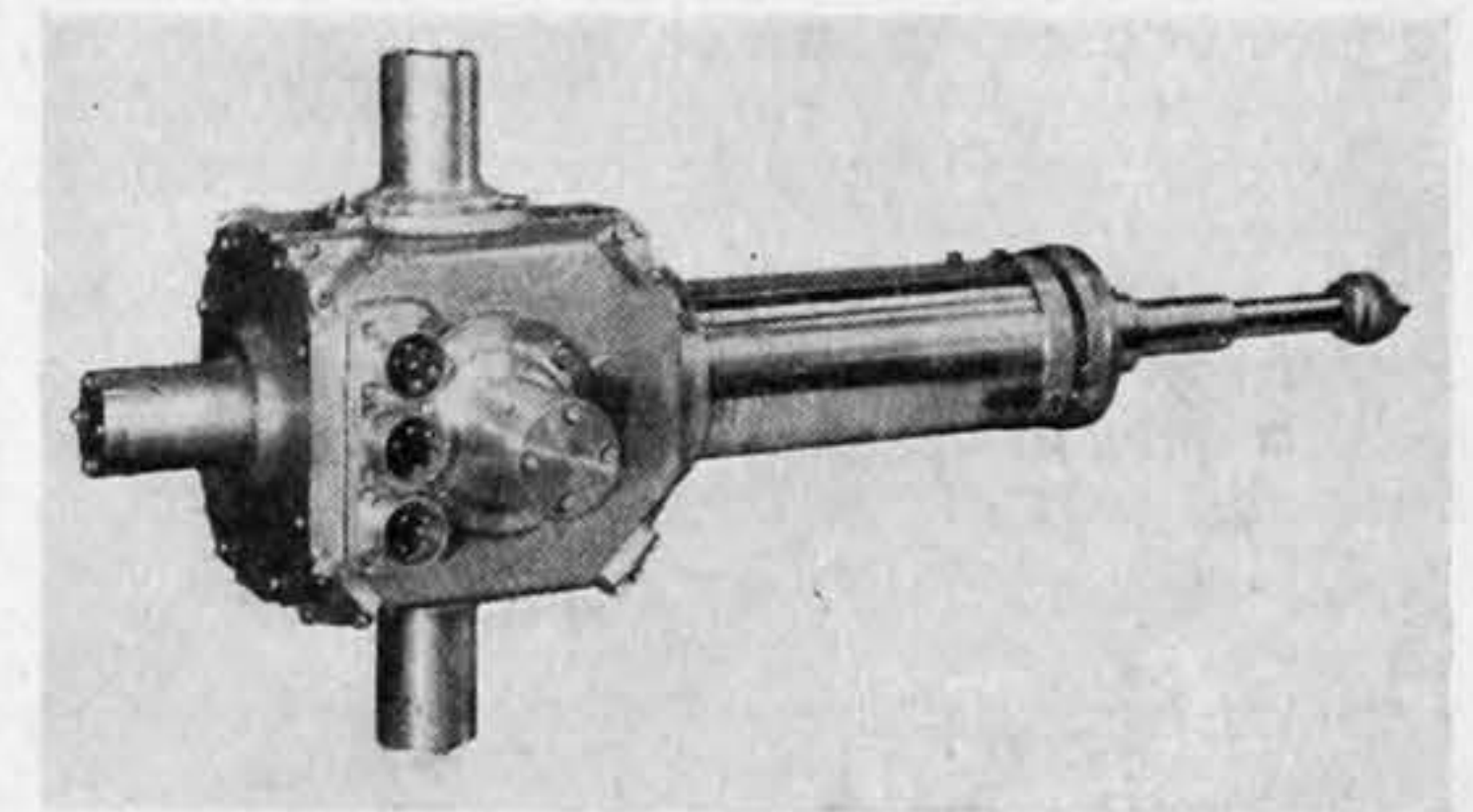


Fig. 7—Three-dimension tracing head

the workpiece. For example, if this directional control is set at 15 deg. with the stylus in contact with the model, then the stylus will track the model along a line which when projected into a plane perpendicular to the spindle (and stylus) axis subtends an angle of 15 deg. with the vertical. The system controls the vertical and transverse feed rates so that they bear a constant ratio to one another of value depending on the setting of the operator's directional control. It also controls the value of the combined vertical and transverse feed together with the value of the depth control feed to give a constant total feed over the surface of the work irrespective of the contours of the model or the setting of the directional control.

This system is most useful for cleaning out detail work and greatly reduces the hand finishing required.

It should be noted that inaccurate setting of the

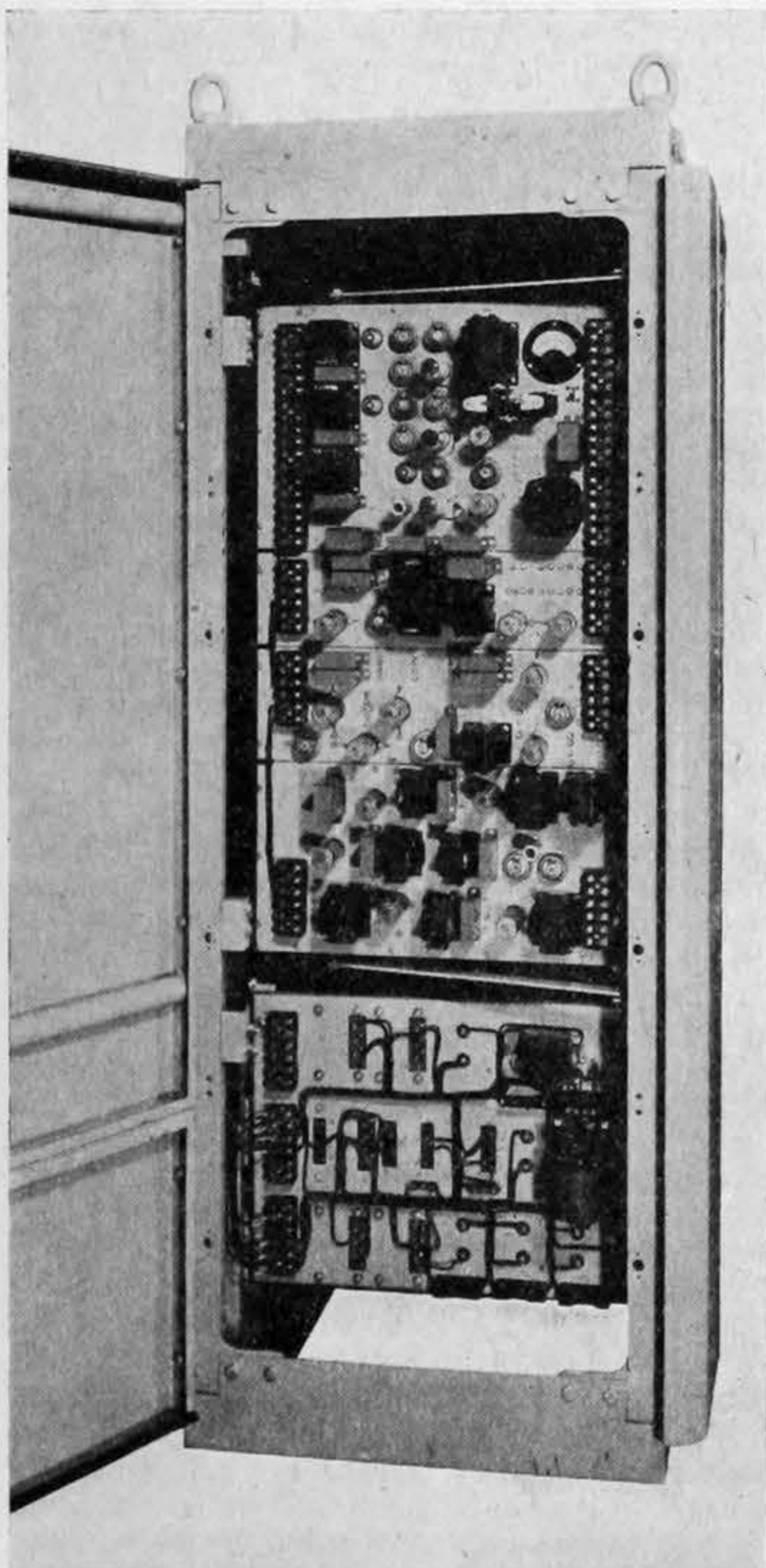


Fig. 5—Typical electronic control cubicle

directional control cannot cause cutting errors. The system will always follow the surface of the model irrespective of the steepness of the contour, which may even include re-entrant cavities if the cutting tool is of a suitable type.

Milling Feed Control.—When a machine is equipped with electronic tracer control the feed motors and control system can usually be employed to provide ordinary milling feeds with finger-tip control, giving an infinitely variable feed range of approximately 20 : 1. This can, of course, be extended by change gears.

Machine Tool Backlash and Spring.—It must be stressed that the performance of any copying system depends on the mechanical properties of the machine to which it is applied. The backlash between the feed motors and tracing head, and elastic yield or "wind-up," must be kept to a low figure; in some cases stick/slip effects in slide-ways may impair the performance.

For tracing speeds up to 4in per minute backlash of 0.010in or even more may be tolerable, but as tracing speeds are raised the adverse effects of backlash and yield become more pronounced.

At 60in per minute a backlash of 0.010in causes a noticeable surge in the system, and consequent marking of the workpiece as the backlash zone is traversed. This must be reduced to about 0.004in to give good results.

Template Mounting.—It is essential that the template or model be rigidly located with respect to the work, otherwise vibration set up in the machine when cutting will cause the template to vibrate and result in rough or inaccurate work.

Linear Actuator.—For applications requiring short linear travels not exceeding 6in, The British Thomson-Houston Company, Ltd., can provide a linear actuator having a peak thrust of 500 lb and a maximum feed rate of 100in per minute.

This device, which is essentially a compact combination of electric motor, gear reduction and special low-friction lead screw, converts the electrical output of the control system into linear motion with high efficiency. It has a high mechanical stiffness and will withstand shock loads, such as are experienced when taking an intermittent cut.

pressure against both the bullet and the cartridge case, the latter being supported by the bolt plus the pressure of the return spring. This pressure accelerates both the bullet and the bolt plus the cartridge case, but in opposite directions, and, as the weight of the bullet is considerably less than that of the combined weight of the bolt and cartridge case, it attains a much greater velocity than that of the bolt and cartridge case. By the time the bullet clears the muzzle both have reached their maximum velocity, but the cartridge

TABLE II

Calibre	(0.354in)
Length :	
Butt folded	19in
Butt extended	28in
Weight :	
Machine gun only	6 lb (approx.)
With full magazine (34 rounds)	7 lb 10 oz (approx.)
With full magazine and bayonet	8 lb 4 oz (approx.)
Length of barrel	7.8in
Number of grooves	6
Pitch of rifling	1 turn in 9.84in
Twist of rifling	Right hand
Sight radius	16.1in
Type of sights	Rear : aperture Fore : blade
Sight range	100 and 200 yards
Cyclic rate of fire	550 r.p.m. (approx.)

case has not yet cleared from the chamber, thus preventing the gases from escaping through the breech. The bolt is decelerated by the compression of the return spring.

The empty cartridge case, held against the face of the bolt by the extractor, is carried to the rear, where it strikes the ejector and is ejected through the opening on the right side of the weapon.

The Forward Action.—When the bolt reaches the limit of its rearward travel it is forced forward by the compression of the return spring. During its forward travel the bolt contacts the top round in the magazine and, guided by the magazine lips, the round is fed into the chamber. The bolt then follows up on the round, finally posi-

British Sub-Machine Gun

Details are given of the Sterling sub-machine gun, which replaces the Sten gun in the British Army. The gun can be fired from the hip, shoulder or, in emergency, in pistol fashion, at a rate up to 575 rounds per minute. It weighs 6 lb and the accurate lethal range is 100 yards.

A SUB-MACHINE gun weighing 6 lb which has been adopted by the British Army as a supplementary weapon to the Belgian F.N. rifle, was recently demonstrated at the works of the Sterling Engineering Company, Ltd. It replaces the Sten gun in the British Army and it is claimed to be lighter, safer and more reliable than any sub-machine gun previously made. It is illustrated in Fig. 1. The normal range is 100 yards, though it may be used with effect at longer ranges according to the skill of the firer, but the penetrative power of the bullet will seldom justify fire at ranges in excess of 100 yards (see Table I).

TABLE I—Terminal Velocity of Standard 8-gramme Bullet

Range, yards	Velocity, ft/sec	Kinetic energy, ft/lb
0	1280	447
109	1115	339
218	975	262
327	872	207

It is an automatic weapon, operated by case projection or blow-back action, and can be fired in single rounds or bursts. Normally, it may be fired in bursts of two or three rounds, but on many occasions the aimed single shot will be found effective. The principal technical details are given in Table II.

The forward part of the body, which provides a grip for the forward hand, is perforated to assist cooling of the barrel. Even after prolonged firing this part of the body remains quite cool,

causing no discomfort to the firer. A guard is fitted near the front of the weapon to prevent any possibility of the firer placing his finger too far forward. The trigger mechanism is fitted with a change lever which can be set to give either automatic fire or single shot.

The change lever also has a "safe" position which locks the trigger and sear, irrespective of the position of the bolt. Locking of the bolt in the forward position eliminates the possibility of the round being fired if the carbine is dropped or violently shaken. The rear peephole sight is changed from 100 yards to 200 yards setting by a flip lever.

The bayonet is mounted so that it is offset when the weapon is in the firing position, and when the weapon is held in the "on-guard" position for bayonet fighting, the natural balance of the weapon, with or without magazine, brings the bayonet into the upright position.

FIRING MECHANISM

The Backward Action.—When the cartridge is fired the propellant gases exert an equal

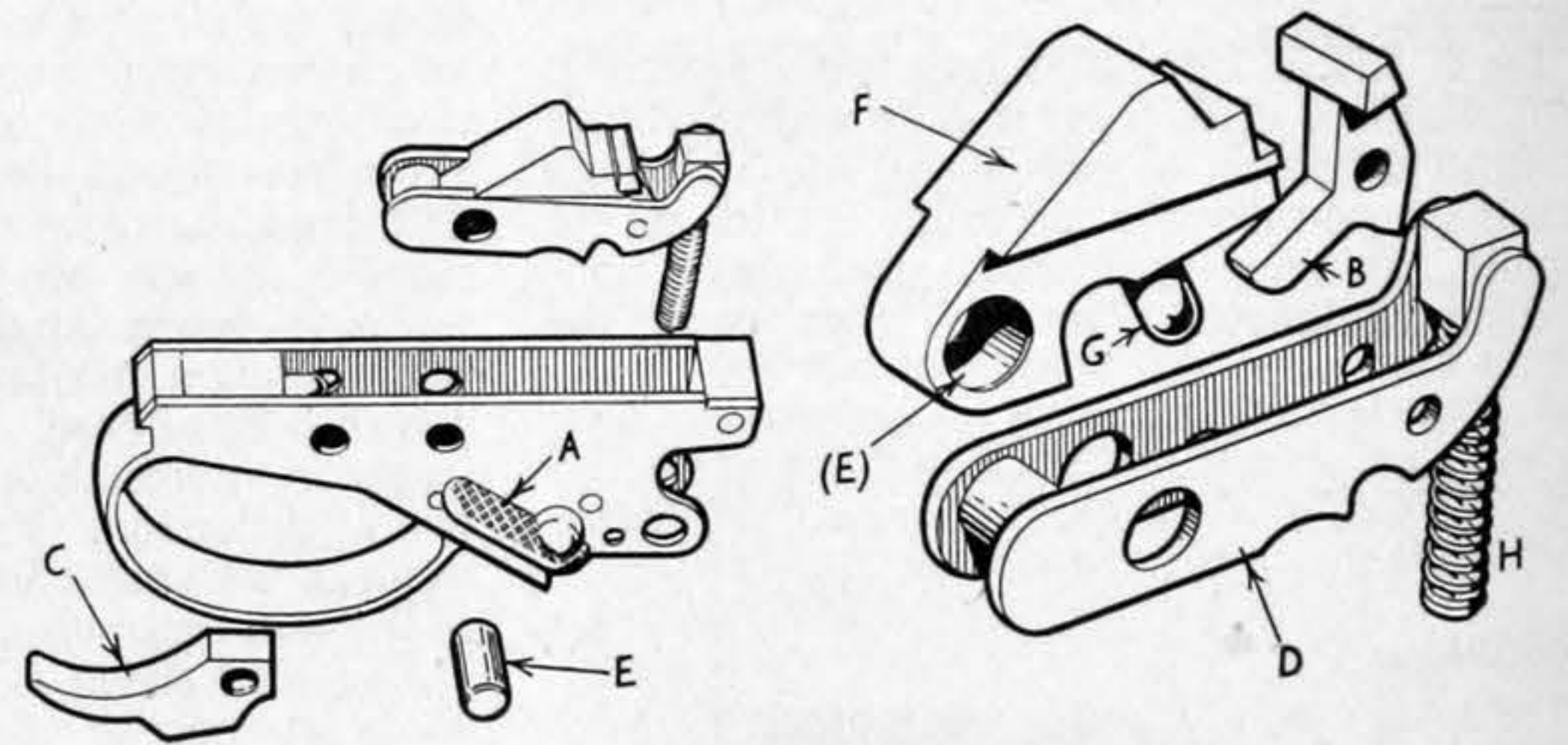


Fig. 2—Component details of the trigger mechanism

tions it in the chamber, and fires it just before the forward movement ceases. During the forward movement of the round from the magazine, the firing pin of the bolt cannot come into line with the percussion cap of the cartridge until the round is actually in the chamber. Upon firing, the backward action again commences.

The action of the trigger mechanism can be explained by reference to Figs. 2, 3 and 4.

Single-Shot Fire.—When the change lever A is set to the single-shot position, the inner arm of the change lever is located under the tail of the tripping lever B (Fig. 3a).

When with the weapon cocked (Fig. 3b), the trigger C is pressed, the sear cradle D is rotated about the sear axis pin E, the sear F is lowered and the bolt is carried forward by the pressure of the return spring (Fig. 3c). During this movement the tail of the tripping lever contacts the inner arm of the change lever causing the tripping lever to partially rotate. Continued pressure on the trigger causes further rotation of the tripping lever until the upper arm disengages from the step on the sear. At the same time, the sear plunger and spring G are compressed (Fig. 3d).

When the round is fired, the sear (Fig. 3e) is held down by contact with the under surface of the bolt, but as the bolt reaches the end of its rearward movement and is clear of the sear, the sear is forced upward by pressure of the sear plunger and spring. Then as the bolt is moving forward, the sear engages against the bent on the face of the bolt and holds the bolt in the cocked position. When the pressure on the trigger is released, the rear end of the cradle rises,



Fig. 1—The Sterling sub-machine gun shown with butt folded and with butt fully extended with bayonet attachment

lifting the tripping lever and causing it to rotate about its axis pin until the upper arm of the tripping lever re-engages on the step of the sear. The trigger must be fully released and again pressed for each single shot.

Automatic Fire.—When with the change lever set at "automatic" and the weapon cocked, the trigger is pressed (Fig. 4), the projection on the upper part of the trigger lifts the end of the sear cradle, rotating it about its axis pin. This depresses the sear, freeing it from contact with the face of the bent on the bolt, and allowing the bolt to fly forward. The movement of the sear cradle compresses the sear cradle spring *H*. The weapon will now continue firing until either the trigger is released or the magazine is empty.

When the trigger is released the sear cradle returns to its former position under the action of the sear cradle spring, the sear is raised into the boltway and contacting the bent on the bolt holds the bolt in the cocked position.

Applied Safety.—With the weapon cocked and the change lever set at safe, the inner arm

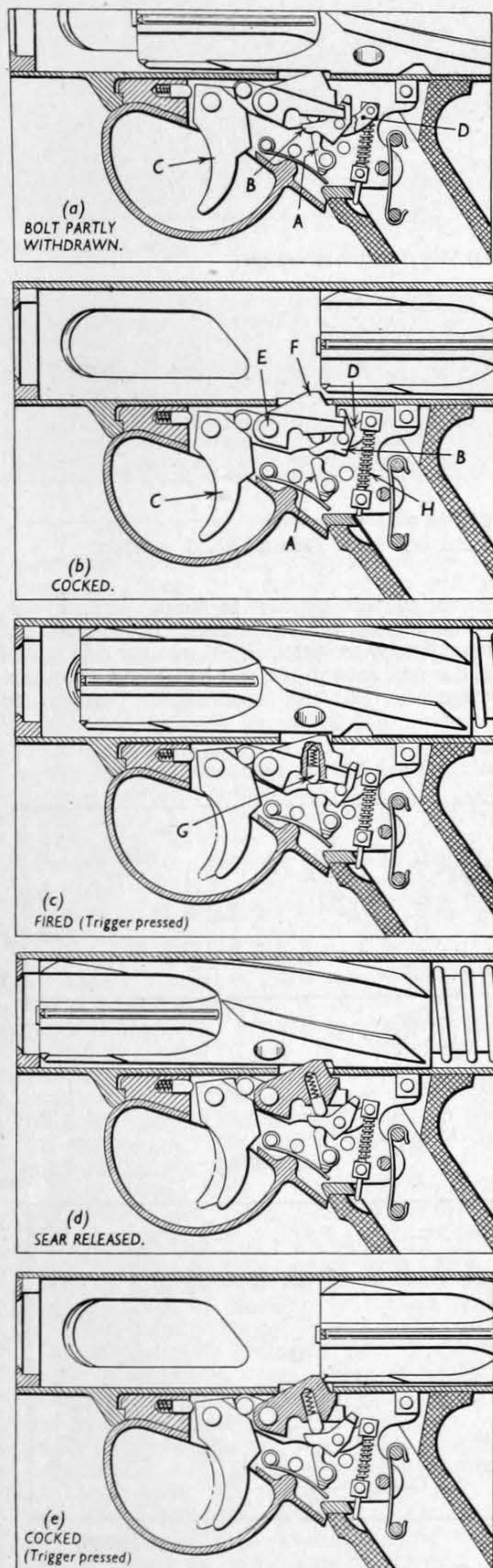


Fig. 3—Action of trigger mechanism for single shot fire

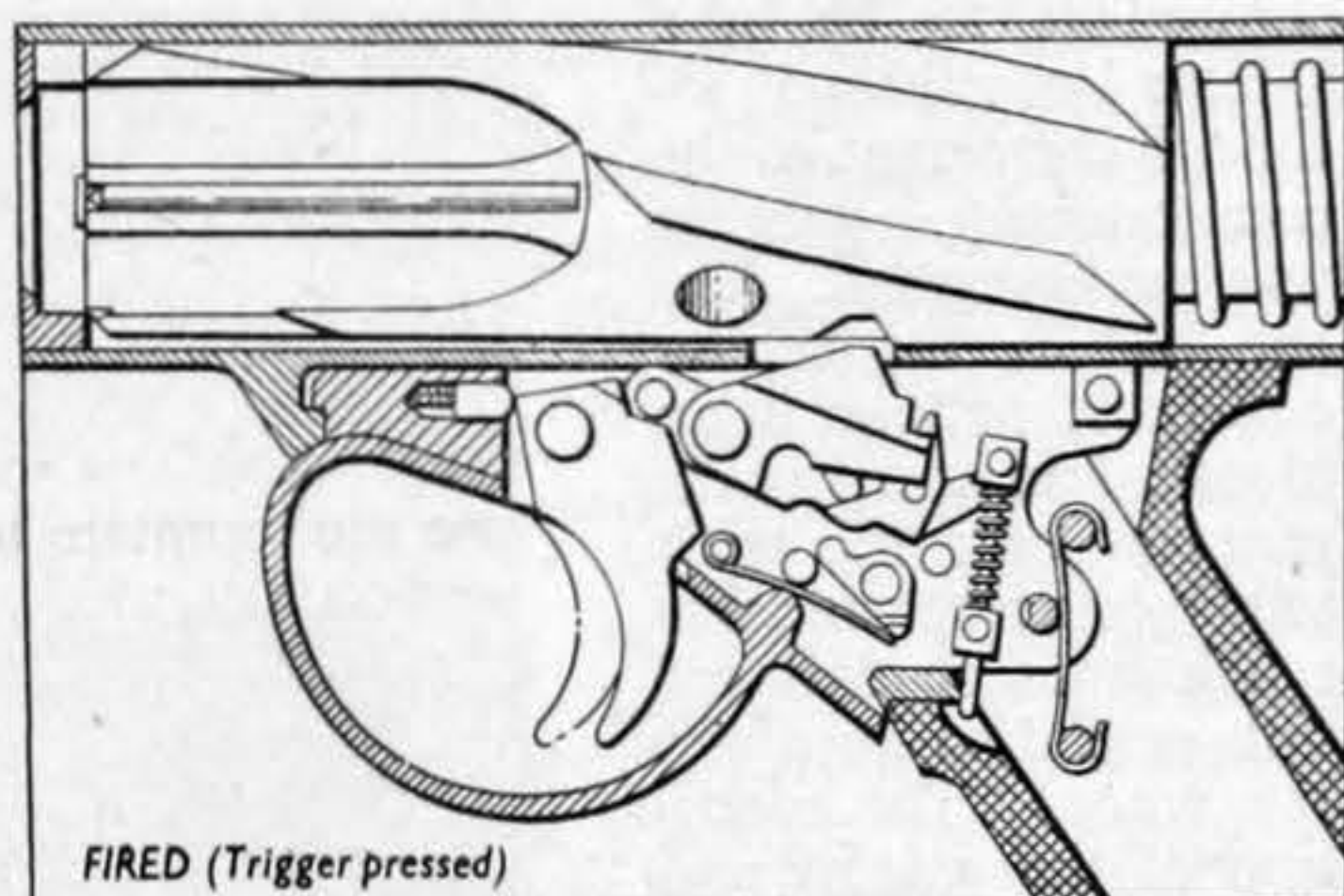


Fig. 4—Action of trigger mechanism for automatic fire

of the change lever is positioned directly under the short arm of the tripping lever. When the trigger is pressed the sear cradle and sear cannot be depressed because the short arm of the tripping lever is held immovable. With the bolt forward, the weapon cannot be cocked because the sear is engaged in the safety slot at the rear of the bolt, and the sear cannot be depressed because it is held immovable.

FABRICATION

The barrel case is of fabricated construction, utilising the more recent methods in electronic and electro-gas brazing. It consists of a steel tube, with prepierced cooling holes, carrying steel pressings (grip plates, foresight guard and back cap lock lever support).

The barrel itself is made from an electrically heated upset forging, machined to close limits. The back cap is machined from a drop forging, and the steel foresight and rear sight are also accurately machined. A reinforced shockproof thermo-setting plastic moulding is used for the grip.

Components of the trigger mechanism are made from drawn steel sections. They are mounted between blanked and pierced side plates, in which all holes are sized in one operation to ensure accuracy. The trigger mechanism, as a whole, is removable from the weapon and is completely interchangeable.

The main part of the recoil mechanism—the bolt—has four helical ribs machined around the external face, which provide the self-cleaning action. Within the front recess of the bolt, the surrounding metal is removed to leave the firing pip and the rear is hollowed out to house the recoil spring system. One side of the bolt is machined away to give magazine clearance and to leave the cartridge pick-up horns. The opposite side carries the extractor.

During the demonstration the gun was fired after (a) being subjected to sandstorm conditions, (b) completely immersed in glutinous mud, and (c) after being subjected to severe icing conditions. Its reliability after these tests, it was stated, was due largely to the self-cleaning action of the breech block. As the sharpened edges of the spiral ribs, to which we have referred, move backwards and forwards inside the casing, they remove any fouling, such as sand, dirt or mud, and gradually drive it out of a specially designed slot below the barrel face and other apertures in the case.

Balance.—The gun is so balanced that when in the firing position with a full magazine, even when held by the pistol grip with one hand only, there is little tendency for the gun to tilt backwards or forwards. Even when firing a burst, this even balance is maintained.

Water Supply Scheme for Glasgow

THE main source of supply of the Glasgow Corporation Water Department has for many years been the catchment of Loch Katrine, the loch itself forming the principal reservoir. It has now been decided to start on a scheme for increasing the area of supply by utilising the next catchment to the East of the Katrine catchment—Glen Finglas. The Corporation obtained powers in 1915, by Act of Parliament, to develop the resources of Glen Finglas with a dam 115ft high, about 800ft long at crest level, and having storage for 3500 m.g. The top water level of the reservoir formed would be 515ft above O.D. and this would supply water

to Loch Katrine, which has a top water level 377.92ft above O.D., through an 8ft diameter tunnel aqueduct 2½ miles in length.

The catchment area above the dam site is 9665 acres with an average annual rainfall of 78in, giving a reliable yield for the 1915 scheme of 20 m.g.d. to Loch Katrine and 10 m.g.d. compensation to the River Turk. Under the 1915 Act the compensation water from Loch Vennacher to the River Teith was to be increased from 44½ m.g.d. to 49½ m.g.d. The 1915 scheme would have been constructed shortly after the first world war, but it was subsequently found more expedient to obtain additions to the supply by raising the level of Loch Katrine. After the year 1919 the consumption of water in the city declined until 1932, but since the last war has increased steadily and it has therefore become necessary to look to Glen Finglas once more for a new source of supply to augment the Loch Katrine works.

The present scheme has attempted to reconcile problems of restricting capital expenditure in the national interest and meeting the future needs of the city's water supply by constructing new works in instalments. It has been decided to proceed at present with a modified scheme consisting of the 8ft diameter tunnel aqueduct and a low intake weir in the River Turk. The Corporation has obtained an Order from the Secretary of State for Scotland for this intake scheme. The estimated yield to Loch Katrine of the intake scheme is 10.3 m.g.d., which, after allowing for additional water to Loch Vennacher to maintain the compensation to the River Teith, will give a net additional reliable yield to the city of 7.2 m.g.d. The tunnel aqueduct of the intake scheme has been designed to form an integral part of the larger scheme, should it become necessary to develop the Glen Finglas catchment further by the construction of a dam as envisaged in the 1915 Act.

A fully automatic intake will divide the river flow so that the amounts between 10 m.g.d. and 70 m.g.d. will pass to Loch Katrine. No water will be abstracted when the river flow is below 10 m.g.d., at these times most of the flow will pass through the orifice fish-pass in the weir. The abstracted water will pass from the intake to the 8ft diameter tunnel aqueduct to Loch Katrine by way of a 12ft diameter tunnel which will be used as a diversion tunnel whenever the dam is constructed. A full investigation of the sites of all the works, including the sinking of exploratory bore-holes, has been undertaken by a consultant geologist.

The contractor for these works is to be A. A. Stuart and Sons (Glasgow), Ltd., and work is expected to begin next month, the contract sum being approximately £550,000. The engineer for the intake scheme is Mr. S. D. Canvin, M.I.C.E., chief engineer and general manager of the water department.

Technical Reports

Note on the Nature of Gases Liberated during Arcing in Oil Circuit-Breakers (Ref. G/T260). By C. E. R. Bruce, M.A., B.Sc., M.I.E.E. The British Electrical and Allied Industries Research Association, Dorking Road, Leatherhead, Surrey. Price 6s., postage 4d.—This report gives in concise tabular form E.R.A. and other data on the composition of gases evolved by arcing in insulating oils. The E.R.A. data already given in Ref. G/XT35 are amplified and in particular, the few results obtained with a naphthene-base oil are quoted. There are no outstanding differences between the latter and those obtained under similar conditions with a paraffin-base oil.

Deposits on Overhead Line Insulators Exposed to Wind-borne Salt Spray (Ref. O/T12). By G. Mole, Ph.D. The British Electrical and Allied Industries Research Association, Dorking Road, Leatherhead, Surrey. Price 12s., postage 3d.—A satisfactory technique has been established and is in operation by the British Electricity Authority for assessing the relative merits of various kinds of overhead line insulators in relation to their performance under conditions of industrial pollution. No corresponding technique is available for assessing the performance of insulators under conditions of salt pollution. In this report an account is given of tests involving exposure of insulators to salt pollution from sea air, to assess the conditions which have to be reproduced when a laboratory test is devised.

Investigation into the Failure of Two 100MW Turbo-Generators*

No. II—(Continued from page 237, February 18th)

By SIR CLAUDE GIBB, C.B.E., D.Sc., M.E., F.R.S.†

This paper describes investigations into the failure of two generators, each of 100MW capacity, installed in the Richard L. Hearn Generating Station at Toronto of The Hydro-Electric Power Commission of Ontario. The author details some general considerations affecting the design of alternator rotors, the selection of materials used, past troubles which had to be avoided, reasons for certain features incorporated in the original design and modified as the result of the failures, and safeguards introduced into current practice to avoid the possibility of a repetition of the failures.

INVESTIGATIONS

THE examination of No. 1 set was proceeding at the time of failure of No. 2 set though progress was retarded as the crane had been put out of commission by the fire. The top half steel end covers at the exciter end had been removed and it was found that the rotor end bell and about 75 per cent of the teeth at the exciter end of the rotor forgings had fractured. The rotor and stator end windings had disintegrated and the stator frame was severely damaged.

The end bell support ring and fan, though damaged and displaced, were intact and the end bell itself was lying amongst the debris in the bottom of the stator casing. The bell was removed with great difficulty and was found to have fractured in one place radially and axially through a line of three ventilating holes on a pole centre-line. Details of the fracture are shown in Fig. 4 (a), (b) and (c).

It was deduced from the appearance of the fracture surface that fracture had started at the hole (No. 38, Fig. 5) nearest to the rotor, that is, the hole on the left of Fig. 4 (b), and at the mid-thickness. From this hole the crack had spread in each direction. There was evidence, too, that when the fracture reached the other two holes it started again in each instance at the mid-thickness.

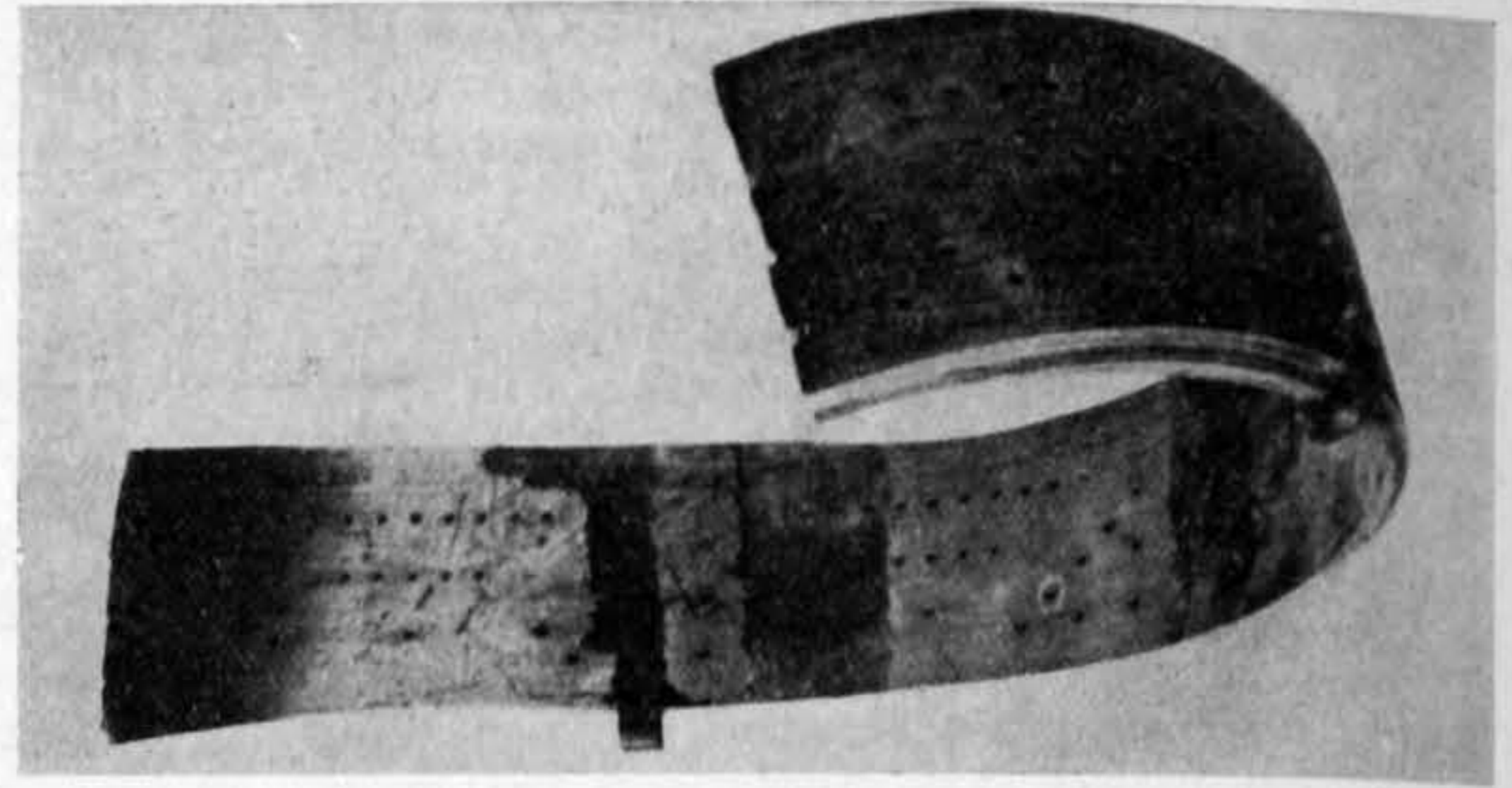
Examination of No. 2 set after the failure

* Abstract of paper, Institution of Mechanical Engineers, London, February 15, 1955.
† Chairman and Managing Director of C. A. Parsons and Co., Ltd.

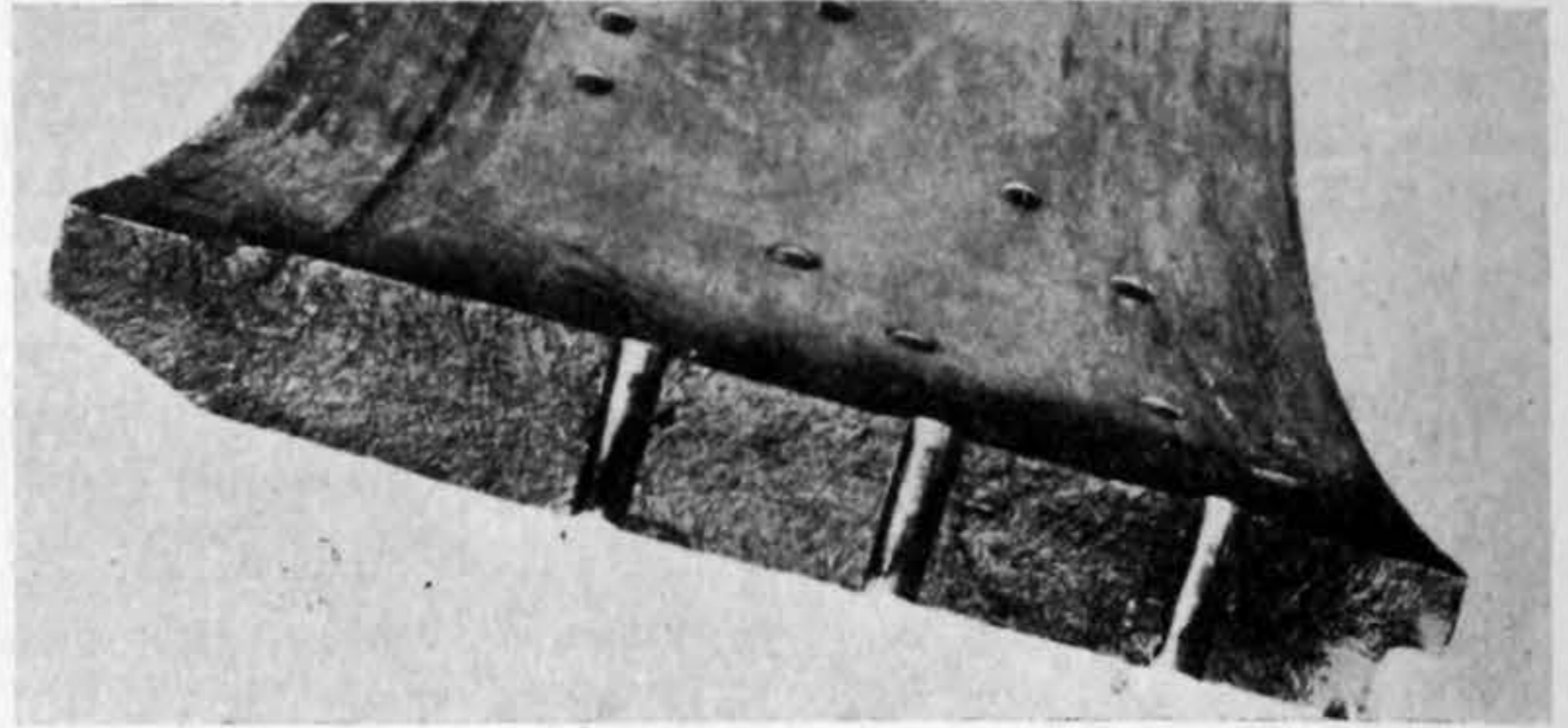
showed it to be in a similar condition although the extent of the consequential damage was not as great. The end bell at the exciter end had fractured in an identical manner, but the number of rotor teeth which had fractured was much smaller and did not extend so far along the rotor. The condition of the stators and rotors at the turbine ends was found to be normal and did not provide a clue as to the cause of the failures. The condition of both windings at this end was excellent, confirming that there had been no hydrogen explosion or fire inside the casings.

A superficial examination of the fracture in the end bells did not reveal any flaws or abnormal features which could be regarded as important. The bells had failed in an identical manner which also seemed to eliminate the possibility of a local fault in the material. The appearance of the surfaces of the fracture indicated that a crack had started near the centre at a ventilation hole and had been propagated normally to the plane of the principal stress to the edge where it was shrunk on to the rotor body. The remaining portion nearest to the balancing ring appeared to have the nature of a shock fracture and to have parted more rapidly. This end of the bell is spigoted into the support or balancing ring which initially would carry some of the loading and the sequence as described

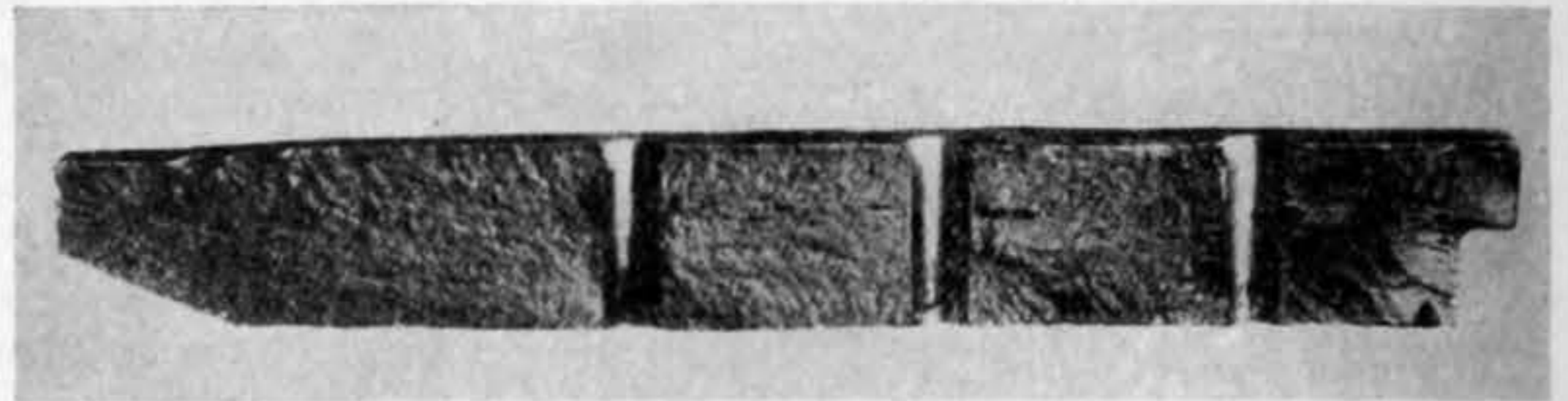
above would appear to be a logical one. The damage was so extensive that it could not immediately be determined whether the initial failure had been in the end bell or the rotor slot wedges or in the rotor body (that is to



(a) On arrival for examination

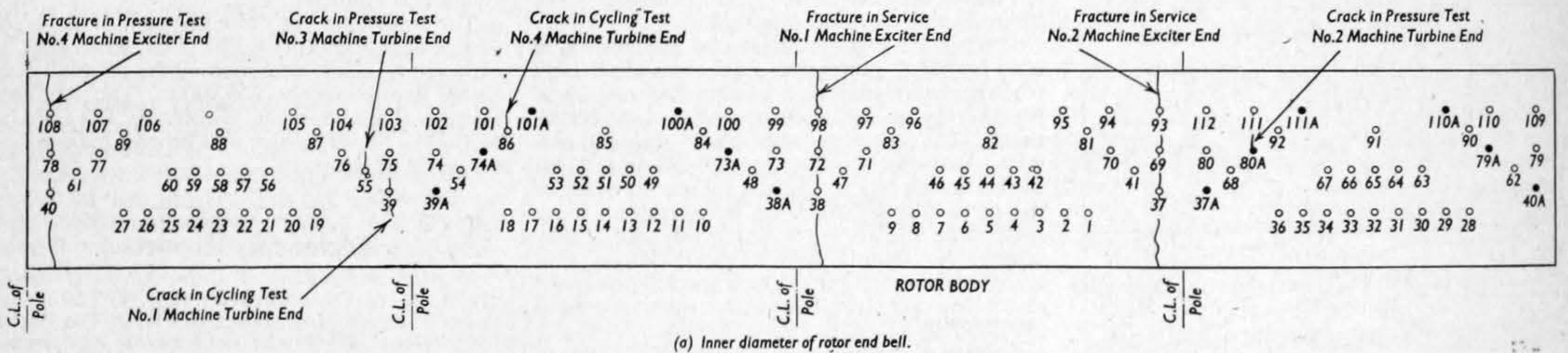


(b) View of fracture on end bell

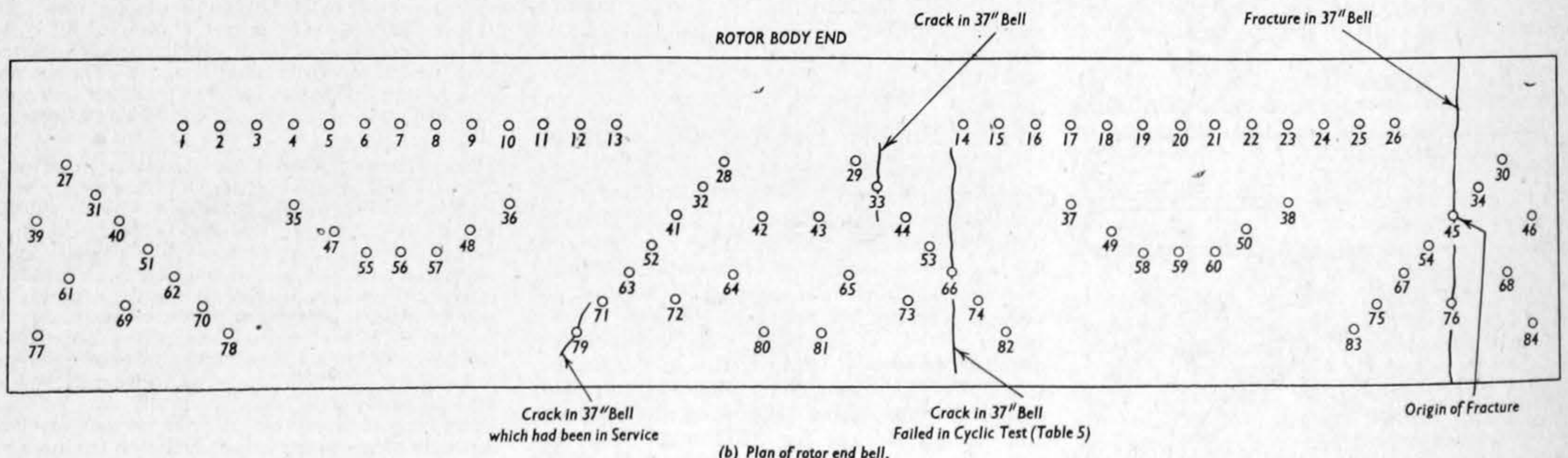


(c) View of fracture on end bell

Fig. 4—Fractured end bell from Toronto No. 1 machine



(a) Inner diameter of rotor end bell.



(b) Plan of rotor end bell.

Holes marked A not drilled in exciter end bell
Fig. 5—Expanded views of rotor end bell

say, failure at the root of the slot teeth). When the first cabled report of the failure of No. 1 machine was received, immediate consideration was given to possible causes, these being assessed in the light of all known experience. A relatively new phenomenon was the subject of investigation at the time of the Toronto failure. This was the cracking of non-magnetic end bells after being stored for a considerable period under damp conditions, and was known as stress corrosion. Such cracking was always distinctive in that the cracks were transgranular and jagged. Since No. 1 60-cycle rotor had been in store for almost two years, the possibility of stress corrosion being the cause was seriously considered but, as will be seen later, this was subsequently proved beyond question not to be the case.

The end bell which failed on No. 1 unit was flown back to England by charter plane for examination and testing.

Two non-magnetic end bells which had cracked seriously whilst being stored on an overseas

The rotors from both Nos. 1 and 2 sets were returned to England and slot wedges carefully removed, examined and tested. No information justifying any suspicion of them could be found. Their physical properties and microstructure were normal and in accordance with specification.

When removing rotor copper from the slots and when examining fractured rotor teeth, a careful study was made of copper marks on the teeth and these appeared to show that the sequence of failure had been end bell first, then rotor winding end turns flying out and fouling stator bore, thus wrenching out slot wedges and allowing copper in the slots to rise and foul the stator bore which, in turn, wrenched off rotor teeth. Test pieces were cut from the rotor and these appeared to clear the rotor from suspicion.

Investigations into the end bell material, stresses, design and manufacture had been proceeding during this time, but it was not until after many weeks of examination that it could, with any certainty, be decided that the cause lay with the end bells.

TABLE IV—Results of Tests on End Bells

End bell	Acceptance tests				Maximum applied hoop stress, tons per sq. in.					Result
	Yield point, tons per sq. in.	Ultimate tensile strength, tons per sq. in.	Elongation on 2in, per cent	Reduction in area, per cent	Rotor body end		Balancing ring end		Mean hoop stress	
					Inside	Outside	Inside	Outside		
Toronto No. 2, turbine end, drilled	49.8	56.8	38	51	36.62	33.27	34.18	30.83	35.69	Cracked through two holes
Toronto No. 3, turbine end, drilled	56.2	61.0	29.5	42	40.28	36.6	37.6	33.91	39.26	
Toronto No. 4, exciter end, drilled	49.6	56.2	39.0	43	42.73	38.82	39.87	35.97	41.64	Fractured through three holes
Toronto No. 4, exciter end, drilled	55.8	60.0	18.5	30	43.20	37.4	41.72	35.98	42.92	
37in bell, 60MW, rotor, drilled	55.4	60.6	23.0	32	41.30	35.83	39.50	34.03	40.70	Cracked at one hole
37in bell, new, drilled...	59.0	63.2	23.5	38	42.13	36.53	40.51	34.91	41.69	
37in bell, new, drilled...	—	—	—	—	50.82	44.12	48.57	41.88	49.85	Expanded without cracking
37in bell, new, drilled...	51.8	57.4	35	49	50.57	43.92	48.24	41.59	49.50	
37in bell, new, drilled...	56.4	60.4	34	33	43.85	39.26	43.85	39.26	43.21	Expanded without cracking
37in bell, new, drilled...	52.8	57.8	34	40						
37in bell, new, undrilled	57.2	60.4	32	45						Expanded without cracking
Toronto magnetic replacement bell, undrilled	47.2	54.0	24	61						
Toronto magnetic replacement bell, undrilled	49.4	56.2	25.5	65						

power station site under damp conditions, had been the subject of investigation in 1953 and early 1954. Both end bells were of similar composition, manufacture and design to the Toronto bells and, by examples commonly observed in steel structures exposed to damp atmospheric conditions, would not have been regarded as badly corroded. A penetrant dye method of crack detection on the areas adjacent to the cracks showed a network of cracks of varying depth, some over 0.06in deep and of a nature which might have led to immediate or early failure had the rotors been put into service. In neither of the bells did the crack commence at, or extend to, a ventilating hole nor were there any corrosion or cracks in ventilating holes.

Although No. 1 60-cycle rotor had been stored for almost two years, the rotor of No. 2 unit had not been stored and at no time had been damp or in any way exposed to conditions likely to lead to corrosion. All the holes in the two Toronto end bells which failed in service were examined with a small boroscope and some of the holes were cut through and examined under the microscope. No signs of the typical stress corrosion network were found.

Every hole in the end bells from the turbine end of units Nos. 1 and 2 and in the four end bells from units Nos. 3 and 4 was examined by the penetrant dye method before and after the hydraulic testing later described. In no instance was any trace of cracking or surface crazing typical of stress corrosion found.

In non-magnetic austenitic steel of the type under investigation, stress corrosion cracks are always transgranular, whilst the cracks in the end bells which either failed in service or were failed by hydraulic testing, were invariably intergranular. A close study of a large number of micrographs, shows clearly that in every case the cracks arising from over-stress are intergranular. The cracks arising from normal fatigue testing on non-magnetic material are generally transgranular but distinctively different from transgranular stress corrosion cracks.

One possible cause of the failures, which had been explored at an early stage, was severe unbalance between phases, possibly due to a single-phase closing of a circuit breaker on a feeder carrying a considerable proportion of the generator output. Such an occurrence had been known on air-cooled machines and had given rise to such overheating of rotor slot wedges and of arcing between end bell and rotor as to be dangerous. In an air-cooled machine the presence of severe negative phase sequence generally becomes evident by smoke from the rotor escaping from the stator casing covers. It was realised that in a hydrogen-cooled generator smoke would never become evident and unbalance in phase current could be all the more serious in consequence. No evidence could be obtained of such unbalance having been present, nor was there any sign of arcing between end

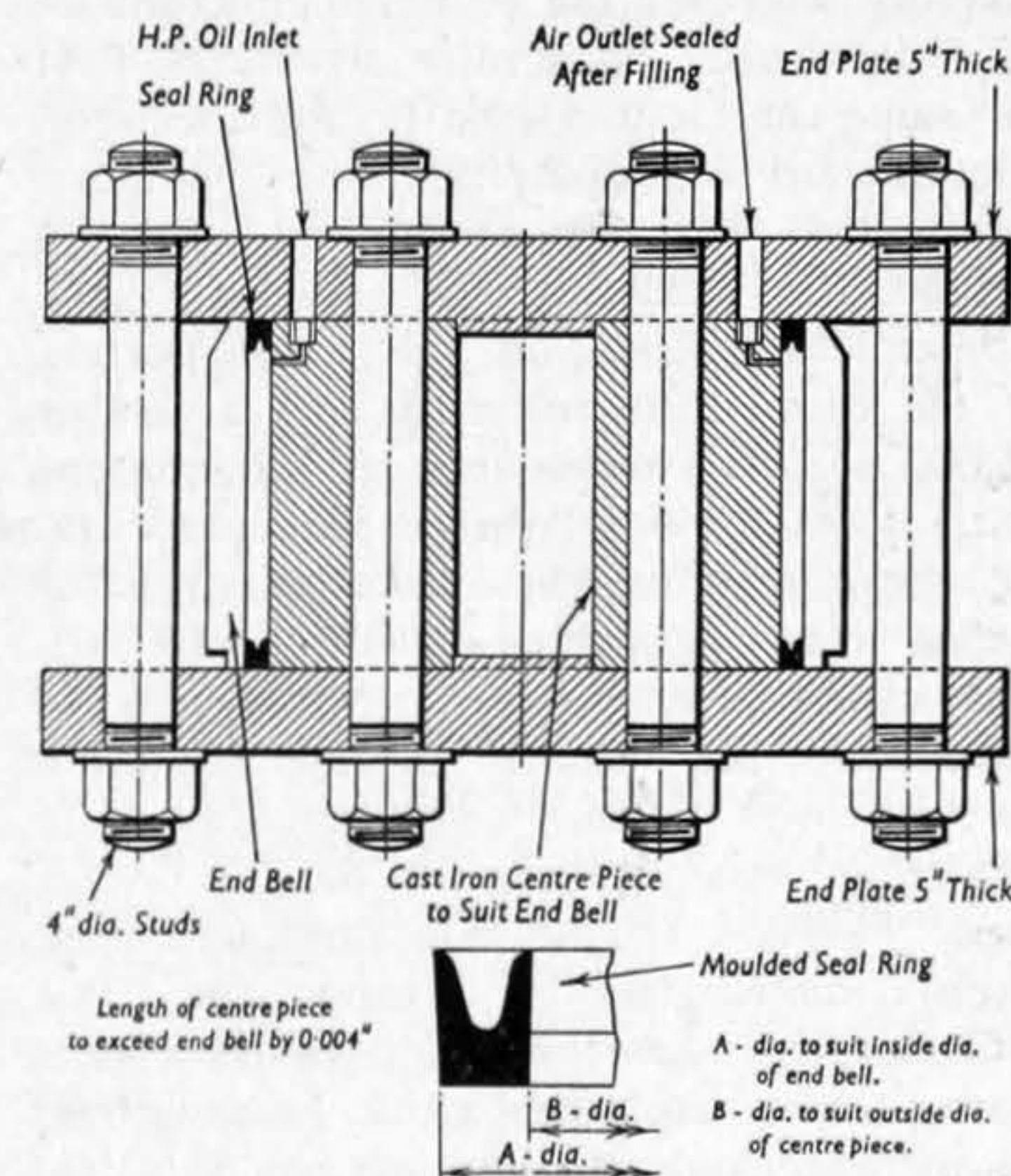


Fig. 6—Rotor end bell test gear

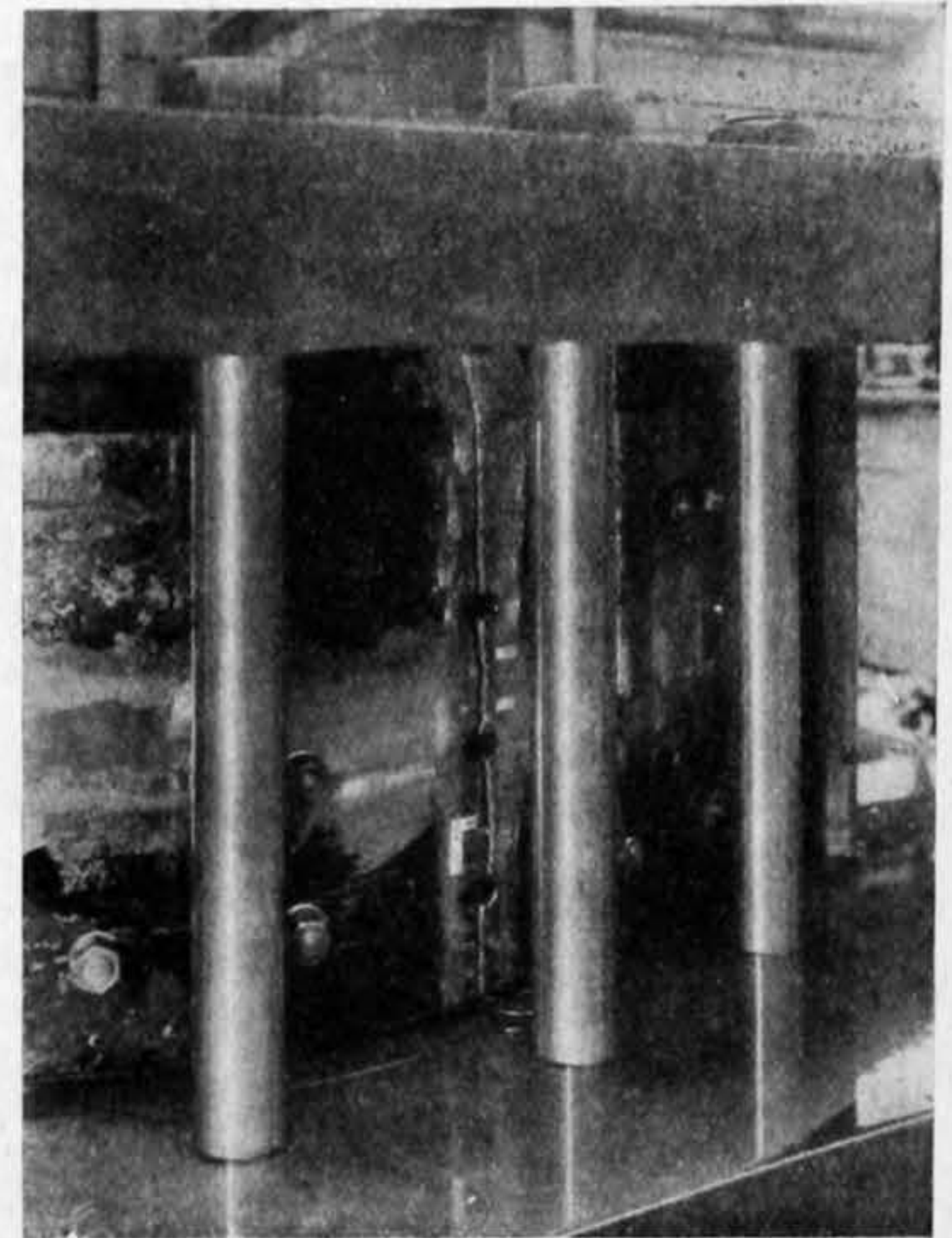


Fig. 7—End bell on hydraulic test showing fracture

bell and rotor body or of overheating of slot wedges. That possible contributory cause was therefore eliminated but the absence of warning of severe electrical unbalance in a hydrogen-cooled generator should be noted and thought given to the desirability of providing some suitable warning system.

Hydraulic testing gear had been made and a series of end bells from the Toronto and other generators (37in diameter bells) were tested to destruction. Fig. 6 shows details of the equipment. Some of the results are given in Table IV.

Because of the danger arising if identification numbers are stamped on end bells, the identification symbols painted on the Toronto bells were removed in the final machining, hence it was not possible to be certain to which end of a rotor a particular bell was fitted. Thus both acceptance tests are quoted.

With the exception of the end bell from Toronto No. 4 exciter end, and one of the 37in diameter bells, all bells which failed under hydraulic test did so by cracking quietly without the crack spreading. The hydraulic pressures to produce a crack at a drilled hole were of the order of 10,000 lb per square inch and, deliberately, small capacity pumps were used, so that if a crack developed a very small leakage of oil reduced the pressure and prevented damage to the test equipment. No. 4 Toronto exciter end bell, however, failed with explosive force indicating a remarkably rapid rate of crack propagation and produced a fracture almost identical with the two failures which occurred in service. The bell at the moment of failure opened out with sufficient force to damage the test equipment. The gap at the fracture must have measured over 3in momentarily and then closed in as shown in Fig. 7.

(To be concluded)

SYMPOSIUM ON THE OBSERVATION OF STRUCTURES.—A symposium on the observation of structures will take place at the Laboratório Nacional de Engenharia Civil, Lisbon, Portugal, in October, 1955. It is sponsored by the R.I.L.E.M. (Réunion Internationale des Laboratoires d'Essais et de Recherches sur les Matériaux et les Constructions), and the following points will be discussed:—Instruments: description and characteristics of the instruments for different measurements such as displacements, strains, stresses, velocities, accelerations, joint movements, temperatures, pore pressures, humidity and propagation of vibrations; techniques: techniques of installation of instruments and of their observation; determination of mechanical properties of materials (steel, concrete, soils, &c.); determination of the loads acting on structures (dead and live loads, wind and earthquake forces, earth pressure); planning the installation and observation of instruments, test programmes and standards for the testing of structures; and analysis and interpretation of results. Particulars may be obtained from the secretary of the symposium, Laboratório Nacional de Engenharia Civil, Av. do Brazil, Lisboa, Portugal.

THE ENGINEER

Vol. 199

FEBRUARY 25, 1955

No. 5170

LEADING ARTICLES—	
Stress and Fatigue	274
Failure of Alternator Rotor End Bells	275
ARTICLES—	
Annual Report of North of Scotland Hydro-Electric Board	257
Association of Consulting Engineers	257
Automatic Oil Burner. (Illus.)	284
British Sub-Machine Gun. (Illus.)	270
Chamber of Shipping Annual Report	257
Electronic Digital Computers. No. II. (Illus.)	266
Electronic Tracer Control of Machine Tools. (Illus.)	268
Failure of Two 100MW Turbo-Generators	276
Ferritic Steels at Low Temperatures	265
Folkestone Warren Landslips	257
Fruit Juice Bottling Factory. (Illus.)	283
Glazing Bar Cleaning and Painting Machines. (Illus.)	283
Institution of Mechanical Engineers	257
International Water Supply Congress	282
Investigation into the Failure of Two 100MW Turbo-Generators. No. II. (Illus.)	272
Investigation of the Factors Contributing to the Failure of Diesel Engine Pistons and Cylinder Covers	284
Iron and Steel Development Programme	257
Lloyd's Register of Shipping	260
Particle Size Distribution Analyser. (Illus.)	283
Pressure Tunnels in London Clay	281

Railway Engineering Prospects. No. II. (Illus.)	258
Report on the "Comet" Accidents. No. II. (Illus.)	264
Water Supply Scheme for Glasgow	271
Wind Tunnel Developments. No. II. (Illus.)	279
800-Ton Plate Stretching Machine. (Illus.)	261
AMERICAN SECTION—	
Fabrication of High Permeability Magnetic Materials. (Illus.)	285
Explosion at the Ridgeland Power Station at Illinois	288
Elevated Temperature Properties of High-Strength Alloys	288
LETTER TO THE EDITOR—	
Railway Workshops	275
LITERATURE	
Books Received	275
NEWS AND NOTES—	
British Patent Specifications. (Illus.)	291
British Standards Institution	292
Contracts	290
Forthcoming Engagements	292
Industrial and Labour Notes	289
Launches and Trial Trips	292
Personal and Business	290
Technical Reports	271

STRESS AND FATIGUE

It is with commendable clarity that the recently published report of the "Comet" inquiry sets out the history of the disasters and of ensuing investigations into the two "Comet" aircraft which crashed under basically similar circumstances in the Mediterranean sea. It clearly accepts the findings of the Royal Aircraft Establishment and notes that the primary cause was structural failure of the pressure cabin brought about by its short fatigue life. These disasters were not preceded by fire, neither the engines nor the controls malfunctioned and it was not established that temperature stresses had in any way weakened the structure. Why was it, then, that an aircraft designed—as the report expresses it—observing the best engineering principles and in which the fatigue life of the cabin had been especially investigated, should so easily fall prey to fatigue? How tragic and simple was the unwitting false premise on which the stress distribution of the cabin was assessed! When conceived in 1946, the aircraft had need to fly at about twice the height of more conventional machines and consequently had to operate with a cabin pressure differential P of $8\frac{1}{2}$ lb per square inch, about 50 per cent higher than those adopted on civil aircraft then in service. The stresses induced by pressurisation are very much greater than those arising from the pure static and dynamic loading in flight even towards the centre, where the latter might be expected to reach a maximum. It was, therefore, clearly a structure in which the fatigue life needed special consideration. The makers recognised this fact. Although the normal strength requirement called for a cabin which would withstand $2P$ before failure, the "Comet" cabin was designed to withstand $2\frac{1}{2}P$. Two specimen sections of the cabin were made on which to conduct extensive pressurisation tests. The company had not, however, carried out a precise assessment of the stress distribution at cut-outs where, from knowledge of pressure vessels generally, local regions of high stress were to be expected. It was maintained

at the inquiry that the methods then available for such an analysis were unreliable and this view was upheld by the court. The stress calculations used to obtain the distribution near the windows indicated a stress of 28,000 lb per square inch under the normal pressure differential. This figure being less than one-half of the ultimate strength of the metal (65,000 lb per square inch) was sufficiently low, the company thought, to meet the economic working life requirement involving, say, about 10,000 pressurisations cycles. When the 26ft long front portion was tested it withstood thirty pressurisations up to $2P$ and then 2000 pressurisations at just over P . As a result of these two test series it was adjudged that the cabin under normal loading conditions would survive 10,000 cycles.

It is relevant to note at this point that according to the report it was not until 1953, and in fact the month following the total loss of the first "Comet" at Calcutta, that the adequacy of the cabin strength requirements was questioned by the Air Registration Board. It then issued proposals which called for 15,000 pressurisations, presumably on a test section, up to a pressure of $1\frac{1}{2}P$, the excess pressure being intended to cover the scatter characteristics of fatigue tests on similar structures. At the same time it proposed pressure tests on windows up to $3P$. By this time "Comet" production was well-established, but no aircraft had exceeded 800 pressure flights. Consequently, tests on the front portion of the cabin were resumed, and a further 16,000 pressurisations were applied, making in all 18,000 cycles. Again, it seemed natural to conclude, after its survival of so many cycles, that the cabin structure was safe. Only subsequent to the investigation of the cause of the "Comet" accidents could it be seen to be specially significant that when failure of this test section did occur the cause was skin fatigue at a window corner. Even immediately following the two "Comet" crashes the results of these tests were so convincing that cabin failure could be included only as one of a number of causes needing investigation. It seemed

neither more nor less likely than others. Only when a complete "Comet" aircraft was tested in a water tank was the weakness of the "Comet" structure stripped of its mystery. After only 1830 simulated flight cycles additional to 1230 pressurised flights in service the fuselage failed. Instead of 18,000 pressurisation cycles it had withstood only 3060. The short fatigue life of the "Comet" had been fully demonstrated, and further investigation was to remove what little doubt remained as to why this short life had been inevitable. As soon as strain gauges were applied to the regions near the windows where failure had occurred stresses much higher than the design stresses were recorded. All the essential ingredients for a premature failure by fatigue were now starkly exposed. They were in no respect irreconcilable with what is properly known about the phenomenon of fatigue. The windows were square with fairly sharply reduced corners. Thus were induced regions of higher stress; and in these localities there were rivet holes intensifying this stress distribution; associated with these rivet holes were fatigue cracks. The common practice of "locating" certain fatigue cracks which occurred in critical places was condoned because it was not thought that the stresses were high, or critical.

The designed fatigue life will be achieved in the "Comet," as the makers have announced, when it has a thicker skin to reduce the general stress levels and when the discontinuities in its structure such as windows are redesigned—as they can easily be—to cause less upheaval of the stress distributions in their localities. The makers were clearly and very understandably deceived by the tests on specimen sections. Indeed, there still remains some doubt as to why those results were so little representative of reality. It is explained in the report that the use of bulkheads to close the section may have introduced favourable end restraints on the skin; in particular, that windows associated with the critical region of the cabin were sufficiently close to this restraint as probably to be affected by it; and that the window distribution was otherwise different. But this may amount to less than a complete explanation. A more subtle cause of the apparent strength of the test section has been suggested by Sir Arnold Hall. He maintains that this section had been effectively prestressed by the earlier $2P$ pressurisations and would consequently enjoy a longer fatigue life. That is a very significant suggestion, and if it can be proved right it might have important consequences for aircraft design. It may thus turn out, when the fated pattern of past events can be reviewed in longer retrospect, that this suggestion will emerge as the most important scientific aspect of the investigation. For, in fact, little else has been learned; there has been no addition to our knowledge of fatigue phenomena; there was nothing strange about the failure itself. Nowhere in the recommendations which conclude the report is there a demand or a plea for a greater knowledge of fatigue phenomena. On the other hand, the report views with much concern the ramifications of plastic flow in high-stressed regions and suggests that this aspect ought to be more fully investi-

gated. It naturally concludes that a wider use of strain gauges should be adopted for the proper and more complete determination of stresses in the skin of the pressurised cabins of civil aircraft.

FAILURE OF ALTERNATOR ROTOR END BELLS

The failure of the two 100MW turbo-alternators at Toronto, which is referred to elsewhere in this issue, differs from the "Comet" aircraft disasters in two important respects. First, the damage to the Toronto generating station fortunately was not attended by any loss of life; secondly, there was no obligation upon the maker, other than a sense of duty, to hold a full investigation and to give wide publicity to the results. Nevertheless, the news of the failure of the two turbo-alternators was immediately transmitted by the manufacturer to the British Electricity Authority, the consulting engineers and to other manufacturers. But the firm was prepared to go much further than that, as was proved by Sir Claude Gibb's recent paper before the Institution of Mechanical Engineers. It called for a good deal of moral courage to present this paper, which takes the form of a report on his company's investigations into the Toronto disasters and, in providing the opportunity for open discussion before the "Mechanicals," Sir Claude has rendered a valuable service to the electricity supply industry as well as the manufacturing industry.

In both the turbo-alternators at Toronto the damage resulted from mechanical failure of the end bells which provide support for the end turns of the rotor windings. The prompt reporting of these accidents allowed the British Electricity Authority to take a number of precautions against the occurrence of similar failures in machines in this country. For example, an examination was made of the end bells of 50MW and 60MW sets having up to 20,000 hours' service; a significant outcome of this action was that, in some of the seventy-four rotors examined, the end bells exhibited stress corrosion cracking to an extent that was sufficient to warrant their rejection from service. In the meantime, as detailed in Sir Claude's paper, exhaustive investigations had been started by the manufacturer of the Toronto sets with the aim of establishing the cause of the failure of the end bells. These end bells, it may be recalled, were made of an austenitic steel which had the electrical advantage of being non-magnetic, but the mechanical disadvantage that the required physical properties could be obtained only by cold working and not by heat-treatment. Ideally the production of these end bells would have required a 12,000-ton forging press, whereas the largest press available at the time was of 4000 tons capacity, and a special step-by-step forging technique had to be adopted. Despite the care taken in stress relieving the work after forging, it is likely that there were residual stresses that were in some measure responsible for the failure of the end bells. The effect of such residual stresses was almost certainly accentuated by the subsequent drilling of ventilation holes which reduced the temperature rise in service but weakened the bell and acted as potential stress raisers.

All the available evidence suggests that, in bells that have failed in service or under

test the origin of the failure is in the holes. It is equally clear, however, from the discussion of Sir Claude's paper that, although the existence of the holes was a major factor in the failure, it was by no means the sole cause. One conclusion that emerged from the discussion was that all forms of notch or stress raisers should be avoided—a point which emphasises the importance of good machine finish. Another conclusion was that, provided the ventilation holes were eliminated, the bells could be stretched by hydraulic pressure applied internally to improve the uniformity of the residual stress distribution resulting from forging. Another important consideration was that the value of the ratio of yield stress to ultimate stress should be such as to allow a certain amount of plastic deformation to take place in service and one speaker in the discussion called attention to the need for standardisation of this ratio. But whatever particular inferences may be drawn from the contributions to the discussion, the most significant general conclusion is the benefit to be derived from frank exchanges of opinion and experience, whereby the lessons learned by one manufacturer may be shared by others. For it is by the free cross fertilisation of ideas that the boundaries of knowledge can best be extended. As Sir Claude reminded his audience at the "Mechanicals," "Progress is made by solving the problems resulting from the making of progress."

Literature

Water Conditioning for Industry. By SHEPARD T. POWELL. London: McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, E.C.4. Price 64s.

WITH the great advance in the science of water treatment in the past decade, one is surprised to find that a book having the title of *Water Conditioning for Industry* should deal so slightly with the many demands by industry for special water requirements in addition to the water required for steam raising. But when one has explored the 500-odd pages one is impressed with the author's completely fresh approach to the subject, and the book should become a standard of reference. The author has produced a most interesting bibliography, which has no less than 322 references to the most modern work on the subject by authors throughout the world.

The early part of the book is very lucid and it goes into sufficient detail for the student and graduate to obtain sufficient grounding of the subject of water treatment. The chapter on Analytical Procedures is also very ably put, so that with a moderate amount of equipment a ready determination can be made of the results of treatment through any modern plant. In the chapter dealing with chemical coagulation a number of interesting graphs have been used, but the value of these graphs would have been considerably increased if the author had given a fairly complete analysis of the water being treated, with the alternative chemical doses. Without this information the experienced reader will know that with a slight change in the character of the water totally different graphs might be produced.

The following chapters dealing with application of Coagulation and Filtration do not go as deeply into the subject as many may find necessary, and one is again reminded

of the considerable difference there exists between American and British practice.

Except for these minor criticisms the book deals with water conditioning for the power house engineer in a very effective manner. The chapter on Demineralisation contains a number of examples which will help considerably with the understanding of a branch of water treatment, which has developed in many directions recently. It is of interest to note that a complete chapter has been devoted to the Internal Treatment by Chemicals, and a further chapter showing how such chemicals can be administered. There is also a chapter dealing with Water Conditioning for recirculating systems. This is a subject in which almost every power station engineer is interested and is well suited for embodiment in such a book. The remaining chapters deal with the design and operation of a number of other items of equipment, which are to-day to be found in any up-to-date boiler house. The inclusion of these chapters will help to make the book of interest to every engineer interested in efficient control of water for steam raising plant.

Letter to the Editor

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

RAILWAY WORKSHOPS

SIR,—In your leading article on the railways in your issue of January 28th, you quite rightly ask the question: "If steam locomotives are not to be built, what is to happen to railway workshops?" The answer is "nothing." They will continue their normal business of locomotive repairs upon which approximately 90 per cent of their workers are at present employed. It is, of course, correct to say that in time they will be repairing electric and diesel locomotives in place of steam. No redundancy of workers would occur, because the normal turnover of labour in the railway shops is about 10 per cent per year and by reducing the rate of intake the total number of men employed could easily be adjusted.

For some years past it has been the policy of British Railways to build their own locomotives and for this reason the locomotive building industry of this country has been denied a home market. Last year my company exported 93 per cent of its output. These orders were obtained in very keen competition with Japan, Germany and other countries, in all of which the manufacturers enjoy the enormous advantage of building all the locomotives required by their home railways.

Now that it is proposed to make the change-over from steam to electric and diesel locomotives, it would appear to be a suitable moment to change the policy of the manufacture of locomotives from the railway shops to the locomotive builders. This would help one of the important exporting industries of this country and bring it into line with its competitors in other countries.

T. A. CROWE,
Chief Managing Director.

North British Locomotive Company, Ltd.
(Glasgow).

February 10th.

Books Received

Servomechanism Practice. By W. R. Ahrendt. London: McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, E.C.4. Price 60s.

Building Materials, their Elasticity and Inelasticity. Edited by M. Reiner. Holland: North Holland Publishing Company, P.O. Box 103, Amsterdam. Price 84s.

The Practical Engineer Pocket Book. Sixty-fifth edition. Edited by N. P. W. Moore. London: Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, W.C.2. Price 12s. 6d.

Failure of Two 100MW Turbo-Generators

INSTITUTION OF MECHANICAL ENGINEERS

AT a general meeting of the Institution of Mechanical Engineers in London on Tuesday, February 15th, under the chairmanship of the president, Dr. R. W. Bailey, a paper entitled "Report on Investigation into the Failure of Two 100MW Turbo-Generators" was presented by Sir Claude Gibb. Abstracts from the paper are reproduced on page 272 of this issue. An abstract of the discussion is given herewith.

DISCUSSION

Mr. V. A. Pask (in a written contribution, read by Mr. A. E. Hawkins): I am sure you will all agree that Sir Claude Gibb has rendered a signal service to both the manufacturing and utility industries in making available the results of his company's prolonged investigations in respect of the failures which occurred to the alternator rotor end bells of two 100MW, 1800 r.p.m. sets in Toronto last April. Immediately these accidents occurred he notified the British Electricity Authority, other turbo-alternator manufacturers and leading consulting engineers, adding that further information would be made available as it was obtained.

Following the preliminary examination made in this country of a broken end bell belonging to No. 1 Toronto machine, I wrote, on behalf of the B.E.A., to all manufacturers suggesting that these serious breakdowns, coupled with the fact the Authority was contemplating machines of materially increased output capacity, indicated the advisability of the Authority and the turbo-alternator manufacturing industry setting up a small committee to make a frank examination of the subject. I stated that whilst there did not appear to be any immediate cause for undue anxiety with regard to B.E.A. plant, it would be prudent to take all reasonable steps to make sure that failures did not arise here, and proposed the following points for discussion:—

(a) That each firm should immediately examine the end bells of a 50MW or 60MW set or sets, which had been in service for up to 20,000 hours. This examination to be in respect of both the metallurgical and mechanical condition of the steel.

(b) To consider the provision of hydraulic testing gear statically to load new end bell rough-turned forgings to some agreed percentage of the yield stress; also as an interim measure, to consider lowering the yield stress from 50 to 45 tons per square inch on the 60MW end bells in an endeavour to improve the ductility of the cold-worked material.

(c) The Authority to obtain from selected stations log sheets showing the hours in service, particularly with regard to the number of stops and starts, and how the hydrogen coolers were operated during such periods with a view to determining the gas and metal temperatures in the vicinity of the rotor body and end bells during such thermo-cycling periods.

(d) That the Authority would consider the more widespread provision of rotor storage space having temperature and humidity control for protecting rotor end bells from possible stress corrosion conditions during the station construction period.

(e) Examine the details of the mechanical construction of the various designs of end bells and caps, having due regard to the

stresses imposed by shrink fits, those caused by the inertia of the end bell, and the internal pressure due to the centrifugal forces of the copper coils and supports.

Dr. C. Sykes, of Thos. Firth and John Brown, Ltd., was invited to attend these proposed meetings. At the first meeting of the manufacturers and the Authority held on May 7, 1954, the foregoing proposals were generally agreed, with certain reservations in respect to the percentage of the yield stress to be imposed when hydraulically testing rough machined forgings, and the lowering of the yield stress by 5 tons to 45 per square inch. The Authority agreed to return complete rotors from its stations to the manufacturers' works so that end bells could be removed for detailed examination and also reassembled under controlled heating conditions, preferably by means of electrically heated jigs.

The preliminary examination of a representative number of end bells distributed amongst various manufacturers indicated that with very few exceptions there was no immediate cause for anxiety. Further examinations are proceeding as and when sets can be taken out of commission, the order being based on hours in service.

Progress has also been made in the evolution of hydraulic testing gear to suit individual designs, some equipped with strain gauge apparatus to check the hoop and longitudinal stresses imposed. Acknowledgment for originating suitable hydraulic testing gear designs should be made to Sir George Nelson and his associates.

Information obtained from the Authority's generating stations indicates that 60MW sets may be subjected to some 50 to 283 starts and stops per annum, and the shut-down periods vary from six hours to thirty-six hours or longer. Investigation has, however, proved that by a simple adjustment of the control valves associated with the dirty and clean water heat exchangers respectively, the re-cooled hydrogen gas temperature may be raised to 80–85 deg. Fah. before shut-down. Further, that this temperature will not drop by more than 3 deg. to 5 deg. Fah. during even a thirty-six to forty-two-hour shut-down period on a normally lagged alternator casing. These conditions can be realised at stations located in the fresh water reaches of a river in even the coldest winter period. The Authority is providing additional air-conditioned storage accommodation at all sites where unavoidable delays in civil construction works may involve storage of an alternator rotor.

We are indeed greatly indebted to Sir Claude Gibb for carrying out the long series of repeated stress cyclic tests by hydraulic pressure upon rotor and bells. These tests so clearly demonstrate that a particular pattern of holes may so appreciably reduce the fatigue strength due to cracks developing at the work-hardened surface of the holes that under repeated applications of a comparatively low stress they can be propagated rapidly as a brittle fracture. This definitely establishes that holes, whether for ventilation or mechanical construction, and in fact that any form of stress raiser caused by sudden changes in section must be avoided.

At the time the Authority gave consideration to the use of 100MW to 120MW sets

requiring larger diameter rotors, a definite direction was given to the manufacturers that no ventilation holes were to be drilled through the bell. In fact, a recommendation was made that they should also be avoided on the 60MW frame. In the light of the research evidence now available this decision would appear to have been a wise measure.

Mr. V. J. Vickers: The two disasters with which the paper deals appear to be identical with the failure in July, 1950, of one of the end bells fitted to the rotor of a 60MW, 3000 r.p.m. machine manufactured by the company with which I am associated. Details of the occurrence have not been previously published, but the information and conclusions were made available at the time to the main manufacturers and users in this country. Fortunately, this incident took place in an overspeed test tunnel during balancing operations at normal speed and before the rotor had been taken up to overspeed. The rotor itself was a complete loss, but the tunnel, which was lined with timber to form a 3ft cavity filled with sand, completely contained the wreckage.

The end bell broke into two pieces. We are only concerned with one of the fractures, since it was clear that the second was the result of consequential damage. A close-up view of this fracture shows it to be generally brittle in nature and seemingly identical in character to that illustrated in Fig. 7 of the paper. Sir Claude Gibb has made the point that in the immediate vicinity of the hole there is no appreciable deformation, but some "necking" becomes evident as the crack extends away from it. Investigation showed that the following were the principal factors which could contribute to a failure of this nature. First, the hole itself is a stress raiser and produces a high local concentration of stress. In addition, the work-hardening properties of this particular material, coupled possibly with a carelessly drilled hole, can produce ideal material properties for the initiation of a brittle fracture. The combined severity of these two effects will be greatly increased should such a hole coincide with a region of high residual forging stress, and also coupled with the cyclic effect.

It was therefore abundantly clear that, while the holes might not be the complete explanation of the failure, they were a major factor. We therefore took the decision immediately to abandon the practice of drilling all end bells whether for ventilation or for other purposes. Furthermore, all machines of similar size in the course of manufacture or in service were withdrawn. A number of smaller machines with end bells with physical properties characterised by an unduly small ratio between ultimate and yield strength were withdrawn from service. At the same time, the policy was adopted of not using any ring in which the ratio of yield to ultimate strength indicated inadequate capacity of the material to undergo further plastic deformation, although the ring in all respects comes within the requirements of the ordering specification.

While I agree with the author's estimate of the increase in average temperature rise of the rotor winding as the result of omitting the ventilation holes, I cannot subscribe to his opinion that their retention is necessary in order to prevent coil distortion.

The investigations into the failure of the 60MW rotor referred to showed, as the author has remarked, that the holes *per se* were not sufficient to account for the failure, and support for this view is given by the fact that other identical rotors had already been overspeeded. Work on the general problem has been proceeding ever since, and

it became evident very early on that in any one ring very wide variations can exist in physical properties, and in particular in the residual forging stresses arising from the method of cold working over a mandrel. This led to the introduction in 1950 of hydrostatic testing of every forging before it is passed for use.

As a means of producing more uniform properties throughout the rings it has been our practice from the start to produce a maximum hoop stress in the rings equivalent to 95 per cent of the lowest value of yield stress obtained on any of the acceptance tests, which figure is considerably higher than that mentioned by the author. Some non-uniform permanent set invariably results, indicating that there has been a redistribution in stress, or that there are some areas having lower than average strength which receive the necessary additional working.

Experimental results confirm that stretching by means of internally applied pressure does in fact greatly improve the uniformity of residual forging stress distribution. There can, I suggest, be little doubt that any method of forging which ensures uniform working of all the material in the ring, in contrast to the step-by-step method used in the case of the Toronto rings and also for the rings on the 60MW rotor which failed in 1950, will produce a much more uniform distribution of these stresses. One ring possessing an undesirably high ratio of yield to ultimate strength did fracture explosively while undergoing this test.

Mr. Harry West : It can be shown, and it is important to realise, that the stress pattern which arises when drilling a ring is such that the surface stress can reach theoretically some three times the normal hoop stress. Therefore, it does not seem difficult to realise that rings do fail at a low figure of hoop stress when it is possible to have high stress on the surface of the holes, and also where material has been work hardened and has therefore lost most of its ductility. It is in a right state for starting a crack, and once you have started a crack the failure of the ring follows.

[The speaker showed a slide illustrating a form of end ring devoid of holes or notches and mounted on an end plate free from the shaft. He said that, since 1928, this design had been used successfully for 800 rings.]

Professor G. W. Austin : On the question of working on and preparing the rings, I should like to know whether any high-temperature treatment is carried out. Very often material of this description is heated to quite a high temperature and then quenched. I do not know whether that happened in this case.

I think that the author compared this failure with the brittle fracture of mild steel. In the case of low-alloy steels there is another brittle phenomenon known as tempered brittleness, and it is possible to see a network that is reminiscent of austenitic network. In the case of tempered brittle metal it is the grain boundary which is the weak point, and by suitable treatment it has been possible to avoid this brittleness and susceptibility to it. I think that in the same way by treatment and alloying we shall be able to get rid of the grain boundary weakness in the end bells.

Dr. Charles Sykes : The end bells which the author has been talking about this evening were manufactured by my company so you can imagine the importance which we attached to this investigation. I should like to thank the author for the completely frank and open manner in which he has conducted all his discussions with us on

these problems, and to say that we have had full facilities to co-operate throughout this investigation.

I should answer Professor Austin's point by saying that this material is treated at 1050 deg. Cent. prior to cold working. Subsequent to the Toronto failures we have speeded up the cooling arrangements and have made them much more uniform, with the result that we have reduced the precipitation at the grain boundaries and have obtained better Izod. At the same time tension through the ring has been reduced.

Mechanical test figures are now available for No. 1 turbo-end cap. That was the one which failed after seventy-six cycles. It failed at hole 39 and at hole 39a. Tests have been made on the material between the two holes and the results are very similar but slightly superior to those recorded in Table IX of the paper for No. 4 machine, the exciter end. I think that in considering the various possibilities contributing to these failures one should include the internal stress which is set up in the immediate vicinity of the hole due to the drilling. Whilst the internal stress system will be very local the stresses themselves might be very high.

We have carried out a number of tests on rings which have been hydraulically tested in the manner described by Mr. Vickers, and we do confirm that that evens up the internal stresses quite substantially.

The cyclic tests have emphasised the importance of the fatigue properties of end bell materials, and we have in hand an extensive series of fatigue tests. As the author has pointed out under the results of Wohler fatigue tests, the fatigue limit is about 21 tons per square inch and the ratio of the fatigue limit to the ultimate tensile strength is about 0.35 compared with 0.46 for heat-treated steels. The fact is that the Wohler fatigue limit of this material is practically the same whether the material is soft, having a yield point of 25 tons per square inch or whether it is cold worked to 50 tons per square inch. It looks as though fatigue ratio decreases with the degree of cold working.

I think that the data recorded in the paper indicate that all forms of notch should be eliminated and that the shrink fit stress should be kept as low as possible in order to provide the maximum margin of safety against various types of fatigue load which will occur in service. There is an additional very important reason for keeping the shrink fit stress low. Evidence is that when stress corrosion does take place it occurs when the end bells are stationary when condensation can occur. The rate of stress corrosion varies exponentially with the stress, and the stress when the rotor is stationary is, of course, the shrink stress, so it is desirable to keep this as low as possible.

Mr. L. E. Benson : Like other speakers, I have come to the conclusion on reading the paper that the ventilating holes were the major cause of the disaster, also that without ventilating holes the rings would have had quite a generous margin of safety.

I think that it is not perhaps realised how serious the weakening effect of the drilled hole can be in austenitic steel. The weakening effect can arise in three ways—by stress concentration ; secondly, by strain hardening effect which limits the ductility of the material and, thirdly, possibly by local heating during drilling operations which, if severe, could leave the surface material in a state of initial tension when cooled down again.

Referring more particularly to the strain

hardening effect, drilling in austenitic steel is a most difficult operation, and it is almost certain to be accompanied by severe distortion as shown, for example, in Fig. 10 (c) of the paper, and by the severe strain hardening as indicated by the recorded hardness figure. It is desirable, of course, that strain hardening effects on machining should be minimised not only so far as surface inside holes are concerned but also on the outer and inner surfaces. We have, therefore, standardised our finish machining conditions, that is, tool type, shape, speed, feed, and so forth.

Apart from stress concentration effects it may be helpful to mention that we have evidence for suspecting that machine finish, and in particular strain hardening, may affect the susceptibility of this material to stress corrosion cracking. The evidence is that on our own stress corrosion tests we do not obtain cracking under conditions which we understand other workers would regard as quite dangerous. For instance, even micro-examination at 100 diameters has not shown cracking on specimens tested at 30 tons per square inch in wet air and CO₂ for 500 hours or at 20 tons per square inch in sea water for 2000 hours.

Mr. J. T. Moore : Having been intimately connected with the investigations following the failure of the 37in diameter non-magnetic end bell referred to by Mr. Vickers, I should like to emphasise the quite remarkable similarity between this failure and those described by the author. Not only were the end bells of the same material, but they were also manufactured round about the same time. The extensive investigations following the bursting of the 37in end bell in 1950 showed that while holes in the end bells were probably not the sole cause of the failure, they were undoubtedly largely contributory when used in the particular cold-worked material, especially when the ratio of yield to ultimate tensile strength is high.

I feel very strongly that with this cold-worked non-magnetic material for use in end bells the ratio of yield to ultimate is of vital importance, and I would like to suggest that the various parties concerned in this country, both manufacturers and users, should get together and establish a national standard for the maximum acceptable ratio of yield to ultimate. I feel it could be the forerunner of corresponding international standards.

On the assumption that an acceptable ratio of yield to ultimate is established and that holes are not in future drilled in non-magnetic end bells of any size and thus the question of the finish on the holes does not arise, a pressure test on the lines described by the author and by Mr. Vickers would seem to be advisable as the only means of finding the occasional rogue end bell. As a further safeguard I feel that after machining, magnetic end bells (undrilled of course) should be subjected to a low-temperature annealing to remove as far as possible surface stresses without impairing the main properties of the material. I do not profess to be a metallurgist and would welcome the views of specialists present on this question of low temperature annealing after machining.

Mr. F. Shakeshaft : The dimensions of end bells for output capacities of 60MW or 200MW are very similar, the latter being only some 8 to 14 per cent larger in diameter. Opinions differ, however, as to the yield and ultimate strength required of the material from which the 200MW rings are made.

The favoured ratio between the yield and ultimate strength of materials is around 85 per cent, but the consensus of opinion is that the existing yield strength of 50 tons per

square inch be increased by some 10 to 14 per cent, that is, to 55 to 57 tons per square inch, or in about the same ratio as the increase in diameter of the end bell. This might involve a major change in the alloy used for the forgings.

A new alloy containing 18 per cent manganese and 3 per cent chrome is being tried out on the Continent, but to date little experience has been gained of its behaviour in practice; some Continental alternator engineers have named it a "young" steel and await further results. It is not their intention to use this new alloy for 37in diameter rotors, but to adhere to an alloy similar to that now used in this country.

I suggest that the problem is not one of simply designing for an increase of 8 to 14 per cent in rotational stresses computed under uniform temperature conditions, but of designing to avoid, under service conditions, any dangerous increase in compound stresses caused by temperature differences as between rotor body and end bell. This problem must also be solved when aiming to achieve around $3\frac{1}{2}$ times the electrical output from a rotor of only some 20 to 30 per cent increased volume.

The experience already gained from semi-direct cooling of the winding in the rotor slots, together with the evidence made available in this paper, indicate that additional metallurgical and heat transmission research work is needed. Further, that an exhaustive investigation into the mechanical design details should also be made before the fifty new large-capacity alternators enter the manufacturing stage. The application of semi-direct cooling to the rotor body winding has already shown the importance of adjusting the hydrogen flow through individual bars so as to avoid uneven cooling of the rotor body. If uneven cooling occurs it results in the bending of the rotor body and consequent heavy mechanical vibration.

Temperature differentials as between the rotor body and the end bell may induce excessive combined hoop and bending stresses in the end bell. An examination of Fig. 20 (c) in the paper would show that whilst the mean hoop stress in the end bell required to balance the forces imposed by the inertia of the bell and the centrifugal action of the end windings is $19\frac{1}{4}$ tons per square inch, the maximum stress at the point of shrink fit between end bell and rotor body is about $32\frac{1}{2}$ tons per square inch under the temperature differential quoted. This stress gives a factor of safety of around 1.5 only at normal speed on a yield stress of 50 tons per square inch.

This raises important design matters. First, would it be wiser to shrink the end bell on both the rotor body and the carrier ring? Secondly, would it be wiser to support the carrier ring on a separate sleeve either secured to the end of the rotor body or from a shaft seating adjacent to the body? One manufacturer in this country and another in the United States have had satisfactory results with shrink fits as low as two-thirds that now used when supporting the bell from the rotor body alone. This kind of construction stresses the end bell more uniformly under stationary and uniform temperature conditions, and gives rise to smaller variations in stress with differential temperatures caused by service operating conditions.

Mr. L. W. James: With regard to the effects of single-phase loading, whilst it has been fairly rare in the past to experience trouble in air-cooled machines, on most occasions when heavy unbalanced loading has occurred smoke or the smell of hot insulation around the machine has given warning before serious damage has taken

place. As stated by the author, it is not possible to notice in this way overheating effects of the type occurring under unbalanced loads with totally enclosed hydrogen cooled machines, and we must rely on some more accurate method for detecting this effect. In addition, the present-day use of large numbers of main circuit breakers not having the three phases mechanically interlinked has increased the risk of single-phase loading.

Some eighteen months ago it was agreed that all large hydrogen-cooled generators being installed on the British system should be protected against unbalanced loading by a suitable negative phase sequence relay, arranged to trip the machine off after a time delay depending on the degree of unbalance. An alarm would also be given as soon as the unbalanced loading reached such a value that there was risk of damage to the machine so that the operators would have warning that the protection would trip the machine if no action were taken to reduce the unbalanced loading.

Dr. H. E. Davies: It can be shown that the presence of holes of relatively small size in comparison with the main section of a metallic material can give rise to a system of tri-axial stresses at the holes which can result in failure of the material by brittle fracture. The stress system at the holes is such as to inhibit plastic flow of the metal at these points, with the result that fracture takes place with little or no deformation. The description and illustrations of the failure of the end bells on the Toronto machines present evidence which indicates beyond reasonable doubt that this was the method by which they failed.

Work hardening of the material, especially locally at the areas of stress concentration, also inhibits plastic flow, and increases the tendency to brittle fracture, but the stress concentration due to the presence of the holes and the fact that the material itself is cold worked throughout its mass would tend to override any tendency for fracture to commence in a hard hole as against a relatively soft one, as was observed in one or two of the author's tests when bursting rings.

Susceptibility to brittle fracture is also a property of the material itself, and it would be interesting if the author could inform us whether he has carried out any tests, similar to those conducted on mild steel, which would indicate the propensity of this non-magnetic steel to brittle failure.

It seems extremely likely that in this design of end bell for a 100MW machine, the limit of dimensions for this material has been passed when failure by brittle fracture will be almost certain, when it can be propagated by suitable stress raisers.

Although no indications have been forthcoming in this investigation to indicate that stress corrosion has played any part in the failure of these end bells, nevertheless this kind of cracking was uppermost in our minds when we first heard of the disaster, since the susceptibilities of the quality of steel to this type of cracking had been amply demonstrated in the past. The B.E.A., along with manufacturers, as you have already heard, took active steps to examine as many end bells as possible for this type of cracking. Up to the present some seventy-four end bells have been examined, ten of which have exhibited stress corrosion cracking of varying degrees of intensity, some sufficient to cause rejection of the bells as being unsuitable for further service.

Mr. A. W. C. Hirst: I think that the author and his associates deserve praise for not having jumped to what might have been regarded as the obvious conclusion

that holes were the sole cause. In casting round for other contributory factors they have obtained a great deal of information which has been made available to other designers who have not had similar experience and may be able therefore to avoid similar trouble in the future.

With regard to the question of ventilating holes, the author suggests that if they are carefully ground and honed the stress at which the bell would fail might be considerably raised. I wonder whether any tests have been carried out to justify that statement or to show to what extent it may be effective.

The Author (in reply): I should be glad if Mr. Hawkins would convey my own thanks and those of my colleagues to Mr. Pask and his colleagues for the consideration and help which they have at all times given us in this investigation. Had I felt that the mere elimination of ventilating holes was the complete answer, this paper would never have been written. I can assure you that ventilating holes, important though they are, are not the complete answer, and anybody who thinks that they are is living in a fool's paradise. I should like to thank Dr. Sykes and his colleagues for the very fine way in which our two teams have collaborated in trying to get to the bottom of this.

In reply to Mr. Moore on the question of the ratio of yield to ultimate tensile strength, we should, of course, like at least something lower than 80 per cent, but I am afraid we have to take what we get, having in mind the necessity for a non-magnetic composition. Consequent upon the Toronto failures, we have lowered the yield point specified to 45 tons per square inch instead of 50 tons per square inch. We think that that is in the right direction, but when one has to go to still higher stresses one may be forced to reconsider the specification.

In reply to Mr. James, so far as the temperature rise of Nos. 3 and 4 units is concerned, they are back in service with magnetic caps and all we can say is that we have been agreeably surprised that the increase in temperature rise has not been more than it is. There has been some, but nothing like as much as we had expected.

Dr. Davies drew attention to stress corrosion. I am not sure whether, in presenting the paper, I said that the opposite end to the roller which had cracked whilst in storage, which was put under the hydraulic test, failed at a mean hoop stress of 30 tons per square inch, thus indicating that although the crazing and surface corrosion appears to be relatively slight, the danger of it is very great.

Mr. Hirst raised the question of size effect. In the paper you will see that it is pointed out that the 37in bells and 56in bells appear to behave much the same, certainly within the bracket of experimental error one would expect both as to failure under hydraulic test, single application and failure under cyclic hydraulic testing. I mentioned the figure of 203 cycles for the Toronto size cap under a stress range of 0 to 40 tons per square inch. Simultaneously, a 37in cap is being cycled over the same range and at three o'clock this afternoon that had withstood 74 cycles.

WATER METERS.—A new range of water meters has been developed by George Kent, Ltd., of Luton. The new "Master" meter, as it is known, is made in $1\frac{1}{2}$ in, 2in, 3in and 4in sizes. It is a pipeline semi-positive rotary piston meter, designed for the accurate measurement of water flow at temperatures not exceeding 120 deg. Fah. The $1\frac{1}{2}$ in, 2in and 3in sizes have a maximum counter registration of 10,000,000 Imperial gallons, while the 4in has a maximum of 100,000,000 Imperial gallons.

Wind Tunnel Developments

No. II—(Concluded from page 246, February 18th)

At the Royal Aircraft Establishment, Farnborough, and the National Aeronautical Establishment, Bedford, a number of new wind tunnels have been, or are being, constructed. Others are being operated or adapted to exploit a new technique for working in the transonic region with slotted working sections. At Bedford, where much of the research on supersonic craft will be conducted, the research facilities include tunnels which in design and in respect of automatic measuring and instrumentation equipment compare with the most modern of those known to exist. Amongst the installations mentioned below is a pressurised spinning tunnel, a large transonic and a large subsonic tunnel, and some small supersonic tunnels.

SPINNING TUNNEL AND HIGH-SPEED LABORATORY

THE main purpose of the vertical spinning tunnel is to observe behaviour of free models in spinning flight and particularly to investigate methods of recovery from a spin. This tunnel is nearly completed and will be operating in a few weeks' time. The structure weighs 1200 tons and is shown with the high-speed laboratory in our illustration.

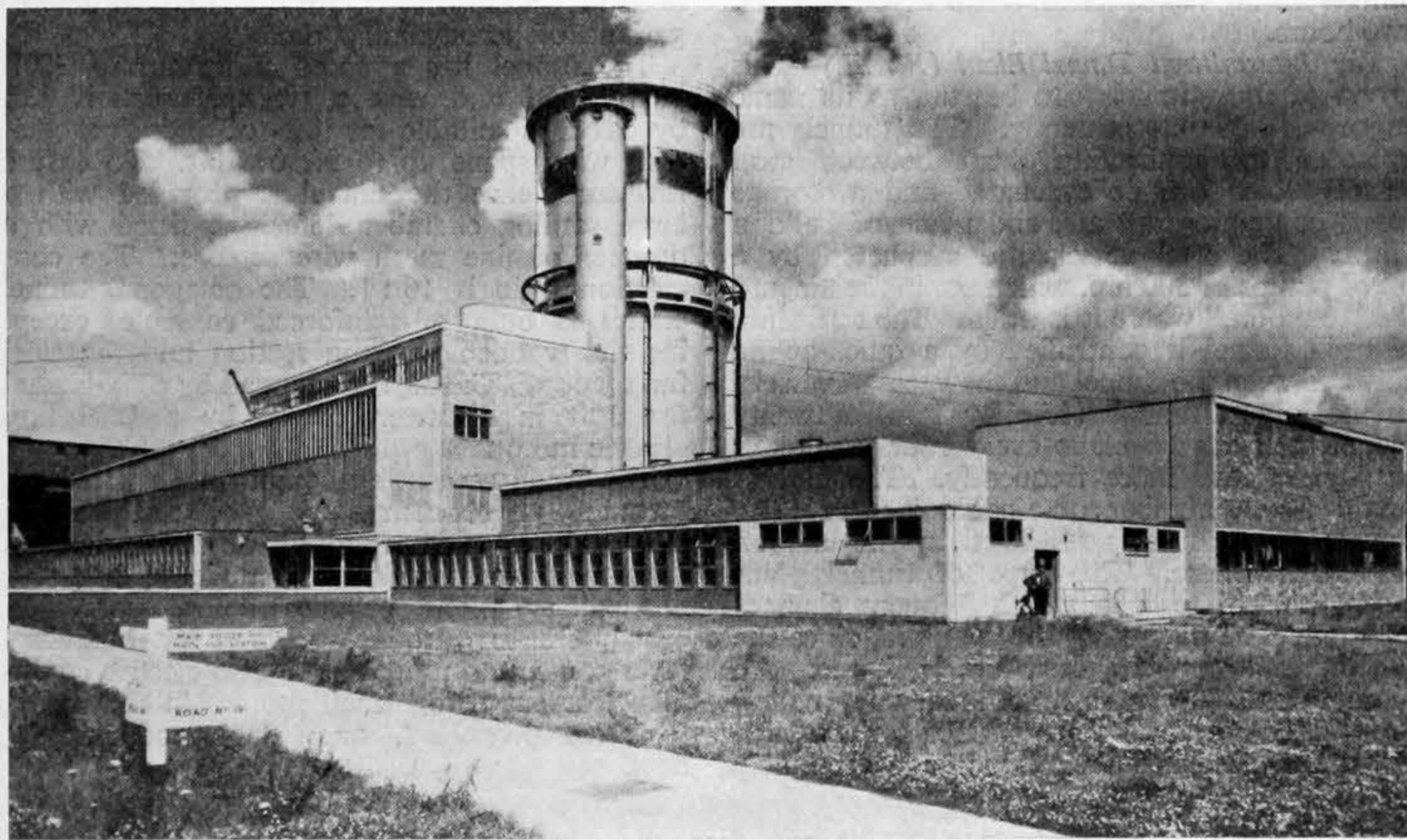
The tunnel consists of a vertical steel shell about 80ft high and 45ft diameter, with a fan and internal ducting to provide an air flow up the working section in the middle and down an annular return circuit. The working section is 15ft diameter and models up to about 3ft wing span can be tested.

The tunnel can be pressurised to 4 atmospheres absolute, and arrangements are provided whereby the model can be launched into the air stream and brought back to the launching chamber at the end of a test by an operator who is right

9in square to be run at Mach numbers up to 3 or $3\frac{1}{2}$. An auxiliary pump is used to evacuate the circuit or pressurise it to 4 atmospheres absolute. Optical and pressure plotting equipment is installed.

Eleven-Foot Wind Tunnel. (R.A.E.)—This closed circuit tunnel, which has been in operation since 1943, is used in cases where the airstream can be regarded as virtually incompressible. It is limited to a top speed of 400ft per second (275 m.p.h.), at which speed the fan horsepower is 4000 h.p. Cold brine for air cooling can be circulated through the cascades of metal turning vanes which are situated at the corners of the tunnel circuit. The driving fan is 17ft in diameter and the maximum section of the tunnel is 24ft square. There is a sudden contraction of ratio 6.3 : 1.

With the aid of three fine-mesh screens, a honeycomb in the maximum section, gradual diffusion, and the sudden 6.3 : 1 contraction, a



High-speed laboratory and vertical spinning tunnel

outside the tunnel. The model will be viewed by means of television equipment and also through a periscope.

The air flow is produced by a fan driven by a 1500 h.p. electric motor (3000 h.p. overload capacity), and a sensitive speed control is provided by hydraulic adjustment of the blade pitch. The operator adjusts the upward air speed until it equals the rate of descent of the spinning model, which is thereby sustained within view in the working section. The maximum air speed is 60 m.p.h. at full pressure and 95 m.p.h. at atmospheric pressure.

Apart from free spinning tests the tunnel can also be used for aerodynamic force measurements on a model mounted on a rotating support.

High-Speed Laboratory.—This plant, which is nearly completed, will comprise four test bays in which small supersonic tunnels can be installed. A common air supply is provided by a 4000 h.p. compressor, which is also used for charging the vertical spinning tunnel. This supply enables tunnels with working sections from 4in to about

uniform stream of air of low turbulence is achieved in the working section, flow uniformity being of the order of one part in a thousand, and a turbulence level down to one part in 10,000.

The working section is fitted with an overhead balance, which measures lift, drag and pitching moment, and from which models may be suspended in the working section by means of struts or wires. There is also another balance, below the tunnel floor, which can measure all six components of force and moment (lift, drag, side force, rolling moment, yawing moment and pitching moment). The lower balance is of considerable mechanical interest in that all moving parts of the balance frames slide freely relative to one another on thin films of compressed air. The lift force can be measured on both upper and lower balances to an accuracy of a few tenths of a pound over a total range of about $1\frac{1}{2}$ tons. The range and accuracy of the other components are in proportion to these figures. Typical models might have a wing span of about 7ft, i.e. about one fifth fighter aircraft size.

The 8ft by 6ft Transonic Wind Tunnel (R.A.E.).—The 10ft by 7ft "high-speed tunnel," which has been operating at the R.A.E. since 1942 is being converted. In its new form the main fan power is being increased from 4000 h.p. to 12,000 h.p., which will enable tests to be made at higher pressure giving increased Reynolds number. An auxiliary compressor of 8000 h.p. and a transonic working section have also been added to enable the Mach number range covered by the tunnel to be increased from 0.95 to about 1.15. In this transonic ventilated working section, a proportion of the air circulating round the tunnel is extracted by the auxiliary compressor and returned to the main air circuit on the downstream side of the fan.

A special building has been erected to house the new 8000 h.p. compressor, together with the ducting which will bring the air from the tunnel proper and return it after compression, plus a cooler and control apparatus.

In the modified tunnel the models used will be subjected to large forces. A typical one might have a span of 2ft and wing area of approaching 2 square feet. The load experienced by its wings, corresponding to the lift on the actual aircraft, might reach $\frac{3}{4}$ ton. All the models must be made with a wide margin of safety, so that they will not collapse under the air loads. Any part of the model which broke off would almost certainly wreck the tunnel fan and cause a major breakdown. The measurements, taken electrically, will appear automatically as typed records. The conversion is expected to be completed in the coming autumn. The contraction ratio of the tunnel is 9.4 : 1. It can operate up to a Reynolds number in high-speed tests, per foot wing chord, of 3.5 million and at low speeds, per foot wing chord, 0.6 million to 5,000,000.

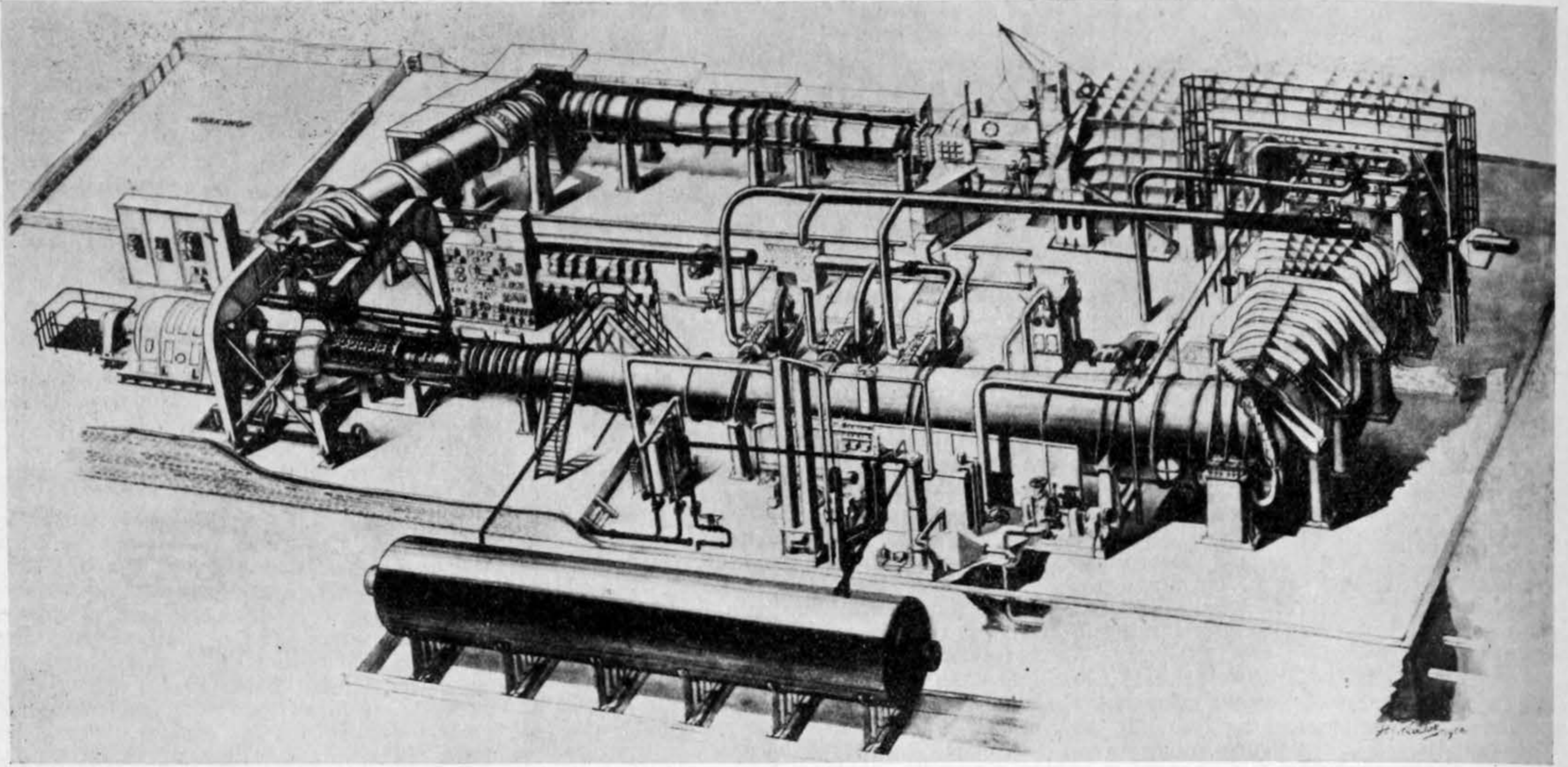
The 2ft by 1½ft Transonic Wind Tunnel: The "By-Pass Tunnel" (R.A.E.).—This tunnel has been designed to make economical extra use of the 8000 h.p. compressor which is being installed as part of the above conversion. It is being built in a by-pass or cross pipe between the ducts connecting the compressor with the large tunnel, and an arrangement of isolating valves enables the compressor to be used as the main drive or air circulator for the by-pass tunnel when the 8ft by 6ft is resting (as when the latter's test model is being altered). The working section will be 2ft by 1½ft.

This tunnel is expected to run at speeds up to about Mach 1.4. Not only will it be ultimately useful for preliminary work on aircraft designs to be later tested in the 8ft by 6ft transonic tunnel—of which it will be one-quarter the linear size—but it will be a useful research tunnel also. It is expected to study with it also the design of transonic working sections. The Reynolds number at high Mach number per foot chord is 4,000,000.

The H.A.T.P. Supersonic Laboratory (R.A.E.).—After the close of World War II, research on reciprocating engines at R.A.E. was abandoned and, with interest growing rapidly in flight at speeds greater than the speed of sound, the plant that had been in use for testing the performance of engine components at high altitudes was adapted to provide the motive power for six small supersonic tunnels.

This test plant consisted of eighteen Nash Hytor water-sealed vacuum pumps and three Brown Boveri centrifugal exhausters; equipment was also available in the form of two Butterley refrigerating engines and an activated alumina drier for reducing the water content of the air to be used in the supersonic tunnels to absolute humidities of less than 0.02 per cent. More recently, further plant has been installed, consisting of two Jaeger seven-stage centrifugal compressors and seven Bristol "Hercules" centrifugal superchargers, to boost the pressure of the air up to 5 atmospheres before reaching the tunnels. The tunnels and plant are arranged so as to give each tunnel a choice of plant from which to run and in some cases more than one tunnel can be run at the same time. To give the required conditions for some tests, however, all the plant is needed and under these conditions the total horsepower used is over 15,000.

The working sections of the six tunnels range in size from 5in square to 10in square and were designed to cover a Mach number range from 1.3 to 4.8. The maximum stagnation pressure



1ft 6in by 1ft 6in supersonic wind tunnel at Farnborough

which can be obtained varies with Mach number from atmospheric at $M=1.3$ to 5 atmospheres in the smaller tunnels at Mach numbers greater than 3.0.

Each tunnel has been adapted for investigations into a particular aspect of the problems of supersonic flight so as to avoid long delays while different test rigs are being changed. The tunnels are used for testing designs of air intakes for gas turbines and ramjets and for investigations into the characteristics of boundary layer flow and aerodynamic heating problems. One of the tunnels has been developed so that tests can be made in which the hot gas stream from an engine, for example, is reproduced in the wind tunnel model; this is mainly for the investigation of the pressures on the model in the vicinity of the jet stream.

The 1½ft Square Tunnel (R.A.E.)—The 18in square tunnel is a continuously operating tunnel driven by a 7000 h.p. Escher Wyss synchronous motor coupled directly to a seven-stage axial flow compressor. A feature of this compressor is that the rotor blade pitch setting can be varied in order to control the pressure ratio, whilst the rotor itself is turning at 3000 r.p.m. The highest Mach number of the tunnel is 2.2 and the stagnation pressure can be varied between 0.1 and 2.8 atmospheres. The recording of data during a tunnel run is fully automatic. The results are recorded

directly by an electric typewriter and also in the form of punched cards. The punched cards are fed to an automatic computing machine which converts the results to the final coefficient form required. Sets of measurements at each of three model attitudes can be recorded every minute during the course of a run which may last two hours.

The Intermittent Tunnel Plant (R.A.E.)—This group of four tunnels can be run, as its name suggests, only intermittently. The tunnels are operated by connecting them between steel vessels which can be evacuated and a storage vessel containing dry air, and made of balloon fabric. The steel vessels are evacuated by a set of pumps of 300 h.p. which pump the air into the "balloon," where it is dried. The operation of each tunnel is controlled by a quick-acting valve between the tunnel and the vacuum vessels. In the largest tunnel (15in by 16in) a twenty second run can be made every twenty minutes or shorter runs more frequently. The highest useful Mach number obtainable is 4.5. The stagnation pressure is restricted by the balloon to 1 atmosphere. This type of tunnel plant lends itself to tests in which frequent changes of a model configuration are required, since the starting and stopping procedure is simple. An example is the measurement of loads on a rudder, elevator or aileron control surface on a model. For such models it is difficult to design a remotely

operated system for changing the control angle.

13ft by 9ft Low Speed Tunnel (Bedford).—The main function of N.A.E. is to obtain design information for high-speed aircraft and this tunnel is used for testing the performance of those aircraft at low speed for landing and take-off, and also for more fundamental investigations of aerodynamic theory.

The tunnel has a speed range up to 300ft per second and with a working section 13ft by 9ft it is suitable for tests of aircraft models with wing spans up to 9ft or 10ft. To ensure low turbulence the tunnel is provided with a large settling chamber 46ft high fitted with a number of fine mesh wire screens. The contraction ratio is 16:1. The octagonal tunnel circuit is built of reinforced concrete, except for the wooden working section and the steel fan section. The air is circulated by a six-bladed fan 30ft in diameter, driven by a 1500 h.p. electric motor.

The usual measuring equipment is provided, including a six-component overhead balance and banks of manometers for obtaining detailed pressure distributions over the model surface.

Auxiliary plant includes compressors and evacuators for producing flow for boundary layer control on models, and also electric equipment for supplying small motors in the model to drive propellers, or a fan producing jet flow.



13ft by 9ft reinforced concrete low-speed wind tunnel at Bedford

It will have been noticed that the large-scale plants we were shown cover the Mach number range from up to $M=2$ or 2.5 , leaving the higher speed range to small plant. This is the present position, but design work has been going on for some time on large-scale plant to fill the Mach number range 2 to 4.5.

The choice of 4.5 to 5 as the upper limit of Mach number for supersonic tunnels is not arbitrary, but represents a natural limit set by liquefaction of the air in the tunnel. As air expands through a nozzle to these very high Mach numbers it becomes cold, and starting from normal room temperature, by the time a Mach number of 4 is reached the air will be so cold (about 400 deg. Fah. of frost) that it liquefies and the tunnel becomes filled with a mixture of air and tiny droplets of liquid air, which make testing impossible. A solution is to heat the air in the tunnel and a new tunnel has been designed in which air, heated to 600 deg. Cent. by passing over red hot plates, passes through a quartz working section at speeds up to eight or nine times the speed of sound.

The planning and aerodynamic design of the new test equipment described in these notes has been done by the Ministry of Supply staff at R.A.E. and N.A.E. The constructional work has been the responsibility of Ministry of Works, which placed the contracts, supervised the manufacture and erection of the plant and buildings, and in many cases played a major part in the design.

Pressure Tunnels in London Clay

The Metropolitan Water Board, in co-operation with the Building Research Station, has carried out extensive tests on a pressure tunnel built in the London clay and lined with wedge-shaped precast concrete segments. An exhaustive account of the design and construction of the tunnel and of the tests carried out and the instruments developed for them was given on Tuesday, February 15th, in a paper presented at the Institution of Civil Engineers. Brief abstracts from the paper are reproduced herewith.*

THE Ashford Common tunnel, on which most of the work described in this paper was carried out, is intended to form the main supply from Queen Mary reservoir to the new Ashford Common filtration works and is 1882.6ft long between centres of shafts. The ground level along the line of the tunnel is about 41 O.D., the normal hydraulic gradient line in service will be between 70 and 74 O.D., and the level of the tunnel centre line varies between -48 O.D. and -46 O.D. It was designed to carry 200 m.g.d. and, to deal with possible future hydraulic conditions, it would in any case have been necessary to construct even a surface conduit at a considerable depth. It was therefore decided to construct a deep tunnel and to take advantage of the earth pressure to resist internal pressure. Construction of the tunnel began in January, 1952, and was completed in May, 1952. The tunnel was first filled in March, 1953.

The tunnel lining was of the Don-Seg type.† Each ring had an internal diameter of 100in, an external diameter of 112in, a length of 21in, and consisted of ten equal wedge-shaped segments. Each segment was 33.5in along the intrados at the wide end, 29.3in at the narrow end, 21in longitudinally, 6in thick, and weighed about 360 lb. The longitudinal edges were brushed with bitumen paint and allowed to dry before erection. Alternate segments were placed in a ring with the wide end against the last assembled ring and the ring was then tightened by using the shield jacks to wedge home the intermediate segments with their narrow ends towards the last assembled ring. No special order of closing was specified and different gangers used different methods.

Borings put down on the line of the tunnel proved the existence of a surface layer of water-bearing gravel 15ft to 20ft thick and, below that, hard London clay to below the line of the tunnel.

Other geological records for the area indicate that the London clay extends to about 350ft below the surface.

Basis of Design.—Very little data existed on the earth pressures to be expected on tunnel linings in London clay at such a depth. It was generally thought that, after a sufficient lapse of time, the pressure on the tunnel lining would approximate to a pressure equivalent to the full depth of overburden. The basic assumption of design was that the earth pressure on the tunnel rings should be not less than the water pressure. On the assumption that the internal surfacing of the lining was watertight the tunnel rings would not then be subjected to tension since the water pressure would merely reduce the compressive stress arising from earth pressure. There are, of course, no connections such as bolts between the segments, and the tunnel rings are incapable of taking any tension.

If the lining or its internal surfacing were not watertight it should make no appreciable difference to the stresses in the tunnel segments. The only difference would be that the water pressure would then tend to act directly against the clay instead of acting through the segments, but would similarly reduce the compressive hoop stress on the lining.

The normal water head on the tunnel will be 74 O.D., with ground level approximately 41 O.D. Assuming the weight of earth is double that of water and that ultimately the earth pressure would equal overburden pressure, the water pressure would equal the earth pressure with the tunnel at a depth of 33ft. There was, however, a possibility that the head could rise to about 100 O.D. and this pressure would require a depth of 59ft. The cost of placing the tunnel at a greater depth was comparatively small, and it was decided to drive it with a level axis at about 90ft below ground level. This was considered to give an adequate factor of safety. It was decided also that the London clay could safely be relied upon for watertightness. The clay is fissured, but the fissures are closed in the undisturbed condition and it was considered that no significant leakage could take place through the 70ft of clay overlying the tunnel.

The tunnel was driven wholly from the west shaft. The shafts had an internal diameter of 12ft and were lined with bolted precast concrete segments. Subsequently, when the tunnel had been driven, a thin welded steel pipe of 9ft diameter was placed inside the shafts and turned about 12ft inside the tunnel, the space between the steel pipe and shaft lining being filled with concrete. Four short lengths of cement linings of different types were applied in the tunnel.

Shield.—The tunnel was shield-driven, the shield had ten hydraulic rams, one to each segment in the ring. The usual function of a shield is to act as a protection against bad ground, but in this type of tunnel where the lining is precast and is not grouted the primary function of the shield is to cut a circular hole of an exact diameter. The protective function is secondary, because this type of lining would not be used in bad ground. This function of the shield has not hitherto been given sufficient consideration. In the authors' view the methods normally used for fabricating shields are not always sufficiently accurate for a precast concrete lining of fixed diameter driven in hard clay.

When the clay is exposed behind the shield the pressure is released and the clay expands. When the lining is erected and tightened the clay is, to some extent, recompressed. It is important, therefore, to get the correct relation between shield diameter and lining diameter, which makes proper allowance for expansion of the clay and produces the required degree of compression in the ring and corresponding pressure against the clay.

Erection of Lining.—The method of closing a tunnel ring of this type involves considerable movement of the individual segments both circumferentially and longitudinally after the segments are first placed in position. This movement may be 5in longitudinally and 3in circumferentially, and takes place under varying loads. The friction between the materials is high and more than 80 per cent of the final jacking force was lost in friction. The effect of these movements under load is that it is difficult to keep the segments in their correct final posi-

tions in the ring and bearing uniformly against each other.

The final positional errors may be small, but this type of ring requires an exact diameter, and unless this is achieved the circumference of the ring becomes irregularly larger and difficult to close. The longitudinal joints become eccentrically loaded with high local stresses and the risk of spalling increases. If a segment is not driven fully home the protrusion of the segment into the transverse joint interferes with the correct positioning of succeeding rings and the transverse gaps tend to increase. As a result of these factors the final jacking pressure fluctuates considerably from ring to ring, the average final jacking pressure used ranging from about 2000 lb to 2500 lb per square inch on a 7in diameter ram. Sometimes the pressure went up to the limit of the gauge, 3500 lb per square inch, and occasionally even this did not suffice to close the ring completely.

Transverse gaps between segments also arise from corrections of line and level. Such gaps may be the source of erosion behind the linings in water tunnels. The authors suggest that corrections of line and level need be made much less frequently in water tunnels than in railway tunnels. Considerable errors are of no great consequence, provided that the invert will drain satisfactorily when the tunnel is empty, whilst a reduction in the number of corrections would enable better fitting of rings to be obtained.

EXPERIMENTAL INVESTIGATIONS

The full scope of the experimental work that would be necessary could not be envisaged at the outset and much additional work had to be undertaken. Modifications were necessary and new instruments were designed and made as construction proceeded and more information was gained, but the experimental work could not be allowed to interfere with tunnelling which proceeded continuously. The prime object of the investigation was to find out whether it was necessary to line such a tunnel with a steel waterproof inner lining to resist internal water pressure. Secondly, it was desired to obtain as much information as possible on the behaviour of such tunnel linings when used both in dry tunnels and hydraulic tunnels under pressure.

The broad outline of the investigation was as follows:—(1) To measure the direct radial earth pressure on the lining and record its change with time; (2) to measure the hoop thrust in the tunnel lining and similarly to record its change with time; (3) to measure the deformation of the rings with the tunnel empty; (4) to investigate the mechanics of erecting the lining; (5) to investigate the changes in earth pressure, hoop thrust, and movement of the lining as the tunnel is charged with water.

The most significant result of the measurements was that practically all the pressure on the lining arises from the initial jacking force. The only possible indication of an earth pressure effect as normally understood is a slight increase in pressure towards the end of the first year. It might indeed be expected that little earth pressure would develop because of the high compression strength of the clay (300 lb per square inch average). Simple elastic theory of a weighted homogeneous medium shows that even if the clay received no support from the lining whatsoever the maximum shear stress in the clay would be not more than 80 lb per square inch, or only about half the strength of the clay. In these circumstances the stress on the lining depends almost entirely on the conditions during the erection of the individual rings.

A complete understanding of the changes in size and shape of the shield, of the unlined hole, and the lined hole has not been obtained, chiefly on account of difficulties of taking detailed observations at the shield itself. The shield is a difficult object to measure, but when it was taken out of the tunnel it was practically circular and certainly not elliptical to the extent of 0.5in like the finished tunnel lining. The elliptical shape of the finished lining may arise from one or both of two causes: (a) the shield may become elliptical itself in travelling through the clay; (b) the clay may be more compressible in the vertical than in the horizontal direction and thus the lining would expand more in the vertical direction in the course of jacking. The authors

* "Investigations into the Design of Pressure Tunnels in the London Clay," by F. Tattersall (new works engineer, M.W.B.), T. R. M. Wakeling (senior assistant engineer, new works, M.W.B.) and W. H. Ward (deputy head, soil mechanics division, B.R.S.). The tunnel contractor was Kinnear Moodie and Co., Ltd.
† For references see the original paper. The Don-Seg lining was described in THE ENGINEER of February 2, 1951.

consider that the second cause is more likely because the clay is slightly laminated in the horizontal plane. The very small change in shape of the lining after construction, i.e. a decrease of 0.06in diameter vertically and an increase in diameter of 0.02in horizontally was not associated with any measurable change in the distribution of lining pressure. The net decrease in circumference of the tunnel by 0.05in probably results from extrusion of bitumen paint at the joints.

Any change in the condition of the clay behind the lining associated with construction cannot be detected by water content measurement, but this is not a sensitive method of measuring changed conditions in an over-consolidated clay.

Observations made during the period when the tunnel was empty indicated that the London clay, owing to its high strength, was capable of sustaining a wide variation of pressures imposed on it by the tunnel lining. The magnitudes of these pressures appeared to be largely determined by the conditions during the erection of individual rings of segments.

It was noticed when tightening the rings that, although driven in pairs, one segment was always the last to be jacked home. This segment is often referred to in the paper as the key segment, and it was during its movement that the jack thrust, and also the pressures on the lining, built up noticeably. It was also clear that there was considerable friction between adjacent segments, and between the backs of the segments and the clay.

During 1953 and 1954 the tunnel was subjected to three complete cycles of filling with water under pressure and emptying. During the second cycle the head was increased to a maximum of 160ft above invert, but owing to leakage past a temporary bulkhead in the unfinished surface conduit, this pressure could not be maintained. However, a head of 140ft above invert was maintained sufficiently long for a set of readings to be obtained. In the third cycle the tunnel was maintained at Queen Mary reservoir level for more than seven months in order to investigate longer term changes from water pressure. No leakage of water from the tunnel has been detected. During the periods when the tunnel was filled to Queen Mary reservoir level water was flowing through at varying velocities up to 0.75ft per second.

The results showed that the net earth pressure on the tunnel lining decreased with increasing internal water pressure and increased again as the water pressure was reduced. Most of the change in lining pressure occurred very rapidly during the time required to alter the water pressure, but small changes continued for some time later. In tests 1 and 2 the tunnel was filled at a slow rate such that lining pressures appeared to have become steady at each applied water pressure, whilst in test 3 it was filled more rapidly. The tunnel was emptied at approximately the same rate in each test.

For the first filling the rate of decrease of lining pressure was rather irregular, but while emptying the tunnel and during the second and third tests an almost linear relation was obtained between earth pressure on the lining and the internal water pressure. Observations of changes in both radial earth pressure and hoop thrust were generally consistent, and showed that the change in radial earth pressure on the lining was about two-thirds of the change in internal water pressure. This ratio did not vary significantly with the rate of filling the tunnel, but was slightly higher for emptying than filling.

The original large variations in radial pressure round the rings were not eliminated when the tunnel was filled with water, but some redistribution occurred during each filling, particularly the first. There was also a tendency for a small overall increase in radial pressure by the end of each test cycle.

Since the net radial earth pressure on the lining decreased by only about two-thirds of the applied internal water pressure, none of the test rings ever became completely unstressed, even though the internal water pressure was greater than the average radial pressure on these rings when the tunnel was empty. Because of this changes in diameter were everywhere small and appeared in general to show a linear increase with increasing internal water pressure. These small changes

are a function of the relative elasticities of the clay and concrete ring, and at Queen Mary reservoir head the increases in diameter were generally between 0.01in and 0.02in.

All the movement gauges fitted across the longitudinal segment joints consistently showed that no measurable movement had occurred. This result is in agreement with pressure measurements, and is confirmed by a visual inspection of the tunnel and its trial lengths of cement rendering, all of which were in perfect condition.

The longer term effects of internal water pressure were investigated in test 3. The earth pressure on the lining increased slightly for about one month after the internal water pressure was applied, and thereafter remained sensibly constant during the subsequent six months. Immediately after emptying the tunnel the average radial pressure on the lining was rather greater than at the start of the test, but pressures decreased slightly so that by the end of the following two months a steady pressure had been attained of approximately the same value as at the start of the test.

The tunnel diameters, after their initial increase with internal water pressure, followed the variation in tunnel water temperature. However, superimposed on the temperature effect was a second variation in which the lining was changing shape, the vertical diameter increasing while the horizontal diameter decreased. This change in shape is opposite to that recorded when the tunnel was empty and is best seen in the records of diameter changes measured by the micrometer rod. The changes in shape are very small, the greatest change in diameter being about 0.02in, and six months after the end of test 3 the tunnel had reverted to the stable shape attained before any of the filling tests were commenced.

Before the tunnel is charged with water the loading on the lining consists of a radial pressure and circumferential shear, both of which vary round the ring. Internal water pressure superimposes on this system a uniform opposing radial pressure.

Improvements in Design.—It seems highly desirable that movement of the segments during tightening of the lining should be avoided, if possible. In the Don-Seg design movement is necessary so that the last segment can be inserted radially. Movement of the segments during tightening could be avoided if only a single tapered key segment was provided and the remainder of the longitudinal joints were parallel to the centre line. The key could then be inserted longitudinally from the leading end without serious inconvenience. In such a ring all the segments could be placed direct into their final position and there would be no movement of any segment during closure except the very small amount of radial movement owing to a slight increase in diameter.

It is difficult to see how the segments in such a lining could become displaced during tightening and it might confidently be expected to be better fitting with more uniform bearing between segments, have lower maximum stresses, and a constant prestress in the ring.

It is also very desirable that a small latitude in the circumferential length of each ring should be available. This can be obtained by making the key segment shorter in length than the normal type and designed so that the small end, when in the normal position, is at the rear end of the ring. There would then be a small gap at the end of each key segment, which could afterwards be filled up by hand. The required latitude in jacking the ring would be obtained by over or under-driving the key segment relative to its normal position. The Board intends to construct a further length of tunnel in the near future to these improved designs and using lubrication between the segments and the clay.

Economic Savings.—The advantages of the system described here may be illustrated by the following example. It is admittedly a very favourable example, but it represents an actual practical case. The Metropolitan Water Board has powers to construct two large reservoirs in the Thames Valley. When these powers were obtained in 1946 it was intended to connect the outlets of these reservoirs to that of an existing reservoir and with filtration works in the same area, all by means of surface conduits. To empty the reservoirs and to overcome the friction head

it would have been necessary to construct a large pumping station at each reservoir, with a total installed capacity of the order of 12,000 w.h.p. The total length of conduit would have been about 10½ miles, all subject to a high head because of the high friction from a relatively small diameter conduit.

It has now been decided to replace these conduits by a deep tunnel system. The tunnels will be driven in approximately straight lines from station to station and the total length will be only 8½ miles against 10½ miles for surface conduits. The tunnel will also be made considerably larger in diameter than would the surface conduits, reducing very considerably the friction head. The tunnel will be well below the hydraulic gradient line all the way, so that the water will flow by gravity to the end of the tunnel. Here the water can be pumped by existing machinery, which will lift the water to the filtration works. None of the three pumping stations at the reservoirs will be necessary since all the pumping will be performed at the existing station. The total pumping head in the tunnel scheme will be only 40ft. In the surface conduit scheme the pumping head would have been about 100ft. About 110 acres of land would have been required for the surface conduits and practically none for the tunnel scheme. The total cost of the tunnel scheme is about £1,750,000 less than the surface scheme.

An example which illustrates the saving in cost between an unlined tunnel and a lined tunnel, in circumstances not particularly favourable to the former, is the River Thames-Lee Valley tunnel. The original proposal for present requirements was for a 75in diameter steel-lined tunnel to carry 70 m.g.d., which required a friction head of about 115ft. It has now been decided to omit the steel lining, but, to meet certain imposed conditions, the diameter has been increased to 102in, which has reduced the friction head to 23ft. The tunnel has now become a gravity tunnel and the pumping will be performed by submersible pumps in the terminal shaft. The saving in capital cost compared with the unlined tunnel is about £1,000,000.

International Water Supply Congress

AN international Water Supply Congress and Exhibition is to be held in London next July at the Royal Horticultural Society, Westminster. The congress will be the third of its kind, organised by the International Water Supply Association, but the exhibition is to be held in conjunction with it for the first time; the exhibition is intended to give delegates an opportunity to see some of the latest equipment provided by manufacturers who specialise in water supply. The congress includes excursions to various water supply undertakings around London, and tours lasting up to six days of undertakings in other parts of the country. The papers to be presented at the congress are as follows: "Protection of Pipelines Against Water Hammer," by C. Dubin (France); "Pumping Station Equipment," by H. R. Lupton (Great Britain); "Design of Service Reservoirs and Water Towers," by H. Bjorklund (Sweden); "Aeration and Deferrisation," by L. H. Louwe Kooijmans (Netherlands); "Factors of Safety in Supply and Delivery Systems," by A. Vibert (France); "Use of Electronic Apparatus in Waterworks Practice, with special reference to Waste Detection," by R. E. A. Despiegelaere (Belgium); "Comparison Between Slow Sand and Rapid Filters," by A. Van de Vloed (Belgium); "Training of Waterworks Operators," by H. R. Davenport (Great Britain); and "Methods of Charging for Water," by E. Sherman Chase (U.S.A.).

SEVENTH GERMAN HANDICRAFTS AND TRADE FAIR.—The seventh German Handicrafts and Trade Fair will take place in Munich from May 6 to May 15, 1955. Of the total space of 790,000 square feet, of which 250,000 square feet are under cover, about 60 per cent has already been taken by exhibitors from Europe and from overseas. Two-thirds of the fair area is available to craftsmen, the remainder to the supplying industries. In addition, there will be four special exhibitions devoted to "New Design in Construction," "International Sample Show of Arts and Crafts," "German Arts and Crafts," and to fashions. Full information, including information about rail fare concessions to visitors, may be obtained from the Verein fuer Handwerks-Ausstellungen und Messen e.V., Munich 12, Theresienhoehe 14.

Fruit Juice Bottling Factory

RECENTLY the factory building, of which we include an exterior view, designed to house the fruit juice bottling plant of British Vitamin Products, Ltd. ("Britvic"), was completed and work had already commenced upon the installation of the various process units. At present the company is carrying on its business in a number of centres dispersed in the Chelmsford area, and the new factory will enable the various units to

hydro washing machines and in the main factory area ventilation is by roof extractor units. Fluorescent lighting is fitted throughout the production area and the main electrical supply is by 11,000V switchgear and transformer. For process work and for heating the factory and offices steam is supplied by two oil-fired Paxman "Economic" boilers, each having a capacity of 10,000 lb per hour at 212 deg. Fah., and the plant is designed to meet an average operating load of 7500 lb of steam. In addition to the



Exterior view of factory looking from the off loading end

operate under one roof. The whole scheme has been developed by C.A.S. (Industrial Developments), Ltd., and this company, which is organised to a certain specific plan, undertook the design and construction work and is also responsible for the leasing of the factory. The building of this particular factory has been carried out under the same system which has been employed for the construction of a number of industrial premises. In brief, C.A.S. (Industrial Developments), Ltd., provides an industrial development consultancy service, locates suitable sites, designs and constructs the industrial buildings to specific requirements, and then arranges a long-term lease at an economic rent with the manufacturing company concerned. The work of the development company is conducted by a team representative of each branch of the building industry to give complete integration of the professional and contracting sides of the industry.

The new factory covers an area of 113,000 square feet and has been built at a cost of £380,000 in a period of forty-seven weeks, and involving the erection of 475 tons of structural steel, the laying of 6000 square yards of roadways, 30,000 square feet of vertical window glazing and over 1 mile run of roof glazing. The building is 600ft in length by 150ft wide and consists of two bays, each having a clear span of 75ft with steel stanchions spaced 15ft apart and carried on independent concrete foundations and roof trusses having a clear height of 20ft. Self-coloured vermiculite plaster, which does not need painting but only occasional washing down, is used for the internal finish of the 9in Leca block external walls, above which are continuous glazed steel sashes. Insulated metal wall panels, clad with aluminium sheet, form the upper part of the walls. Reinforced concrete foundation beams spanning between the bases of the stanchions carry the external walls. Troughed aluminium decking in association with two layers of insulation board and two layers of felt has been used for the roof, the glazing of which consists of aluminium double glazing bars with non-actinic glass fitted externally and wired cast glass internally.

There are covered loading bays, one at each end of the factory, and these have the external openings fitted with Bolton gates and the internal openings equipped with Aberdeen overhead doors. The general floor level is 3ft above that of the loading bays and the floor, which is designed to carry a load of 7 cwt per square foot, is 1½in thick granolithic concrete laid monolithically with 6in thick reinforced concrete on consolidated hardcore. The floor in the syrup room is laid with special acid-resisting tiles and this room has a filtered plenum ventilation system. Vapour extractors are fitted over the Pasteurisers and

heating units, steam heated radiant panels are placed over the internal loading doors to minimise draughts and make up for heat loss. Buildings ancillary to the main factory include a two-storey office and canteen block, workshops and vehicle maintenance bays, garages and wash-down and a boiler-house.

In planning the site provision has been made to add an additional three bays. With that in view the wall on the south side of the factory is temporary, to permit easy removal, while the steel windows and glazing can be removed to form part of the new external wall when the extension is built.

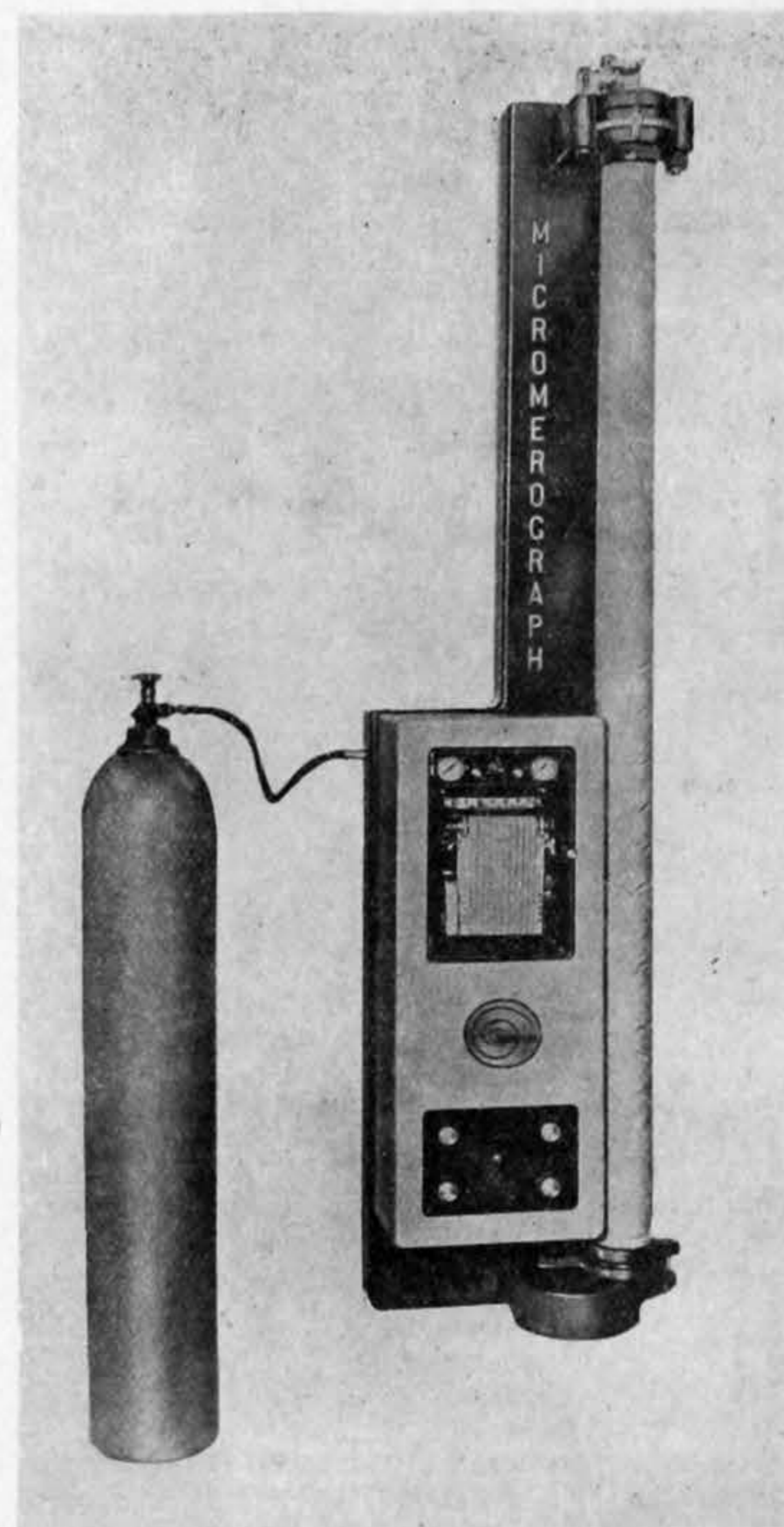
Particle Size Distribution Analyser

IN many industrial applications of powders, as well as in research, it is necessary to know the distribution of sizes in the material. For sub-sieve classification various methods are available, one of which is based on Stoke's Law for the fall of spherical bodies through a viscous medium.

The accompanying illustration shows an analyser which makes use of this principle. In the Sharples micromerograph, made by the Sharples Corporation Research Laboratory, Philadelphia, U.S.A., a sample of approximately 1/10 gramme of powder is broken up by a jet of dry nitrogen and injected into a sedimentation column. The particles settle out at the bottom and a continuous indication of weight is obtained by means of an automatic torsion balance and recorded on a time chart.

According to Stoke's Law, the settling time for any particular component of the sample is proportional to the square of its diameter d , if spherical, or equivalent diameter if non-spherical, and is directly proportional to its density ρ . This relationship allows the diameter to be determined if the density is known. The conversion of the time scale on the chart into $d\sqrt{\rho}$ may be performed by superimposing a standard transparent template on the chart. The range of particle sizes which can be measured varies from 1 to 250 microns, depending upon the density.

At the head of the column is situated the injecting mechanism. It consists of a small pressure chamber filled with dry nitrogen, which is discharged by means of a solenoid valve and blows the powder sample through the de-agglomerator. This is a diverging conical nozzle in which a cone is concentrically mounted. By varying the gas pressure and the position of the cone along the axis the swirl imparted to the powder in the annulus may be adjusted to suit the fineness of the powder. The sample reaches the top of the column as a small cloud, which is



In this size distribution analyser, the particle sample (1/10g.) is broken up and injected by nitrogen pressure into the top of the 220cm settling column. A continuous record of weight against settling time is obtained by means of an electronic torsion balance

sufficiently large to allow each particle to fall without collisions and yet is small enough to keep errors due to differences in settling distance to a minimum.

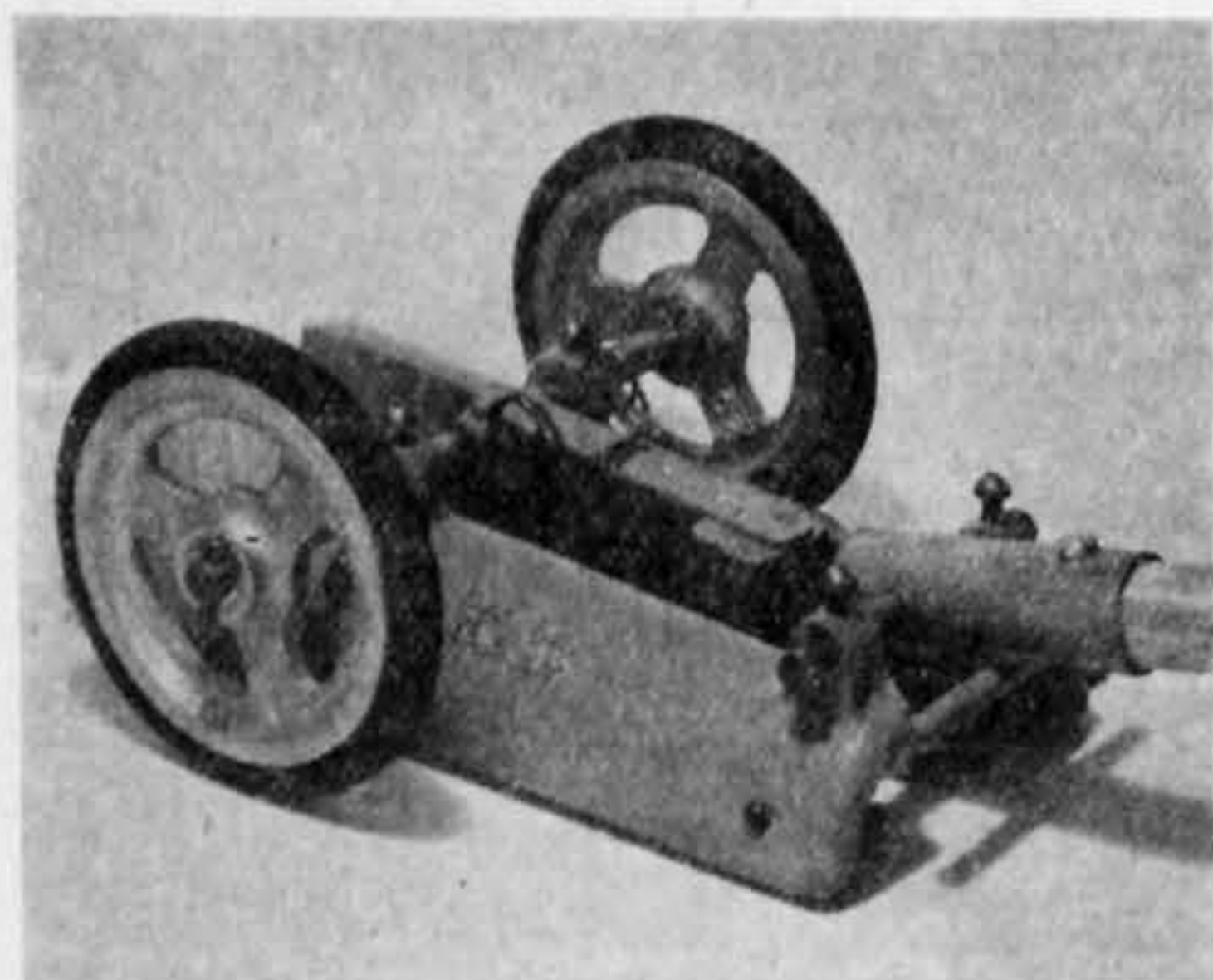
The column of 3½in internal diameter and 85in length is made from aluminium and is insulated by a "fibreglass" blanket. After being allowed to settle through a distance of 220cm the size fractions are collected on the pan of an automatic torsion balance. The arm of the balance is kept in the null position by an electronically controlled balancing current which also passes through the recorder. It is stated that a test requires only about fifteen minutes of the operator's time and results are very accurately reproducible. Total duration of a test is from a quarter of an hour to three hours, according to particle size and density. The instrument is marketed in this country by Sharples Centrifuges, Ltd., Tower House, Woodchester, Stroud, Gloucestershire.

Glazing Bar Cleaning and Painting Machines

Two machines have been developed by the White Bar Painter Company, Ltd., Chipping Campden, Glos, to reduce the time, trouble and expense involved in cleaning and painting glazing bars on the roofs of nursery glasshouses and industrial establishments. Where large glazed areas are involved it is often necessary to erect staging or temporary walkways to obtain satisfactory access to bars for cleaning and painting by the usual hand methods. The new machines are designed for operation with a long handle by a man standing on a convenient roof valley or permanent central walkway adjacent to the glazed area.

The cleaning machine, shown in one of the illustrations on page 284, consists of two side members mounted on rubber-tyred wheels. Each of these side members has on its inner side a wire brush with the bristles pointing inwards and

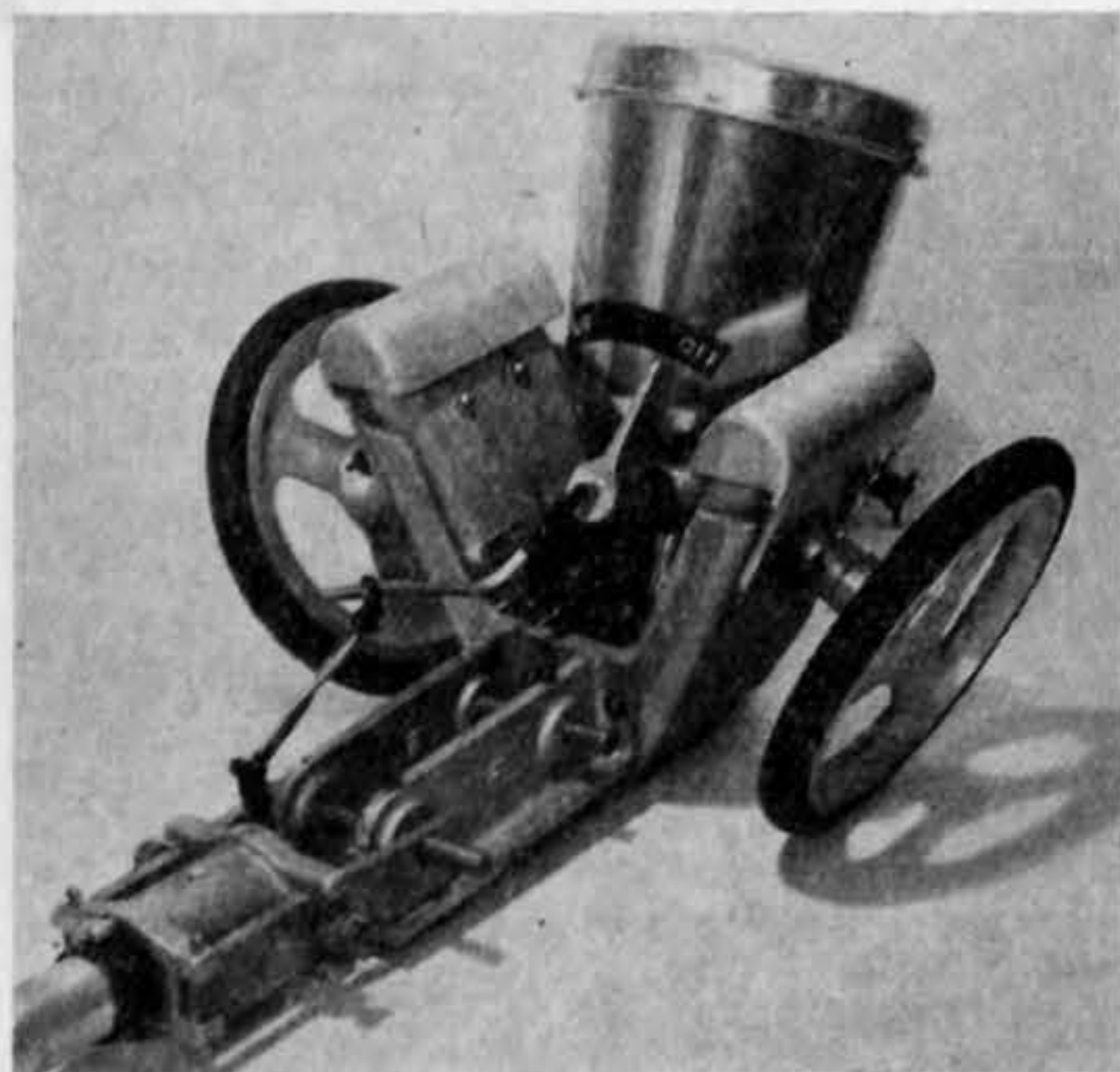
downwards. These two brushes clean the sides of the glazing bar. Set between them is a spring-loaded wire brush with its bristles pointing downwards, and this third brush serves to clean the top of the bar. The side members of the machine are held together by rods on which their spacing can be adjusted and they can be locked in position to suit the width of the glazing bars.



Glazing bar cleaning machine

A tubular holder is pivoted on the rear spacer bar and an aluminium alloy handle, in sections which can be assembled up to a length of 18ft, can be locked into this holder. The machine weighs some 10½ lb. When it is set astride a glazing bar, with the wheels resting on the glass at each side, the brushes of the machine remove loose paint, dirt, &c., as it is pushed up and down the bar.

The painting machine, to be seen in our second illustration, also consists of two side members, which are adjustable for width to suit all glazing bars from ½in to 1½in wide. Paint is gravity fed on to the top of a glazing bar from the aluminium container at the front of the machine. The paint is then brushed on to the sides and top of



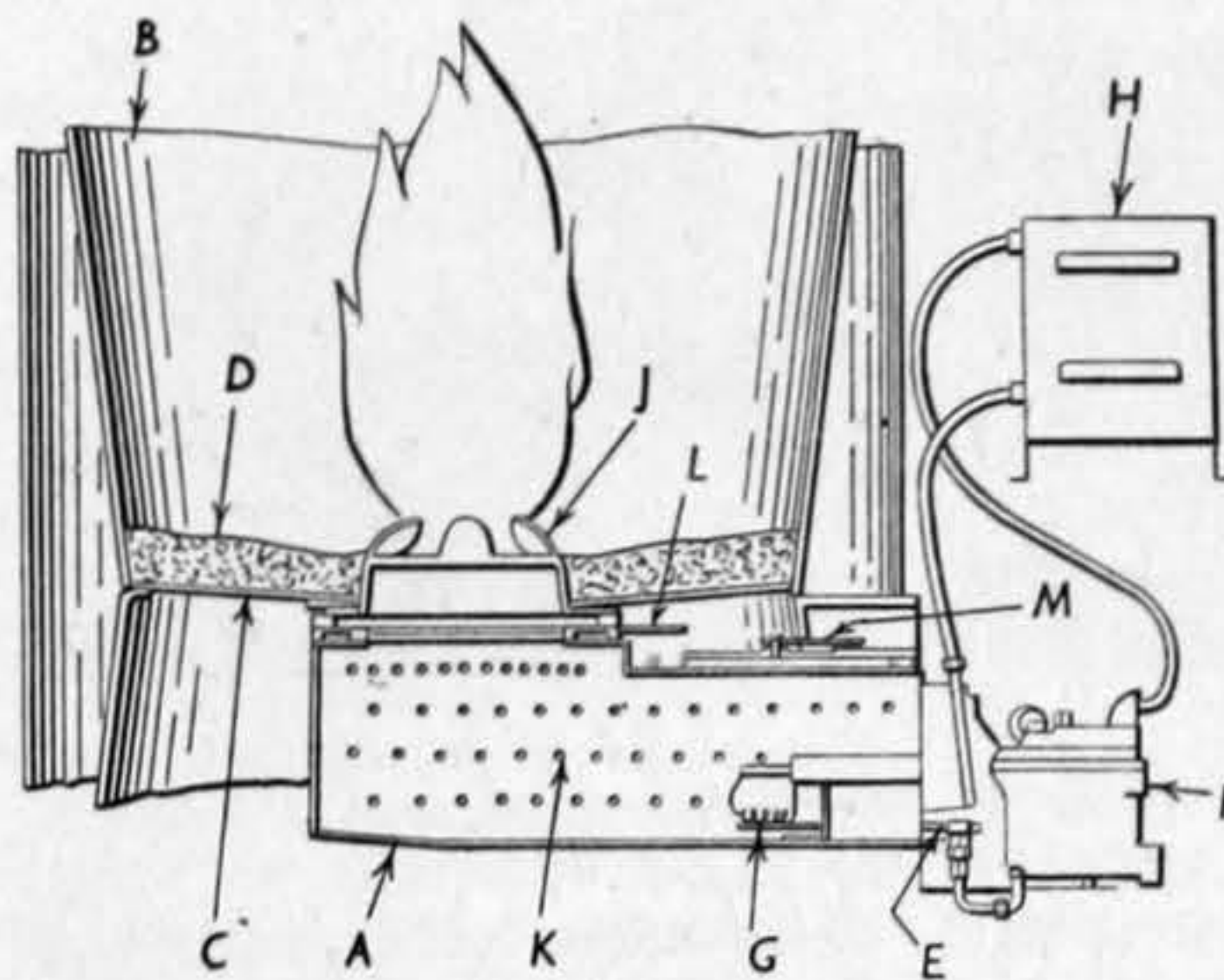
Glazing bar painting machine adjustable for width to suit bars from ½in to 1½in wide

the bar by nylon brushes set at an angle on the side members of the machine. These brushes are carried in holders which are spring-loaded in a downwards direction towards the glazing bar. The spindle of each wheel is extended through the side casting and has keyed on its inner end a four-sided cam. As the wheel turns this cam repeatedly strikes a plate on the brush holder and the movement it imparts serves to agitate the brush as it spreads the paint to simulate hand painting.

Extensions of the side members form a guide in which there are coned wheels, each wheel having a face presented at 45 deg. to the edge of the glazing bar. The two 45 deg. faces thus form a 90 deg. "vee," which is adjustable in accordance with the width of the bar and ensures that the alignment imparted by the brushes is maintained as the machine is drawn along. A valve on the paint container is opened and closed through links to control the flow of paint when the handle is twisted by the operator.

Automatic Oil Burner

AN automatic, self-lighting burner for light furnace oil is being manufactured under licence by D. E. Stuttard, Westfield Mill, Mytholmroyd, Halifax, Yorkshire. The accompanying illustration shows the No. 1 "Little" burner installed in a domestic boiler, by means of a mild steel plate fitted in place of the grate. After adjusting the screw legs so as to level the burner, plastic refractory is placed to form a hearth and all doors and damper openings are sealed. The flame contacts the metal surfaces of the boiler directly, which makes for efficient heat transfer. In operation, a thermostat-controlled fuel valve admits oil at the front end where an asbestos pad brings it into contact with a 3V igniter coil operated at the same



- A—Burner.
- B—Domestic appliance.
- C—16 S.W.G. mild steel plate.
- D—Plastic refractory hearth.
- E—Oil inlet.
- F—Flow control valve and safety float.
- G—Igniter coil.
- H—Transformer.
- J—Burner rings.
- K—Primary air holes.
- L—Secondary openings.
- M—Catalytic heat control.

Automatic oil burner

time. The oil is lit and as it gradually spreads over the level bottom, soon generates sufficient heat to cause the flame to rise to the burner throat. The combination of primary air holes in the sides of the burner and of secondary air openings at the burner rings, together with a catalytic heat control, is stated to ensure complete and smokeless combustion. The temperature of the burner bottom gradually increases from front to rear, i.e. in the direction in which the oil spreads, with the result that the lighter fractions evaporate first so that "cracking" is avoided and no carbon deposits are formed. It is claimed that the installation operates over long periods without requiring attention, cleaning being necessary possibly once a year. A manually controlled version is also available for sites without an electricity supply. This can readily be converted to fully automatic operation later.

Investigation of the Factors Contributing to the Failure of Diesel-Engine Pistons and Cylinder Covers

ON Friday, February 11th, a paper with the title "An Investigation of the Factors Contributing to the Failure of Diesel Engine Pistons and Cylinder Covers," was presented before the North-East Coast Institution of Engineers and Shipbuilders by D. Fitzgeorge, B.Sc. (Eng.), Ph.D., and J. A. Pope, D.Sc., Ph.D., Wh.Sc.

In this paper describing researches carried out on behalf of the British Shipbuilding Research Association, the stresses that occur in combustion chamber parts are discussed with regard to their nature, magnitude and likely contribution to failure. The physical and mechanical constants of the material which affect the thermal stresses are given, and the modifying influence of plastic deformation is considered.

It is deduced that cracks which commence at the hot side of the walls are due to residual stresses on cooling down, following plastic flow while running. This form of crack is shown to be most likely to occur in cast iron (where ductility is low) and the authors have not so

far encountered it in steel components. The danger spots are in the hot face of the cover (particularly where high thermal compressive stresses occur initially as a result of asymmetry) and in the hot face of the piston crown. The second principal cause of failure is the fatiguing action of the repeated combustion pressures, combined with the tensile stresses occurring as a result of temperature gradients in the walls. The cracks occur at the horizontal junction of the crown and wall of pistons, and where webs and other scantlings meet the cover plate in cylinder covers. Failures of this kind commence at the cooled side of the walls and occur in steel as well as cast iron components. The effects of growth, additional stresses accompanying load changes, and the fluctuating surface stresses caused by the varying gas temperature are small.

Typical failures are discussed and radial cracks in cylinder covers and circumferential cracks in pistons are selected for detailed study. Direct estimates of the initial thermal compressive stresses in an unsymmetrical cover range from 16 to 28 tons per square inch and, being higher than previous estimates, these values support the residual stress theory of failure. A theoretical investigation of the stresses in an idealised piston shows that cracking at the junction of the crown and skirt is caused by fatigue, and this finding is confirmed by an examination of four actual failed pistons. Calculated stress curves are drawn showing the variation of piston stresses with changing wall and crown thickness, the stresses due to combustion pressure being independent of the scale of the piston, but dependent on its proportions. This applies to the thermal stresses also, provided that the temperature distribution is the same. Since the piston temperatures increase with increasing size, the thermal stresses in large pistons are greater than in small ones. The stresses produced by the combustion load are shown to be smallest when the crown and wall are thick. For low thermal stresses, a thin crown is necessary; for low thermal stresses in the wall the wall should be thick, but a thick wall causes high thermal stresses in the crown.

An example has been worked out to show graphically the variation in the overall stress conditions at the inner edge of the wall and at the inside face of the crown centre as the crown and wall thicknesses are varied. For the conditions assumed, the wall and crown should be approximately of equal thickness and one-tenth of the piston diameter. These figures include consideration of the compressive stresses in the hot face of the crown.

The conclusion is drawn that where circumferential cracking has occurred in the wall, in the absence of cracks elsewhere, design changes should be directed at reducing the stresses at the position of failure, even though the stresses at other vital positions may be increased as a result. This requires the wall to be thickened, which would raise the temperature of the upper ring, but the tendency would be counteracted by the cutting of suitable grooves in the piston wall. Alternative designs are suggested which might be useful in overcoming cracking troubles in the pistons of large or highly rated engines.

The qualities required in a material to resist failure by residual stress when used in engine components are: (1) High-tensile strength, little affected by continued exposure to the working temperatures; (2) high ductility, little affected by small amounts of repeated plastic strain; (3) low Young's modulus in elastic range; low stress-strain ratios in plastic range; (4) low coefficient of expansion and Poisson's ratio; (5) high thermal conductivity; (6) high creep resistance.

The qualities required to resist fatigue failure, in addition to a high fatigue strength, are identical with (3) to (5) inclusive. A high notched fatigue strength under mildly corrosive conditions is required in the range 50 deg. to 250 deg. Cent., low creep resistance being beneficial in this case, since creep allows the relaxation of the mean tensile stress.

The result of temperature measurements on oil-cooled and water-cooled pistons are given in an appendix; the highest temperature recorded for the oil-cooled piston was 700 deg. Fah. (370 deg. Cent.), while that for the water-cooled piston was 730 deg. Fah. (388 deg. Cent.).

Fabrication of High-Permeability Magnetic Materials

BY OUR AMERICAN EDITOR

As a result of the enormous rise of the electrical industry in the past half-century, iron and the ferro-magnetic alloys of iron have come to be regarded as one of the basic materials of electrical and electronic engineering. The current demand for such high-permeability magnetic materials in various special forms has caused a number of American manufacturers of laminations and cores to install specialised rolling, slitting and roller levelling equipment. This article reviews the special properties aimed at and the current processing methods being employed.

THE improvement in the properties of magnetic materials has probably been one of the most remarkable metallurgical developments of the present century. In the early 1900s, sheet iron or mild steel of relatively good purity was the only high-permeability magnetic material in general use in the electrical industry. Then Sir Robert Hadfield discovered that a silicon-iron alloy made a superior transformer core due to its having a low hysteresis loss, a high electrical resistivity, a low eddy-current loss and certain non-ageing properties. This discovery laid the foundation for the development of flat rolled silicon steel for use in the manufacture of electrical equipment. However, more than a decade passed before any systematic determination of the properties of the various grades of silicon-iron was completed. This work demonstrated the extraordinary magnetic and electrical properties of "electrical steel" and helped to bring about its widespread use, particularly in the United States. It was found that this new material could reduce to less than one-third the eddy current and hysteresis losses which had been encountered in the mild steel previously used for magnetic assemblies. Already at this early stage of development it was realised that the magnetic properties of the material were affected seriously by three basic manufacturing steps: the chemical control of analysis, the rolling of ingot to sheet, and the heat-treatment of the final product.

SILICON STEELS

To-day, silicon steels are being produced in the United States for electrical use containing up to approximately 5 per cent silicon and have been classified commercially with respect to their composition and application as follows:—

(1) Steels containing 0.5 to 1.5 per cent silicon. This class is used principally in the cores of rotors and stators of rotating machines such as motors and generators. Steels with silicon contents in the low end of this range may also be used for stationary field poles and other magnetic circuits wherein high permeability is required. Steels containing about 1 per cent silicon are also used for reactors, relays and small intermittent duty transformers.

(2) Steels containing 2.5 to 3.5 per cent silicon. This class is used in motors and generators of average to high efficiency and in small to medium-sized intermittent duty transformers, reactors and electrical motors.

(3) Steels containing 3.8 to 5 per cent silicon. These steels are used in the highest efficiency motors and generators, in all kinds of transformers for power purposes, and in wireless transformers and other wireless equipment.

The American Iron and Steel Institute has compiled the most commonly accepted classification of eight basic grades of "electrical sheet." The classification is based on maximum core loss values determined by the Epstein test, as specified in A.S.T.M. Standard A-34.

GRAIN ORIENTATION

While the early hot-rolled silicon steel sheets brought about a significant core loss reduction, they still had relatively poor permeability. This obstacle was largely overcome as a result of the important work undertaken by N. P. Goss, of the Cold Metal Process Company, of Youngstown, Ohio. Combining cold reduction on a reversing rolling mill with intermediate anneals,

Goss obtained a high degree of preferred orientation of the silicon-iron crystals. This process was patented in 1933 and became the basis of modern production technique in the field of "grain-oriented electrical steels." With the recent growth of the electrical and electronic industries in America, it is not surprising that the market for silicon steel has been continually increasing. Last year, for example, some 750,000 tons of all grades of silicon sheet and strip were produced, of which about 20 per cent were grain-oriented material. In the past, the Allegheny Ludlum Steel Corporation, of Pittsburgh, Pennsylvania, and the Armco Steel Corporation, of Middletown, Ohio, were the major producers of grain-oriented silicon steel, but, at present, both the Crucible Steel Company of America and the U.S. Steel Company are also entering the field.

Modern grain-oriented silicon steels, which have almost 95 per cent of their grains oriented in the rolling direction, have led to reductions of some 60 per cent in the size and weight of electrical distribution transformers. This valuable saving is directly due to crystal anisotropy in the silicon-iron sheet, which causes directionality of magnetic properties. It is now well known that the crystals, or cubes, which comprise the iron-silicon lattice are magnetised most easily in a direction parallel to the crystal edge (100), are more difficult to magnetise in the direction of the face diagonal (110), and are most difficult to magnetise along the crystal diagonal (111). The present methods of processing result in the best magnetic properties being obtained in the rolling direction, so that transformer cores are generally designed in such a manner that the main flux path is in the same direction. The importance of the directional effect is indicated by the fact that the core loss at 15 kilogauss in the transverse direction may be as much as two and a half times the core loss in the rolling direction, and the permeability at this same induction in the rolling direction may be fifty times the permeability in the transverse direction.

Until the 'forties, most silicon-iron materials were hot rolled into sheets by the pack rolling process in America. In recent years, there has been a marked change to the production of relatively long hot rolled coils on continuous tandem strip mills, which, in turn, are cold reduced to thin gauges on reversing cold strip mills. Cold reduction is now particularly widespread in the manufacture of the alloys of lower silicon content which show relatively little brittleness. One of the most significant modern developments in the field of grain-oriented silicon steels has been the demand for and production of ever thinner gauges of strip. While not many years ago, 29-gauge (0.014in) sheet and strip was the lightest available material, the miniaturisation and micro-wave performance requirements of radar and telecommunications equipment led to 0.012in, 0.004in and 0.005in, and, finally, to 0.003in, 0.002in and 0.001in grain-oriented silicon steel strip being produced. To-day's electronic computers call for even thinner tape-wound cores, and a four-high mill with extremely small diameter work rolls is being used successfully in the United States to produce " $\frac{1}{8}$ mil" (0.000125in) tape!

TAPE-WOUND CORES

The majority of magnetic cores in America to-day are still made up of stacked flat lamination

stampings, such as the standard "E" and "I" lamination. However, as the gauges of magnetic materials have become thinner, there has been a tendency toward the use of tape-wound cores. The stamping, annealing and handling of laminations lighter than 0.014in is often difficult and becomes altogether impractical in the case of ultra-thin gauge stock of 0.002in and less. As illustrated in Fig. 1, tape-wound cores are made in the form of a rectangular "C" by winding a strip of the magnetic material on a mandrel, bonding the resulting loop, and cutting the bonded loop into two parts, which can then be assembled in such a way as to link a coil electromagnetically. In addition to the rectangular "C" shape, cores are also made in the form of a rectangular "E" and a round toroidal. They are especially effective when used in iron-core inductors, such as transformers and reactors, because their construction and final assembly with a coil utilise only the direction of rolling of the material to form the direction of the flux in the magnetic path of the core-coil combination.

These tape-wound cores are now commercially available in the United States in several lamination thicknesses and cover a wide field of applica-

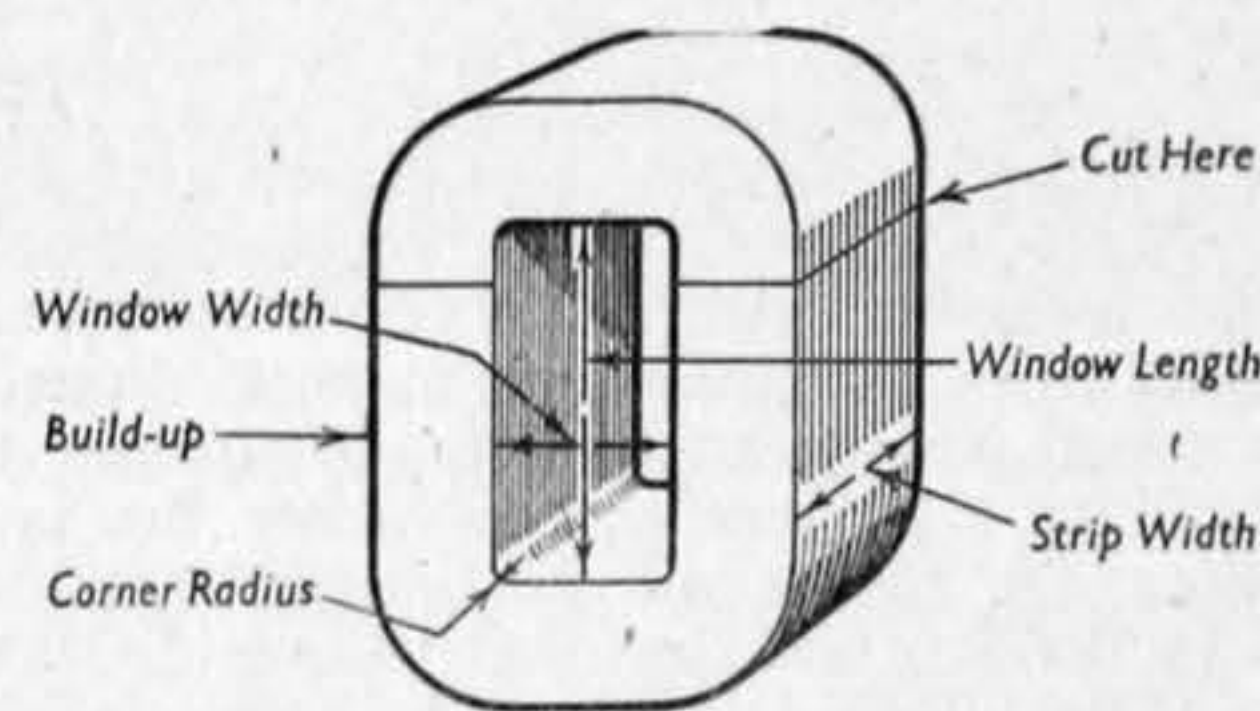


Fig. 1—Tape-wound rectangular "C" core for single-phase transformers and reactors

tion from power distribution frequencies to the very high frequencies used in electronic components. The single-phase 0.012in cores are commonly used at power distribution frequencies, ranging from 50 to 400 c/s, to make use of the excellent high density permeability and to increase the output or to reduce the size of intermittent duty transformers, such as resistance welding or X-ray transformers. The single-phase 0.004in and 0.005in cores offer the advantage of lower loss at higher frequencies and are therefore primarily employed in aircraft or shipboard circuits operating at frequencies ranging from 320 to 5000 c/s. In these cores, a reduction in thickness has been obtained without the sacrifice of permeability or saturation level, so that reductions in weight and space or improvements in operating characteristics are possible even at the high frequencies.

The single-phase 0.001in, 0.002in and 0.003in cores have found their chief application in pulse transformers and similar components. Here their thinness of lamination without sacrifice of permeability and the high space factor of the core, together with high saturation permit the design of small, high-performance components. The excellent magnetic and loss characteristics have also proven very advantageous in the design of transformers and reactors for alternating voltage applications up to 500 kc/s. Rectangular "C" cores made from highly grain-oriented 0.002in material have been found to give excellent results in pulse transformers. Since the cores are made from highly grain-oriented strip, they have excellent d.c. characteristics. The coercive force of the silicon-iron alloy is low (0.45 at $B=10,000$ gauss); they have a relatively low remanence density ($B_r=4700$ at $B=10,000$ gauss); their saturation level is extremely high (above 20,000 gauss), and the magnetising force at values less than saturation is quite low ($H=25$ at $B=16,500$ gauss).

The three-phase 0.012in, 0.004in and 0.005in, and 0.002in "E" cores now offer a solution to the problem of a small, light-weight, three-phase transformer utilising the high permeability and low loss characteristics of the silicon steel cores. Consisting of two-piece construction and three winding legs of equal cross section they are made in a variety of gauges to cover all frequencies of operation. Finally, the 0.012in, 0.004in and 0.005in and 0.001in, 0.002in and

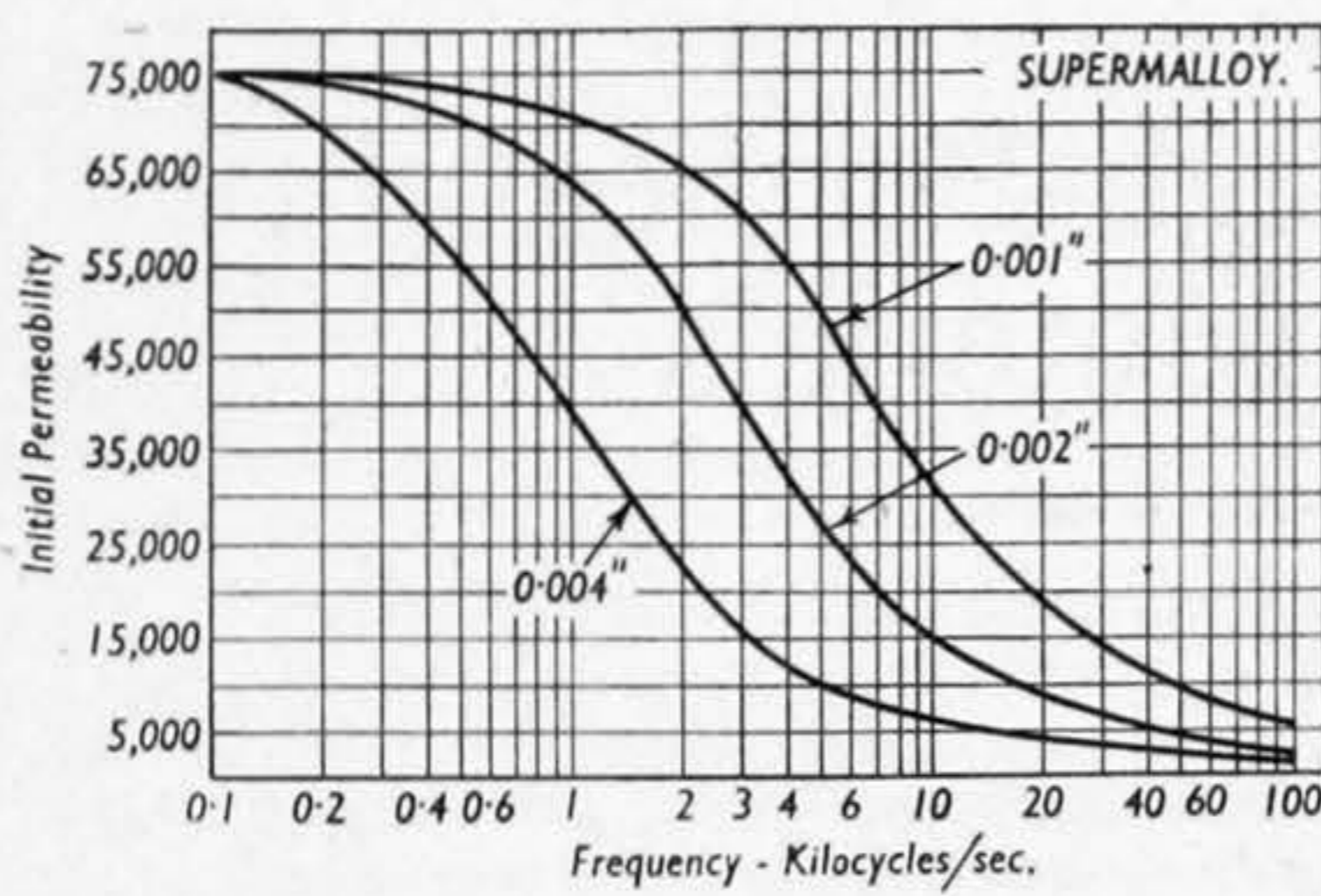
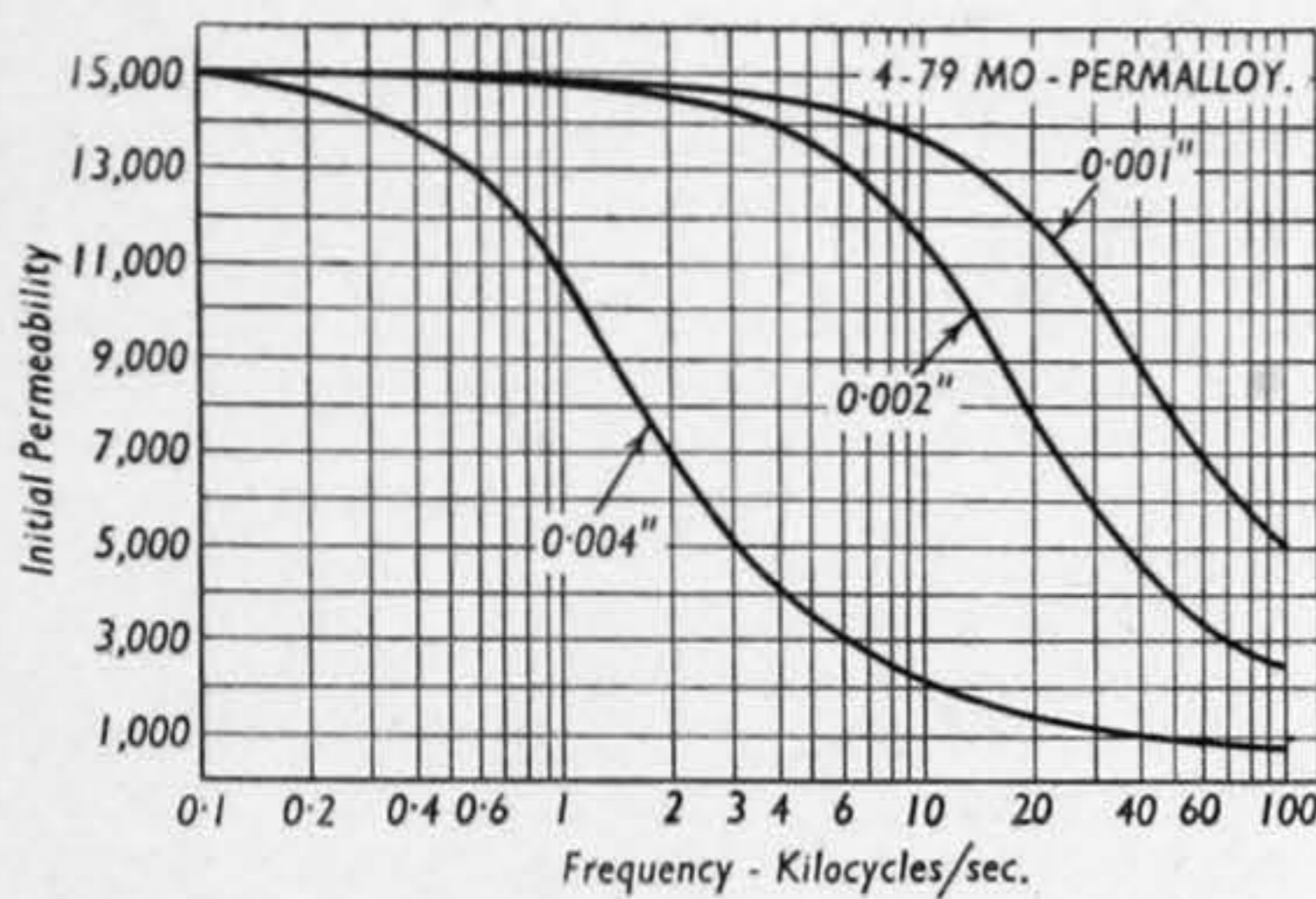


Fig. 2—Relationship between initial permeability and tape thickness

0.003in round toroidal cores offer the advantages of high permeability and low hysteresis loss without impairment due to a magnetic joint. Made in all gauges they offer a solution to any magnetic amplifier, reactor or current transformer problem where material quality is of prime importance.

NICKEL-IRON ALLOYS

The search for materials of even higher permeability than that possessed by silicon steel led to the development in the early 'thirties of the nickel-iron alloys, also known as "perm-alloys." It was found that through the control of the nickel content, alloys could be obtained ranging from practically non-magnetic materials to those having maximum obtainable permeabilities. In general, the higher the nickel content, the higher will be the permeability at low inductions, and the lower will be the saturation of the alloy. In many applications in which higher operating densities are encountered, it has been found desirable to sacrifice the extremely high permeability obtained at low flux densities in favour of higher saturation. Alloys in the 45 to 50 per cent nickel range have proven particularly satisfactory in this respect and to-day are being manufactured by various American companies under the trade names of Allegheny "4750," Carpenter "49," Armco "48," Permenorm, "45 Permalloy," Westinghouse "Hipernik" and "Orthonol." Grain orientation plays an important part in obtaining the best possible magnetic properties in these alloys, and in certain instances cold reductions of 99 per cent without intermediate anneals are required to develop these properties. The addition of between 4 and 5 per cent molybdenum to the high nickel-iron alloys has resulted in new materials of relatively low coercive force which

are now finding wide application in tape-wound cores for pulse transformers. Representative examples are the "4-79 Mo-Permalloy" (79 per cent Ni, 4 per cent Mo, 0.3 per cent Mn, 16.7 per cent Fe) and the "Supermalloy" (79 per cent Ni, 5 per cent Mo, 0.3 per cent Mn, 15.7 per cent Fe) high permeability materials made by the Arnold Engineering Company, of Marengo, Illinois. The latter alloy is capable of an initial permeability as high as 100,000 at a flux density of 20 gauss and a frequency of 100 c/s, and its coercive force at saturation is only 0.004 oersted. The graphs reproduced in Fig. 2 indicate how much higher an initial permeability can be obtained in these materials by rolling the strip to lighter gauges.

Another interesting material now being cold worked on four-high and cluster rolling mills into ultra-thin gauge strip is the "Vanadium Permendur" (49 per cent Co, 2 per cent V, 49 per cent Fe) alloy of the Allegheny Ludlum Steel Corporation. The alloy has a very high per-

operations as rolling, slitting and levelling, nowadays practically all the major American producers of laminations, cores and related electrical and electronic equipment have installed processing equipment in their own works. The advantages to be gained from this approach are many, and with a reasonable consumption potential of magnetic material it is not difficult to amortise the investment in such machinery in a few years. While a few companies have gone to the extent of installing their own induction or vacuum melting furnaces to obtain control of chemical analysis, the majority are satisfied with the analyses commercially available from the mills and thus can limit their own processing operations to break down rolling, finish rolling, slitting and levelling as well as heat-treatment.

ROLLING OPERATIONS

To enable the entire range of rolling operations—from the hot break down of, say, 2in ingots to the finishing of 0.00025in tape—to be performed in only one machine, an interesting two-high/four-high combination rolling mill was recently developed and is now finding extensive application in the American "magnetics" industry. The machine is shown in Fig. 3 breaking down an ingot of vacuum cast, 50 per cent Ni, 50 per cent Fe alloy, using the two-high set-up. It may be considered primarily as a two-high mill designed so that the rolls can be raised sufficiently to insert between them a set of two small-diameter work rolls. Alternatively, it may be regarded as a four-high mill with driven back-up rolls designed to facilitate rapid change-over, to a conventional two-high configuration by the withdrawal of the two work rolls, as illustrated in Fig. 4. In the latter use, the original back-up rolls thus

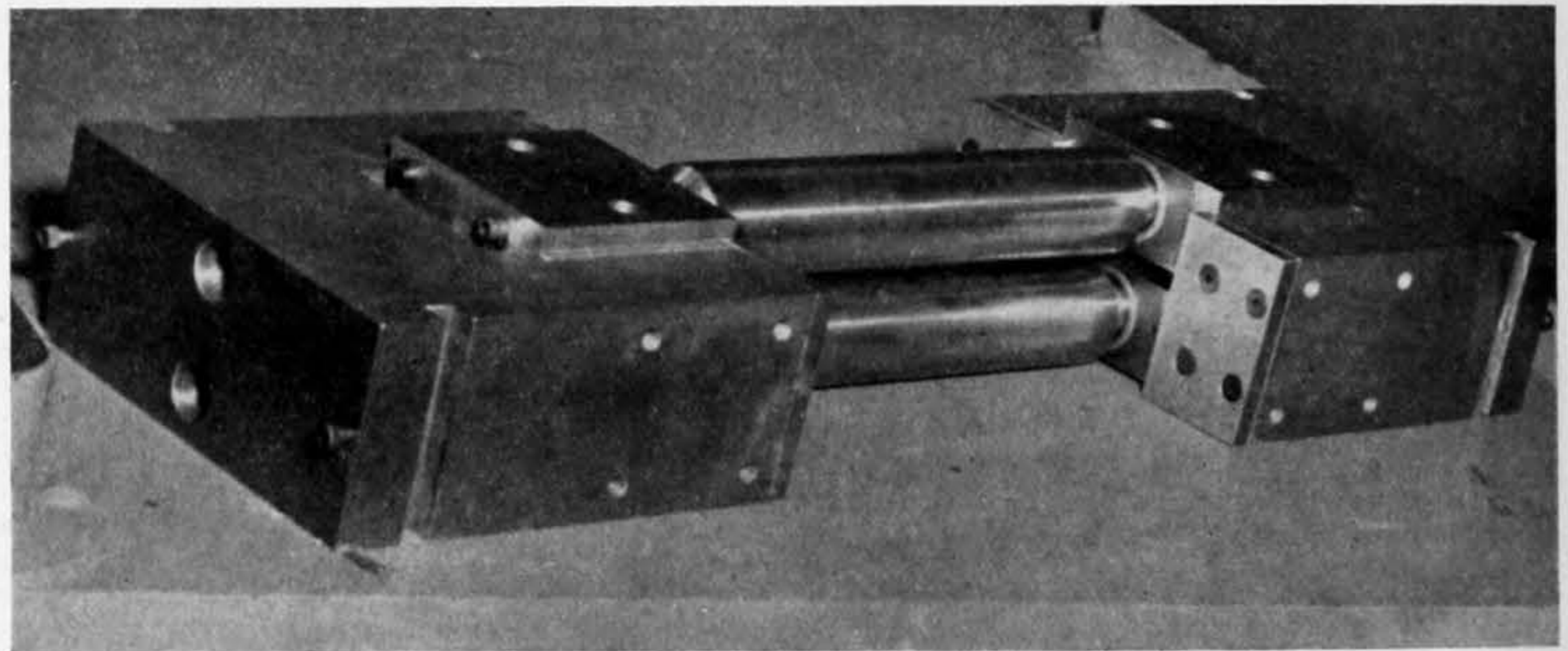


Fig. 4—Small diameter work roll assembly after withdrawal from mill



Fig. 3—Ingot break-down on two-high/four-high combination rolling mill, using the two-high arrangement

meability at very high flux densities, but is rather difficult to work due to its cobalt content. The need to preserve strategic alloying elements in critical supply, such as nickel and cobalt, has led to the recent development of methods of working the aluminium-iron alloys. The most promising analysis is the "16-Alfenol" (16 per cent Al, 84 per cent Fe) material which has been produced in the form of strip as thin as 0.0003in by employing "warm" rolling at 575 deg. Cent. to reduce the strip from about 1/8in to about 0.010in and cold rolling it at room temperature on small work roll diameter mills down to finishing gauge. The work on this material conducted at the U.S. Naval Ordnance Laboratory, Silver Spring, Maryland, has resulted in obtaining an initial permeability as high as 4200, a coercive force as low as 0.024 oersted and a maximum permeability of 115,000. The relatively expensive melting and rolling procedures required have so far limited the application of this alloy, but it is expected to have a promising future once fabrication costs can be lowered.

The quality of modern high-performance electronic equipment is so greatly affected by the properties of either lamination stampings or tape-wound cores that American manufacturers of these assemblies recently adopted the "do it yourself" approach. Thus, while a few years ago, only the steel mills performed such

become the work rolls in the two-high arrangement. It is well known that the object of all forms of backed-up rolling mills is to obtain the largest practical reductions in the diameter of the work rolls. Extensive research into the cold rolling of strip has established that—for a given material reduction and width—the roll load, rolling torque, rolling horsepower and lateral spread of the strip decrease with the diameter of the work rolls. Consequently, for a mill of given roll load capacity and horsepower greater reductions may be taken with work rolls of smaller diameter. The reduction in lateral spread with reduction in work roll diameter also has considerable practical advantage in rolling the harder magnetic materials since it reduces the tendency of the strip edges to tear or crack. The "stiffness" of the backed-up four-high mill and the ease with which its small work rolls can be crowned have made it possible to produce extremely accurate strip with practically no gauge variation across its width. Finally, a smaller work roll permits thinner strip finishing gauges even in highly work-hardened materials since the length of the flattened arc of contact between the work rolls and material—and, hence, the roll load and rolling torque—decreases with decrease in work roll diameter.

The following table lists several representative

reduction schedules taken in finish rolling "Hipernik," 3¼ per cent silicon steel, and "4-79 Mo-Permalloy" on a combination mill equipped with 5in diameter back-up and 1½in diameter work rolls:—

Material, "Hipernik"; initial size, 0.125in x 4in; initial hardness, Rockwell B-92

Two-High Operation		
Pass No.	Thickness	Per cent reduction
1	0.080	36
2	0.050	37
3	0.032	36
4	0.020	37

Four-High Operation		
Pass No.	Thickness	Per cent reduction
5	0.013	35
6	0.009	31
7	0.0065	28
8	0.005	23
9	0.004	20
10	0.0034	15
11	0.003	12

97.5 per cent total reduction in eleven passes without intermediate anneals.

Material, 3¼ per cent silicon steel; initial size, 0.115in x 4in; initial hardness, Rockwell B-74.

Two-High Operation		
Pass No.	Thickness	Per cent reduction
1	0.090	22
2	0.070	22
3	0.055	21
4	0.044	20
5	0.035	20
6	0.028	20

Four-High Operation		
Pass No.	Thickness	Per cent reduction
7	0.020	29
8	0.015	25
9	0.0115	23
10	0.009	22
11	0.007	22
12	0.0055	21
13	0.0045	18
14	0.004	11

96.5 per cent total reduction in fourteen passes without intermediate anneals.

Material, "4-79 Mo-Permalloy"; initial size, 0.010in x 4in; initial hardness, Rockwell B-85.

Four-High Operation		
Pass No.	Thickness	Per cent reduction
1	0.007	30
2	0.005	29
3	0.0035	30
4	0.0025	29
5	0.0019	24
6	0.0015	21
7	0.0012	20
8	0.0010	17

90 per cent total reduction in eight passes without intermediate anneals.

The above results indicate the very considerable reductions and the thin gauges obtainable from such mills equipped with relatively small diameter work rolls. In response to the growing demand for ultra-thin gauge magnetic tape, the machine is now being furnished with even smaller work rolls down to ½in diameter, facilitating the production of "½ mil" tape. With this ability to reduce magnetic materials from the ingot all the way down to such ultra-thin gauges, the mill has proven one of the most popular machines in the processing field. In such an all-purpose mill there is much to be gained from

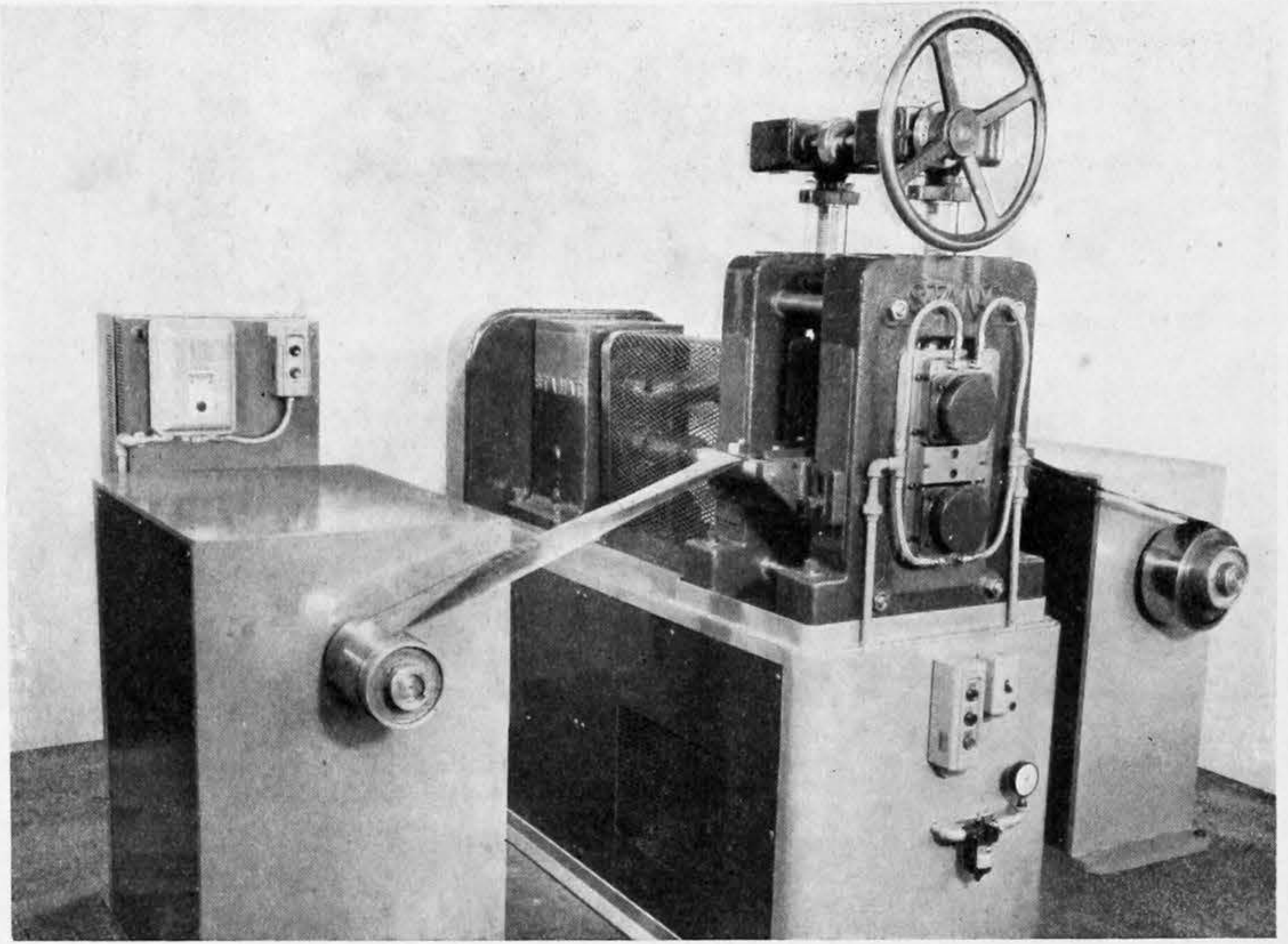


Fig. 5—Cold reduction of light gauge "Hipernik" strip with application of front and back tension

driving the back-up rolls rather than the work rolls. Despite the original objection to this method on the ground that slippage would occur between the work rolls and the back-up rolls, extensive and successful service of four-high mills driven by back-up rolls in the American metal industry has proven the soundness of this design. The back-up drive eliminates one of the most serious disadvantages of the conventional four-high mill driven by work rolls, viz., the limitation in torque that can be transmitted by the relatively small roll necks and spindles without exceeding their permissible torsional strength. Another valuable property of the back-up drive is its ability to overcome the lateral bowing-out of the small work rolls when heavy reductions with high front tension are taken, as in the coiling arrangement shown in Fig. 5. Driving the back-up rolls causes a torque reaction on the work rolls which tends to bend them toward the entry side of the mill, i.e. in the opposite direction to the force exerted by the coiling reel. By balancing this torque reaction and the strip tensions, the tangential force on the work rolls can be eliminated altogether.

SLITTING OPERATIONS

Slitting is one of the most important processing

operations affecting the ultimate performance of the magnetic assembly. Hence, it is not surprising that practically all American core producers have installed their own rotary gang slitting lines in recent years. The large steel mills are generally not willing to slit to the narrow widths and close tolerances required in core manufacture. For example, 1in is the minimum width of silicon steel strip normally furnished by the steel mills, with a plus or minus 0.008in variation from the specified width being allowable. Difficulties may also be experienced with what the mills call "a slit edge commercially free from burrs." Such an edge is not sufficiently smooth for many core winding applications, a fact which has been largely responsible for the consumers of silicon steel and nickel alloy strip deciding to "slit" their own.

Figs. 6 and 7 show representative high-speed slitting lines in use at the works of an American strip consumer. The popularity of these machines is due particularly to the close width tolerances (plus or minus 0.0015in) and the perfectly smooth strip edges they produce, even on silicon steel. These results are obtained largely by the use of a special slitter design incorporating a "floating" upper arbor which allows the indi-

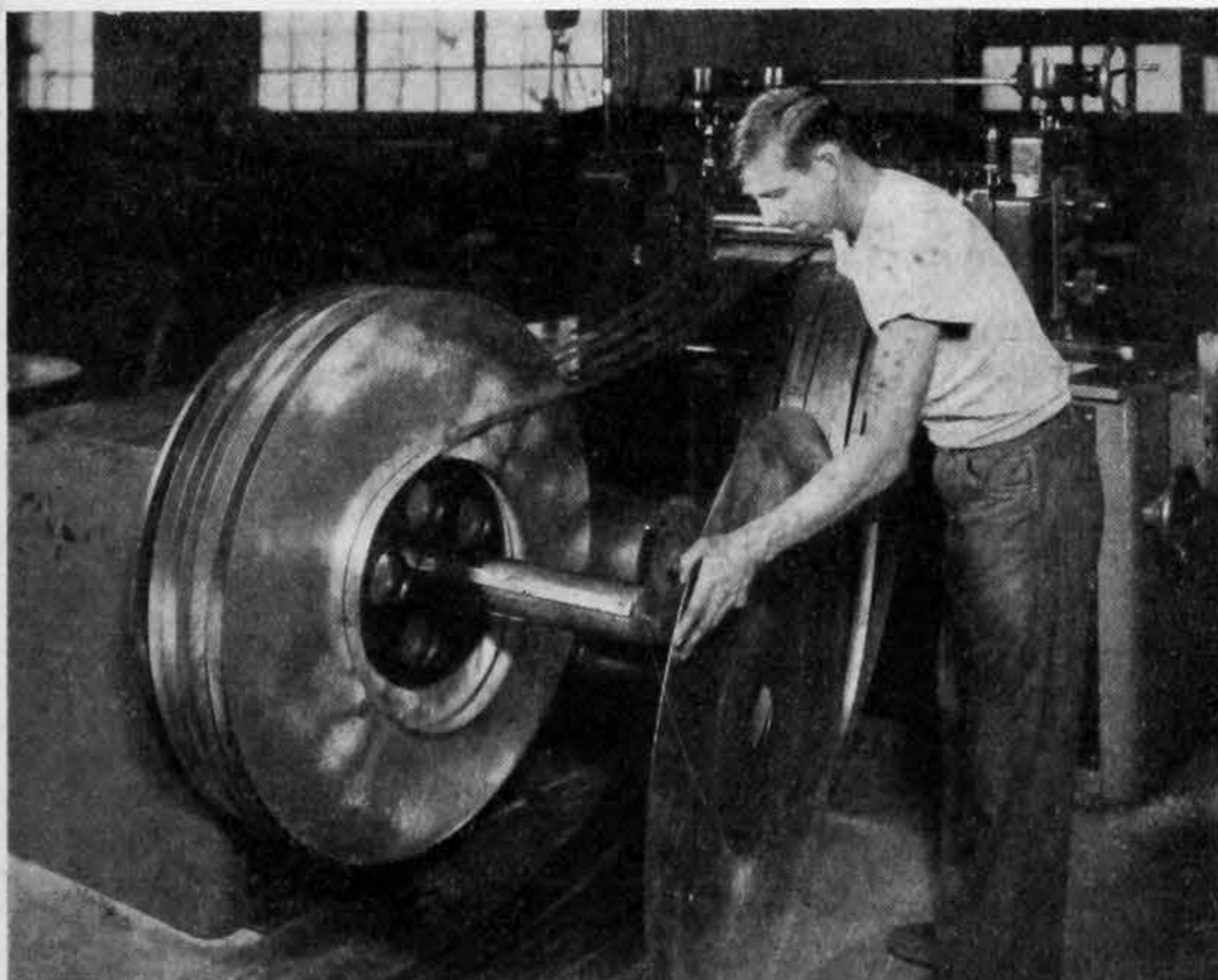


Fig. 6—Setting up core plate recoiler on 24in slitting line

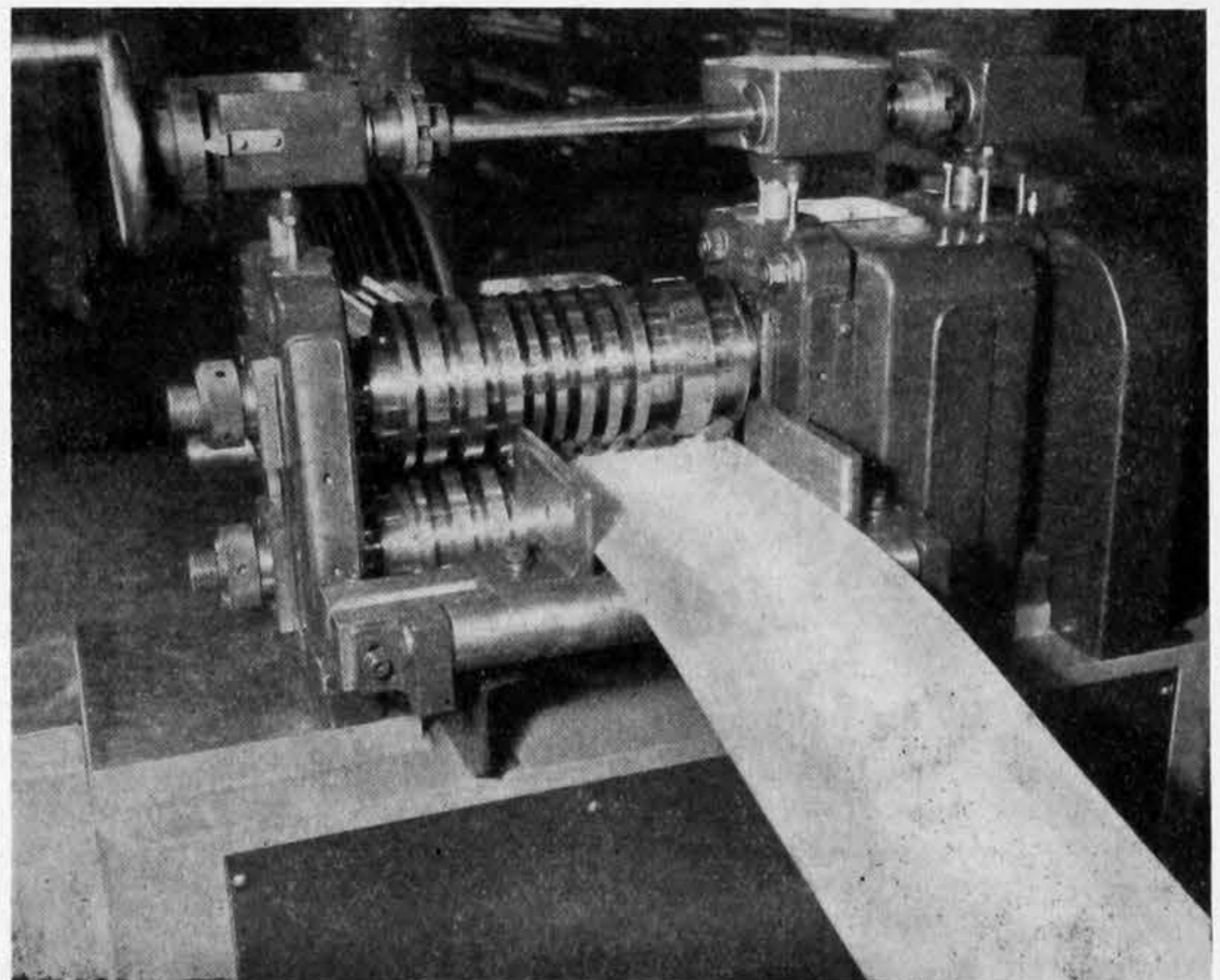


Fig. 7—12in slitting line cutting 0.014 thick silicon steel

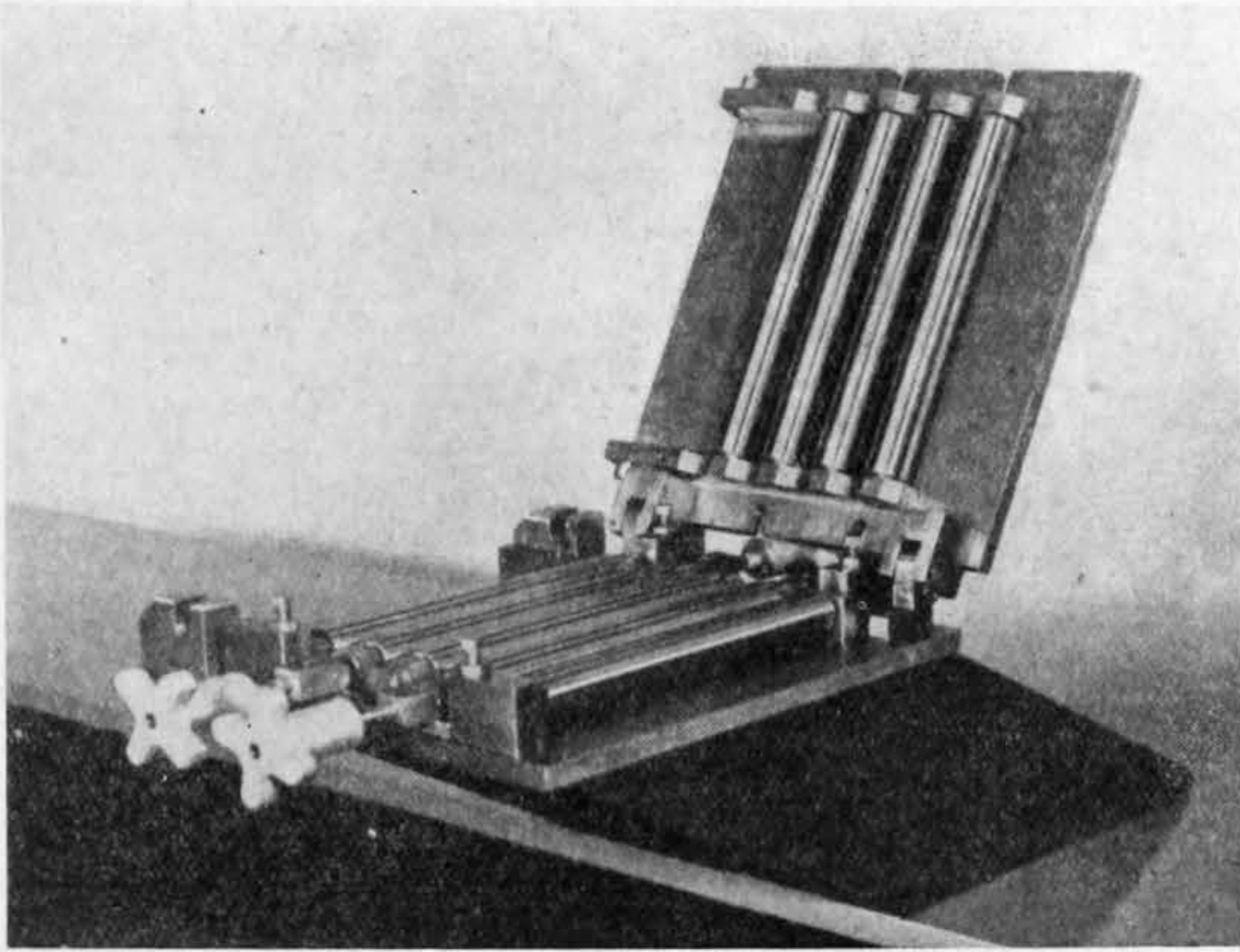


Fig. 8—Pull-through roller leveller mounted on slitting machine between cutters and recoiler

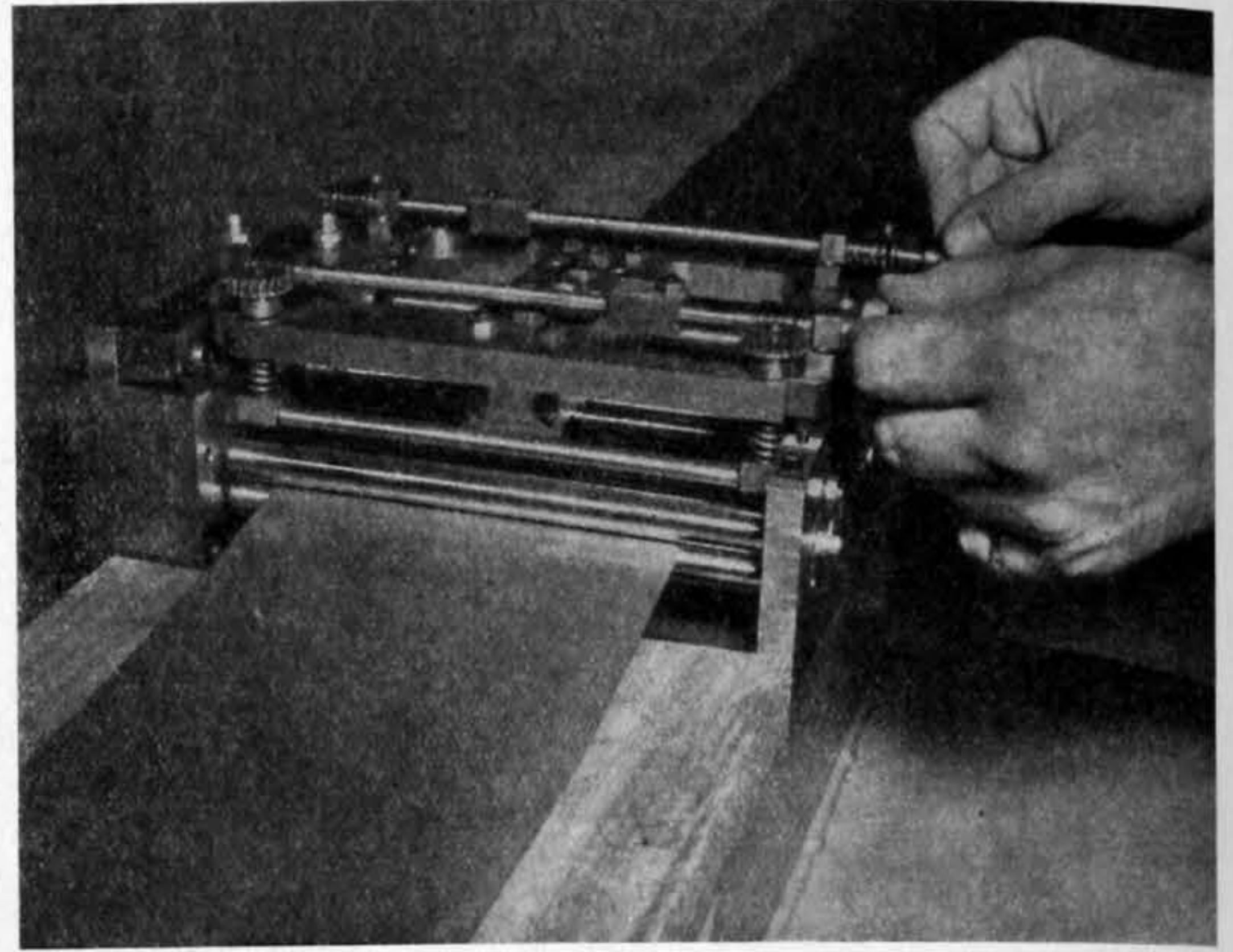


Fig. 9—Miniature roller leveller for straightening light gauge silicon steel and nickel alloy strip

vidual upper knives to find their own perfect alignment relative to their opposite numbers on the lower arbor. Other important factors contributing to the quality of the slit strands are the heavy-duty, high-precision needle roller bearings in which the arbors turn and the single handwheel worm drive screwdown mechanism which ensures simultaneous and, hence, perfectly parallel, raising and lowering of the upper arbor. Probably the most useful details of the slitting lines shown are their core plate recoilers. The core plate method of winding the slit strands has many advantages over the conventional solid or collapsible drum method, particularly in connection with a low-cost slitting installation for the production of relatively narrow strands at the consumer's works. Each core plate has two starting slots, one for thin and one for thick stock, and three radial banding slots. On setting up the line, each slit strand is looped around the core plate and then inserted in a starting slot, as illustrated in Fig. 6. Once the slitting operation is completed, the tightly wound slit coils are banded circumferentially and then can be removed easily from the recoiler shaft, together with their respective core plates. All danger of coil telescoping or unwinding is thus eliminated and perfectly shaped coils are obtained. In handling magnetic materials, the slit coil frequently is left on the core plate for transfer to the pay-off stand of the next processing machine; alternatively, the coil is radially banded on a bench, and the core plate is knocked out finally.

Another interesting aspect of the slitter contributing to the quality of the resulting strands is the recoiler tension control. When slitting light gauge materials, conventional recoilers often tear the stock due to incorrect winding tension being applied. On the machines shown in Figs. 6 and 7, tension is adjustable through a slip clutch, while the slitter is running by the use of a handwheel which is conveniently situated at the operator's station. Since the magnitude of winding tension required varies with the material, the number of strips being cut, the width and thickness of the strands, and the coil diameter, such ready adjustability of tension is necessary to facilitate perfect slitting results being obtained.

LEVELLING OPERATIONS

The photograph reproduced in Fig. 8 shows a pull-through roller leveller mounted between the cutters and the recoiler of a silicon steel slitting line. This arrangement allows the slit strands to be cold worked slightly in passing through the levelling rolls prior to being wound up on the recoiler. This cold work tends to reduce the core loss of the material which had been raised in the preceding coiling and slitting operations. The levelling unit illustrated has nine 1 in diameter rolls arranged in a hinged frame to facilitate quick opening for strip threading purposes.

The recent trend toward ever lighter gauges of magnetic materials has led to the development

of the high-precision miniature roller leveller illustrated in Fig. 9. This machine has been installed by a prominent American manufacturer of laminations and cores to obtain perfectly flat strip in gauges down to about 0.005 in and in widths up to 6 in. The leveller comprises thirteen $\frac{3}{8}$ in diameter by 8 in face width levelling rolls and two $\frac{5}{16}$ in diameter by 8 in face width exit pinch rolls. To obtain the maximum levelling action, all fifteen rolls are positively driven and the $\frac{3}{8}$ in diameter rolls are backed up centrally against undue deflection. Adjustment of the leveller is performed by means of worm drives at the front and the rear of the unit.

In summary, the manufacturers of laminations and cores in the United States have found themselves being able to produce magnetic assemblies of improved performance, thanks to the availability of the special processing equipment reviewed. A rolling mill installation is used to furnish grain-oriented strip reduced to ultra-thin gauges; a slitting line is used to supply strands having extra close width tolerances and burr-free edges, and a roller leveller is used to provide low core loss sheet of perfect flatness resulting in the highest possible stacking factor obtainable in the final magnetic assembly.

Explosion at the Ridgeland Power Station in Illinois

ONE of the worst accidents to occur in the electrical industry during 1954 was an explosion in the low-pressure turbine of a new 150MW, cross-compound, steam turbo-generator at the Ridgeland power station of the Commonwealth Edison Company, at Stickney, Illinois. The explosion occurred on Sunday, December 19th, at 11.19 p.m., as the unit was being brought into service. The blast destroyed the turbine, and flying metal and debris caused considerable damage to the station building and adjacent units. Two men were killed and five others injured in the accident that threw the station out of operation. The station's 600MW total capacity represents some 18 per cent of the Commonwealth Edison generating capacity of 3422MW, and its loss made it necessary for the company to ask 100 of its largest customers to cut load by 25 per cent. The unit involved in the blast was the latest of four similar units at Ridgeland, having been placed in service in August, 1954. It consists of a 50MW, 3600 r.p.m., high-pressure, and a 100MW, 1800 r.p.m., low-pressure element, which are normally operated cross compounded. Steam is supplied to the unit from a single boiler at a throttle pressure of 1800 lb per square inch and a temperature of 1050 deg. Fah. The low-pressure element of the unit has an intermediate as well as a low-pressure turbine on its shaft. It was in the low-pressure turbine that the failure occurred. This led to an explosion, but no fire followed. No cause has yet been determined. The unit was operating at close to normal speed at the

time of the failure. The blast destroyed the 100MW low-pressure turbine, and, according to the company, it will take several months before it can be replaced. The high-pressure, 50MW machine is believed to have suffered relatively minor damage.

The damage to the building included holes in the roof of the turbine room ranging in size from 1 to 50 square feet. Flying debris also drove several holes into the walls. The reinforced concrete floor was broken in a few places by heavier turbine fragments falling through it. A substantial portion of the estimated damage to the plant and equipment is covered by insurance and by the guarantee of the manufacturer, the Allis-Chalmers Manufacturing Company. Two of the three remaining 150MW units in the power station were returned to service on the Tuesday following the accident, and the third was returned to service early on Wednesday. Interconnections with neighbouring grids made it possible for the company to secure 200MW of generating capacity and to carry the load of its normal winter peak week with a minimum of curtailment in service. As yet no official estimate of the damage to the plant and equipment has been made, pending a complete and detailed examination of the equipment affected; however, it is believed to run to a total of several million dollars.

Elevated Temperature Properties of High-Strength Alloys

A 208-PAGE report entitled *Report on the Elevated Temperature Properties of Selected Super-Strength Alloys* has been published by, and is now obtainable from, the American Society for Testing Materials, of Philadelphia, 3, Pennsylvania (price 4.75 dollars). Primarily, the report is a graphic summary of the elevated-temperature strength properties of thirteen selected high-strength alloys. It includes 116 summary curves showing tensile strength; 0.2 per cent offset yield strength; per cent elongation and reduction of area; stresses for rupture in 100, 1000, 10,000 and 100,000 hours when available, and stresses for creep rates of 1 per cent in 10,000 and 100,000 hours. A brief description of each alloy is included which gives chemical composition, recommended heat-treatment, and short instruction relating to forging and machining. These alloy descriptions are intended to furnish the reader with a basis of comparison so that he can refer to the optimum processing conditions recommended by the producer of each alloy when using the data. An appendix contains some very short-time rupture data for several of the alloys, and a compilation of the chemical compositions of approximately 100 American and foreign high-strength alloys. The following alloys are the ones covered in detail by the report:—19-9DL, 16-25-6, Discaloy 24, A-286, N-155, S-590, S-816, Haynes Alloy No. 25, Refractaloy 26, Inconel "X," M-252, Haynes Alloy No. 21, Haynes Alloy No. 31.

Industrial and Labour Notes

Reorganisation of the National Coal Board

Just over a year ago, the National Coal Board invited five industrialists to advise it on a review of its organisation. They constituted an advisory committee on organisation, under the chairmanship of Dr. A. Fleck, who is the chairman of Imperial Chemical Industries, Ltd. Last week, the committee's report to the Board was published. It contains a detailed review of the Board's organisation and also several suggestions and recommendations.

A statement about the report was made in the House of Commons on Wednesday of last week by the Minister of Fuel and Power, Mr. Geoffrey Lloyd. He said that one recommendation in the report had been addressed to him and that action upon it must precede consideration of the report by the Board. That recommendation was that the National Coal Board should consist of twelve members, namely, a chairman and a deputy chairman, six other members who would give the whole of their time to the Board's work, and four part-time members. This recommendation added that the Board should now be reorganised in the way proposed and that such reorganisation should be carried out "as a matter of urgency." The Minister went on to say that the Government had decided to accept the recommendation and to act upon it at once. To facilitate the reorganisation, the chairman, the two deputy chairmen and all other members of the existing Board had expressed their willingness to resign their offices, if asked, and in some cases, the Minister said, he had made the request. A new Board would take office on February 21st. The Minister then announced that Sir Hubert Houldsworth would remain chairman, and that Mr. James Bowman would become deputy chairman. In addition to the chairman and deputy chairman, the six full-time members of the Board would be: Sir Andrew Bryan, Mr. J. Latham, Dr. W. Reid, Mr. W. H. Sales, Mr. R. E. Thomas, and Mr. A. H. A. Wynn. Each of the full-time members, the Minister explained, would share fully in responsibility for the Coal Board's general policy, having at the same time a special concern with one aspect of its activities. Four part-time members would be appointed, the Minister added, and one of the first tasks of the new Board would be to consider the report as a whole, and its many recommendations.

Recruitment and Training for Management

The British Institute of Management has published this week a report entitled *The Recruitment and Training of Men Intended for Management Positions*. This report has been prepared by a study group composed mainly of senior managers from nine leading concerns in various industries.

The report includes chapters on sources of recruitment, wastage among trainees, the budget of trainee requirements, methods of selection, induction and follow-up. Training arrangements are dealt with in some detail and financial arrangements, including levels of remuneration, are reported upon. One chapter is devoted to "problem cases" encountered even after the most careful selection, and at the end of the report a number of specific recommendations are put forward by the study group which has prepared it. Among the appendices to the report, there is an estimate of the movement of university graduates into the working population and a detailed description of the selection procedures, including group techniques, of three companies. Another appendix summarises the advantages and disadvantages of the use of the "personal assistant" role in training.

In presenting this report, the British Institute of Management says that throughout industry, and particularly in the larger and medium-sized concerns, more and more attention is being paid to the need for the planned development of the next generation of managers. In this country an increasing number of courses in management studies is being offered by universities, technical colleges, and specialist institutions, whilst within

many companies there is a steady growth in the introduction of organised management training schemes.

The report is available, price 5s., from the British Institute of Management, 8, Hill Street, London, W.1.

European Steel Production

The United Nations Economic Commission for Europe has stated in its *Quarterly Bulletin of Steel Statistics* that crude steel production in Europe last year broke all previous records. European steel production in 1954 is estimated at 81,820,000 metric tons, an increase of 9 per cent over the output of the preceding year. If the U.S.S.R. is included, then steel production last year is put at 122,820,000 metric tons. Steel production in Western Germany last year, the *Bulletin* says, was the highest since the war.

It is also explained in the *Bulletin* that, in the first ten months of last year, the annual rate of exports of finished steel from the United Kingdom, Austria, Western Germany and the Netherlands was higher than in any of the years 1951-1953, while in Belgium and Luxembourg and France-Saar steel exports approached the 1951 record. Steel imports, it is added, were running at a higher annual rate during the first ten months of 1954 than in any post-war years. The steel imports of Sweden and Switzerland were at a high rate during the first ten months of last year, and tended to increase in the later months of the year. About raw materials, the *Bulletin* shows that scrap imports into Western Germany in the third quarter of 1954, amounting to 142,000 tons, were at the highest rate so far attained in the post-war period. Scrap imports into the United Kingdom in the same quarter, at 189,000 tons, were lower than in any of the preceding five quarters.

European Coal and Steel Community

In our issue of December 31st last, we published the details of the agreement between the United Kingdom Government and the High Authority of the European Coal and Steel Community, which was formally signed in London just before Christmas. On Monday last, in the House of Commons, a motion ratifying the agreement was passed.

The motion was proposed by Mr. Duncan Sandys, Minister of Housing and Local Government, who, in his former office of Minister of Supply, was closely concerned in the discussions leading up to the agreement. He pointed out, in his speech, that coal and steel were the basic materials upon which almost all modern industry rested. The decision of the six member-countries of the Community to create by progressive stages a common market in these two vital materials, and to set up joint institutions to control it, was undoubtedly, Mr. Sandys said, an outstanding event in international economic relations. Britain's output of coal and steel was greater than that of any other country in Western Europe, but the six member-countries together produced slightly more coal than we did and twice as much steel. Since, Mr. Sandys continued, these were two of this country's greatest industries, it was clear that the fiscal and commercial policies which the Community might at any time decide to pursue must be a matter of very great interest and importance to this country. In the same way, the policies which this country decided to adopt in the same sphere were of considerable concern to the countries on the Continent. In conclusion, Mr. Sandys said, the Government did not regard the agreement as an end in itself. The agreement provided the machinery to facilitate consultation and co-operation. It created a framework within which it was sincerely hoped a closer association between Britain and the Community would progressively develop.

Suggested Reorganisation of Remploy, Ltd.

When answering a question in the House of Commons last week, Mr. Harold Watkinson, the Parliamentary Secretary to the Ministry of

Labour and National Service, said that last year Remploy, Ltd., seriously outran its expenditure, and savings were to be effected by not replacing workers leaving and not by the discharge of disabled workers. Further, by steps taken to reduce overheads some 226 administrative and staff workers not engaged on production had been declared redundant. Of these, eleven were seriously disabled and had been offered employment on production. Following this announcement the Association of Supervisory Staffs, Executives and Technicians, submitted proposals to the Minister of Labour for the reorganisation of Remploy, Ltd. It suggested that the part-time board of directors should be disbanded and replaced by a full-time board consisting of a chairman, managing director, personnel director and a financial director. The Association contended that the factories should be kept fully employed through contracts from Ministry of Supply departments, local authorities and nationalised industries. At the same time, trading in commercial markets should be restricted to those trades where experience had proved that satisfactory arrangements on a local basis could be made. This would enable overheads to be reduced by abolishing a large and costly sales organisation and eliminate some of the expenses it incurred.

Industrial Development in Northern Ireland

It has been stated that, by the end of last year, as a result of Government assistance to industry in Northern Ireland, 32,000 people had been added to the labour force. It is anticipated that this figure will increase to nearly 42,000 when various projects reach fruition. Several firms have agreed to establish themselves or to expand their activities in Northern Ireland, but have not yet begun production. The additional number of people to be given employment by these firms when their plans mature is put at over 54,000.

The Northern Ireland Government says that the grants likely to be paid in respect of cases approved to date under the Re-equipment of Industry Acts are estimated at approximately £4,500,000, of which almost £2,000,000 has already been paid. These Acts have been followed by the Capital Grants to Industry Act, under which grants are available of 25 per cent of capital expenditure upon new or additional building, and upon plant and machinery. A scheme has also been introduced to lessen the burden of the high cost of coal to industrialists using more than 50 tons of coal (or its electricity or gas equivalent) in a year. The present rebate is £1 a ton.

Up to the end of last year, the Ministry of Commerce of Northern Ireland had built twenty-four new factories, purchased twelve and extended six, at a cost of more than £4,000,000, thus providing over 2,200,000 square feet of floor space. In addition, the estimated expenditure on factories either under construction or approved at the end of the year was about £6,500,000.

Wholesale Prices

In its review of the movement of wholesale prices during 1954, the Board of Trade says that, after falling 15 per cent in 1952 and 7½ per cent in 1953, prices of basic materials rose by nearly 3½ per cent last year. Wholesale prices thus finished the year 46 per cent higher than they had been five and a half years previously when the new series of wholesale price index numbers began. By contrast, producers' prices for manufactured products, after falling 1½ per cent in 1952 and just over 1 per cent in 1953, rose by only 1½ per cent in 1954, finishing the year 26½ per cent higher than they were in 1949. The Board of Trade says that the much smaller price increase over the past five and a half years in manufactured products was due mainly to the fact that wages rose less steeply than material prices in that period. Since 1952, however, increases in wages have played a relatively more important part in the tendency for manufacturing costs to rise.

Personal and Business

Appointments

MR. D. COLBRIDGE has been appointed chief methods engineer of A.P.V.-Paramount, Ltd.

MR. R. B. W. BOLLAND has been appointed a director of Head Wrightson Aluminium, Ltd.

K.L.M. ROYAL DUTCH AIRLINES announce the appointment of Mr. F. E. Pearce as regional press officer.

MR. STANLEY CLARK has been appointed chief executive of the Society of Motor Manufacturers and Traders.

VACUUM OIL COMPANY, Ltd., announces the appointment of Mr. T. H. Burrell as package co-ordinator.

MR. C. J. CARTER has been appointed director of instrument research and development at the Ministry of Supply.

DR. H. G. TAYLOR, director of research of the British Welding Research Association, has been elected president of the Society of Engineers.

LEYLAND MOTORS, Ltd., states that it has retained Mr. E. H. C. Leather, M.P., as a consultant on economic affairs, particularly in connection with export activities.

GENERAL SIR KENNETH N. CRAWFORD has been elected to the board of Cyanamid Products, Ltd., the London subsidiary of the American Cyanamid Company of New York.

THE ORGANISATION FOR EUROPEAN ECONOMIC CO-OPERATION announces the appointment of Monsieur Roger Grégoire as director of the European Productivity Agency.

DUNLOP, Ltd., states that Mr. B. J. Haill, general works manager of the Brynmawr and Cwmavon factories, has been appointed general works manager at the Cambridge Street factory, Manchester.

JOHNSON AND PHILLIPS, Ltd., Charlton, London, S.E.7, states that Mr. G. T. W. Whitehead, M.I. Mech.E., formerly assistant general manager (works), has been appointed general manager (works).

MR. W. P. WARREN, A.M.I.E.E., has been appointed general manager of Cantie Switches, Ltd., Bromborough, near Chester. He was formerly assistant chief commercial officer (industrial) of the South Wales Electricity Board.

THE SHIPBUILDING EMPLOYERS' FEDERATION announces that it has appointed Mr. Norman A. Sloan, Q.C., as director designate with a view to his succeeding Sir John S. Boyd, when he retires a year hence, as permanent vice-president of the Federation.

C.A.V., Ltd., Acton, W.3, states that Mr. S. F. H. Parsons, formerly director and chief engineer, is now acting as a special duty director in a consultative capacity. Mr. K. Brook, formerly chief experimental engineer, has been appointed to the board as an executive director.

PROFESSOR ARNOLD TUSTIN, M.I.E.E., has been appointed to the chair of heavy electrical engineering at the Imperial College of Science and Technology as from August 1st next. Professor Tustin is at present head of the department of electrical engineering at Birmingham University.

MR. W. YOUNG, a senior engineer and ship surveyor in the London district marine survey office of the Ministry of Transport and Civil Aviation, has been appointed principal officer of the West of Scotland survey district, Glasgow. He succeeds Mr. G. Burdon, who has been appointed deputy engineer surveyor in chief.

THE GENERAL ELECTRIC COMPANY, Ltd., announces that Mr. R. N. Millar, lately chief mechanical engineer to the British General Electric Company (Pty.) Ltd., Australia, has been appointed to take charge of its newly formed industrial atomic energy section. The new organisation is located at the company's Erith works which is under the direction of Mr. Arnold Lindley. It will develop designs of plant for the utilisation of atomic energy in power station generating equipment, and it is the intention of The General Electric Company Ltd., to provide most of the equipment for atomic power stations from within its own manufacturing organisation.

Business Announcements

AYLESBURY TURNED PARTS (TRUE SCREWS), Ltd., states that it will shortly occupy new office premises at 43, High Street, Aylesbury, Bucks.

MULLARD OVERSEAS, Ltd., states that Mr. K. O. Rees, manager of the electronic tube department, is making a tour of the Near East and India.

MR. MILES BEEVOR, managing director of the Brush Group, Ltd., is making a tour of the Union of South Africa and Northern and Southern Rhodesia.

THE UNITED STEEL COMPANIES, Ltd., Sheffield, has opened a district sales office at 55-56, Scottish Provident Buildings, Donegal Square West, Belfast (telephone, Belfast 29604).

DUNLOP SPECIAL PRODUCTS, Ltd., states that the London sales office of its flexible plastics division has been moved to Allington House, 136-142, Victoria Street, S.W.1 (telephone, Victoria 6868).

TEDDINGTON INDUSTRIAL EQUIPMENT, Ltd., states that MacCarthy and Co. (Engineers), Ltd., 12, Grey Street, Newcastle upon Tyne, is acting as distributor of "Teddington" control equipment in the north-east.

BIRLEC, Ltd., Tyburn Road, Birmingham, states that its London area office has been moved to Ediswan House, 155-161, Charing Cross Road, W.C.1 (telephone, Gerrard 8660). The firm's Newcastle upon Tyne office is now c/o the British Thomson-Houston Company, Ltd., 9, Higham Place, Newcastle upon Tyne, 1 (telephone, Newcastle 25040).

Contracts

BRITISH INSULATED CALLENDER'S CABLES, Ltd., has received an order from the Electricity Commission of New South Wales, Australia, for the supply of 30,000 yards of high-voltage cable to form a double-circuit 8½-mile link between Bunnerong power station and the Canterbury substation in Sydney. The cable is expected to be in operation early next year. It is a three-core, 132kV impregnated pressure cable, which will be manufactured in England, although its installation and maintenance will be carried out by an affiliated Australian company, British Insulated Callender's Cables (Australia), Pty., Ltd. The route is in the Sydney metropolitan area, through heavily built-up districts, and includes a crossing of Cooks River.

BRITISH RAILWAYS (London Midland Region) announces that contracts have been placed with Leonard Fairclough, Ltd., Adlington, Lancs, for modernisation of the examination and repair shop at Crewe North motive power depot, and for the reconstruction and widening of bridge No. 35 at Holmes Chapel on the Crewe-Stockport line; with Samuel Butler and Co., Ltd., Albion Works, Stanningley, near Leeds, steelwork contract for the reconstruction and widening of bridge No. 35 at Holmes Chapel, on the Crewe-Stockport line; with William Freer, Ltd., 36-40, Wellington Street, Leicester, for the ventilation system in the boiler and welding shop at Derby locomotive works; with R. W. Naylor, Ltd., Soho Wharf, Whitmore Street, Birmingham, for new awnings over platform 4, and new drainage to platforms at Crewe station; with the Butterley Company, Ltd., Butterley, near Derby, for the construction of a new intersection bridge carrying the N.C.B. access lines over the London Midland main line, Clay Cross to Cudworth, on the Derby-Leeds line.

Miscellaneous

GERMAN WELDING CONGRESS.—The German Welding Society has issued the programme for its annual meeting and congress which is to take place in Frankfurt/Main from June 13-16, 1955. Details may be obtained from Deutscher Verband Fuer Schweisstechnik e.V. (22a), Düsseldorf, Harkortstrasse 27.

GRAVITY SURVEY OF N.W. SWITZERLAND.—A detailed account has recently been published of a gravimetric survey carried out over 250 square miles north-west of Zurich. The paper, entitled "Schweremessungen Nordwestlich von Zurich und ihre Geologische Interpretation," by Peter Gretener, is obtainable from the Geophysical Institute of E.T.H., Leonhardstrasse 33, Zurich 6, Switzerland.

PULVERISED FUEL ASH FOR ADEN HARBOUR WORKS.—Shipments are now being made of pulverised fuel ash from the British Electricity Authority's power station at Littlebrook (Dartford) for the new harbour works at Aden. The initial contract is for 1450 tons to be used as a partial replacement of cement in the concrete works. The contractor is Pauling and Co., Ltd., and the consulting engineers are Sir Bruce White, Wolf Barry and Partners. It is expected, the British Electricity Authority states, that this initial order for Aden will lead to other markets abroad. The British Electricity Authority has now appointed an ash marketing officer in its commercial department.

EXTRUDED PTFE ROD AND TUBE.—Crane Packing, Ltd., of Slough, has developed and installed a plant for extruding PTFE rod and tube up to 4in outside diameter in standard lengths of 3ft or longer to special order. This company is now also supplying the material in the form of rounds from ½in to 2in diameter and 5in to 3in long, discs ½in to 12in diameter up to 0.0625in thick, rings ½in to 6in diameter and ¼in to 1in square section, and cylinders from ½in to 6in internal diameter and from 1½in to 2in long. For use in packing valve stems, &c., PTFE cord ¼in diameter is made in continuous lengths of 250ft. The firm also states that it has developed a technique for applying PTFE dispersion coatings on moderately large articles.

VENTILATION FITTING.—Richard Crittall and Co., Ltd., announces the addition of a unit known as the "D" Deflecto grille to its range of ventilation fittings. It is similar in design to the standard model, but instead of having two sets of individually adjustable blades, the vertical rear blades only are arranged thus, whilst the horizontal front blades are linked for collective adjustment, remaining parallel to each other through the full angle of deflection. Length of throw and zone of movement in the horizontal plane are thus controlled by the individually adjustable rear blades, and directional movement in the vertical plane is controlled by the front interlinked blades. The appearance of the unit has been improved by the use of smaller front blades set closer together, and a narrower flange.

DAMPED TRANSVERSE VIBRATIONS OF STRUTS.—This treatise, entitled "Über Biegeschwingungen Stabformiger Bauelemente mit Abstrahlungs Dämpfung," by W. Kellenberger, deals with the vibrations of slender structural elements under conditions of internal and external damping, including damping due to loss of energy to the supports. A numerical example is given to show the magnitude of these effects for a case of resonance. The rapid decrease of the resonant frequency with increased elastic damping is shown both analytically and graphically. Dynamic damping factors (both calculated and measured values) are discussed and tabulated, and it is shown how they can be determined experimentally, e.g. in a model. The paper may be obtained from the Geophysical Institute of E.T.H., Leonhardstrasse 33, Zurich 6, Switzerland.

METROPOLITAN WATER BOARD'S ANNUAL REPORT.—The fifty-first annual report of the Metropolitan Water Board for the year 1953-54 has now been published. The text of the report is divided into four sections, which may be summarised briefly as follows, viz.:—The constitution of the board, number of staff employed, wages and working conditions, information relating to the capital debt of the Board, interest charges, collection of water charges, sources of supply, statistics and general information of supplies and works; purity of the supply; and miscellaneous information concerning the Board's undertaking. The appendices to the report consist of statistical tables relating to supplies from the various sources, mains, filters, storage, rainfall, and bacteriological and chemical examinations. The report may be obtained from Staples Press, Ltd., 14, Great Smith Street, Westminster, S.W.1, price 5s.

PREVENTION OF CORROSION.—The results of prolonged investigation into the causes and inhibition of corrosion are dealt with in a booklet issued by the British Iron and Steel Research Association. The subject is discussed under three main headings—corrosion in air, water, and soil. In dealing with structural steels, the importance of good basic design is stressed. Apart from avoiding opportunities for the lodgment of moisture and atmospheric grime, sound design acts as an important inhibiting agent by encouraging efficient maintenance. In connection with the protective painting of steel the important factors are stated to be thorough surface preparation, the use of a suitable inhibitive priming paint, and adequate thickness of the complete painting scheme with finishing coat. Corrosion in water is treated from two aspects—ship structure and shore installations. Corrosion in soil is treated with special reference to graphitisation, arising from anaerobic environment in heavy soils. The booklet is obtainable from B.I.S.R.A., 11, Park Lane, London, W.1, at 2s.

PRECISION ALLOY STEEL CASTINGS.—Some five years ago, B.S.A. Tools, Ltd., developed a process for the precision casting of milling cutters which had a metallurgical structure and mechanical properties closely resembling those of conventional high-speed steel cutters. As a result of further development work a new company, Precision Alloy Castings (Birmingham), Ltd., Kitts Green, Birmingham, 33, was recently formed for the development and application of the precision casting process to a much wider field. This firm states that it can supply castings in almost any kind of steel and, depending upon size and complexity of the castings, a limit of ±2 per cent can be maintained on important dimensions. At present some forty different steels are being cast by the process, including case hardening, carbon and alloy tool steels, and heat and creep-resisting steels. It is claimed that castings can be produced which will meet the mechanical requirements of all the B.S.I. and D.T.D. specifications for castings, and in some cases closely approaching the properties called for in the B.S.I. and D.T.D. specifications for steel in the wrought condition.

FOURTH WORLD PETROLEUM CONGRESS.—We are informed by the British National Committee that the Fourth World Petroleum Congress will be held in Rome from June 6th to June 15th in the Congress Building at the Universal Exhibition grounds. The topics which will be discussed are divided into sections as follows:—Geology and geophysics; drilling and production; oil processing; production of chemicals from petroleum, properties and applications; composition of petroleum, analysis and testing, measurement and control; utilisation of oil products; construction of equipment, materials, corrosion; transport, storage and distribution; economics, statistics and education. During the congress the following four lectures of general interest will be given:—"Major Oil Developments," by Mr. C. A. P. Southwell, managing director, Kuwait Oil Company, Ltd.; "The Principles of Fundamental Research in the Design of Petrochemical Equipment," by Professor J. Jungers, of the University of Louvain; "Energy Resources," by Professor W. K. Lewis, of the Massachusetts Institute of Technology; and "The Development of Natural Gas Industry in Italy," by Ing. E. Mattei, chairman of "Ente Nazionale Idrocarburi," Rome.

British Patent Specifications

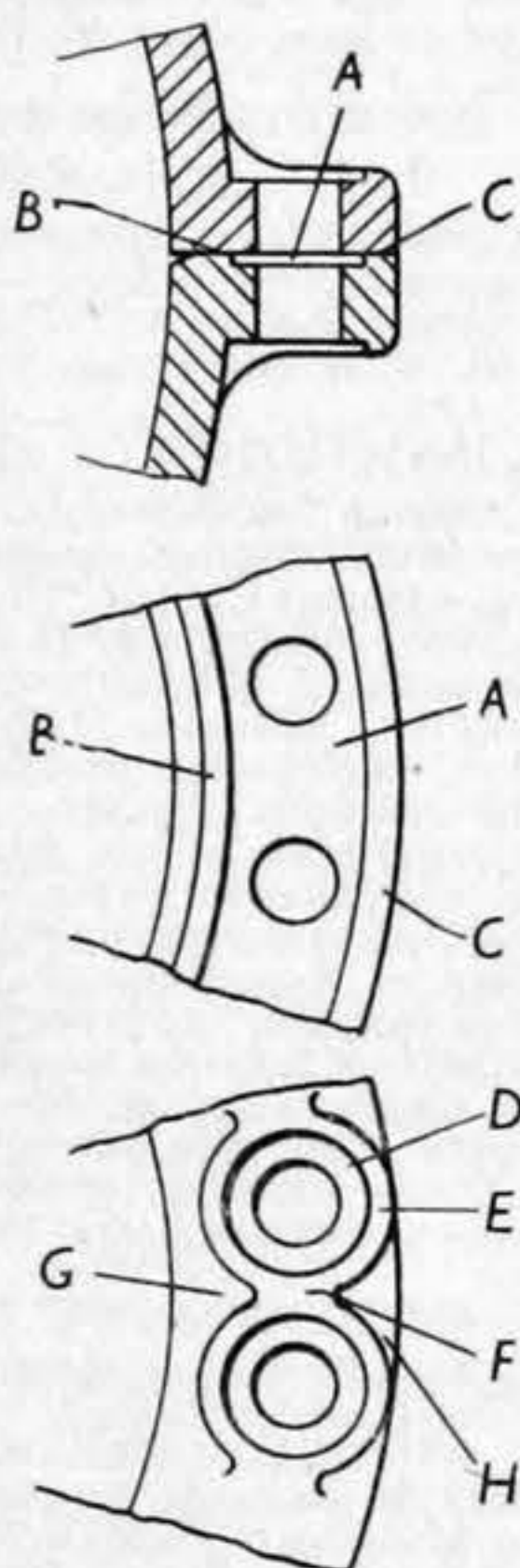
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

STEAM AND GAS TURBINES

722,391. November 14, 1952.—**BOLTED FLANGE JOINTS FOR CASINGS OF STEAM AND GAS TURBINES,** Brown, Boveri et Cie., Aktiengesellschaft, Mannheim, Germany.

Special difficulties are encountered in connection with bolted flange joints for high-pressure steam and gas turbines because the usual jointing varnishes or pastes cannot withstand the high temperatures which are usual nowadays. For this reason the sealing flanges are generally scraped and have to provide a tight joint without any additional jointing materials. The object of the invention is to overcome this disadvantage by means of a more expedient construction of the sealing and supporting fillet. In the upper view of the diagrammatic drawing a cross-sectional view of a flange joint where the milled out portion *A* within the area of the bolts and the remaining sealing fillet *B*, as well as the supporting fillet *C*, is shown. The centre view shows a view of a flange surface with a sealing fillet *B* and a supporting fillet *C* arranged in the usual manner parallel to the centre line of the bolts. By way of comparison the lower view shows a view of a flange surface constructed in accordance with the invention. *D* indicates the annular recessed portion around the bolts, whilst *E* is the circular sealing fillet located around the recess *D*. Between two neighbouring sealing fillets, if these do not intersect, a short bridge piece *F* can be provided. The surfaces *G* and *H* have only to be slightly recessed when the flanges are comparatively thick and the bolts near each other. When the flanges are thin and the bolt pitch is large these surfaces are sufficiently flexible. —January 26, 1955.

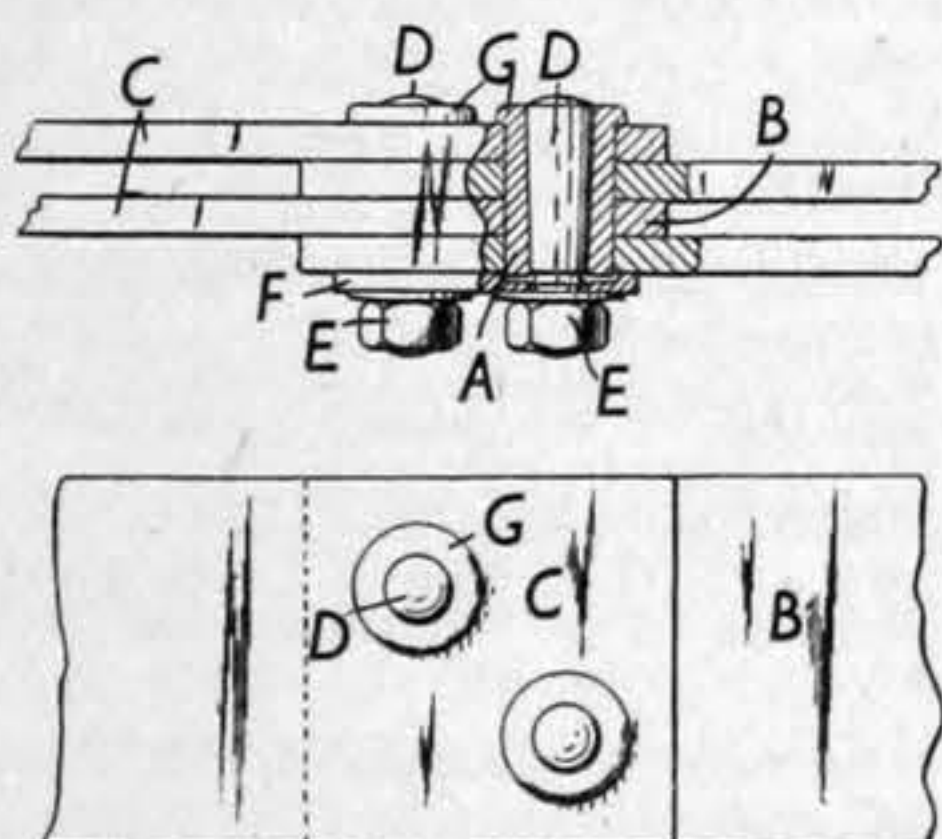


No. 722,391

ELECTRICAL ENGINEERING

717,640. September 5, 1953.—**ELECTRICALLY CONDUCTIVE JOINTS,** High Duty Alloys, Ltd., 89, Buckingham Avenue, Trading Estate, Slough. (Inventors: Raymond Ford Hanstock and Christopher Elderfield.)

The invention relates to improved means for obtaining and maintaining pressure over areas of contact between different members of a joint to ensure permanent electrical continuity. Referring to the drawing, a ferrule *A* is inserted through coaxial holes bored for it in the interleaved conductive strips *B* and *C*. It fits closely in the holes, which are



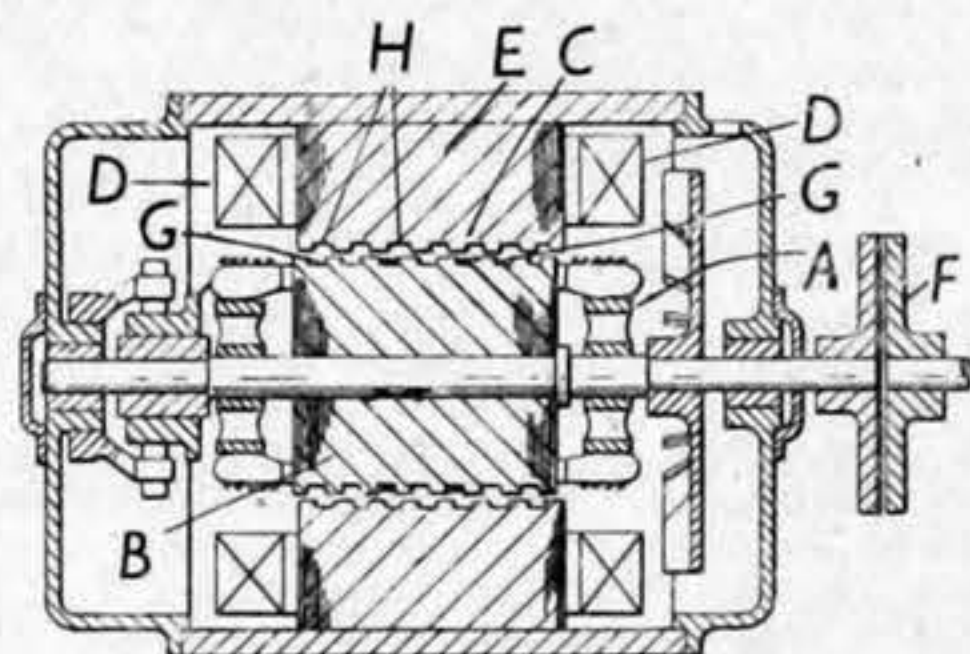
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preferably reamed to give a drive fit. The ferrule is made of a comparatively soft metal so that it can be expanded. The ferrule has a tapering hole to receive a taper-pin *D* which can be drawn into the ferrule by means of a nut *E* to expand the ferrule. The nut is screwed on a threaded shank at one end of the taper-pin and applies axial pressure to a ring or pressure-plate *F* designed to bear against one busbar at the end of the ferrule adjacent the nut.

At its other end the ferrule is formed with a flange *G* designed to bear against the busbar at that end of the ferrule. The busbars are thus clamped together when the nut is tightened. The action of tightening the nut draws the taper-pin into the ferrule and produces a very high radial pressure between the mutually contacting surfaces of the ferrule and busbars. To ensure permanent maintenance of the required pressure a Belleville or springy washer is interposed between the nut *E* and the pressure-plate *F*. —October 27, 1954.

718,728. February 6, 1952.—**DYNAMO-ELECTRIC MACHINES,** Selectra, Ltd., 42, Selcroft Road, Purley, and Ernst Wolfgang Krebs, of the company's address.

The invention relates to dynamo-electric machines and particularly to electric motors, and is concerned with providing means for producing a strong axial thrust on the rotating member, tending to return it to a position of magnetic equilibrium, if it is displaced from that position. The drawing shows a direct current or synchronous motor having d.c. excitation of constant ampere turns, and an armature *A* including a generally cylindrical laminated core *B* which rotates in a substantially cylindrical tunnel formed by the faces of the laminated salient

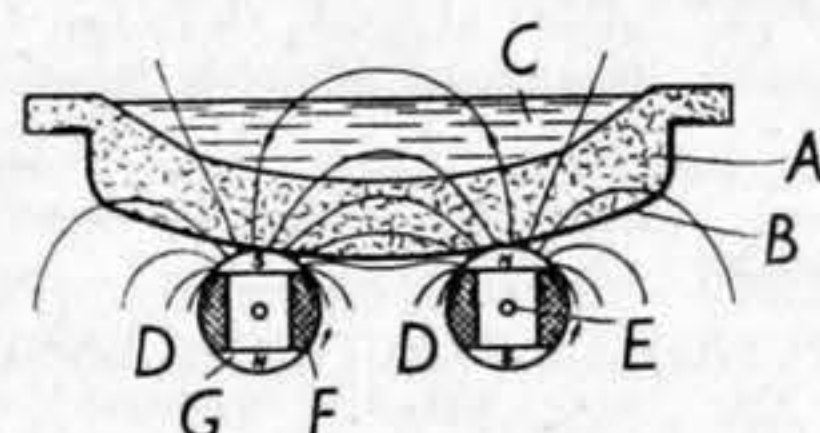


No. 718,728

poles *C* which carry the field windings *D* in the stationary field magnet core *E*. The armature is mounted on a shaft carrying a friction clutch *F* engaged by the axial movement of the armature and shaft to the right and the bearings of the shaft are arranged to permit such axial movement. The armature core *B* is provided with a series of shallow equally spaced circumferential grooves *G* of rectangular cross-section, which face an equal number of grooves *H* having similar section and spacing around the face of the tunnel of the field magnet. The depth of the grooves is between one and four times the radial width of the air gap between the faces of the opposed magnetic cores *B* and *E*, and the width of the grooves is between five and twenty-five times the width of the air gap. This arrangement provides a substantially constant axial thrust in the direction indicated by the arrow over a certain range of axial displacement of the shaft, so that the thrust will not be disturbed by the wearing of the clutch lining or by slight maladjustment. Modified forms of grooves for squirrel-cage induction motors are also shown in the specification. —November 17, 1954.

721,121. August 7, 1953.—**INDUCTIVE STIRRING DEVICE FOR METALLURGICAL FURNACES,** Allmanna Svenska Elektriska Aktiebolaget, Vasteras, Sweden.

The invention concerns an inductive stirring device for the molten charge of an arc furnace, open hearth furnace or hot metal mixer. As shown in the drawing, *A* is the lining of the furnace bottom, *B* the non-magnetic shell and *C* the molten metal charge. The magnets *D* are rotated in either direction by the shafts *E*, *F* are the magnet windings and *G* the pole shoes. In order that the magnets



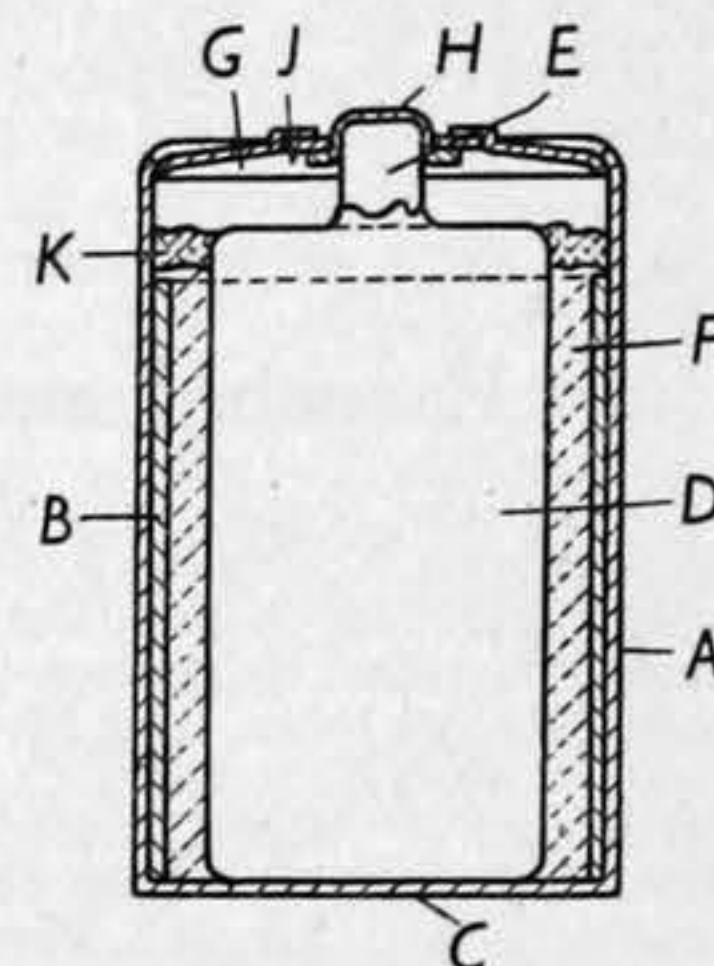
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shall not demagnetise each other too much, the distance between the rotating shafts should be at least equal to twice the length of the magnets in the direction of the pole axis. It is not necessary for the pole axes to be parallel to one another, for they can be displaced in relation to each other up to 45 deg. For effective stirring of the molten charge in the whole furnace, the whole stirring device, and possibly the bottom lining of the furnace as well, may be made rotatable in relation to the furnace. Moreover, to achieve a rotation of the surface of the charge so that deslagging is facilitated, the whole stirring device may be made movable in relation to the vertical axis of symmetry of the furnace, in

the case of a circular furnace, or in relation to the vertical plane of symmetry in the case of a rectangular furnace; or the stirring device may be permanently arranged asymmetrically with respect to this axis or this plane. —December 29, 1954.

721,442. May 10, 1951, **ELECTRIC PRIMARY CELLS.**—The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2, and Philip Fanthorpe Harrison, of The General Electric Company, Ltd., Carbon and Battery Works, Witton, Birmingham.

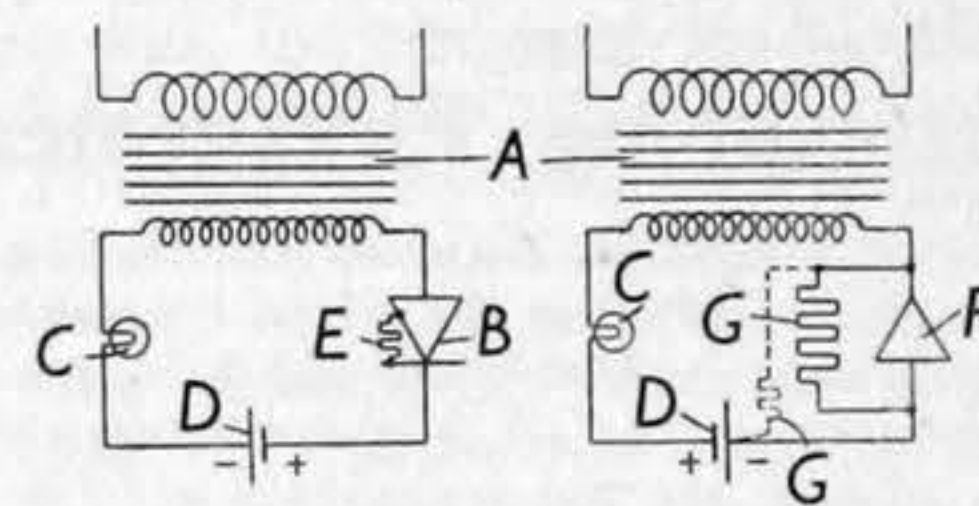
The invention relates to electric primary cells and particularly to electric primary cells of the kind having an outer steel casing. Referring to the drawing, the cell, which is leak-proof, comprises an outer tinned steel casing or container *A*. It is of the standard size for leak-proof cells and placed inside the casing is a ring *B* of zinc in the form of a split cylinder, the ring being sprung into the casing and electrically bonded by soldering. The ring *B* rests on the bottom *C* of the casing and terminates at a point about two-thirds the way up. The inside of the casing is unprotected in any way except by the tinning. Mounted inside the zinc ring *B* is a standard cell dolly *D* having a central carbon electrode *E*, depolariser (not visible), electrolyte *F*, &c., and the top of the casing is closed by a sealing lid *G*, the top edge of the casing being turned over and down on the lid, and an aperture in the centre of the lid being closed by a metal cap *H* on the dolly *D* and an insulating washer *J*. An electrolyte seal *K* is provided. Since the zinc electrode *B* has no bottom and zinc is not used to form the upper part of the outer casing as in a conventional cell, there is an approximate saving of about two-thirds of the weight of zinc over conventional cells. Further, the zinc electrode can be made more cheaply from strip material than the standard casing which has to be impact extruded. A second construction specially designed for use with electric bells is also shown in the specification. —January 5, 1955.



No. 721,442

722,323. September 5, 1951.—**RENEWING EXHAUSTED PRIMARY ELECTRIC CELLS OR BATTERIES,** Ernst Beer and Henri Bernard Beer, both of 58, Schenkweg, The Hague, The Netherlands.

The invention relates to a process and apparatus for renewing or reactivating exhausted primary cells. Very favourable results can be achieved if a current is passed through the cells or batteries which consists at the end of 80 to 90 per cent of pure alternating current and 20 to 10 per cent of continuous or pulsating direct current. In the left-hand drawing *A* indicates a mains transformer to the secondary winding of which the treating circuit



No. 722,323

is connected, including a half-wave rectifier *B*, a signal lamp *C* and the cell *D* to be treated. The polarity of the rectifier and the connection of the battery or cell to be treated are such that the direct current component of the treating current flows oppositely to the direction of the current delivered by the battery or cell during discharging. The rectifier in this case is assumed to be a rectifier with a grid leak, which is diagrammatically shown by the resistance *E*, so that it lets through an adequate percentage of pure alternating current. As it is difficult to ensure satisfactory uniformity in the manufacture of such rectifiers, it is better to use a normal rectifier *F* (as shown in the right-hand view) which is bridged by a resistance *G* of adequate value. This resistance may alternatively be built-in in a cell or battery specially manufactured for the treatment. In practice the terminal voltage of the treating circuit is chosen to be slightly, e.g. 10 per cent, higher than the final peak voltage of the cell or battery to be treated. It is claimed that experiments with hearing aid dry batteries and pocket lamp batteries have shown that by a treatment according to the invention the life of such batteries can be lengthened to twenty to thirty times the normal life. —January 26, 1955.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

FLANGED STEEL PLUG VALVES FOR THE PETROLEUM INDUSTRY (EXCLUDING WELL-HEAD AND FLOW-LINE VALVES)

No. 1570 : 1955. Price 10s. This revised standard specifies requirements for flanged steel lubricated and non-lubricated plug valves having straight-way ports; three-way and four-way valves are not covered. The range of valve sizes in most classes is from 1in to 24in with primary service pressure ratings of 150 lb to 2500 lb per square inch. It deals with design and manufacture, materials, workmanship, tests, marking, inspection and despatch. Wherever possible, this standard is intended also to apply to valves fitted with internal body or port liners or applied hard facings on either bodies or plugs.

Launches and Trial Trips

WARRINGA, cargo liner; built by The Burntisland Shipbuilding Company, Ltd., for Huddart Parker, Ltd.; length between perpendiculars 320ft, breadth 49ft 6in, depth moulded to shelter deck 29ft 8in; four cargo holds, twelve 5-ton, four 10-ton and one 25-ton derricks, electric deck machinery, four 140kW diesel-driven generators; Ailsa-Doxford oil engine, four cylinders, 480mm diameter by 1660 combined stroke, 2000 b.h.p., heavy fuel oil. Launch, February 9th.

ISANDA, oil tanker; built by the Chantier et Ateliers de Saint-Nazaire-Penhoet for the French Shell Company; length overall 660ft, length between perpendiculars 631ft, breadth 86ft 9in, depth 45ft, draught 33ft 11in, deadweight 31,500 tons; thirty oil cargo tanks, trial speed 16.7 knots; one set of double-reduction geared C.E.M.-Parsons turbines taking superheated steam at 640 lb per square inch and 840 deg. Fah. from two "P.41" Penhoet water-tube boilers, 13,750 s.h.p. at 105 r.p.m. of propeller. Trial, February.

BIBLOS, oil tanker; built by the Chantiers de la Ciotat for the Compagnie Navale des Pétroles; length overall 651ft 3in, length between perpendiculars 607ft, breadth moulded 83ft 8in, depth 43ft 8in, draught loaded 33ft, deadweight 29,600 tons, speed loaded 15 knots, twenty cargo oil compartments; one Burmeister and Wain diesel engine of 11,250 b.h.p. Trial, February.

TAMBA, shelter deck cargo ship; built by the Ateliers et Chantiers de la Loire for the Cie des Chargeurs Réunis; length overall 453ft 7in, length between perpendiculars 433ft 1in, breadth moulded 61ft, draught 24ft 1½in, deadweight 8000 tons; eight passengers; two decks, five holds, sixteen 5-ton, one 25-ton and one 50-ton derricks, electric deck machinery; one nine-cylinder Sulzer diesel engine. Trial February.

GAILLON, cargo liner; built by the Chantier et Ateliers de Saint-Nazaire-Penhoet at the Chantier de Normandie for the Cie d'Orkigny; length overall 438ft 2in, length between perpendiculars 413ft 6in, breadth moulded 56ft 1½in, depth 34ft, draught loaded 23ft, deadweight 7700 tons; two decks, five holds, eleven 5-ton and one 15-ton derricks, electrical deck machinery, one 156kW turbine-driven generator, three 100kW diesel-driven generators, loaded service speed 13.5 knots; one set of geared turbines, 3500 s.h.p., steam supplied at 526 lb per square inch and 750 deg. Fah. by two "P.41" Penhoet boilers. Trial, February.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME and PLACE at which the meeting is to be held should be clearly stated.

BRITISH INSTITUTION OF RADIO ENGINEERS

Thurs., March 3rd.—MERSEYSIDE SECTION: College of Technology, Byron Street, Liverpool, 3, "Electronics in Industry," Symposium, 7 p.m.—N.W. SECTION: Reynolds Hall, College of Technology, Sackville Street, Manchester, "Computing Circuits in Flight Simulators," A. E. Cutler, 7 p.m.

CHEMICAL SOCIETY

To-day, Feb. 25th.—ABERDEEN BRANCH: Robert Gordon's Technical College, Aberdeen, "Corrosion Processes: Their Causes and Prevention," F. Wormwell, 7.30 p.m.
Thurs., March 3rd.—BRISTOL BRANCH: Chemical Department, The University, Bristol, "The Fuel Scientist: Training and Using Britain's Greatest Asset," A. L. Roberts, 7 p.m.

ILLUMINATING ENGINEERING SOCIETY

To-day, Feb. 25th.—BIRMINGHAM CENTRE: Regent House, St. Phillips' Place, Colmore Row, Birmingham, Annual General Meeting, "Terms and Techniques for Satisfactory Lighting," J. G. Holmes, 6 p.m.
Mon., Feb. 28th.—LEEDS CENTRE: E.L.M.A. Lighting Service Bureau, 24, Aire Street, Leeds, 1, "Prescribing for Seeing," M. L. Berson, 6.15 p.m.—LEICESTER CENTRE: E. Midlands Electricity Board, Charles Street, Leicester, "Lighting Maintenance Problems," J. W. Strange, 6 p.m.
Wed., March 2nd.—EDINBURGH CENTRE: Manor Club, 12, Rothesay Place, Edinburgh, "The Evaluation of Lighting," R. G. Hopkinson, 7 p.m.—NEWCASTLE CENTRE: New House, Pilgrim Street, Newcastle upon Tyne, "The Design and Application of Flameproof Lighting Equipment," D. A. Strachan, 6.15 p.m.
Thurs., March 3rd.—CARDIFF CENTRE: S. Wales Electricity Board's Demonstration Theatre, The Hayes, Cardiff, "The Architects' Approach to Artificial Lighting," J. D. Layton, 5.45 p.m.—GLASGOW CENTRE: Institution of Engineers and

Shipbuilders, 39, Elmbank Crescent, Glasgow, "Flicker in Relation to Fluorescent Lighting," R. G. Hopkinson, 7.30 p.m.—NOTTINGHAM CENTRE: E. Midlands Electricity Board, Smithy Row, Nottingham, "Colour and Colour Vision," W. D. Wright, 6 p.m.

INCORPORATED PLANT ENGINEERS

To-day, Feb. 25th.—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham, "The Scientist and Non-Scientist in Industry," J. H. Fremlin, 7.30 p.m.
Mon., Feb. 28th.—W. AND E. YORKSHIRE BRANCH: The University, Leeds, "Steam Trapping is Common Sense," F. Blezard, 7.30 p.m.
Tues., March 1st.—LONDON BRANCH: Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, Annual General Meeting, 7 p.m.
Wed., March 2nd.—KENT BRANCH: Bull Hotel, Rochester, Annual General Meeting, 7 p.m.—LEICESTER BRANCH: College of Art and Technology, The Newarke, Leicester, "Lubrication," H. E. Priston, 6.30 p.m.
Thurs., March 3rd.—PETERBOROUGH BRANCH: Campbell Hotel, Bridge Street, Peterborough, "Space Heating," G. A. Rooley, 7.30 p.m.—SOUTHAMPTON BRANCH: Polygon Hotel, Southampton, Annual General Meeting, 7.30 p.m.
Mon., March 7th.—DUNDEE BRANCH: Mather Hotel, Dundee, Annual General Meeting, followed by a Film, 7.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Wed., March 2nd.—LANCASHIRE BRANCH: Engineers' Club, Albert Square, Manchester, "Melt Quality Control in Non-Ferrous Foundries," F. Hudson, 7 p.m.
Fri., March 4th.—TEES-SIDE BRANCH: Teesdale Hall, Head, Wrightson and Co., Ltd., Thornaby-on-Tees, "The Exothermic Feeding of Castings," D. V. Atterton, 7.30 p.m.

INSTITUTE OF FUEL

Thurs., March 3rd.—WESTERN MEETING: The University, Bristol, "The Fuel Scientist: Training and Using Britain's Greatest Asset," A. L. Roberts, 7 p.m.
Fri., March 4th.—S. WALES SECTION: Y.M.C.A., Kingsway, Swansea, "Atomic Energy," P. McNair, 6 p.m.

INSTITUTE OF MARINE ENGINEERS

To-day, Feb. 25th.—S. WALES SECTION: Technical College, Mount Pleasant, Swansea, "Marine Diesel Engines," A. G. Arnold, 7 p.m.
Mon., Feb. 28th.—N.E. COAST SECTION: Technical College, Northgate, Darlington, "Metallurgy in Marine Engineering," J. E. Garside, 7 p.m.
Tues., March 8th.—85, Minories, London, E.C.3, "Application of Modern Instrumentation and Distance Control of Machinery," R. H. Paddon Row, 5.30 p.m.

INSTITUTE OF METALS

Tues., March 1st.—OXFORD LOCAL SECTION: Cadena Café, Cornmarket Street, Oxford, "Plutonium: Some Properties and Handling Problems," W. B. H. Lord, 7 p.m.
Thurs., March 3rd.—BIRMINGHAM LOCAL SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Recent Developments in Stainless Steels," J. I. Morley, 6.30 p.m.—LONDON LOCAL SECTION: 4, Grosvenor Gardens, London, S.W.1, "Physical and Chemical Processes Occurring in the Electrolytic Production of Aluminium," T. G. Pearson, 6.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Tues., March 1st.—N.W. CENTRE: Victoria and Station Hotel, Preston, Selection of Papers from Members, 7.30 p.m.
Wed., March 2nd.—E. CENTRE: Canteen, Eastern Counties Omnibus Company, Ltd., Norwich, "Modern Design and Methods of P.S.V. Body Construction," 7 p.m.
Thurs., March 3rd.—WESTERN CENTRE: Rougemont Hotel, Exeter, "Electrical Equipment Appertaining to Commercial Vehicles," R. H. Lewis, 7.30 p.m.
Mon., March 7th.—N.W. CENTRE: Engineers' Club, Albert Square, Manchester, "Lockheed Hydraulic Servo Systems for Heavy Goods and P.S. Vehicles," 7.30 p.m.—SCOTTISH CENTRE: North British Station Hotel, Edinburgh, "Steering Geometry and Wheel Balance," A. J. Hardman, 7.30 p.m.

INSTITUTE OF WELDING

To-day, Feb. 25th.—BIRMINGHAM BRANCH: Midland Institute, Paradise Street, Birmingham, 1, "The Inspection and Testing of Welds," A. H. Goodger, 6 p.m.—S. LONDON BRANCH: Technical College, Kingston, "Fusion Welding," V. W. Clack, 7 p.m.
Wed., March 2nd.—E. OF SCOTLAND BRANCH: Chamber of Commerce, Charlotte Square, Edinburgh, "Low Hydrogen Electrodes," Mr. Oldridge, 7 p.m.—MANCHESTER BRANCH: College of Technology, Manchester, "Some Welding Problems in the Chemical Industry," E. J. Heeley, 7.15 p.m.
Thurs., March 3rd.—N.E. (TYNESIDE) BRANCH: Mining Institute, Neville Hall, Newcastle upon Tyne, "Site Welding," W. C. Holliday, 7 p.m.—PORTSMOUTH BRANCH: College of Technology, Portsmouth, "The Productivity Aspect of Welding," A. G. Thompson, 7 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Wed., March 2nd.—N.W. BRANCH: The University, Leeds, "Instrumentation of a Nuclear Power Plant," P. V. Koller, 7 p.m.

INSTITUTION OF CIVIL ENGINEERS

To-day, Feb. 25th.—YORKSHIRE ASSOCIATION: Hotel Metropole, Leeds, "Folkestone Warren Landslips," and "Folkestone Warren Defences," A. M. Muir Wood, 7 p.m.
Tues., March 1st.—ROAD MEETING: Great George Street, London, S.W.1, "Prestressed Concrete Roads," J. P. Stott, 5.30 p.m.
Thurs., March 3rd.—N.W. ASSOCIATION: Engineers' Club, Albert Square, Manchester, "Some Aspects of Airport Development," J. L. Kay, 6.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Tues., March 1st.—MEASUREMENTS SECTION: Savoy Place, London, W.C.2, "Iron Losses at High Magnetic Flux Densities in Electrical Sheet Metals," F. Brailsford and C. G. Bradshaw; "An Improved Precision Permeameter," C. D. Mee and R. Street, 5.30 p.m.
Wed., March 2nd.—RADIO SECTION: Savoy Place, London, W.C.2, "Some Comparative Directional Measurements on Short Radio Waves Over Different Transmission Paths," E. N. Bramley; "Some Aspects of the Rapid Directional Fluctuations of Short Radio Waves Reflected at the Ionosphere," E. N. Bramley; "On the Rapidity of Fluctuations in Continuous Wave Radio Bearings at High Frequencies," W. C. Bain; "Sources of Error in U-Adcock High-Frequency Direction Finding," K. C. Bowen, 5.30 p.m.—S.W. SCOTLAND SUB-CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Safety in the Use of Portable and Transportable Electrical Equipment in Industry," J. W. Bunting, 7 p.m.—N. MIDLAND CENTRE: Town Hall, Barnsley, "Electricity in Mines," C. D. Wilkinson, 7 p.m.—LONDON STUDENTS' SECTION: Savoy Place, London, W.C.2, "The Application of the Rotary Amplifier," D. A. Alexander, 6.30 p.m.
Thurs., March 3rd.—ORDINARY MEETING: Savoy Place, London, W.C.2, "The Electrical Engineering Industry in the Post-war Economy—II," G. L. E. Metz, 5.30 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., March 8th.—39, Elmbank Crescent, Glasgow, "The Design of Cavitation-Free Ship Screws and Their Behaviour in the 'Behind' Condition," W. P. A. van Lammeren and J. D. van Manon, 7.30 p.m.

INSTITUTION OF HIGHWAY ENGINEERS

Fri., March 4th.—Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, "Research in Soil Stabilisation," F. H. MacLennan, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Feb. 25th.—INDUSTRIAL ADMINISTRATION AND ENGINEERING PRODUCTION GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, Discussion: "Choice of Tolerance in Relation to Production," 6.45 p.m.—SOUTHERN SECTION: Municipal College, Anglesey Road, Portsmouth, "Disc Brakes Applied to Road Vehicles," J. O. Starling, 7 p.m.
Wed., March 2nd.—WESTERN GRADUATES' SECTION: Pump Room, Bath, "Problems Encountered in the Design of Automobile Valve Gear," G. E. D. Ross, 7.15 p.m.
Fri., March 4th.—APPLIED MECHANICS' GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, "Practical Design Criteria for High-Speed Journal Bearings," Discussion, 6.45 p.m.
Tues., March 8th.—AUTOMOBILE DIVISION: GENERAL MEETING: 1, Birdcage Walk, Westminster, London, S.W.1, "Analysis and Interpretation of Service Records," A. T. Wilford, 5.30 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Tues., March 8th.—ORDINARY MEETING: Institution of Electrical Engineers, Savoy Place, London, W.C.2, "Some Non-Linear Magnetic Devices and Their Application to Telecommunications," J. W. McPherson, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Wed., March 2nd.—GLOUCESTER AND DISTRICT SECTION: Belle Vue Hotel, Cheltenham, Gloucestershire, "Modern Methods of Production Control," E. J. Thomas, 7.15 p.m.—HALIFAX SECTION: White Swan Hotel, Halifax, "Work Measurement Research," T. U. Matthew, 7 p.m.—MANCHESTER GRADUATE SECTION: Reynolds Hall, College of Technology, Sackville Street, Manchester, Annual General Meeting, followed by a Film Show, 6.45 p.m.—NOTTINGHAM SECTION: Victoria Station Hotel, Milton Street, Nottingham, Annual General Meeting, followed by Films on Production Engineering, 7 p.m.—WOLVERHAMPTON SECTION: Technical College, Wolverhampton, Annual General Meeting, followed by "Radio-active Isotopes," F. Scott, 6.45 p.m.
Thurs., March 3rd.—GLASGOW SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, Annual General Meeting and Open Discussion, 7.30 p.m.
Fri., March 4th.—SOUTHERN BRANCH: Polygon Hotel, Southampton, Annual General Meeting, 8 p.m.

INSTITUTION OF THE RUBBER INDUSTRY

Mon., Feb. 28th.—Engineers' Club, Albert Square, Manchester, "Limitations of Rubber," G. Gee, 6.45 p.m.
Tues., March 8th.—LONDON SECTION: "Oversea" League, Park Place, St. James's, London, S.W.1, "Changes in Rubber-like Materials by Exposure to High Energy Radiation," A. Charlesby, 7 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Feb. 25th.—Pepys House, 14, Rochester Row, London, S.W.1, Adjourned Annual General Meeting, followed by Informal Meeting: "Some Stages in the Refining of Crude Oil," H. W. D. Hughes, 7 p.m.
Fri., March 4th.—Pepys House, 14, Rochester Row, London, S.W.1, Film Evening, 7 p.m.

LONDON ASSOCIATION OF ENGINEERS

Sat., March 5th.—The Alliance Hall, Palmer Street, London, S.W.1, "Raising of H.M. Submarine 'Truculent,'" 6.30 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

Fri., March 4th.—Engineers' Club, Albert Square, Manchester, "Electronic Aids to Production," N. W. S. Ingles, 6.45 p.m.

MINISTRY OF WORKS

Tues., March 1st.—Technical College, Chesterfield Road South, Mansfield, "Application of Soil Mechanics to Buildings," A. L. Little, 7.15 p.m.
Wed., March 2nd.—Co-operative Hall, Kingston Square, Kingston-upon-Hull, "Shell Roofs," R. Jones, 7.15 p.m.—King's College, Newcastle upon Tyne, Discussion, "Efficiency in the Building Industry Depends Upon Team Work—The Architect, Builder and Craftsman," 7 p.m.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, Feb. 25th.—Mining Institute, Newcastle upon Tyne, "Investigation of Blistering and Mildew of Motor Cars in Course of Transport by Sea to Australia," E. A. Shipley, 6.15 p.m.

REINFORCED CONCRETE ASSOCIATION

Tues., March 1st.—N.W. BRANCH: College of Technology, Sackville Street, Manchester, "Reinforced Concrete Detailing," G. A. Simpson, 6.45 p.m.
Wed., March 2nd.—N.W. BRANCH: Liverpool Engineering Society, The Temple, Dale Street, Liverpool, "Reinforced Concrete Detailing," G. A. Simpson, 6.30 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., March 1st.—SECTION LECTURE: 4, Hamilton Place, London, W.1, "The Scientific Approach and Research in Aircraft Production," J. V. Connolly, 7 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Mon., Feb. 28th.—12, Great George Street, London, S.W.1, "Historic Buildings: Their Preservation and Use," J. Chuter Ede, 5.30 p.m.

ROYAL SANITARY INSTITUTE

Fri., March 4th.—SESSIONAL MEETING: The Guildhall, Kingston-upon-Hull, "The Water Supply of Kingston-upon-Hull—Past, Present and Future," T. H. Jones; Film, "An Epidemiological Approach to Health Education," William Ferguson and M. O. H. Beverley, 10 a.m.

SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS

Mon., March 7th.—College of Technology, Pond Street, Sheffield, "The Place of Shell Moulding in the Foundry," B. H. C. Waters, 7.15 p.m.

SOCIETY OF INDUSTRIAL ENGINEERS

To-day, Feb. 25th.—Engineers' Club, Albert Square, Manchester, "Production Control," S. Wright, 7 p.m.
Sat., March 5th.—Building Centre, 425, Sauchiehall Street, Glasgow, "Practical Time Study and Effort Rating," J. Jones, 10 a.m.