THE ENGINEER

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CONTENTS

ECONOMICS, THE GOVERNMENT AND ORGANISED LABOUR

If neither the Government nor the unions give way there must be an outbreak of industrial strife in this country within the next few months. For the Government, influenced by the weakness of sterling internationally, is determined to prevent further inflation at home whilst the trades unions appear bent upon forcing home the usual round of annual wage claims As usual, economists, often apparently influenced by the colour of their politics, assess the economic situation of the country in a wealth of different ways. One prominent group, indeed, appears to fear that the Western world is about to experience another depression possibly comparable with that of the 'thirties and, consequently, sees the Government's deflationary policies as heading directly for that disaster. Yet one thing cannot be gainsaid. Wages in this country have risen by 61 per cent since 1950 and real wealth by only 12 per cent, prices in consequence having risen by 43 per cent. No doubt salaries and certain other sources of incomes have followed much the same course as wages. The chief sufferers have been those living upon fixed incomes. It is obvious that wage rates have increased at a rate far above that of the increase in total output within the country.

There are, of course, those who argue that the inflationary effect of too rapid a rise in wage rates can be beaten by pressing up production sufficiently fast. They point, in particular, to the experience of Western Germany where wage rates have risen since 1950 by 59 per cent, but prices by only 14 per cent. In our view, however, they overlook a special factor that has been ruling there. In Western Germany, after the war, because shattered cities and industries had to be rebuilt, the production of capital goods bore at first a very high proportion to total output. Since then the output of consumption goods has been built up, with the consequence that the rate of production of capital goods has formed a decreasing percentage of total output. In such circumstances, a rate of wage increase exceeding that of total output may still equate quite closely to the rate of increase of the output of consumption goods, with the consequence that the price level for those goods remains reasonably stable. Western Germany had, too, the advantage of an influx of people from the East, who could be drafted into output for consumption, though their presence as a reservoir of unemployed did not apparently force restraint in wage claims. By contrast, in this country, recently, we have been attempting the exact opposite. We have been trying to increase the proportion of the total national output represented by capital goods. The effect would be necessarily inflationary, even if the increase of wage rates were closely pegged to the increase of national output, since the increase in output for consumption lags behind the increase in total output. If, in fact, as has been Britain's experience, wage rates tend to increase more rapidly than total output, it becomes very inflationary indeed !

Figures are often published to indicate that this country is not devoting enough of its total output to capital development as compared with other nations, and very disturbing those figures are. For example, real wealth in the United States has advanced since 1950 by about 24 per cent as compared with 12 per cent here, presumably because a higher proportion of total output in the United States is going into the creation of new and more highly productive equipment. If this country is to maintain its standards of living comparable with those of other nations, it is clearly essential that a higher proportion of its total output should henceforth be devoted to capital production. Unfortunately, however, lacking co-operation from organised labour, the Government has been driven to cut back upon capital production in order to prevent an inflationary rise in costs which would have affected export prices and, consequently, the balance of trade and the international respect accorded to sterling. In addition, it is being driven towards a head-on collision with organised labour over wage claims. But it will be tragic if the consequence is a wave of strikes. For, whether they win or lose the battle, wage-earners cannot appreciably increase their real wealth by making inflationary wage claims. What they may do, if they win, is to force the Government—as, indeed, they are already forcing it—to cut down upon the output of capital goods, that is, to reduce instead of to increase the proportion of output devoted to capital production. But since the rate of increase in the output of consumption goods is dependent on the rate of increase in the output of capital goods any such cutting down of capital production decreases the rate at which real wealth expands. That, surely, is not an end for which the trades unions wish to fight! We, thus, see no good reason, if hot tempers are given time to cool, why organised labour should not co-operate with, rather than oppose, the Government. For both have the same objects, to raise national output and, hence, standards of living as fast as possible and to stabilise prices. There is in reality nothing much to fight about.

THE ATOMIUM THING

When Hazlitt saw the Royal Pavilion at Brighton he was moved. "It seems," he wrote, "as if the genius of architecture had at once the dropsy and the megrims. Anything more fantastical, with a greater dearth of invention, was never seen. The King's Stud (if they were horses of taste) would petition against so irrational a lodging." His tour of France and Italy was more than a century too early ; it should have been arranged so that he could have looked in at Brussels next spring. The reactions of such a pungent critic when introduced to that gigantic edifice, the Atomium, a model of which is depicted on page 687, would, indeed, have been awesome. After all, the Royal Pavilion only attempts to characterise a little light-hearted seaside gaiety. But the Atomium is heavy with symbolism, as well as with steel ; it stands for the captured secrets of the atom—if that phrase may be pardoned—and it is, indeed, a tribute to man's imagination ! The elegant equations of the nuclear physicist and the inspired engineering design of our newest industry have been transmuted, without shame or modesty, into a crude and improbable assemblage of enormous balls.

But it is not to be assumed, because of the predominance of this thing, that the Brussels exhibition will be a sort of atom-age pawn shop ! As it is shaping up at present, the exhibition shows every sign of being highly successful. The architecture alone will make a visit worth while. No expense is being spared by the participants to show off their country, or organisation, to the best advantage. Whether it is wise to devote all this money and energy to such a temporary cause is an open question ; but that decision has been taken, and now all preparations are going ahead with enthusiasm. The British contribution to the exhibition has been organised partly by the Government, and partly by the Federation of British Industries. The latter body has built a large and elegant building in which British products will be shown. The British Government's part of the exhibition is noteworthy for an original approach. Instead of designing a special exhibition building, it was decided to design the display itself, and then fit the buildings round it, a procedure with which any industrialist would sympathise. The result will be an atmosphere of tradition, in the first hall, yielding abruptly to one of futuristic achievement in the second. Here, important scientific advances made recently in this country will be exhibited. Readers of this journal will be familiar with many of them—the Dounreay project, the heart and lung machine, and new equipment for radio astronomy. Those not so directly connected with engineering are, however, equally fascinating : they include a demonstration of the chemical basis of heredity, which depends on properties of nucleic acid for "coding" genetic information, exhibits on the isolation and analysis of vitamin B12 (which can be used to cure pernicious anæmia), the technique of deep ploughing and the significance of trace elements in agriculture, and the development of rootstock for fruit tree propagation, and of new forms of weedkiller. By concentrating on a few important developments, this section of the exhibition is likely to be truly educational. It shows promise of avoiding the criticism levelled at the "scientific bric-a-brac" characteristic of the Festival of Britain, and of presenting those with a knowledge of only one of the many branches of science and technology with an opportunity of appreciating major achievements in other fields.

A HALF-TON "SPUTNIK"

Half a ton ! The world was astonished a few weeks ago when the Russians put the "Sputnik" weighing 180 lb into an orbit round the earth. For that object weighed ten times more than the expected size of the promised American satellite and was, moreover, set up in an orbit more difficult to achieve than that which the Americans planned to use. But half a ton in an orbit of greater mean radius than that of the "Sputnik" ! It has been made obvious that the whole tempo of Russian research into rockets has been higher than that of the Americans and there is a distinct suggestion that it has been not only better directed but also better inspired. How very much we should like to have particulars of the rocket used and, more particularly, about the propellants, which may have a higher specific impulse than anything the Americans contemplate using. Also we should like to know whether the new object separated from the last-stage rocket, as the "Sputnik" did, or whether, there being no separation, part of the weight can be accounted for by the burnt-out rocket.

It is possible that the advanced state of Russian rocket development may be due to an earlier start having been made upon it in Russia than in America. There is, however, another possible and more disturbing explanation. We have a high admiration for American vigour and determination. But even Americans themselves can often be driven to admit that the quality of fundamental research in their country falls below that attained in Europe. There is a tendency in the U.S. to assume that provided sufficient money is poured into a project success must be achieved. In Europe, where the monetary resources are less, more weight is given to the quality of the research work, to hard, constructive thinking, and to the inspiration that so often follows from hard fundamental thought. Americans must pardon us for thinking that neither in the development of the atomic bomb, nor of radar, nor of several other wartime inventions would progress have been made so rapidly had not European scientific inspiration been combined with American resourcefulness in solving production problems. In the development of rockets, and perhaps also in the development of atomic explosives—the Russians, it will be recalled, developed hydrogen bombs as quickly as the Americans—American insularity has, we suggest, done great harm. Through the operation of the McMahon Act designed to prevent American discoveries reaching the Russians, American science has been cut off from contact with European science. That, a secondary effect of the Act, has, we suggest, had the most damaging consequences. Possibly McCarthyism, by discouraging certain scientists from undertaking researches to which security regulations would apply, also had damaging consequences. In the outcome it is obvious that the Russians have achieved a long lead in the design of rockets. We are not unduly alarmed, as it seems to us unlikely that the U.S.S.R. has any more desire to start a new and destructive world war than has the West. But upon grounds of safety the nations of the West must be drawn closer together, particularly in the scientific field. Meanwhile, we congratulate the Russians on their very remarkable achievement, whilst hoping that their further advances will be made towards the peaceful objective of exploring space rather than threatening the world with inter-continental ballistic missiles armed with nuclear warheads.

A Seven Day Journal

The Queen's Speech

AMONGST matters of interest to engineers in the Queen's Speech at the opening of Parliament last Tuesday there was a reference to the Government's intention to pursue its endeavours to achieve an agreement on disarmament, " mindful that at this momentous time the advance of science into the unknown should be inspired by the hopes and not retarded by the fears of mankind." The Government is also resolved to take all steps necessary to maintain the value of our money, to preserve the basis of full employment by restraining inflation, to strengthen our balance of payments and to fortify our reserves, upon which depends the strength of the sterling area as a whole. The Government believes that these purposes should command the support of all sections of the nation. Amongst financial measures to be laid before Parliament there is one for the establishment of a conservancy authority for Milford Haven to regulate the increased maritime traffic which should result from the projected development of this harbour. A Bill is to be introduced to improve the arrangements for the industrial rehabilitation, training and resettlement of disabled persons.

" Know-Why " and Windscale

ON October 29, at the Atomic Industrial Forum Banquet held in New York, a speech on Britain's nuclear power programme was delivered by Mr. W. Strath of the U.K.A.E.A. He explained the difference between the American and the British positions with regard to power from conventional sources. Having no significant supplies of oil or natural gas and little water power, the U.K. now found itself with many of its best coal mines worked out. The possibilities of nuclear power had opened up at a time of great need, and their rapid development was essential to the country. After saying that there had been much fruitful collaboration between the U.S.A. and the U.K., particularly in the exchange of ideas that he described as " know-why," Mr. Strath concluded with some remarks on the recent accident at Windscale. He pointed out that the reactor concerned had not been operating at the time. The staff had been carrying out routine maintenance of a sort required on graphite-moderated reactors, particularly those operating at low temperatures. This was because of the so-called Wigner effect, a storage of energy resulting from irradiation of the graphite. Periodic annealing of the latter was required to release the stored energy.

Part of the reactor core was overheated during the annealing process on this occasion, and the resulting chemical reaction between the uranium and the cooling air led to a further rise in temperature. Oxidation of some uranium fuel elements followed, and fission products—particularly radioactive iodine—boiled off. The filters at the top of the stack normally stopped 99 per cent of any radioactive particles in the exhausted cooling air, but the iodine passed through in gaseous form to contaminate some of the countryside. This kind of accident could not happen in a power station like Calder Hall. The operating temperature of the graphite in these stations was higher, so that less energy was stored, and some annealing was going on all the time. Also, the coolant was carbon dioxide, much less reactive chemically than air, and this was circulated in a closed system preventing the release of fission product into the atmosphere. It was of the greatest importance, Mr. Strath said, that we should learn all the lessons we could from the accident, pooling knowledge and experience between all countries and all individuals concerned with nuclear energy. The fullest possible account of such occurrences and their consequences should be published as quickly as the facts could reliably be established. It was from experience and understanding and not from the assertions of experts, however eminent, that public confidence in atomic energy would develop. Only thus would the hazards of atomic power be brought into proper perspective for comparison with the hazards from coal, oil, chemicals and transport. There was no reason to suppose that the comparison would be unfavourable to nuclear power.

The Engineer

100 Years Ago

(NOVEMBER 6, 1857)

" THE TYNE PIERS "

" These piers will be carried into a depth of fifteen feet, and about 1,000 feet beyond Spar-Hank, the seaward limit of the jurisdiction of the commissioners. The funds for the execution of the work are raised by a tonnage rate on shipping—1d. per ton upon coasting vessels, and 2d. per ton upon foreign, up to a certain point. The commissioners have also Parliamentary powers to borrow £200,000 upon the security of the rates, powers that they have not yet exercised. The south pier will be 4,200 feet long, and the width between the two piers will be 1,100 feet. The river commissioners are just completing one extensive dock in the harbour, and have procured Parliamentary powers to build another.

" The North-Eastern Railway Company are also building a large dock on the Tyne. The enormous trade of the port is shown by the fact that last year 27,294 vessels, with cargoes amounting to 3,940,033 tons, were cleared inward and outward from the Tyne, and the more especial object of an inspection on Tuesday was to point out to the local members the advantages that would accrue to the trade of the district if the Government were assisting the commissioners to carry the piers into twenty-five or thirty feet of water, and thus make the Tyne a harbour of refuge. Down to the present time, though the Tyne, Tees and Wear have 100,000 vessels entering them annually—one-sixth of the trade of the whole kingdom—no great national work has been undertaken between Flamborough Head and the Firth of Forth for a harbour of refuge for shipping in a gale of wind. . . . On a former occasion the River Tyne Commissioners offered to lay down a pound for every pound that might be advanced by the Government, and they seem determined that next session of Parliament they will have their case fairly brought before the country."

Road Improvement Schemes

THE London County Council has now given approval to a road improvement scheme announced last April, for Hyde Park Corner and Marble Arch. It comprises : a larger roundabout at Hyde Park Corner ; a two-lane underpass between Piccadilly and Knightsbridge; a subsidiary roundabout just north of Apsley House ; the conversion of Park Lane and the east carriageway of Hyde Park into dual one-way carriageways; modifications at Marble Arch where traffic going eastward along Oxford Street will be separated from traffic going to Edgware Road or Bayswater Road. There will be control by traffic lights at the Park Lane gates. Present estimates put the cost at about £4,500,000. Parliamentary legislation will be needed before the scheme can be started.

An improvement scheme on the Great North Road is being opened to traffic this week, the Ministry of Transport and Civil Aviation states. It involves dual carriageways between Alconbury Hill and Woolpack Cross Roads in Huntingdonshire, a distance of 5 miles. Each carriageway is 24ft wide. Work on the first 3 miles of this scheme was carried out by A. Monk and Co., Ltd., and was started in August, 1956, and completed in June of this year. The remainder of the scheme was reserved for experiments undertaken in conjunction with the Road Research Laboratory, and as it was necessary to avoid the wet sub-soil conditions of the winter, the work on the 2 mile experimental length was not started until April of this year. The contractor for the experimental work was George Wimpey and Co., Ltd. The whole of the work was carried out under the supervision of the County Surveyor of Huntingdonshire County Council, Mr. T. H. Longstaff, M.I.C.E.

Atmospheric Pollution

THE report on the investigation of atmospheric pollution in the year ended March 31, 1955, has now been published. The Director of Fuel Research reports within it upon the work of the Fuel Research Station on the abatement of air pollution. It is pointed out that, because of the seasonal nature of the demand and the impossibility of storing gas or electricity for the winter, domestic heating must continue to be mainly by solid fuel, and that reduction of pollution must be achieved by replacing coal with smokeless fuel. The coke normally produced at gasworks by carbonising strongly-caking coals is not a popular fuel : even in the improved grates that have been installed in recent years, only large coke fires can be satisfactorily maintained and regulated. To produce, under conditions not widely different from normal gas manufacture, a more combustible coke, selected weakly-caking coals have been carbonised in Woodall-Duckham intermittent vertical chambers. In a 16in open firegrate, many of these cokes lit easily and gave an attractive appearance to the fire.

The widely prevailing belief in the stee industry that a smoky atmosphere is necessary in metallurgical heat-treatment furnaces has been shown to be unfounded. With coal as fuel all steels except plain carbon-manganese alloys, and probably high-silicon steels, can be successfully treated in atmosphere 10 to, say, 70 per cent, weak : the carbon-manganese steels can be successfully heat-treated with town's gas as fuel and 0–20 per cent excess air. High silicon steels would probably require heat treatment in a muffle with a protective atmosphere.

Theory of Shaft Whirling

By E. DOWNHAM, B.Sc. (Eng.), Ph.D., A.F.R.Ae.S.*

No. V—THE INFLUENCE OF PLAIN BEARINGS ON SHAFT WHIRLING

(Concluded from page 628, November 1)

The previous articles in the series have been concerned primarily with the establishment of a theoretical approach on the assumption that the stiffnesses and inertias of the shaft-rotor system were known. In this article, some experiments are described which were designed to show the effect of bearing length, bearing clearance and lubricant viscosity on the critical whirling speeds of a simple shaft rotor system supported in plain bearings with drip-feed lubrication. The critical speed of a two-bearing shaft-rotor system is shown to depend on rotor unbalance for bearings of normal clearance. When the clearance is small relative to the bearing length, unsymmetric stiffness characteristics are obtained which result in two critical speeds instead of one. The lubricant in a drip-feed bearing is shown to have a stiffening effect, with consequent increase of critical whirling speed. It is also shown that the critical whirl amplitudes with dry bearings can be appreciably larger than those obtained with lubricated bearings.

THE experiments described previously have shown that the theory of shaft whirling enables accurate calculations of the critical speeds of a system to be made, providing accurate knowledge is available regarding the effective inertia and flexibility coefficients of the rotating parts. The difficulties of obtaining this information for such things as gas turbine rotors of complex structure has already been emphasised, having regard to the actual rotating parts and assuming known support characteristics. In the majority of such cases the non-rotating part of the engine influencing the support characteristics is the turbine casing containing the bearings. As the relative movement between shaft and bearings is small, and the latter are usually roller or ball bearings, it is relatively safe to assume point support of the shaft at the bearings and consider only the flexibility of the turbine end casings. However, there are many systems susceptable to whirling problems in which shafting is supported in plain bearings which may or may not be assumed to provide point support, and experience has shown that in many cases where the stiffness and inertia of the rotating parts of a system are easily calculated, critical speeds measured have still differed appreciably from those calculated.

The following experiments have been carried out on a larger model rig than those previously described, in order to investigate the magnitudes and effect of the forces arising from a conventional plain bearing of varying length. Here it is shown how with bearings of small clearance the critical speed is a function of the unbalance on the rotor. Also with a high degree of rotor balance it is demonstrated that even drip-feed lubrication can have a powerful effect on the effective stiffness of a shaft in plain bearings. The results of these experiments are thought to be unique and demonstrate the advantages of using model rigs of simple construction, in conjunction with modern techniques of vibration measurement, to investigate whirling phenomena.

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Description of the Experimental Rig

Details of the experimental rig are shown in Fig. 1. The whirling system consists of a hollow shaft, 1·2in O.D. by 1in I.D. and 36in long, carrying a rotor rigidly fixed at its centre. The shaft is supported by plain phosphor bronze bearings at either end, the distance between the inner faces of the bearings being 29½in. To minimise the flexibility of the supports the bearings are located in housings made from 3in thick steel plate, rigidly attached to a channel section base. The bearing lengths vary from 3·25in to 1·25in, and bearing clearances of 0·004in and 0·001in are used. Spiral grooves are cut in the bearings for lubricating purposes. Drip-feed lubricators mounted in the bearing housings supply lubricating oil to the bearings.

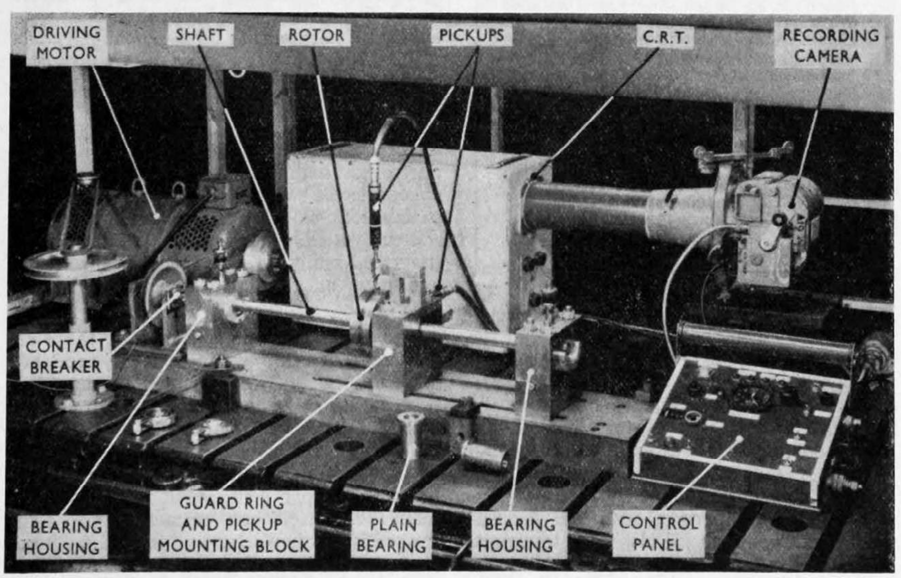


Fig. 1—Details of the experimental rig

The shaft is belt-driven from a variable-speed motor, with a flexible coupling between the driving pulley and the driven end of the shaft. The shaft speed is recorded by a moving film camera using a contact breaker on the driving pulley in conjunction with a fifty cycle timing trace obtained from the a.c. mains. The motion of the centre of the shaft is measured by means of two linear translation inductance pickups, mounted at right angles to each other, on a steel block similar in shape to the bearing housings. This block is rigidly attached to the base of the rig near the rotor and serves also as a guard ring to limit the whirl amplitude of the shaft.

The pickups consist of a dust core attached to one end of a spindle ; on the other end of the spindle is a shoe, which is held constantly in contact with the shaft by means of a light spring. The dust core moves inside a coil wound on a hollow insulated core, which is fixed to the body of the pickup and is hence held rigidly relative to the baseplate. Any relative movement between the centre of the shaft and the baseplate causes the position of the dust core to change relative to the coil, with a consequent change of inductance of the instrument, which is linear over a range of $\pm 0{\cdot}2$in. By using the appropriate electronic circuits the variations of inductance are converted to voltage variations which are applied to the X and Y plates of a C.R.T. The vertical pickup is connected to the Y plates, and the horizontal pickup to the X plates ; the overall gain of each circuit is the same. Using this method, the motion of the shaft at the rotor is magnified and reproduced on the C.R.T. screen, and then photographed by means of an F.24 camera. Calibrations are made by inserting feeler gauges between the pickup head and the rotor, and measuring the resultant deflections on the camera screen. Records of shaft speed and whirl path were taken simultaneously.

The Calculated Flexibilities of a Shaft in Plain Bearings

Consider a shaft supported in two plain bearings as shown diagrammatically in Fig. 2.

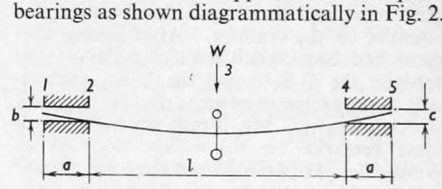


Fig. 2

The length of shaft between bearings is l and the length of the bearings is a. The bearing clearances are b and c respectively ($b<c$). If the shaft is subjected to a gradually increasing load at its centre (point 3) the end conditions will change as the load increases. From zero to a load W_b the shaft will be simply supported at points 2 and 4. For a load W_b the point 1 is assumed to make contact with the top of the bearing and the shaft is then constrained at points 1, 2 and 4. Finally, when a load W_c is reached, point 5 also makes contact with the top of the bearing and the shaft is then constrained at points 1, 2, 4 and 5.

For the three conditions mentioned above the stiffness of the shaft will be as follows :—

Case I.—Simple Support at Points 2 *and* 4.

y_{33}=deflection at point 3 due to unit load there

$$=\frac{l^3}{48EI}=0{\cdot}000356\text{in/lb.}$$

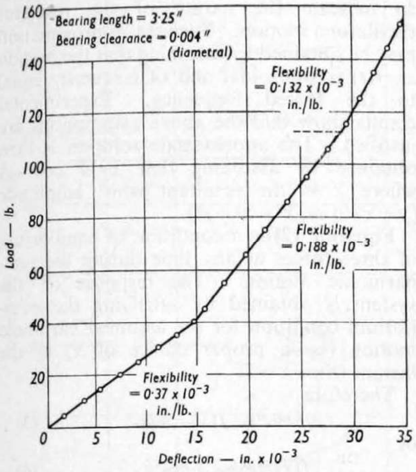


Fig. 3—Static load deflection curve

Case II.—Shaft Supported at Points 1, 2 *and* 4.—When the shaft is supported at points 2 and 4 the flexibility coefficients are assumed to be as follows :

y_{13}=deflection at 1 due to unit load at 3 =deflection at 3 due to unit load at 1

y_{33}=deflection at 3 due to unit load at 3

y_{11}=deflection at 1 due to unit load at 1.

With no constraint at point 1 a load of (W_b+1) at 3 would cause deflections $Y_1=(W_b+1)y_{13}$ at 1 and $Y_3=(W_b+1)y_{33}$ at 3.

The constraint provided by the bearing at point 1 reduced Y_1 to b, i.e. by an amount equal to $(W_b+1)\ y_{13}-b$, and $b=W_b y_{13}$. Therefore

Reduction in deflection at point 1

$$=(W_b+1)y_{13}-W_b y_{13}$$

$$=y_{13}.$$

Therefore

The effective reaction at 1

$=\frac{y_{13}}{y_{11}}$ which results in a decrease in deflection at 3 of $\frac{y_{13}}{y_{11}}\cdot y_{31}=\frac{y_{13}^2}{y_{11}}$.

Let

Y_{33}=deflection at 3 due to unit load at 3 for the case where the shaft is constrained at points 1, 2 and 4, i.e. when the shaft load increases from W_b to W_b+1

then

$$Y_{33}=(W_b+1)y_{33}-\frac{y_{13}^2}{y_{11}}-W_b y_{33}=y_{33}-\frac{y_{13}^2}{y_{11}}$$

where

$$y_{11}=\frac{a^2(l+a)}{3EI},\ y_{33}=\frac{l^3}{48EI},\ y_{13}=\frac{al^2}{16EI}$$

i.e.

$$y_{11}=0\cdot000076\text{in/lb},\ y_{33}=0\cdot000356\text{in/lb}$$

and

$$y_{13}=0\cdot000118\text{in/lb}$$

for a length of shaft of $29\frac{1}{2}$in between bearings and $3\frac{1}{4}$in bearing length. Therefore

$$Y_{33}=0\cdot000172\text{in/lb}.$$

Case III.—Shaft Supported at Points 1, 2, 4 *and* 5.—Consider a load (W_c+1) at 3 and let $b=c$. The latter assumption will simplify the analysis without changing the result.

For simple support at points 2 and 4 the points 1 and 5 would deflect by $(W_c+1)\ y_{13}$.

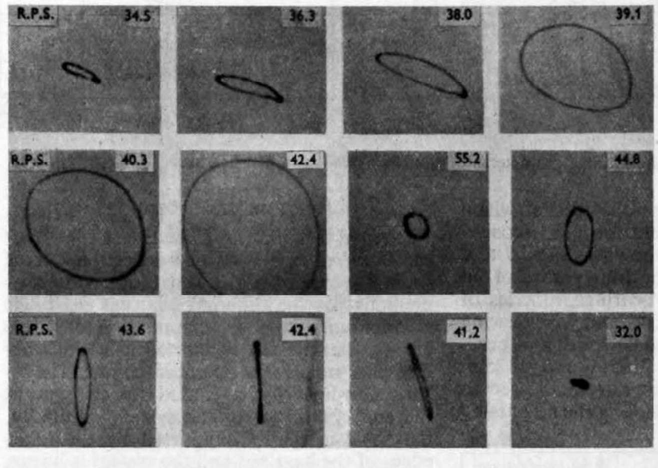


Fig. 5—Records of whirl amplitudes and paths of a shaft-rotor system rotating in dry bearings

This deflection is reduced by bearing reactions at points 1 and 5 to a value $C=W_c y_{13}$, i.e. by an amount y_{13} as in Case II.

Consider unit loads simultaneously placed at points 1 and 5. Then deflections at points 1 and 5 will be equal to $y_{11}+y_{15}=Y_{11}$, say, therefore

$$Y_{11}=\frac{a^2(l+a)}{3EI}+\frac{a^2l}{6EI}=\frac{a^2(3l+2a)}{6EI}$$

$$=0\cdot000111\text{in/lb}.$$

The reactions at points 1 and 5 are given by y_{13}/Y_{11}.

Therefore

the resultant deflection at $3=\frac{2y_{13}^2}{Y_{11}}$ and

$$Y_{33}=y_{33}-\frac{2y_{13}^2}{Y_{11}}=0\cdot000126\text{in/lb}.$$

In this case Y_{33}=the deflection at 3 due to unit load at 3, i.e. when the load at 3 increases from W_c to W_c+1.

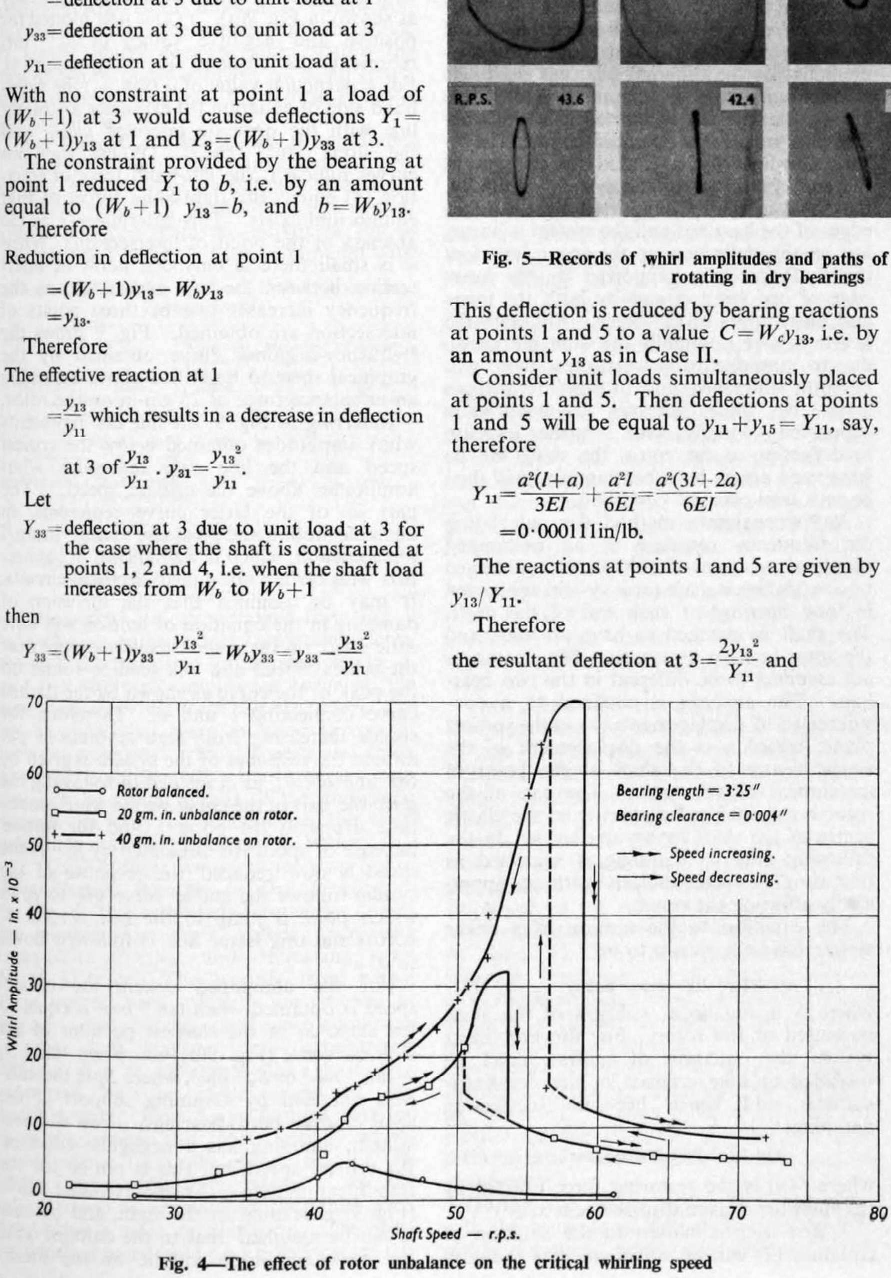


Fig. 4—The effect of rotor unbalance on the critical whirling speed

Details of the Experiments

1. *The Effects of Rotor Unbalance on the Critical Whirling Speed.*—Bearings of length 3·25in and clearance of 0·004in were fitted and a series of experiments carried out to investigate the effect of rotor unbalance on the critical whirling speed of the system. A load-deflection curve was plotted for static loading at the rotor (Fig. 3). The deflections at the rotor at which the flexibility of the system changed were noted. The unbalance on the rotor was then adjusted by attaching small weights at a radius of 2in, so that at the critical whirling speed the whirl amplitudes came successively within each of the three stiffness ranges of the system mentioned above. Amplitude-frequency curves were plotted (Fig. 4) for the different unbalance conditions. In Table I (page 663) the experimental results are compared with theoretical calculations of critical whirling speed. The calculations were made using estimated and measured stiffnesses.

2. *The Whirling Characteristics of the Shaft Rotor System Rotating in Dry Bearings.*—Whilst investigating the effects of rotor unbalance on the critical whirling speed, it was observed that when the oil supply to the bearings was cut off the mode and amplitude of vibration of the shaft near the critical whirling speed were affected. The general change in the whirling characteristics of the system was so marked that it was considered to be of sufficient interest to warrant a separate investigation. With the rotor balanced, within experimental limits, the system was run in dry bearings of 0·004in clearance and 3·25in long. Whirl amplitudes were measured in the usual way. Records covering the speed range are shown in Fig. 5, and the whirl amplitude-frequency curves are shown plotted in Fig. 6. In order to clarify some of the effects recorded during these experiments visual observations using stroboscopic light were made, with the bearings bored out to 1·236in diameter, giving a clearance of 0·036in between shaft and bearing. It was anticipated that the effects would be more marked when the shaft was running in bearings with excessive clearance.

3. *The Effect of Bearing Dimensions and Lubrication on the Critical Whirl Amplitude and Frequency.*—During the experiments described in section 1 it was observed also that when the rotor unbalance was small, i.e. when the shaft was whirling with support at the inner edges of the bearings only, the shaft did not always have the same critical whirling speed. Further investigations of this phenomena showed that when the temperature of the oil leaving the bearing increased the critical whirling speed decreased. It appeared, therefore, that the viscosity of the lubricating oil in the bearings had an effect on the whirling of the shaft, and tests were carried out to investigate this effect.

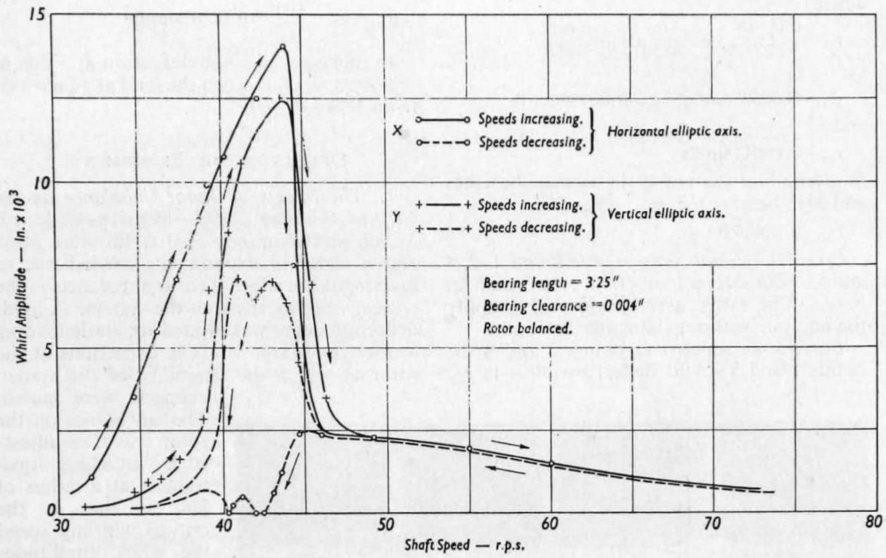


Fig. 6—The whirling characteristics of a shaft running in dry bearings

Four grades of oil were obtained of which the specific gravity-temperature and viscosity-temperature curves are shown in Figs. 7 and 8 respectively. Using the four grades of oil in turn to lubricate the bearings, a series of experiments was then carried out with bearing clearances of 0·004in and 0·001in, and bearing lengths of 3·25in, 2·25in and 1·25in. After each test the bearings were allowed to cool, so that the temperature of the oil passing

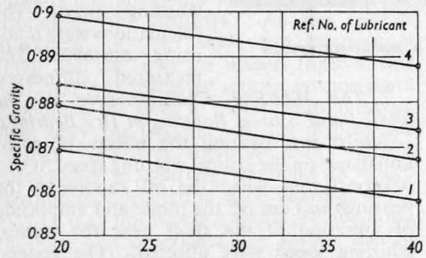


Fig. 7—Specific gravity/temperature chart

through the bearings during each test was approximately constant. This temperature was measured approximately by means of thermometers placed against the inner faces of the bearings close to the shaft, so that with a liberal supply of oil being fed to the bearings there was a constant flow over the thermo-

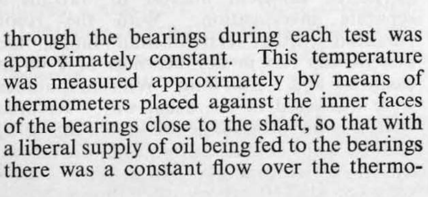


Fig. 8—Log log viscosity/temperature chart

meter bulb as the oil left the bearing. The errors arising from the approximate method of measuring oil temperature were minimised to some extent by keeping the temperature gradient of the oil flowing through the bearing as small as possible.

Experimental Results

1. *The Effect of Rotor Unbalance on the Critical Whirling Speed.*—Load-deflection curves similar to that of Fig. 3 were obtained experimentally for the different bearings used. It is apparent, from an examination of these curves, that a shaft supported in plain bearings has non-linear stiffness characteristics. This non-linearity is caused by changes in the end conditions of the system. Initially, the shaft is simply supported by the inner edges of the bearings and the system is linear, but as the deflection at the rotor increases the shaft becomes supported by the inner edge of one bearing and by both the inner and outer edges of the other. Although the bearings have nominally the same clearance, due to manufacturing tolerances, there will be some difference, and in this intermediate state the shaft becomes asymmetrically supported. Finally, with a further increase in deflection at the rotor, the shaft will be supported across both bearings and will then be in a semi-encastré condition.

An approximate method for calculating the frequency response of an undamped non-linear system of this kind is obtained by considering a shaft-rotor system supported in long bearings at each end of the shaft. The shaft is assumed to have no mass and the rotor to have a mass m. The clearances are assumed to be different in the two bearings. The analysis is confined to a consideration of displacements (x) in the vertical plane, where x is the displacement of the elastic centre of the shaft at the point of attachment of the rotor. The c.g. of the rotor is assumed to be offset from the elastic centre of the shaft by an amount h. In the following analysis damping is neglected as this simplifies the analysis without appreciably affecting the result.

The equation to the motion of a linear system has been shown to be

$$m\ddot{x}+b\dot{x}+Sx=mh\omega^2 \cos \omega t \quad . \quad . \quad (1)$$

where S is the linear stiffness of the shaft measured at the rotor. For the non-linear system the equation of motion must be modified to take account of the non-linear stiffness and hence becomes (neglecting damping):

$$m\ddot{x}+f(x)=mh\omega^2 \cos \omega t \quad . \quad . \quad . \quad (2)$$

where $f(x)$ is the restoring force exerted by the shaft for a given displacement x.

A first approximation to the solution of equation (2) will be sufficient, it is thought, to indicate the nature of the resultant oscillatory motion. Such an approximation may be obtained by assuming that the motion $x=f(t)$ is sinusoidal and of frequency equal to the forced frequency. Experimental results show that the above assumptions are justified. The approximate solution is then obtained by assuming that $x=\bar{x} \cos \omega t$, where $\bar{x}$ is the resultant whirl amplitude ($y=\bar{x} \sin \omega t$, $\bar{x}^2=x^2+y^2$).

Equation (2) is a condition of equilibrium of three forces at any time during the non-harmonic motion. The response of the system is obtained by satisfying the equilibrium condition for the assumed harmonic motion (by a proper choice of x) at the instant when $x=\bar{x}$.

Therefore

$$-m\omega^2\bar{x}+f(\bar{x})=mh\omega^2 \quad . \quad . \quad . \quad (3)$$

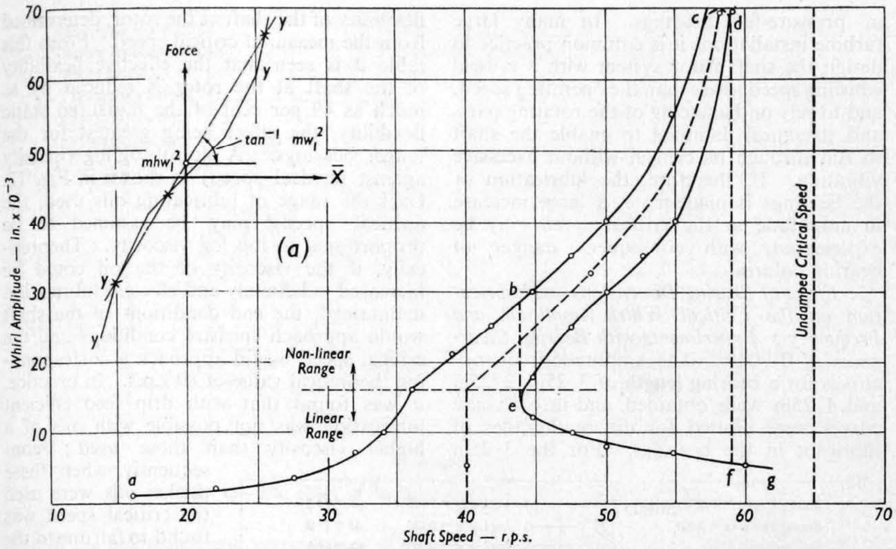
or

$$f(\bar{x})=mh\omega^2+m\omega^2\bar{x} \quad . \quad . \quad . \quad . \quad (4)$$

When $x=0$ the three forces are zero (provided $f(o)=0$) so that the equilibrium condition is again satisfied. For most values of x between 0 and $\bar{x}$ the equilibrium condition is violated, but this is of little consequence as it is the maximum value $\bar{x}$, of x, that is significant in the analysis. Values of $\bar{x}$ for various values of ω are obtained graphically as shown in Fig. 9(a). $f(\bar{x})$ is first plotted for positive and negative values of $\bar{x}$; this represents the left-hand side of equation (4). For a particular value of ω (say, ω_1) the right-hand side of equation (4) expresses a straight line with the ordinate intercept $mh\omega_1^2$ and the slope $\tan^{-1}(m\omega_1^2)$. Where the two curves intersect, the left-hand force of equation (4) equals the right-hand force, so that equilibrium exists. This determines $\bar{x}$ as the abscissa of the point of intersection. When ω is small there is only one point of intersection between the two curves, but as the frequency increases two or three points of intersection are obtained. Fig. 9 shows the frequency-response curve obtained by the graphical method described above assuming an unbalance force of 25 gm-in on the rotor.

Referring to Fig. 9, the line *abc* represents whirl amplitudes obtained below the critical speed and the line *defg* represents whirl amplitudes above the critical speed. The part *de* of the latter curve represents an unstable motion and gives rise to the " jump " phenomenon, which is well known in connection with certain non-linear electrical circuits. It may be assumed that the inclusion of damping in the equation of motion will have little effect on the response curve except near the critical speed and will tend to round off the peak of the curve as shown by the dashed curve connecting *c* and *d*. Therefore, for speeds increasing from zero revolutions per minute the response of the system is given by the line *abcd*; at *d*, instead of following the unstable part of the curve *de*, the whirl amplitude drops to the point *f*, and for further increase of speed is represented by *fg*. If the speed is now reduced the response of the system follows the stable curve *gfe* to *e*, at which point a jump to the line *abc*, at *b*, occurs and this latter line is followed down to *a*.

For the undamped system the critical speed is obtained when $\tan^{-1} m\omega^2$ is equal to the slope S_3 of the steepest portions of the stiffness curve (Fig. 9(a)) i.e. when $\tan^{-1} S_3 = \tan^{-1} m\omega^2$ or $S_3=m\omega^2$, where S_3 is the stiffness obtained by assuming support of the shaft across both bearings. For a linear system, damping has a negligible effect on the critical speed, but this is not so for the non-linear system. As the response curve (Fig. 9) is leaning to the right, and because it can be assumed that in the damped case the peak amplitude will lie on the mean-



Figs. 9 and 9 (a)—Theoretical amplitude frequency curve for a system with non-linear stiffness

frequency line, it is obvious that the critical speed will, in general, be a function of the peak amplitude, which in turn is a function of damping and rotor unbalance. However, for the case where the critical whirl amplitude is small enough for operation within the first range of linear stiffness, S_1, at all times, the system is linear and the critical speed is given by $\omega^2 = S_1/m$.

Fig. 4 shows the experimental amplitude-frequency curves for rotor unbalances chosen to give critical whirl amplitudes in each of the three ranges of flexibility. The critical speeds obtained from the curves of Fig. 4 are tabulated in Table I and compared with

TABLE I—*The Effect of Rotor Unbalance on the Critical Speed*

Rotor balance	End conditions	Whirl amplitude at critical speed, in	Measured critical speed, r.p.m. (Fig. 7)	Calculated critical speed, r.p.m. (Fig. 8)
Rotor balanced	Shaft supported at points 2-4	0·005	42	40
20gm-in of unbalance added	Shaft supported at points 1, 2 and 4	0·030	52	49
40gm-in of unbalance added	Shaft supported at points 1, 2 4 and 5	0·070	58	57

the theoretical criticals obtained from Fig. 9 by assuming critical whirl amplitudes identical with the measured amplitudes of Fig. 4, and that the peak amplitudes occur on the mean-frequency line of the response curve. The results show that there is good agreement between calculated critical speeds and those obtained experimentally, but accurate estimates of the critical speeds of the non-linear system can only be made when the whirl amplitude at the critical speed is known.

2. *The Whirling Characteristics of the Shaft-Rotor System Rotating in Dry Bearings.*—In Fig. 6 the amplitude-frequency curves are plotted for shaft speeds increasing from 32 to 60 r.p.s., and decreasing from 60 to 32 r.p.s. The records from which these curves were plotted are shown in Fig. 5. The critical speed and amplitude of the shaft during these experiments indicate that at all times the shaft was supported on the inner edges of the bearings only. Figs. 5 and 6 show that for increasing speeds the shaft initially whirls in an elliptic form, the major axis of the ellipse being almost horizontal. As the critical speed is approached the whirl path approaches a more circular form. The critical whirling speed is 44 r.p.s.; to increase the speed of the shaft above this speed required an appreciable increase in power from the motor, more than is usually required to take a shaft through its critical speed. However, once the shaft speed increased above the critical speed the whirl amplitudes decreased rapidly. It is significant that these curves, for increasing speeds, are similar in shape to those obtained from the forced vibration of a linear system having dry friction damping.

For speeds decreasing from 60 to 32 r.p.s. the whirl response of the shaft is entirely different from that for increasing speeds. The whirl path is again elliptical but the major elliptic axis is vertical. The critical speed is slightly lower than before. As the shaft passes through its critical, the horizontal axis of the ellipse decreases and for a short period between 42·4 and 40·6 r.p.s. is negative, indicating a reverse whirl. Below 40·6 r.p.s. the shaft suddenly resumes a steady whirl of more circular form. During repeat tests, the shaft always showed the same tendencies of whirl both for increasing and decreasing speeds. It was not always possible to reproduce the narrow band of reverse whirl due, probably, to a variation in the state of dryness of the bearing, although it was obvious from visual observations on a monitor C.R.T. that the shaft always approached this condition up to the point where the horizontal elliptic axis became zero.

The effects described above were also obtained when the bearings were bored out to give 0·036in clearance on the diameter. For these tests visual observations were made using stroboscopic light. At shaft speeds around 22 r.p.s. there was a pronounced hammering of the shaft in the bearings; the motion was one of rocking of the shaft in the bottom of the bearing, the vertical amplitude of the rotor being small and the horizontal amplitude being relatively large. At about 35 r.p.s. there appeared to be a resonant condition of vibration indicative of a critical whirling speed. Finally, at about 38 r.p.s., a further hammering of the shaft in the bearings occurred. This was best reproduced by driving the shaft at higher speeds and reducing speed until the hammering occurred. Under these conditions the motion of the shaft in the bearings was predominately vertical with a similar motion at the rotor.

During the investigations in connection with the bearings of large clearance, another rather disconcerting phenomenon was found to occur intermittently. As the shaft speed was decreased slowly in the neighbourhood of the critical whirling speed of 38 r.p.s. the shaft became violently unstable. There was a loud bang and the amplitude at the rotor became large enough to cause the shaft to run round the inside of the guard ring, the shaft speed being greatly reduced due to an increased load on the driving motor. It was found by experiment that by further reducing the motor speed the vibratory level could be reduced until it was finally possible to withdraw the guard ring, leaving the shaft vibrating in the bearings with an amplitude of approximately 0·125in. With the guard ring withdrawn the shaft speed was about 1·5 r.p.s. and the rotor was whirling in the reverse direction to the rotation at approximately 18 c.p.s. The application of a vertical force (by hand) of about 10 lb was sufficient to overcome the friction forces driving the whirl. The shaft would then run steadily in the bearings when the load was removed.

An explanation of the dynamics of the dry friction whirl is given by considering a section through a plain bearing of centre O_1 radius r_1 (Fig. 10). In the bearing is a shaft of

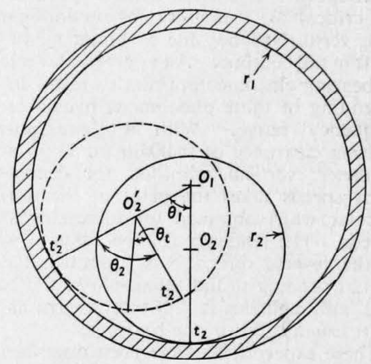


Fig. 10—The dry friction whirl

radius r_2 centre O_2, which is initially resting in contact at the point t_2 at the bottom of the bearing. The coefficient of friction between the shaft and bearing is assumed to be sufficient to prevent slip so that if the shaft is turned anti-clockwise it will roll round the inside of the bearing. Assuming that the point of contact between the shaft and bearing moves from t_2 to t_2' the centre of the shaft moves from O_2 to O_2' through an angle θ_1 about a centre O_1, in a clockwise direction. The radius $O_2\ t_2$ which was originally vertical is now represented by $O_2'\ t_2$ at an angle θ_t to the vertical. Let angle $t_2\ O_2'\ t_2' = \theta_2$. From geometry of the system

$$\theta_t = \theta_2 - \theta_1$$

and

$$r_1\theta_1 = r_2\theta_2$$

therefore

$$\theta_2 = \frac{r_1}{r_2}\theta_1$$

therefore

$$\theta_t = \left(\frac{r_1}{r_2} - 1\right)\theta_1 = \frac{r_1 - r_2}{r_2}\theta_1$$

i.e. when the shaft rotates through one revolution about its centre, the centre of the shaft rotates through $\frac{r_2}{r_1 - r_2}$ revolutions about the centre of the bearing in the opposite direction to the initial rotation of the shaft. In the case of the bearing with large clearance $r_2 = 0{\cdot}6\text{in}\ (r_1 - r_2) = 0{\cdot}018\text{in}$ and the frequency ratio is 33·4 : 1. Measurements were taken on the rig at varying shaft speeds and the results tabulated in Table II.

TABLE II—*The Critical Frequencies of a Shaft Rotating in Bearings of Excessive Clearance*

Shaft rotational speed, r.p.m.	Whirl frequency C.P.M.	Frequency ratio
92	2290	24·9
90	2270	25·2
85	2250	26·4
80	2240	26·7
75	2040	27·2
65	1900	29·2
60	1850	30·8

It is seen that the ratio between shaft speed and frequency of vibration approaches 33·4 : 1 as the shaft speed becomes small but that, probably due to slipping between shaft and bearing, as the shaft speed increases this ratio decreases progressively.

From the results of these experiments with dry bearings it is apparent that the dry friction forces arising from the bearings can have an appreciable effect on the nature of the shaft vibrations. There appear to be three types of motion of the system ; at speeds below this critical there is a rocking of the shaft in the bottom of the bearings, resulting in a predominantly lateral vibration of the rotor ; as the shaft speed increases the rotor whirls in the normal manner, and as the shaft speed is decreased from a speed above the critical the rotor vibrates predominantly in a vertical plane, due to bouncing of the shaft in the bearings. An appreciable increase in bearing clearance appears to result in the spreading of these phenomena over a larger frequency range. With a more normal bearing clearance of 0·004in on 1·2in shaft diameter, vertical vibration for decreasing shaft speeds takes the place of the normal circular whirl obtained for increasing shaft speeds. The tendency for the shaft to whirl in the reverse direction is probably due to partial running round the inside of the bearings, although this is very intermittent as the shaft usually slips in the bearings.

These experiments have been described in detail to illustrate the effects of dry friction forces on the whirling of the system. However, the most important practical effect of lack of lubrication in plain bearings may be found from a comparison between Figs. 6 and 11, which give amplitude-frequency curves for dry and for well-lubricated bearings. For the dry bearing the amplitude of whirl at the critical speed is 0·014in, whereas with a thin oil for lubrication the amplitude is seen to be reduced to 0·005in. In this case the lubrication was effected by drip feed and the shaft unloaded. It is probable that this reduction of amplitude of whirl when the bearings are lubricated would be greater in the case of a heavily loaded shaft supported in pressure-fed bearings. In many large turbine installations it is common practice to design the shaft rotor system with a critical whirling speed lower than the operating speed, and to rely on balancing of the rotating parts and structural damping to enable the shaft to run through its critical without excessive vibration. If, therefore, the lubrication of the bearings is inadequate, a large increase in amplitude at the critical speed may be experienced, with consequent danger of bearing failures.

3. *Effect of Bearing Dimensions and Lubrication on the Critical Whirl Amplitude and Frequency ; Experiments with Bearing Clearances of* 0·004*in.*—The amplitude-frequency curves for a bearing length of 3·25in, 2·25in and 1·25in were obtained, and in each case curves were plotted for different grades of lubricant in the bearings. For the 3·25in bearings (Fig. 11) the rotor was balanced, but in the other two cases the unbalance on the rotor was increased by 20 gm-in because an increase in the rotor unbalance was found to improve the consistency of the results. In all three cases, however, the whirl amplitude at the rotor was small enough to ensure that the shaft would be supported by the inner edges of the bearings only.

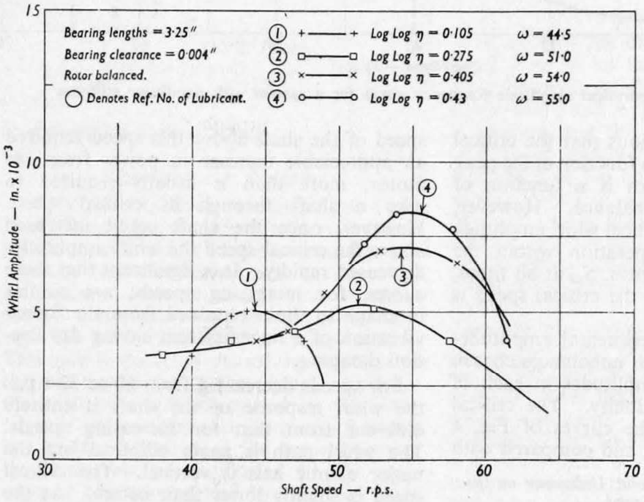


Fig. 11—The effect of lubrication on the critical whirling speed

These experiments show that the oil in the bearings has an appreciable stiffening effect on the shaft, the stiffening increasing with the oil viscosity. In Table III the results have been tabulated, including the effective flexibility of the shaft at the rotor, determined from the measured critical speed. From this table it is seen that the effective flexibility of the shaft at the rotor is reduced by as much as 49 per cent of the measured static flexibility, the effect being greatest for the longer bearings. A plot of log log viscosity against (critical speed)² is shown in Fig. 12. Over the range of lubricating oils used, the (critical speed)² may be assumed to be proportional to log log viscosity. Theoretically, if the viscosity of the oil could be increased indefinitely and efficient lubrication maintained, the end conditions of the shaft would approach encastré conditions and the critical speed would approach a corresponding theoretical value of 80 r.p.s. In practice, it was found that with drip feed efficient lubrication was not possible with oils of a higher viscosity than those used ; consequently, when these thicker oils were used the critical speed was found to fall due to the bearing being only partially lubricated.

Effect of Bearing Dimensions and Lubrication ; Experiments with Bearing Clearances of 0·001*in.*—Amplitude - frequency curves for the 3·25in long bearings with 0·001in clearances are plotted in Fig. 13. The whirling characteristics of the system supported in bearings of length 3·25in and 2·25in are more complex than would be expected. Fig. 14 shows a series of records taken over the appropriate frequency range for the 2·25in bearing. The shaft has a critical whirl at 57·4 r.p.s., the whirl form being elliptical with the major axis of the ellipse in the horizontal plane. Above this speed the whirl amplitudes decrease but the major

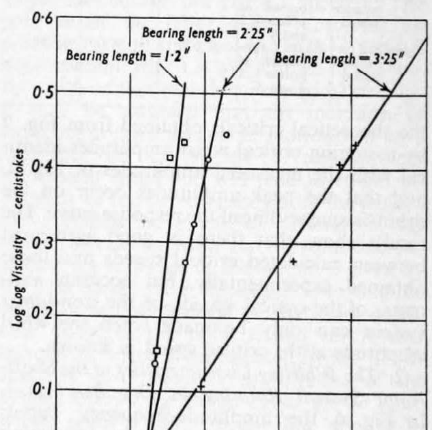


Fig. 12—The effect of lubrication on the critical whirling speed

axis of the ellipse is re-orientated as the shaft speed increases. Above 64 r.p.s. the whirl amplitude increases until at 65·2 r.p.s. there appears to be a second critical whirl of an elliptic form with the major axis almost vertical, the minor axis having small amplitude. The curves of Fig. 13 show the varia-

TABLE III—*The Effect of Lubricant Viscosity on the Critical Whirling Speed*

Bearing clearance=0·004in.

Bearing length, in	Log Log viscosity of oil	Critical speed, r.p.s.	Effective flexibility at rotor in/lb,	Measured static flexibility at rotor, in/lb	Per cent change in flexibility
3·25	0·105	44·5	$0·286\times10^{-3}$	$0·370\times10^{-3}$	−23
3·25	0·275	51·0	$0·218\times10^{-3}$	$0·370\times10^{-3}$	−41
3·25	0·405	54·0	$0·198\times10^{-3}$	$0·370\times10^{-3}$	−46
3·25	0·43	55·0	$0·188\times10^{-3}$	$0·370\times10^{-3}$	−49
2·25	0·137	41·0	$0·337\times10^{-3}$	$0·368\times10^{-3}$	−8
2·25	0·27	43·0	$0·307\times10^{-3}$	$0·368\times10^{-3}$	−17
2·25	0·32	43·75	$0·296\times10^{-3}$	$0·368\times10^{-3}$	−20
2·25	0·41	44·75	$0·283\times10^{-3}$	$0·368\times10^{-3}$	−23
2·25	0·44	46·75	$0·266\times10^{-3}$	$0·368\times10^{-3}$	−28
1·25	0·135	41·0	$0·337\times10^{-3}$	$0·333\times10^{-3}$	+1
1·25	0·41	42·0	$0·323\times10^{-3}$	$0·333\times10^{-3}$	−3
1·25	0·43	43·0	$0·306\times10^{-3}$	$0·333\times10^{-3}$	−9
1·25	0·43	43·0	$0·306\times10^{-3}$	$0·333\times10^{-3}$	−9

Bearing clearance=0·001in.

Bearing length, in	Log Log viscosity of oil	Critical speed, r.p.s.		Effective flexibility at rotor in/lb ($\times10^{-3}$)		Measured static flexibility at rotor, in/lb ($\times10^{-3}$)	
3·25	0·105	55·5	65·0	0·199	0·135	0·175	0·107
3·25	0·275	56·5	66·5	0·178	0·129	0·175	0·107
3·25	0·400	60·0	67·3	0·156	0·126	0·175	0·107
2·25	0·195	54·0	64·0	0·194	0·139	0·160	0·114
2·25	0·330	55·5	65·0	0·184	0·134	0·160	0·114
2·25	0·430	57·0	65·75	0·175	0·127	0·160	0·114
1·25	0·105	45·0		0·280		0·358	
1·25	0·400	45·0		0·280		0·358	

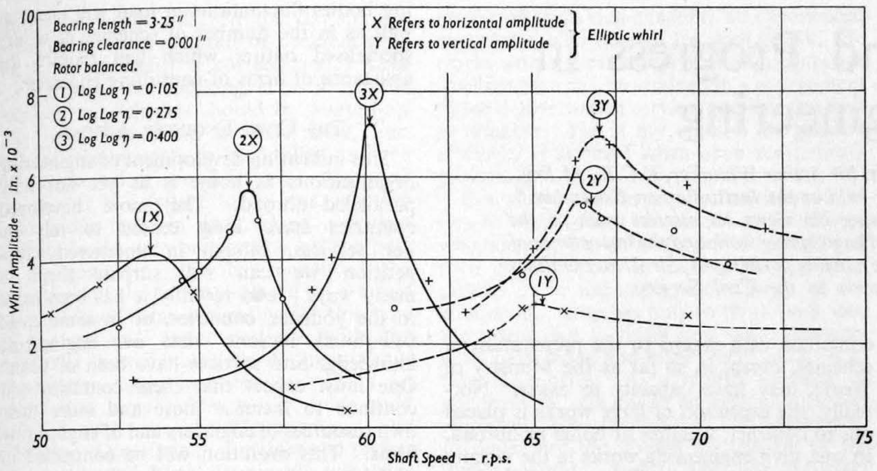


Fig. 13—The effect of lubrication on the critical whirling speed

tion of the horizontal and vertical axes of the elliptic whirl against shaft rotational speed. The viscosity of the lubricating oil was found to affect the stiffness of the system in a similar way to that observed with the bearing of 0·004in clearance. Both the critical speeds are affected in a similar manner (Fig. 15).

The explanation of the two critical speeds is found by considering the end conditions of the stationary shaft. The effective weight of the shaft and rotor (which is concentrated at the centre of the shaft) is approximately 17 lb. The flexibility of the shaft (at the centre) assuming support at the inner edges of the bearings is 0·00035in/lb. This static load on the simply supported system would cause an initial deflection of about 0·006in at the centre of the shaft. This is sufficient to cause one end of the shaft to make contact with the top of the outer edge of the bearing. For a superimposed vertical load directed downwards, the shaft flexibility will be appropriate to the case of a shaft simply supported at one end and supported across the bearing at the other. For a superimposed vertical load directed upwards, the flexibility will be appropriate to the case of simple support at both bearings. Finally, for a horizontal load in either direction, the shaft flexibility will be appropriate to conditions between the two for vertical loading. For the static case there are therefore three different flexibilities to consider.

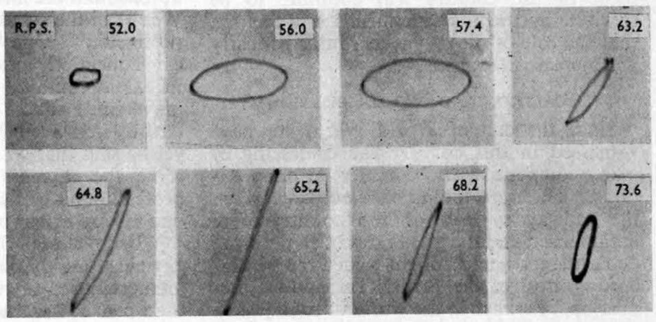
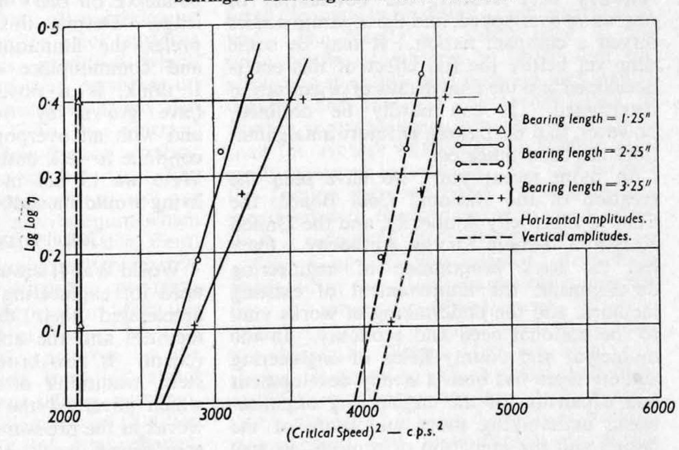


Fig. 14—Records of whirl amplitudes and paths of a shaft rotating in plain bearings 2·25in long and 0·001in clearance



Bearing clearance; 0.001 inch.

Fig. 15—The effect of lubrication on the critical whirling speed

Consider next the flexibility of the system when whirling. Due to small bearing clearances, at a critical speed the ends of the shaft will whirl around the bore of the bearing. For the condition where the shaft end, which was initially in contact with the top of the bearing, is in contact with a point at 90 deg. to its initial position, the two vertical flexibilities will now apply to the horizontal axis and the horizontal flexibility will apply to the vertical axis. The rotating system therefore has asymmetrical stiffness, as the flexibilities in the direction of the major axes will fluctuate four times per revolution of the shaft. For this reason it is to be expected that the whirl characteristics of the system will be complex.

There is no measurable difference in the critical speed with change of lubricant when the bearings are shortened to 1·25in, and the whirl form is circular as would be expected.

Effect of Bearing Dimensions and Lubrication on the Critical Whirl Amplitude and Frequency; the Damping Effect of Lubricating Oil in the Bearings.—As mentioned previously, there is a marked decrease in whirl amplitude at the critical whirling speed when the bearings are adequately lubricated. In the case of bearings with 0·004in clearance there was no consistent effect on the whirl amplitude as the viscosity of the lubricant is increased, although Fig. 11 shows a tendency for the amplitude at the critical speed to increase as the viscosity of the lubricant increases. The increase in unbalance for the tests of the 2·25in and 1·25in bearings appeared to mask this tendency. For bearings of 0·001in clearance and 3·25in and 2·25in long there was again a tendency for the amplitude at the critical speed to increase with increase of viscosity of the lubricant.

Conclusions

Tests with dry bearings show that lack of lubrication in plain bearings can have a marked effect on the form of whirl at the critical speed. The most important effect is the large increase in amplitude at the critical speed that would result from failure of the lubricating system. This is an important factor, especially in cases where a system is designed to have a critical speed below the operating speed, in which case a large amplitude of whirl may build up whilst running through the critical.

The length of bearing has no effect on the critical speed (except through the stiffening effect of the lubricant) unless the clearance is small or the unbalance forces are large, in which case the system will have non-linear stiffness characteristics and the critical speeds can only be estimated on the assumption of a known critical whirl amplitude or an accurate knowledge of the unbalance force and the damping in the system.

In the design stage, therefore, it would be necessary to calculate critical speeds assuming first a critical whirl amplitude within the first range of linear stiffness (support at the inner edges of the bearings only) and then a critical whirl amplitude which would be the maximum tolerable for smooth running of the system. Operating speeds should then be avoided between the two calculated criticals.

Due to initial bending under static load, a horizontal shaft-rotor system supported in long bearings (say L/D ratio greater than 2) is shown to be capable of having two critical speeds, near to, but less than, the speeds obtained by assuming linear stiffness with three or four point support by the bearings. Ideally, a system of this type should be designed to operate at speeds below the critical speed calculated on the assumption of linear stiffness with simple support at the inner edges of the bearings, or above that critical speed calculated on the assumption of linear stiffness with four point support across the bearings.

An appreciable increase in effective stiffness can be achieved by increasing the viscosity of the lubricant, which acts as an auxiliary spring inside the bearings. The tests on variation of lubricant viscosity also show a tendency for the amplitude at the critical speed to increase as the viscosity increases, particularly when the unbalance forces are small.

Acknowledgments

The author's thanks are due to the Ministry of Supply for permission to publish the material in the series and for the use of some of the illustrations.

The photographs showing the model whirling rig (page 552), details of the model shaft rotor system (page 588) and details of the experimental rig (page 660) are Crown copyright reserved, and reproduced by permission of the Controller, H.M. Stationery Office.

Organisation and Progress in Civil Engineering

The Institution of Civil Engineers' president, Sir Arthur Whitaker, K.C.B., M.Eng., gave his presidential address at a meeting held at the Institution on November 5. Abstracts from Sir Arthur's address, giving his views on matters such as the organisation of bodies which undertake civil engineering work and the importance of work overseas, are reproduced here. In the opening paragraphs, Sir Arthur outlines the functions of civil engineers in the Civil Service.

THROUGHOUT my professional life I have been connected with the sea and it might be considered, in conformity with custom, that this address should refer to the important works on which I was engaged. Since, however, I was for the major part of my career a professional civil servant and having regard to the increasing importance of public engineering bodies, it seems to me to be appropriate that I should comment on the place of engineering organisations in the life of our country to-day.

The functions of civil engineers vary in the several Government departments. In the Admiralty and in the Air Ministry, for example, the staffs perform all the duties inherent in the formulation and construction of works, the execution of surveys, the preparation of designs and drawings, and either the preparation of contract documents and the subsequent supervision of the contract or, alternatively, in the direct execution of the work. In the Ministry of Works less direct work is done, while in the Ministry of Transport and Civil Aviation, the Ministry of Agriculture, Fisheries and Food, and the Ministry of Housing and Local Government the preparation of schemes and the execution of works is performed by other organisations, for example, local authorities. Finally, there is the Department of Scientific and Industrial Research. There is thus a wide diversity of duties performed and any analysis of the trend of civil engineering activities in the civil service must have regard to these variations.

Some difference of function arises in the Admiralty and in the Air Ministry because the engineering departments there exist solely to serve the defence services and are required to perform their tasks at home and abroad, wherever the armed forces are based. The Admiralty establishments are concentrated for the greater part at or close to the Royal Dockyards or Fleet Bases, and this concentration has required comprehensive and balanced professional staffs to undertake much of the civil engineering work required in the districts. Combined with these staffs are substantial labour forces competent to undertake large engineering works. In the last war the liability to air attack and the development of the Fleet Air Arm led to the dispersal of establishments and to the need for civil engineering works throughout the country. The development of nuclear attack and the prospect of guided missiles being used in future wars emphasise the continued need for a comprehensive civil engineering body.

One of the main factors to be considered in relation to the defence departments is the capacity for rapid and efficient expansion in times of crisis or war and for functioning immediately and effectively anywhere in the world. In times of peace pressure for reduction of expenditure is relentless and this in turn requires reductions in staff. To maintain the utmost efficiency in war it is necessary that in peace as much professional work as is possible should be undertaken by the department's own staff. In normal times the tendency is for the departments to be self-contained with regard to the preparation of schemes, except in so far as the Ministry of Works may have capacity to assist. Normally, the execution of large works is placed out to contract, whether at home or abroad. In war, civil engineering works in the vicinity of zones of armed conflict are usually performed by the uniformed engineer services, but elsewhere by civilian contractors and labour forces.

The scope of the Ministry of Works for engineering works is extensive and covers most of the governmental constructional programme outside the defence services. In recent years it has embraced the engineering works arising from the nuclear energy programme, for which security considerations are paramount, and the latter will undoubtedly dictate that the works requirements resulting from the development of this new and great phase in the engineering development of the country will continue to be serviced by them. One surmises, therefore, that the role of the engineers in this Ministry will increase in scope.

Coalition and Nationalisation

Since the end of World War I we have witnessed in this country the coalescing of many competitive and commercial organisations. The outstanding case occurred when the railway systems of the country were nationalised and the great railway engineering departments were brought under the centralised control of the British Transport Commission. Perhaps in the world of to-day such an amalgamation was inevitable. The technical problems undertaken by the several railways were similar, the boundaries of operation overlapped, and the separate bodies served a compact nation. It may be some time yet before the full effect of this act is developed and the final details of organisation determined. It can hardly be doubted, however, that the pattern of future amalgamations has been indicated.

In more recent years we have seen the creation of the National Coal Board, the Central Electricity Authority, and the United Kingdom Atomic Energy Authority. Each has its great programme of engineering development, the improvement of existing facilities, and the undertaking of works vital to the national need and economy. In the municipal and county fields of engineering activity there has been a steady development and expansion of the engineering organisations, undertaking more and more of the design and the execution of projects, as well as the ever-present maintenance.

This pattern of progress seems destined to continue in this country and one must expect the engineering organisations to consolidate and expand, and in special cases to amalgamate. This will be specially important in areas where the requirements are either too extensive for, and beyond the scope of, the local engineering resources, or are of an intermittent nature which does not warrant the setting-up of a direct organisation. Even in the areas of operation of the larger engineering bodies fluctuations in load will occur as well as in the number of schemes of a very specialised nature which will require the assistance of firms of consulting engineers.

The Civil Engineer Abroad

This increasing development of engineering organisations at home is as yet not fully paralleled abroad. The more developed countries have long ceased to rely on our services, though in unfettered competition we can still surpass them in many ways ; and recently it has been more to the younger countries, or in some cases new-found nations, that our engineering knowledge and services have been of value. One must expect that these countries will continue to increase more and more their own resources of engineers and of engineering firms. This evolution will be controlled in part by the degree to which other nationals are or can be trained in technology and in the engineering profession, and for some time yet the advantage will be with the more industrial nations. However, the present pressure throughout the world of engineering progress will impel all peoples to increase their educational and training facilities as a matter of national pride and to lessen their dependence on other nations. At the moment we may be shielded from the full impact of this.

The greatest limiting factor to our efforts in recent times has been the insufficiency of engineers for the work to be done here and abroad, and the interruption caused by World War II in the steady flow of engineers to the profession. One wishes that technological education and the needs to improve its extent could be met more quickly. Many universities and technical colleges have already improved their facilities, but it cannot yet be said that we are in the position best to serve the nation's need. The engineering profession never stays still, and at no time can one say we are at a period of consolidation.

Work overseas brings added interest to an engineer and frequently affords a relatively greater degree of responsibility, age for age, than can be reached here on account of the fewer opportunities for consulting colleagues in the profession and of the greater dependence on one's own training and knowledge. Despite this there are many who prefer the limitations of the more usual and commonplace career at home. This, I think, is a pity, for as a nation we have grown by our activities overseas, and with an overpopulated island we must continue to seek outlets abroad for our skill. Were we to fail in this our standards of living would inevitably fall.

Competitive Tendering

World War II brought an awareness of the need for engineering to all the nations and accelerated their desire to improve the facilities and the abilities to be more self-reliant. It also brought a loosening in the stern traditions of competitive tendering, which governed the placing of engineering works in the pre-war world. So much of the engineering work had been to meet war needs, when time was a governing factor which usually outweighed the cost, whether of money, manpower or materials. Work had to be started when only the main requirements could be defined by the military planners and the engineering design had to be developed as work went on. Normal contracting consequently had at times to be abandoned and standards had to be lowered. The return to normality has not yet been attained and may take many years yet, but I believe that in the end competitive tendering will win the day to the exclusion of other methods of deciding contracts. If my belief is correct, and I have good grounds for thinking it is, it will be essential that schemes should be worked-up fully before tendering is undertaken, and that the requirements to be fulfilled and the risks to be taken are defined as closely as can be. It is a failure to do this, whether from undue haste in undertaking a project or from inadequate preparation on the part of the engineers, that has enhanced the attractions of the contract placed on a target basis. I have some sympathy for this type of contract, as my experience with the Admiralty showed how a strong direct-labour organisation could be fitted for taking on urgent and large public works, and could function with considerable economy and efficiency. Occasionally it is right and proper to use a direct-labour organisation, as when a scheme carries uncertainties, and when in pricing the project contractors obviously cover themselves with a financially unacceptable degree of safety. There is much attraction in having available an experienced contractor, who is fitted for such a task. He works with a greater degree of administrative freedom than can be attained in a government or local government service, and this freedom is valuable. Yet in my opinion the greatest efficiency is attained when open competition prevails.

Every organisation requires constant attention to keep up and to enhance its standards, whether they lie in the quality of its staff and their leadership, or in the handling of manpower, or in increasing the efficacy of the equipment. One has only to think back into the recent past to recall how some organisations have faded and others have come on to take their place. As a nation we came to greatness on our ability to lead and on our efficiency under competition. It behoves us to remember this to-day on the eve of the nuclear world ; and in the face of fiercer competition to repeat the quality and the content of the achievements we have witnessed in engineering during the life of this Institution.

Lubrication with Molybdenum Disulphide Formed from the Gas Phase

By F. P. BOWDEN and G. W. ROWE*

THE lubrication of surfaces at high temperatures is nowadays of considerable technical importance. Many of the conventional liquid lubricants break down at temperatures of a few hundred degrees Centigrade, and use is made of solid lubricants, such as graphite, molybdenum disulphide and other lamellar solids. The firm attachment to the surface of these solid films is important. If the solid film is formed *in situ* by chemical reaction on the surface, the attachment may be improved. If the surface is heated in an appropriate gaseous atmosphere this formation may be accomplished. Lubrication from the gas phase has the additional advantage that the film can be reformed in operation if the relevant mechanical parts are surrounded by the gas.

It is well known that if molybdenum disulphide is rubbed on to steel surfaces a thin surface film is produced which has good lubricating properties, persisting up to reasonably high temperatures. It has also been shown (Bowden, 1950) that sintered molybdenum forms a low-friction coating when heated in hydrogen sulphide gas. The present experiments have been carried out (Rowe, 1953) with pure molybdenum which was initially heated to about 1400 deg. Cent. in a high vacuum (10^{-3} microns) to remove surface contamination. When the specimens were cooled to room temperature after this treatment the coefficient of friction between them was high, $\mu=2\cdot0$, and rose as the specimens were reheated until at about 1100 deg. Cent. complete seizure occurred. Purified hydrogen sulphide gas was admitted at a low pressure (0·01–0·1 atmospheres), and at room temperature. It was immediately adsorbed on to the surface, reducing the friction to $\mu=0\cdot9$. When the molybdenum was heated in the gas, chemical reaction occurred and the friction fell to $\mu=0\cdot2$ at 800–900 deg. Cent. Specimens cooled after about twenty minutes' heating in H_2S at 850 deg. Cent. were seen to be covered with a thick, purple film, which gave good lubrication. An X-ray diffraction study by D. R. Ashworth showed this film to consist of molybdenum disulphide. The film was stable and gave low friction in vacuum, when the H_2S was pumped away, at temperatures up to 800 deg. Cent. Above 900 deg. Cent. the film decomposed and the friction rose rapidly.

Specimens were also prepared in two other ways : by heating lightly-oxidised molybdenum in carbon disulphide vapour, and by rubbing pure molybdenum disulphide crystals on to the metal in air, using a degreased cotton pad. The results are summarised in the table below. It should be noted that the springs in the apparatus used are very lightly damped and that the static coefficients of friction recorded are in general much higher than the average steady-motion friction normally measured industrially. For comparison the friction between solid graphite sliders measured with this apparatus in air is about $\mu=0\cdot2$, rising to $\mu=0\cdot6$ after outgassing.

The films of molybdenum disulphide produced in these ways have similar properties at moderate temperatures, but the behaviour at higher temperatures shows that the chemically formed films are more persistent. It would be expected that these films would have a better bonding to the surface than a film which is formed simply by rubbing molybdenum and molybdenum disulphide together under light pressure.

An attempt was made to lubricate steel surfaces in this way. Molybdenum disulphide rubbed on to steel gave a fairly low friction, $\mu=0\cdot4$, in vacuo, and protected the surfaces from seizure up to 700–800 deg. Cent., but the friction was high, $\mu=1\cdot5-2$. Further experiments were performed with steel on to which a molybdenum layer had been deposited by sputtering. This again showed good lubrication when rubbed with MoS_2, but only at low temperatures. When the steel coated with sputtered molybdenum was heated in H_2S the coating spalled off. Both molybdenum and iron readily form sulphides when cleaned and heated in H_2S. The disruption of the coating is probably due to the attack of the iron by H_2S, which easily penetrates the discontinuous molybdenum layer and forms iron sulphide. It is thus difficult to produce a film of MoS_2 on steel in this way, unless the molybdenum is thick and impervious to gas. The same argument also suggests that the protection from seizure afforded by a layer of molybdenum disulphide rubbed on to steel is actually due to iron sulphide at high temperatures. It is noteworthy that the friction exhibited under these conditions is high, as recorded in the preceding paragraph, and that the protection breaks down at a temperature close to that observed by Bowden and Young (1951) for the breakdown of iron sulphide films on iron (about 700 deg. Cent.).

The free energy of formation of NiS, according to Osborn (1950), is $\Delta F=-38$, and of MoS_2 is -40, so molybdenum sulphide should form preferentially in a nickel-molybdenum combination. If, therefore, an impervious nickel barrier is interposed between the iron specimen and its molybdenum coating, the formation of MoS_2 should be possible without chemical attack of the substrate metal. Steel specimens were plated with nickel on top of a flash of copper and molybdenum was sputtered on to the nickel. A coating of MoS_2 was formed when this complex was cautiously heated in H_2S at 800 deg. Cent. and a low friction was recorded subsequently at room temperature. It is considered that evaporation or plating of the molybdenum on to the surface would be preferable and give a more continuous film The molybdenum may also be deposited on the metal surface by spraying.

These observations provide further evidence that films formed by heating molybdenum in hydrogen sulphide or in carbon disulphide vapour can give low friction at high temperatures even in vacuo. If destroyed during rubbing, the films are readily reformed in hydrogen sulphide gas, so that in this atmosphere the surfaces will continue to give a low friction. In this manner a gas may act as an effective lubricant if it reacts with the surface to form a compound of the appropriate structure. The lubrication of molybdenum cutting tools by gaseous hydrogen sulphide has been described earlier (Bowden and Tabor, 1954). These general conclusions apply, of course, to other solids which form compounds of this type. For example, titanium di-iodide has a layer-lattice structure, and surface films giving low friction between titanium sliders at high temperatures can be obtained by heating the clean metal in iodine vapour (Rowe, 1956). It appears that such compounds will give good lubrication at all temperatures for which the films themselves are stable on the surface. If the appropriate gas or vapour atmosphere is maintained the worn films can continuously be repaired during the sliding process.

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	Coefficient of friction								
Denuded Mo in vacuo	2·0	—	2·1	2·3	2·5	—	2·8	3·6	Seizure
Denuded Mo in H_2S	0·9	0·45	0·3	0·2	0·2	0·2	0·3	0·45	—
Oxidised Mo in CS_2	0·9	0·6	0·5	0·4	0·4	—	0·3	0·4	0·5
Mo with MoS_2 rubbed on in air. Run in vacuo	0·1	0·2	0·3	—	0·3	0·35	0·4	0·7	1·1
Mo with MoS_2 formed *in situ*. Run in vacuo	0·2	—	0·2	—	0·2	—	0·3	0·45	0·5
Specimen temperature, deg. Cent.	18	600	700	750	810	870	940	1020	1130

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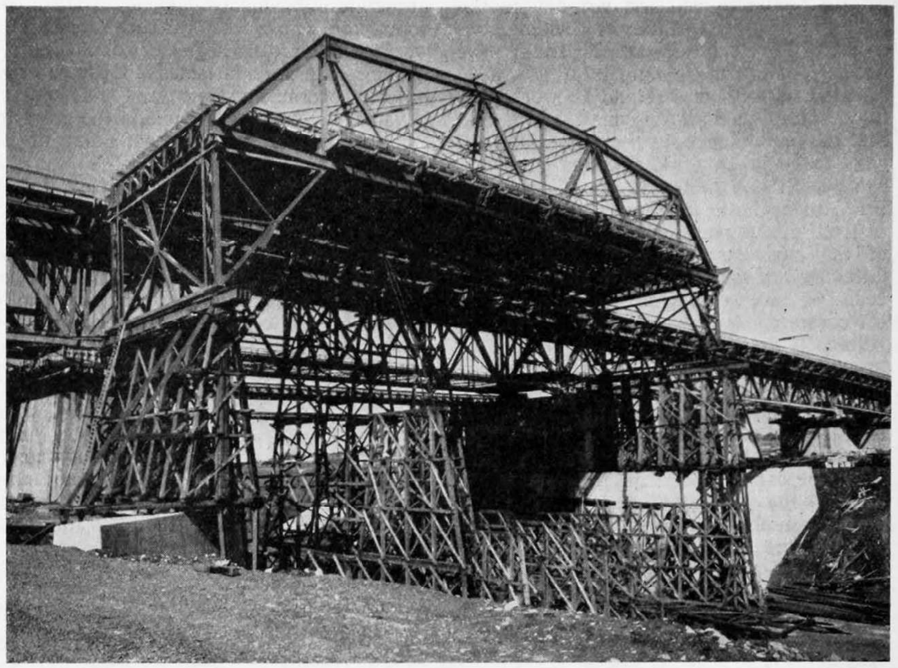
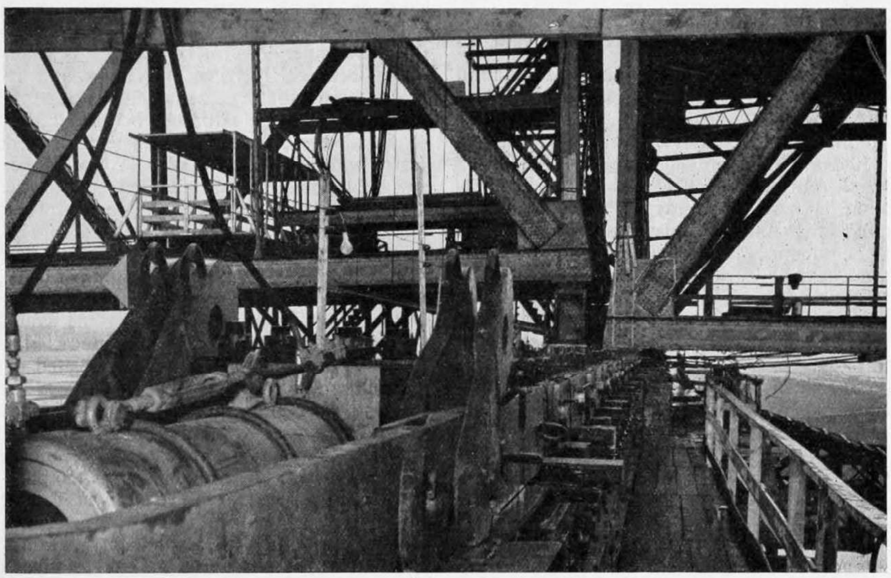
Raising the Jacques Cartier Bridge—Montreal

The southern part of the Jacques Cartier bridge is being regraded over fourteen spans to give a clearance of 120ft over the St. Lawrence Seaway, which will pass under the centre of this part of the bridge. The spans involved are of 250ft, 200ft, 150ft and 125ft, and are braced steel trusses with the bridge deck at the upper chord level. Regrading involves jacking these spans, in varying amounts and according to a rather complicated schedule, and replacing the 250ft span under which the Seaway will pass by a " through " truss, with the roadway at the bottom chord level. Our first illustration shows the new " through " truss of 248ft span, mounted on trestles ready for translation into position. The " deck " truss, which is to be moved out, can be seen in the background. The temporary steelwork can be distinguished from the steelwork of the new truss itself, which is Warren-braced, with vertical members, and with an additional triangular panel at each abutment below the roadway level, which carries the bearings of the new span and mates with the " deck " trusses on each side



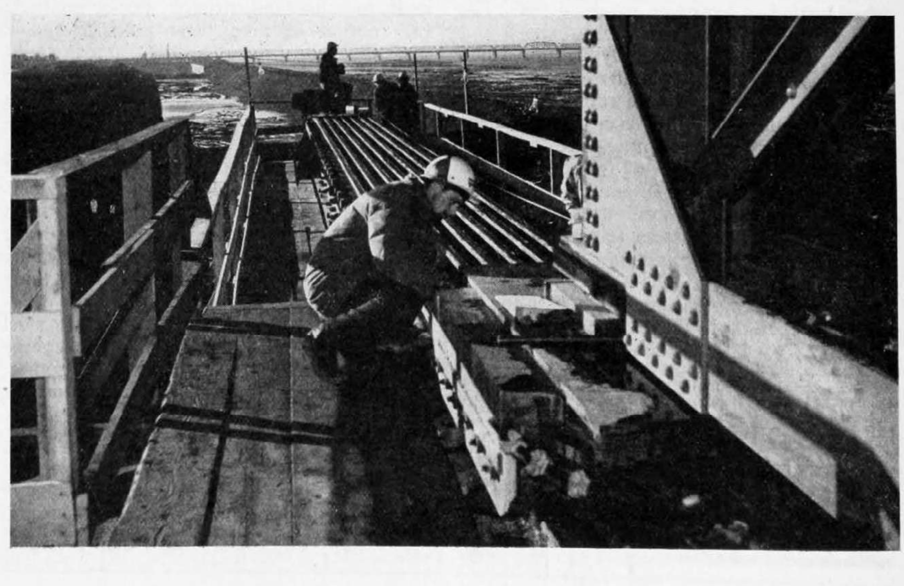


The new and old spans are coupled together and mounted on eight roller trucks each containing forty-two 6in diameter rollers. These trucks travel on two runways, each consisting of seven rails, and are pulled through a chain of links by double-acting hydraulic jacks, one of which is at the downstream end of each runway. The jacks have a combined capacity of 500 tons and a stroke of 4ft. Links are removed after each stroke, the jacks are retracted, reconnected and the process repeated until the translation has been accomplished. The power is supplied by electrically driven hydraulic pumps delivering oil at pressures up to 6000 lb per square inch. Our second illustration shows a downstream runway and one of the two jacks, and the link chains used to pull the spans across. The third illustration depicts an upstream runway with one of the eight roller trucks on which both old and new spans were mounted. The bridge was closed on the morning of Sunday, October 20, and the spans were changed in five hours

The St. Lawrence Seaway Authority's consultant for this work is Dr. Pratley, and the contractor is the Dominion Bridge Company. Principal data for the " translation " operation are :

Length of span between runways, feet	245
Centre to Centre of trusses on :	
New span, feet	66
Old span, feet	40
Width of roadway on :	
New span, feet	60
Old span, feet	48
Height of underside of new span above channel bottom, feet	140
Length of travel, feet	78
Total length of runway, feet	220
Weight of :	
New span, tons	1600
Old span, tons	1500
Total weight moved, tons	3100

The new span will subsequently be jacked up a further 37ft. The highest jacking lift is about 50ft, and the incurred clearance 80ft. Jacking of the spans is in 6in increments, and the bridge remains open to traffic continuously. The jacking sequence was described in " The Engineer " of November 6, 1956. The raising operation will take two years altogether, and cost 7,000,000 dollars



LETTERS AND LITERATURE

Letter to the Editor

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

ENGINEERS AND CARS

SIR,—The leading article in THE ENGINEER for October 25, "Engineers and Cars," while very clearly outlining the present position both in this country and the Continent, call for certain comment and also technical correction. That the leading motor-car manufacturers of this country are at all events as far as the public goes reluctant to break new ground is perfectly well understandable in view of the fact that their entire production resources are being utilised in meeting the present demand for their products. The same holds also for Germany as far as the firms are concerned who manufacture conventional motor-cars. The extremely interesting and potentially important developments in the direction of small cars of 600 c.c. downwards which are now taking place in that country are due to the efforts which are being made by the motor-cycle industry to fill the gap left by the rapidly diminishing demand for the motor-cycle proper. This vigorous and concerted effort is in marked contrast to the position in this country, but in fairness to our own industry it must be stated that on the Continent the system of differential taxation is a very real help to the maker of a small car of this class. We can expect the next year or so to see considerable developments in this direction, but it would appear that the cycle in Germany will again follow the familiar course of the miniature car growing in size until it is barely distinguishable from its existing brethren.

On one important technical point I must take issue with you and that is the common fallacy that by fitting petrol injection to a two-stroke engine its road manners and general flexibility can be greatly improved. This is definitely not the case. An improvement in fuel consumption can naturally be obtained as the loss of fuel attendant on scavenging can be avoided and, as in any other petrol engine, a small gain in power can be obtained by providing better breathing; but in a petrol injected two-stroke engine, just as in the case of one with a normal carburettor control at part throttle is obtained not as in the four-stroke case by reducing the total charge in the cylinder, but by readmission of exhaust gases and the consequent alteration in mixture ratio. As the engine is throttled down this soon reaches the border line of inflammability and misfiring occurs. An incidental point is that the relatively small range of manifold depression in the two-stroke engine makes it very difficult indeed to devise and operate a satisfactory control for a petrol injection system. I would say that this statement is based on a very considerable amount of work carried out by my firm on the subject and what is perhaps still more important is the fact that no German two-stroke cars are now being sold fitted with petrol injection systems.

The other point on which I must take issue with you is the reliability of the British car. It is the policy of my firm to keep closely in touch with development and production both here and on the Continent, and during the last ten years a large number of representative cars, both British and foreign, have passed through the hands of our technical staff and our proving laboratory. In most cases these have been driven for large distances. There is, of course, a considerable difference between the characteristics of different makes, but on the whole British cars are definitely not inferior to Continental or American makes, while the cars which have given the longest trouble-free mileages have most definitely been produced in this country. There is certainly no ground whatever for the statement that the British car becomes dangerously defective after two years use in this country.

E. A. WATSON
Chief Engineer, Joseph Lucas, Ltd.

Birmingham, October 30, 1957.

[We fully endorse Mr. Watson's last sentence. Upon reading again certain words we used in our article, we can see them to be unclear. They were not intended to convey that the British car becomes dangerously defective after two years' usage.—ED., THE E.]

Book Reviews

Realities of Space Travel. By L. J. CARTER. Putnam and Co., Ltd., 42, Great Russell Street, London, W.C.1. Price 35s.

THE British Interplanetary Society was founded in 1933 and during the first few years of its life suffered many insults—much as did the Aeronautical Society during the last century. At the beginning of the last war it went into hibernation for the duration and was restarted in 1946. Largely owing to the German wartime development of the rocket it was now taken far more seriously and as time has gone on more and more scientific workers have joined. The Society has, since 1946, produced a regular bimonthly Journal (it only managed a small irregular publication before the war) in which it has published the lectures read at its London meetings and numerous articles ranging from popular reviews to original mathematical research. The Society's membership has always been on the increase and the consequent demand for back numbers has meant that most issues have been out of print within a few months. The Council of the Society has obviously realised that many of these papers are of more than passing interest and has assembled in this book a well-balanced selection from the past ten years' issues.

Twenty-four papers are reproduced and these are grouped under the headings, "Introduction to Astronautics," "The Satellite Vehicle," "Interplanetary Flight," "Physical Factors in Space Flight," "Biological Aspects of Space Flight," "Targets for Tomorrow" (Astronomy), "The Development of Astronautics," "Establishments and Testing Stations," "History of Astronautics" and "The Distant Future." There is unfortunately nothing to explain how the papers were chosen or for what class of readers the book is intended. It is quite clearly not on the level of the majority of recent works on space flight as a number of articles are of quite a mathematical character. Taken as a whole, however, the book is very readable and will give an excellent and sober picture of the problems which have to be solved before space flight can be achieved. Although the papers have been taken from *Journals* published over quite a long period few of them appear to be dated and, in some instances at least, they have obviously been brought up to date. The restrictions placed on the Editor by having to choose only such material as had appeared in the *B.I.S. Journal* is noticeable only in the section "Establishments and Testing Stations." Here there are two papers only, originally published in 1948 and both are very much dated. During the past five years a tremendous amount of information has been released on the various American rocket research establishments and the uninitiated could easily form a wrong impression of the scale of American activities from this section. This is, however, a minor criticism of an excellent publication.

This is the only book published to date to deal with all aspects of space-flight in a technical manner and is strongly recommended to any technical person who would like to read an accurate and unembellished account of the present state of the art.

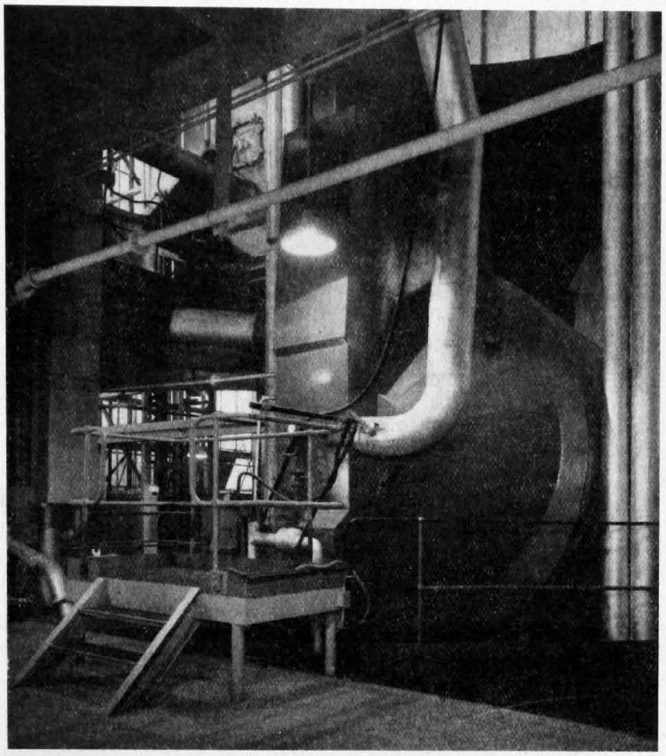
Design of Reinforced Concrete. By B. W. BOGUSLAVSKY. The Macmillan Company, New York, 10, South Audley Street, London, W.1. Price 42s.

THIS is a textbook suitable for students or designers who may wish to refresh their knowledge or to refer to certain design methods not available in other publications. The structural properties of steel and concrete are first discussed, followed by the analysis of frames as elastic systems by moment distribution. Over 200 pages are then devoted to the design from first principles of beams, columns, slabs, footings and retaining walls. Illustrative examples are given and the detailing of reinforcement is discussed. The elastic analysis of arches is given and the use of the elastic centre for simplification is explained. The theory of design and its application to typical bridges is covered in just over fifty pages: examples are given. The design of prestressed concrete beams is explained without unnecessary elaboration. A complete account is included of the full procedure of designing framed buildings, including detailing beams, columns, floor slabs and footings. The book includes empirical formulæ for estimating the cross sectional dimensions of prestressed concrete beams, a direct method of designing eccentrically loaded cracked columns and a detailed presentation of the method of two-cycle moment distribution, which the author claims is the quickest method of dealing with continuous structures. The book can be recommended to students and engineers generally, although when empirical methods are referred to, the A.C.I. code is used.

Books Received

Basic Soils Engineering. By B. K. Hough. The Ronald Press Company, 15, East 26th Street, New York, 10, New York State, U.S.A. Price 8 dollars.

Generation, Transmission and Utilization of Electrical Power. Fourth edition. By A. T. Starr. Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2. Price 27s. 6d.

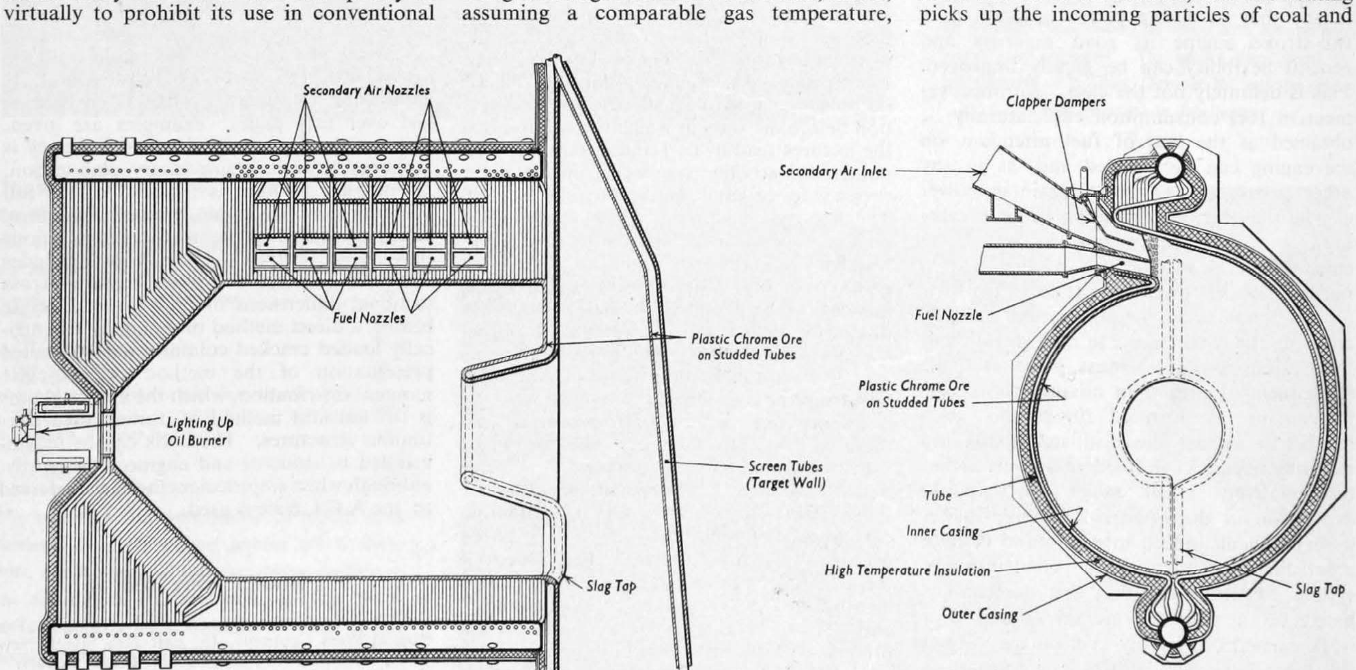


Cyclone Fired Boiler Installation

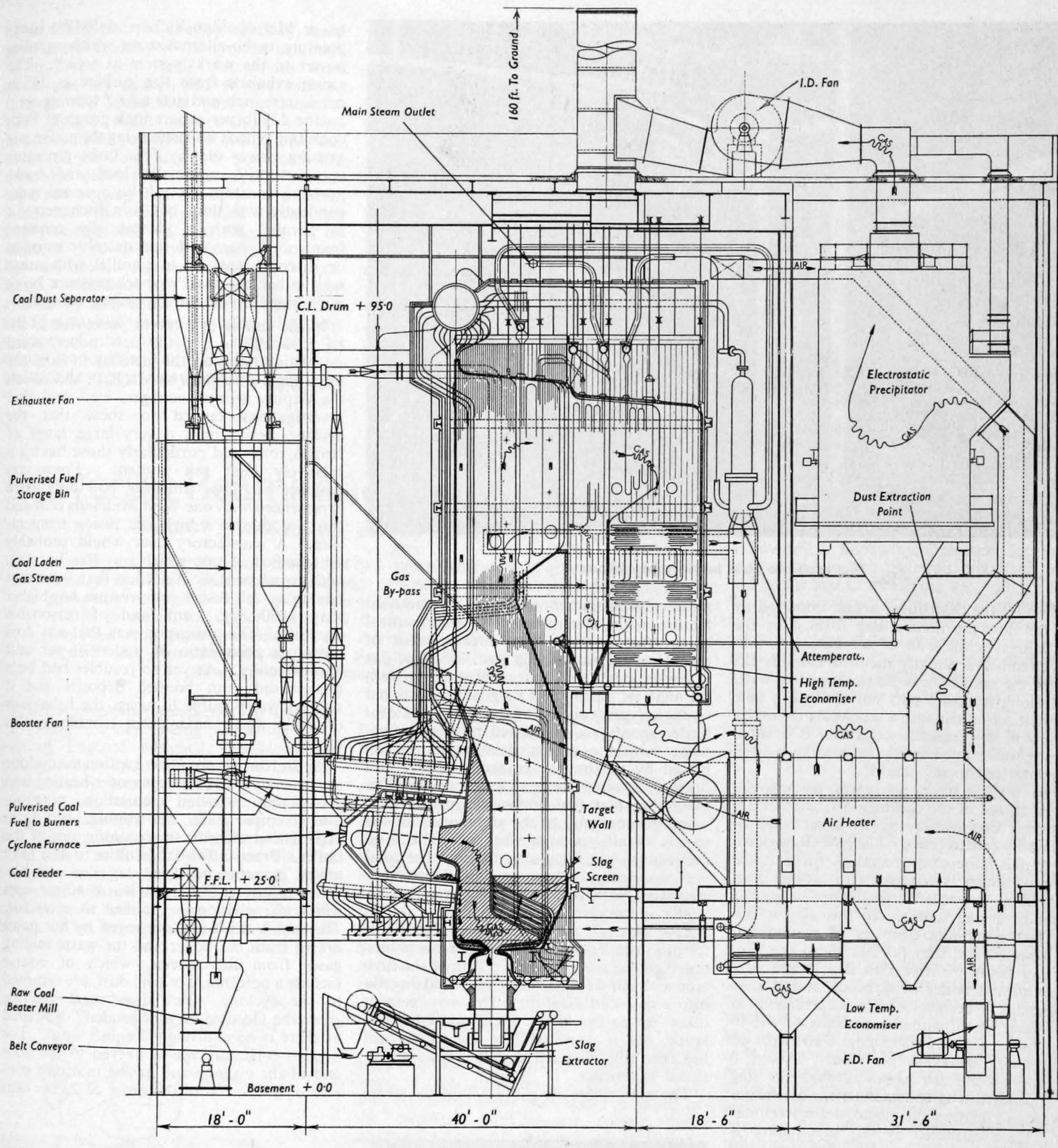
The first industrial cyclone fired boiler to be installed in this country is now in operation at the Kynoch works of the Metals Division of Imperial Chemical Industries, Ltd. This boiler was supplied by Babcock and Wilcox, Ltd., and delivers 200,000 lb of steam an hour at 925 lb per square inch and 915 deg. Fah. to a 6·5MW back-pressure turbo-alternator set. Its designed gross efficiency on gross calorific value of the fuel specified is 87·8 per cent, and it is stated to now be operating consistently at an efficiency of just under 90 per cent. The cyclone furnace, to be seen on the left, and the front wall enclosing the throat were prefabricated and erected as complete single units.

WHEN it was decided some three years ago to install a titanium melting plant at the Kynoch Works, Witton, of the I.C.I. Metals Division a primary necessity was the installation of additional generating plant in the works' power station. To overcome the existing space limitations and comply with local controls in connection with smoke and dust emission, it was decided to install a boiler plant of Babcock and Wilcox, Ltd., design equipped with cyclone firing. This cyclone fired installation—the first to be put into service in this country—is stated to be operating consistently, at an efficiency of slightly under 90 per cent. In addition to its efficient performance, the boiler has a further advantage in that it will operate satisfactorily on coal of such low quality as virtually to prohibit its use in conventional plant. The problem of fly ash disposal is eliminated as the ash is discharged from the furnace in the form of a granular slag which is readily usable on civil works. The relatively small amount of fly ash reaching an electrostatic precipitator is returned and recirculated in the furnace, where it is reduced to slag.

The high efficiency of cyclone fired boilers is, in the main, due to reduction of flue gas losses. The maker points out that the modern conventional coal burning plant needs some 25 per cent more air than is theoretically necessary to provide satisfactory combustion—a cyclone fired boiler operates most efficiently on about 8 per cent excess air. This considerably reduces the weight of gas being discharged from the stack and, hence, assuming a comparable gas temperature, gives a corresponding reduction in energy loss. The principle of cyclone firing, it will be recalled, consists of crushing coal and introducing it on a tangential stream of primary air into a cylindrical furnace chamber in such a way that it is centrifuged on the walls of the furnace. (In another, axial, form of construction the fuel is introduced at one end and the swirling effect is produced by a scroll.) In the furnace, burning out of the fuel is completed by a stream of high temperature secondary air injected tangentially at a very high velocity. The very high temperature at which the furnace is operated maintains the ash in a molten condition when it is liberated from the fuel. This molten ash forms a slag coating over the inner surface of the furnace, and this coating picks up the incoming particles of coal and



Construction of a tangentially fired cyclone furnace



General arrangement of a cyclone furnace boiler installation

retains them till the burning process is completed. The molten slag flows down the walls to the bottom of the furnace and out through a hole in the front, or boiler, end, where it drops into a water quench which reduces it to an easily handled granular form.

The general construction of a cyclone furnace such as the 9ft diameter unit installed at the I.C.I. works, can be seen in one of the drawings we reproduce. The furnace is in the form of a cylindrical chamber which may be set at a slight angle in the front of a radiant furnace and communicating with it by a re-entrant throat. The furnace chamber comprises a series of closely pitched water tubes, the inner surfaces of which are studded and covered with a plastic chrome-ore refractory material. The outer surfaces of the chamber are fitted with an insulated steel casing. The furnace tubes are connected to inlet and outlet headers which form part of the natural water circulation system of the boiler.

The new boiler installation at Kynoch works was designed to the following requirements :

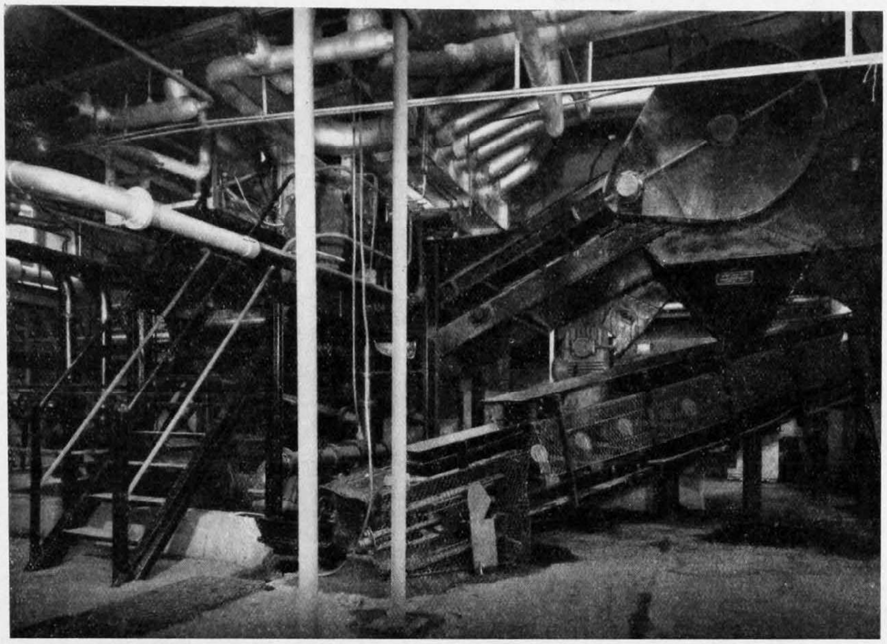
Evaporation	200,000 lb per hour
Steam pressure...	950 lb per square inch
Steam temperature	925 deg. Fah.
Feed temperature	320 deg. Fah.
Fuel specification :	
C.V.	>9000 B.Th.U. per pound
Grindability	>50 Hardgrove

Ash fusion characteristics (semi-reducing atmosphere):

	Limits	Normal
Initial deformation ...	>1050 deg. Cent.	1240 deg. Cent.
Fluid temperature ...	<1400 deg. Cent.	1300 deg. Cent.

Gross efficiency on gross C.V.	87·8 per cent

The general arrangement of the installation can be seen in the drawing on this page. Raw coal from a hopper is delivered by vibratory feeders into a beater mill situated in the basement of the plant. This mill coarsely pulverises the coal to a condition in which 50 per cent will pass through a 200 mesh screen. This product is picked up in an inert gas stream which carries it up through dust separators and deposits it into the pulverised fuel storage bins. From these bins the coal passes to the cyclone combustion chamber through four variable speed feeders, and the speed setting of these feeders closely controls the rate of coal delivery with the primary air and hence the boiler output. The stream of coal passing into the chamber meets a high velocity tangential stream of secondary air preheated to 600 deg. Fah., and combustion takes place with extreme rapidity due to the scrubbing action of this secondary air. The coal dust removed by the separators leading to the storage bins is introduced into the furnace at the secondary air supply nozzles of the cyclone. The high temperature generated causes the ash particles to melt



Slag extraction plant below cyclone furnace

and under the centrifugal action imparted by the air flow the molten slag formed by the ash clings to the wall of the chamber. As the chamber is slightly inclined towards the boiler the molten ash flows down its walls and along its lower part out through a hole where it runs down into a secondary chamber. A hole in this secondary chamber is situated over a water quench into which the molten slag falls and forms granules.

The high temperature gases passing out of the throat of the combustion chamber are deflected downwards by a target wall of refractory coated tubes. The gases flow down on to the floor of a secondary furnace, the floor of which is covered with molten slag, and then upwards through the staggered tubes of a slag screen. In this slag screen the last remaining droplets of molten ash are trapped and they fall back into the pool of slag below. After this slag screen is a conventional boiler of Babcock and Wilcox "Radiant" design, which is arranged to give final steam outlet conditions of 925 lb per square inch and 915 deg. Fah. with an output of 200,000 lb per hour. About 8 per cent of the ash passes through the slag screen and this is collected in the air heater passes and finally in an electrostatic precipitator. Dust extracted by this precipitator is returned to the raw coal feed system and eventually re-circulated to the cyclone furnace where it is reduced to slag. It is stated that the dust burden of the exit flue gas was found to be 0.033 grain per cubic foot, or less than 10 per cent of the expected minimum.

The molten slag gravitating from the furnace drops into the water immersed slag extractor shown in one of our illustrations. This extractor consists of a drag scraper conveyor which continually removes the slag granules from a water filled trough, the level of which is maintained by four nozzles arranged to impart a circular motion just below the surface of the water. This swirling motion is designed to ensure that large pieces of slag are broken up and the slag drawn from the trough is delivered by chutes to a disposal belt conveyor.

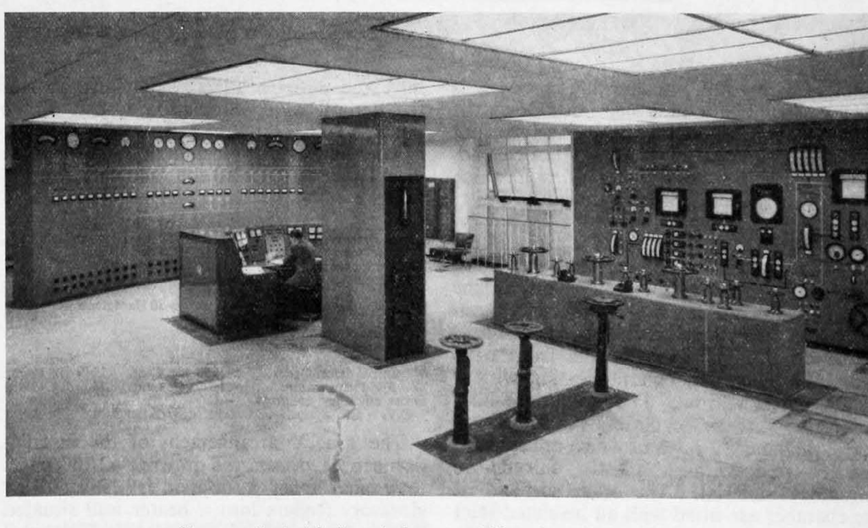
The boiler is fitted with fully automatic control equipment supplied by George Kent, Ltd. The fuel/air ratio is initially obtained by both total air flow and fuel controllers being set by the main impulse from the master pressure controller; an unusual feature in the system being the final control of the fuel/air ratio by a measurement of excess oxygen in the flue gas. The flue gas is continuously and automatically analysed, the analyser putting out a signal proportional to the oxygen content of the gas. The coal feeder speeds are controlled by a main impulse from the master pressure controller, biased by the oxygen controller signal and finally corrected by a closed loop impulse from the total fuel transmitter, this latter being proportional to the summation of the speeds of all operating feeders. The total fuel transmitter impulse is fed into the total fuel controller, where it is continuously compared with the combined pressure controller and oxygen analyser signals.

The control panel, designed by I.C.I. for this installation, can be seen in our photograph of the control room. It is of the flow type with full-size instruments inserted directly into a coloured diagram. This arrangement takes up rather more than normal panel space, but it is stated that the experiment has been fully justified by subsequent operational experience.

The new boiler installation supplies steam to a Metropolitan-Vickers 6·5MW back-pressure turbo-alternator set which supplies power to the works system at 6·6kV. The steam exhausts from this turbine at 235 lb per square inch and acts as a "topping set" on the 225 lb per square inch group of Babcock and Wilcox boilers serving the previously existing power plant. This turbo-generator is fitted with automatic load and back-pressure controls. It can be operated independently with these controls disconnected; in parallel with a substantially constant frequency system with the controls connected or disconnected, or in parallel with other sets, either the load or back-pressure being maintained by the corresponding controls.

In the course of a recent press visit to the I.C.I. works to see the new boiler, some interesting notes on the installation from the users angle were given by Mr. R. P. McCulloch the deputy works manager, who said that investigations tended to show that the cyclone would burn a very large range of British coals and particularly those having a relatively high ash content. From experience to date, difficulty had only been experienced with one West Midlands coal and this was due to a high ash fusion temperature. A satisfactory coal would probably be specified as one which was free burning, with an ash content of not less than 6 per cent having an ash fusion temperature not higher than 1400 deg. Cent. and of reasonable viscosity. The indication was that any coal having a silica ratio of under 70 per cent is satisfactory. As yet no troubles had been experienced with bonded deposits and it was not yet possible to assess the behaviour of coals which have given trouble in this respect.

Apart from a tube failure within the cyclone in the early stages, due to over-heating and caused by restricted circulation, probably due to pipe scale, no troubles had been experienced with the heat transfer side of the boiler. Practically all difficulties to date have arisen in achieving free slag flow over the wide variations of load down to 40 per cent which the plant was specified to cater for. The fuel is dried and conveyed by hot gases drawn from the boiler and the waste milling gases from this circuit, which of course include a percentage of coal dust, are returned to the cyclone. For these waste milling gases the German word "bruden" was used as there is no equivalent English word. The bruden originally was conveyed to the nose end of the cyclone and as the moisture content of the coal is of the order of 20 per cent



Steam and electrical control room at Kynoch works power-house it was found that the cooling effect of these gases caused freezing of the cyclone at about 70 to 75 per cent load. Alterations were made and the bruden fed to the cyclone through two spare coal ports, and whilst this effected slight improvement it was not possible to slag freely down to less than about 60 per cent load. It was therefore decided to make a radical alteration by providing a new tapping from the boiler at a hotter point, and this, together with operational improvements, has enabled slagging to be achieved to loads below 50 per cent. The bin and feeder system enables a "quick freeze" technique to be adopted in the cyclone by milling at full rate and taking full advantage of the cooling effect within the cyclone of the bruden. Conversely, in raising load milling can be omitted for a period long enough to achieve free slag flow.

The return gas from the mill was originally vented axially into the cyclone ; this seemed to cause over-cooling and was changed to a tangential position adjacent to the re-entrant throat, with better results. A considerable improvement in cyclone temperature resulted from the reduction of the quantity of vent-gas and improvement of drying in the mill by changing the gas take-off point from the boiler from behind the first pass to the superheater to the top of the open pass.

Cyclone firing involves completely new considerations in the selection of fuels. Ash content was of relative insignificance, the two main points of significance being ash behaviour at elevated temperature and the amount of moisture in the fuel. Complete ash analysis is a relatively new technique and B.C.U.R.A. is at the moment giving this problem much deserved attention.

Universal Beams and their Application

By S. BARLOW, M.I.Struct.E., and G. FOSTER, A.M.I.Mech.E.

A rolling mill equipped for the production of a comprehensive range of broad flange beams is due to start production next spring. An outline of the function of this mill, followed by an appraisal of the advantages of the range of beams and columns which will be produced, as compared with the British standard range of sections, are contained in a paper presented to the Institution of Structural Engineers on October 31. Abstracts from the paper, the title and authors of which are given above, form the substance of this article.

THE approaching completion by Dorman Long of a new rolling mill in the north east of England designed specifically for rolling a new and wide range of efficient beam and column sections, is a matter of great importance, and its impact on structural engineers and other users of beam and joist shapes will be considerable. The mill, which is being installed at the new Lackenby steel works, is a universal beam mill which will roll a comprehensive range of efficient beam sizes to be known as universal beams. The largest will be 36in deep with 16½in wide flanges and the smallest 6in deep with 6in wide flanges. The mill will also be capable of rolling any of the present range of British Standard sections, but it is expected that the more efficient universal beams will quickly supersede the British Standard joists in the medium and heavy range. It is therefore probable that, in addition to the new universal beams, only angles, channels and piling will be rolled in the new mill.

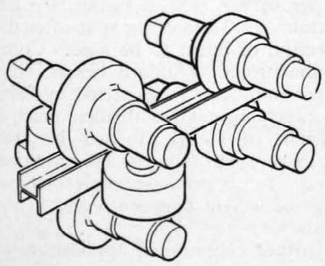


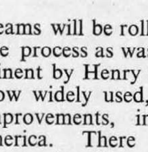
Fig. 1—Roll arrangement in universal mill

The production of universal beams will represent the climax of a great scheme of iron and steelworks development undertaken since the war. In carrying through this scheme, over £60,000,000 will have been spent. The universal beam mill itself is costing £18,000,000. Steel for beam production will be supplied from the Lackenby steel plant which was completed in 1953 at a cost of £8,250,000.

The new universal beams will be rolled by fundamentally the same process as was first developed on the Continent by Henry Grey. This process is also now widely used, with modifications and improvements, in the United States of America. There have, however, been great advances in mill engineering and practice since the last new full range beam rolling mill was installed in the U.S.A. in 1930. In consequence, a great deal of research, planning and design has gone into the new universal beam mill which embodies many new and unique features as well as the development of old, well-proved rolling techniques. It is hoped to begin experimental rolling early in 1958.

Beam Rolling Technique

Towards the end of the nineteenth century attempts were made to roll beam sections larger in size, especially in flange width, and with less flange taper than could be rolled in the two-high conventional rolling mill, equipped with horizontal rolls only. Experiments centred around a roll stand with two vertical and two horizontal rolls mounted in the same vertical plane. Although many experiments were made, no solution to the difficult rolling and engineering problems involved was found until an Englishman, Henry Grey, successfully developed beam rolling in a four-roll mill at Differdange, Luxembourg. This mill, laid down in 1902, was the first commercially successful plant and was capable of producing beam sections up to 1m (39·37in) deep and with a flange width of 300mm (11·8in) and taper of 4½ deg. The mill, rebuilt in 1912 and again in 1930, to-day produces the full range of sections listed in the German Standard list, ranging from 100mm by 100mm to 1000mm by 300mm, all with near parallel flanges.



Since this first successful mill was established, further beam mills have been built, one at Illsede-Hutte, Peine, Germany, and five in America—three by the Bethlehem Steel Company and two by the United States Steel Corporation—making a total of seven beam mills in existence at the present time. Recently Inland Steel Company has carried through a major reconstruction of its existing heavy section mill in order to be able to produce beams up to 24in deep.

Beam and column sections are also rolled with near parallel flanges on modified two-high reversing mills on the Continent, and more recently, in one mill in the United Kingdom. Such modified mills produce a joist in conventional roll passes and remove the rolling taper in a single four-roll or universal pass. They do surprisingly good work, but are less flexible than true four-roll beam mills. They are limited in the width of flange produced and in the number of different flange thicknesses which are possible without excessive roll changing.

The mill at Lackenby applies modern mill engineering to the four-roll technique and will be the first of its kind in this country and the most advanced of this type in the world. It will be capable of producing a very wide range of beams and columns and each will be produced with a range of flange and web thicknesses giving much narrower modulus steps than have hitherto been available in the United Kingdom.

The universal beam will be rolled in passes between four rolls and will be shaped by direct rolling pressure and the faults of indirect shaping will be substantially avoided. Fig. 1 is a diagrammatic illustration showing the roll arrangement for beam rolling in the universal mill and Fig. 2 stages in universal beam rolling.

The universal mill rolling unit consists of a four-roll or main stand, with a two-high supplementary stand in line with and as close to the main stand as possible. Horizontal and vertical rolls are adjusted between passes and reduction in the thickness of both web and flange takes place in the main stand. The supplementary stand has two rolls only and works the edges of the flanges, squaring up and controlling their length.

In the main stand the setting of the vertical and horizontal rolls for each separate pass is arranged so that the elongation of the web and the flange is controlled with precision, ensuring that all parts of the section being rolled elongate equally, thus avoiding rolling stresses. There are no closed passes to cause difficulties due to the flanges sticking in the rolls and the flange taper can, therefore, be very small. The production of beams with

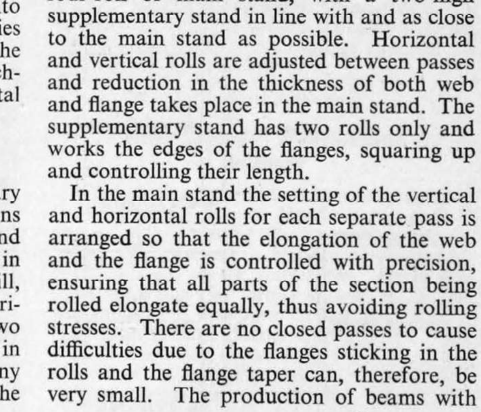


Fig. 2—Stages in universal beam mill rolling

very wide flanges, with little or no flange taper and very thin webs is, therefore, possible in such a mill.

The new mill comprises a blooming mill with rolls 50in diameter, the working faces of which are 112in long, followed by universal roughing and finishing units having rolls up to 53in diameter. The two latter units have independently driven supplementary roll stands controlling the flange length of the beam. Initial shaping in the blooming mill will produce an H-shaped bloom with a web some 3in thick. A number of passes are worked in each stand and all rolls have to be adjusted for each pass to arrange correct drafting on the web and flange of the beam. Drafts and motor speeds for each pass will be predetermined and a preset screwdown mechanism will enable the operator to achieve all settings at the depression of a single push-button.

The settings of the roll openings for the final pass in the finishing universal stand will determine web and flange thickness of the finished beam. Variations in this setting will enable beams of approximately the same depth and flange width but with different web and flange thicknesses to be produced without the necessity of changing rolls.

It must be made clear, however, that the inner profile of the section remains constant and any variation in flange thickness affects to a small degree the overall depth of the beam. As an example, a 10in by 10in beam weighing 49 lb per foot measures 10in by 10in, but when increased to 60 lb per foot the overall size increases to 10¼in by 10$\frac{1}{16}$in, i.e. each flange is increased in thickness by ⅛in and the web by $\frac{1}{16}$in. By further roll adjustment other weights are obtained up to 112 lb per foot and the section size for this weight will be 11⅜in by 10$\frac{7}{16}$in.

Provided the ratio of flange to web thickness is approximately the same, any flange thickness up to, say, 1½in for the deepest beams and 3in for the heaviest stanchion is technically possible (Fig. 3). For commercial reasons the number of beam and stanchion sections to be produced will have to be limited, but a very large range will be available.

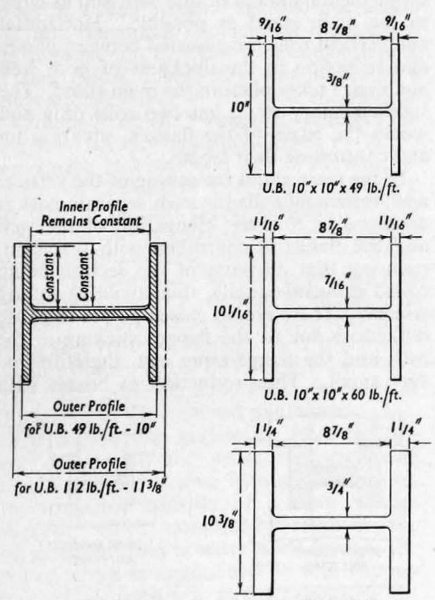


Fig. 3—Effect of roll adjustments

It is intended to produce an economical range, based on the American list of sizes, but with additions to meet British requirements. The sizes to be rolled range from 8in by 5¼in by 17 lb to 36in by 16½in by 260 lb for beam sections, and from 6in by 6in by 20 lb to 14in by 16in by 426 lb for column sections.

In deciding the range, close study was given to the features and limitations of the British Standard beams and columns and full information of the demand over a number of years for sections rolled in American mills was made available by the American operating companies.

It is proposed to roll to the American Standard list of rolling tolerances now almost universally accepted. Two forms of section will be produced : (*a*) beam sections which will be rolled with a small flange taper of 2 deg., 52 min.; (*b*) column sections which will have nominally parallel flanges. The toes of both beam and column sections will be square, as shown in Fig. 4.

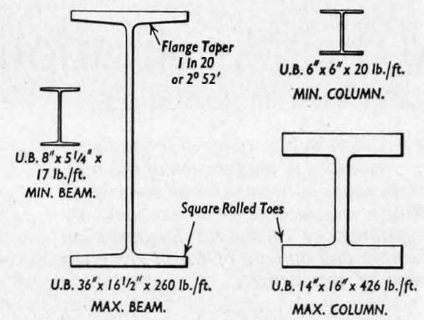


Fig. 4—Shape of universal beams and columns

Equipment is to be installed at the mill to split beams through the web to form large tees, which will be straightened in special machines prior to despatch.

The present intention is to roll forty-four different sizes of beam sections and twenty-seven column sections. The beams cover a range of fifteen serial sizes, many of which have three or four specified weights per foot. The columns cover a range of six serial sizes, one of which has seven different weights per foot and all have flange widths approximately equal to the depth of section.

In addition to the twenty-one sets of rolls required to produce this range of universal beams, provision has been made to roll twenty sizes of angles, channels and piling. The manufacture of these rolls, some of which weigh over 30 tons each, has presented the British roll maker with many technical problems. Although it is expected that rolls will have a reasonable life, the magnitude of the roll cost per ton of beams produced can be gathered from the fact that the cost of the initial supply of rolls to cover the range proposed is £1,000,000.

Beams

In practically all cases the new sections, when compared with their nearest equivalent in the British Standard range, have advantages in either the physical properties or in weight, or both. A comparison between the two indicates that for approximately the same weight per foot, the universal beams provide section moduli as much as 10 per cent above those for the best beams at present available.

The new mill will make available in this country a large number of beam sizes having heavier weights and greater strengths than are rolled here at present. The largest beam section of the new range, namely, 36in by 16½in by 260 lb per foot, has a modulus of 951·1 cubic inches, approximately 4½ times the strength of the 24in by 7½in by 95 lb per foot beam, which is the deepest British Standard normal section with a modulus of 211·09 cubic inches. Fig. 5 shows the scale difference between some examples of the present British Standard range and the new universal beams.

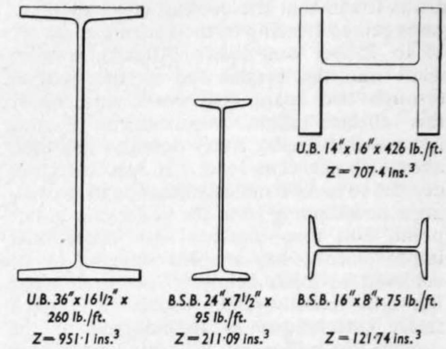


Fig. 5—Comparison between universal and B.S. beam and column sections

The wider flanges in the new range of beams and also the fact that flange and web thicknesses can be increased in the rolling process, will enable rolled sections to be used in many cases where previously it was necessary to compound British Standard beams. As an example, a 21in by 13in by 112 lb per foot universal beam having a modulus of 249·7 cubic inches is comparable with a compound of 21in by 12in composed of a 20in by 7½in by 89 lb per foot British Standard beam and two 12in by ½in flats. This section weighs 133½ lb per foot and has a modulus of 254·2 cubic inches. The universal beam is 84 per cent of the weight of the compound with a modulus of 98 per cent of that of the compound.

Far exceeding the importance of saving steel in such cases are, of course, the other savings effected, namely, the big reduction in fabricating cost and perhaps even more important the reduction in fabricating time.

Another comparison of interest is in regard to the deflection of beams. Since the introduction of the 1948 edition of B.S.S. 449, permitting a maximum flange stress of 10 tons per square inch in beams, the limiting deflection of 1/325th of the span often dictates the section of beam to be used. Compared with the present standard beams, considerable economy can be expected by using the new universal beams with their much larger " moment of inertia divided by weight " ratio, where stiffness is the criterion for design. In certain examples considered savings of weight between 6 and 8 per cent were shown.

A further economical application will be that of using one beam split into two tees to make the upper and lower boom of lattice girders. There are many possibilities for this type of girder, as it is unnecessary to introduce gusset plates for the attachment of the diagonal and vertical members of the booms. Similarly, gussets can be avoided in roof truss construction by using the long stalk tees cut from universal beams as rafters.

Columns

The wide flange sections of the new range are specially advantageous for columns. The wider flange gives a better distribution of the metal about the weaker axis, with a corresponding increase in the least radius of gyration.

The advantages of universal columns over the British Standard columns are even more marked than for beam sections. For the same weight per foot the universal column will carry a load approximately 25 per cent greater than the British Standard column on a length of 12ft and for longer lengths the load increase is even greater.

It is well known that the British Standard range is lacking in suitable column sizes. The most popular British Standard column section generally available is undoubtedly the 10in by 8in, and this is often used as the core section of a column, the flanges being reinforced by flange plates to increase the carrying capacity as required. This form of construction is quite economical in weight of steel, but uneconomical from a fabrication standpoint.

In very special cases of heavy columns where even the largest and heaviest section of universal column is inadequate, as may arise in multi-storey building construction, there will be a core section available. This is a 14in by 16in by 320 lb per foot universal section rolled primarily for the purpose of adding outer plates and slabs, either by riveting or welding, to form the required section. Obviously such sections will carry exceptionally heavy loads and even with the workmanship required in the formation of such columns they will compare very favourably with members which at present have to be built up either from three slabs welded in " H " form or from a section of which a British Standard beam or beams form the core.

16mm Sound Film Projection with 2kW Xenon Lamp

A 16MM SOUND-FILM projector with a light source consisting of the new "Mazda" Xenon arc lamp has been developed and produced by The British Thomson-Houston Company, Ltd., Rugby. The Xenon lamp (" Mazda " XE/D), which is illustrated in Fig. 1, is a high-intensity light source suitable for horizontal operation. It has a nominal rating of 2000W and works from a 28/30V d.c. supply, taking a maximum current of 100A. The colour temperature is about 5600 deg. K., the emitted light covering the whole visible spectrum from ultra-violet to infra-red. No warming period is required and the arc strikes to full brilliance immediately it is switched on. It is stated to give nearly four times the brilliance of a 750W tungsten filament lamp. The lamp itself consists of three electrodes—anode, cathode and igniter—enclosed in a gas-filled envelope which is of fused silica, approaching optical quality and is strong enough to need no protective casing.

The projector, which is designated 450-X, is a development of the B.T.H. 450 projector, redesigned to accommodate the new lamp. The components are rearranged to suit the new form of lamphouse which is at right angles to the optical axis of the projector. The lamphouse contains the lamp mounting (which is adjustable for initial alignment of the arc and then needs no more attention), the high voltage supply unit for arc ignition and the condenser-lens/rear-mirror system which concentrates the maximum amount of light into the projector beam. A small blower provides ventilation of the lamphouse and cooling of the lens system. The hose connection which directs the cooling air can be seen at the bottom of Fig. 2. Interlocks are fitted to prevent the door from being opened while the lamp is alight. To take advantage of the greatly increased light output from the new lamp, a " Cinemascope " attachment can be mounted in front of the projection lens, the fitting being hinged to swing aside when not in use.

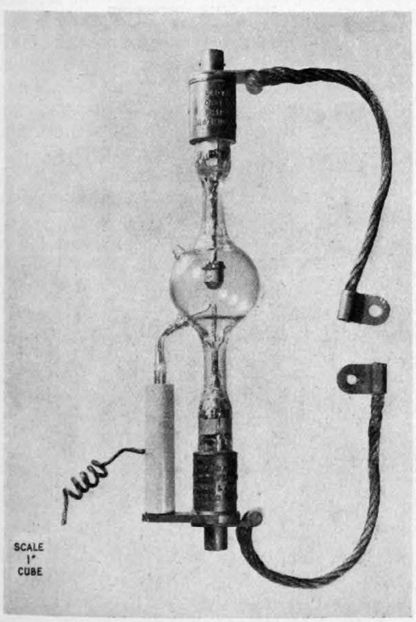


Fig. 1—2kW Xenon lamp. When fitted to a 16mm projector it gives a screen illumination of 1000 lumens, which is about four times that of a 750W tungsten filament lamp

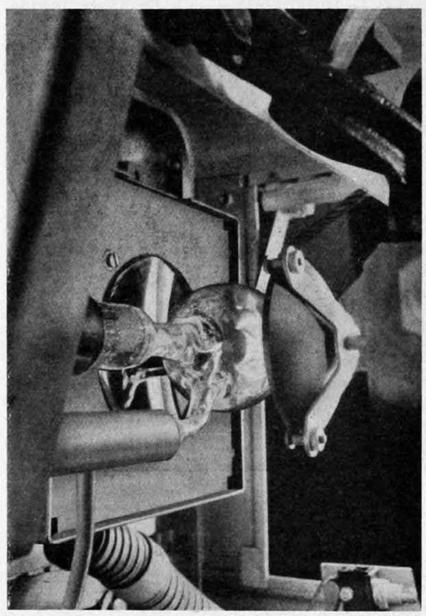


Fig. 2—2kW Xenon lamp mounted horizontally in the lamphouse of the B.T.H. 450-X projector. The flexible hose at the bottom carries the cooling air

The sound-head has been redesigned to reproduce either optical or magnetic sound tracks, as required. In other respects the 450-X projector is identical with the 450 projector.

As illustrated in Fig. 3, the projector/lamphouse assembly is mounted at operating height on the supply cabinet. This cabinet contains a single-phase transformer and germanium rectifier, incorporating voltage-doubling and smoothing circuits ; the d.c. output is 20/30V at 100A. A standard 450-projector mains-rectifier unit is included to supply power for the projector motor and the 30W amplifier. A 7in diameter axial-flow fan cools the germanium rectifier.

The controls are arranged below the operating side of the projector and consist only of push buttons for the mains supply contactor and for the lamp. The lamp can be switched " on " or " off " at will. A mains isolating switch-fuse is fitted inside the cubicle.

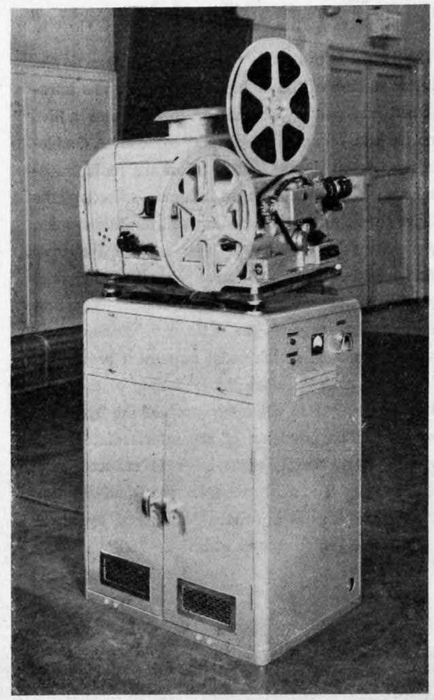


Fig. 3—In the B.T.H. 450-X projector shown here the lamphouse is at right angles to the optical axis and is designed to carry the 2kW Xenon lamp. The projector is mounted on its power supply cabinet

The whole equipment will operate direct from a domestic a.c. 15A power supply point. The only other connection required is for the loudspeaker, for which a socket is provided on the projector.

Under normal conditions, with the projector running and using a 2in f/1·5 projection lens, a total screen illumination of 1000 lumens is obtained, that is about four times the light output of the modern 750W tungsten-filament lamp ; it follows that the Xenon lamp will give a screen picture twice as wide and twice as high, for the same brilliance.

Atomic Energy Symposium in Sydney

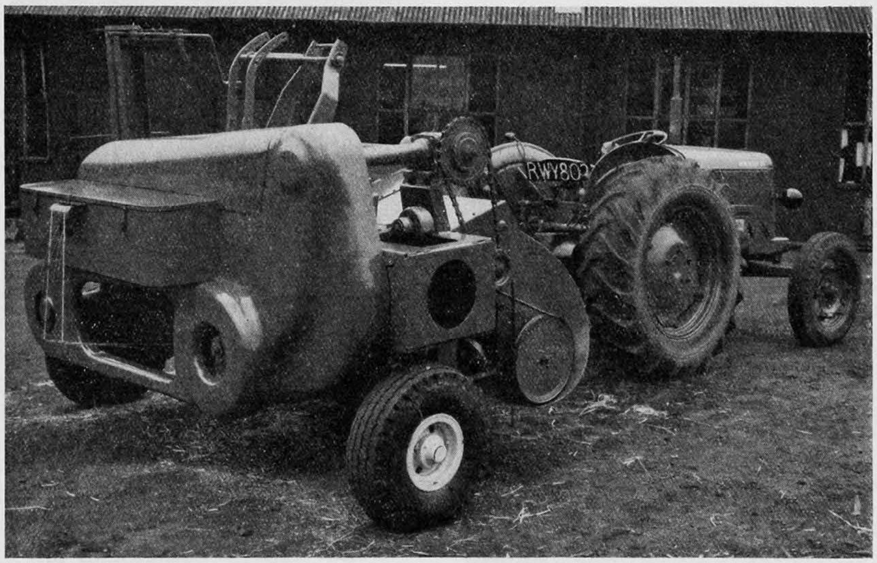
IT has been announced that a major symposium on the peaceful uses of atomic energy will be held in Sydney during the week June 2 to 6, 1958. The symposium is being sponsored by representatives of the universities, professional institutes, industrial firms, power authorities, Commonwealth and State Departments and the Australian Atomic Energy Commission. There is to be discussion of the technical and scientific aspects of the peaceful uses of atomic energy. Particular attention is to be given to the part atomic energy will play in the development of Australia. A special exhibition is being organised to show developments in uranium mining, research into nuclear power, and the industrial uses of radioactive isotopes.

Scientific and technical papers are invited for presentation at the symposium. The exact title and a résumé must be submitted not later than December 30, 1957, and the final draft not later than March 15, 1958. Preprints will be sent to those attending the symposium, and the papers will be taken as read at the sessions themselves ; the authors will have ten minutes in which to present their papers, so allowing time for discussion.

An enrolment fee of four guineas is required, but will be waived for foreign visitors. Assistance will be offered in obtaining accommodation. Further information is available from the Symposium General Secretary, A.A.E.C. Research Establishment, Sutherland, New South Wales, Australia.

Farm Machines

The David Brown 900 "Livedrive" tractor is the latest version of the 40 h.p. diesel which was introduced last year. This model incorporates a live power take-off and live hydraulic system. A double-action clutch is provided to allow the main transmission to be disengaged without affecting the drive to the power take-off or the hydraulic system. An advantage claimed by the makers for their design is the provision of three separate and distinct phases in the engagement of the clutch. The first movement disengages the main transmission; the second phase of clutch pedal movement provides a "neutral zone" before the beginning of the third stage, namely, the disengagement of the hydraulic system. The provision of the intermediate stage ensures that clutch plate wear is reduced to a minimum. To accommodate the double-action clutch the chassis has been lengthened by about 3½in, compared with the "900"



This pick-up baler is driven from the power take-off of a tractor. The ram moves at right angles to the forward travel of the machine, thus delivering the bale at the side of the machine. This gives the tractor driver good visibility not only of the pick-up reel, but also of the other working parts of the machine, and of the completed bale; the transverse motion of the ram is also designed to obviate shock on the tractor drawbar, making uphill working easier. Side delivery of the bale enables the crop to be fed directly into the bale chamber, where it is immediately compressed by the ram. To ensure even density of the bales the entry of the crop into the bale chamber is controlled by adjustable forks. The length of the bale is simply adjusted by a single bolt, and the density is adjusted by a hand screw, which contracts or expands all four sides of the compression chamber simultaneously. The side-delivery arrangement means that the working width of the baler (11ft 6in) is greater than normal, but by folding the compression chamber, and by swinging the drawbar into its alternative position, the transport width is reduced to 8ft 3in. A one-piece glass fibre moulding forms the guard for the ram drive mechanism

The rotary tiller has been designed to combine the action of a disc harrow and rotary tine cultivator. This illustration shows the implement in its transport position. There are four blade-carrying axles, two on each side of a central beam, which are linked in diamond formation. A vertical pivot attaches this assembly to the headstock. In order to give the forged steel blades the best possible chopping and tilling action, the axles are set at an angle to the line of travel. Yet each pair of axles can move up and down independently of the others, giving the implement a "ground-hugging" flexibility. This flexibility enables the implement to be converted quickly to its transport position, by swinging up the axles and locking the headstock pivot. The tiller is made in three widths, 7ft 6in, 8ft 10in, and 9ft 10in, to suit tractors of varying horsepower

Farm Machinery Production at Leigh

Two years ago, Harrison, McGregor and Guest, Ltd., joined the David Brown Companies. As a result of the merger, an extensive programme of modernisation and expansion is now in hand at the Albion Works, Leigh, Lancashire. The first stage of the programme has been completed and new implements and machines are being added to the products of the company.

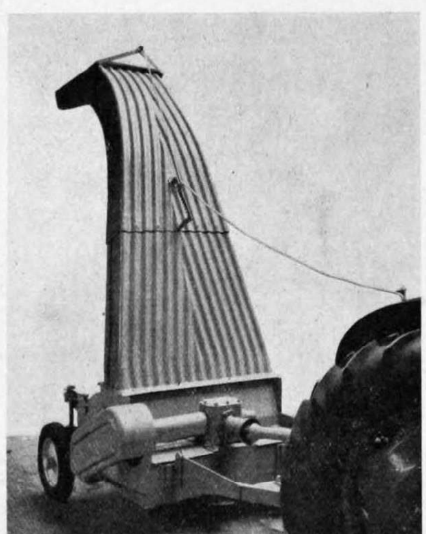
THROUGHOUT the past eighty-five years agricultural machines and implements of many kinds have been produced at the Albion Works, Leigh, Lancashire, of Harrison, McGregor and Guest, Ltd. When the firm was started in 1872, under the title of Harrison, McGregor and Co., its principal activity was the manufacture of chaff cutters. But other products were soon forthcoming. The progress made in the early years of the Albion Works can be best appreciated by comments in THE ENGINEER of December 14, 1877. There, in a description of the machines at the Smithfield Show, it was stated : " Messrs. Harrison, McGregor and Co. show several of their reapers and mowers, which, owing to their really good design and workmanship, have already secured a position in the first ranks of the most successful machinery, though the manufacturers have but two or three years entered the list of competitors. Their self-raker reaper recommends itself on account of its superior simplicity."

The " self-raking " and " back delivery " reapers, as well as " Albion " reaper-binders, were in demand for many years. In fact, as recently as ten years or so ago, the firm met a request from U.N.R.R.A. for about 200 " sail " reapers (as distinct from self-binders) as it was realised that these machines could fill an urgent need in some particular territory where there were no operatives sufficiently skilled to handle equipment that was much more up to date ! At the beginning of this century, manufacture of " Albion " self-binders was started and, in fact, continues to-day for, despite the increased and increasing use of combine harvesters, there is still a call for their immediate predecessor. In a recent conversation with Harrison, McGregor and Guest, Ltd., we learned that a week or two ago a request arrived from a farmer in Australia for a spare part for a binder purchased in 1913, the request being accompanied by ten shillings to cover the present cost ! At the same time, it was recalled that, over fifty years ago, two " Albion " binders, each with a cutting width of 6ft, were hitched to an " Ivel agricultural motor "—the predecessor of the modern tractor—and successfully operated in tandem to harvest a corn crop.

An extensive programme of reorganisation and reconstruction is now in progress at the Albion Works, Leigh. It was put in hand two years ago, when Harrison, McGregor and Guest, Ltd., became a part of the David Brown Companies of Huddersfield. The tractor division of the David Brown Companies was established in the 1930s at Meltham, Huddersfield, and up till recently the David Brown tractors and the tillage implements designed for use with them have been manufactured at the Meltham factory. The Meltham factory is, however, now concentrating solely on tractor design and production, and the implement manufacture has been transferred to Leigh. The programme at Leigh has been based on a systematic overhaul of the entire production plant. The first steps have included enlarging and re-equipping the experimental department and extending the field testing facilities.

The manufacturing and assembly departments of the works are also being modernised, a project which has involved the replacement of some dilapidated buildings and the conversion of others. For implement production at Leigh, fabricated steel components are being used instead of iron castings wherever possible. On that account, the iron foundry has been closed and is being replaced by a combined fabrications assembly and spray painting department dealing with the bigger products such as combine harvesters, balers and forage harvesters. Among the new equipment in the fabricating section there is a 90-ton hydraulic press and also a dynamic balancing machine for testing the drums of combine harvesters. The saw mill and wood-working departments have been completely rehoused, and to deal with packaging for export a case-making department has been established. Another new department is that which has been equipped to develop the use of glass fibre for various parts of the implements and machines which are to be made at the Albion Works.

Combine harvesters, pick-up balers and manure spreaders being assembled at the Albion Works



Forage harvester for cutting, chopping and loading grass and other crops. It is designed for operation by tractors of 20 h.p. and upwards

New Products

Just over a year ago, the David Brown 5ft power take-off driven combine harvester was put into production at the Albion Works, and the manufacture was also started of a redesigned version of the " Albion " manure spreader. This week, the David Brown Companies have announced the introduction of four new machines which are to be made at Leigh. They are a pick-up baler, a forage harvester, a rotary tiller and a front loader. At the same time, a new version of the David Brown " 900 " tractor is going into production at the Meltham plant at Huddersfield. The tractor, baler and rotary tiller are illustrated and briefly described on page 676.

The forage harvester, known as the " Hurricane," is illustrated on this page. It is designed for operation by tractors of 20 h.p. and upwards, and the makers describe it as a machine which will cut, chop and load any crop from grass to bracken. In operation the tractor, forage harvester and the trailer into which the crop is deposited follow in line, so that only one man, the tractor driver, is needed to control the equipment. The drive is taken from the tractor power take-off shaft by a gearbox which is centrally mounted at the front of the forage harvester. From this gearbox the power is transmitted by a cross shaft and couplings to vee belts which drive the cutter drum. The drum, which is mounted on self-aligning bearings, carries twenty flexible arms, each of which is fitted with an L-shaped cutting knife ; the length of cut can be varied between 2in and 8in, and, if required, the knives can be replaced by a set of chain links for pulverising the crop to be handled. The normal speed of the drum is 1600 r.p.m., and as the crop is chopped and lacerated it is blown through the chute into the trailer behind. The direction of flow is controlled by a hood which can be positioned by a rope, from the tractor seat, as indicated in our illustration. The chute, incidentally, is an example of the use at the Albion Works of glass fibre. It may be added that the overall width of the " Hurricane " is 5ft 3in, and its height, with the chute, 10ft.

The front end loader, which has been designed for use with the David Brown " 900 " tractor, is said to be capable of lifting over half a ton to a height of 9ft. It has an unusually high pivot point, so that weight transference to the rear wheels of the tractor is assisted as the bucket is loaded. The loader is carried on a three-point support frame which is mounted well forward on the tractor in a position which permits the load to be discharged 4ft clear of the tractor bonnet and which also facilitates the fitting of a tractor cab if required. The boom comprises two tubular steel lift arms strengthened by a double cross member, and the backward swing is controlled by adjustable stops. Two hydraulic rams, which are operated by the tractor's hydraulic lift lever, raise and lower the boom, and the tipping of the loader bucket is effected by a hand lever attached to a cross shaft at the base of the lift arms. A bucket return latch mechanism coupling the operating lever cross shaft and the loading bucket has been incorporated in the design. When the lift arms are raised, latches engage with the bucket control arms, which are free to rotate round the boom support shaft. These control arms are pushed backwards so as to retain the bucket in the loaded position. The load is discharged by means of the operating lever, the action of which frees the latches from the bucket control arms, the laden bucket automatically tilting forward and discharging its load. On lowering the bucket, the latches revert to the engaged position, and the loader is ready for the next lift. Two alternative ram positions are provided, one for maximum lift and the other for maximum outward pressure. Attachments available for use with the loader are a seven-tine manure fork (as shown in an accompanying illustration), a 9 cubic foot capacity dirt bucket, a sixteen-tine root bucket, and a loader platform comprising a steel-framed wooden extension, 72in long and 29½in wide, which is fitted over the manure fork tines.

Front end loader, shown here with manure fork attachment

During a visit last week to the tractor division of the David Brown Companies, at Meltham, we saw all the new machines being demonstrated. At the same time, we were shown a narrow version of the 14 h.p. " 2D " diesel tool frame tractor, which is being made specially for work in vineyards and on fruit farms. Its overall width is 41in. The original " 2D " was described in our issue of December 2, 1955.

Automatic Production Lines for Tapered Roller Bearings

A new factory of British Timken, Ltd., has been equipped for the continuous automatic production of tapered roller bearings required in large numbers. At present it is turning out about 3,000,000 bearings a year, mainly for the automobile industry, and has an ultimate potential of 5,000,000 bearings in sizes between 1½in and 3in diameter.

An investigation was started about five years ago by British Timken, Ltd., into the economic possibilities of a highly mechanised system for the continuous production of tapered roller bearings of one size required in relatively large numbers. It was found, however, that there was insufficient demand for any one size of product to occupy fully such a line, and a compromise was reached whereby a degree of flexibility in respect to size would justify such a project. A new factory was then laid down and equipped with lines for the production of one size of cup and cone. As a result of some three years' development and operating experience with this line, it was decided to increase the number of bearing sizes to be manufactured in this manner. The two original lines were disassembled and the factory was rearranged to house two improved cup and two improved cone lines as it was thought that the future promised sufficient standardisation of bearing sizes to warrant these plans.

The annual production rate of the new factory at present averages some 3,000,000 bearings of sizes between 1½in and 3in outside diameter. These tapered roller bearings are supplied in the main to the motor-car trade, both at home and overseas. The firm states that this figure of 3,000,000, however, is not the designed optimum output, and as the demands for new sizes of bearings become of sufficient volume to be economically worth while to tool, they will be added to the production range of the new lines, until the desired maximum output of 5,000,000 bearings a year is attained.

The new factory, which has a floor area of 33,000 square feet, is divided into three main departments—an automatic machine shop for producing machined components from tube ; a hardening shop for heat-treatment of machined pieces; and a grinding shop which includes the cup, cone and roller grinding, as well as the assembly, greasing and packing sections. The sections and most of the individual machines are connected by specially developed mechanical handling and feeding systems incorporating storage units and operating in conjunction with automatic loading and unloading mechanisms on the machines themselves.

In the automatic department extensive use is made of carbide tools on both the single and multi-spindle machines, and this form of tooling, which was specially developed for the new project, has been widely adopted in the main shops of the British Timken works. This department is divided into four main production lines. On the first line three single-spindle automatics built to the firm's own requirements, produce cups ranging from 2¼in to 3in outside diameter, and discharge via conveyor and elevator units into storage bins. From these bins the cups are delivered on to gravity chutes, on which they are automatically turned into the correct position for presenting to a chamfering machine and then a peripheral marking machine. The second line is equipped with two carbide-tooled, five-spindle Wickman automatics, producing cups from 1½in O.D. to 2¼in O.D. Chamfering of the cups is done on these machines and a single-deck spiral brush feeder is used to supply the cups to a separate marking machine.

The third line, used for the production of the larger cones, is at present being changed

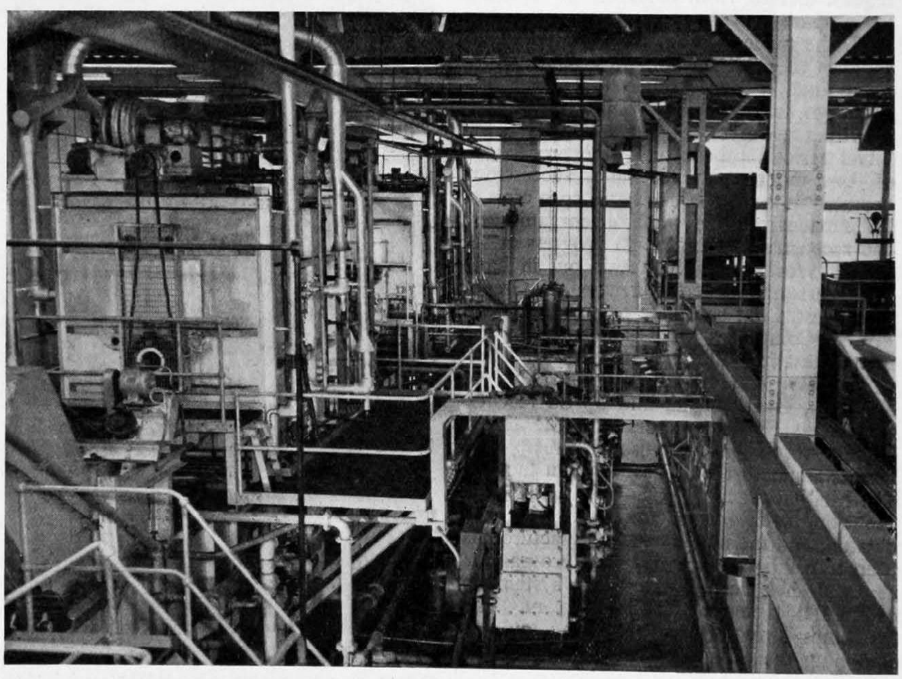


Fig. 1—Heat-treatment section for bearing cones

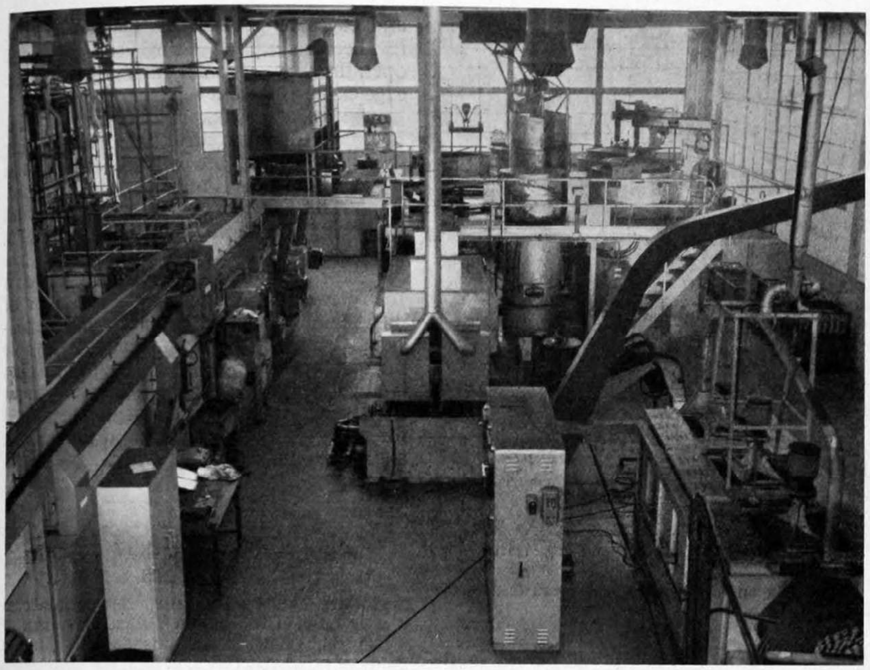


Fig. 2—Heat-treatment section for bearing cups

from high-speed tooled 2¼in four-spindle Acme Gridley automatics to carbide tooled 2¼in, six-spindle Wickman machines, which are capable of an included final chamfering operation as with the small cups. Cone marking on the broad face is done with a 25-ton crank press, incorporating a fixture specially designed to avoid rib distortion during pressing. A single-deck brush feeder again provides buffer storage between the automatics and the marking machine. The fourth line arranged for making small cones consists of three 1⅝in, four-spindle Acme Gridley automatics with a separate vertical chamfering machine and marking machine. A small bulk storage hopper and sorting mechanism are used to supply cones for chamfering and marking as for the large cups.

The parts produced on each automatic line are separately elevated into large bulk storage hoppers, situated between the automatic and heat-treatment departments. These hoppers are of sufficient capacity to enable complete tooling changes to be made in the auto shop without disrupting production in the subsequent departments. Swarf ejected from multi-spindle machines is conveyed in ducts by pneumatically operated forks, whilst the single-spindle machines are cleared by high pressure coolant jets in a separate duct. Both systems deliver to a swarf house where the swarf is crushed and loaded in a container for collection.

To reduce the time involved in changing over machines for different cup and cone sizes and to eliminate need for adjustments on a machine, the tool sets for the various operations are preset in blocks, with the use of special fixtures, and held in readiness for replacement or changes in component size.

In the heat-treatment department the parts are first carburised for seven and a half hours to ten hours at 920 deg. Cent., giving a case depth of 0·035in to 0·055in, depending on the size and the section of the component. This is followed by quenching in oil ; the parts are then hardened by reheating to 780 deg. Cent. and quenching in oil ; finally, tempering is carried out at 165 deg. Cent. for two hours and the parts allowed to air cool. Two entirely different installations are used for this purpose, and are differentiated by the fact that certain of the larger thin section cups require controlled jig quenching during the hardening process to avoid distortion, and to maintain minimum grinding stocks. Jig quenching, therefore, is an operation which needs to be included for some cups but is unnecessary for all cones in the present range.

In the cone treatment section, to be seen in one of the photographs we reproduce, the cones are vibrated from bulk storage and elevated at controlled rates into a continuous rotary spiral carburising furnace. After quenching at the discharge end of this furnace, the cones pass through a spiral washing machine before entering the hardening furnace, and they are washed again between the hardening quench and the tempering furnace. All three of these furnaces are gas-fired and separate sulphur extraction and " RX " gas generating plants are provided to treat the town's gas before its supply as the carburising medium. Propane is finally added to the treated town gas before entry to the carburising furnace.

The second heat-treatment section for the cups consists of two electrically heated pit carburising furnaces, a quench receptacle capable of circulating oil at 2400 gallons per minute, and a circular trichlorethylene vapour degreaser. This cup treatment section is shown in Fig. 2 ; the complete equipment is grouped within a circle of 7ft radius. Movements of work between operations in the cup section are not fully automatic but are effected by a central crane used for lifting stacks of three nickel chrome work containers. Components are vibrated into the containers from bulk storage, carburised, quenched and then emptied into the hopper of a jig hardening equipment. This cup hardening operation consists of reheating the parts to 780 deg. Cent. and then jig quenching for a period varying between seven and ten seconds. The equipment used is completely automatic and its sequence timing is controlled from a central station, by-passing being provided at the quench end to ensure that only parts which have been heated and jig quenched the required time pass on to subsequent operations. The cups are fed from a hopper at one end of the furnace on to a unit which ensures that they are fed in the correct position into an eight-lane distributor. This distributor feeds the cups into the pusher fed lines of the furnace. Two lanes of components are fed forwards in the furnace at each cycle of the pusher gear, so that each pair of lanes in turn deposits a pair of cups into the quenching jig at the far end at predetermined intervals. Should a cup jam in the quenching jig or otherwise prevent the full stroke of the plug, a by-pass flap opens upon discharge and the piece is diverted from the subsequent cooling oil bath.

From this oil cooling bath the parts are elevated to pass through a continuous tempering furnace which has a variable speed drive, and a spreader device to ensure even distribution of parts on the belt. Tempering is followed by shot blasting in a continuous shot blasting machine which has been developed by the firm for handling both cups and cones. As the components are conveyed round in this machine on pegs they are rotated to ensure complete removal of scale from all parts.

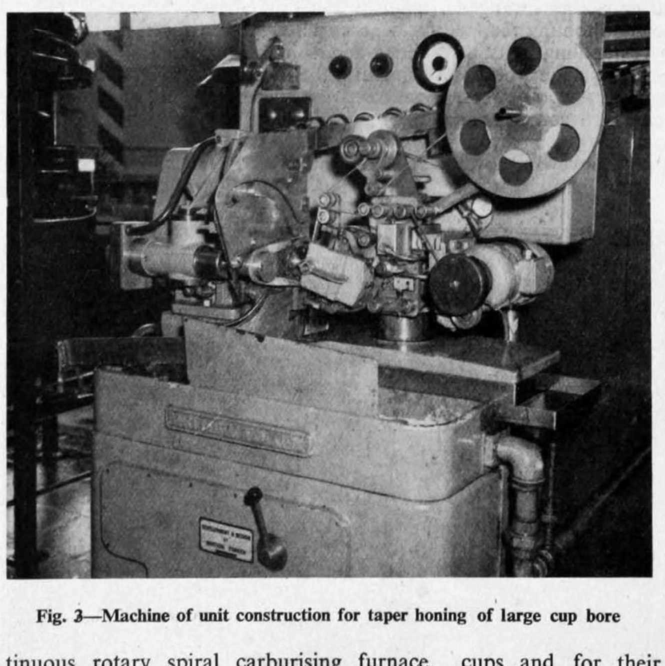


Fig. 3—Machine of unit construction for taper honing of large cup bore

From the heat-treatment section the components are delivered in four distinct lines to the grinding department, where individual grinding lines are installed for the larger and smaller cups and for their corresponding cones. Both the cups and the cones are held in bulk storage hoppers and automatically supplied to the grinding lines as required. All the machines in this grinding department are equipped for automatic loading and unloading and automatic size control devices to ensure a consistent quality with continuous production. Several machines are of the firm's own unit design, whereby standard units are built up in different forms to comply with individual part requirements. A

Fig. 4—Cone grinding line with brush feeders at top end feeding on to circulating conveyors feeding the machine work chutes

typical example of this form of unit construction is the cup bore honing machine we illustrate in Fig. 3. In this machine a standard base, workhead feeding unit and size control gear are used with a special abrasive tape honing head. This head feeds a short length of fresh abrasive tape to the reciprocating honing nose between each cycle, so that a readily controllable and known amount of material is removed from each part to give a consistently high finish.

On both the cup and the cone lines mechanical handling and storage equipment is provided between the various operations. Spiral brush feeders can be seen at the heads of the cone grinding lines illustrated in Fig. 4. These feeders have their capacities arranged to suit current production and tooling change requirements. Other part handling units, at or between the machines, include vertical chain elevators, one-way turn-over devices, cup alternators which can turn components back-to-back, and circulating conveyors. These sectional circulating conveyors cover groups of machines with similar total capacities and they continuously circulate components to the machine feed chutes. When each chute is full the surplus components continue to circulate on the same section of conveyor, waiting to fill a vacant position in the machine-feed chute. Finished ground components leaving the machines are elevated to the next conveyor section, where a similar process takes place before the next operation. A system of limit switches controls the work flow on to a conveyor, allowing sufficient storage during circulation to cover routine stoppages such as grinding wheel changes.

Rollers are supplied to this factory in a semi-finished hardened condition from the main works. The two different types at present required in the factory are ground and graded on the two continuous lines to be seen in the illustration, Fig. 5. They are produced as necessary in a number of different predetermined grades or size groups, each group differing by less than 0·00025in, or half grades of 0·000125in in body diameter. The assembling of the cones, rollers and cages to produce the finished bearings has been reduced to a single semi-automatic operation, one assembly and one automatic cage closing machine serving each line.

Inspection throughout the factory is on a statistical quality control basis, checks being taken at the machines by patrol inspectors at regular intervals. Production personnel are responsible for intermediate spot checks, and for taking the appropriate action depending on the results of their own and the patrol inspector's findings. In addition there is 100 per cent inspection at completion of manufacture on certain visual and dimensional standards. Throughout the whole factory, work flow to any group of machines is regulated at strategic points to prevent bottlenecks, the electro-limit switches used for this purpose being arranged to maintain a predetermined level of work.

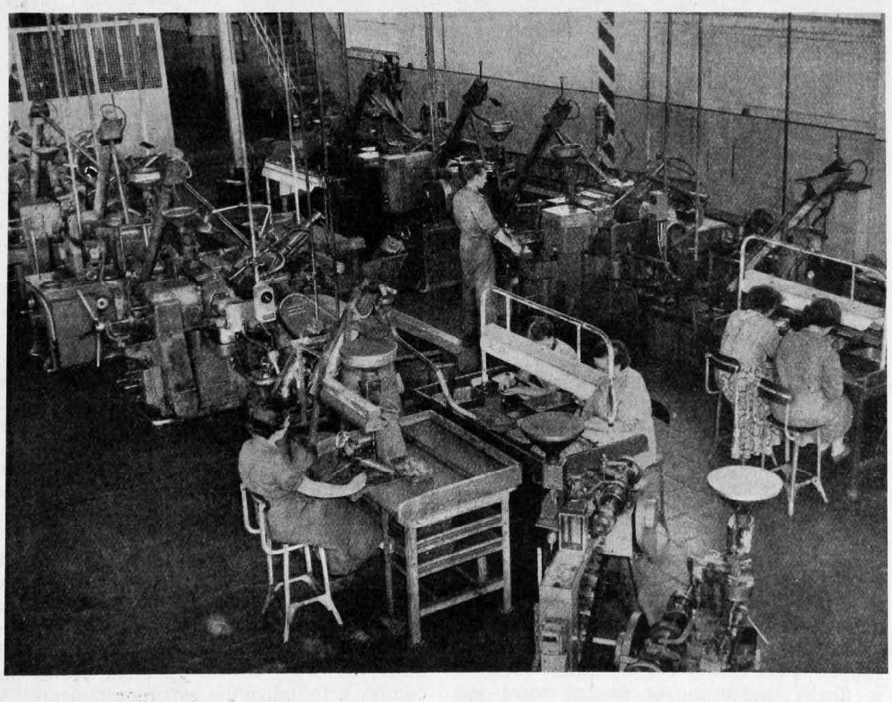


Fig. 5—Roller production line with visual inspection benches and grading machines in the foreground

Laboratory for Study of Fan Acoustics

A NEW acoustic laboratory has been erected and is now in use at the Tottenham works of Keith Blackman, Ltd. It is designed for the study of noise generation in fans, the suppression of this nuisance, and procedures for the assessment of fan assemblies.

The laboratory consists of two brick shells, one inside the other, with a 4in to 6in space between. The outer shell is of 14in brickwork, the inner of 9in. The complete structure rests on a concrete foundation laid on a cork raft 2in thick. The roof is also double, the inner and outer sections being made of precast concrete slabs with a 9in space between. These air spaces are for ventilation, as described later. Supported from the inner walls and ceiling, and leaving a further 3in space, is a timber framework carrying mineral wool, sound-absorbing slabs. The double doors are lined with sound-absorbing pads. To exclude sound as much as possible, the joints between timber, steel and brickwork are sealed with a compound and door edges are fitted with rubber sealing strips.

The base on which equipment is placed for testing is a solid concrete block measuring 10ft by 5ft by 2ft 6in, resting on a 2in cork mat. It is surrounded on the four sides by a 2in air space and covered by insulating pads. The base is set in a pit in the laboratory's cork-covered floor.

Ventilation is by a centrifugal fan, driven by a d.c. motor which permits wide variation in speed. The fan is in a brick housing isolated from the laboratory. Air ducts are lined with acoustic felt, which, together with flexible connections, inhibit transmission of noise. As the volume of the chamber is large, ventilation in the generally accepted sense is not necessary for the two technicians normally present. However, the insulation against noise also insulates against heat exchange in either direction, and the whole of the power input to machines under test must be dissipated as heat within the chamber. The filtered air introduced into the chamber is therefore controlled by the exhaust fan to dissipate heat at up to 25 b.h.p.

Instrumentation includes an audio-frequency acoustic spectrometer made by Brüel and Kjœr, Copenhagen. This provides for either manual or automatic switching to scan the range of frequencies. There are twenty-seven fixed one-third octave filters for the main standard frequencies. Reverberation time, sound level and the frequency response of microphones and loudspeakers can be recorded. It is stated that the accuracy of this equipment is better than ± 2 per cent. There is also a sound level meter comprising a sensitive non-directional microphone, a variable-gain amplifier, rectifier and indicator. Response is claimed to be very rapid, with ballistic characteristics similar to those of the human ear ; heavy damping can be applied to give the average level of fluctuating sounds. An analyser is provided to measure the relative amplitude of the component frequencies in a sound. Stroboscopic instruments and mechanical speed indicators are included in the equipment.

New Buildings at the Radiochemical Centre

A new laboratory and a new office block were opened by the Marquis of Salisbury at the Radiochemical Centre, Amersham, on November 1. The demand for radioactive products has been multiplied more than three times in the last three years; the annual sales value is now £400,000 for some 18,000 consignments, over 70 per cent of which go abroad. The new facilities necessitated by the increase in business —and by the higher standards of safety now observed—are briefly described below.

ON Friday, November 1, 1957, two new buildings were inaugurated at the Radiochemical Centre by the Most Honourable the Marquis of Salisbury. The buildings are a radiochemical laboratory and a block of offices, needed to meet the increasing demand for radioactive products. The total staff at Amersham is now some 200.

The new laboratory is a single-storey building of 12,000 square feet and is the second part* of a group of buildings designed for separation of pure radioactive isotopes from irradiated materials, synthesis of "labelled" compounds for research, and manufacture of radiation sources for industrial and medical use. The scale of radioactive operations will be about 100 times greater than previously.

The administrative building houses the commercial department, which now deals annually with some 18,000 consignments of radioisotopes exceeding £400,000 in sales value. Over 70 per cent of this total is exported to some fifty different countries, mostly by air.

The smaller laboratories opened three years ago were the first in this country designed to house isotope production processes (hitherto, the work had been done in more-or-less conventional laboratories with improvised equipment). The plants have worked satisfactorily, producing in simple form such isotopes as iodine-131, phosphorus-32, sulphur-35 and carbon-14. Production has generally increased to between two and three times the 1954 level and there have been substantial improvements in quality. For example, the best "carbon-14" made recently has been nearly 50 per cent isotopic as compared with less than 2 per cent three years ago. The larger laboratory is necessary because of the increasing scale of operations, the greater diversity of work and the higher standards of protection that are now in vogue. The older plants were adequately shielded for amounts of γ-ray emitter up to about 10 curies, but the present need is for equipment capable of handling up to 1000 curies. At this level the radiations scattered back from the ceilings become important and heavy top shielding is necessary. The new plants have been designed to conform with the recent recommendations made by the Medical Research Council and the International Committee on Radiological Protection. The radioactive materials are strictly localised in vacuum cabinets with adequate shielding. There are two large open working areas which are provided with good ventilation and a separate drainage system. One of the areas is sufficiently large to accommodate a 3-ton gantry.

The facilities for processing fission products are being improved. Cæsium-137 and strontium-90 have to be manufactured in the various special forms required by industry (for example, for radiography). There is also need for increased quantities of the "minor" fission products—promethium, cerium-144, yttrium-91, zirconium and niobium-95, &c. For these purposes a "hot cave" is being constructed and is about half complete. It has three interconnecting compartments which can accommodate up to 1000 curies of cæsium-137. The shielding is 3ft of dense (155 lb per cubic foot) concrete bricks. The windows contain concentrated zinc bromide solution. Three pairs of the Argonne pattern of manipulator are being installed. The caves are intended for chemical work with highly toxic materials, and it has therefore been necessary to provide them with metal liners, each measuring about 7ft by 8ft by 15ft, which will be kept under slightly reduced pressure to prevent the escape of radioactive dust. This is the first time, so far as is known, that the manipulators have been used for this class of work in caves which are not only fully shielded but are also completely enclosed.

A remotely controlled miniature machine shop at the Radiochemical Centre, Amersham. New buildings have been completed, at a cost of £200,000, housing equipment and administrative services to cope with the greatly increased world-wide demand for radiochemicals

To provide for radiochemical work on some of the less common isotopes, a system of standard boxes is being installed for use with fixed gloves or tongs. The boxes are transportable and interchangeable; they can be connected together to form larger units, and when in use they are tethered to the service mains by flexible connections. The transfer of processes from the more conventional laboratory fume hoods to this new system is necessarily protracted, as each one has to be specially devised and equipped, but some boxes are already in operation with sulphur-35.

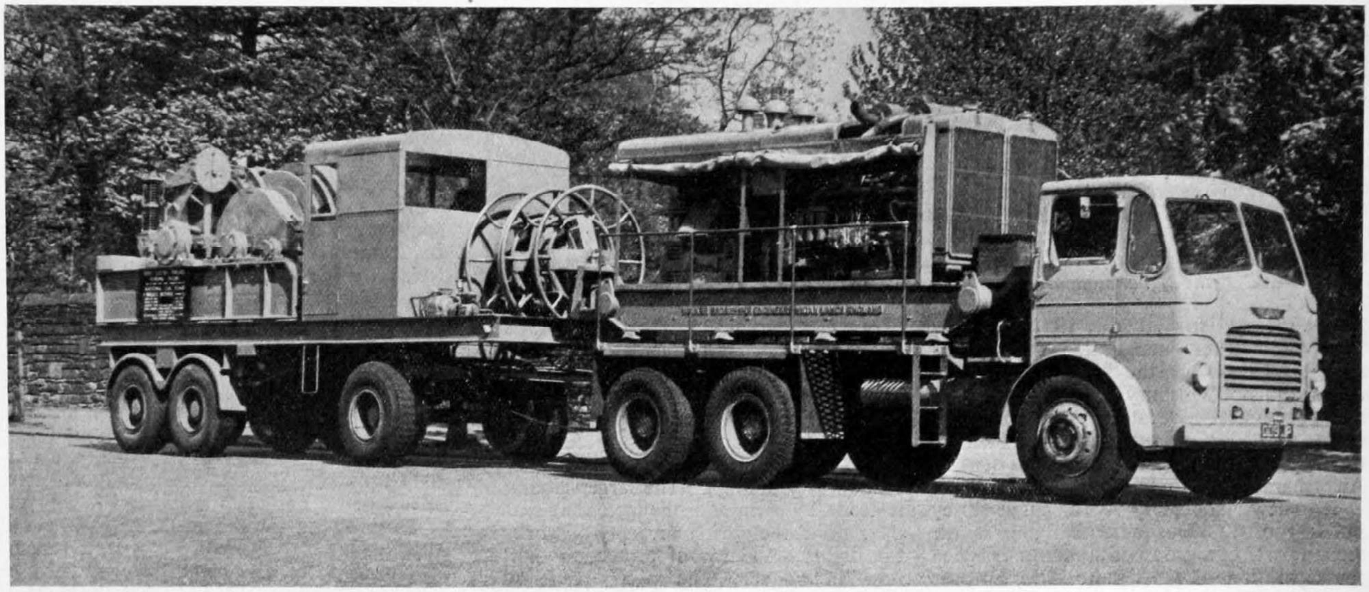
In researches by the radioactive tracer method, carbon-14 remains pre-eminent and there is a buoyant demand for compounds labelled with this isotope, particularly from biochemists. As all compounds have to be derived from radioactive carbon dioxide, the primary source of carbon-14, much effort is devoted to the synthesis of compounds by chemical methods. This section has added more than a hundred new compounds to the Centre's list during the past three years.

Standards applied to labelled compounds are constantly improving. Specific activities are now commonly 5 to 10 millicuries per millimole compared with 1 to 2 millicuries per millimole three years ago, and they may be much higher in exceptional cases. In general the standard of purity which is now expected for labelled compounds is much higher than for inactive chemical reagents; radiochemical impurities amounting to only 1 part in 10,000 can be significant to a discriminating user. In some cases the limit of radiochemical purity is now set by the susceptibility of a compound to decomposition under the influence of its own radiation. Techniques for minimising this effect are being studied.

Notwithstanding the great variety and quantity of isotopes now produced artificially, the demand for products of the natural radio elements has not declined. The production lines for filling radium containers (for both medical and industrial purposes) have been entirely rebuilt so that all manipulations are done remotely and the work is totally enclosed. A new plant has also been installed for producing polonium-beryllium neutron sources which are now in demand industrially for well-logging and for experimentation with reactors. These may contain 5 to 10 curies of polonium per source.

For β-ray emitters which are to be used clinically or industrially, the preferred form is metal foil or plaques. Some 8000 sources of this kind have been manufactured during the past three years, mainly for thickness gauges and static eliminators. Improved manufacturing techniques have made it possible to handle much larger quantities in this way.

* The first was commissioned in April, 1954. See THE ENGINEER, April 16, 1954, page 574.



Diesel-electric portable mine winding equipment in transit

Portable Emergency Mine Winding Engines

WE illustrate on this page one of nine diesel-electric portable winding engines which are being manufactured by Walker Brothers (Wigan), Ltd., for the National Coal Board for emergency winding work at collieries in the event of a breakdown of the main winding gear. This type of equipment was first developed in 1940 by Walker Brothers (Wigan), Ltd., to provide an emergency means of winding should a colliery headgear be damaged by enemy action. The new units, which have been designed and built in collaboration with J. Wood and Sons, Ltd., and the British Thomson-Houston Company, Ltd., comprise a tractor, on which is mounted a diesel generating set, and a trailer carrying the winding engine and control cab. Seven of the equipments being supplied are designed to raise a total suspended load of 5 tons from a depth of 3000ft at a mean rope speed of 12ft per second, and two to raise a total suspended load of 3 tons from a depth of 1800ft at 10ft per second.

In the 5-ton winder a Rolls-Royce, C8NFC, twin-engine power pack, with engines rated at 420 b.h.p. at 1200 r.p.m., drives a B.T.H. generator, with a continuous output of 165kW, 320V, supplying current for a 200 h.p. winder motor. The 3-ton equipment has a C6NFC twin-engine power pack with engines of 236 b.h.p. at 1200 r.p.m., coupled to an 85kW, 440V generator, supplying current to a 120 h.p. winder motor.

The makers state that for this equipment either a Leyland " Hippo " or a Scammell " Mountaineer " tractor can be used, an advantage in using the " Mountaineer " being that a Rolls-Royce engine can be fitted, thus giving the advantage of a common engine for the tractor and generating equipment. Mounted on this tractor is the skid-mounted diesel-engined generating station, which may be operated *in situ* on the tractor, or lifted off and operated on level ground if required. Each engine of the power pack drives a reduction gearbox through a plate clutch, and the generator is driven through a flexible coupling from the common output shaft of this gearbox. A saddle-mounted exciter on the generator provides the generator and motor field excitation, together with the control circuit requirements.

The rigid six-wheeled trailer is equipped with pneumatic tyres for movement on the road, and standard gauge rail wheels on the axles inside the road wheels for manœuvring in sidings on site. If desired, the trailer can be adapted for travel on main railway lines. The front end of the trailer is mounted on a turntable which, to facilitate final manœuvring, can be controlled by a hydraulic steering arrangement, operated from the driver's platform. The rear portion of the trailer is carried on a bogie assembly, consisting of two axles rigidly attached by beams which, in turn, are centre located by trunnion blocks.

Integral with the rail wheels on the rear bogie are brake drums fitted with heavy duty brakes of plunger design, which can be actuated either by handwheel on the driver's platform, or by the energising of air cylinders in the brake linkage from the tractor itself.

The bed for the winding engine, which is integral with the trailer, carries the winder motor, reduction gearing, shafts and winding drum. The winder motor drives the high speed pinion through a flexible coupling and this pinion, in turn, engages a wheel mounted on the second reduction shaft. Also carried on the second reduction shaft is the pinion engaging with the final drive gear on the drum shaft. The barrel-type winding drum has cast steel sides incorporating the main brake paths. A dial depth indicator mechanically driven from the drum shaft is arranged with two reduction gears, so that the full dial can be used for full depth or half depth winds.

Caliper brakes on the winding gear are independently operated by helical spring nests in compression and, through air cylinders controlled by a valve operated by the driver's hand lever, the brake operating levers are lifted against the springs for brake release. When the supply of air to the cylinder is reduced, the spring nests apply the brakes, and in the event of failure in the air supply, the brakes fail to safety.

The main electrical equipment supplied by the British Thomson-Houston Company, Ltd., comprises the winder motor and control equipment and the d.c. generator and exciter The motor is controlled by the Ward-Leonard system, and the control equipment consists of a master controller and generator field rheostat, both coupled together and operated from the driver's lever. The contactor control panel houses forward and reverse contactors which close the generator field circuit on to the exciter supply, the appropriate contactor being selected by the master controller according to the direction of movement of the driver's lever. The main d.c. loop connecting the armatures of the motor and generator is connected by the two cables between the tractor and trailer, special terminal boards with sockets being provided on each vehicle for bolted plug connection. Two smaller multicore cables are used for the control, auxiliary and alarm circuits.

When the winder motor is lowering a load it is possible for the system to regenerate, and the regenerative power is absorbed by the diesel engine being driven above its normal speed; thus the necessity for resistances with the more common rheostatic braking is obviated.

The protection of the winder is based on a safety contactor controlling an electrically operated air valve, which, when de-energised, allows the emergency brakes to be applied. The protective devices included in the coil circuit of the safety contactor include overload contacts controlled by an overload relay in the main d.c. loop between motor and generator, overspeed contacts on the overspeed device, overwind limit switch, brake interlock switch, diesel engine overspeed contacts, and emergency stop push-button. Operation of any of these protective devices causes the emergency brakes to be applied.

A control pedestal is provided in the driver's cabin, on which are mounted a rope speed indicator and a duplex pressure gauge recording the service brake cylinder air pressure and receiver air pressure gauge. The emergency stop push-button and safety circuit reset button are fitted centrally on this pedestal. Warning lamps, fitted on the pedestal, include low oil pressure (on diesel engines), low fuel level, high cooling water temperature, low air pressure (for brake system), alarm supply alive lamp, and brake wear alarm. A set of conventional miniature shaft signal lamps is also mounted on this pedestal for controlling winding operations, and telephones are provided for communication between driver and pit top.

PLUTO Becomes Critical

THE U.K. Atomic Energy Authority reports that PLUTO,* the latest material testing reactor at Harwell, became " critical " at 7.50 p.m. on Friday, October 25. PLUTO was designed and built to provide intense neutron fluxes for the simulation of conditions in advanced power reactors. Materials and components are to be tested in experimental assemblies called " loops," built into tubes (" holes ") near the core of the reactor. PLUTO has fewer "holes" than DIDO,† which was formally started at Harwell in November last year, and to which it bears some resemblance. At full power PLUTO is expected to generate a peak flux of 10^{14} neutrons per square centimetre per second with a heat output of 10MW. The fuel is highly enriched uranium, and heavy water is used both as a moderator and as the coolant. The core is an array of twenty-six vertical boxes roughly forming a cylinder. The boxes are made up of curved uranium-aluminium alloy plates to form the fuel elements. Control is by moving seven cadmium-sheathed arms in the core between the fuel elements. The circulating heavy water, which is forced upwards through the fuel element assembly for cooling, is contained in an aluminium tank surrounding the core. This tank in its turn is surrounded by a graphite reflector sealed into a helium-filled steel tank and

* Similar to the Dounreay materials testing reactor (DMTR) described in THE ENGINEER, May 24, 1957, page 786.

† THE ENGINEER, December 7, 1956, page 812.

by the concrete biological shield. Heavy water is pumped through the core tank from outside the reactor. Heat is transferred to a secondary coolant (ordinary water) in an exchanger placed in the heavy water circuit. The secondary coolant dissipates its heat to the atmosphere through cooling towers outside the reactor building. The whole of the reactor zone is enclosed in an air-tight shell with controlled entrances so that accidental releases of radioactivity can be confined. Four of the eighteen " holes " pass horizontally through the reactor. These will be used to hold large-scale " loops " in which fuel, canning materials, coolants, moderators and constructional materials will be tested. The reactor will also be used to produce cobalt-60 at high activity levels for hospital and industrial use.

The reactor and its associated plant and buildings were designed and constructed by a U.K.A.E.A. team in association with the Ministry of Works and Head Wrightson Processes, Ltd.

1250 h.p. Diesel-Electric Locomotives for British Railways

THE first of twenty mixed traffic A1A–A1A diesel-electric locomotives ordered by British Railways from Brush Traction, Ltd., of Loughborough, was handed over to the Eastern Region last week. These 1250 h.p. locomotives have been designed and built to the requirements of the British Transport Commission under the direction of Mr. R. C. Bond, the Chief Mechanical Engineer, and Mr. S. B. Warder, the Chief Electrical Engineer of the British Railways Central Staff, and they are to be placed in service on the former Great Eastern line at Stratford for working freight trains within the Eastern Region.

The new locomotive can be seen in the accompanying illustration, and its leading particulars are given in the table below. The locomotive under-

Particulars of 1250 *h.p. Diesel-Electric Locomotive*

Weight	104 tons
Maximum height	12ft 7in
Maximum width	8ft 9in
Length over buffers	56ft 9in
Bogie wheel base	14ft
Minimum curve negotiable	4½ chains
Maximum speed	75 m.p.h.
Starting tractive effort (26 per cent adhesion)	42,000 lb
Tractive effort :	
One-hour rating	25,300 lb at 14·3 m.p.h.
Continuous	22,400 lb at 16·5 m.p.h.
Engine	1250 h.p. at 850 r.p.m.
Generator continuous rating	823 kW, 686 V, 1200A
Traction motors :	
Continuous rating	250 b.h.p., 343V, 600A, 485 r.p.m.
One-hour rating	247 b.h.p., 312V, 660A, 420 r.p.m.

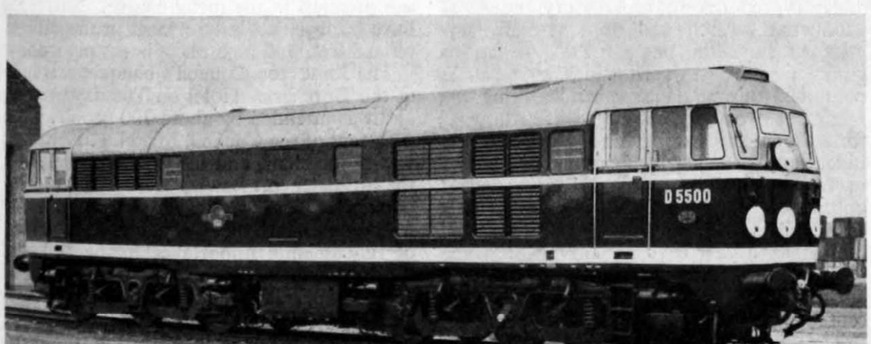
frame is built up of four main longitudinals, which are welded at each end to drag boxes and reinforced by welded cross members, the frame being covered by an unbroken deck of steel plate. Its superstructure is built up of sections, including two cab ends, four removable roof sections, and six removable side sections, which extend the full length of the engine on each side, carried on a framework of angle and top-hat sections. The cast steel bogie frame is supported on four coil springs which rest on drop equalisers between the outer and inner axles. The weight of the locomotive is carried on swung and sprung bolsters on the bogie, each bolster being supported on four elliptical springs carried on two spring planks. One spring plank is situated on each side of the centre axle of each bogie, and is in turn suspended by swing links from the bogie side frames. Roller bearing axleboxes are fitted throughout, and manganese steel liners are provided on all wearing faces of the boxes and guides.

As can be seen in the illustration, there is a driving cab at each end of the superstructure, and a point of interest is the inclusion of a corridor connection which can be used to give access between the units when locomotives are operated in multiple. Each driving cab has the driver's controls on the left-hand side and an assistant driver's position on the right-hand side. The large window areas and relatively narrow pillars give unobstructed vision from both control positions.

The locomotive is powered by a Mirrlees twelve-cylinder, turbo-charged, four-stroke, oil engine, developing 1250 b.h.p. at 850 r.p.m. The welded bed-plate of this engine carries the crankshaft bearings and is extended to provide the foot mounting for the generator to which the engine is directly coupled. This generator provides power to each of the four traction motors, which are hung on the outer axles of the two bogies. These driving axles are fitted with Hoffmann tubes for the suspension of the traction motors, the nose of each motor being suspended by a flexible link from the centre transom. An auxiliary generator mounted on a shaft extension of the main generator has a continuous rating of 30kW, 110V, 273A, and supplies power for all the auxiliaries except the radiator fan and the engine lubricating and cooling water pumps.

The locomotive is controlled by varying the excitation of the main generator and the speed of the engine, current for the field excitation being supplied by the auxiliary generator. The main control cubicle is mounted in the generator compartment, and has large doors giving full and easy access to all the equipment. In the driver's cab a single handle on the master controller provides for engine starting, forward and reverse running, and all running notches.

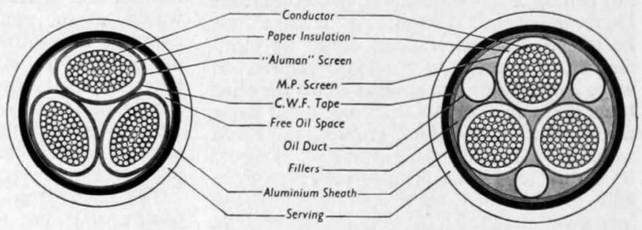
Compressed air braking equipment is provided for the locomotive and Westinghouse vacuum equipment for the train brakes. The driver's brake consists of a vacuum valve which operates the train brakes and automatically operates the locomotive brakes through a proportional valve. A second air brake valve for independent braking of the locomotive is supplied as well as a hand-operated brake. A " dead man " pedal is fitted in each driving position, and a " hold off " plunger on the non-driving side of the cab with a five to seven seconds delay gives a driver time to cross the cab, to observe signals say, without the brakes being applied. Although the locomotives are initially intended for freight working an automatic oil-fired Spanner train heating boiler has been included for use when hauling passenger trains.



A1A-A1A, 1250 h.p. diesel-electric locomotive for the Eastern Region of British Railways

Ductless Shaped-Conductor Oil Filled Cable

A 33kV ductless oil-filled, three-core cable with shaped conductors has been developed by British Insulated Callender's Cables, Ltd., Bloomsbury Street, London, W.C.1. We learn that this cable, together with an associated range of joints and terminations, has passed the type-test require-



Comparison between conventional cable and ductless shaped-conductor oil-filled cable for 33kV

ments of the area electricity boards in this country.

In the D.S.O. cable, as it is called, the main innovation is the introduction of shaped conductors, such as are commonly used in 33kV solid-type cables. It is the shaped cores which made a three-core ductless oil-filled cable possible, the free space between the cores being utilised for oil flow. Circular conductor oil-filled cables incorporate metallic spiral ducts for this purpose, since they include paper fillers to give the sheath sufficient support to maintain its circular construction.

The D.S.O. cable is available with either copper or aluminium conductors over the range of sizes 0·20 to 0·60 square inch (125 to 390 square millimetres) and either lead sheath or seamless aluminium sheath may be supplied. When a lead sheath is used metallic tapes are applied over the sheath to enable it to withstand the internal oil pressure. The aluminium sheath requires no such reinforcement owing to its greater inherent mechanical strength. Anti-corrosion protection is achieved by an overall serving composed of a layer of self-bonding rubber tapes sandwiched between P.V.C. tapes and covered by a wrapping of bituminised hessian tape. This serving is available in several forms to meet particular cable or site requirements and is completely satisfactory under the most onerous conditions.

The adoption of the D.S.O. cable design has resulted in cables of reduced diameter, as can be seen from the comparison made in the accompanying diagram. This improvement, together with the omission of built-in ducts and fillers and the reduced oil volume of the D.S.O. cable compared with the corresponding circular conductor cable, has naturally lowered the cost. The employment of an aluminium sheath, which requires no reinforcement, results, in general, in a still more economical oil-filled system.

The D.S.O. cable is designed to operate at a maximum conductor temperature of 85 deg. Cent., which has been the accepted standard for oil-filled cables in Great Britain for several years. The current ratings are similar to those of equivalent circular conductor oil-filled cables and are some 20 to 25 per cent greater than those of equivalent 33kV solid cables.

COAL CONVEYOR BELTING.—As a result of extensive experiments a new lightweight, non-inflammable belt has been developed for colliery conveyors by Rubber Improvement, Ltd., Wellingborough, Northamptonshire. This belt is composed of three plies of " Terylene " reinforced fabric coated with p.v.c. It is about half the thickness of a conventional p.v.c. coated six-ply cotton belt, whilst being lighter and more flexible.

Industrial and Labour Notes

Wages

When Parliament resumed after the summer recess last week, there was a two-day debate in the House of Commons on the economic situation. Inevitably, in the course of it, there were several references by members on both sides of the House to wages and profits.

In opening the debate, on Tuesday of last week, the Chancellor of the Exchequer, Mr. Thorneycroft, said that the Government was not taking over the control of either the wage or the profit levels in the country, and he did not believe it was seriously suggested that the Government should do so. At the same time, he added, no Government could be indifferent to the problem of wage increases. If wage increases on the scale at which they had been given in the past, and were still being demanded, were, in fact, granted, the result would be a disaster to the country ; it would be a disaster to the firms which gave them and to the men who got them. Wage increases unrelated to, and going far beyond, the general growth of real wealth within the country, the Chancellor continued, were by far the greatest danger which had to be faced. Those who asked for wage increases, those who granted wage increases, and those who adjudicated about wages should have that fact firmly in the forefront of their minds. Any large mistake at this stage, the Chancellor emphasised, could do grievous damage to the nation as a whole. On the following day, the Minister of Labour, Mr. Iain Macleod, elaborated some of the Chancellor's comments on wages. He made it quite clear that the Government was not attempting to instruct arbitration tribunals. The Government, he said, did not seek industrial unrest and would not encourage others to create or to maintain it. But, he stated, if, after the processes of bargaining had been completed and reference to arbitration had been made, if that was appropriate, serious industrial trouble still came, the Government would not hesitate to meet that situation.

Before the end of last week, trade union leaders had made their comments on wage demands which are being put forward at the present time. The leaders of the two principal railway unions emphasised, for example, that wage claims already submitted to the British Transport Commission would be pressed " probably right to the final stage." Another comment, by the general secretary of the Confederation of Shipbuilding and Engineering Unions, was that Government pronouncements had undermined the impartiality of industrial courts and that grave doubts would be thrown on the whole basis of free negotiations.

The Forty-Hour Week

One of the resolutions passed at the Trades Union Congress in September pledged " full support to affiliated unions in their efforts to secure a shorter working week with no loss of pay for their members." During the last few days, the British Employers' Confederation has issued a statement which explains that, in present circumstances, the general adoption of a forty-hour week without loss of pay would add at least £1000 million to the national wages bill in the course of a full year.

The statement points out that, though standard weekly hours vary from industry to industry, a standard week of forty-four or forty-five hours is most widely adopted ; the reduction of the standard week from forty-four to forty hours without loss of pay would therefore mean an increase of 10 per cent in hourly wages, and the reduction from forty-five to forty hours would be correspondingly greater in effect. At the present time, the average hours being worked by men throughout manufacturing industry are over forty-eight a week, which means, in general, about four hours overtime a week. Under present conditions, therefore, the British Employers' Confederation says, reduction of the standard week to forty hours would mean approximately eight hours overtime at an overtime rate based on the increased hourly rate. The statement claims that the total effect of these increases in hourly rates and overtime pay would be to increase manufacturing costs by approximately 2s. 6d. in the pound with corresponding increases in prices to the consumer.

The Confederation ends its statement by commenting that to maintain, let alone to increase, the present standard of living means that production must be at least maintained at its present level. The idea, therefore, that working hours could be reduced to forty a week and overtime abolished is completely unrealistic in the present circumstances. With the possible development of a European Free Trade Area, the Confederation says, the opportunities of expanding markets for this country are great, but they will only be seized if costs are kept competitive.

Iron and Steel Board

The Ministry of Power has announced that Sir Archibald Forbes has intimated that he would like to relinquish the chairmanship of the Iron and Steel Board. When the Board was established in 1953, Sir Archibald was appointed its chairman, and originally agreed to serve for two years. He has continued in the office, but feels that he can ask to be relieved of it now that the Board has presented its report on the development of the iron and steel industry into the 1960s. The Minister of Power has regretfully agreed to Sir Archibald's request. Sir Archibald has agreed to remain in office for a few months, the statement adds, in order that certain matters concerned with the Board's business may be completed under his chairmanship.

Production Trends

According to *Bulletin for Industry*, which is prepared by the Treasury, industrial production, which had been virtually unchanged since the end of 1955, began to climb again last spring. The advance continued during the summer, carrying the index back to the post-war peak. Allowing for seasonal adjustment, the *Bulletin* says, the index rose one point in February, two points in May and three points in June, and it appears to have stayed up in August ; it is estimated that it was then about 6 per cent more than a year earlier. Taking the three months June, July and August together, the increase over a year earlier was around 3 per cent.

The *Bulletin* goes on to state that the rise in the index of industrial production this year has occurred almost wholly in manufacturing and mining. This is in sharp contrast with last year, when manufacturing output declined and was only partly offset by increases in building and public utilities. Within the manufacturing industries, the output of the large engineering, shipbuilding and electrical goods group has continued to expand. A marked improvement was shown after the strikes in March and early April, and by June the output of the group was 9 per cent up on January. The rise in capital goods output has continued. Furthermore, the *Bulletin* observes, the output of chemicals and steel has been at an accelerating rate.

The improvement in mining, however, has been less marked than in manufacturing. Allowing for the differing incidence of holidays, mined coal production in the first five months was over 5 per cent higher than a year earlier. But since the beginning of June it has been running below 1956, and in the third quarter of this year it was 1·4 per cent below a year earlier. In the first forty-one weeks of this year, total coal output was 1·4 per cent up on a year earlier.

The Joint Iron Council

Last Tuesday, the Joint Iron Council, which comprises the Council of Iron Producers and the Council of Ironfoundry Associations, held its annual convention in London. The annual report of the executive committee, which was approved, reviews the work of the foundry pig iron producing and ironfounding industry over the period January 1, 1956, to June 30, 1957.

This report says that, during the period reviewed, the output of iron castings, after reaching record figures in the first and second quarters of 1956, began to be affected by the continuing recession in the motor industry in the third quarter. This recession spread to other industries in the last quarter and, the report comments, iron castings production was quite severely affected. But under the influence of the improved situation in the automobile industry, castings production rose slightly in the first quarter of this year, and by the end of the second quarter had increased to almost record levels. Throughout 1956, the output of castings for the engineering industry in general ran slightly above that for 1955, the emphasis being on the machinery and electrical engineering sections. In the engineering and shipbuilding section, strikes affected castings output in the first quarter of this year, and there was further decline in the second quarter. The report points out that the general easing in the rate of production in the iron foundries has had its effect on the production of pig iron and this has been intensified by a slightly increased use of scrap in the metal charge. Surpluses have been particularly evident in the case of refined iron and high phosphorus pig iron.

The Joint Iron Council's banquet was held at the Dorchester Hotel on Tuesday evening and was attended by about 700 people. The president of the Council, Mr. N. P. Newman, was in the chair, and the principal guest was the Minister of Power, Lord Mills. Proposing a toast to " The Industry," Lord Mills emphasised that iron founding remained of fundamental importance in the development of mechanical, electrical and nuclear engineering. He went on to talk about the need for resources of capital and trained manpower to grapple with the problems ahead, and in this context Lord Mills warned that the days of easy profits and increased incomes regardless of production were over. The financial policies of the Government, he added, had been designed to create the atmosphere in which inflation could be beaten.

Reconstruction of August Thyssen-Hütte

No. II—(*Concluded from page* 650, *November* 1)

Before the war, the August Thyssen-Hütte formed the largest unit of the Vereinigte Stahlwerke steel combine, which itself was the second largest steel producer in the world, after the United States Steel Corporation. Its peak production was in 1938, *when the output of crude steel amounted to* 2,400,000 *tons. After the war production equipment was largely dismantled with the principal exception of most of the blast-furnaces. Rebuilding began in* 1950, *and has proceeded rapidly, so that an annual steel production of* 2,400,000 *tons is again within sight. Here we outline the historical background, and describe some aspects of the reconstruction.*

Basic Bessemer Steel Plant

The Basic Bessemer Steel Plant is equipped with three mixers and six converters, the last converter and mixer coming into operation during April of this year. The plant has a capacity of 110,000 tons per month.

Completion of the new oxygen plant has made possible the production of oxygen-blown ("VK") steel, which is stated to approach the quality of open hearth steel. About 15,000 tons "VK" steel were made last year. Blowing with air results not only in loss of heat to the inert nitrogen but leads to chemical absorption of a small quantity of that element which in concentration of over 0·015 per cent makes the steel brittle. By increasing the proportion by volume of oxygen in the air blast from 21 per cent to 35 per cent, the amount of nitrogen blown through the melt is halved. This reduces the absorption of nitrogen to safe values, and, because of the higher temperature generated, enables more scrap to be added.

Oxygen Plant

In December 1955, the new oxygen plant came into service. It is capable of producing 1800 cubic metres per hour of 98 per cent pure oxygen and 800 cubic metres per hour of 99·5 per cent pure oxygen. The former quality is used mainly for making basic Bessemer steel, the latter for cutting, flame scarfing and welding.

The plant consumes 14,700 cubic metres of air per hour which, after filtering, is compressed by a turbo-compressor to 4·5 atmospheres gauge, and passes through a heat exchanger to the separation plant. The separated gas passes back through the other side of the exchanger and in so doing cools the incoming air. The oxygen is compressed and delivered into the mains or stored in bottles, while the nitrogen is blown off.

No. 2 Open Hearth Steel Plant

This was one of the departments which suffered only partial dismantling. Two of the six furnaces were removed, two more were in a damaged condition and two survived intact. The first furnace was taken back into operation in October 1951 and the last came into service three years later. This section has a staff of 550 men working three shifts (400 men on Sundays). Output is 35,000 tons per month.

No. 1 Open Hearth Steel Plant

Replacing the former plant which was dismantled, No. 1 plant produced its first charge on February 25 of this year. A second furnace was commissioned in March, and the two remaining ones are now due to be commissioned. The furnaces are stated to be the largest on the Continent. They hold 250 tons, are of American design and are fired by oil and coke oven gas.

The ladle crane is claimed to be the largest in the European Coal and Steel Community with a main lifting capacity of 375 tons, and auxiliary hoists of 110 and 30 tons, respectively. With a staff of 192 men, an output of 55,000 tons per month is achieved which can be raised to 61,000 tons per month with continuous operation. The introduction of continuous working is at the time of writing still the subject of some controversy although it has met with the approval of the new men concerned and of their unions. Under the new schedules, each worker would get in addition to his annual leave, ninety-one free days per year, as well as a further thirteen free Sunday mornings.

Cogging Mills

Since all three cogging mills of the old August Thyssen-Hütte were dismantled, one stand of the one remaining heavy finishing mill had to be used for this purpose. A new cogging mill was put into service in May 1953; it has an output of 120,000 tons per month. A second slab cogging mill came into operation on April 1 of this year. Its output of up to 200,000 tons per month is mainly for the hot strip mill.

Heavy and Medium Finishing Trains

There is one heavy finishing train with a capacity of 100,000 tons per month. Some of its output goes to the medium finishing train with a total capacity of 10,000 to 20,000 tons per month.

The rolling programme is very varied and comprises some 125 profiles and semi-finished products.

Wide Strip Hot Rolling Mill

The hot strip mill, Figs. 3 and 4, the first of its kind in Germany, was commissioned on March 3, 1955. It is a 66in mill capable of producing continuous strip in widths up to 1500 mm and thicknesses from 1·5mm to 6·35mm as well as plates up to 12mm thick and 9m long. A maximum width of 1500mm was chosen because only 3 per cent of all sheet production requires to be wider than this, and the demand can readily be filled by re-rolling 1500mm stock in sheet mills. Until the summer of last year, production was at the rate of 35,000 tons per month with single-shift working, but the plant is stated to have an annual capacity of 2,000,000 tons.

Constructional work of the strip mill was begun in September 1953, the buildings being begun in April of the following year and the installation of the plant in July. The whole of the work was thus completed in one and a half years, except for the shear lines which were added in June, 1955.

The mill is housed in five bays, i.e. slab storage, motors, rolling mill, coil storage and finishing. Total roofed floor space is 50,000 square metres with an overall length up to 414m and overall width up to 150m. The structure required about 15,000 tons of steel. About 7500 tons of the existing steel structure and 12,000 cubic metres of masonry had to be demolished. The foundation required excavation of 200,000 cubic metres, and the placing of 50,000 tons of concrete, with 4000 tons of reinforcement. 15,000 square metres of windows—all vertical—had to be glazed. Gas, water and compressed air lines total 10km, with diameters up to 2·5m, and several hundred kilometres of electric cable were laid.

In order to correct the effects of possible mining subsidence, all important foundations were equipped with hydraulic jacks. Thus the finishing stands rest on an 4500-ton reinforced concrete slab supported at three points on spherical bearings which can be hydraulically raised and adjusted for height if necessary, the whole weighing 18,000 tons.

Electricity is supplied at 110kV and transformed to 25kV in the works substation. Water (of which up to 4000 cubic metres per hour are required) is continuously passed through a settling and filtration plant and re-circulated.

Steel for manufacture into strip is supplied from the steelmaking plant in the form of 8 to 16-ton ingots and after reheating in the soaking pits is rolled into slabs of 100mm to 200mm thickness and lengths up to 6m, which weigh between 3½ and 8 tons. The width is from 600mm to 1550mm, corresponding to that of the finished strip. After shearing to length by means of hydraulic shears, the slabs are put into storage. Their surface is checked after cooling and where necessary is cleaned up by flame scarfing.

Three pusher furnaces, each 29m long by 6·5m wide, and having a capacity of 100 tons per hour, are used for reheating the slabs. A mixture of coke-oven and blast-furnace gas, in counter current, is used to heat the preheating, heating and holding zones of the furnaces through which the material is transported on water-cooled beams.

Leaving the pusher furnaces at a temperature of 1280 deg. Cent., the slabs pass between a pair of scale breaking rolls which are followed by upper and lower descaling jets fed with water at 100 atmospheres.

Descaling is followed by roughing in four stands spaced at distances of 16m, 24m and 39m. Each mill is four-high and driven by a 5kV, 4500 h.p., three-phase synchronous motor. Stands Nos. 2, 3 and 4 are equipped with vertical rolls for edging. An overall reduction to 18mm

Fig. 3—The 66in hot continuous strip mill. In the foreground are the six finishing stands

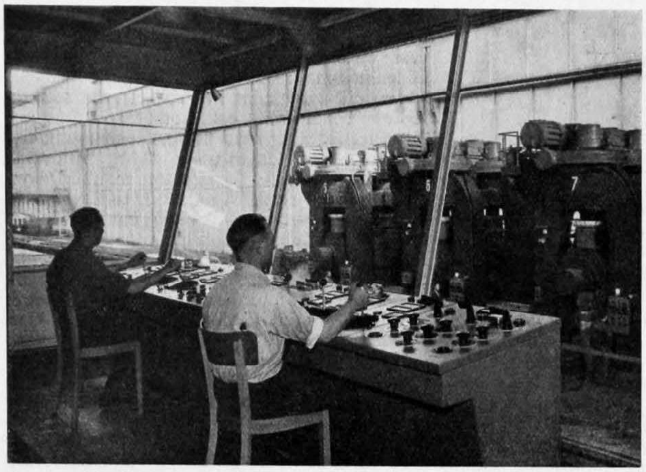


Fig. 4—Control cabin of finishing stands (Nos. 5-10) of wide strip hot rolling mill

thickness is achieved, resulting in a strip length of up to 54m. Shears for cropping the ends, and descaling rolls, are provided.

The finishing train consists of six four-high stands, each driven by an 800V, 5000 h.p., d.c. motor. The motors are supplied from grid-controlled mercury arc rectifiers, so as to obtain the necessary speed control. Whereas the roughing stands roll in succession, the finishing stands work simultaneously, the strip speed increasing at each stand, until the strip emerges at a speed of up to 10m per second in lengths of up to 600m. The strip is quenched by water jets placed over a 110m long run-out table, is then coiled and transferred to storage.

Control of the mill is from ten control desks (Fig. 4), only the setting of the rolls and inlet guides being done at the stands themselves. Measurements include temperature and thickness as well as rolling pressures and speeds.

Most of the coils are further reduced in Thyssen or outside cold rolling mills, the rest being transferred to the adjacent shearing shop equipped with a continuous shearing line which permits continuous adjustment, trimming, slitting and cutting, and is equipped with piler and output conveyer.

Continuous Cold Strip Mill

Some of the hot-rolled strip is further reduced in the continuous cold strip mill. Trials of this mill began in May of last year, after one and a half years' construction. The plant is fully mechanised and with its four-stand tandem mill is the only one of its kind in Germany (Fig. 5). It is capable of processing one third of the present output of the hot strip mill, converting the hot-rolled material to cold-rolled strip or sheet between 0·3mm and 1·5mm thick.

In the layout of the plant, the main difficulties were the lack of available space and the danger of ground subsidence due to coal mining. In view of the fact that the whole area had originally been marshland which had been filled in to a height of 10m to 15m, all heavy structures have to be founded on piles. Although an existing building could be taken over for the pickling plant, additional space had to be provided for the rolling mill and annealing plant, in the three new bays each 230m long and 30m wide. These are similar to the hot strip mill and total 43,000 square metres of floor space with the possibility of extension to 110,000 square metres. In the pickling line, after uncoiling, the hot-rolled strip passes through the stitching or welding machine where consecutive lengths are either stitched or welded together. After cleaning up the weld, the strip passes through the 85m long pickling trough where the surface is cleaned by sulphuric acid ; the strip is then washed, dried and lightly oiled and wound into coils of 12 to 16 tons.

The strip is now ready for cold rolling. In the four stands of the cold rolling mill, which are arranged in tandem, reductions to 55 to 15 per cent of the original thickness are effected in a single pass, at speeds of 350m to 900m per minute, tension between stands being 15 to 30 tons. Output is coiled into lengths of 2km to 6km.

For obtaining deep-drawing qualities, annealing is carried out at 650 deg. to 740 deg. Cent. in one of the twenty bell furnaces which have been installed. These furnaces are fired with blast furnace gas, and each can hold two to four coils stacked vertically. To protect the coils, they are placed under a hood filled with a controlled atmosphere. The whole annealing process, including cooling down to 150 deg. Cent. by means of a cooling bell, takes about three days.

After annealing the strip is dressed in a single-stand temper mill where it is given a 0·5 to 3 per cent reduction, and is then cut into various widths or into sheets or sold as coils. In the construction of the foundations for the tandem and temper mills, about 12,100 tons of concrete were used. Provision was made, as in the case of the hop strip mill, to rectify any misalignment due to subsidence by means of oil-hydraulic jacks. For this purpose the pickling trough, for instance, rests on a bridge structure which in turn is supported on three points and can be raised and levelled by jacks.

For the d.c. motors of the tandem mill, rectified three-phase current is obtained by means of mercury arc rectifiers ; this is thought to be an innovation.

Power Installations

No. 1 power house which dates from 1907, eventually came to house twelve gas-engine-dynamo sets and eleven blowers. After the first world war this was supplemented by No. 2 power house, which, when completed in 1923, had eleven gas-engine-driven dynamos, three steel-plant blowers, two turbo-generating sets and two turbo-blowers, one of the blowers being later re-equipped with a 5MW generator from Marxloh power station, closed down in 1930. No. 3 power house had two blast-furnace blowers and one steel-plant blower. This installation was very badly damaged by bombs. About one year ago, August Thyssen-Hütte possessed a total of twenty-three gas-engine generating sets totalling 66,300 h.p. with a further two sets under construction. In power house 1 there were installed twelve blast-furnace blowers of 1800 to 2600 h.p. each, capable of supplying 50,000 cubic metres per hour at 1·2 atmosphere gauge.

The number of blowers, it was stated, was to be increased to fourteen by rebuilding two from power house 3. No. 2 power house was still being reconstructed. Four of the old gas-engine-driven 3·6MW dynamo sets were again working and there were three 5MW, 5kV turbo sets. Also in No. 2 power house were installed three air compressors for supplying the works at 8 atmosphere gauge. The five blast-furnaces then in operation required 260 million cubic metres of air per month at 1·2 atmosphere gauge, while the basic Bessemer plant used another 50,000,000 cubic metres at 2·7 atmosphere gauge.

About 10,000 cubic metres per hour of cooling water was supplied to the blast furnaces by six circulating pumps, each with a rated capacity of 1740 cubic metres per hour. The cooling water is reclaimed and recirculated.

Near the works power houses stands the new Hamborn power station which came into service in April 1955. It is half-owned by the works which also receives half the current. As an indication of the quantities involved, works consumption in March 1956 amounted to approximately 16,500,000kWh. Some 5,000,000kWh were derived from the grid of Rheinisch-Westfälisches Elektrizitätswerk, and 3,000,000kWh were supplied to outside consumers. Steam consumption was 45,000 to 50,000 tons per month.

Concrete Factory

Among the secondary products of the August Thyssen-Hütte the most important are blast-furnace slag and Bessemer slag which are ground and used as fertilisers. Mention may be made of the lightweight concrete manufactured there since the beginning of 1954. Operating under Swedish licence, the plant makes "Siporex" expanded concrete, producing nearly one quarter of the whole German output. With the installation of two further autoclaves, it is intended to double the present output of 120 cubic metres per day.

The expanded concrete is produced from a ground mixture of blast-furnace cement, sand and water, by adding aluminium powder which in the alkaline mass acts as a frothing agent owing to the evolution of hydrogen. The concrete (which may be reinforced) is cast into oiled moulds and cut to shape after the initial setting. The concrete blocks are cured for twenty-four hours in two autoclaves, 22m long by 2·4m in diameter, each of which holds twelve moulds. By choosing the correct conditions, a concrete is obtained which weighs only about one-quarter of ordinary concrete, and which can be sawn and nailed. Most of the pores are large, and not connected, so that the concrete is non-absorbent.

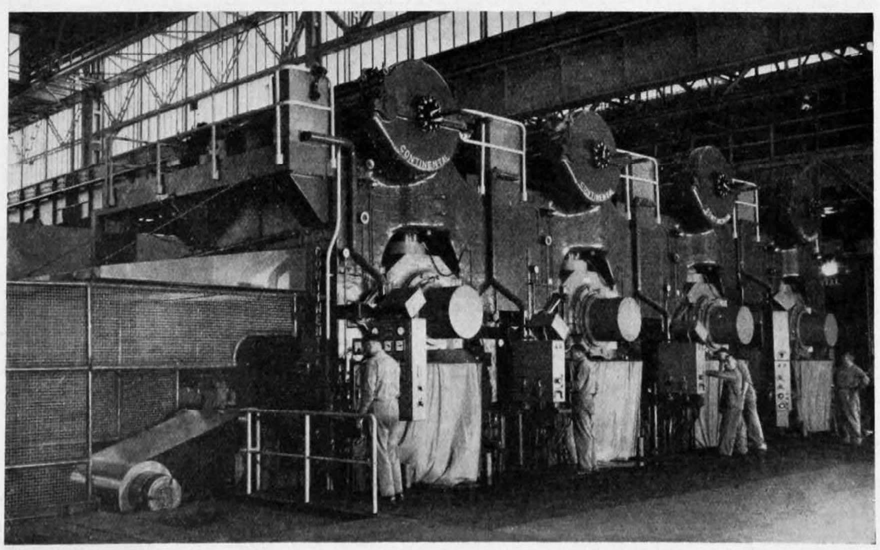


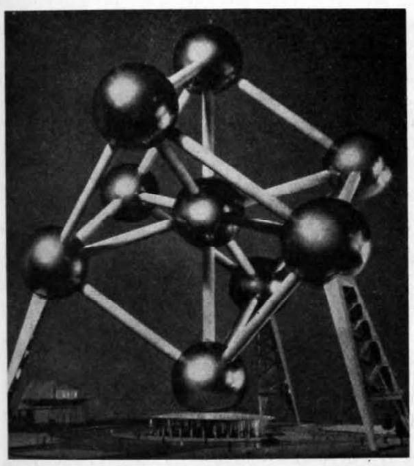
Fig. 5—Continuous four-stand cold rolling mill, for producing strip up to 1500mm wide and 0·3mm to 1·5mm thick, at speeds of 350m to 900m per minute

1958 World Exhibition at Brussels

THE World Exhibition which will open in Brussels next spring will be on a lavish scale. Many of the buildings are already taking shape, and it is clear that a very unusual panorama of architecture and structural engineering will be presented to the visitor and will stimulate his curiosity even before he pays attention to the exhibits themselves, which will be housed within this extraordinary collection of buildings.

The exhibition site is almost a square mile in extent, in wooded suburban parkland. It consists of a Belgian section, with buildings dedicated to various of the arts, sciences and trades, an international section, and then a collection of national buildings, where each country will parade its own special achievements and graces.

We were recently invited to visit the exhibition and see the progress achieved up to now in constructing the various buildings, by the British Electrical and Allied Manufacturers Association, the body which is to be a principal exhibitor in the pavilion of British industries. A short account of the exhibition, and particularly its buildings, may therefore not be out of place. It is too early yet to give a detailed account of the interesting structural engineering work in many



A model of the " Atomium " which will be the central structure of the world exhibition in Brussels

of the buildings, but we hope to return to the subject in greater detail when the constructional work is completed. And since the exhibits themselves will concentrate to an appreciable extent on recent advances in science and technology, they, too, will doubtless repay further attention later on. The theme of the exhibition is stated to be " the contribution of the countries of the world to the advancement of mankind and the development of a better understanding between peoples."

The Belgian Section

The buildings in the Belgian section include several which were built for the 1935 exhibition, and have been in use for various exhibitions since that time. These buildings are being reconstructed, sometimes using temporary methods of construction, to alter their architectural appeal so that in their modified form they contribute to the general scheme of the section as a whole. The halls are named after the subjects they will serve—textile industry, food, aeronautics, chemical industries, and so on. A point of unusual interest is the inclusion of a structure representing civil engineering. It consists of a gigantic tapering cantilever, counterbalanced by a suspended hall. The cantilever will be 80m long and a footbridge to an adjacent building is to be suspended below it.

The " Atomium "

Most exhibitions of this kind aim at a plan with some dominating " feature " built at a commanding point on the site. The Eiffel Tower and the " Skylon " spring to mind as examples.

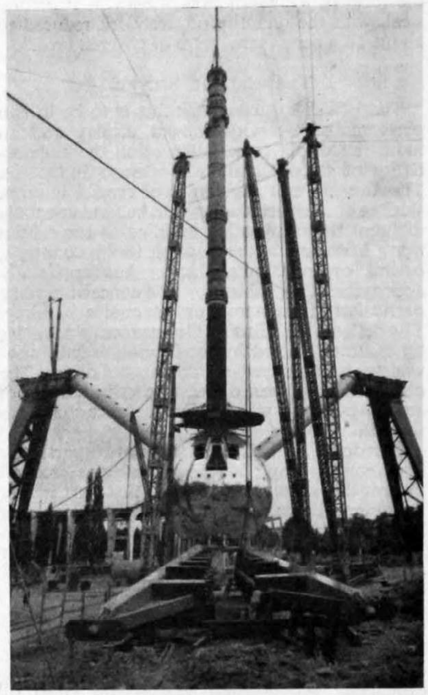
For this purpose the organisers of the Brussels exhibition have chosen a structure which they have called the " Atomium." A model of the " Atomium " is depicted in the accompanying illustration, from which it may be seen that it consists of nine spheres, carried by a tubular framing in such a manner that they delineate a cube positioned with one diagonal vertical, and with the spheres at each corner, and one in the centre. This configuration is intended to symbolise the dispositions of atoms in a crystal, and serve as " a cynosure and emblem " for the exhibition, where the peaceful applications of atomic energy will be prominently shown.

The " Atomium " will be very large, with the spheres 18m in diameter, the tubes between them 3m in diameter, and the total height 110m. Escalators and lifts will be placed in the tubes and there will be exhibits in each sphere. Structurally, the " Atomium " will be of steel. The spheres will be clad with aluminium, however, with a shiny finish. Our second illustration shows erection of one of the shear legs, which carry the lower spheres. These shear legs are carried on ball joints. The lowest tier of the structure, i.e. the three spheres carried directly on the shear legs, the lowest sphere, and the connecting tubes, comprises the first stage of erection. Then the central sphere is built into the vertical shaft and connected with the three spheres already in position, and the topmost sphere built at the upper end of the shaft. This phase of erection has now been reached. The final phase will involve positioning the three spheres on the upper corners of the cube.

The National and International Pavilions

Fifty nations are to be represented at the exhibition. The largest pavilions are those of Russia and the United States. The Russian building is at present at a comparatively early stage of construction ; it will be a vast and imposing building. The United States pavilion is circular in shape with a diameter of 340ft. There will be no interior columns in the building, an inner circular ring being supported from the circumference by high-tensile steel cables.

The French contribution to the exhibition is also a large one, and the French building is particularly ambitious structurally. It is a complicated design in structural steel, embodying



An early stage in the erection of the "Atomium." The substantial proportions of the various structural steel elements are apparent

two doubly-curved roofs—hyperbolic paraboloids —in which steel cables are stretched to form the shape of the roof. The German buildings are much more modest, and demonstrate the characteristic cleanness of German design in structural steel.

Six world organisations have buildings at the exhibition site. The United Nations building is a dome, 160ft in diameter and 50ft high, supported at six points, the lower edge of the dome forming a series of circular arcs between these six points.

Generally, the buildings are noteworthy for the extensive use of prefabrication. One building utilises a proprietary system of trusses formed from steel rods welded together. Aluminium trusses are used in another case. In the smaller buildings the use of timber is striking, and there are several original designs in timber. In fact, one building consists of portal frames in timber, spanning over 40m. The O.E.E.C. building is in

The Crystalline Hall at the British section of the Brussels Fair. In the background is the Hall of Technology

the form of a "saddleback," built in structural steel, with the quantity of steelwork reduced to about 1 kg per square metre of covered area.

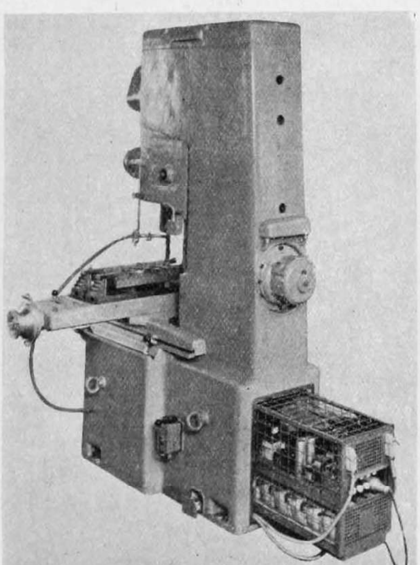
THE BRITISH SECTION

The British exhibit at the fair is to be in two parts, namely, a Government display and an industrial display, the latter being the responsibility of the Federation of British Industries. The Government pavilion is of special interest, since in one respect it appears to be fundamentally different from any other building at the exhibition. Each architect responsible for his country's, or his organisation's, display has apparently approached the problem by first conceiving some particularly imaginative or impressive building. The design of the British Government's pavilion, by contrast, started by considering exactly what was to be displayed inside the building. The display having been decided upon in detail, the actual building was designed functionally to serve it.

The display is, in fact, to be in two parts, the first emphasising tradition, and the second present-day achievements. The first part is in a building called the crystalline hall, which will have a church-like interior, with subdued lighting. From this atmosphere the visitor will turn abruptly into the open atmosphere of the hall of technology, and be confronted with a panorama of the Dounreay project. In this hall, basic advances in science and technology of first importance which have been made in this country over the past few years will be demonstrated and explained. An open-air section—the court of Commonwealth development and other courtyards—will lead to the British industries pavilion, where an exhibition space of 60,000 square feet has been provided.

Production Jig Borer

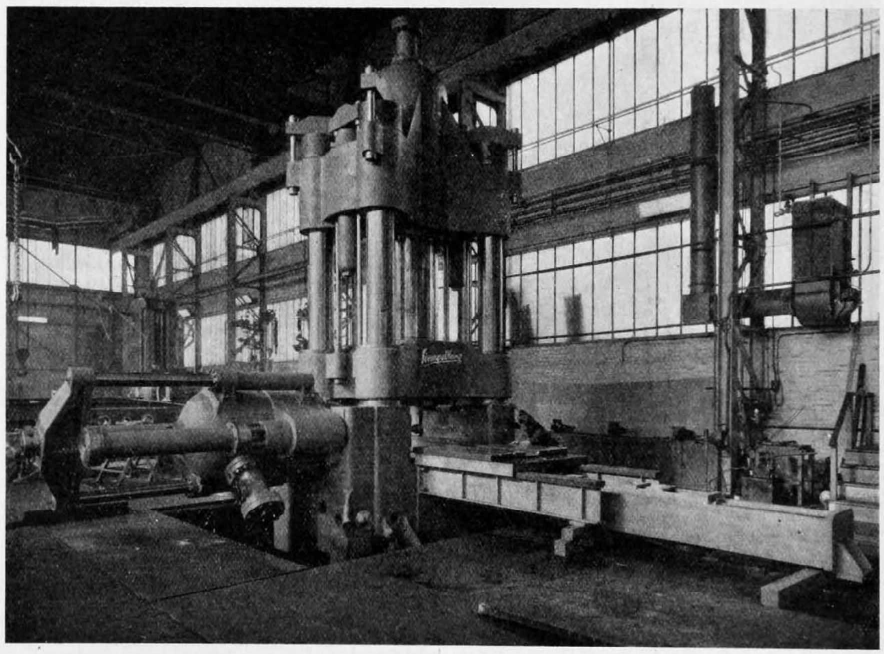
We have received details of the "Model UB2" production jig borer made by Wiener Werkzeug- und Werkzeugmaschinenfabrik Ing. Frank and Co., Vienna XX, Hellwagstrasse 4–8. The machine, which is built under a German licence, is shown in the accompanying illustration. It was designed with the idea of building a reliable and accurate yet simple machine tool which would be suitable also for production. Because of the stability of the metal and other characteristics, it is not necessary to house the machine in a temperature-controlled room. The jig borer has a main drive with 60–300 r.p.m. infinitely variable speed in either direction, achieved by means of a magnetic amplifier; this is stated to be a novel departure. As shown in the illustration, the amplifier chassis is housed in the back of the machine. The amplifier causes little heating, hardly more than 6 deg. Cent. in twenty hours' continuous service, and by virtue of special plastic foam insulation, what little heat is generated is kept away from the column and table. Press buttons are provided on the moving table, which serve to actuate the hand and automatic spindle feeds; the rotational speed is controlled by means of a potentiometer. Further press buttons operate the vertical movement of the headstock. The 710mm by 320mm co-ordinate table has precision scales in both directions and slip gauge supporting "vees" for production setting. Scale readings are to 0·001mm and accuracy for all table settings is claimed to be ±0·004mm. The four motors which are fitted develop together 5·5 h.p. Net weight is 3600 kg.



Production jig borer with magnetic amplifier speed control. The chassis housing the amplifier is seen pulled out of the column

Universal Forging Press

A combined forging and extrusion press has been designed and built by Maschinenfabrik G. Siempelkamp and Co., Krefeld. As may be seen from our illustration, which shows the press in the maker's works, the vertical down-stroking forging cylinder is mounted on four columns; in addition, there is a horizontal extrusion cylinder. A bed is mounted at right angles to these two cylinders, which is fitted with a table on which dies may be moved in and out of the press. This table also carries the charging equipment for the extrusion press.



Universal forging and extrusion press, with 2000-tonnes vertical forging ram and 1500-tonnes horizontal extrusion ram. The arrangement includes a transfer table for the dies and extrusion billets

The forging ram can exert up to 2000 tonnes and has a stroke of 1500mm. Die space is 1500mm by 1500mm by 210mm high. The table movement is 2150mm. Both the approach and pressing speeds are adjustable and have maximum values of 250mm and 75mm per second respectively, while the speed of retraction is 250mm per second. Normally forging is carried out with about twenty strokes per minute. For fast forging, whether by hand or automatically, this speed can be raised to about eighty strokes per minute.

When used as an extrusion press, a maximum pressure of 1500 tonnes can be exerted by the horizontal cylinder which has a stroke of 840mm. The closing pressure of the chamber is 60 tonnes, the opening pressure 120 tonnes, and the stroke of the ram 840mm. Ram speeds can be varied; forward speed is up to 250mm, extrusion up to 75mm, and retraction speed up to 250mm per second.

In the design of this press, working stresses were kept very low in order to decrease the deflections and enable the press to work with a maximum of load eccentricity. Upper and lower crossheads are held against the nuts by means of tiebars, as the illustration clearly shows. This arrangement obviates the necessity to have the columns stepped and at the same time facilitates assembly of the press. The moving crosshead is provided with adjustable guides by means of which the clearance may be varied to suit the application and any wear may be taken up. The considerable press speeds are stated to be chiefly due to the design of the main control valves, which are servo-operated.

In the lower crosshead a 70-tonnes ejector is fitted for use in die-forging. The extrusion cylinder and the operating cylinder for the chamber are connected by means of two pre-tensioned columns. Where complicated, sectional forging dies have to be used, the extrusion ram can be used to move and support the closing section.

British-Swedish Atomic Collaboration

An agreement between Great Britain and Sweden has been signed in Stockholm for an exchange of information regarding the peaceful use of atomic energy, in the first place regarding atomic reactors. Means will be provided for Sweden to purchase research reactors from Great Britain as well as fuel and other materials for them. Moreover, Swedish research workers will receive facilities for study at British institutions. The agreement comes into force immediately and is valid for a period of ten years.

Present atomic projects in Sweden include a reactor to use enriched uranium fuel and light water as moderator, and further, the building of a uranium factory with a capacity of 120 tons a year at Kvarntorp or Billingen. There is also a project to start industrial production of heavy water in collaboration between the A.S.E.A. company and A.B. Atomenergi, the national nuclear power development company. For the year 1958–59, A.B. Atomenergi requests government appropriations of 138 million kronor, more than double the appropriations for the current budget year.

Richmond - San Rafael Bridge

BY OUR AMERICAN EDITOR

No. II—(*Continued from page 653, November 1*)

The Richmond - San Rafael Bridge connecting the towns of Richmond and San Rafael across the northern part of the San Francisco Bay in California, was opened to highway traffic on September 1, 1956. The main structure has a length of 21,343ft. A main and a secondary channel are each spanned by a three-span structure with, in each case, a 1070ft main span and two 535ft spans ; vertical clearances above the channels are 185ft and 135ft, respectively. Initially, only the upper deck of 36ft width was opened ; the lower deck, also of 36ft width, was completed in August, 1957, and the bridge now has six 12ft traffic lanes in operation.

THE substructure contract, valued at 14,235,000 dollars was awarded to the joint venture of Ben C. Gerwick, Incorporated, and Peter Kiewit Sons, Company, of San Francisco, in February, 1953. It provided for the construction of seventy-nine piers of reinforced concrete supported on steel H-piles, except as noted, to provide the foundations for the structural steelwork of the bridge crossing. During construction in the vicinity of Castro Rocks, bedrock was encountered at higher elevations than indicated by the foundation explorations. It was necessary to raise the bottom elevations of bell piers Nos. 56 and 57, and to modify the construction of bell pier No. 55. All of the piers are of the same general class in that they are designed to be supported on steel H-piles driven to required bearing in hard strata, such as bedrock or compacted sands and gravels. However, the methods of constructing the piers, for the conditions existing at the site, varied widely and may be classified as to construction under the headings of land piers, shallow water or cofferdam piers, and bell piers for use where water and great depths of soft clays and silts overlie the bedrock or the compacted sands and gravels. Of the seventy-nine piers, nine are built on land, eight are built in cofferdams in the shallow waters near the eastern bridge terminus, and the remaining sixty-two are of special construction for the bell pier designs.

Initial surveys for substructure construction included the establishment of detailed horizontal and vertical controls for land piers, and other work incidental thereto. The specifications provided that tne contractor develop and construct such stable temporary structures or other devices as would enable the engineers to establish thereon controlling centre lines and grades for the location and control of pier construction, including excavation. The contractor developed a triangle-shaped, braced tower capped by a platform. The towers were 40ft to 70ft in height, with three braced legs of 10in diameter steel pipe set 16ft apart. A derrick placed each tower in approximate position with the bottom portion extending below the mud surface and the top rising to about 15ft above the water surface. The derrick held the tower in position while 8in diameter steel pipe piles, in lengths up to 160ft, were driven through the pipe legs of the braced tower to hold it securely in its proper position. Where tidal currents were swift, additional bracing piles of steel pipe were driven to increase the lateral stability of the tower. Sand was also placed in the annular spaces between the pipes to minimise movement of the tower and platform.

After the tower was completed, accurate survey points were established on the working platform by precise triangulation, including night observations from several points in the survey and triangulation net. Frequent checks were made from adjacent towers and from land stations, to detect possible movements of the towers due to settlement, currents or accidents. Bench marks were also provided on each tower.

The contractor's procedure for substructure work assumed that materials and equipment were immediately available to construct the land and the cofferdam piers and that special equipment and methods would be required for constructing the bell piers. Since materials and equipment were available, and survey control from land stations could be provided, construction of land and cofferdam piers began soon after the contract was signed. In fact, their scheduled construction was advanced by almost six months. This necessitated changes in construction procedures at piers Nos. 77 and 78 as described later.

For the bell piers, the contractor elected, generally, to use reinforced precast concrete shell sections, excepting tapered and shaft sections of four-bell piers, in lieu of stiffened steel plate sections previously used for similar piers. The contractor's choice of construction methods for the bell pier designs was further predicated on : (1) the fabrication of the precast concrete shell sections in his casting yard at Petaluma, California, with planned barge delivery of elements to the bridge site ; (2) the construction of special floating equipment such as pile drivers, derricks, and a concrete plant for concrete emplacement at the site, and (3) the shipment of steel H-piles from eastern rolling mills to the yard of Gilmore Fabricators, Incorporated, at Oakland, where they were welded to proper lengths and carried by barge to the site for driving.

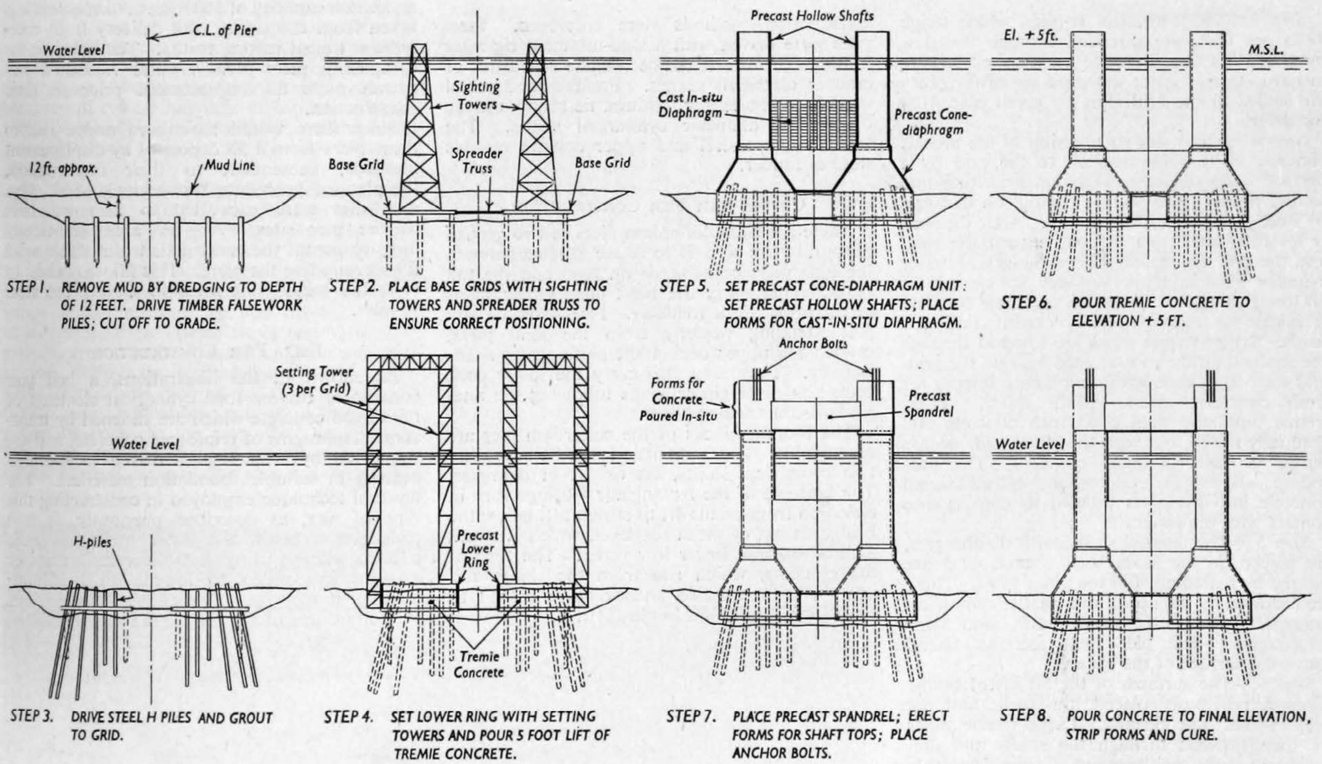


Fig. 4—Sequence of major steps in the construction of the bell piers

Since the most interesting construction work was involved in bell piers, their construction is summarised in the following steps referred to in the accompanying illustrations.

Step 1.—The soft material below the mud surface is excavated to a depth of approximately 12ft at the site of the pier. Timber piles are then driven and the tops cut off, by an underwater saw, to an exact elevation ready to receive and support a precast concrete mat, or base grid, and the construction loads imposed thereon.

Step 2.—Each concrete mat is 1ft in thickness, slightly larger in diameter than the base of the pier for which it is designed, and has cast-in H-shaped slots to receive the steel H-piles. The mat is placed by a derrick barge using a lowering cage which is equipped with a centring mast.

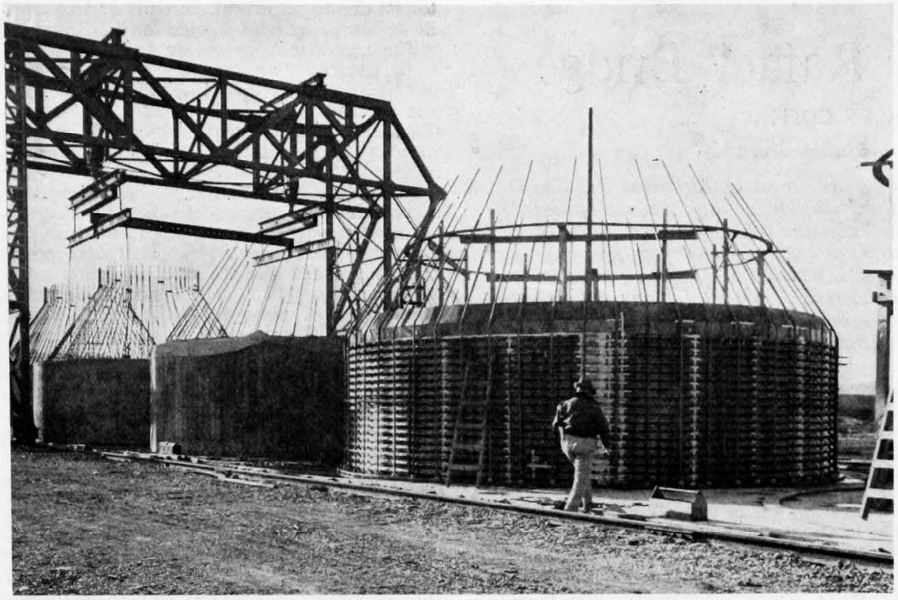


Fig. 5—Construction of lower pier shells weighing up to 50 tons each at the concrete casting yard

Step 3.—The 14in steel H-piles, which weigh 89 lb per foot, are threaded through the slots by divers and then driven to the required bearing in hard strata. After the piles are driven, they are sealed in the grid slots by grout placed by the divers.

Step 4.—The lower ring section of the precast concrete shell is lowered on to the grid by a derrick barge utilising a triangular lifting and setting tower. The shell is centred on the grid by steel guides cast into the grid. After the shell is levelled, any open spaces between the shell and the grid are sealed. Then the grid, interior cylinder walls and pile surfaces are cleaned of all foreign material. A 5ft lift of tremie concrete is placed to support further construction and loads. Large tremie pipes are lowered through the shafts until their lower ends bear on the grids and their tops, each with an attached hopper for fresh concrete, extend above water. These tremie pipes are then filled with concrete and gradually raised, but with the lower ends always buried in fresh, or unset, concrete. This procedure allows the deposition of additional concrete into the mass without its coming into contact with the water.

Step 5.—The tapered shells, with diaphragms, are placed on the lower shell section and are centred by matching with the lower rings. These are followed by the upper and smaller cylindrical sections, forming the pier shafts, and their diaphragms. The pier shaft sections extend above the surface of the water.

Step 6.—The surfaces of the 5ft lift of tremie concrete previously placed, the shells and the steel H-piles are cleaned. Large tremie pipes are then lowered through the shafts and diaphragms for the emplacement of tremie concrete to elevation plus 5ft in the manner described above.

Step 7.—Concreting above elevation plus 5ft and the setting of anchor bolts for the steel superstructure follow more usual methods of construction.

Step 8.—The tops of the piers are accurately levelled to receive the steel tower bents supporting the truss spans.

Land Pier Construction

The nine land piers, Nos. 66 to 74, are generally similar to the cofferdam piers except that there are separate footing blocks under each shaft connected by a tie beam. Steel H-piles were driven to tip elevations of less than 50ft. The bottom of the footings range in elevation from 0ft to plus 9·5ft, while the tops of the columns, or bridge seats, rise to elevations between plus 48ft to plus 58ft. These piers were built within the confines of an operating commercial gravel plant, but work was conducted with a minimum of interference to either party. Conventional construction methods were employed. Steel piles were driven with a skid-mounted rig after footing excavations had been made with truck or crawler clamshell cranes. Prefabricated metal moulds were used for footings, tie beams and the 6ft or 7ft diameter cylindrical shafts. The falsework, spandrel and upper column moulds were of timber.

Coffer dam Pier Construction

There are eight cofferdam piers in two groups of four. Piers Nos. 75 to 78 are situated between the nine piers constructed on land and the toll plaza. They carry the 100ft plate girder spans of the upper deck roadway. Piers Nos. 62 and 65, extending westerly from the land piers, carried the upper deck 100ft plate girder spans initially. They now also carry the lower deck transition plate girder spans following the final six-lane construction phase.

The footing blocks of the cofferdam pier are rectangular. They support a lower tie beam and two cylindrical shafts, 6ft or 7ft in diameter. The bottoms of the rectangular footings vary in elevation from minus 4ft to minus 14ft below the bridge datum of mean sea level, which is about 3ft above mean lower low water. The tops of the columns, which rise from the shafts and contain the embedded anchor bolts, extend to elevations of plus 36ft to plus 61ft.

Because of the shallow water at the cofferdam pier sites, dredging to obtain sufficient depth to bring in other floating construction equipment was the first operation. Steel bearing piles were then driven by a floating pile driver with pendulum leaders using either a Vulcan No. 0 or a McKiernan-Terry No. 80-C hammer. Piles were driven to bedrock at elevations varying to minus 50ft. Bearing values were specified as 100-ton minimum for each pile. While the plant was in position for driving the bearing piles, timber falsework piles were driven to support the cofferdam frame. The cofferdams consisted of interlocking steel sheet piling, driven through the mud into firm material and braced by timber or steel frames. Seals of tremie concrete, 3ft to 4ft in thickness, were poured, after which the cofferdams were unwatered so that all subsequent work was done in the dry.

Sectional metal moulds were used for footings, beams and the cylindrical shafts. The spandrels were formed by plywood-on-timber falsework, as were the square columns rising above the spandrel to the bearing seat level of the upper deck girder spans. The concrete surfaces exposed to sea water were protected with applications of bituminous coating.

Four steel sheet pile cofferdams were constructed simultaneously. After completion, the steel piles were removed for re-use. Various pieces of floating equipment were used during construction of the cofferdam piers, including three large derrick barges, one of which had a maximum capacity of 160 tons. All concrete was taken from the shore, with delivery from commercial transit mixing trucks. The schedule for completing piers Nos. 77 and 78 would not permit mole fill emplacement prior to their construction.

Since there would have been undue risk to these piers from a fill deposited by displacement methods, subsequent to their construction, the planned procedure was revised. Soft clays and silts were excavated to firm materials at the pier sites over an area sufficiently large to permit the construction of a stable sand fill surrounding the piers. This fill was raised to elevation minus 10ft prior to driving the steel H-piles.

Bell Pier Construction

As shown in the illustrations, a bell pier consists of two or four cylindrical elements of reinforced concrete which are stiffened by transverse diaphragms of reinforced concrete, and are supported by steel H-piles driven to specified bearing in suitable foundation materials. The unusual technique employed in constructing this type of pier, as described previously, is that construction below the water surface may be effected without using deep-water cofferdams or caissons less suited to foundation conditions existing at the site. In general, the elevations of the bottoms of the bell piers were established

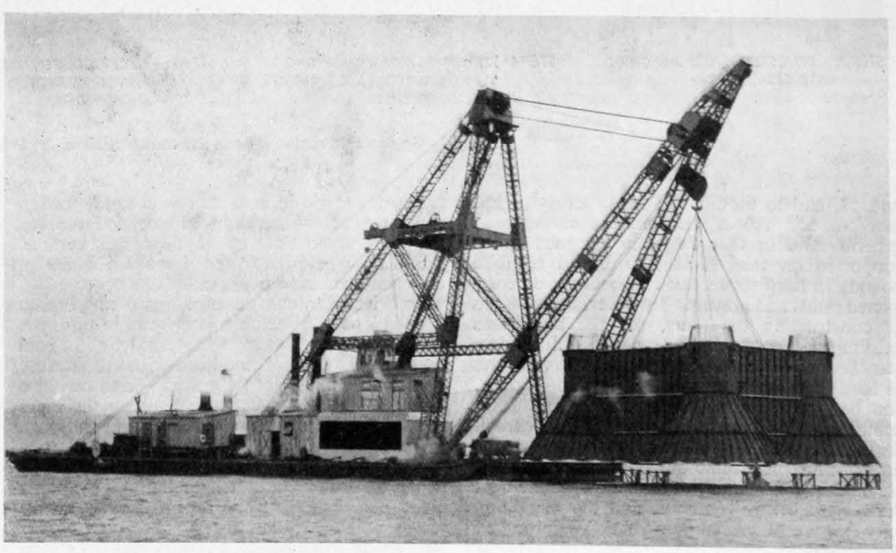


Fig. 6—Floating derrick crane "Pacific Atlas" lowering one of the precast cone-diaphragm sections for pier No. 44

at approximately 10ft below the mud line, and ranged from a high level of minus 20ft to a low one of minus 62ft. Under the 100ft plate girder spans and certain of the 289ft truss spans the structural concrete of the piers is carried to bridge seat elevations as high as plus 73ft. Most of the piers, however, were built to a bridge seat elevation of plus 27ft above which steel towers carry the bridge spans. The general bell pier construction procedure was as follows :

After survey control points were established for several of the piers, mud was excavated at each pier site to a general level of approximately 12ft below the existing mud line. Clamshell dredges were utilised for the work. Materials removed were disposed of in approved dumping grounds by bottom dump barges. The excavation provided vertical and horizontal clearances beyond the neat pier limits to allow for anticipated sloughing of the side slopes. After dredging was completed at a pier, timber piles up to 75ft in length were driven within the footing areas. These piles were driven at carefully predetermined points. The piles served to support the base grids in which slots fixed the steel H-pile locations. The number of piles used varied with the size of the footings and the construction procedure for a particular pier. All piles were driven to a minimum indicated bearing of 15 tons. A floating pile driver was equipped with underwater leads and a McKiernan-Terry No. S-6 hammer for this work. It also had an underwater saw for cutting off the timber piles to the designed grade for the bottom of the bell pier. This circular saw, 48in in diameter, was supported in the extension leads and powered by an oil turbine engine which could be operated under water. Working in calm water, remarkable accuracy of cut-off has been obtained. Checks with a plumbed pipe level rod indicated an overall variation of less than $\frac{1}{2}$in for the piles in a pier group.

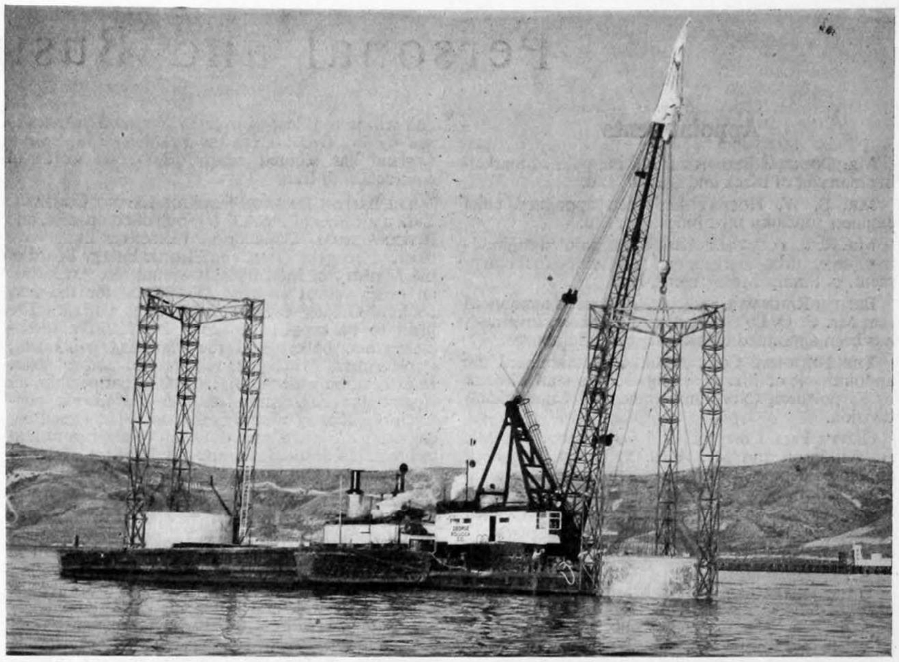


Fig. 8—Erection of steel guide towers along the sides of a bell pier shell for location during lowering

The base grid was a disc, 12in thick, of reinforced concrete. It had reinforcing extending into the tremie concrete of the pier, and ultimately became the lower 1ft of the bell pier. In the grid there were accurately positioned close-fitting H-shaped slots through each of which a steel bearing pile was driven. Three equally spaced steel guide shoes were also cast into the grid to assist in centring the lower shell section during its emplacement. The grids were formed and poured in the contractor's casting yard at Petaluma, and were then transported by barge to the pier site. Steel lifting lugs were cast into the grid, to which a lifting spider of steel beams was attached when the grid was to be lifted into position. On the spider there was mounted a four-legged steel sighting tower, 16ft square at the base and 50ft to 60ft in height. A centre line was established from the grid to the centre of the tower above water. The tower and attached grid were then lifted by a floating derrick which lowered the unit on to the timber supporting piles. The grid was positioned laterally by simultaneous observations from survey control towers and land stations to the centre line noted. Portable two-way wireless sets were used to facilitate this survey control.

After a mat was placed for one bell of a pier, a steel truss was fastened to it by divers and connected to the other mat when it was being lowered into position. The connecting truss served as a guide for placing the second unit and ensured that they remained properly located with respect to each other during succeeding operations. Bell pier grids for certain of the smaller 100ft girder span piers were cast in pairs with a concrete strut between them. These were placed as a unit, using shorter three-legged sighting towers.

The steel H-piles in each bell, both plumb and battered, were arranged radially on concentric circles. The battered piles were situated in the outer or in the outer and adjacent interior circles in each bell. All battered piles in the outer circles were sloped at 1 horizontally to 4 vertically, and in the adjacent interior circle at a slope of 1 horizontally to 6 vertically. During the operation of positioning the piles for driving through the grid slots, the driver was oriented to the proper azimuth for the particular piles by the use of a Sperry gyro-compass. A plumb pilot pile was the first one driven near the centre in each bell. This pile was cut to a length in excess of that specified, or to such other length as estimated from driving records in adjacent areas. From the results obtained with the pilot piles, the lengths of the remaining piles for a pier were estimated, so that they could be assembled, spliced, if necessary, and delivered by barge to the site. Pending the fabrication and delivery of ordered lengths for a particular pier, additional pilot piles were driven in several successive piers. When the ordered pile lengths were available, the driver returned to the first pier to drive the piles. Plumb piles guided by a diver were driven in a pier prior to driving the battered piles.

When all plumb piles had been driven, divers placed grout around them at the grid slots, using a flexible tremie tube with grout fed from a source above the water surface. Each grid slot fitted quite closely about the pile section, and, where necessary, to avoid grout leakage, slots were caulked at the lower surface of the grid. Tests of this grouting procedure were made prior to construction at the site. The grouted vertical piles served to prevent any movement of the grid during the driving of the batter piles. After the grout had hardened sufficiently, the batter piles were driven. The batter was controlled by the tilt back leads of the driver, which locked into preset positions ; minor adjustments of slope were made by shifting hull ballast.

(To be continued)

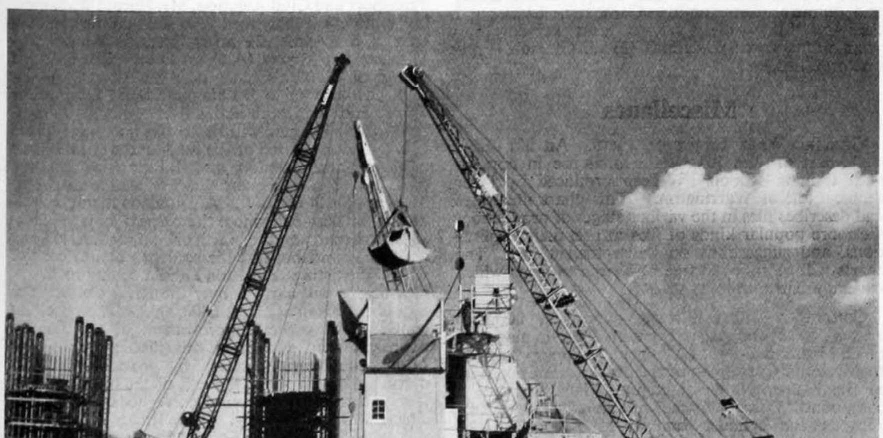


Fig. 7—Floating concrete mixing plant " Pacific Mixmaster " capable of batching and mixing 100 cubic yards per hour

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Electromagnetic Vernier Angle Resolver.—An electromagnetic transducer for resolving angles with an accuracy better than ± 3 seconds of arc has been developed by Bell Telephone Laboratories, New York. There it has been used as an " angle encoder " to convert the angular displacement of a shaft to a numerical representation acceptable to a digital computer. The vernier resolver is a variable-coupling transformer ; two output voltages are produced and they vary in amplitude as the sine and cosine, respectively, of (in this case) 27 times the angular displacement of the rotor. All the windings are on the stator the rotor being free of sliding contacts.

Personal and Business

Appointments

MR. DOUGLAS BROWN has been appointed marketing manager of Black and Decker, Ltd.

MR. S. W. HOBDAY has been appointed chief engineer to Camp Bird Industries, Ltd.

MR. K. B. YOUNGMAN has been appointed engineer-in-charge, turbo-chargers and gas turbine fuel equipment, of Simms Motor Units, Ltd.

BRITISH RAILWAYS, Scottish Region, has announced that Mr. G. D. D. Greig, district engineer, Inverness, has been appointed district engineer, Edinburgh.

THE NATIONAL COAL BOARD has announced the appointment of Mr. A. Wedgwood as staff director of its northern (Northumberland and Cumberland) division.

OLIVER PELL CONTROL, Ltd., announces that Mr. A. Wilkinson and Mr. A. S. Mellanby have been appointed deputy sales managers in its technical sales organisation.

MR. W. B. SALLITT, A.M.I.Mech.E., has been appointed personal assistant to the managing director of the Superheater Company, Ltd., for the development of nuclear power.

THE UNITED GLASS BOTTLE MANUFACTURERS, Ltd., has announced that Mr. L. R. Smith has been appointed a director of its subsidiary company, Dilworth and Carr, Ltd.

MR. FRANKLIN THOMAS ANDREWS has been appointed Commodore Chief Engineer Officer of the British India Steam Navigation Company's fleet in succession to Mr. K. A. Miller, who has retired.

VICE-ADMIRAL SIR FRANK MASON has been appointed consultant to the management of Metropolitan-Vickers Electrical Company, Ltd., following his recent retirement as Engineer-in-Chief of the Fleet.

THE BRITISH TRANSPORT COMMISSION has announced that Mr. A. H. Passey, rolling stock engineer, chief engineer's department, B.R.S. headquarters, has been appointed supplies officer, British Road Services, in succession to Mr. B. E. Murchison.

MR. JOSEPH MACDOWALL has been appointed leader of the Royal Society international geophysical year Antarctic expedition at Royal Society Base, Halley Bay, from January, 1958, until the party returns to the United Kingdom in the spring of 1959. He succeeds Colonel Robin Smart, the present leader, who accepted the appointment only for the current year.

THE ROYAL MILITARY COLLEGE OF SCIENCE, Shrivenham, Wilts, states that three new chairs have recently been created at the College and the following appointments have been made :—Dr. A. Charlesby, Professor of Physics ; Mr. A. D. S. Carter, Professor of Mechanical Engineering, and Mr. Alan Lee, Professor of Electrical Engineering (Radar and Telecommunications). Professor J. Diamond, Professor M. H. L. Pryce and Dr. R. P. Bell have been appointed members of the advisory council, which advises the War Office on matters of policy, in place of members whose term of office has expired.

Business Announcements

THE INSTITUTION OF CHEMICAL ENGINEERS states that it has joined the European Federation of Chemical Engineering.

ABBOFLEX, Ltd., states that it has moved to a new factory at Walnut Tree Close, Guildford, Surrey (telephone, Guildford 5893).

MR. T. E. HOUGHTON, M.I.C.E., M.I.Mech.E., M.I.E.E., states that he has retired from the board of the general chemicals division of Imperial Chemical Industries, Ltd., and from the position of power department manager of that division.

THOMAS WHITE AND SONS, Ltd., Laighpark, Paisley, and WILSON BROTHERS (LEEDS), Ltd., state that they have reached an agreement, making Thomas White and Co., Ltd., sole selling agent for England, Scotland and Wales, of the woodworking machinery manufactured by Wilson Brothers (Leeds), Ltd.

THE MAGNETIC EQUIPMENT COMPANY, Ltd., Lake Works, Portchester, Hants, has announced that Europe Technic S.P.R.L., of Charleroi, no longer represents the company in Belgium, and that it has appointed La Thermo-Technique S.P.R.L., 52, Avenue de l'Hippodrome, Brussels, as its sole representative for Belgium.

Contracts

LEYLAND MOTORS, Ltd., is to supply to the National Iranian Oil Company sixty " Super Hippo " vehicles with 16,000-litre (3500-gallon) fuel oil tanks, at a cost approaching £250,000. They are to be used for distributing fuel through mountainous territory, and will join a fleet of over 350 Leyland vehicles in use by N.I.O.C. Over the past eighteen months Leyland has secured nearly £2,000,000 worth of contracts with Iran.

THE BRITISH THOMSON-HOUSTON EXPORT COMPANY, Ltd., a member of the A.E.I. group of companies, and INTERNATIONAL COMBUSTION (EXPORT), Ltd., have received from the Water and Electric Energy Board of the Ministry of Industry and Commerce, Argentina, an order valued at over £30,000,000 for the new 600MW Greater Buenos Aires power station. The plant to be supplied includes five 120MW turbo-alternators, boilers and fuel handling equipment, transformers, switchgear, motors and control gear. In association with the B.T.H.-I.C.L. partnership, an Argentinian consortium of civil engineering contractors will carry out the civil works. The consulting engineers are Merz and McLellan (plant layout and technical co-ordination), and Sir William Halcrow and Partners (civil work).

STEEL STRUCTURES, Ltd., one of the Howard group of engineering companies, has been awarded a contract worth nearly £1,000,000, with part payment in dollars, for a mobile oil drilling platform. The contract has been placed by the DeLong Corporation of America. This 3000-ton drilling platform, 200ft long by 100ft wide and 16ft deep, will be completely self-contained with air-conditioned accommodation for a crew of thirty men. It will have its own generators, drilling rig, with mud hoppers, capable of drilling down to 15,000ft below the sea bed, and a helicopter platform. The hull is raised and lowered on four retractable legs and is designed to operate in water up to 150ft deep. It is due for completion next summer, and will be used in the search for oil in south-east Asia by one of the large oil companies.

THE CENTRAL ELECTRICITY AUTHORITY has placed contracts during the past month for power stations amounting in the aggregate to £8,682,000. The principal contracts include: Belvedere power station, near Erith, structural steelwork (Sir Wm. Arrol and Co., Ltd.); Northfleet power station, high-pressure pipework and valves (Babcock and Wilcox, Ltd.) ; West Thurrock power station, access roads, siding, drainage and preliminary works (G. Percy Trentham, Ltd.) ; Staythorpe " B " power station, Newark, ash and dust handling plant (Babcock and Wilcox, Ltd.) ; Willington " B " power station, near Derby, three cooling towers (Mitchell Construction Company) ; Rugeley power station, coal handling plant (International Combustion Products, Ltd.) ; Uskmouth " B " power station, Newport, main foundations (John Morgan (Builders), Ltd.), and ash and dust handling plant (Babcock and Wilcox, Ltd.) ; Skelton Grange " B " power station, Leeds, circulating water pumps and equipment (Drysdale and Co., Ltd.), and coal handling, storing and reclaiming plant (International Combustion Products, Ltd.) ; Ffestiniog hydro-electric scheme, Stwlan dam, pressure shafts and tunnels (Cementation Company, Ltd.), and Padiham " B " power station, near Burnley, site preparation and foundations (M. J. Gleeson (Contractors), Ltd.).

Miscellanea

GRAPHIC WALL CHART ON FILES.—An illustrated wall chart on files for instructional use in apprentices' training schools has been produced by Peter Stubs, Ltd., of Warrington. This chart illustrates and describes files in the various stages of production, the more popular kinds of files in use, their applications, and suggestions on their efficient use. The charts will be supplied free of charge to firms which have apprentice training schools.

COMPOUND DIESEL ENGINE.—The first issue of *This is Napier*, the quarterly external affairs magazine of D. Napier and Son, Ltd., includes an appreciation by Mr. E. E. Chatterton of the development potential of the high-speed diesel engine. This discloses a compound " Deltic " engine with an axial compressor between the cylinder banks ; 5500 h.p. would be available for fighting vessels, and 3500 h.p. continuously. Examples of the engine are, we learn, already running ; the turbine and crankshafts are linked by a fluid coupling instead of, as in the " Nomad," a variable ratio mechanical drive.

ANTI-VIBRATION PADS FOR MACHINE MOUNTING.—Notes have been received from Vulcascot (Great Britain), Ltd., 87–89, Abbey Road, London, N.W.8, of some of the many applications of " Vulcascot " anti-vibration pads as used for the mounting of machines. These pads consist of a sheet of oil-resistant synthetic rubber with grooves at right angles on the upper and lower faces. The material is supplied in sheets 18in square or 36in by 18in and $\frac{5}{16}$in thick, so that pads can be cut to suit the size of the machine. Pads can normally be loaded to 50 lb per square inch and when fully loaded should not be compressed to less than $\frac{1}{4}$in thick. Very heavy machines can be supported if necessary on two or three layers of the pads. In addition to damping out vibration and noise, the pads also in many cases eliminate need for the use of holding down bolts for machines.

CAULDON CEMENT WORKS.—In our description of Cauldon cement works in THE ENGINEER of October 11, 1957, on page 532, we described P.H.I. Engineering, Ltd., who supplied the two raw meal grinding mills and the coal pulverising mill to the works, as agents for the Pfeiffer organisation. P.H.I. Engineering, Ltd., informs us that it is an independent British engineering company, and is the main licensee for this country and for the British Commonwealth for the patent for MB mills granted to Dipl.-Ing. Max Berz and Gebr. Pfeiffer Barbarossawerke A.G., Kaiserslautern. The firm points out, furthermore, that the reason for the mills being imported from Germany was due to the short delivery period required, which could only be maintained by obtaining the mills from manufacture abroad.

ADAPTOR CHUCK.—We are informed that the firm of Clarkson (Engineers), Ltd., of Nuneaton, has introduced an adaptor chuck, with a range of cutters from $\frac{1}{16}$in to $\frac{3}{4}$in, similar to the company's existing small capacity chuck, but fitting directly into the large capacity " Autolock " chuck. The body of the new chuck is made to fit the bore of the large chuck, replacing both the sleeve and collet. This adaptor chuck is particularly suitable for use with large milling or boring machines, and avoids the difficulty of changing chucks when the draw bar is not easily available. The large capacity " Autolock " covers a range of cutters from $\frac{13}{16}$in to $1\frac{3}{4}$in, so that if it is necessary to use a smaller cutter whilst carrying out a series of operations with the large chuck, considerable time saving is made.

THE 1958 BRITISH ELECTRICAL CONFERENCE.—In order to focus world attention on the achievements of the British electrical industry, a conference is being organised to take place in Brussels on May 16 and 17, 1958. Membership of the conference is restricted to representatives nominated by the associations and firms supporting the British electrical and allied industry's collective exhibit at the 1958 Brussels World Exhibition, and to certain scientific and professional bodies. The programme is to include lectures by Sir Gordon Radley, Director-General of the British Post Office, on " Communication between Nations and Peoples," and by Sir John Cockcroft, Director of the Atomic Energy Research Establishment, Harwell, on " Nuclear Energy, the Power of the Future." Those interested should write to the Organising Secretary, 36, Kingsway, London, W.C.2.

LONDON COLNEY BY-PASS.—The Minister of Transport and Civil Aviation, Mr. Harold Watkinson, has announced that work is to start on the construction of a by-pass, $2\frac{1}{4}$ miles long, on the London-Glasgow trunk road (A.6) to divert traffic from the village of London Colney near St. Albans. A contract has been let to J. Laing and Sons, Ltd., for the work which will take about twelve months to complete. The by-pass will lie to the north-east of the village and form one of the links in the chain of new roads linking London and Birmingham. It will have two 24ft wide carriageways within an overall highway width of 100ft. A roundabout will be built at the northern end where the by-pass joins the existing trunk road and the North orbital road, A.405, and another roundabout at the southern end to connect with the existing trunk road and a county road. A new bridge will carry it over the River Colne. The cost is estimated at about £400,000. It is proposed to continue the general improvement of the London approach road system in this district in the near future, the Ministry states, by providing two 24ft carriageways on the A.6 south of the by-pass, where it runs through open country, in place of the existing single 30ft carriageway. This length of road will link with the proposed South Mimms by-pass, which will also have two carriageways. A similar improvement is proposed on the North orbital road between London Colney by-pass and the beginning of the St. Albans by-pass at Park Street. It is expected that most of the through traffic at present using A.6 north of London Colney will then be diverted on to this new route which also leads to the proposed London-Birmingham motorway. The section of A.6 which would thus be by-passed runs through residential areas forming the outskirts of St. Albans, and has a single 30ft carriageway. The work will be carried out for the Ministry of Transport and Civil Aviation under the supervision of Mr. C. H. ffolliott, B.A., M.I.C.E., County Surveyor for Hertfordshire County Council, the agent authority.

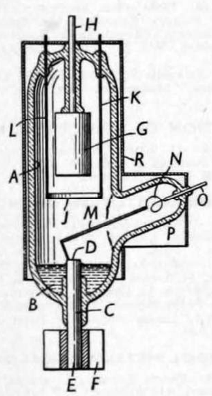
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each.

ELECTRICAL ENGINEERING

783,773. June 5, 1952.—Mercury Vapour Electric Discharge Apparatus, Hans Carl Bertele, 6, Warren Road, Purley, Surrey.

The invention relates to mercury vapour electric discharge apparatus of the type comprising an envelope enclosing an anode and a cathode between which, in operation, an electric discharge takes place in an atmosphere containing mercury vapour provided by vaporisation from a reservoir of liquid mercury within the envelope. The design shown in the drawing is suitable for currents of 3A to 10A. An envelope *A* of glass has a cup-shaped base containing a pool of mercury *B*. A rod *C* of impervious arc-resisting metal, such as molybdenum or tungsten, is sealed through the base of the envelope and the top *D* of the rod projects above the surface of the pool of mercury. The end *E* of the rod *C* outside the envelope is provided with cooling fins *F*. It will usually not be necessary to blow air over the fins, as circulation by convection will normally be adequate. An anode *G* is mounted in the upper part of the envelope and an anode lead-in rod *H* is sealed through the top of the envelope. A control electrode *J* is disposed between the anode and the top surface of the rod and is supported by means of two lead-in rods *K* and *L* which are sealed through the top of the envelope. A starter electrode *M* is mounted on a spring *N*, through which it is connected to a lead-in rod which is sealed through the end of a side arm *O* of



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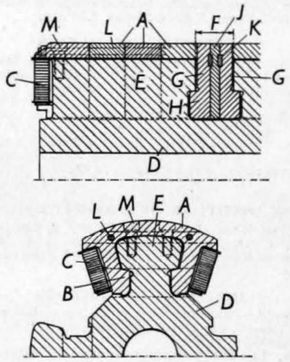
the envelope. An electro-magnet is provided for raising and lowering the starter electrode in conventional manner. The whole of the envelope *A* except the base is shrouded. During manufacture a film of mercury is formed on the top *D* of the rod *C*. In starting, a source of starting potential is connected between the starter electrode and the cathode rod *C* and the starter electrode brought into contact with the film of mercury on the top surface *D* of the rod. This initiates the discharge which can be transferred to the anode *G* by the application of a suitable potential to the control electrode *J* in conventional manner. The discharge spreads rapidly over the whole of the film of mercury on the top *D* of the rod. The shroud *R* is for ensuring that the temperature of the envelope *A* is maintained above the saturation temperature of the mercury vapour in the apparatus. Without the shroud, conditions can readily arise in which the temperature of part of the envelope falls below that of the top surface *D* of the rod *C*; should this occur, the condensation of vapour would cease on the surface and interrupt the operation of the apparatus. The control electrode *J* may also be employed as a "keep-alive" electrode. Several alternative designs are also shown in the specification. —*October* 2, 1957.

782,958. September 30, 1955.—Revolving Field for Electrical Machines with Salient Poles, Aktiengesellschaft Brown Boveri and Cie, of Baden, Switzerland.

The object of the invention is to construct a magnet wheel for electrical machines with salient poles which are composed of a number of solid parts and are secured to the magnet wheel by means of a claw connection. The construction is suitable for very high-speed machines and high limit loads. The drawing shows part of the magnet wheel of the multi-pole synchronous machine. The individual poles of the revolving field consist of several solid cast or forged steel parts *A* which form the actual pole shoe and part of the pole core *B*. *C* indicates a pole coil which is mounted on the magnet wheel *D* before the pole is assembled. For securing the pole parts *A* to the magnet wheel the wheel is constructed with claw-like elements *E* which project into the pole core. The pole parts *A* of a pole are assembled as follows: the magnet wheel is provided with a transverse slot *F* for each pole, each slot having a width at least as great as a pole part *A*. The pole parts are inserted successively into the slot *F* and then moved in the axial direction along the magnet wheel *D* into the desired position within the pole coil *C*. After all pole parts *A* of a pole have been inserted, pieces *G* for filling the slot *F* are inserted, these pieces



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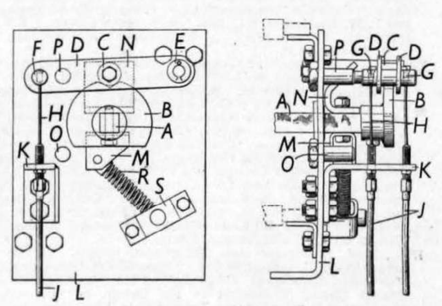
having projections *H* which engage with the transverse slot. Finally, a locking plate *J* is fitted. The centrifugal forces acting on the plate are transmitted by keys *K* to the filling pieces *G*. The elements *G* and *J* as well as the pole parts *A* are prevented from shifting in the circumferential direction by means of continuous longitudinal bolts *L*. The outer pole parts *A* which, in addition, have to transmit the centrifugal forces in the copper coils to the magnet wheel, are provided, furthermore, with screws *M* which result in part of the centrifugal forces being transmitted directly to the claws *E* of the magnet wheel, thus reducing the stresses. The transverse slots *F* are most conveniently located at about the centre of the magnet wheel, although a symmetrical distribution of the pole parts *A* with respect to the transverse slot is not absolutely necessary. The described magnet wheel construction is very favourable as regards mechanical stresses. As a result, it is now possible to run at a higher speed than formerly. It is, for instance, possible to increase the maximum allowable speed of a phase compensator by 50 per cent.—*September* 18, 1957.

782,118. July 22, 1954.—Electric Switching Arrangements, The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2, and George Hollings Jenkins, of The General Electric Company, Ltd., Engineering Works, Witton, Birmingham.

The invention relates to electric switching arrangements, particularly for electric power stations, in which it is usual to use electric contactors in conjunction with isolating switches. Referring to the drawing, the mechanism is shown in the position for



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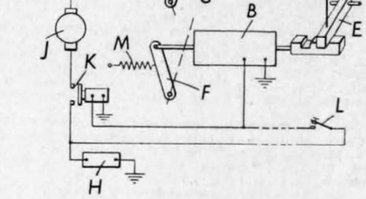
which a latch type contactor is latched and an isolator switch in series with the contactor is closed. The isolator switch is moved from this closed or "On" position by rotation of a shaft *A* which is fitted with a suitable isolator operating handle. A cam *B* is fitted on the shaft and engages with a cam follower *C* connected between a pair of parallel arms *D* which form a lever. The arms are joined and pivoted at one of their ends by a pivot pin *E*. The other end of each of the arms are joined by a cross member *F* which has two apertures *G*. In these two apertures are fitted, by suitable nipples, the ends of the moving wires *H* of a pair of bowden wire controls, the associated ends of the outer stationary sheaths *J* of the bowden wire controls being fitted to an angle bracket *K* bolted to a support *L*. The shaft *A* has a pair of projections *M* and *N* bolted to it, one of which, when the shaft is in either of two positions, abuts against stops *O* and *P* and so limits the rotation of the shaft. The projection *M* has one end of a spring *R* fitted to it, the other end of the spring being suitably fixed to the support *L* by a bracket *S*. When it is desired to move the isolator switch from the "On" position, the isolator operating handle is rotated, thus rotating the cam *B* against the action of the spring *R*. During the first few degrees of rotation of the cam *B*, the lever is rotated about its pivots to pull the moving wires *H* of the bowden wire control and thus move the moving wires relatively to their sheaths *J*. The cam is so shaped that this initial movement is sufficient to effect tripping of the latching mechanism of the contactor by one of the moving wires *H* and thus trip the latch-type contactor. Further rotation of the isolator operating handle opens the isolator switch, such further rotation being limited by the stops *O* and *P*. The cam and rotating lever would be mounted in a cubicle with the isolator operating handle on the front of the cubicle and the second bowden wire control may be used to unlock the cubicle door.—*September* 4, 1957.

INTERNAL COMBUSTION ENGINES

784,400. June 18, 1954.—Remote Control System for Diesel Generator Sets, Peter John Brogan, P.O. Box 2713, Nairobi, Kenya.

The invention relates to a remote control system as applied to the starting and stopping of diesel-engined electrical generator sets having engine starter windings incorporated in the generator, in which a control button or switch operates selectively two



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electrically operated actuating devices controlling the fuel injection of the engine and the decompression lever. Referring to the drawing, two solenoids *A* and *B* are shown, *A* being arranged to operate the decompressing lever *C* of the engine and also by means of a Bowden cable *D* an interlocking device *E* which controls the action of solenoid *B*, which, in turn, is arranged to operate the engine "stop" lever *F*, the levers *F* and *G* being spring loaded towards the "run" and "full compression" positions respectively. Solenoid *A*, having an especially heavy winding to carry the full starting current, is electrically connected to battery *H* via starter windings *J* and starter-solenoid switch *K*. Solenoid *B*, directly operated by control switch *L*, desirably a press-button switch, is connected in parallel to the energising windings of starter-solenoid switch *K*. To stop the engine the control switch *L* is closed for about three seconds, thereby closing switch *K*, and then opened. As the back e.m.f. produced in the starter windings *J*, which are turning at full generator speed, is greater than the voltage available from the battery, the solenoid *A* does not operate, but the solenoid *B*, receiving the higher voltage of the back e.m.f., operates against the action of the return spring *M* and suspends fuel injection. The interlocking device then engages and retains the fuel control in the "stop" position. To start the engine the control button is again pressed for about three seconds, i.e. long enough for the engine to pick up its normal starting speed, thereby operating the starter-solenoid switch *K*, which, in turn, energises the starter windings *J* and the solenoid *A*. Solenoid *A* operates to decompress the engine and disengage the interlocking device *E*. The fuel control lever *F* is held in the "stop" position by the solenoid *B* until the remote control switch *L* is released and only then, under the action of the return spring *M*, returns to the "run" position.—*October* 9, 1957.

Launches and Trial Trips

GRECIAN EMBLEM, cargo ship; built by the Blythswood Shipbuilding Company, Ltd., for Olinares Compania Naviera S.A. Panama; length 470ft, breadth 63ft 2in, depth 41ft 8in, deadweight 13,900 tons on 30ft 10½in closed shelter deck draught; trial speed 17 knots; two complete decks, five cargo holds, one 30-ton, four 10-ton and six 5-ton derricks, electric winches; three 250kW diesel driven generators; Rankin and Blackmore-Scott-Doxford opposed piston diaphragm, two cycle oil engine, five cylinders, 700mm diameter by 2320mm combined stroke, 6200 b.h.p., equipped to burn heavy fuel. Trial, September 4.

WAROONGA, cargo liner; built by Barclay, Curle and Co., Ltd., for the British India Steam Navigation Company, Ltd.; length overall 520ft, length between perpendiculars 485ft, breadth moulded 68ft 3in, depth moulded to shelter deck 42ft 3in, load draught 28ft 1½in, deadweight 11,500 tons, gross tonnage 10,000; five holds, eighteen derricks, electric winches; four 300kW diesel driven generators; one set of double reduction geared compound turbines; 10,850 s.h.p.; two Babcock and Wilcox integral furnace boilers supply steam at 500 lb per square inch and 800 deg. Fah. Trial, September 6.

ABEL TASMAN, single deck cargo ship; built by Hall Russell and Co., Ltd., for H.C.S. Coasters Pty., Ltd., Melbourne; length between perpendiculars 290ft, breadth moulded 44ft 6in, depth moulded 22ft 3in, deadweight 3500 tons; two holds, derricks to lift 7½ tons, electric winches; three 150kW diesel driven generators; Sulzer two-stroke, diesel engine, five cylinders 2000 b.h.p. at 155 r.p.m. Launch, September 10.

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.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Mon., Nov. 11.—CENTRAL LONDON BRANCH: White Hall Hotel, Bloomsbury Square, W.C.1, "Infra Red Heating," H. S. Carter, 6.30 p.m. ★ N.W. LONDON BRANCH: Century Hotel, Forty Avenue, Wembley Park, "Application of the Cathode Ray Tube," C. H. Gardener, 8.15 p.m.

Tues., Nov. 12.—OXFORD, READING AND DISTRICTS BRANCH: The University, London Road, Reading, "Motor Control Gear," R. F. Mathieson, 7.15 p.m. ★ PORTSMOUTH BRANCH: Wiltshire Lamb Hotel, Portsmouth, "Water Heating Electrically," L. E. Hughes, 7.30 p.m. ★ YORK BRANCH: Royal Station Hotel, York, "Electrode Boilers," D. Stretton-Smith, 7.30 p.m.

Wed., Nov. 13.—BIRMINGHAM BRANCH: Exchange and Engineering Centre, Stephenson Place, Birmingham, 2, "Light Sources," G. V. McNeill, 7.30 p.m. ★ BRADFORD BRANCH: Midland Hotel, Bradford, "Electric Motor Control and Overload Protection," S. H. Harding, 7.30 p.m.

Thurs., Nov. 14.—S.W. LONDON BRANCH: Prince of Wales Hotel, Wimbledon, S.W.19, "Electricity Supply to the London Underground System," H. L. Buckman, 7.45 p.m.

Fri., Nov. 15.—OXFORD, READING AND DISTRICTS BRANCH: Regent's Park College, Pusey Street, Oxford, "Transformer Construction and Design," 7 p.m.

BRITISH COMPUTER SOCIETY

Mon., Nov. 18.—L.C.C., County Hall, London, S.E.1, "Applications of a Computer to the work of Norwich Corporation and Plans for future use," A. J. Barnard, 6.15 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., Nov. 13.—W. MIDLANDS SECTION: Technical College, Wulfruna Street, Wolverhampton, "Cold Cathode Switching Techniques," J. H. Beesley, 7.15 p.m. ★ N.E. SECTION: Institution of Mining and Mechanical Engineers, Neville Hall, Westgate Road, Newcastle upon Tyne, "Electronic Control of Machine Tools," H. Ogden, 6 p.m.

Thurs., Nov. 14.—N.W. SECTION: Reynolds Hall, College of Technology, Sackville Street, Manchester, 1, "Some Electronic Techniques Used in Textile Research," J. B. Todd, 6.30 p.m.

CHEMICAL SOCIETY

Thurs., Nov. 21.—Burlington House, Piccadilly, London, W.1, Meeting for the reading of original papers, 7.30 p.m.

DIESEL ENGINEERS AND USERS ASSOCIATION

Thurs., Nov. 21.—Caxton Hall, Westminster, London, S.W.1, "Fuel Injection Equipment," G. R. Green, 2.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Mon., Nov. 11.—SHEFFIELD CENTRE: Grand Hotel, Sheffield, Presidential Address, E. B. Sawyer, 6.30 p.m.

Tues., Nov. 12.—NEWCASTLE UPON TYNE CENTRE: Technical College, Sunderland, "The Design of Lighting Glassware," S. S. Beggs, 6.15 p.m. ★ STOKE-ON-TRENT GROUP: North Stafford Hotel, Stoke-on-Trent, "Shop Window and Store Lighting," R. L. C. Tate, 6 p.m.

Thurs., Nov. 14.—Royal Institute of British Architects, Portland Place, London, W.1, "School Design," D. L. Medd, 6 p.m.

INCORPORATED PLANT ENGINEERS

Mon., Nov. 11.—MERSEYSIDE AND N. WALES BRANCH: The Blossoms, City Road, Chester, "Industrial Lubrication," G. Stott, 7.15 p.m. ★ DUNDEE BRANCH: Mathers Hotel, Dundee, "Manufacturing Experiences," J. Lomax, 7.30 p.m.

Tues., Nov. 12.—MANCHESTER BRANCH: Engineers' Club, Albert Square, Manchester, "Nuclear Power," 7.15 p.m.

Wed., Nov. 13.—E. MIDLANDS BRANCH: County Hotel, Theatre Square, Nottingham, "Life of a Factory Inspector in India," B. W. Glover, 7 p.m. ★ WESTERN BRANCH: Grand Hotel, Bristol, "Some Aspects of Flue Gas Corrosion," P. F. Corbett, 7.15 p.m.

Thurs., Nov. 14.—N.E. BRANCH: Roadway House Oxford Street, Newcastle upon Tyne, "Steel Production by Modern Methods," G. E. Hemming, 7 p.m.

INDUSTRIAL WELFARE SOCIETY

Fri., to Mon., Nov. 15 *to* 18.—Grand Hotel, Brighton, Conference on "Trends in Apprenticeship Training,"

INSTITUTE OF BRITISH FOUNDRYMEN

Tues., Nov. 19.—E. ANGLIAN SECTION: Public Library, Ipswich, "Effect of Moulding Methods on the Physical Properties of Sand Moulds," W. B. Parkes, 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Mon., Nov. 11.—JUNIOR LECTURE: East Ham Technical College, London, E.6, "The Junior Engineer's First Trip to Sea," H. C. Gibson, 7 p.m.

Tues., Nov. 12.—Memorial Building, 76, Mark Lane, London, E.C.3, "Heat Balance Calculations and their Use in the Installation Design of Steam Turbine Merchant Ship Propulsion Machinery," E. Tyrrell, 5.30 p.m. ★ SOUTHERN JOINT BRANCH: Technical College, St. Mary Street, Southampton, "Cargo Handling and Associated Deck Machinery," J. West, 7.30 p.m.

Wed., Nov. 13.—SCOTTISH SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Developments in Marine Electrical Installations with particular reference to A.C. Supply," A. N. Savage, 7.30 p.m.

INSTITUTE OF METALS

Mon., Nov. 11.—SCOTTISH LOCAL SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Vacuum Metallurgy," F. C. Weil, 6.30 p.m.

Tues., Nov. 12.—OXFORD LOCAL SECTION: Cadena Cafe, Cornmarket Street, Oxford, "Recent Advances in Iron-Making," 7 p.m. ★ S. WALES LOCAL SECTION: Royal Institution, Swansea, "Nuclear Power," L. Rotherham, 7 p.m.

Thurs., Nov. 14.—17, Belgrave Square, London, S.W.1, "The Low-Temperature Deformation of Metals," T. H. Blewitt, 6.30 p.m.

INSTITUTE OF NAVIGATION

Fri., Nov. 15.—Royal Geographical Society, 1, Kensington Gore, London, S.W.7, "Doppler Navigation," G. E. Beck, C. M. Moorhen, P. Houghton, C. S. Hurst, D. O. Fraser and T. Gray, 5.15 p.m.

INSTITUTE OF PHYSICS

To-day, Nov. 8.—MANCHESTER AND DISTRICT BRANCH: Bragg Lecture Theatre, The University, Manchester, "River Waves," M. J. Lighthill, 6.45 p.m.

Tues., Nov. 12.—ELECTRONICS GROUP: 47, Belgrave Square, London, S.W.1, "Crossed Field Interaction in Microwave Valves," W. E. Willshaw, 5.30 p.m.

Thurs., Nov. 14.—LIVERPOOL AND N. WALES BRANCH: University College of North Wales, Bangor, "Polar Wandering and Continental Drift," S. K. Runcorn, 5.45 p.m. ★ MIDLAND BRANCH: Exchange and Engineering Centre, Birmingham, Annual General Meeting, "Time Measurement," F. A. B. Ward, 7 p.m.

Fri., Nov. 15.—S. WALES BRANCH: University College, Swansea, "Atomic Clock," L. Essen, 5.15 p.m. ★ NON-DESTRUCTIVE TESTING GROUP: The University, Sheffield, "The Physical Properties of Glasses and their use in Control Tests in the Glass Industry," R. W. Douglas, 6.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

To-day, Nov. 8.—WESTERN CENTRE: Rougemont Hotel, Exeter, "From the Laboratory to the Road," T. I. Fowle, 7 p.m. ★ S. WALES CENTRE: S. Wales Institute of Engineers, Park Place, Cardiff, "Disc Brakes and Independent Suspensions," J. Pearson, 7 p.m.

Mon., Nov. 11.—E. REGIONAL CENTRE: Houldsworth Hall, 90, Deansgate, Manchester, "The Manumatic Gearbox," P. J. Holman, 7.45 p.m.

Tues., Nov. 12.—MIDLANDS CENTRE: Exchange and Engineering Centre, Stephenson Place, Birmingham, "The Ability to Stop," H. Clements, 7.30 p.m. ★ EASTERN CENTRE: Golden Lion Hotel, Ipswich, "Exhaust Brake Design and Operation," A. G. Slee, and W. K. Cox, 7 p.m.

Wed., Nov. 13.—SOUTHERN CENTRE: Royal Star Hotel, Maidstone, "The Operation and Development of Disc Brakes," T. J. Phipps, 7.30 p.m.

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

Mon., Nov. 11.—Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, "Careers in Agricultural Engineering," the first of a series of lectures on training for a career in agricultural engineering, speakers J. E. Bywater and W. H. Cashmore, 3 p.m.

NSTITUTION OF CIVIL ENGINEERS

Tues., Nov. 12.—Great George Street, Westminster, London, S.W.1, "Plastic Design of Pitched Roof Portal Frames," Jacques Heyman, 5.30 p.m.

Wed. to Fri., Nov. 13 *to* 15.—Great George Street, Westminster, London, S.W.1, Conference on the Highway Needs of Great Britain.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., Nov. 11.—INFORMAL MEETING: Savoy Place, London, W.C.2, Discussion on "Ought Electricity to be used for Space Heating in Domestic Premises," opened by D. J. Bolton, 5.30 p.m. ★ N.E. CENTRE: Neville Hall, Newcastle upon Tyne, "Cathodic Protection," L. B. Hobgen, K. A. Spencer and P. W. Heselgrave, 6.15 p.m. ★ WESTERN CENTRE: S.W. Electricity Board, Bristol, "Electrical Floor Warming," J. W. Moule, 6 p.m.

Tues., Nov. 12.—LONDON GRADUATE AND STUDENT SECTION: Savoy Place, London, W.C.2, "Manufacture of Electric Cables," J. D. Navey, 6.30 p.m. ★ CAMBRIDGE RADIO AND TELECOMMUNICATION GROUP: Cavendish Laboratory, Free School Lane, Cambridge, "Some Radio Aids for High-Speed Aircraft," J. S. McPetrie, 8 p.m. ★ N.E. CENTRE: College of Further Education, Workington, "Cathodic Protection," L. B. Hobgen, K. A. Spencer, and P. W. Heselgrave, 7 p.m. ★ N. MIDLAND CENTRE: Technical College, Bradford, Discussion on "The Teaching of Radio and T.V. Servicing," opened by G. N. Patchett, 6.30 p.m. ★ N. IRELAND CENTRE: Queen's University, Belfast, "Choice of Insulation and Surge Protection of Overhead Transmission Lines of 33kV and above," A. Morris Thomas and D. F. Oakeshott, 6.30 p.m.

Wed., Nov. 13.—RADIO AND TELECOMMUNICATION SECTION: Savoy Place, London, W.C.2, "Broad-Band Slot-Coupled Microstrip Directional Couplers," "The Application of Printed Circuit Techniques to the Design of Microwave Components," "Re-Entrant Transmission Line Filter using Printed Conductors," J. M. C. Dukes, 5.30 p.m.

Thurs., Nov. 14.—UTILIZATION SECTION: Savoy Place, London, W.C.2, "D.C. Winder Drives using Mercury-Arc Rectifier/Inverters," L. Abram, 5.30 p.m. ★ S. MIDLAND CENTRE: Midland Institute, Birmingham, "Some Engineering Problems in the Industrial Development of Nuclear Energy," Sir Claude Gibb, 6 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Nov. 8.—GENERAL MEETING IN CONJUNCTION WITH THE BRITISH NUCLEAR ENERGY CONFERENCE: 1, Birdcage Walk, Westminster, London, S.W.1, "Vacuum Techniques in the Atomic Energy Industry," H. Kronberger, 6 p.m.

Tues., Nov. 12.—AUTOMOBILE DIVISION GENERAL MEETING: 1, Birdcage Walk, Westminster, London, S.W.1, "The Suspension of Internal-Combustion Engines in Vehicles," M. Horovitz, 6 p.m. ★ S. WALES BRANCH: S. Wales Electricity Board, Kingsway, Swansea, "The Application of Computers to the Control of Machine Tools," D. Rogers, 6 p.m.

Wed., Nov. 13.—STEAM GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on "Steam Conditions in Relation to the Size of Units," 6.45 p.m. ★ E. MIDLANDS GRADUATE SECTION: Technical College, Lincoln, "Nuclear Power," 7.15 p.m. ★ YORKSHIRE GRADUATE SECTION: Visit to Calder Hall Power Station, 2 p.m.

Thurs., Nov. 14.—EASTERN BRANCH: Hoffman Hall, Chelmsford, "Worlds' Largest Walking Drag-Line Excavator," C. McL. Cameron, 7.30 p.m. ★ Yorkshire Branch: The University, Leeds, "The Design of Bolted Flanged Joints of Pressure Vessels," G. F. Lake and G. Boyd, 6.30 p.m.

Fri., Nov. 15.—THOMAS HAWKSLEY LECTURE: 1, Birdcage Walk, Westminster, London, S.W.1, "Vibration: A Survey of Industrial Applications," J. P. den Hartog, 6 p.m. ★ SCOTTISH BRANCH: Robert Gordon's College, Aberdeen, "Recent Developments in Propulsion Machinery and Refrigeration Equipment for Deep Sea Trawlers," G. C. Eddie, 7.30 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Tues., Nov. 12.—INFORMAL MEETING: Fourth Floor, Waterloo Bridge House, London, S.E.1, "Recent Developments in the Cabling and Wiring of Telephone Exchanges," T. F. A. Urben, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, Nov. 8.—IPSWICH AND COLCHESTER SECTION: Golden Lion Hotel, Cornhill, Ipswich, "Developments in Machine Tool Drive Units," L. A. Childs, 7.30 p.m.

Mon., Nov. 11.—LEEDS SECTION: Hotel Metropole, King Street, Leeds, 1, "The Development of Rubber in Engineering," E. S. Kendall, 7 p.m. ★ SHEFFIELD SECTION: Grand Hotel, Sheffield, "Spark Erosion Process," L. Adcock, 6.30 p.m.

Tues., Nov. 12.—OXFORD SECTION: Town Hall, Oxford, "People In Industry—The Changing Pattern of Industrial Society," E. W. Hancock, 7.30 p.m. ★ HALIFAX AND HUDDERSFIELD SECTION: White Swan Hotel, Halifax, "High Frequency Heating and Induction Hardening," R. H. Barfield, 7.30 p.m.

Wed., Nov. 13.—BIRMINGHAM SECTION: Midland Hotel, New Street, Birmingham, "Industrial Research in the Oil Industry," Dr. Davies, 7 p.m. ★ WOLVERHAMPTON SECTION: Technical College, Stafford, "Education of the Production Engineer in Industrial Engineering," J. France, 7.15 p.m. ★ LIVERPOOL SECTION: Exchange Hotel, Tithebarn Street, Liverpool, 2, "Material Purchase as an Aid to Production," D. H. Brandon, 7.30 p.m. ★ PRESTON SECTION: Municipal Technical College, Blakey Moor, Blackburn, "Modern Welding Processes," M. E. Lardge, 7.30 p.m. ★ DUNDEE SECTION: Timex Works, East Kingsway, Dundee, "Quality Control," G. S. Sharp, 7.30 p.m.

Thurs., Nov. 14.—DONCASTER SECTION: Technical College, Doncaster, "Factory Records," Mr. Bridgland, 7.15 p.m. ★ LONDON SECTION: Royal Empire Society, Northumberland Avenue, London, W.C.2, "Paper Production," I. Hendry, 7.15 p.m.

Fri., Nov. 15.—SWANSEA SECTION: Central Library, Alexandra Road, Swansea, "Master and Man," E. C. Gordon England, 7.30 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Thurs., Nov. 14.—11, Upper Belgrave Street, London, S.W.1, "Structural Features of the new Binns Store in Middlesbrough," F. R. Bullen, 5.55 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Nov. 8.—INFORMAL MEETING: Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Television," T. M. C. Lance, 7 p.m.

Mon., Nov. 11.—SHEFFIELD AND DISTRICT SECTION: Livesey Clegg House, 44, Union Street, Sheffield, 1, "Metals in the Modern World," A. G. Quarrell, 7.30 p.m.

Fri., Nov. 15.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Some Aspects of Town Gas Distribution," J. E. Gray, 7 p.m.

LIVERPOOL METALLURGICAL SOCIETY

Wed., Nov. 13.—Picton Library, Liverpool, "Application of Inert Gas Electric Arc Welding," P. J. L. Leder, 7 p.m.

Thurs., Nov. 14.—Liverpool Engineering Society, The Temple, Dale Street, Liverpool, "Corrosion and Microstructure," C. Edeleanu, 7 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

Fri., Nov. 15.—Engineers' Club, Albert Square, Manchester, "The Runcorn-Widnes Bridge," J. Kenneth Anderson, 6.45 p.m.

NEWCOMEN SOCIETY

Wed., Nov. 13.—Science Museum, South Kensington, London, S.W.7, Annual General Meeting, "The Structural Use of Iron in Antiquity," S. B. Hamilton, 5.30 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Fri., Nov. 15.—Mining Institute, Newcastle upon Tyne, "The Standardisation of Large Tankers," N. Carter, 6.15 p.m.

REINFORCED CONCRETE ASSOCIATION

Wed., Nov. 13.—11, Upper Belgrave Street, London, S.W.1, "The Production and Quality Control of Sand and Gravel Aggregates," B. L. Morton, 6 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., Nov. 12.—SECTION LECTURE: 4, Hamilton Place, London, W.1, "Some Problems of Stability and Control," H. H. B. M. Thomas, 7 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Mon., Nov. 11.—12, Great George Street, Westminster, London, S.W.1, Presidential Address, W. M. Balch, 5.45 p.m.

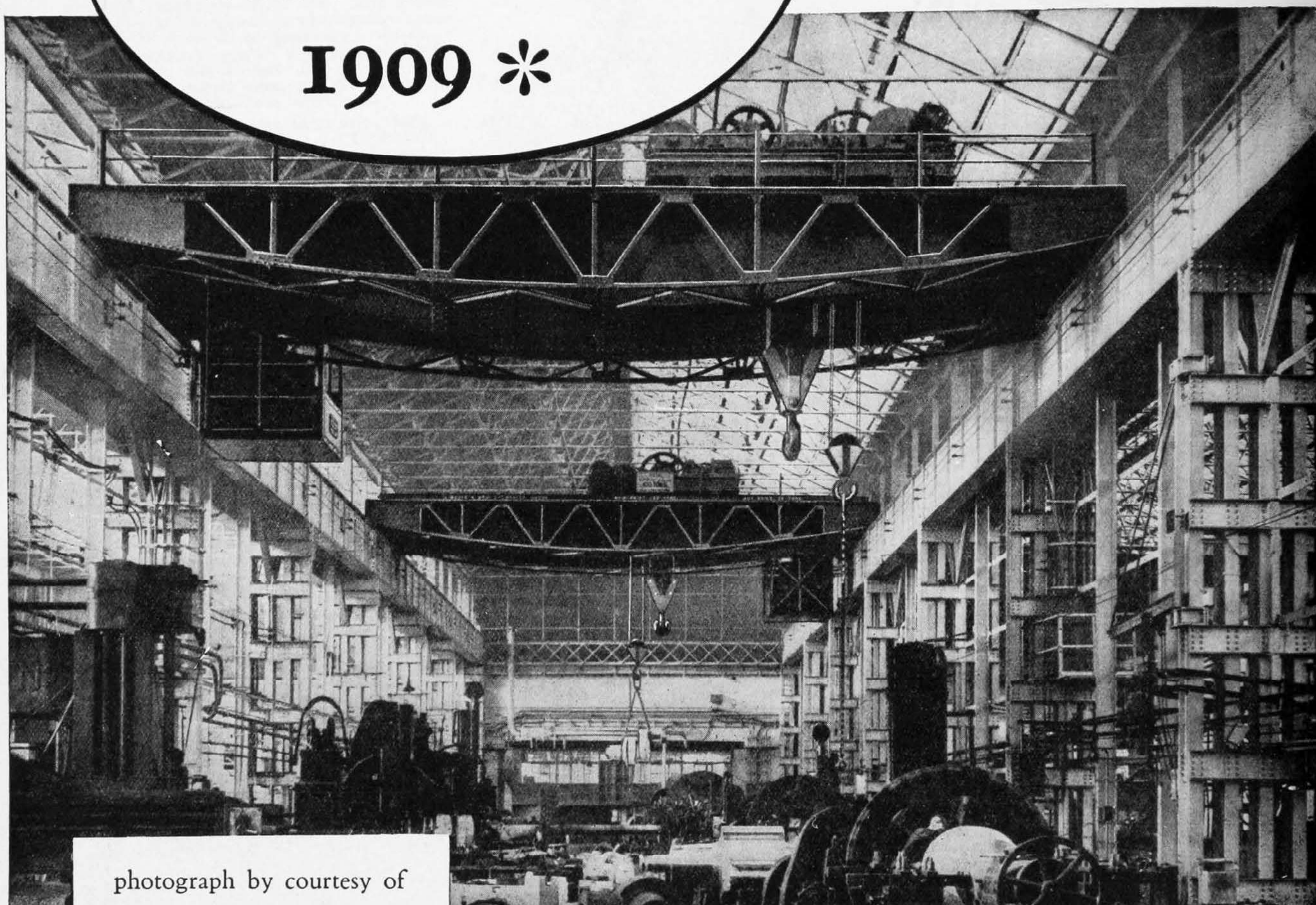
Thurs., Nov. 14.—12, Great George Street, Westminster, London, S.W.1, "A Day in the Life of a District Surveyor," E. J. Fisher, 5.45 p.m.

SHEFFIELD METALLURGICAL ASSOCIATION

Tues., Nov. 12.—B.I.S.R.A., Hoyle Street, Sheffield, "Some Metallurgical Problems in the Production of Cast Steels," W. J. Jackson, 7 p.m.

Advanced Engineering Courses

Operational Research. UNIVERSITY OF BIRMINGHAM. Institute for Engineering Production, "Southfield," 16, Norfolk Road, Edgbaston, Birmingham, 15. Residential executive course, Monday, November 25 to Friday, December 6. Fee £50.



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