OBITUARY

B. P. Ingamells, C.B.E.

An appreciation by Vice-Admiral Sir Frank Mason, K.C.B. (Chairman of Council)

I have not known Philip Ingamells as long or as well as have many others, but I have been associated with him long enough to know that the world is a poorer place without him.

I think I would describe him as a straightforward man who steered a steady course whatever difficulties stood in the way of doing so; even if this involved unpopularity. Not that he was unpopular; on the contrary he was widely liked and respected and those who had the privilege of knowing him more closely held him in much affection.

Perhaps two of his qualities, that will be an abiding memory, are his integrity and his courage. No one who was present in the Mansion House on 7th May 1962, will ever forget his gallant speech made in conditions of bodily suffering which would have daunted a lesser man.

All this stemmed from his Christian Faith, which was his foundation and strength. In that Faith he still lives and in so doing gives us both an example and an inspiration.

Bernard Philip Ingamells, C.B.E. (Member 5931) was born in Grimsby on the 15th July 1901. From 1917 to 1922 he served an apprenticeship with Nibromo Ltd. and R. H. Charlton and Co. Ltd. Following this he served as a marine engineer, first with Ellerman Lines, Ltd. and then with Scottish Tankers Ltd. In 1928 he came ashore, and for a period of three years was employed in the drawing office of Cammell Laird and Co. Ltd.

In 1931 Mr. Ingamells joined the Mercantile Marine Department of the Board of Trade as a surveyor and in 1939 was appointed to the Merchant Shipbuilding and Repair Department. Control of this department was taken over by the Admiralty in 1940. Shortly after the end of the war he became Principal Licensing Officer for Merchant Shipbuilding and Repairs in North East England. He was appointed Deputy Director of the Department in 1948 and to the Director's post in 1950. The department was transferred from the Admiralty to the Ministry of Transport in 1959 with Mr. Ingamells remaining its Director. His valued work was recognized by the award of the C.B.E. in the New Years Honours List, 1954. Mr. Ingamells was widely known and highly regarded in the shipping industry.

He became a Member of the Institute in 1928 and was elected a Member of Council in 1953. For the next nine years, in addition to his work on the Council, he served on the General Purposes Committee, the Finance Committee, and the Special Committees for the nomination of President and Vice-Presidents. As an active member of the General Purposes Committee he was personally concerned in the discussions that led up to the decision to expand the Institute's organization both at home and abroad. He was a strong supporter of the Institute's overseas activities and, in particular, the formation of the Canadian and Indian Divisions.

Mr. Ingamells was elected Vice-Chairman of Council for 1960-61 and then Chairman for 1961-62. Although his health had begun to deteriorate during the summer of 1961, he was indefatigable in his work on behalf of the Institute, and December of that year saw him, in company with the Secretary, attending the Conference on Shipping and Shipbuilding in Bombay.

As Chairman of the Special Committee for organizing the International Conference in London in May 1962, Mr. Ingamells willingly did an amount of work beyond that usually demanded of a Chairman of Council. His undimmed spirit of service carried him through to the beginning of the Conference when, though visibly very ill, he took part in the opening ceremony and after the luncheon at the Mansion House on the 7th May, made a memorable and moving speech. Within an hour of returning home from this function he was removed to hospital where he died on Monday, 14th May.

A service of thanksgiving, attended by his wife and daughters and members of the family, as well as by a large congregation representative of the shipping industry, was held at St. Olave's Church, Hart Street, in the City of London, on Tuesday, 22nd May 1962.

George Thompson (Member 6399), Principal of Swansea College of Technology, died at his home on 26th April 1962. He was 64 years of age.

He served his apprenticeship with Messrs. Campbell and Isherwood of Bootle, Liverpool, and studied at the University of Liverpool, where he obtained his degree as a Master of Engineering. He spent eight years at sea between 1918-26 with Canadian Pacific Steamships Ltd. and held an Extra First Class Board of Trade Engineer's Certificate.

Among the various teaching posts he held in technical establishments were those as lecturer in the Department of Marine Engineering at the Central Technical School, Liverpool and head of the engineering department of Poplar College of Engineering and Navigation. In 1935 he was appointed principal of Swansea Technical College, as it then was, and was to hold this position for the next twenty-seven years until his sudden death.

With acknowledgements to the South Wales Evening Post

One of Mr. Thompson's first tasks at Swansea was the institution of a junior technical school which was founded in 1936 with thirty boys. His own senior establishment was to have formed part of the University of Wales, but a new institution was set up to fulfil the technical role within the university and the degree work taking place at Swansea was removed to the new university college. Principal Thompson was therefore left with a vacuum, which had to be filled without competing with the work of the new institution. As a consequence of this, his policy was formed along the lines of providing craft courses not only to supply industry with trained personnel, but also with potential foremen and managers.

At the outbreak of the Second World War, the Swansea College became a civilian military training establishment with large numbers of Army and Air Force personnel among the pupils. At one time a two-shift system had to be initiated, and further difficulties were created in 1941 when the chemistry and metallurgy departments were destroyed. After the war the junior technical school became a separate entity as a secondary technical school, and day classes at the senior college brought even closer links with local industry, with whom Mr. Thompson had always maintained the most cordial relations.

Mr. Thompson took a keen interest in the affairs of local technical and professional institutions, and for many years acted as Vice-President at Swansea for this Institute, to whose membership he was admitted in 1930. He was also a member of the Institution of Mechanical Engineers, Swansea Rotary Club and Glanmor Bowls Club. He was a Freemason.

Joseph Elias Pearson (Member 16521) was born on 20th September 1894. Between 1909-15 he was an apprentice with C. R. Toomer Ltd. of Tyne Docks, and for the next four years he served as third and second engineer with Robert Ropner and Co. Ltd. In 1919 he obtained a First Class Ministry of War Transport Steam Certificate and later added a Motor Endorsement.

He continued to serve in seagoing capacities with companies which included Sir Arthur Sunderland Ltd., the Court Line Ltd. and Morel Ltd. In the latter part of his seagoing career he served as a chief engineer. In 1936 Mr. Pearson was appointed marine and engineer superintendent of Morel Ltd. and remained in this post until 1957 when he joined the Faros Shipping Co. Ltd. In November 1961 he left them to take up an appointment with Gibbs (Ship Management) Ltd. of Newport, Mon., which position he held up to the time of his death on 1st April 1962.

William George Smith (Member 7600) was born on 2nd January 1889 and served his apprenticeship at Forges et Fonderies de Maurice, Mauritius between 1907-12.

He obtained a First Class Board of Trade Engineer's Steam Certificate and sailed with the British India Steam Navigation Co. Ltd. between 1912-23, when he was appointed chief engineer of the port department and engineer surveyor at Port Louis, Mauritius. In May 1949 Mr. Smith retired from this post and for nine years afterwards was employed as chief engineer aboard local ships until failing eyesight brought a stop to his active business career. After an operation on his eyes in London, he planned to resume work, but his health had already begun to decline and his plans were therefore not implemented. Mr. Smith held the patent for his design for the improvement of boiler tubes.

Mr. Smith became a Member of the Institute on 2nd July 1934. He died on 3rd September 1961.

Research in Mechanical Engineering at the National Engineering Laboratory

F. D. PENNY, B.Sc.(Eng.), M.I.Mech.E.*

The paper reviews the purpose, staff and facilities, organization, and programme of research of the National Engineering Laboratory. It gives some details of selected research projects in hand or recently completed. These include the use of moiré fringe techniques in metrology and in the automatic error correction of machine tools; research on hydrodynamically lubricated journal bearings and on pressurized fluid bearings and slideways; a study of the lubrication of hypoid gears; the causes of noise in machine elements; hydrostatic transmissions; steam tables for higher pressures and temperatures; heat transfer to fluids flowing in pipes; the design of a fully cavitating axial-flow pump; improvements in steam condensers; the effect of very high pressures on materials; fatigue crack growth; and the problem of creep. The relationship of the Laboratory with industry is also examined.

PURPOSE OF THE NATIONAL ENGINEERING LABORATORY

The Laboratory is one of fifteen research stations founded by the Department of Scientific and Industrial Research. In the Act[1], which provided for the Department to be set up in its present form, the Research Council, its governing body, was ". . . charged with the organization, development and encouragement of scientific and of industrial research and with the dissemination of the results of such research . . ." It was to "a) encourage and support scientific research in universities, technical colleges and other institutions; b) establish or develop institutions . . . for investigation and research relating to the advancement of trade and industry; and c) take steps to further the practical application of the results of scientific and of industrial research . . ." In exercising these functions the Council was to ". . . have regard, consistently with the national interest, to similar or related activities carried on by other persons."

The Research Council expects the National Engineering Laboratory "to establish the principles and extend the knowledge of mechanical engineering science so as to provide industry with the information it requires for the solution of its own particular problems"[12] . In doing so, it is to have special regard to research needs of industries that lack an adequate scientific background and to research problems that are common to more than one industry. It must carry out research on matters of broad interest to users, as well as more particular researches in co-operation with industry wherever possible, so as to appreciate more fully industry's problems and to recognize the fields in which more basic research is most urgently needed. Finally, it must disseminate the results of research and secure their application.

STAFF AND FACILITIES

The Laboratory was set up in 1947; its nucleus was the Engineering Division of the National Physical Laboratory, then about 50 strong. At the present time the staff numbers approximately 630 of whom some 140 are graduates or have equivalent professional qualifications. In the main, they are mechanical engineers and physicists, but electrical engineers, chemists, metallurgists and mathematicians are also included. Of the industrial staff of more than 200, nearly 150 are skilled men of one sort or another. By 1970 it is expected that the staff will number about 1,000.

The Laboratory was planned to occupy a 68 acre site in the "new town" of East Kilbride and building commenced in 1949. Meanwhile temporary accommodation was occupied in the nearby village of Thorntonhall. The first buildings at East Kilbride were occupied in 1951 and construction has since proceeded steadily. At the present time, about two-thirds of the buildings originally planned have been completed and nine-tenths of the staff are accommodated on the main site. Some £2m. have already been spent on buildings and services and a further £1¾m. on plant and experimental facilities. The annual budget of the Laboratory excluding new buildings, which are provided for separately, is about £900,000. The present state of development of the site is shown in Fig. 1.

The Stephenson building, so named after the first President of the Institution of Mechanical Engineers, was the first building to be occupied on the site. It contains comprehensive equipment for materials testing, including rotating-bending machines of 45 ton-inches capacity and direct-stress fatigue testing machines of up to 60 tons capacity. Facilities for photo-elastic stress analysis and for metallurgical examination are also included. Until recently, the equipment for work on the properties of materials at elevated temperatures was also housed in this building but it is now being installed in a building of its own.

The Reynolds building[25] was specially designed for research into and testing of hydraulic machinery. It includes a water-turbine test rig[39] in which model turbines of up to 250 h.p. can be tested at heads up to 300ft. Recently this facility has been equipped with automatic digital recording devices so that the results of experiments can be recorded on punched tape and subsequently processed rapidly on the Laboratory's digital computer. There is also a measuring circuit for the calibration of flowmeters which includes a constant-head tank, a series of test lines and a weigh-tank of 30 tons capacity. Meters of up to 24in. diameter can be calibrated. A closed-circuit test rig allows the performance of pumps to be determined with a high degree of accuracy. The building also includes an aerodynamics laboratory where

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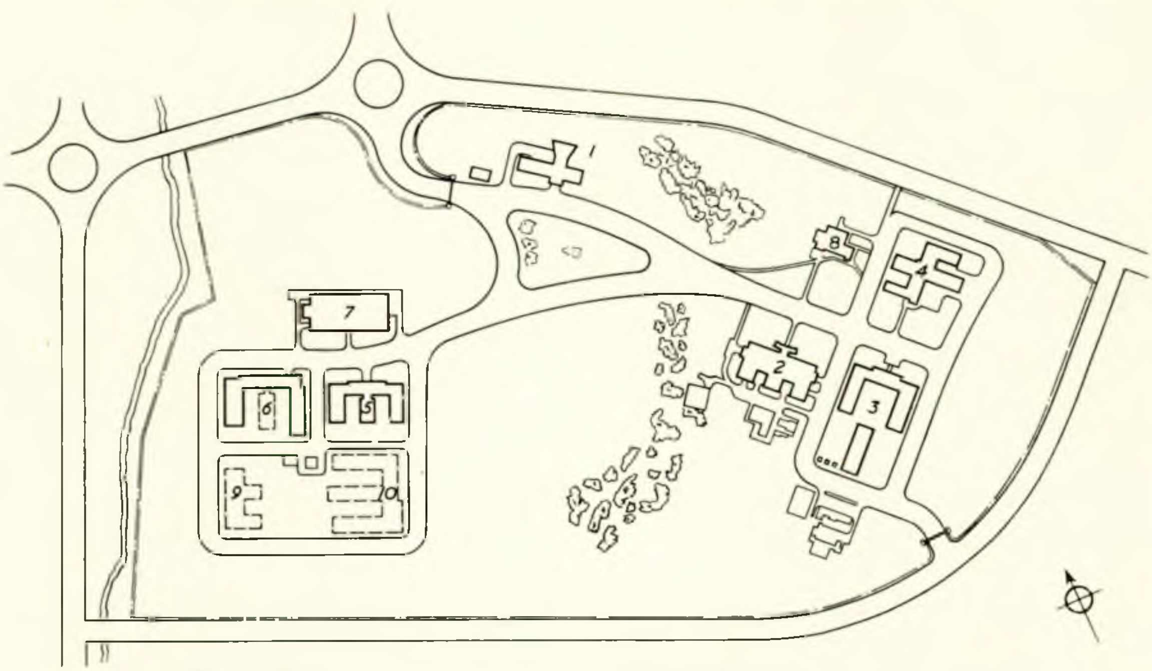


1 James Watt building (administration and services)
2 Maudslay building (central workshops)
3 Rankine building (heat transfer)
4 Reynolds building (fluid mechanics)
5 Stephenson building (materials)
6 Whitworth building (machinery)
7 Fairbairn building (high temperature materials)
8 Staff Restaurant
9 Bramah building (fluid power—future)
10 Nasmyth building (plasticity and lubrication—future)

FIG. 1—*Site plan of National Engineering Laboratory*

tests of fans and blowers, as well as of air models of water pumps and turbines, can be carried out. For the time being, development of oil hydraulic and pneumatic devices is also carried out in a laboratory in this building.

The Whitworth building[35] provides facilities for engineering metrology in a temperature and humidity controlled laboratory of some 6,500 sq. ft., equipped with a wide range of measuring instruments, many of the Laboratory's own design. Of particular interest are comprehensive facilities for the measurement of gears[36]. An automatic lead-screw measuring bench allows lead screws to be examined rapidly, and corrections required can be carried out on a lead-screw correcting lathe. Recently a master gear generator, capable of producing gears of up to 48in. diameter and 4in. face-width within a tolerance half that required for Grade A machines to B.S. 1498: 1954, was installed. The machine was designed in the Laboratory. The building also includes a large laboratory for research into mechanisms, where precision dynamometers of N.E.L. design and of up to 300 h.p. are available, together with power circulators for gearing research. There is an anechoic chamber for noise research and two other such chambers are being provided in an extension to the building, now in course of construction, which will also provide an addition to the metrology laboratory and a laboratory for machine-tool research and development.

The Rankine building[13] [38] was designed for research in heat transfer, heat exchange and applied thermodynamics. At present only two thirds are used for this purpose, the remainder being used for work on the plastic properties of materials and on formation processes. The building is well provided with services including 20,000lb./hr. of steam at 100lb./sq. in., half of which can be superheated to 750 deg. F.; and 3,000lb./hr. of steam at 750lb./sq. in. and 750 deg. F.; cooling water supplies to dissipate approximately 10,000,000 B.t.u./hr. are available. Electrical supplies for experimental purposes are provided by a 1,000 kVA. stabilized transformer which maintains a voltage constant within $\pm\frac{1}{2}$ per cent for all normal fluctuations of the mains voltage. Part is available as three-phase, four-wire, 50 c/s a.c. 415 V. between phases, and part as three-wire d.c. 240 V. between each outer and mid wire. In addition there is a variable low-voltage system of 1,000 kVA. total capacity. This is three-phase, four-wire, 50 c/s a.c. with a voltage between phases variable between 60 and 415 V. stabilized, and also between 0 and 60 V. unstabilized. It is arranged in five 200 kVA. blocks of power, two or more of which can be connected in parallel. The building also houses the Laboratory's DEUCE computer and its ancillaries. Equipment for metal forming includes presses of up to 500 tons capacity.

The Maudslay building houses the Laboratory's central workshop. This is equipped as a general jobbing shop dealing with a wide variety of components of moderate size, but specializing perhaps in work of very high precision, such as originates from the needs of the Machine Tool and Metrology Division. There is also an apprentice workshop giving initial training to both craft and student apprentices. One wing of the building is at present used for research in machinability and the mechanics of cutting.

The James Watt building provides accommodation for administrative and information staff as well as for photographic and photoprinting services. It contains two features worthy of special mention: a central library with a very thorough coverage of the field of mechanical engineering, and a lecture theatre seating up to 225 persons and equipped with a wide range of projection facilities. Arrangements for simultaneous translation will be provided if experience shows that these are necessary.

The building most recently completed is the Fairbairn building, designed for research into the high temperature properties of materials. Some 250 tensile creep machines are being installed as well as equipment for the study of complex-stress creep and of the high temperature fatigue properties of materials. Special arrangements have had to be made to secure the continuity of electrical power supplies to this building. A second 11 kV. supply fed from an independent source is being brought eight miles from Hamilton to the site. In addition there is a Diesel-powered stand-by generator designed to start automatically should the mains supplies fail. The building also contains an extensive extraction system.

Two other new buildings are at the planning stage. One, to be called the Bramah building, is being designed for research into and development of hydrostatic transmissions and other fluid power devices. The other, which will be called the Nasmyth building, will be the largest building on the site. It will have a four-storey office and laboratory block in which facilities for radioactive-tracer work and dust-free laboratories for the study of wear will be provided. Other laboratories will provide facilities for the study of the plastic properties of materials, for metallurgy and for electron microscopy. Three large test bays will provide facilities for the study and development of formation processes, for full-scale bearing research and for high pressure research. It is hoped that both these buildings will be available in 1964.

ORGANIZATION AND PROGRAMME

The Laboratory is governed by a small Steering Committee, three members of which are drawn from industry and the universities, and two (the Director of the Laboratory and a member of D.S.I.R. Headquarters' staff) are ex officio. It is "responsible to the Research Council for the selection of projects and for the allocation of effort to them within the financial resources allocated to the Laboratory and such other limits as may from time to time be imposed by the Council"[11]. It reports annually to the Council, submitting a research programme for the following year. The research work of the Laboratory is divided between three Groups; Group Superintendents, while in direct control of their Groups, have a special responsibility for maintaining contact with industry. The day-to-day supervision of research is the concern of Heads of Division, of whom there are two or more in each Group. Supporting services, administrative, information and workshop, are organized separately from the Groups. The organization chart is shown in Fig. 2. The three research Groups are concerned with problems of materials, fluids and machinery respectively, and this division is repeated in three small sub-committees which the Steering Committee have appointed to advise them. The members of the sub-committees are also drawn mainly from industry and from universities, and the Director or Deputy Director and Group Superintendent are ex officio members.

The programme of research of the Laboratory is shown in Table I. Only the main headings have been included but each main heading is further broken down into a number of topics, each of which is tackled by a research team. In addition to carrying out its own programme of research the Laboratory welcomes the opportunity to undertake work for industry on repayment terms. This may be either tests, or special investigations or larger items of sponsored research work. Normally the Laboratory reserves to itself the right to publish results of general interest and to patents, but by paying a special surcharge the sponsor can retain all rights to the work. Arrangements can be made for members of the Laboratory's staff to carry out work in industry or for firms' staff to carry out research or development work of mutual interest in the Laboratory.

It is impossible within the present paper to give a full account of all the research work carried out in the Laboratory. A number of projects which it is thought will be of particular interest have therefore been selected from the programme of each Group and these are described.

TABLE I

Machinery Group

- Basic and applied research in metrology and the provision of a specialized service to industry.
- Application of automatic control and error correction systems to machine tools and measuring instruments.
- Research on mechanical power transmissions, especially gears, to increase their load carrying capacity and increase their efficiency.
- Research on plain bearings to establish improved methods of design, particularly for high speed bearings.
- Improvements in the kinematic design of machine tools, including studies of vibration characteristics, the effect of cutting conditions, and research into fluid slideways and other bearings.
- Studies of the causes of noise and vibration in machinery and methods for their reduction.
- Development and application of hydrostatic transmissions for industrial and transport use.
- Studies of oil hydraulic and pneumatic systems and components including automatic control techniques.

Fluids Group

- Study of the properties of fluids of importance in the design and operation of mechanical plant and equipment.
- Basic research in heat transfer including the study of relevant phenomena and the effects of geometrical features.
- Basic and applied research to enable improvements to be made in the design of:
  - a) water turbines, pumps and pump turbines
  - b) fans and blowers.
- Development of improved methods and equipment for the accurate measurement of fluid flow.
- Applied research to enable improvements to be made in the design of heat exchangers for the power and process industries.

Materials Group

- Basic research into the plastic behaviour (including flow and fracture) of materials and theoretical studies in plasticity.
- Basic and applied research into the effect of high pressures on the properties of materials and the application of ultra-high pressures and high temperatures in the production of new materials.
- Studies of established and new processes of metal forming and metal cutting and of tool wear.
- Basic and applied investigations of fatigue of metals over a wide range of conditions to enable existing materials to be used more economically and to help in the development of better materials.
- Fundamental studies of the mechanism of fatigue and of plastic deformation.
- Basic and applied research to improve the strength and behaviour in service of engineering components, joints and structural elements.
- Application of analytical and photo-elastic methods of stress analysis to components and structures.
- Basic and applied investigations of the causes of wear and of the failure of components to establish improved methods of prevention.
- Basic research into the mechanics of creep under complex stress systems.
- Determination of the tensile creep properties of materials and the co-ordination and dissemination of creep data.
- Basic and applied research into fatigue at high temperatures.
- Basic and applied research into pitting failure.

SELECTED PROJECTS—MACHINERY GROUP

a) Diffraction Gratings and their Use in Metrology

The Laboratory has co-opted with the National Physical Laboratory in developing the use of transparent scales (gratings)

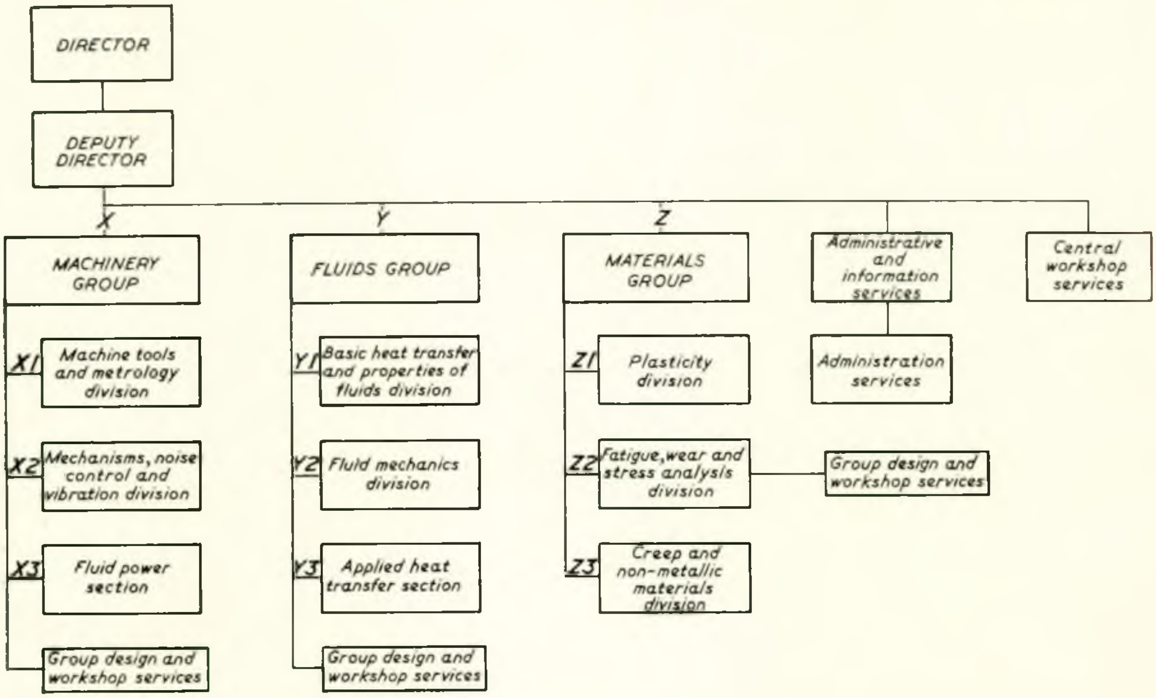


FIG. 2—*Organization of National Engineering Laboratory*

for measurement purposes[2]. When two similar transparent scales are placed face to face with the scale lines not quite parallel, alternate dark and light bands known as moiré fringes are produced. They provide a convenient means of magnifying the relative motion of the scales and can be observed photo-electrically. A similar means can be used for the accurate measurement of angular displacement and for this purpose precision radial scales are needed. The Laboratory has developed a new technique for the production of master radial scales with errors not greater than ±2 seconds of arc. The conventional method is to rule the complete scale on an aluminized glass disc using a circular dividing engine with a diamond tool. This is a lengthy process occupying ten days for a 30,000 line scale, and difficulty is encountered due to wear of the cutting tool and due to short-term periodic errors in the dividing engine. In the N.E.L. method[37] only a small segment having the required line spacing is ruled. The master scale is then produced photographically from the segment using the table mechanism of the dividing engine to index a glass plate coated with photographic emulsion through angles containing an integral number of lines. The plate is exposed to light passing intermittently through the segment until all the lines have been overprinted the same number of times. By this means short-term periodic errors are eliminated and the time of preparation of a typical scale is reduced to a few hours. The average cumulative pitch error in a typical 10-in. diameter scale does not exceed ½ second of arc. Photographic copies of master radial scales of various diameters and pitches have been supplied to industry and arrangements have been made for further copies to be produced commercially. Radial scales have many applications in metrology. One example is their application to a gear testing machine. In this development the gear under test is mated with a master gear. Radial gratings with photo-electric reading heads are mounted concentrically with a test gear and the master gear and are chosen such that the ratio of the number of lines in the gratings is the same as the gear ratio. If the velocity ratio of the gears is constant the signals derived from the two reading heads should remain exactly in phase. Phase differences measured represent variations in velocity ratio and these can be related to dimensional errors in the test gear.

The use of gratings also makes possible dynamic metrology, which may be defined as the measurement of a machine or mechanism while operating under load. One application at the Laboratory was to the measurement of the performance of a gear hobbing machine[36]. Radial gratings were fitted to the hob spindle and to the machine table as shown in Fig. 3. Each grating was fitted with a reading head and once again phase differences between the signals produced were recorded and represent errors in the mechanism under test. The chart record in Fig. 4A shows the errors between the hob and machine table over one complete revolution of the latter. It reveals, in addition to cyclic errors of hob and worm frequency, the complete range of pitch errors in the machine master wheel. A second system was used to measure the errors between the linear traverse of the hob saddle and the rotation of the feed screw (Fig. 4B). In this case the motion of the hob saddle is measured by means of a linear grating but the principle involved is the same.

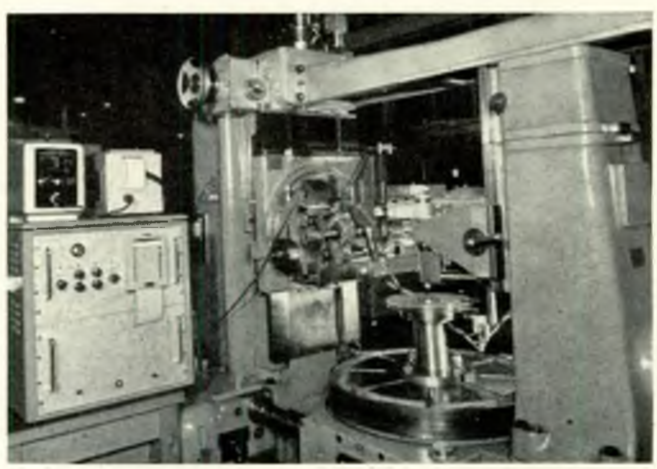


FIG. 3—*Gear-hobbing machine fitted with grating measuring systems*

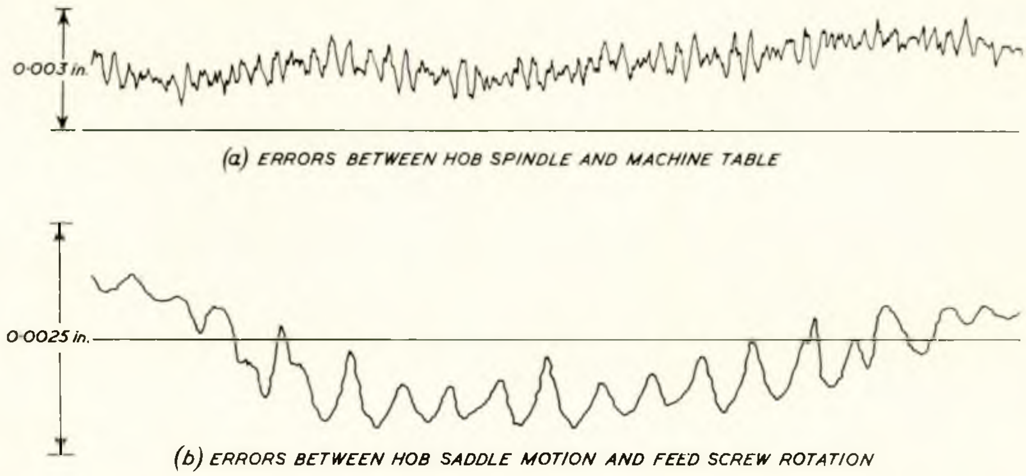


FIG. 4—*Relative errors in a 30-in. gear hobbing machine*

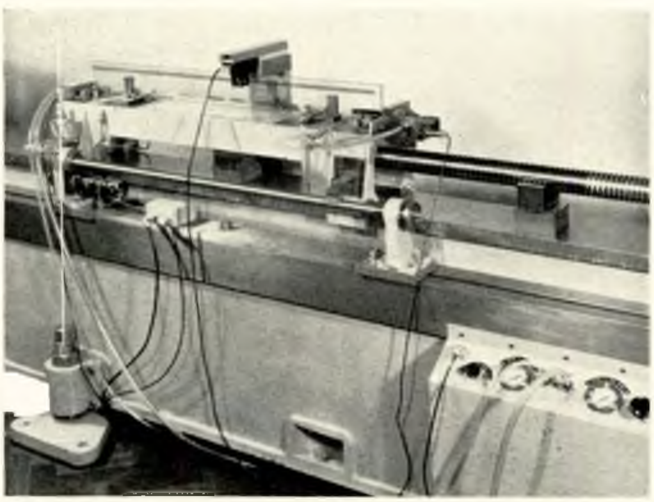


FIG. 5—*Lead-screw measuring bench*

Another application of gratings in metrology is to the automatic lead-screw measuring bench[36] already mentioned. The test screw is mounted above a girder-type surface plate along which travels a carriage supported on air-lubricated bearings (Fig. 5). On the carriage is mounted a precision linear grating and a retractable inductive gauging unit. This unit contacts successive flanks of the screw thread and enables their position to be related automatically to the precision grating. The bench will take lead screws up to 15ft. long and measurements are made to an accuracy of 0·0001in.

b) Error Correction and Automatic Control of Machine Tools

We have seen that errors in mechanisms can be measured and recorded by means of moiré fringe systems. These error signals can be fed-back by means of a servo loop so as to reduce or "correct" the error. In association with a well known firm of manufacturers, N.E.L. applied such a correction system

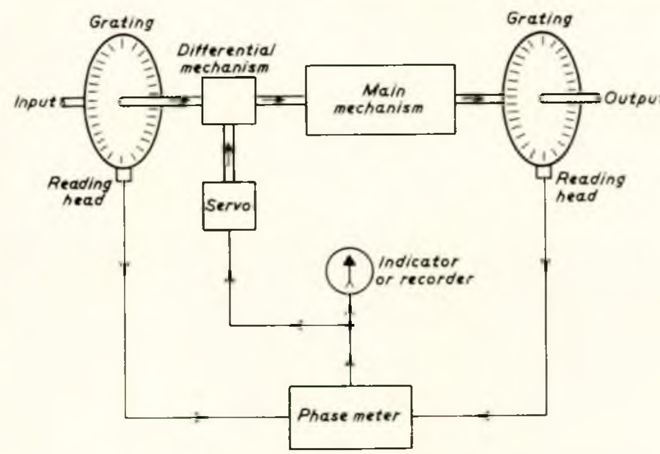


FIG. 6—*Typical automatic error-correcting system*

(Fig. 6) to the table drive of a standard 30-in. gear-hobbing machine. Radial scales were built into the work-table and into the driving shaft, and the output signals from the associated reading heads were fed to a phase meter[36]. The output voltage from the phase meter, proportional to the error in relative motion between the work-table and the driving shaft,

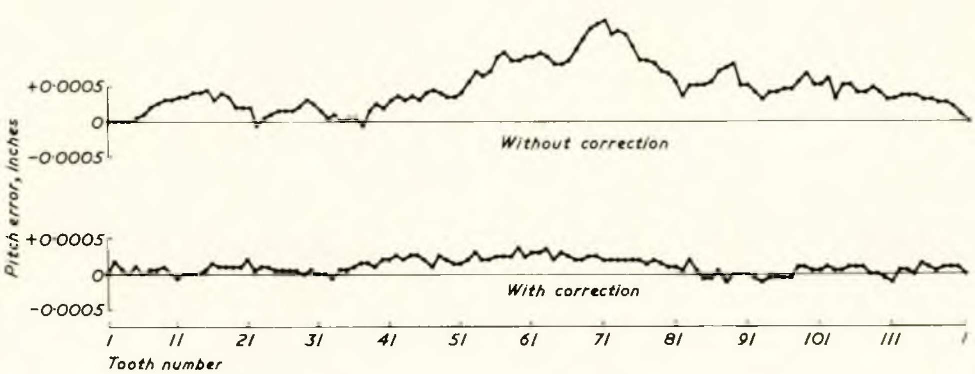


FIG. 7—*Cumulative pitch errors for spur gears cut on error-corrected hobbing machine*

is then fed to a servo motor which advances or retards the driving shaft by means of a differential mechanism. Fig. 7 shows the pitch errors in two spur gears cut on the machine, one with the error correcting system inoperative and the other with the system operating. It will be seen that the cumulative pitch error is reduced by a factor of nearly four when the error correcting system is in operation.

In the systems described so far it is essential that the gratings shall be chosen to have the same ratio as the gearing or other mechanism to be measured or corrected. This was, of course, a severe limitation. Recently batching counters[30] have been developed and used to overcome this difficulty. They consist essentially of devices arranged to emit one pulse for each X pulses fed in, where X is any integral number between 1 and 999. If a batching counter is used between each reading head and the phase meter, any ratio likely to be required can be obtained. There is thus no need to change the gratings and identical sets of gratings can be used for a variety of purposes.

So far, the use of an error correcting system to correct errors in a mechanical mechanism has been described. Instead the signal from the driven member could be compared with a pulse train produced electronically. Comparison with a suitable constant frequency source could be used to simulate a lead screw but it would be equally easy, for example, to simulate a lead screw with a logarithmic or sine law pitch by comparison with a suitably modulated frequency source.

c) Research on Hypoid Gears

For some time there has been doubt about the extent of the hydrodynamic film existing between meshing hypoid gear teeth and about the action of extreme pressure (E.P.) lubricants. Two unphosphated rear axles were connected back to back to form a power loop[9]. The pinion of the test axle was insulated electrically from the rest of the apparatus and contact was made with the gears through graphite bushes bearing on the driving flanges of the pinion and axle. The contact

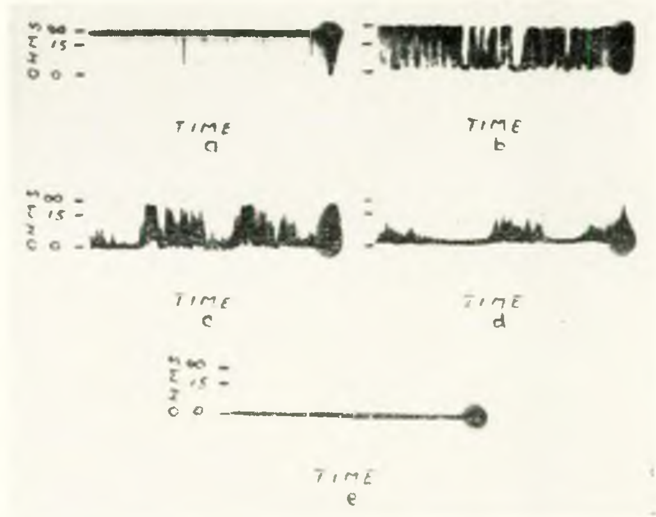
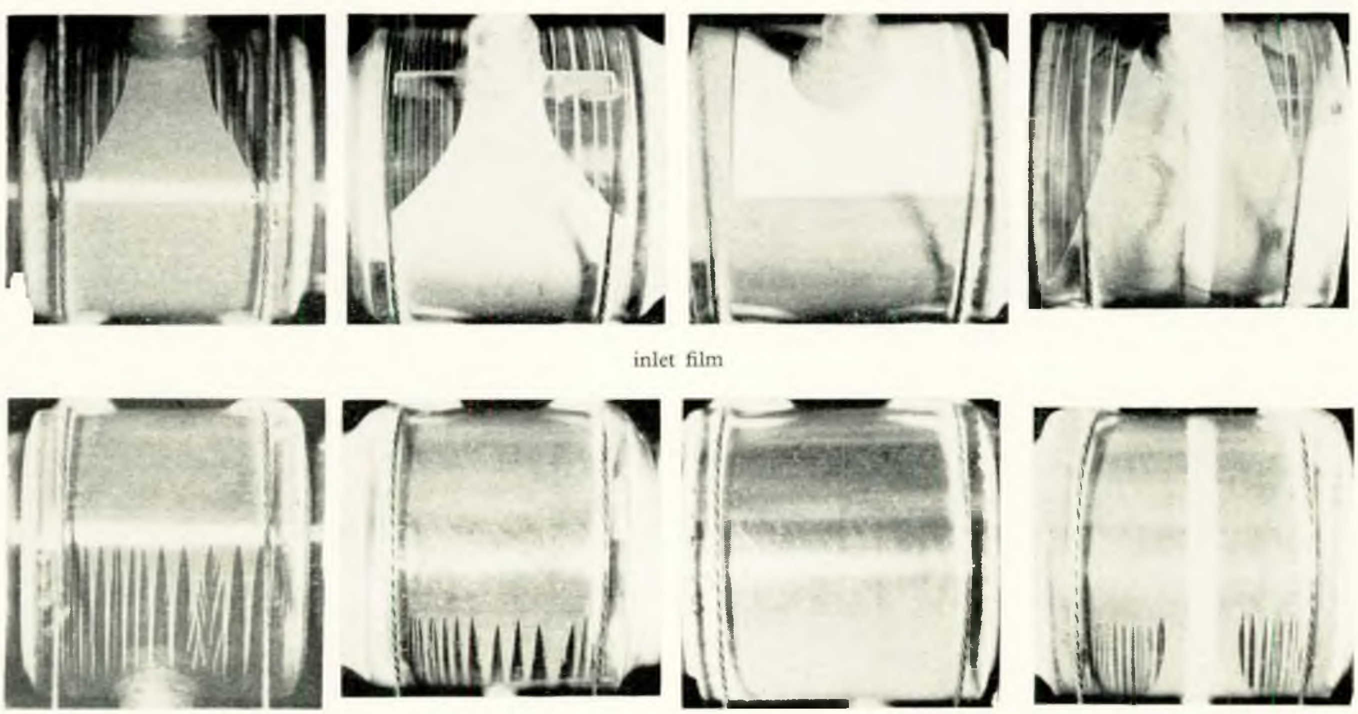


FIG. 8—*Typical contact-resistance/time records for hypoid gears*

resistance between meshing teeth was measured and the presence or absence of a lubricant film was deduced from the resistance measurements. Typical recordings are shown in Fig. 8. These correspond to about one-quarter turn of the pinion, or the engagement of two successive teeth of each gear. Two sets of experiments were carried out. The first was made with gears which had been carefully run in. These were run at speeds up to the equivalent of 60 miles/hr. under overload conditions and at temperatures up to 100 deg. C. Although the results confirmed predictions, based on conventional theory, that speed and increasing lubricant viscosity promote film formation while load and increasing temperature have the



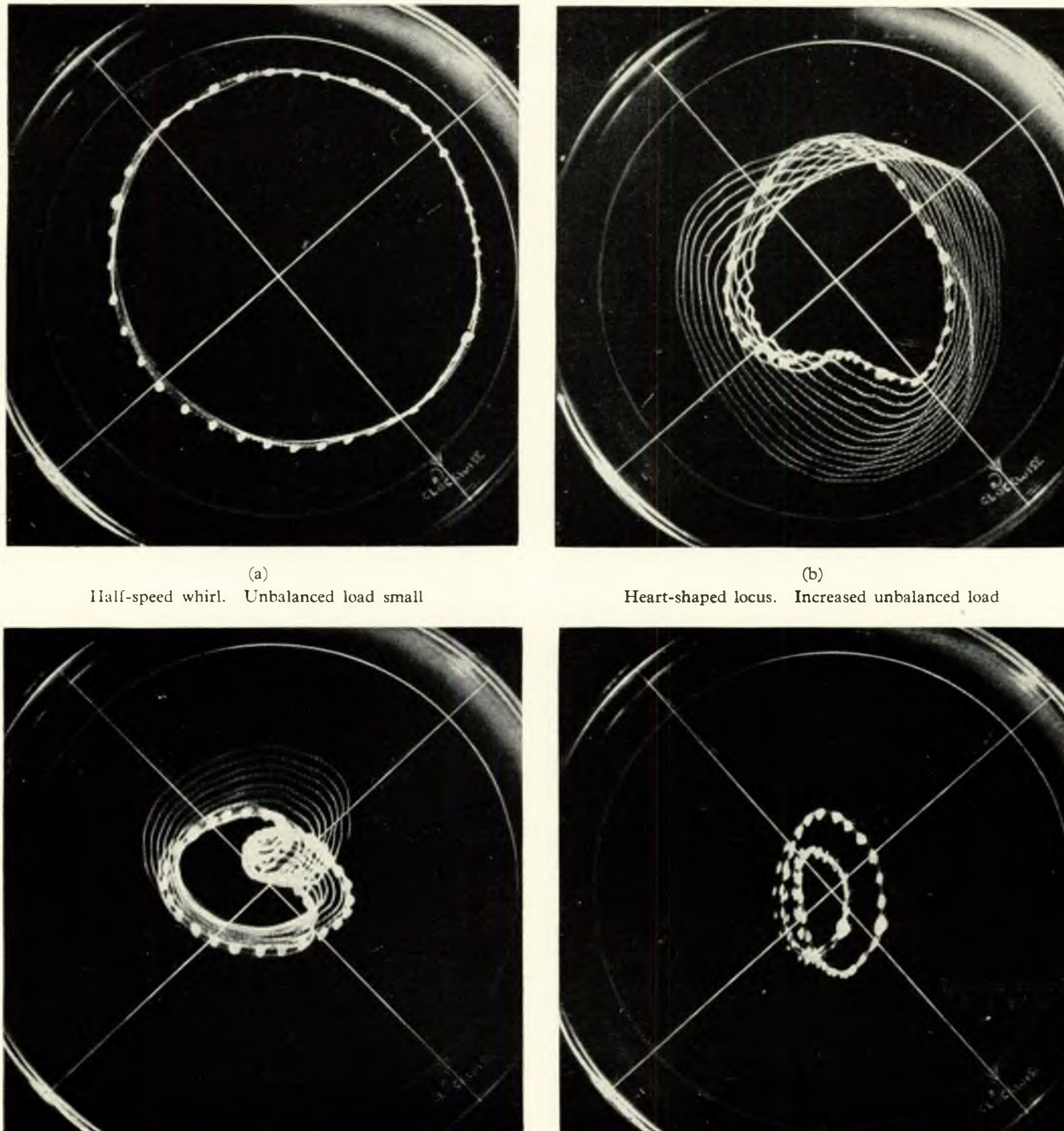
outlet film

(A) Single-hole (B) Single-hole with axial groove (low entry-pressure) (C) Single-hole with relieved area (D) Circumferential groove

FIG. 9—*Typical oil-film patterns in 1-in. diameter journal bearings with various oil entries*

opposite effect, hydrodynamic conditions of lubrication were found to exist much more often than had been expected.

In the second set of tests the running-in process was investigated. "Green" gears were run with an E.P. lubricant at a constant slow speed. The load was increased by increments, running being continued at each load until it appeared that equilibrium conditions had been obtained. The lubricant temperature was limited to 100 deg. C. by external cooling. After each increment of load, resistance gradually increased to a maximum value after about 10 hours. When the next increment of load was added there was a reversion to low resistance; a similar deterioration was also observed when the axle was allowed to cool and was then restarted from cold under the same load. When the gears had been fully run-in and were then restarted from cold, deterioration was not so marked. It appears that the main action of E.P. lubricants



(a)
Half-speed whirl. Unbalanced load small

(b)
Heart-shaped locus. Increased unbalanced load

(c)
Epitrochoid. Increased unbalanced load

(d)
Development of synchronous ellipse. Unbalanced load large

FIG. 10—*Changing pattern of shaft locus with increasing out-of-balance load*

is to provide surface protection during periods when there is no hydrodynamic lubrication, on starting and stopping and during part of the meshing cycle, and generally to maintain a surface finish conducive to hydrodynamic lubrication. The E.P. lubricant appears to be operative at high surface temperatures. Local surface temperatures of up to 700 deg. C. occur frequently in hypoid gears.

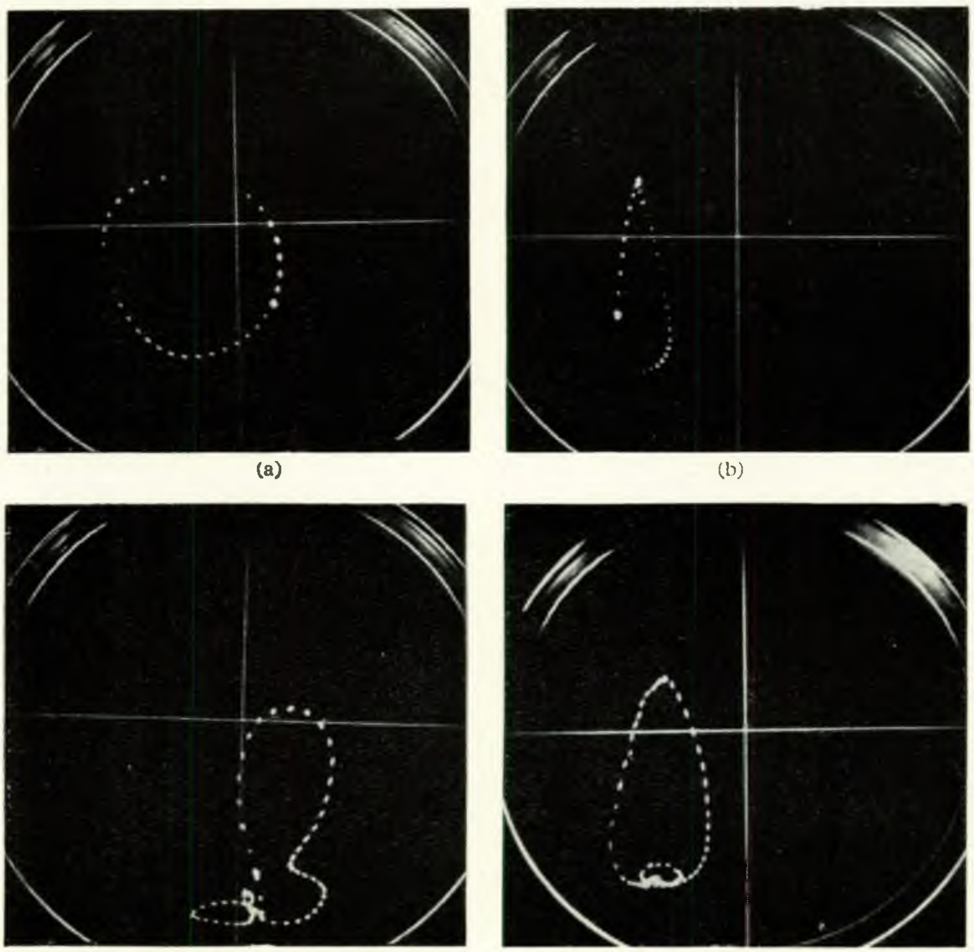
Other experiments[8] were made to simulate the reaction between sulphur or sulphur compounds (such as those used in E.P. oils) and metal which takes place in these short-period, high-temperature flashes. Pulses of electric current were passed through metal wires immersed in liquid paraffin containing the sulphur or sulphur compounds labelled with a radioactive isotope of sulphur. The radioactivity of the wire after the test gives a measure of the average thickness of film deposited. The first few pulses caused a very fast reaction in which a relatively thick surface film was built up. This was followed by a much slower diffusion process. If, however, there was a preformed surface film, or if phosphorus or chlorine compounds were present, the initial fast reaction was slowed down or even suppressed; the slow reaction, controlled by diffusion, was not affected to any extent. It seems clear that the initial fast reaction is a significant phase and it was found to depend on temperature.

d) Research on Plain Bearings

The Laboratory has developed techniques using transparent bearing bushes and an ultra-violet light source which allow the oil film in plain bearings to be observed under various conditions of load and speed[10]. An example is shown in Fig. 9. More recently experimental work has been concentrated on three investigations: the performance of high-speed plain bearings under steady loads; the effect of combined gravity and unbalanced loadings; and the performance of plain bearings under impulsive loadings in an internal combustion engine.

A rig was designed in which 2-in. diameter journal bearings could be run at up to 60,000 r.p.m. and the load, and oil supply pressure and temperature could be varied. The performance of a number of bearing configurations has been recorded and data on power losses, oil temperature rise, oil flow rate and bush surface temperature obtained. Various clearances, length/diameter ratios and oil supply arrangements are included. More recently a novel transducer system has been developed to allow the shaft position under load to be measured. The results will be published in due course.

Another rig allows 1-in. diameter journal bearings to be loaded by means of a variable eccentric load with combined gravity and unbalanced loads, and a transducer system[24] provides a means for measuring the shaft position with respect to the bush. Pairs of inductive transducers are mounted in the horizontal and vertical planes and the out-of-balance signals produced in bridge networks are displayed on a cathode ray tube and appear as the locus traced out by the shaft centre with respect to the fixed bush. It has been found that, as the ratio of out-of-balance load to gravity load varies, the character of the shaft motion changes as shown in Fig. 10. With small unbalanced loads a circle of high eccentricity is traced out with a frequency slightly less than half the rotational speed of the shaft—the familiar "half-speed whirl". As the degree of unbalance increases this circle develops into a heart-shaped figure with an internal loop (an epitrochoid). When the unbalanced load greatly exceeds the gravity load, the



(a) Engine motored with rotating inertia only

(b) Engine motored with rotating and reciprocating inertia

(c) Engine running under load

(d) Engine running light

FIG. 11—*Displacement loci of a Diesel engine crankshaft journal*

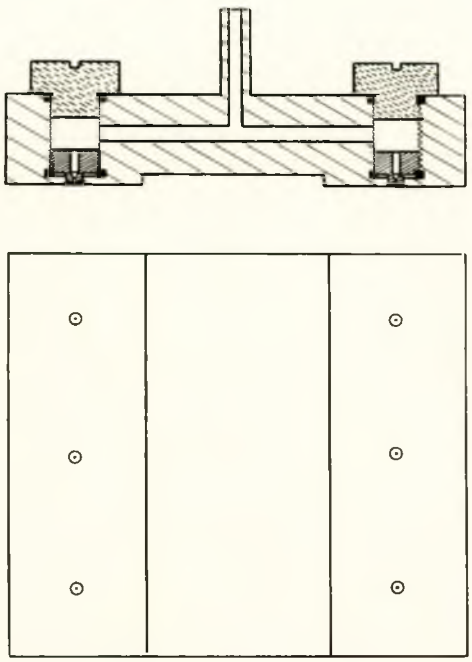
internal loop develops further and the locus becomes approximately elliptical, but is now of low eccentricity and synchronous with the shaft.

In the third investigation, inductive transducers of a similar type are used to measure the position of one of the main bearings of a four-stroke Diesel engine. Again, the trace on the cathode ray tube represents the locus of the centre of the crankshaft relative to the bush. The shaft position is located on the trace by brightening pulses at 20 deg. intervals with an additional pulse at top dead centre. Measurements of shaft displacement have been made with the engine motored and when run under its own power over the full range of loads and speeds of the engine; typical records are shown in Fig. 11. By arranging the transducers to measure the total gap instead of the shaft displacement, distortion in the bearing bush can also be measured. It is possible that the method can be developed for measuring the performance of bottom end bearings as well as of main bearings.

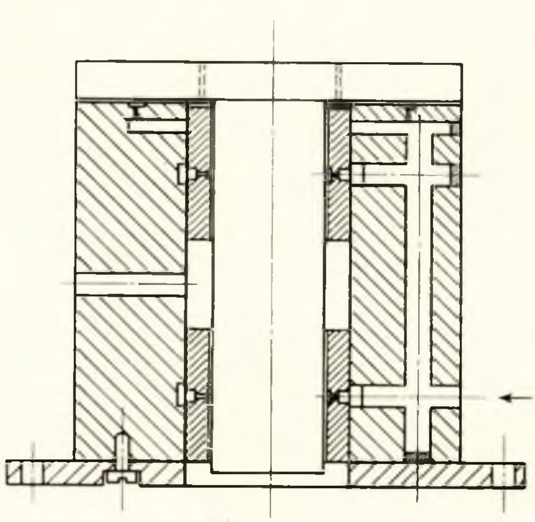
Concurrently, considerable efforts have been made to interpret the experimental results on a theoretical basis. Whilst some progress has been made, this work has shown the inadequacy of existing methods of predicting the performance of journal bearings, particularly at high speeds.

e) Externally Pressurized Fluid Bearings

Research has been carried out on externally pressurized air bearings; both slideway and journal bearings have been studied[40]. Typical configurations are shown in Fig. 12.



(a) FLAT



(b) JOURNAL

Fig. 12—*Typical pressurized air-lubricated bearings*

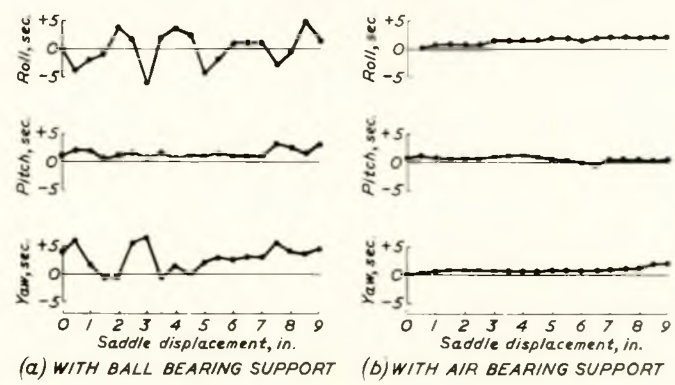


Fig. 13—*Comparison of saddle performance with ball-bearing and air-bearing support*

Such bearings have the advantage of very low friction, both when starting from rest and whilst in motion, and are free from wear since there is no metallic contact between the two parts of the bearing. A further advantage accrues from their tendency to maintain a constant mean air gap regardless of local irregularities in the two surfaces.

Design data have been determined for flat bearings relating load-carrying capacity, bearing stiffness, lift and air flow with bearing geometry and air supply pressure, all under static conditions. The effect of alternating loads has been studied and the dynamic stiffness of typical bearings determined. Air bearings were used to support the carriage of the automatic lead-screw measuring bench, already referred to, after comparative tests with the carriage supported on three precision ball bearings had shown that both the roll and yaw errors were greatly, and the pitch errors appreciably, reduced by this means (Fig. 13). Air bearings have also been

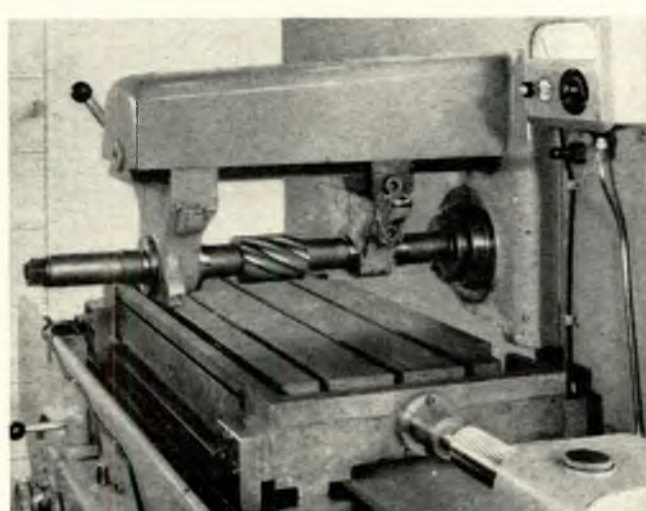


Fig. 14—*Milling machine with air-lubricated table*

fitted to the table of a horizontal milling machine (Fig. 14) and a recirculating ball lead-screw was substituted for the existing traversing mechanism. The bearing had a stiffness of about 1,000,000lb./in. and the traversing motor could be reduced from 2 h.p. to less than 0·1 h.p. Climb milling of mild steel was carried out successfully, an acceptable surface finish being obtained with a cut of $\frac{1}{4}$in. and feeds of up to 5in./min. More recently the compound slideways of a vertical milling machine have been converted to air bearings having a stiffness of about 4,000,000lb./in. A prototype compensated air bearing, which has almost infinite stiffness under slowly varying loads, has been developed. This is achieved by automatic alterations of supply pressure as the load changes.

Research on air journal bearings showed that they can provide very high rotational accuracy. An experimental vertical air journal bearing having a diametral clearance of 0·001in., in which the steel shaft was precision ground and the brass bushes diamond turned, was found to rotate to an accuracy of 5×10^{-6}in. under conditions of constant radial load and slow speed of rotation, i.e. its axis of rotation shifted less than 5×10^{-6}in. during one revolution. A roundness measuring instrument[34] using a bearing of this type has been developed and is now being produced commercially. Air journals have also been used in applications where very low friction is required, for example, in a fractional horsepower dynamometer developed at the Laboratory for the measurement of losses in small transmission units to a high order of accuracy[21]. Another application was to a machine for testing high-speed ball bearings[20]. In this case, air bearings were chosen because the machine was required to operate for long periods of time at speeds of up to 60,000 r.p.m. with negligible vibration. More recently air bearings have been used in an experimental grinding head; preliminary trials suggest that the surface finish achieved will not be inferior to conventional grinding heads, while the starting up time will be greatly reduced.

Some work has also been carried out on pressurized oil bearings. Comparative tests have been made on oil and air supported slideway bearings on the horizontal milling machine; no significant differences in surface finish appeared in preliminary cutting tests. Pressurized oil trunnion bearings have been extensively used in larger dynamometers.

f) Noise Generation in Machine Elements

A rig was developed[5] in which ball bearings of up to $\frac{7}{8}$-in. bore could be run under various combinations of radial and axial loads at speeds of up to 3,500 r.p.m. in an anechoic chamber. The driving motor and lubrication system were situated in an adjoining room, and even with the quietest bearings the noise produced by the rig was much less than that produced by the bearing under test. The noise level was found to increase with speed but was not affected by variations in radial and axial load, except at extremely low axial loads when an irregular noise was produced. Both precision and commercial grades of bearings were tested, and while precision bearings were in general quieter, some of them were noisier than the quietest of the commercial grade. It was found that one of the most important dimensional factors was the sphericity of the balls. All the balls were very closely spherical, but sets of balls with departures from sphericity of the order of 20 micro-inches showed an increase in noise level of about 20 db. compared with ball sets with departures from sphericity of only 5 micro-inches. Departures from circularity of the tracks, within the limits found within the bearings available for test, had no significant effect on noise. The effect of diametral clearance was studied using fifteen sets of balls in a single pair of tracks, the balls being graded at intervals of 0·0001in. from 0·0007in. above the standard diameter to 0·0007in. below it. Diametral clearance was shown to have little effect on the noise produced by the bearing except at low speeds. Mishandling of the bearing produced an appreciable increase in noise, and bearings which had been sufficiently maltreated to cause indentation of the tracks emitted a high pitched whine. Moderate care in assembly would normally be expected to prevent any increase in noise. It is clear that the noise generating properties of conventional ball bearings are affected mainly by errors in sphericity of the balls, and that other dimensional factors are much less important.

Some noise tests have also been carried out on gears[6]. Hobbed and shaped gears were run under similar conditions and the results are shown in Fig. 15. The general noise level of the power circulating machine is also shown from a test in which the gears were replaced by rubber rollers. As has been noted by other workers, the noise level at tooth contact frequency does not seem to depend on gear accuracy. It is clear that much more work remains to be done both on the causes of noise in gearing and on the fundamental cause of noise when two surfaces roll in contact.

g) Hydrostatic Transmissions

Two types of machine have been developed in the Laboratory and each can be used either as a pump or as a

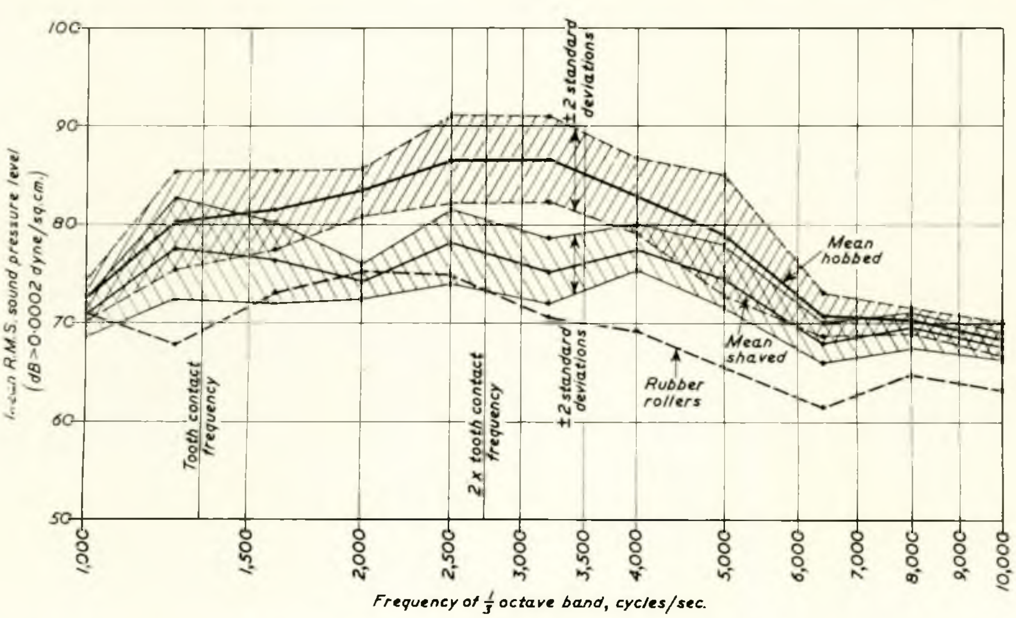


FIG. 15—*Curves of gear noise*

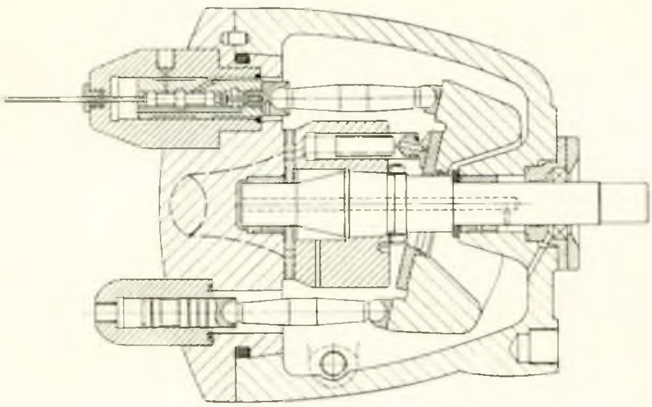


FIG. 16—*Section of swash plate machine*

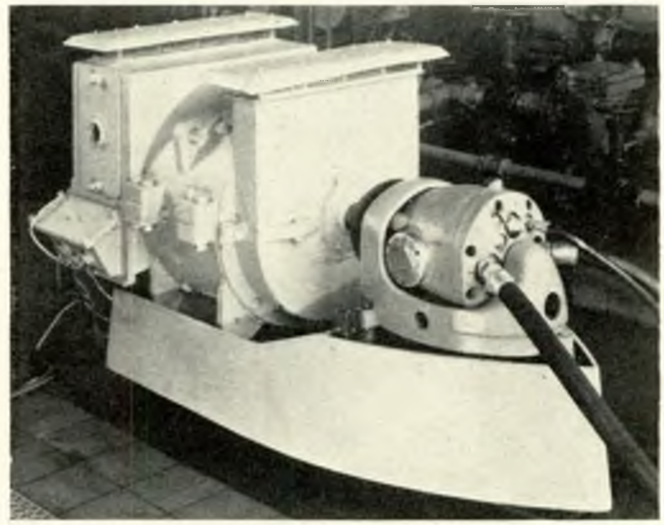


FIG. 17—*Swash plate pump*

motor. Each can be connected back to back with a similar machine to provide power transmission. In one the aim has been to obtain high efficiency, long life and quietness of running, while in the other low price has been considered of prime importance at the expense of efficiency and quietness, though a reasonable life was regarded as essential. The basic design[15] of the first machine is shown in Fig. 16. The arrangement with its axial pistons and swash plate is familar, but there are a number of novel features most of which are being patented. The cylinder block is fixed to the shaft, thus eliminating the need for universal joints. This is made possible by carrying the port plate on the shaft and by carefully balancing it to float on leakage oil between the face of the body and the pump block. Mechanical bearings have been avoided entirely and the main bearings are lubricated by bleeding off some oil from the delivery side; lubrication at the slipper pads is provided in a similar way. The setting of the port plate is adjusted automatically with varying delivery pressure to give minimum noise; this feature need not be included if other than the lowest attainable noise levels are required. The basic machine (Fig. 17) was designed to transmit 30 h.p. at about 3,000lb./sq. in. delivery pressure and 2,000 r.p.m. By increasing the delivery pressure and speed, up to 90 h.p. has been transmitted with the same machine. After some initial difficulties many hundreds of hours of running have been carried out at various speeds and pressures using the conventional hydraulic oils, and up to 1,000 hours running has been achieved with a water base non-flammable fluid.

The performance of the machine measured in the Laboratory is shown in Fig. 18. Fig. 18A gives the performance on half stroke and Fig. 18B on full stroke, when used as a pump. Fig. 18C and Fig. 18D give the performance at half and full stroke respectively when used as a motor. Thus, the maximum efficiency of two machines used back to back as a transmission is 85 per cent if friction losses in the connecting pipework are small enough to be ignored. This is obtained when the pump, absorbing 16½ h.p. at just over 1,000 r.p.m., is delivering 35 cu. in./sec. (7·6 gal./min.) of oil at a delivery pressure of 3,000lb./sq. in.; the motor then delivers 14 h.p. at just below 1,000 r.p.m. These figures are for the machine adjusted for minimum noise; slightly higher efficiencies can be obtained if adjustments are made for maximum efficiency.

A larger machine has been designed to transmit a nominal 200 h.p. at 1,800 r.p.m. and 3,000lb./sq. in. It is hoped that this machine will withstand operation at 3,000 r.p.m. and 5,000lb./sq. in.; at this rating it should transmit 500 h.p. Only about a hundred hours running as a pump at up to design speeds and pressures have been completed on this prototype machine.

The second type of machine[16], designed for low cost, is the radial ball-type machine shown in Fig. 19. The cylinder block, integral with the main shaft, rotates within an eccentric

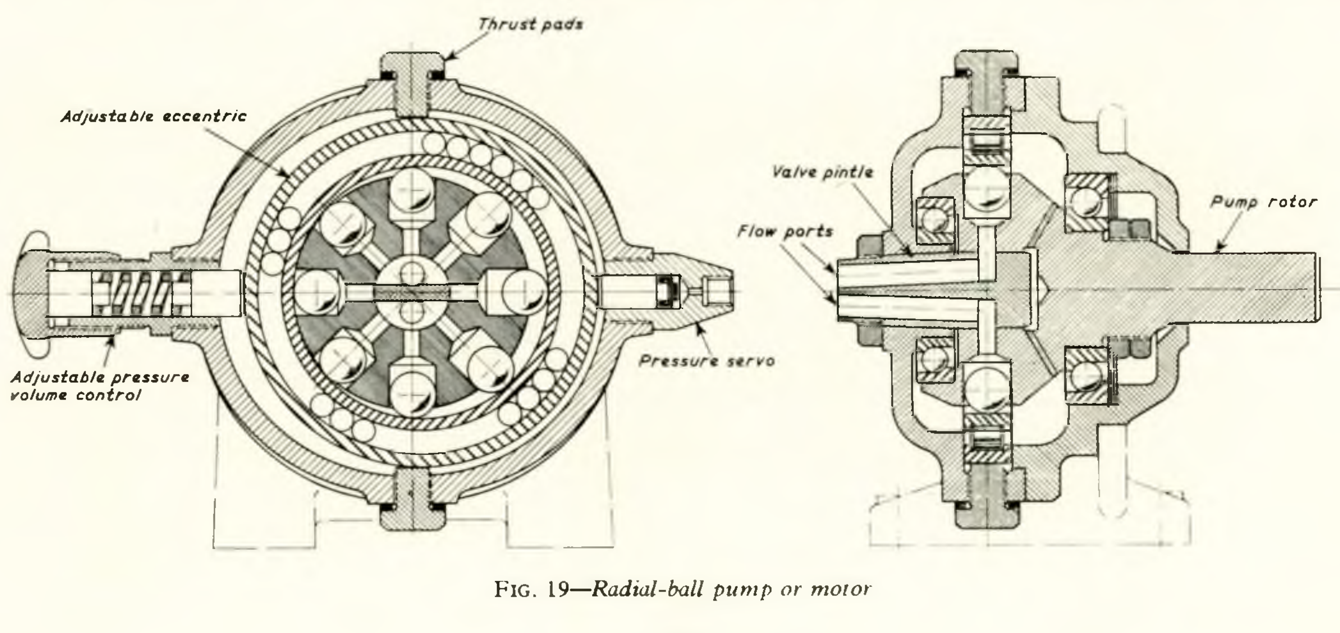
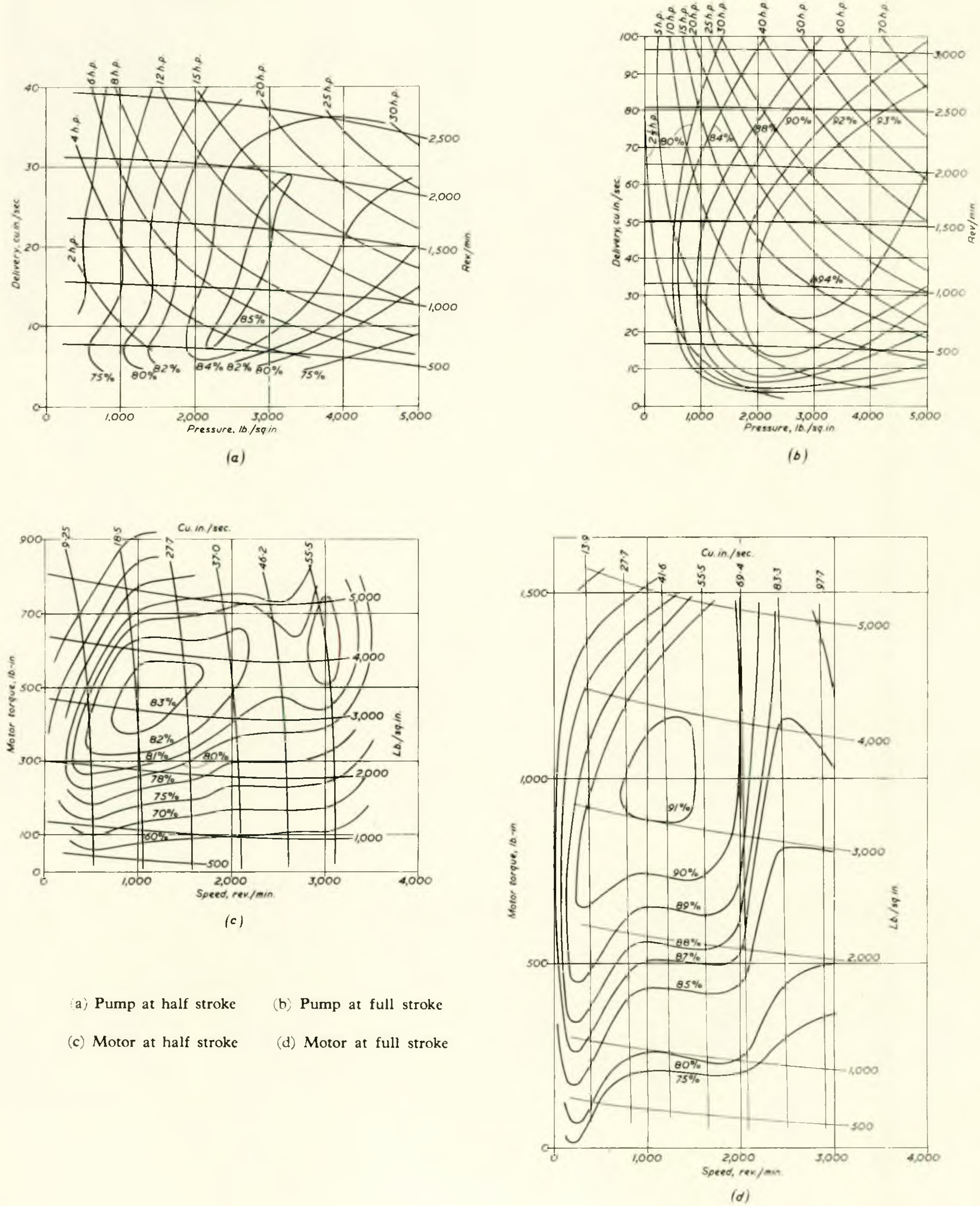


FIG. 19—*Radial-ball pump or motor*



(a) Pump at half stroke (b) Pump at full stroke

(c) Motor at half stroke (d) Motor at full stroke

FIG. 18—*Performance curves for swash plate machine*

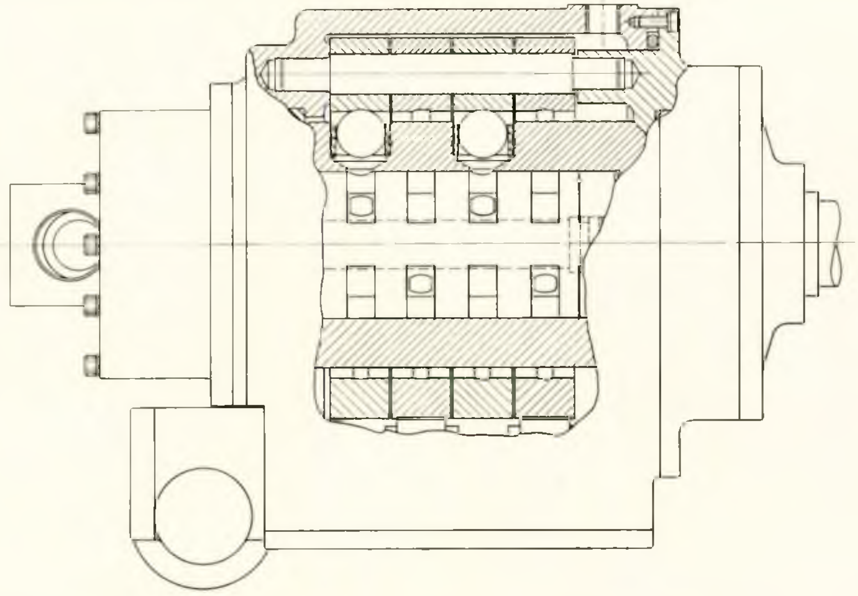


FIG. 20—*Part section of a four-row ball pump or motor*

race. Standard bearing balls are used as the pistons and these reciprocate, their stroke being controlled by adjusting the eccentricity of the race. The central pintle valve floats and can be adjusted to minimize noise. The machine is designed to work at pressures of up to 2,500lb./sq. in. and 2,000 r.p.m. The nominal rating of a single-row unit, such as that illustrated, is 15 h.p. A number of such units can be stacked together on a single shaft to give larger powers. A four-row unit is shown in section in Fig. 20. Fig. 21A and Fig. 21B show the performance of the four-row unit when used as a pump and motor respectively. A rotating race rather than a fixed race, and particular ball and race dimensions were selected so as to give an acceptable fatigue life. The vertical boring machine[17] which has been widely exhibited (Fig. 22), utilizes a four-row pump and two four-row motors for the main drive. A second hydrostatic transmission, using ball

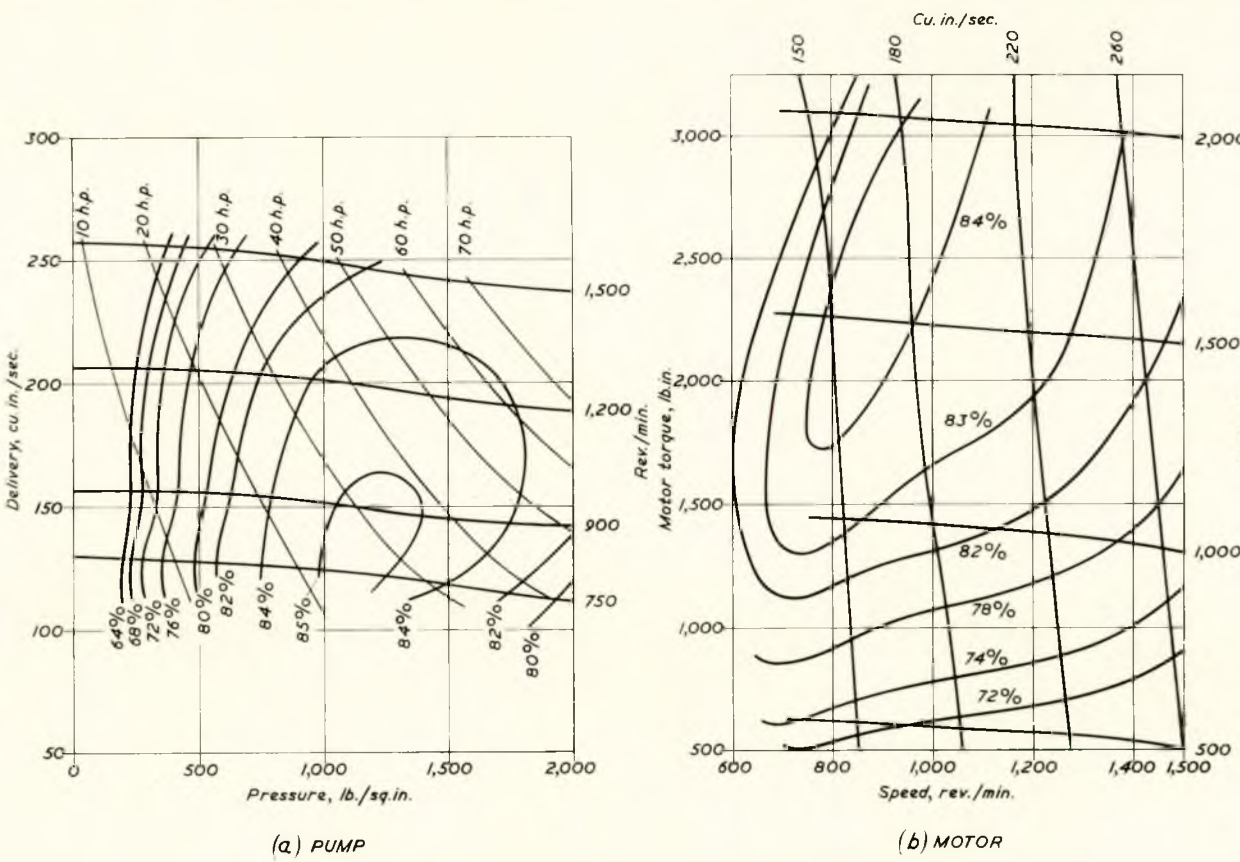


FIG. 21—*Performance curves for a four-row ball machine*

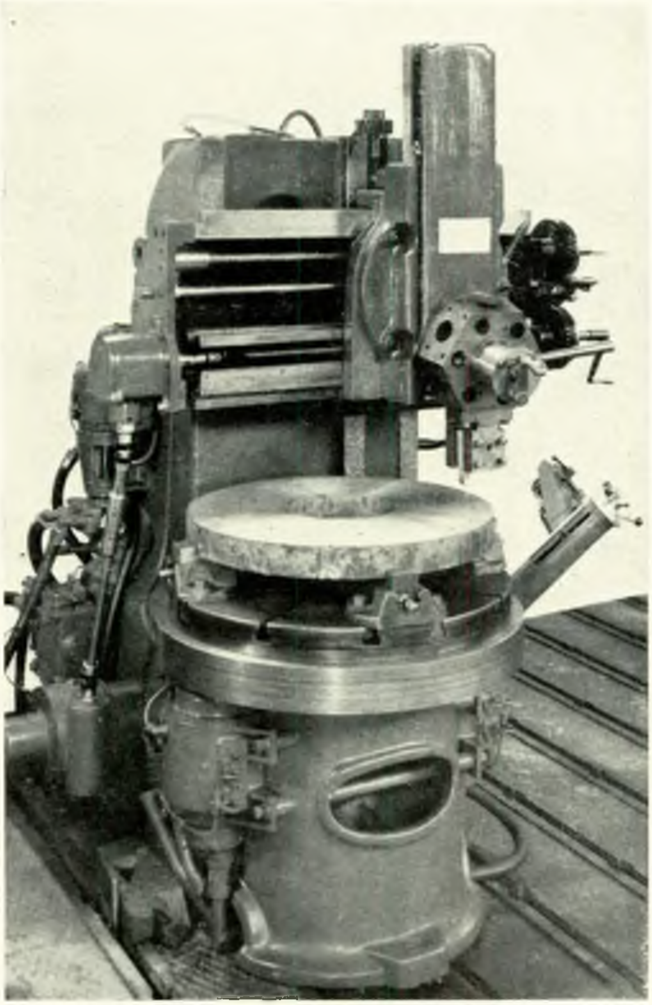


FIG. 22—*Vertical boring mill fitted with hydrostatic power transmissions*

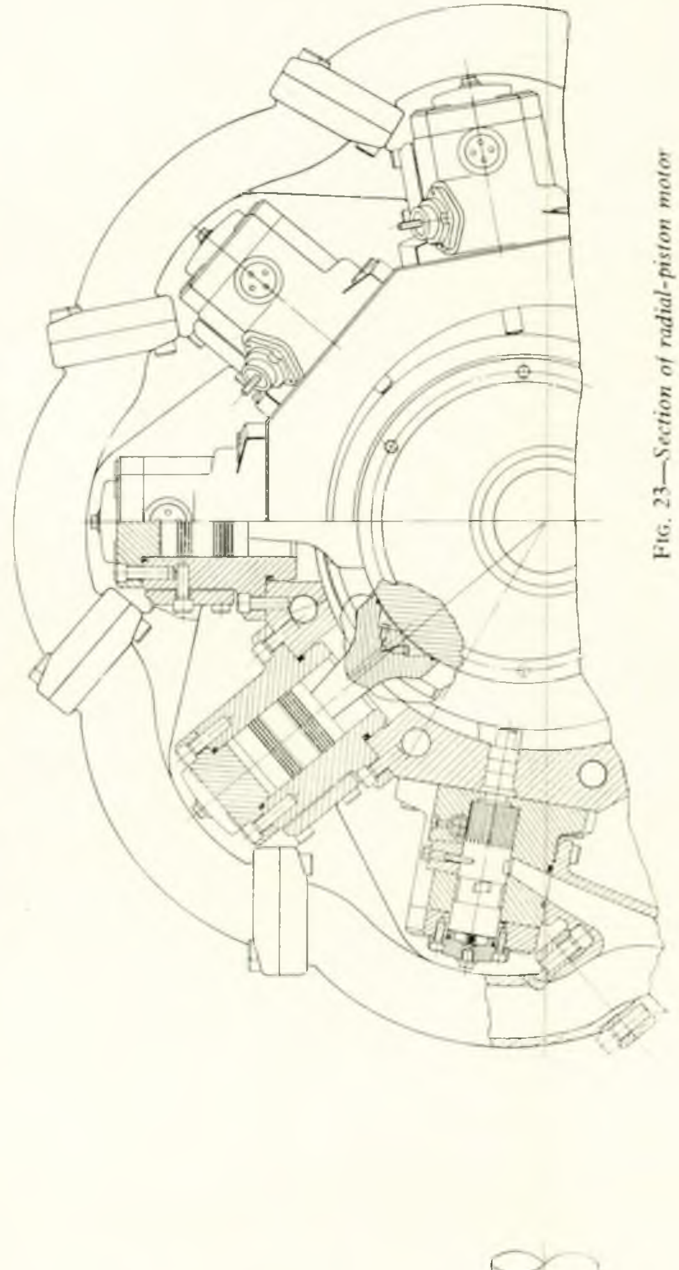


FIG. 23—*Section of radial-piston motor*

units, provides the traverse drive. The use of a hydrostatic transmission for the main and subsidiary drives provides a ready means of maintaining a constant cutting speed as the tool traverses in a facing cut.

A third machine has also been developed, but this is designed solely as a motor and not as a reversible machine. The basic design is shown in Fig. 23. This is a low speed radial-piston machine designed to give 200 h.p. at 2,000lb./sq. in. and 500 h.p. at 5,000lb./sq. in. It is thus matched to the swashplate pump already described. The motor has been so designed that a number of similar units can be sandwiched together on a single shaft to provide larger powers. Once again a feature of the design is the use of hydrostatic lubrication and the means provided for adjusting the valves to give minimum noise. The construction of a prototype motor is now well advanced.

SELECTED PROJECTS—FLUIDS GROUP

a) Preparation of Steam Tables

At the Fifth International Conference on the Properties of Steam held in London in 1956, a committee, with members from the United Kingdom, the U.S.A., the U.S.S.R. and Western Germany, was given the task of preparing new draft skeleton tables of the properties of steam, based on all available experimental data and covering temperatures up to 800 deg. C. and pressures up to 1,000 atm. Although the international experimental determinations of properties have not yet been completed, the Laboratory has been investigating numerical methods for producing tables from existing data using its DEUCE digital computer. In the past most tables of thermodynamic properties have been derived from experimental data by graphical methods or by combined graphical and numerical methods. Such methods do not necessarily lead to consistent tables. High speed computers make possible the derivation of an empirical equation of state by purely numerical methods. Having obtained the equation, the production of tables is a simple matter and the tables of properties derived from one mathematical expression are bound to be consistent. Free energy appears to be the best basis for an equation with the widest possible validity. From this function, when given in terms of density and temperature, all the properties of the fluid can be determined by simple mathematical processes. Any empirical expression for the free energy should be based on all the available data but many of these (PVT relations, specific heats, specific enthalpy, Joule-Thomson coefficients) are given in terms of pressure and temperature as the independent variables. Thus it is necessary first of all to derive from the experimental data an empirical expression relating pressure to density and temperature. Much of the work at N.E.L. has been concerned with methods of achieving this.

Although the pressure range up to 1,000 atm. has been considered, it was decided in the first instance to limit the temperature range to temperatures greater than the critical. The equation derived was not good enough in the immediate neighbourhood of the critical point. It predicted a critical temperature about 1 deg. C. different from that generally accepted. More recently[4] the work has been further extended to a wider range of temperatures down to about 200 deg. C. and was conditioned to have the correct behaviour at the critical point. The new equation provides a good fit to the experimental data, the average percentage error in pressure over the whole range of data being 0·24 per cent. The agreement of the equation with the chosen critical point is, of course, exact; in the neighbourhood of the critical point there is still, however, room for improvement. Errors in this region oscillate over the range of $\pm 0{\cdot}5$ per cent. It may prove to be necessary to deal separately with a strip centred round the critical temperature. Although the tables are of a preliminary nature they have demonstrated the possibility of using a digital computer in this type of problem. When the results of the international experimental determinations of properties become available it should be possible to produce authoritative tables reasonably quickly.

b) Heat Transfer to Fluids Flowing in Pipes

A method of determining the effect of bends and changes of section on the heat transfer to a fluid flowing in a pipe has been developed in the Laboratory[14]. Heat is generated in the pipe walls by the passage of a heavy direct current. The thickness of the walls is chosen such that the heat is generated uniformly. The pipe is well insulated externally and the test fluid is passed through it at measured rates. Thermocouples are used to measure the temperature of the pipe wall at a large number of positions, and care is taken to use a sufficiently long straight length of pipe both before and after the feature under test. From the observations of pipe wall temperature local heat-transfer coefficients are calculated. So far, abrupt changes of section, with ratios of up stream to down stream diameter of 0·3, 0·5, 0·8, 1·25, 2·0 and 3·3 : 1 have been investigated using water, and ratios of 0·5 and 2·0 : 1 using air. Single bends having ratios of curvature radius to pipe radius of 21, 8, and 4 : 1 have been examined using water, and so has an abrupt elbow. Work is now proceeding on the effect of 180 deg. bends and on transverse grooves in the pipe. At the same time, flow visualization techniques have been developed to investigate the flow patterns in many of the configurations in order to explain unusual or unexpected variations. Most of the results obtained to date have been published. A typical result is shown in Fig. 24. The flow pattern at a Reynolds number of 1,000 is shown in Fig. 25.

c) Development of a Fully Cavitating (Super-cavitating) Pump

In the last few years much research and development effort has been put into the development of high-speed fully cavitating propellers for fast craft. The theory produced is applicable to the case of an axial-flow pump. At present

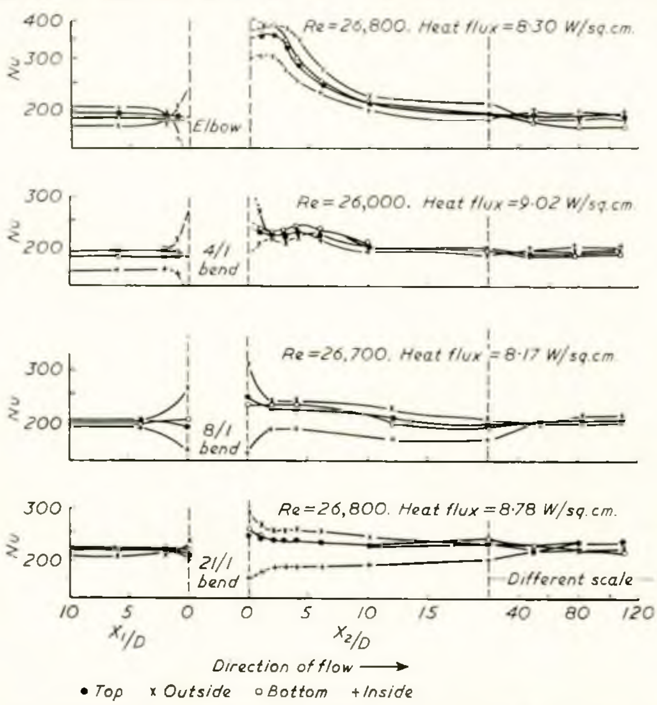


FIG. 24—*Variation of local heat-transfer coefficient along and around pipes containing four different right-angle bends*

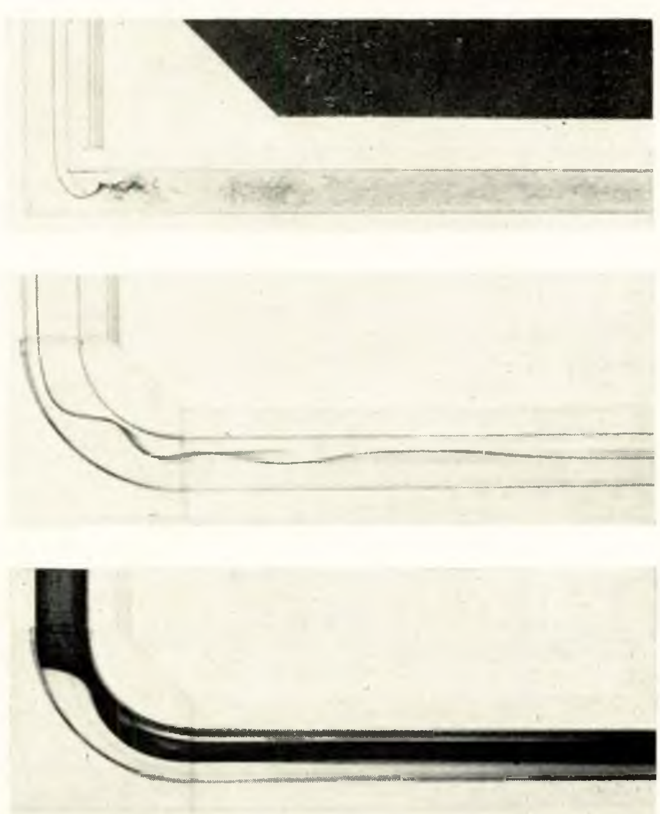


FIG. 25—*Flow visualization photographs at a Reynolds number of 1,000*

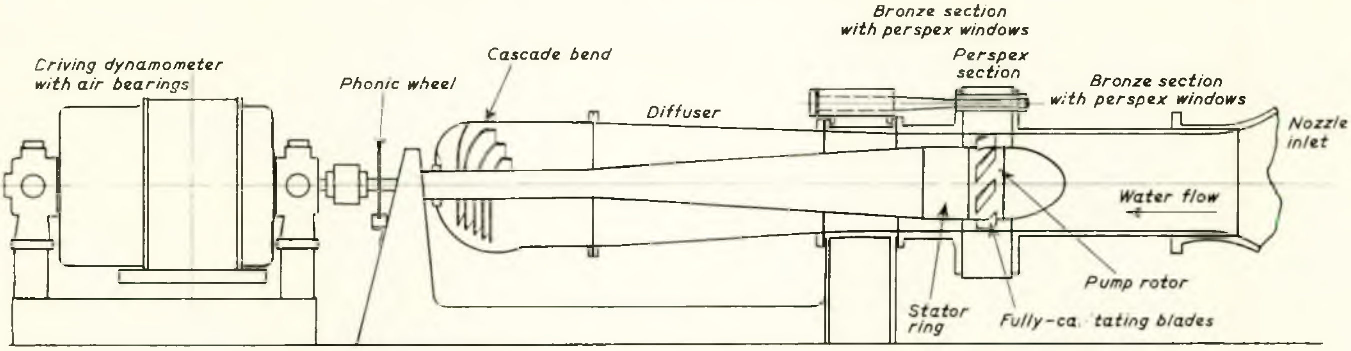


FIG. 26—*General arrangement of experimental rig for work on fully-cavitating pump design*

whirl cavitation imposes severe limitations on the rotational speed and suction performance of axial-flow pumps. Fully cavitating pumps, if they can be developed successfully, should have great advantages in size and wherever volatile liquids have to be pumped. A design procedure has been worked out which makes use of the DEUCE computer, and the design of the first runner for such a pump has been completed. A test rig (Fig. 26) is available and testing of the characteristics of the design will commence shortly. It is, of course, possible that the development of a machine having acceptable characteristics will prove to be protracted.

d) Improvement in Steam Condensers

For some years the Laboratory has sought means by which the mode of condensation of steam could be controlled reliably. Heat transfer coefficients obtained with dropwise condensation are considerably greater than those with filmwise condensation, and the improved heat transfer rates should permit a reduction in the size of heat exchangers or alternatively an increase in the output of existing units. This could lead to reductions in capital costs, in civil engineering costs and, perhaps more important in marine applications, to reductions in plant space. A number of substances have been discovered or developed which will give dropwise condensation under laboratory conditions. Life tests of these substances have been carried out, and in the most recent series five promoters used with four copper alloys, with industrial steam, were investigated. The results confirm that the life, with a single promotion, is severely limited by fouling on the tube surfaces. Tests with periodic injection of promoter into the steam have shown that, with two of the promoters, dropwise condensation can be maintained for more than twelve months while condensing industrial steam. Less than one part of promoter in 10^7 parts of condensate was used in these tests. The overall heat transfer coefficient for brass tubes treated with promoter was found to be about twice that for untreated tubes. Life tests of dropwise condensation promoters have also been carried out on a limited scale under industrial rather than laboratory conditions. The results so far are inconclusive. Close contact is maintained with work on the physical chemistry of the process which is being carried out in the Department's Warren Spring Laboratory at Stevenage.

An experimental 150-tube condenser has been designed and is being installed in the Laboratory, together with its ancillary plant including a desuperheater, air ejector, weighing machines and circulating pumps. The condenser has observation windows and is very fully instrumented. Both the tubes and the baffles can be varied. It is proposed, initially, to examine the distribution of flow through the tubes over a range of cooling water velocities, and thereafter to measure overall heat-transfer coefficients for individual tubes and for the whole bundle, and to determine condensate and steam distribution under various conditions of condensation over a wide range of steam pressures and cooling water velocities. The rig provides for operation at a range of steam pressures from 15lb./sq. in. gauge to 29 inches of mercury vacuum, with cooling water velocities of up to 25ft./sec.

SELECTED PROJECTS—MATERIALS GROUP

a) The Effect of High Pressure on the Properties of Materials

In metal working processes such as extrusion, rolling and wire drawing, deformation takes place in the presence of hydrostatic pressures which may be considerably greater than the yield stress of the metal. The effect of such pressures on material properties has been studied in an apparatus developed at the Laboratory in which pressures up to 100 tons/sq. in. can be sustained[33]. Devices for carrying out both tensile and torsion tests of 1/10-in. diameter specimens have been developed to fit inside the pressure chamber, which is 1¼in. in diameter. In the case of tensile tests, strains are observed photographically through small windows in the pressure chamber, which are suitable for use at pressures of up to 80 tons/sq. in. The pressures are measured by the change in resistance of a small coil of manganin wire immersed in the fluid filling the chamber. Since normal hydraulic oils would freeze at the pressures used, isopentane or a mixture of castor oil and methyl alcohol is normally employed.

Copper, aluminium, zinc and cast iron all showed an increase in ductility with pressure, and in some cases the increase was most marked. Results for aluminium and zinc are shown in Fig. 27. In aluminium, and in copper too, the increase departs little from the straight line previously found by Bridgman[7], but in zinc the transmission from a fully brittle to a fully ductile state occurs quite suddenly over a very narrow range of hydrostatic pressure. Fig. 28 shows the difference in appearance of tensile test pieces pulled under pressures differing by only about 3 per cent.

Consideration of these results suggested that brittle metals, which cannot be cold extruded successfully by conventional methods, might be formed satisfactorily if the hydrostatic stress component in the forming region could be increased. This can be done if the process is carried out in a pressurized fluid.

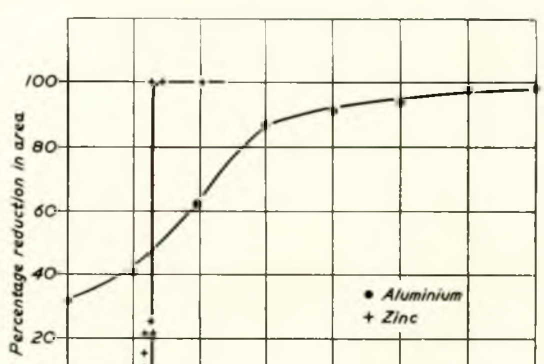
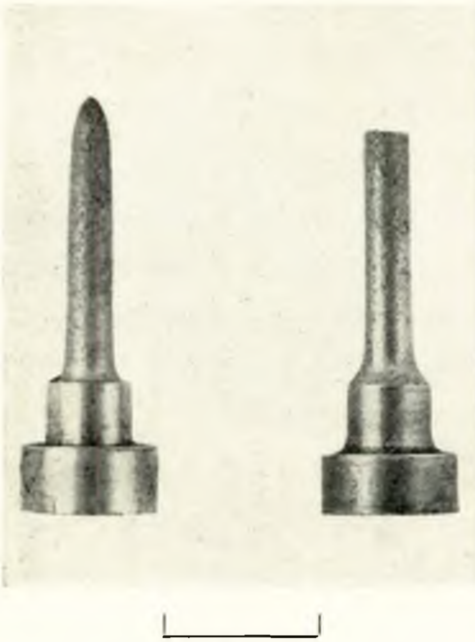


FIG. 27—*Effect of hydrostatic pressure on the ductility of zinc and aluminium*



½-in.

FIG. 28—*Tensile tests pieces of zinc pulled under pressures of 6·5 and 6·3 tons/sq. in.*

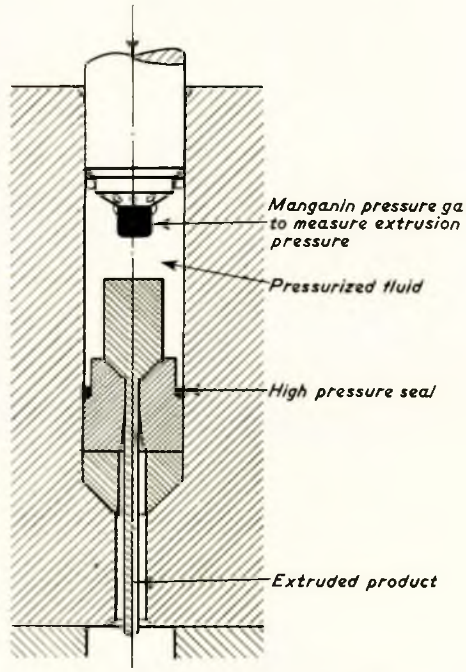


FIG. 30—*Apparatus for cold extrusion by fluid pressure*

Experiments showed that both magnesium and bismuth could be extruded successfully and that pressures of only a few tons per square inch were necessary to inhibit cracking. For bismuth, the critical pressure depends on the extrusion ratio and has a maximum of less than 1½ tons/sq. in. at an extrusion ratio of 2, falling to less than 0·5 ton/sq. in. at ratios of less than 1½ or more than 4. Photographs showing the results of extruding magnesium at both atmospheric and at increased pressures are shown in Fig. 29.

It has also been found that the use of a pressurized fluid in place of the ram in the conventional extrusion process results in a considerable reduction in the extrusion pressure required, and gives a product with a much smaller variation in properties across the section. The billet, which is preformed to fit a conical die entry, is smaller in diameter than in the conventional process so that a fluid pad is formed between it and the container wall as shown in Fig. 30. Friction between the billet and the container is thus eliminated and, since some of the pressurized fluid is partly forced and partly dragged along the conical die face, thereby maintaining lubrication, friction on the die is greatly reduced. The use of small angled dies, made possible by the elimination of the ram, reduces the amount of redundant work which has to be done.

Current research is aimed at combining the two methods. This should allow high-strength brittle materials, such as beryllium and its alloys, to be extruded; the back pressure should allow a sound uncracked product to be produced while the use of a fluid pad and conical die should reduce the extrusion pressures required. The application of high fluid pressures may confer comparable benefits in other formation processes and a programme of work is being considered at the Laboratory.

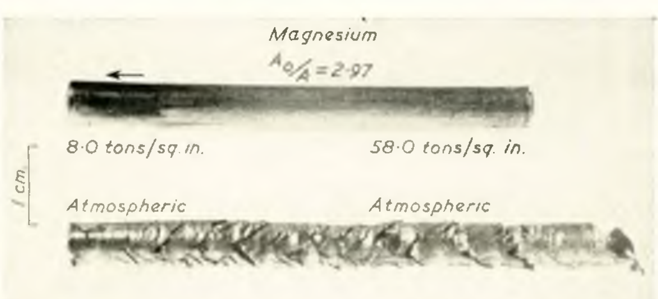
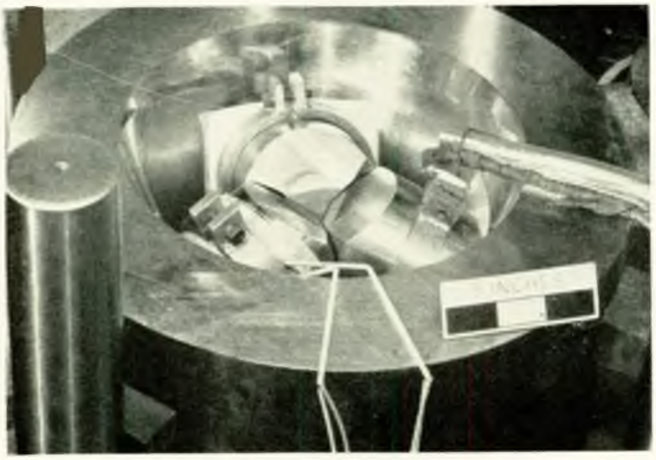


FIG. 29—*Improvement in the cold extrusion of magnesium using hydrostatic pressure*

In order to study the effect of still higher pressures combined with high temperatures, the Laboratory has built a modified form of the Tracy Hall apparatus[29]. This comprises four tungsten carbide faced steel anvils which come together to form a tetrahedral cavity of ¾-in. edge length (Fig. 31). Three of the anvils are adapted to butt on the inner conical face of a steel ring and the resulting wedging action provides the desired thrust when the ring and the fourth anvil are compressed axially in a 500-ton hydraulic press. Teflon sheets are used to ensure a low coefficient of friction and to insulate the anvils electrically from the remainder of the apparatus. The four anvils when fitted together surround a pyrophyllite tetrahedron, which is preformed slightly over size, its edge length being ⅞in. On compression, the excess material extrudes into the gaps between the anvils where it forms an efficient yet compressible gasket seal. The apparatus is designed to work at pressures of up to 100,000 atm. At these pressures no suitable liquids remain unfrozen but pyrophyllite transmits pressure almost hydrostatically; it also provides reasonable electric insulation. The material to be studied is placed in a thin metal tube embedded in the pyrophyllite. If the specimen is to be heated the tube is arranged with contact pieces which make contact with two of the anvils. A heavy current can then be passed through the tube and by this means the specimen can be heated to 2,000 deg. C. or above. The apparatus was first calibrated to relate the hydrostatic pressure obtained to the load exerted by the press, by observing reversible phase transitions in certain metals. The transition point is associated with a change in electrical resistance. Transition points for bismuth, thallium, and barium are now generally accepted. Using this apparatus the Laboratory has been able to repeat the synthesis of diamond from graphite. A specimen composed of alternate graphite and nickel layers with tantalum end-tabs was subjected to a pressure of 75,000 atm. and a temperature of 2,000 deg. C. A cluster of black synthetic



(a)
Three lower anvils mounted inside steel ring showing current lead and thermocouple wire

(b)
One anvil showing cemented carbide insert fitted into steel binding ring, and copper electrical current ring

FIG. 31—*Ultra high-pressure apparatus*

× 200

FIG. 32—*Synthetic diamond produced by N.E.L.*

diamonds was obtained with well-developed crystal faces. The largest produced was 0·3 × 0·3 × 0·4 mm.; a photograph of this diamond is shown in Fig. 32.

b) Formation and Growth of Fatigue Cracks

Research carried out at the Laboratory has shown that the mechanism of crack propagation is different from that of crack initiation. This was brought out by Phillips in a paper[32] presented to the Scottish section of the Institute in January 1959. He described "non-propagating cracks" observed in a series of tests using mild steel, nickel/chromium steel, and an aluminium alloy. More recently[19] it has been shown that for mild steel, a 70-ton nickel/chromium steel, a 4½ per cent copper/aluminium alloy, and copper, subjected to reversed direct stress loading, the critical alternating stress σ required to propagate a crack of length l is given by the equation $\sigma^3 l = C$, where C is a material constant. Values of C obtained for various materials are shown in Table II, column 2.

For a given value of l, the crack will propagate if σ^3 is greater than C/l and remain dormant if σ^3 is less than C/l. If we assume the generally accepted values of plain fatigue limit for these materials, a minimum length of crack which must form before it will propagate is again shown in Table II, column 4. This shows why the fatigue strengths of nickel/chromium steel and of the aluminium alloy are much more dependent on surface finish than are those of mild steel or copper.

In a sharply notched specimen stressed at up to the conventional notched fatigue limit, shallow non-propagating cracks form at the notch root. The conventional notched fatigue

TABLE II

(1) Material	(2) C	(3) Plain fatigue limit (tons/sq. in.)	(4) Minimum length of crack to propagate (in.)	(5) Notched* fatigue limit (tons/sq. in.)	(6) K_f*
Mild Steel	5·5	±13·5	0·0022	±3·9	3·3
Ni-Cr alloy steel	5·5	±32	0·00017	±3·9	8·2
4½ per cent Cu-Al alloy	0·2	±9	0·00027	±1·25	7·2
Copper	0·5	±4	0·0078	±1·7	2·3

* For a sharply-notched specimen of notch depth 0·1 inch

limit σ will then be given by the equation $\sigma = \left(\frac{C}{l_d}\right)^{\frac{1}{2}}$ where l_d is the length of notch plus crack. These are shown for the four materials considered in Table II, column 5, where it is assumed that the notch depth is 0·1in. and that the crack length is small enough to be neglected. Column 6 shows values of the strength reduction factor K_f given by $K_f = \frac{\text{plain fatigue limit}}{\text{notched fatigue limit}}$

These figures show clearly why nickel/chromium steel and aluminium alloys are termed "notch sensitive" while mild steel and copper are termed "notch insensitive". They also explain why devices such as the "notch sensitivity index" have not proved very useful.

The rate of growth of fatigue cracks has also been studied[18] using specimens 10in. wide by up to 1in. thick. These have shown that the crack growth is discontinuous if the applied alternating stress is small. Cracks may lie dormant for considerable periods; at a suitable stress, such a dormant period could be prolonged indefinitely and the crack would be "non-propagating". At higher stress levels growth is continuous and the growth rate for crack lengths of up to $\frac{1}{8}$ of the sheet width may, in general, be represented by $\frac{dl}{dN} = \sigma_a{}^3 l(P + Q\sigma_m)$ where l is the crack length, N is the number of cycles, σ_a is the applied nominal alternating stress, σ_m is the nominal tensile mean stress, and P and Q are material constants. For mild steel and copper Q = 0. The relative rates of growth of fatigue cracks, taking annealed mild steel as 1, are shown in Table III. It should be emphasized that good resistance to the slow growth of fatigue cracks does not necessarily imply good resistance to either fast cyclic or brittle fracture, nor is it possible to predict the ability of a material to resist fatigue crack growth from other standard mechanical properties.

The investigations already described have been supplemented by basic physical studies of the mechanism of the processes involved[23], in order to provide a fundamental explanation of fatigue damage and failure and to define the qualities required of engineering materials to resist such damage.

TABLE III

Relative susceptibility to fatigue crack growth of various materials tested is:

Austenitic steel	0·7
Annealed mild steel	1
Cold-rolled mild steel	1·5 (Some dependence on mean stress, also fast cyclic fracture occurs at small crack lengths)
Cold-rolled copper Annealed copper	4
Pure aluminium	12
4 per cent Cu-Al alloy (L71)	30 (Some dependence on mean stress)
Tufnol	55 (Very approximate. Brittle fracture occurs at small crack lengths)
Zinc	150 (Some dependence on mean stress, also fast cyclic fracture occurs at small crack lengths)
5½ per cent Zn-Al alloy (Alclad) (DTD 687A)	160 (Some dependence on mean stress. Initial period of growth at low stresses gives relative growth rate of 90).

Cold-rolled copper and Alclad may sometimes exhibit an initial period of slower growth prior to the above rates being realized.

It is known that sub-grains are produced in metals subjected to cyclic stressing, and an X-ray micro-beam technique has been used to examine in detail the size and orientation of sub-grains on the fracture surface of specimens of aluminium and mild steel in which a crack has been growing slowly. It was found that the grains ahead of a growing crack broke down into sub-grains of characteristic size and that micro-cracks developed at the boundaries of adjacent sub-grains that had become severely mis-orientated. The main crack front is considered to form by the necking down of the regions between sub-grain and micro-cracks. Two aspects of fatigue crack growth can be interpreted on this model: a) the order of susceptibility to fatigue crack growth in metals is related to the ease of formation of sub-grains and hence to the stacking fault energy; b) the phenomenon of non-propagation of surface cracks is expected when the volume of material ahead of the surface crack which is subject to cyclic plastic strain is too small to allow the characteristic sub-grain structure to develop.

c) *Materials under Static Load at High Temperatures*

A considerable volume of tensile creep testing is carried out in laboratories, in industry, research associations and government establishments to obtain data for design purposes. N.E.L. participates to a limited extent and this ensures that the Laboratory is able to make an independent critical assessment of results reported by others, and can make its contribution to the development of machines, instrumentation and techniques. Research programmes are concerned with the effect of intermittent stress and temperature on tensile creep properties, the effect of atmosphere and surface conditions, the effect of notches and stress concentrations and with a study of creep strain damage so as to extend the knowledge of the capacity of materials to sustain further strain safely either under continued constant, or temporarily increased, stress conditions. An important project is concerned with the verification of extrapolation procedures. Some long-time creep tests have already been carried out and when the new laboratory becomes available, further tests extending to 100,000 hours will be undertaken. It is hoped that this work will lead to improved extrapolation procedures and may reduce the need for long term tests.

For more than twenty-five years, D.S.I.R. has maintained a small team studying the complex-stress creep, relaxation and fracture of metallic alloys. For the last ten years this team has formed part of N.E.L. and a wide range of complex-stress creep machines is available for this work. A comprehensive paper[28] by Dr. A. E. Johnson, the leader of this team, is being published by H.M. Stationery Office. A typical piece of work published recently[26] concerns the behaviour of metallic thick-walled cylindrical vessels or tubes subject to high internal or external pressures at elevated temperatures. In general, the design of these components has been based either on considerations of creep strain only or, in some cases, of elastic strain only. In many cases, however, the working conditions are such that, during the life of the vessels and tubes, both creep and elastic strain in them will be important. A theoretical relation has, therefore, been derived to relate stress, strain rate and time with position along the radius and axis of the vessel or tube. This has been based on a creep-strain/time relation obtained experimentally at the Laboratory over a number of years and for a variety of engineering materials under complex stresses. The theory has been applied to estimate the values of principal stresses and strain rates in tubes for representative cases of six materials at temperatures within their practical working range. These predictions have been compared with those obtained from elastic theory and from the pure creep theory of Bailey[3] which has been much used in practice. The comparison indicates that, for the materials investigated, neither elastic theory nor pure creep theory adequately represents the changing stress distributions and strain rates that occur, although, after considerable periods of time, upon completion of stress redistribution, values based upon the Bailey pure creep theory would not be seriously in error. A complete example of the application of this general theory has been worked out in detail for a 0·2 per cent carbon steel at 450 deg. C. This should be an aid to designers who may wish to use the method.

More recently, the effect of vibratory stress complex-stress creep fracture has been studied[27]. It was known that under conditions of complex-stress creep fracture, metallic alloys fall into two categories: those in which extensive cracking develops during secondary and tertiary creep, where the stress criterion for the time to fracture is the maximum principal stress; and those in which the only cracking occurs at the point of ultimate fracture just before it takes place, where the time to fracture is determined by the von Mises (octahedral) stress. Tests were carried out on tubular specimens of commercially pure copper at 250 deg. C.; copper is one of the materials belonging to the first group mentioned. The tests were made in a combined tension and torsion creep and fatigue machine of novel design. The time to fracture and the characteristics of cracking were determined for conditions ranging from pure complex-stress creep to pure complex-stress fatigue, with intermediate conditions containing various proportions of fatigue and creep stresses. In all cases, the stress criterion of the time to fracture was found to be the maximum principal stress. For a given total stress level it was found that the time to fracture increased as the proportion of fatigue stress increased. The general cracking found in the previous pure creep tests was also observed in the pure fatigue tests and in the combined fatigue and creep tests. For pure creep, the cracking was relatively coarse starting in the interior of the specimen wall, whereas in pure fatigue, the cracks were very fine and started from the surface of the specimen. For combined creep and fatigue both varieties of crack were present, their proportions varying with the relative amounts of creep and fatigue stress. A similar investigation of an aluminium alloy is now in hand; this is one of the materials in the group showing no cracking during pure complex-stress creep.

A Creep Information Centre has been established at N.E.L. so that data on the strength of materials for use at elevated temperatures can readily be made available to designers. It is hoped that it will become the national centre for information on the mechanical properties of materials for use at elevated temperatures but this will require the full co-operation of both material suppliers and users if it is to succeed. Creep and rupture properties of high temperature materials are collected and tabulated. In due course, high temperature data for British materials will be issued in an agreed form, although commercial security may restrict the publication of some of the data supplied. Later on it is hoped to extend the scheme to cover all mechanical properties of British materials used at elevated temperatures, to collect details of testing machines and test procedures, and also to obtain information about foreign materials and equipment.

d) Pitting Failures in Rolling Contact

The pitting failure of roller bearings is now generally regarded as a surface fatigue phenomenon. Using a four-ball machine it has been shown[22] that pitting failure can be greatly accelerated if the lubricant is super-saturated with water. It has also been shown that certain additives, for example isoamyl alcohol, partially counteract the deleterious effect of water in a mineral oil lubricant. A possible mechanism for the phenomenon has been suggested. The hypothesis is that vacancy induced diffusion of hydrogen into the highly stressed surface material produces "hydrogen embrittlement". Using oil containing tritiated water, tests were carried out at various loads. The balls were washed with acetone and partially immersed in a liquid scintillator, and the activity counted. When the part of the driving balls carrying the fatigued track was immersed in the scintillator, counting rates of between 1,000 and 2,000 counts per second were recorded. The unfatigued part of the driving balls gave only about 40 counts per second against a background of 30 counts per second. The activity in the fatigued tracks decreased with time and tended towards the background level after about five days. This seems to support the hypothesis that water contamination leads to hydrogen embrittlement. Further support was provided by a hydrogen analysis of fatigued balls which showed that a small but significant increase in hydrogen content occurred, and appeared to increase with increased time of running in the four-ball machine.

e) The Fatigue Strength of Railway Axles

Tests have been carried out on full size railway axles to assess their fatigue strength when used in the as-forged condition. This was a piece of sponsored work carried out for a British firm. Rotating-bending fatigue tests were first made on machined test pieces taken from various casts of axle steels. There was found to be little difference in their fatigue strengths which were normal for this type of steel. It seemed likely that fatigue cracks could develop at much lower stresses in as-forged axles, and fatigue tests were therefore carried out on full size axles. The conventional rotating-bending fatigue machine to test the full scale axle at its working load would have been expensive and time consuming to make. A resonant test rig was therefore developed. The axle under test, complete with its wheels, was supported on a spring mounted cradle (Fig. 33). Two vibration generators were connected by means

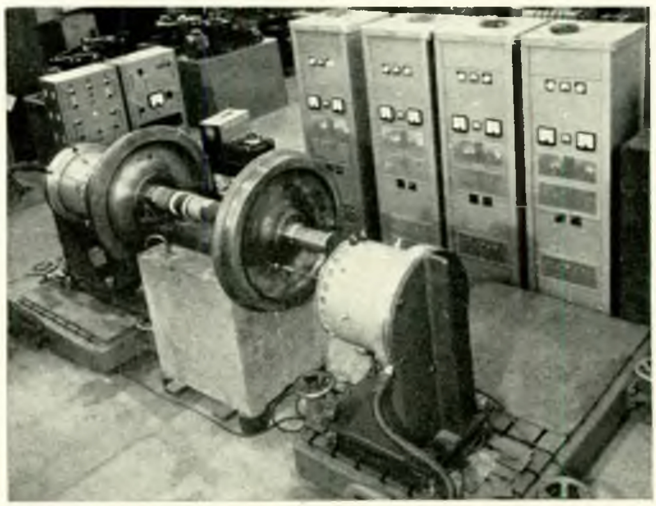


FIG. 33—*Fatigue test rig for full size railway axles*

of drive rods to the two wheels in planes mutually at right angles. The generators were driven in quadrature at the same frequency. In this way the middle of the axle was subjected to rotating-bending stresses similar in form to those imposed when in service. The frequency of the vibration was variable and was adjusted to the resonant frequency of the individual axle. The amplitude was also variable and was used to control the applied stress. Strain gauges were fitted to the shaft at a point midway between the wheels so that the stress could be determined. More than eighty axles were tested to destruction. The tests have shown that the fatigue strength of an as-forged axle may be as low as half that of a machined axle and that the advantages to be gained by machining the middles of the axles outweigh the additional cost. In this case, although the firm concerned paid only the full economic cost, publication of the general results is by agreement with the firm. Had the firm wished they could have paid the surcharge and so have retained ownership of the results.

CONCLUSION AND ACKNOWLEDGEMENTS

An attempt has been made to give a general impression of the research work carried out at the National Engineering Laboratory at East Kilbride. While the projects described are those selected as being most likely to interest marine engineers, they give a reasonably balanced impression of the research programme of the Laboratory as a whole. The

Laboratory's task is to identify the research needs of industry, to carry out those researches appropriate to the Laboratory and to ensure that the results of the researches are applied in industry. The Laboratory can only be successful, particularly in the identification of needs and in the application of results, if it has the active co-operation of industry. Formal arrangements for consultation, through the Steering Committee and its sub-committees, are of course important, but less formal contacts are essential on an ever widening scale if the Laboratory is to be fully effective. This will require not only a willingness on the part of the Laboratory's staff to consult with their industrial colleagues, but also a willingness on the part of industry to make use of the Laboratory and to allow the Laboratory to share its experiences. It is perhaps most important that the Laboratory should be allowed to share experience of failures. In this connexion the Laboratory has been helped very considerably in the materials field by seeing examples of components which have failed in service.

The author gratefully acknowledges the assistance received from his many colleagues and particularly many helpful discussions with the Director of the National Engineering Laboratory, by whose permission the paper is published.

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Discussion

Vice-Admiral Sir Frank Mason, K.C.B. (Vice-Chairman of Council) in opening the discussion, confessed that Mr. Penny had left him with nothing at all to say, even to the point of quoting his own sentence written in the 1959 report! However, it was an opportunity for him to pay tribute to the Director and staff of the Laboratory, and it was a great privilege to be associated with their work. He was Chairman of the Steering Committee, the small body which was mentioned just now. It was small because it was an executive body; if it were not small it would not do very much. Whether what it did now was effective or not, only time would show. But clearly it had to have advice, and it had three sub-committees, the Chairman of one of which was present. He would also take the opportunity of paying tribute to them for the extraordinary amount of work they did in advising on the projects which should be tackled in the various groups and the effort that should be put into them. But the sentence quoted by Mr. Penny was really the crux of it. The Laboratory had a very large amount of unique equipment, and certainly an enormous amount of very good equipment. It was their concern to use it to the benefit of British industry, but it was very difficult, and only time would solve this difficulty. One could only go plugging away on many fronts. Papers were all very fine but they were never read—at least, not by the people who ought to be reading them! The research summaries were pretty good and there was some hope that these might get into the right hands. Just a glance at them would show whether any further information was needed, and whoever wanted it could apply for full particulars. But really the best way was personal contact, which was a slow process spreading out over the years. Half the trouble was that people had never heard of the Laboratory, and a lot of people did not even know that D.S.I.R. stood for Department of Scientific and Industrial Research. Some people had heard of East Kilbride, but they said, "Why was the place put up there?" The answer was that it was a political decision and nothing to do with the Laboratory. His answer to people who said "Where is it?" and "How on earth do you get there?" was that he could get in a longer day at the Laboratory where it was than if it were situated at say Stevenage. It required more effort to get there and more expense but it did not require so much working time, because one could go up by sleeper and fly back; so that it was possible to get there and to spend a very worth while day, or more as one wished. He urged people to go and see the Laboratory, after which they would go again. The first introduction to it was probably better on an open day, which gave a good idea of what was going on, and then they could decide on the basis of that visit what they wished to go back to see. At the last open day there was a gentleman present who had flown from Birmingham to look at one item and then flown back again. Open days were a big strain on the Laboratory but it was absolutely essential to give time to them. In order that visitors should be properly catered for, open days had been arranged every other year, and in 1962 there would be three days in the first week in May. Anyone interested should go. There was a great deal of equipment in the Laboratory and an enthusiastic and highly competent staff, and much public money invested in it. The only way all this could be paid for was in improved goods and services. The Laboratory could go half way to meet industry but industry must come the other half of the way to meet the Laboratory. When they met in the middle he was sure that some great things could happen.

Mr. D. Birchon (Member) said that he would like to congratulate the author on a concise and readable paper, which gave an excellent picture of the broad field of research upon which the National Engineering Laboratory was engaged.

The Parliamentary Act under which the Laboratory was set up mentioned the importance of ensuring that the results of research were properly and promptly applied in practice. The importance of doing so was widely recognized, but it was by no means easy to accomplish.

Progress in mechanical engineering was closely linked with the knowledge and state of development of constructional materials. In the materials field alone, progress was now so rapid and diverse that it was extremely difficult for the engineer to be sure that he was aware of all the information which was both available and relevant to the problems on hand at a particular time. Similarly, it was only too easy for a metallurgist to become so absorbed in unravelling the intricacies of the behaviour of metals that he could forget that he might already be able to advise on the solution of the original problem.

These difficulties arose because they were living in an age of ever increasing specialization, one of the results of which was difficulty in the communication of ideas between people working upon different aspects of the same basic problem.

There were three ways in which this state of affairs could be remedied: firstly, by locating engineers, metallurgists, physicists, chemists and mathematicians under the same roof so that they could bring their skills to bear upon a common problem; secondly, by ensuring that the research programmes were wisely chosen to cover the most important industrial problems; and, thirdly, by endeavouring to make the results

Fig. 34

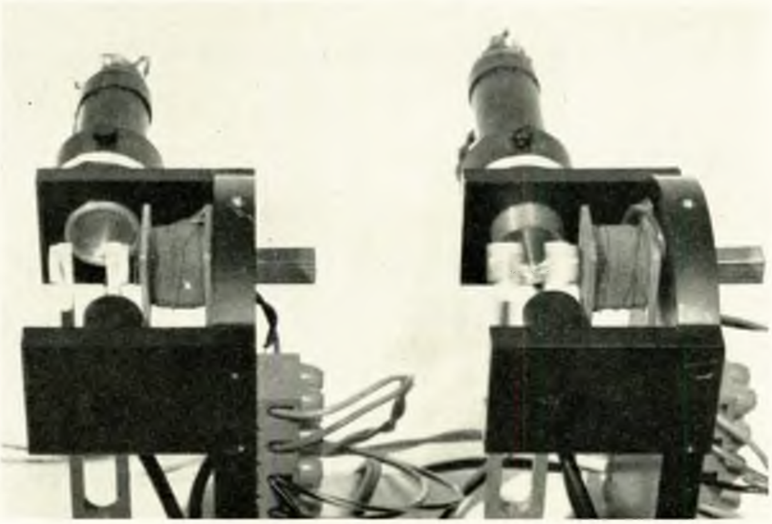


FIG. 35

of the research widely known to all interested parties. As Mr. Penny had shown, these were the aims of the N.E.L. and they explained its unique position and value at the present time.

The author had mentioned the necessity for being allowed to share in experiences of service failures. This feed-back of operational experience was vital in order to ensure that the research was properly orientated towards the most pressing problems. However, this contact was also of the utmost value to industry, since it would help them to be up to date in their knowledge of the behaviour of metals.

It was unfortunately true that service failures continued to occur more frequently than was justified at the present time. Many, if not most, of these failures could be avoided if the designer, and sometimes the user, were aware of all the factors which governed the behaviour of the material in service. One could possibly argue that research should be temporarily halted in order to concentrate on making sure that all existing knowledge was properly applied before adding to the confusion of scientific data which already confronted the engineer. Such a proposition could not be seriously supported, but he wondered if there was a case for setting up a small, independent Materials Information Centre, with the specific purpose of translating existing knowledge of the behaviour of materials into those forms in which the engineer could most conveniently find and use the information, without having to search for it in scientific papers which were often of a highly specialized nature. Perhaps the National Engineering Laboratory would provide the most suitable location for such a group, since it could form a logical extension of the function of the Creep Information Centre which had already been set up there.

In marine engineering more than half of the failures which occurred in service were of fatigue type. This underlined the importance of the work described on the formation and growth of fatigue cracks, in which proper attention was being given to the two stages involved. However, a survey of the fatigue failures which occurred in marine engineering had shown that many of these failures were caused by the establishment of small corrosion-fatigue fissures at the surface. The corrosive agent was provided by salt from the atmosphere, and the corrosion-fatigue mechanism then allowed cracks to form and grow under very small alternating stresses until the cracks might become large enough to permit their further propagation without requiring the assistance of a corrosive atmosphere.

Fig. 34 showed a classic example of corrosion-fatgue cracking and emphasized one of the subleties of fatigue damage in service, because corrosion-fatigue fissures such as those shown could be produced with very little apparent corrosion on the surface of the component. It had also to be borne in mind that under corrosion-fatigue conditions there was no limiting safe range of stress below which fatigue failures could not result. In view of the importance of corrosion-fatigue damage he wished to ask the author if any work was planned upon this subject.

Recent American* † and other work had indicated the value of various surface coatings in increasing resistance to both initiation and propagation of fatigue cracks on specimens tested in air, and practical applications along these lines could prove valuable in service. It had been suggested that since better fatigue properties were observed when air was excluded

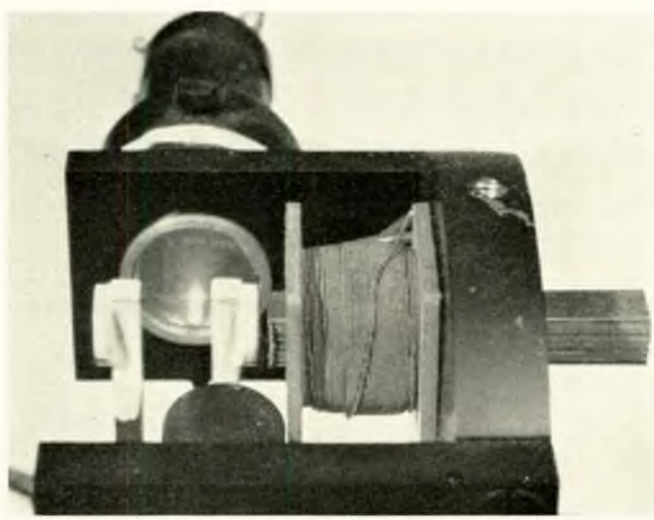


FIG. 36

from the surface of the material, tests conducted in air were really a mild form of corrosion-fatigue. This raised an interesting point, since if this were so it was difficult to understand how one could produce non-propagating cracks by tests conducted in air. Since there was abundant evidence of the existence of non-propagating cracks, would the author care

* "Effect of Organic Compounds on Metal Fatigue". N.B.S. Tech. News Bull. 1960, *44*, 127.

† HOLSHOUSER, W. L. and UTECH, H. P. "Effect of Oleophobic Films on Fatigue Crack Propagation". Trans. A.S.T.M. Preprint No. 72, 1961.

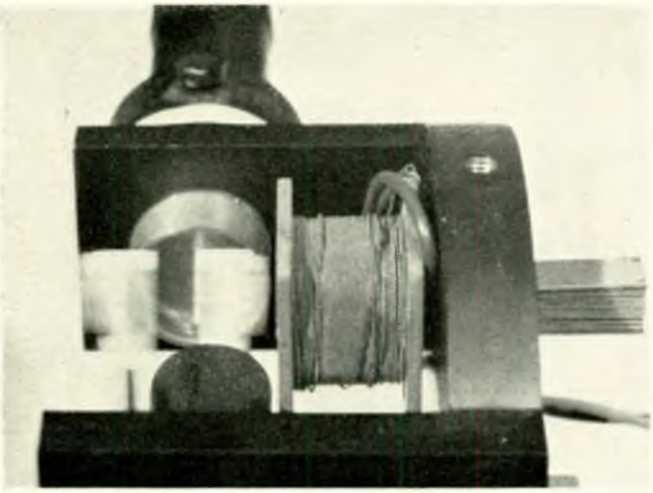


Fig. 37

to comment on the significance of the results of tests conducted in the absence of oxygen?

Elsewhere in the paper the author referred to work being conducted upon means of reducing vibration (and therefore fatigue stresses) and noise. One method of reducing noise and vibration was to introduce damping into the structure. In the past this had been done by mechanical methods, such as friction at joints, etc., or by loading the surface of the material with a plastic composition. Materials now under development at the Admiralty Materials Laboratory combined a high damping capacity with good mechanical properties.

This could be illustrated in a simple way by striking two bells, one of which rang in the normal way, the other being quite dead. (Here the speaker demonstrated the point.) The high damping material also had a tensile strength and hardness greater than that of mild steel, similar ductility, and a basic material cost similar to that of an aluminium bronze. It was therefore a useful structural material. Another way of demonstrating its unusual properties was shown in Fig. 35. The two tuning forks were being excited into vibration with the same input energy, yet the amplitude of vibration of the fork of high damping material was very small compared with that of the brass fork of low damping capacity, shown on the right. This difference in amplitude was shown in greater detail in Figs. 36 and 37.

High damping materials such as this presented the designer with a new dimension in engineering and their possible applications deserved full investigation. Although not mentioned in the paper, some work was being conducted at N.E.L. to investigate the value of materials of this type, and the Admiralty Materials Laboratory were happy to be associated with this work and looked forward to the results of their experiments.

Dr. R. C. Parker said that, whatever might be the views one held on the Common Market, it was very apparent that the prospect of joining it was serving as a tremendous jolt to industry. A manufacturer had one thing in mind, and that was the quick delivery of better products at a lower cost. It was requiring new thought in every section of industry, on costs and sales no less than on research, and it was to be hoped that this would stimulate enquiries on the Laboratory so that the lives of those working there were at least as pressed as those who were doing research in industry!

Against this background Mr. Penny's paper was welcome and challenging, because the Laboratory, if it achieved its object, would have a very great role in the country's future. He did not hesitate to put it as high as that. The words of the author's opening paragraphs which had impressed him were those concerning the fuller appreciation of industry's problems and the recognition of the fields in which more basic research was needed. His own paraphrase was that N.E.L. must learn to be articulate and talk to those who would not read, and to coerce or command those over whom it had no authority.

Dr. Parker gave the example of a works director who had never read technical journals and did not know of the existence of the Laboratory. It was very difficult to impart knowledge to people who were fixed in their habits, but the situation was one that would change if competition became even more fierce.

The author had stated that the subjects reviewed in the paper were those of particular interest to marine engineers. As a matter of interest he had tried the reverse procedure, getting hold of the Transactions of the Institute for the past year and trying to see how many papers were directly concerned with Table I of Mr. Penny's paper. Very quickly he had written down such subjects as the selection of lubricants, excessive wear of cylinder piston rings, and several others, all of which were listed in Table I. This showed that the Laboratory was proving to be quite successful in deciding what were the needs of industry. This exercise had made him speculate further as to whether or not their professional reference was being overdone. He had tried to imagine what the meeting would be like if the author, instead of saying what the Laboratory had done, had drawn attention to what he regarded as engineering mal-practices. It would have been a very lively evening and might have done everyone a great deal of good.

He wished to ask the author what was the attitude of industry in regard to this very excellent research on air bearings. He was aware that there had been co-operation with the machine tool industry. Was this industry urgently pursuing the Laboratory's advice, and what was the attitude of other industries with whom they had had no direct contact?

The Laboratory was spending about £1 million, and he wondered how much of this had been regained through work carried out for sponsored research. But he would not emphasize this too much because clearly the need to do basic research was so great that only a small percentage direct return was justifiable.

Commander J. I. T. Green, O.B.E., R.N. (Member) drew attention to the apparent preponderance of effort on instrumentation in the work being carried out at N.E.L.

As an example the work on gearing appeared to be a continuation of Mr. Tomlinson's work of 30 years earlier, using modern instrumentation. Had this resulted in an all round improvement over the years in the accuracy of gear cutting machines generally?

He also suggested that while work was proceeding on the preparation of new Steam Tables, consideration should be given to those working on projects requiring very low pressures, say 0·1 mm. Hg., by improving the documentation of the properties of steam in these regions.

Mr. G. Victory (Member) said that much of this progress report was like the American space programme, interesting, but out of his orbit. However this did not apply to the section on page 230 dealing with the formation and propagation of cracks. To marine engineers this was of particular interest, and as the section had obviously been very much condensed in order to fit in the wide range of investigations which were carried out at East Kilbride, he felt that this section in particular might be worthy of a little expansion in a written answer. There was a lot of information on fatigue cracks, which were usually associated with reversals of the order of 10^6—major reversals and over. There was something in this paper which hinted that there might have been some experiments at East Kilbride on the formation and propagation of cracks with much lower orders of reversals; in fact, of the sort found in a boiler, in which steam was raised and shut down at reasonable intervals—something of the order of 3,000 or 4,000 reversals in a lifetime. There had been some rather puzzling occurrences on riveted lap joints of auxiliary boilers in which what were apparently fatigue cracks had been propagated in mild steel, apparently from surface irregularities, with comparatively few major stress variations and perhaps Mr. Penny could give some information regarding this type of failure.

In the paper, Mr. Penny gave an equation for the propagation of cracks subject to reverse direct stress loading, which would appear to result in a ¼-in. crack being propagated in mild steel, if the alternating stress were of the order of 3 tons/sq. in. This appeared less than one would expect. Could the author give the limitations of this formula in respect of the number of cycles and the depth of the original crack; for propagation would depend on the depth of the original crack, he would have thought, as well as the length. He was assuming that the figure of 0·1-in. depth, given at the bottom of page 230, referred only to the strength reduction factor K and not to constant C. Later, on page 231, there was an equation for the rate of growth of cracks at higher stress levels involving two constants, P and Q, in which only the value of Q for mild steel and copper was specified. Could the author give some idea of the value for P and state the units involved.

Mr. Bryan Taylor, B.Sc.(Eng.) (Member) said that there were many points of detail in the paper on which comment could be made but he felt that this was hardly the occasion for such a discussion. The paper did provide an opportunity, however, to comment on the organization of engineering research, and in this connexion he was rather disappointed that the author did not touch on the relationship between the N.E.L. and the various industrial research associations and university departments. It would be interesting to know whether the N.E.L. was represented on the research committees of all the research associations where work of a complementary nature to that of the particular association was being carried out at the N.E.L.

To allow for the most economical use of mechanical engineering research facilities, it would appear that work of a more fundamental nature could well be handled by the N.E.L. and the universities, working in close liaison, while the more specialized investigations were handled by the research associations. This state of affairs did, of course, obtain to a certain extent at the moment, but one had the impression that the overall organization of research and its integration could be improved.

This brought him to the question of the function of the various co-operative and national research organizations in regard to development work. The author had mentioned a notable development carried out at the N.E.L. on hydrostatic transmission, and this appeared to be a subject which might well be one capable of further development for applications such as marine propulsion and auxiliary drives. He had been rather interested to hear the author say that in certain cases development contracts had been awarded and co-operation existed between the Laboratory and various industrial firms. Was any such work in progress in connexion with the hydrostatic transmission development? In general it appeared that there was a case in certain industries for more development work to be handled by the research associations. He was thinking particularly, of course, of the marine engineering industry in this connexion.

Another aspect of research which was of particular interest was the dissemination of results. As one with experience at both the issuing and receiving ends of the results of research work, he was well aware of the difficulty of keeping abreast of developments in more than one's own subject. Abstracts of technical literature were most valuable and in this the marine engineering industry was well served by its own research association. In this connexion it would be of interest to know whether figures were available for the proportion of engineering companies who received the research summaries issued by the N.E.L.

On the question of data sheets, he would certainly support the view put forward by the author that summaries in the form of data sheets would be invaluable to people in the industry.

Another point which could not be over-emphasized was the value of personal contact between people in the industry and research associations. This point was touched on by Admiral Mason. Mr. Taylor suggested that research organizations required more the approach of the travelling salesman to bring home to many people in industry the value of the facilities that existed and the help that could be given by organizations such as that described in the paper.

Dr. D. G. Sopwith thought it interesting to recall that 11 years ago he had read to the Institution of Engineers and Shipbuilders in Scotland a paper which had been written by his predecessor, the first director of what was then the Mechanical Engineering Research Laboratory. Dr. Hankins had, unfortunately, most tragically died about two months before the paper was due to be read; but in concluding the paper Dr. Sopwith had read these words by Dr. Hankins: "It will be realized from the foregoing description of the new Laboratory that its main concern will be research in mechanical engineering science on a scale commensurate with the importance of the mechanical engineering industry to the future economy of the country. The organization of the work is scientific and generic, but there will also be a considerable proportion of applied research, particularly in such matters as hydraulic machinery, heat transfer apparatus, and mechanisms, in which previous systematic research has been small and work on certain applied problems is urgently required. The complete results will materially assist in accelerating the general advance of the mechanical engineering industry; at the same time they will also be of considerable service in the practice of civil engineering, electrical engineering and chemical engineering. The author is not going to make facile promises of spectacular new developments arising from the work in a very short time. It is in more gradual developments that one can be quite sure that worth while results will be obtained. The more efficient use of engineering materials, improved methods of design, leading to increases in speed and reductions in weight without running into trouble; more efficient and lighter hydraulic machinery and heat exchangers; improved methods of measurement and their application in industry; the provision of basic scientific and technical data in advance of the immediate needs of the practising engineer so that he can go ahead without delay on a promising new development without taking unreasonable risks; these are the certain results of the research envisaged, each new result and its application not very startling perhaps in itself, but added together and accumulated over a comparatively short period of time, the full effects are surprising and sometimes amazing. Moreover, it will be part of the work to act as far as practicable as a storehouse of information, to know about scientific research and development elsewhere, both in this country and abroad, and at the same time to keep in close contact with industry so that its needs are appreciated, its interests fully maintained, and the work of the laboratory developed on the most fruitful lines".

These remarks, taken in conjunction with what the author had had to say about the present lines on which the Laboratory was working, indicated a continuity of thought from the days of the Committee, under Sir Henry Guy's chairmanship, which in 1946 recommended the setting up of the Laboratory, to the present day Steering Committee under Vice-Admiral Sir Frank Mason, whom he was very glad to have heard speak at this meeting, so that the general objectives remained the same. How far they had been or were being achieved was for others to say.

Correspondence

J. V. Bigg, M.A. (Associate Member), in a written contribution, congratulated the author on a paper which was most welcome, not only for its technical interest, but for the publicity which it gave to the quality and scope of the work undertaken at the National Engineering Laboratory.

As his own particular interests lay in the field of power plant and associated heat transmission problems, he wished to confine his comment to the section of the paper dealing with the investigation into promoters for drop-wise condensation in steam condensers.

Superficially the steam condenser appeared to be a relatively simple piece of apparatus from the design point of view. It was not quite so straightforward when subjected to detailed investigation, but modern techniques of instrumentation and measurement continually increased the limits to which investigation could be carried out.

The enhanced steam side heat transfer rates possible by using drop-wise condensation promoters, had been amply demonstrated on single tube tests under laboratory conditions, but one was now faced with the most difficult part of any development process, the extension of research information of such a nature to a knowledge of behaviour in the full sized plant. Before acceptance by users of drop-wise promoters could be expected, there still remained several features which had to be conclusively demonstrated, chiefly:

1) The life of the drop-wise promotion effect under industrial conditions.
2) The satisfactory dispersal of the promoter over large surfaces under practical conditions.
3) The influence of the promoter chemical on the boiler plant, particularly for high steam conditions.
4) A working yardstick by which the improvement of the average heat transfer rate on the steam side throughout a condenser nest could be gauged, to support the design of full scale plant.

In considering the enhanced heat transfer rates likely to be achieved with drop-wise promoters, the basis of existing design had also to be considered. Investigational work, on full scale plant with unpromoted surfaces, over the years had shown, with well arranged nest configurations, a tendency for the heat transfer rates to be high in those rows of tubes first contacted by the steam (with heat transfer rates of 1,800-3,000 B.t.u. sq. ft. deg. F./hr.). These rates gradually diminished through the nest in the general direction of the air cooling and air suction area, where they fell to lower figures (50-200 B.t.u./sq. ft./deg. F. hr.). Such investigational results had been used in general to provide average rates of heat transfer for the steam side, which could then be used for the whole surface area of the nest. These results led to two possible comments:

a) It could be thought that a degree of drop-wise condensation (or an equivalent effect) already takes place in an unpromoted condenser on the outer rows of tubes, due to the continuous disruption of the water film by the steam flow.
b) In the air cooling section the increased ratio of incondensibles to the steam present in any case reduces the effective steam side heat transfer rate, and the proportionate effect of drop-wise condensation on such lower rates at this part of the nest has to be considered.

It had, therefore, to be substantiated that the relative gain in steam side heat transfer rate as demonstrated by a single (or several) tube test would be reflected throughout a full tube nest. The work being carried out on the experimental 150 tube condenser might prove of extreme interest in providing help to the solution of this problem.

Mr. F. Pollak (Member) wrote that in referring to the "Development of a Fully Cavitating (Super-cavitating) Pump" as there was very little published and indeed known of this subject as applicable to pumps, he would like to put some questions mainly perhaps on aspects as they affected marine applications:

1) For which specific speeds or typical duties would such pumps be envisaged, say for capacities between 500 and 8,000 gallons per minute, and where the speeds as in column (1) of Table IV should be assumed to be limited at present by the net positive suction head available as stated in column (4) of the table? Could a fully cavitating pump be applied for such duties at the higher specific speeds, say as shown in columns (5) and (6)?
2) Was the principle of design of a super-cavitating impeller applicable to some extent to lower specific speeds?
3) What would be the effect of efficiencies as compared with the conventional impeller?
4) What would be the absolute maximum speed for duties as stated, and N.P.S.H. available?
5) Summarizing the above points broadly, what was the expected gain in required N.P.S.H. against conventional axial flow pumps, and could a typical characteristic be shown including any statement of the position and predictability of the instability points usually associated with axial flow pumps?

   It would also be interesting to see the shape of the typical "N.P.S.H. required" curve to see whether there was a similar increase of N.P.S.H. required, especially for quantities in excess of the quantity at the point of best efficiency.
6) Could a general statement be made in which way or for which particular aspect of design a computer was to be used?

   Referring to improvements mentioned when handling volatile liquids, could such impellers handle the same amount of entrained gas with less efficiency drop than a conventional design of the same specific speed or indeed of lower specific speed?

A statement on materials for super-cavitating pumps would be welcome.

Table IV.

Standard pump.				Possible super-cavitating pump.	
1	2	3	4	5	6
Speed, r.p.m.	Specific speed,	Capacity range, single entry impeller, gal./min.	N.P.S.H. (ft.) available at η maximum	Speed, r.p.m.	Specific speed
1,150	3,500	1,200–3,000	19–22	1,750–3,500	5,330–11,000
860	4,500	2,000–4,000	16–20	1,150–1,750	6,020–9,200

Author's Reply

Replying to the discussion Mr. Penny said that he was very glad to have the opportunity to express to Vice-Admiral Sir Frank Mason the Laboratory's appreciation of the very great help and support that it had received from him personally and from the other members of the Steering Committee and its sub-committees. He agreed that personal contacts were the best way to ensure that the Laboratory's work and facilities were known and used in industry and repeated Admiral Mason's invitation to any member, or indeed anyone with an interest in mechanical engineering, to visit the Laboratory. He hoped that members would help to build the bridge between industry and the Laboratory, about which Admiral Mason had spoken.

He thanked Mr. Birchon for his kind remarks and particularly for the suggestion that N.E.L. should set up a Materials Information Centre which would have as one of its main objects, the presentation of existing knowledge of materials and their performance in service in the form most useful to the engineering designer. It was probably true that the majority of service failures could be avoided if existing knowledge was applied. The suggestion was one which would be very seriously considered by the Laboratory.

Mr. Birchon was, of course, well aware of the extensive studies of the effects of corrosive environment on the fatigue properties of materials, which were being carried out in various places and his own laboratory had made a not inconsiderable contribution. One of the difficulties of such work was to generalize the results because slight differences in testing techniques and in the composition of the environment not only affected the fatigue strength but could result in a different order of merit for a group of materials. A programme of work was being carried out at N.E.L. to study the effect of a non-corrosive environment on both crack initiation and crack propagation. This might help to elucidate the role of oxygen in crack formation and growth. Mr. Birchon's contention that tests conducted in air were really a mild form of corrosion fatigue testing, while generally true, must be reconciled with the observed fact that mild steel exhibited a definite fatigue limit in air; this would not be expected in a corrosion fatigue test.

Mr. Birchon's demonstration of the remarkable properties of the materials developed at the Admiralty Materials Laboratory having high damping capacity combined with good mechanical properties was most convincing. He had not been able to refer to the large amount of research on materials carried out in many laboratories but this particular piece of work executed at A.M.L. was worth special mention. N.E.L. was glad to have the opportunity of co-operating with A.M.L. in assessing the value of these materials and in gaining experience of their use in particular applications.

Replying to Dr. Parker, Mr. Penny said that Dr. Parker was one of those who had been prepared to give a considerable amount of their own time to advising and helping the Laboratory and he was very glad that he had agreed to continue to do so as Chairman of one of the sub-committees, the committee concerned with the programme of work of the Machinery Group. The problem of communicating research results to decision makers in industry was, he agreed, a most difficult one; research summaries were one attempt to overcome this Dr. Parker had paraphrased his opening paragraphs and had made the problem seem even more formidable; he was glad that Dr. Parker thought that the situation would change.

Regarding the work on air bearings there was evidence of considerable interest both in the machine tool industry and among machine tool users in pressurized fluid bearings using both air and oil. A number of firms were interested in air bearing grinding heads and one or two were co-operating with the Laboratory in developing designs of their own. A roundness measuring instrument using an air journal bearing based on an N.E.L. design was in commercial production and the Laboratory had also assisted in the design of work tables supported on air bearings to facilitate their positioning by hand. Since many of these investigations were carried out under confidential repayment terms it was not possible to go into more detail. Visitors from the textile machinery industry and the printing machinery industry had expressed an interest in pressurized fluid slideway and journal bearings. There was much less practical interest at present in self-induced air bearings but this might grow as work proceeded.

Of rather less than £1 million spent each year by the Laboratory about five per cent was recovered from industry and a further five per cent from other Government departments for work done mainly for defence purposes. It should not be concluded that the remaining 90 per cent was not worth paying for but rather, as Dr. Parker had inferred, that it was of such general interest that no one firm or organization could properly be expected to pay for it.

Replying to Commander Green, Mr. Penny said that he made no apology for the preponderance of references to instrumentation. In order to understand any phenomenon it was first necessary to measure, and express in quantitative terms, what was going on. This was particularly true of mechanical engineering where such measurement was one of the main tasks of N.E.L.

The work on gearing was, as Commander Green had suggested, a continuation of work begun by Dr. Tomlinson thirty years ago. This was a result of a decision to set up the Laboratory at East Kilbride to continue and expand the research in mechanical engineering previously carried out at the National Physical Laboratory at Teddington. As a result of this work, in which many firms and laboratories had participated, but in which N.E.L. had played its full part, the accuracy of gear cutting machinery generally had improved, in some cases by as much as a factor of ten. For example, cyclic errors in the table drive of large gear hobbing machines such as were used to cut marine gearing had been reduced from an average of about 0·002in. in the early war years to 0·0001 to 0·0002in.

To meet the requirements of the International Conference on the Properties of Steam, attention had been concentrated on properties at higher temperatures and pressures. The Laboratory would note the need for improved documentation of the properties at very low pressures and would consider what it could do to meet these needs.

Replying to Mr. Victory, Mr. Penny said that a full account of work on crack initiation and propagation carried out at the Laboratory was available in the form of N.E.L. Reports, which could be obtained free on application to the Laboratory. A fuller account was also given by Frost in the Journal of Mechanical Engineering Science, 1962, No. 4; this reference also gave values of P and Q for various materials. The Laboratory had not carried out crack growth tests lasting only 3,000 or 4,000 cycles as this would result in crack growth rates too high to be measured accurately with current techniques.

Mr. Penny said that his explanation of the type of specimen on which crack propagation work of the N.E.L. had been done, appeared to have been inadequate. In all cases plate or sheet specimens were used, containing either edge or central cracks simulated, in some cases, by very fine saw cuts. The crack front was a straight line through the specimen thickness and the crack was thus rectangular in shape, of width equal to the specimen thickness and of uniform length. This crack length l was that used in both the formulæ quoted. In the second formula, which described the results of tests in which the specimens were never in compression, $\sigma_m > \sigma_a$. In the type of specimen described N.E.L. would expect a $\frac{1}{4}$in. crack to propagate in mild steel at an alternating stress of greater than about 2·8 tons/sq. in. In Table II the notch depth of 0·1in. was taken as length l in order to calculate the notched fatigue limit which would of course, vary with varying notch depths; C, on the other hand, was independent of l.

In reply to Mr. Taylor, Mr. Penny said that universities should be free to choose whatever subjects for research interested them, although he expected that in mechanical engineering they would in practice continue to do more fundamental research rather than specialized investigations. He agreed that the general division of interest between N.E.L. and the research associations should be as stated by Mr. Taylor but warned that this should not be too rigidly applied. If N.E.L. was to understand and appreciate what were the real needs of industry it was essential that it should undertake a proportion of shorter term, more applied, research and development. Conversely those research associations which undertook a proportion of more fundamental work were right to do so and he would like to see them all taking this attitude. It would enable them to recruit and retain staff able to interpret the latest researches to their colleagues and to the industries they served as well as to make their own contributions to these researches. If they did not do so there was a danger of their adopting too superficial and empirical an approach. N.E.L. was able to influence the work of research associations either directly, in those cases where it was represented on the appropriate research committee, or indirectly through the departmental representatives. He thought that there was direct representation wherever the work was complementary to that carried out at N.E.L. Each year, before the Laboratory's programme was decided, the Director invited all the other Government laboratories, research associations and nationalized industries who might be working in the same field, to come to a series of meetings at the Laboratory to discuss the proposed programme and to say what they themselves proposed to do. The object was to avoid unprofitable duplication and by no means was all duplication unprofitable, and to recognize and fill any important gaps which might be disclosed. He thought that this had worked reasonably well but agreed that the overall organization of research and its integration could be improved. So far as sponsored development work was concerned, N.E.L. would not undertake work merely because a sponsor was prepared to pay for it. It would only do so if the Director and the Steering Committee were satisfied that the work was both important in itself and appropriate to the Laboratory. He could confirm that sponsored projects in hand included work in connexion with hydrostatic transmissions but, since an essential feature of these arrangements was their confidential nature, he could say little more about them; the only one concerned particularly with marine applications was sponsored by Admiralty whose support had been most valuable in the development of the two families of transmissions described in the paper.

Of the 5,400 research summaries issued by the Laboratory, the largest block, 4,150, went to firms; 450 to universities and technical colleges; 230 to private individuals; over 100 to the technical press; 100 to nationalized industry; 100 to research associations and the Atomic Energy Authority; 50 to Commonwealth organizations of various sorts; and the remainder to other bodies. Nearly all the large and medium sized firms in the engineering field were included in the 4,000 addresses in private industry.

Mr. Penny said that he greatly appreciated Dr. Sopwith's contribution which showed how the present aims of the Laboratory were derived from those which had been laid down by its first Director and earlier by the Guy Committee. What Dr. Sopwith had not said was that he had himself been the Director of the Laboratory for most of its life and it was largely due to his foresight and leadership that the Laboratory had developed so successfully. Mr. Penny added that he had been proud to join the Laboratory comparatively recently and looked forward to sharing in the task of guiding its future development under Dr. Sopwith's direction.

In reply to written contributions Mr. Penny commented that Mr. Bigg, to whom the Laboratory also owed a debt of gratitude for his help, had summarized clearly what further information was required before dropwise promoters were likely to be accepted by users of condensers. The work of N.E.L. and of a team in the Department's Warren Spring Laboratory at Stevenage, was directed to finding answers to some of these problems, particularly to points 1 and 4. From the figures quoted by Mr. Bigg it seemed that there might be scope for greater precision in design leading to a reduction in condenser size and therefore price, even for filmwise condensation. Both modes would therefore be studied in the experimental 150 tube condenser. He looked forward with great interest to the results of the work now starting.

Before replying to the interesting points raised by Mr. Pollak he first re-emphasized that the work was only in the

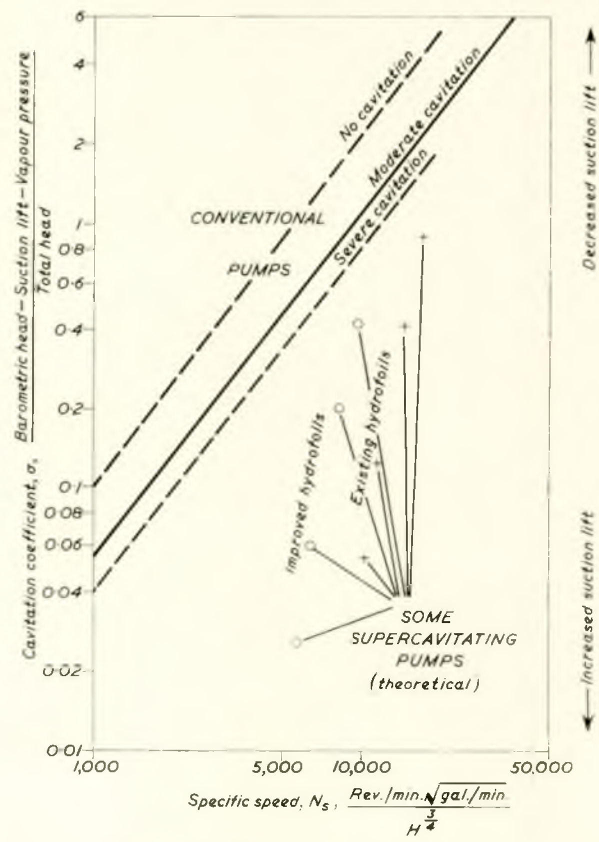


FIG. 38—*Cavitation characteristics*

initial stage of exploring the possibility of making use of cavitation. In introducing his paper he had said that, in order to give a more balanced impression of the work of the Laboratory he had deliberately included an investigation in its early stages; this was such a project.

Fully cavitating or "super-cavitating" pumps seemed likely to be most suitable for a range of specific speeds from 5,000 to 17,000. One of the requirements for such a pump was that there should be ample space between the blades for a cavity to develop without choking the passages. It followed that axial or mixed flow types were preferred and that specific speeds below 5,000 were unlikely to show practical advantages. From this it was concluded that the duties specified in Table IV could be met at approximately the speeds, etc. given in columns 5 and 6. The advantage would be that much lower net positive suction heads could be tolerated. This point was illustrated in Fig. 38 which showed design points for a series of theoretically practical pumps; the N.P.S.H. was equal to the product of the cavitation coefficient σ and the head across the pump. It must be emphasized that these design duties were the result of a theoretical study and extensive experimental development would be required before they could be confirmed.

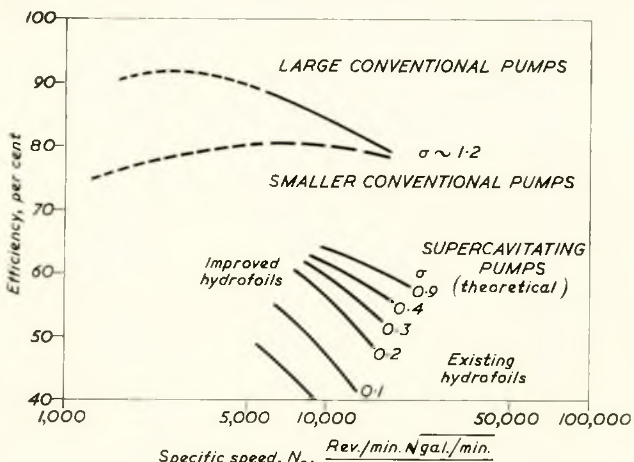


FIG. 39—*Efficiency curves*

At low specific speeds when relatively high heads were to be generated, the "super-cavitating" pump could be used upstream of a conventional centrifugal pump, both running at high speeds, the former acting as a pressure booster to overcome the difficulties experienced with the latter at high suction heads. Preliminary tests had confirmed that efficiencies were lower than in a conventional axial-flow pump but, in compensation, the speed and suction lift had been doubled Although improvements in performance were anticipated as understanding of full cavities and their influence on flow patterns improved, Fig. 39 showed the best predictions of efficiency which could be made at present. The critical factor was the balance between the gain in weight reduction and operating conditions against the sacrifice in efficiency.

The main limits on N.P.S.H. were the circuit characteristic itself and the gas content of the liquid being pumped. These might enforce a limit on maximum speed before the blade stresses themselves imposed a restriction. It was considered that a speed of over 5,000 r.p.m. was practicable for a 12in. diameter unit. Fig. 38 illustrated that an N.P.S.H. of only one twentieth of that for a conventional pump was feasible. Experimental work had shown that the performance characteristic was generally similar to that of a conventional axial-flow pump. There was little variation of N.P.S.H. required over the complete flow range; this variation was normally necessary to prevent cavitation.

At N.E.L. the computer would be used for studying two aspects of the problem. When sufficient data had been assembled, a large number of designs could be processed, varying parameters over a wide range to determine the optimum design for a particular duty. In addition fundamental studies could lead to improved blade profiles and a better knowledge of hydrofoil characteristics generally.

The improved performance when pumping volatile liquids resulted from the fact that the pump could be operated under conditions of continuous cavitation. Under these conditions the efficiency was expected to be better than would be obtained with a conventional pump running with full cavitation.

Until further research had been completed a statement on what materials were most suitable for "super-cavitating" pumps could not be made. Work was in progress on the cavitation erosion resistance of a variety of materials; various techniques were being used to assess them including drop impact, magnetostriction and Venturi accelerated flow.

INSTITUTE ACTIVITIES

Minutes of Proceedings of the Ordinary Meeting Held at The Memorial Building on Tuesday, 13th February 1962

An Ordinary Meeting was held by the Institute on Tuesday, 13th February 1962 at 5.30 p.m., when a paper entitled "Research in Mechanical Engineering at the National Engineering Laboratory" by F. D. Penny, B.Sc.(Eng.), was presented by the author and discussed.

Mr. B. P. Ingamells, C.B.E. (Chairman of Council) was in the Chair and thirty-five members and guests were present.

Seven speakers took part in the discussion which followed.

The Chairman proposed a vote of thanks to the author which was greeted by acclamation.

The meeting closed at 7.30 p.m.

The Summer Golf Meeting at Sunningdale Golf Club

The Summer Golf Meeting was held at Sunningdale Golf Club, Ascot on Thursday, 7th June 1962, when, in bright sunny weather a record number of fifty-two members took part in the morning and afternoon competitions.

Mr. C. A. Larking (9) won the Morning Medal Competition for the Institute of Marine Engineers' Silver Cup with a net score of 59. Mr. G. McGavin (18) was second with a net score of 71.

The afternoon Bogey Greensome Competition was won by Mr. A. Walker (9) and Commander A. B. Dickie (10) 1 down. Messrs. D. G. Welton (8) and L. E. Hardy (18), also with the score of 1 down were second, the winners having the better net score over the last nine holes.

Mr. Stewart Hogg, O.B.E., Chairman of the Social Events Committee presented the prizes. He welcomed the many new members on this occasion and expressed the appreciation of all the members to the Committee of the Suningdale Golf Club for allowing the Meeting to be held at their club.

It was announced that the Autumn Meeting would be held at Worplesdon Golf Club on Tuesday, 25th September 1962.

Section Meetings

South Wales

The Annual Golf Meeting of the South Wales Section was held on Friday, 15th June 1962, at the Glamorganshire Golf Club, Penarth.

Thirty-two members and friends attended. The David Skae Cup was won by Mr. D. Barwell (Associate Member) and the Visitors Tankard by Mr. E. Warrington. Mr. W. E. Brennan (Member) obtained the best net score for Members and Mr. W. D. Kendall, the best net score for Visitors. The best net score for the middle six holes was gained by Mr. T. C. Bishop (Member).

Mr. D. Skae (Chairman of the Section) presented the prizes to the winners.

A vote of thanks to the Glamorganshire Golf Club was proposed by Mr. F. F. Richardson (Member) and was replied to by the Captain of the Club.

Mr. Skae responded to the vote of thanks to the Presiding Chairman, which was proposed by Mr. J. Wormald, B.Sc. (Member).

Election of Members

Elected on 10th July 1962

MEMBERS

Arthur James Bissett
Kunwar Singh Chauhan
Cleveland Trevor Dawson
Anthony Sebastian Vital de Melo
John Alfred Eades
John George
Edmund Bryant Good, Cdr., R.N.
Alan Greenacre
John Thomas Leech, Lt. Cdr., R.N.
Bhalchandra Nagesh Lele, Cdre., I.N.
Cecil Frederick Morrow, Cdr., R.N.
Sydney Arthur Ranger, Lt. Cdr., R.N.
Anthony Ridgers, Eng. Lt. Cdr., R.N.
William Frederick Rogerson
Hendrik Rouws
Hendrik Spruyt
James Walker
Norman Waterworth

ASSOCIATE MEMBERS

Ronald George Babb, Lieut. R.N.
William John Birch, Lieut., R.A.N.
Terrence Edward Boyle
Robert William Burrell
Brian Caine
Suresh Chandra
Sila Pete Costa
Robert Brian Cox
Elliot Ernest William Cross
William Anthony Dempster
William Frank Druce
Hiron Moy Ghatak
Stanley Goff
Sydney Joseph Goldsmith
Gilbert Gabriel Haddow
Moazzam Hussain, Lieut., P.N.
Edward John Hutchinson
Kenneth Colin Jean
Alan Johnson
P. V. Joshi
Ian Lloyd
Andrew McIntosh
Adi Pillai
Muttath Rajagopalan
Pramud Rawat
Douglas Gordon Shon
Anthony Simpson
William Stonehouse Stacey
Robert Desmond Stevens
James Todd
Anthony Tregoning
James Turnbull
Leslie Fraser Watt
Michael William Weeks
Brian Ellis Whiting

OBITUARY

John Roy Beveridge (Member 3365) who died on 18th May 1960 at the age of 66 years, was born at Bridge-of-Weir, Scotland in 1893. The son of a Lloyd's Register of Shipping Surveyor, he spent most of his youth in Belfast, being educated at Methodist College and the Royal Belfast Institute. He served his apprenticeship with Harland and Wolff Ltd. and later returned to Scotland, where he took his Bachelor of Science degree at Glasgow University.

After spending three years at sea with the Naval Transport Service, during which time he gained his Second Class Board of Trade Certificate, he joined John H. MacIlwaine and Co., consulting naval architects and engineers of Belfast. He remained with this firm for four years, serving as an assistant superintendent engineer and consulting engineer. In 1922 he joined Lloyd's Register as an engineer surveyor at Newcastle, remaining with the Society until his retirement in 1953.

In 1924 he was married to Miss Austen, the daughter of a Lloyd's Register Surveyor.

Mr. Beveridge was perhaps best known for his work in connexion with the approval of machinery plans in the London and Glasgow office of Lloyd's Register.

He was elected an Associate of the Institute in 1918 and transferred to Life Membership in 1920. He was also a Member of the Institution of Engineers and Shipbuilders in Scotland.

James Douglas Cameron (Member 2815) was born in 1885, was educated at Glasgow Technical College and apprenticed to John Brown and Co. (Clydebank) Ltd. from 1900 to 1905. On completing his apprenticeship he worked in their drawing office before joining the Orient Line in 1909. At the time of his joining, the company was carrying out a building programme of five 12,000-ton ships and Mr. Cameron was appointed a junior engineer of the s.s. *Orsova*, the first of these new vessels, and sailed on her maiden voyage in that year.

After three and a half years at sea, during which time he obtained his Board of Trade Certificates (including his Extra First Class Certificate), Mr. Cameron came ashore to join the staff of the Superintending Engineer. For a short period in 1913-14 he was employed as a draughtsman.

During the First World War Mr. Cameron served in the Royal Navy from 1915-19. After demobilization he returned to the Orient Line as Assistant to the Superintending Engineer and was appointed Superintending Engineer in 1938.

After the Second World War, in addition to his normal duties as Superintendent, Mr. Cameron was occupied with the engineering problems associated with the company's rebuilding programme, which included three large passenger liners, the s.s. *Orcades, Oronsay* and *Orsova*, each of 42,500 s.h.p., which were put into service before he retired in November 1954, after 45 years service with the company.

Mr. Cameron, who died suddenly on 20th April 1962, was, by virtue of his position, well known, and, by virtue of his personal qualities, well liked. He joined the Institute in 1913.

William Cone Heck (Member 10704) was born on 28th March 1899. He served two terms as an apprentice to Ruston and Hornsby Ltd. of Lincoln, between 1915-18 and 1919-21, his indentured service having been interrupted by service in the Royal Navy in the intervening period. After completing his apprenticeship he joined the Royal Australian Navy as an engine room artificer and served with this service until 1926, when he joined Elder Dempster and Co. Ltd. During this period he gained a First Class Ministry of War Transport Steam Certificate and a Motor Endorsement.

In 1932, Mr. Heck began a 30-year association with Insurance Engineers Ltd. as an engineer surveyor, and subsequently became well known to industrialists over a wide area in the East Midlands. He was based at first in Lincoln and later at Nottingham. He rejoined the Royal Navy in the Second World War and was promoted Engineer Lieutenant Commander, R.N.R. After his release from service in 1947, he returned to Insurance Engineers Ltd., with whom he was serving at the time of his sudden death.

Mr. Heck was active in Freemasonry and was a past master of the Trident Lodge in Nottingham. He was elected a Member of this Institute in March 1946.

Gerard McGahan (Member 23569) was born on 23rd June 1911. He obtained his technical education at Sunderland Junior Technical School between 1923-26 and at Sunderland Technical College where he attended evening classes and student apprentice day sessions from 1927-30. He served his apprenticeship with MacColl and Pollock Ltd., marine engineers and boilermakers of Sunderland, where he gained experience on erection of marine steam engines and auxiliary machinery.

In 1931, after finishing his apprenticeship, Mr. McGahan took up his seagoing career and for the next ten years was employed continuously in steam and motor vessels in grades from junior engineer to senior second engineer. He was awarded his First Class Ministry of War Transport Steam and Motor Certificate in January 1941. For the next seven years, he worked as an inspector in mechanical engineering to H.M. Office of Works, where he was responsible for testing firefighting equipment in use ashore and afloat. From 1949 to 1960 Mr. McGahan was again employed at sea as second, then chief, engineer aboard passenger and mail ships, but from July 1951 he entered the service of the South Eastern Gas Board. In September 1960 he resigned his post to enable him to pursue higher studies.

Mr. McGahan, who was elected a Member of the Institute in April 1961, was unfortunately obliged to curtail his studies owing to worsening health, and in September 1961 occurred his untimely death. He was 50 years of age.

Douglas Frank Westbrook, M.B.E. (Member 16236) died in Hillingdon Hospital, Middlesex, on 16th January 1962, aged 62 years. In 1915 he passed a Civil Service examination to enter the Royal Navy as an artificer apprentice and from then until 1919 he served as apprentice fitter and turner. In 1920 he qualified as an engine room artificer 4th class and, after further examinations, was promoted warrant officer. In 1940 he became a commissioned engineer and after passing a maintenance engineering course in 1948/49 he was promoted Lieutenant (E).

Lieutenant Westbrook was then appointed engineer officer in charge of destroyers in the Reserve Fleet at Harwich and held this post until 1953 when he was made Engineer Officer of H.M.S. *Mull*. In 1955 he was elected a Member of the Institute. After his retirement from Naval Service, Lieutenant Westbrook joined the office of The Drayton Regulator and Instrument Company at West Drayton, Middlesex.

John Henry Wilson, B.Sc.(Durham)
Ronald Archibald Wilson
John Aitchison Wood
Hercules Wright

ASSOCIATES
Sabry Arabi
George Borger
K. S. Chandran, Cd. Eng., I.N.
Peter Alan Gill
William Lloyd Hutcheson
Maurice Edward Jenkins
Stanley Francis Port Louis
William Alfred McKinstry
Amar Singh, Cd. Eng., I.N.

GRADUATES
Eustace Ambatielos, B.Sc.(Durham)
Probir Kumar Banerjee
Ronald Anthony Blenkinsop
Anthony John Dias
Charles Stewart Figes
Peter John Hoskin, Lieut., R.N.
Richard Martin Whitney Kent
Ernest August Maier
S. K. Parulekar, Lieut., I.N.
Ezekiel Baruk Reuben
Terence Charles Roomes
Ambarish Sen
C. L. Seshadri
S. H. Shetti
V. K. Srivastava
A. K. Tewari
Hugh William Fraser Watt

STUDENTS
Emanuel G. Adebowale
M. N. Chakravarty
M. Dharmarao
S. Ghosh
Stephen Russell Hill
William August Koubek
Pillai Manoharan
M. Mazaheri, Sub. Lieut., I.N.
B. Nath
Victor Stephen Park
R. S. K. Hari Rao
R. A. E. Samson
Narendra Singh
N. A. J. Toomer
F. C. Vanderplank

TRANSFERRED FROM ASSOCIATE MEMBER TO MEMBER
Peter Jones
Clifton John Olliver
Ir Otto Jan Van Der Vorm
Donald Edmund Walters

TRANSFERRED FROM ASSOCIATE TO MEMBER
Joseph Gamble
Alastair MacGregor MacAdam
Robert Gordon Taylor
Edward Wiltshire Ward, Lt. Cdr., R.N.

TRANSFERRED FROM GRADUATE TO ASSOCIATE MEMBER
Demitrios Boucoyannis, B.Sc.
George Gordon Griffiths
Martin Redfern Hankey
Pierre Joseph L'Angellier
James Stuart McIndo
Arthur Nightingale
Karra Prakash
Robert Bell Smith
R. P. Titina

TRANSFERRED FROM STUDENT TO ASSOCIATE MEMBER
Ronald Antony Allcroft Gibbons
Geoffrey William Goodbody
Alan Miles

TRANSFERRED FROM STUDENT TO ASSOCIATE
Thomas Michael Crompton

TRANSFERRED FROM STUDENT TO GRADUATE
Frank Walter Axe
James William John Hewitt
Irving Malcolm Levington

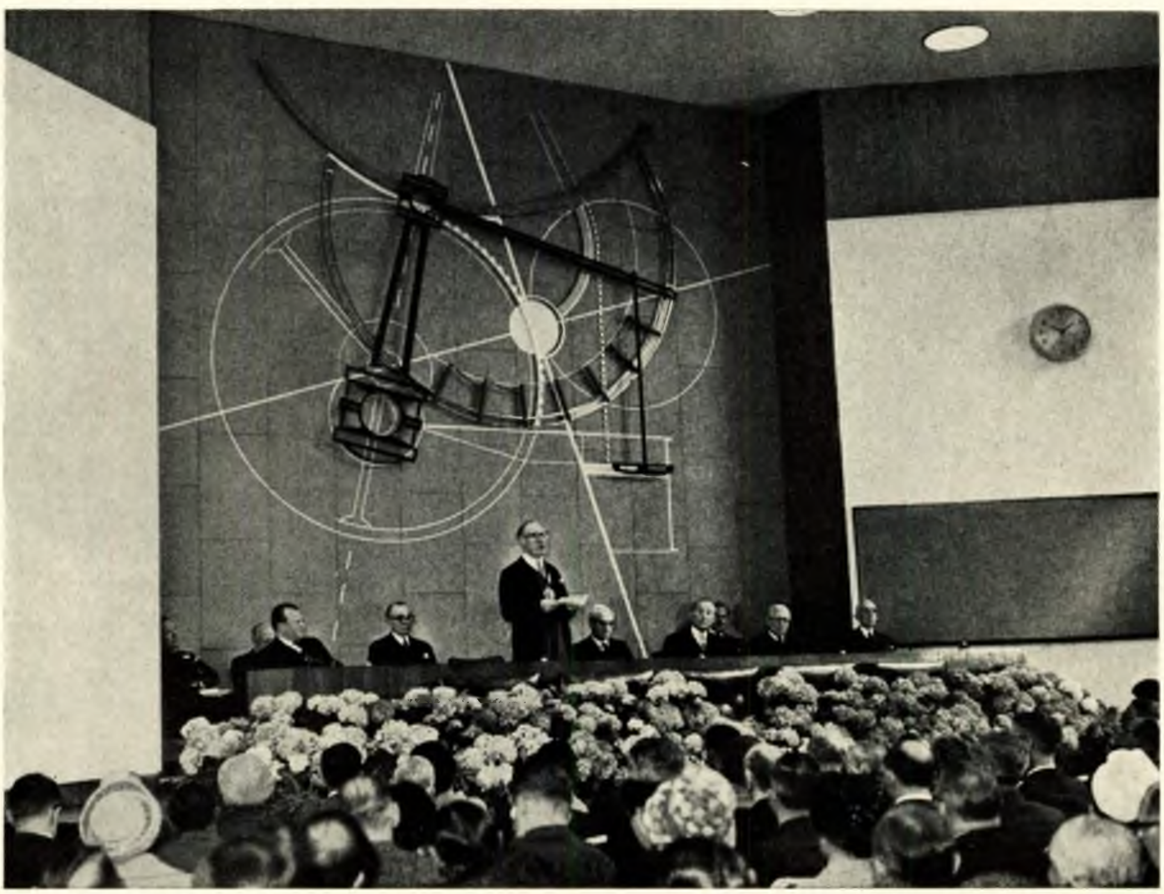
TRANSFERRED FROM PROBATIONER STUDENT TO GRADUATE
Kenneth Allport
Brian Joseph Matthews
Basil John Reed
Paul Charles Keats West

TRANSFERRED FROM PROBATIONER STUDENT TO STUDENT
David James Michael Ashcroft
Peter James Carney
Timothy Mitchell
Ian Craig Scott
Christopher David Whittaker

International Conference of Marine Engineers

7th—12th May 1962

Fifty-four delegates and their ladies from Commonwealth and other overseas countries attending the Conference, arrived in London on Sunday, 6th May, and were welcomed in the Mount Suite at Grosvenor House, Park Lane, by the Conference Committee and Members of Council. Over three hundred members and their ladies participated in the various Conference activities.



The Right Honourable The Lord Mayor of London, Sir Frederick Hoare opening the Conference in the Lecture Hall of the Memorial Building. With him on the platform are: (seated, from left to right) Mr. R. Cook, M.Sc. (Chairman, Papers and TRANSACTIONS *Committee) Mr. S. Hogg, O.B.E. (Chairman, Social Events Committee) Mr. Sheriff C. S. P. Rawson (Associate) Commander F. M. Paskins, O.B.E., R.D., R.N.R. (Vice-Chairman of Council), Mr. J. Calderwood, M.Sc. (Vice-President) presiding, The Right Honourable Sir Harry Hylton-Foster, Q.C., M.P., Speaker of the House of Commons, Colonel E. Hutchins, D.S.O., City Marshal, Vice-Admiral Sir Frank Mason, K.C.B. (Chairman of Council) and Mr. B. P. Ingamells, C.B.E. (Chairman, Conference Committee)*

The official proceedings of the Conference were opened in the Lecture Hall of the Memorial Building at 10 a.m. on the morning of Monday, 7th May, by The Right Honourable The Lord Mayor of London, Sir Frederick Hoare. Mr. J. Calderwood, M.Sc. (Vice-President) in the Chair, presiding, was supported by The Right Honourable Sir Harry Hylton-Foster, Q.C., M.P., Speaker of the House of Commons, Mr. Sheriff C. S. P. Rawson (Associate), Vice-Admiral Sir Frank Mason, K.C.B., Chairman of Council, Commander F. M. Paskins, O.B.E., R.D., R.N.R., Vice-Chairman of Council, Mr. B. P. Ingamells, C.B.E., Chairman of the Conference Committee, together with Mr. R. Cook, M.Sc., Chairman of the Papers and TRANSACTIONS Committee and Mr. S. Hogg, O.B.E., Chairman of the Social Events Committee.

Mr. Calderwood, in opening the proceedings, welcomed the Lord Mayor and delegates from other societies, the Institute's overseas Divisions and Sections and members from home and overseas. He hoped that they would all find the Conference valuable technically, the contacts amongst themselves useful and the social events enjoyable.

Mr. Calderwood then read a telegram received from the President of the Institute, His Royal Highness The Prince Philip, Duke of Edinburgh as follows: "I regret that it has not proved possible for me to attend the First International Conference to be held by the Institute of Marine Engineers. The theme, The Design, Construction and Operation of Modern Marine Propelling Machinery is one which interests me very much and with nuclear power now actually driving vessels at sea this is a challenging moment for all professional marine engineers. Other and newer methods of transport have tended to distract people's attention from the very great advances that have been made recently in ship design and propulsion. I hope this conference will give new encouragement to marine engineers to make the most of modern scientific invention to keep shipping in the forefront of cheap and easy long distance transport. PHILIP." Mr. Calderwood proposed a reply which was agreed. "The delegates, Members of Council and members of the Institute present at the opening of the International Conference of Marine Engineers were greatly encouraged by your stimulating message, which was received with much pleasure."

Mr. Calderwood then called upon the Right Honourable The Lord Mayor, Sir Frederick Hoare, to open the Conference.

THE LORD MAYOR said: It is with the greatest pleasure that I welcome delegates to the first International Conference of Marine Engineers to be organized by the Institute. I am delighted that no fewer than fifteen nations are represented. Since its foundation, 70 years ago, the Institute has grown enormously, especially during the last seven years, when its membership has increased from 10,000 to over 15,000.

There is one special link with the Institute which gives me a great personal interest in the Conference; for the past six months I have been both under the protection and also under the vigilant eye of two watchdogs, one of whom, Sherriff Christopher Rawson, is a member of the Institute. No Lord Mayor could have two better companions to help him through his year of office. I am not the least surprised that the Institute receives such excellent service from its members, for everyone knows that each time he travels in ships propelled by marine engines his life depends upon the efficiency of the product.

Enormous sums have been spent upon research into ways of driving a ship faster and still with absolute reliability, but I am not sure that the same amount of attention has been given to the problem of getting the cargo into and out of ships quickly. A big contribution to this problem might be made if there were greater liaison between those who build and design ships and those responsible for loading and unloading. This would improve productivity and lower costs.

The problem has been especially studied in Rotterdam, where facilities for handling all cargo are so good that we have lost much of our trade. I have no doubt that the British Ship Research Association is making every endeavour to overcome the various problems in order that orders for British shippers will increase, thus bringing a return to prosperity to the yards.

It was 45 years ago that the Institute first settled in London, and I am delighted that the City Corporation was able to help after the War, when the Institute was looking for a suitable site. From the earliest days the City of London, through the Livery Companies, has supported every effort to improve standards of craftsmanship and integrity. Over the

Mr. J. Calderwood, M.Sc. opening the proceedings. Seated, from left to right: Mr. Sheriff C. S. P. Rawson, Commander F. M. Paskins, O.B.E., R.D., R.N.R., the Right Honourable The Lord Mayor of London, Sir Frederick Hoare, Vice-Admiral Sir Frank Mason, K.C.B., and Mr. B. P. Ingamells, C.B.E.

years a great contribution has been made towards this splendid objective both through education and through the support of institutes such as the Institute of Marine Engineers, which sought to raise the standards of its profession.

It would never be the skyscrapers that would make the City of London great; it would be the achievement of the very highest world-wide reputation for trust and integrity.

VICE-ADMIRAL SIR FRANK MASON, K.C.B. (Chairman of Council) rose to thank the Lord Mayor for opening the Conference. He said: Those who live in London do not need to be told about the pressure on the Lord Mayor's time and about the many varied calls which are made upon him in his year of office. The Institute is extremely grateful to the Lord Mayor for making time to open the proceedings. It is also the Institute's good fortune to have with it Sir Harry Hylton Foster, who is not only a Member of Parliament for the Cities of London and Westminster but also the Speaker of the House of Commons. It is a unique occasion, because Sir Harry had told him that he met the Lord Mayor only at dinners.

The City of London, situated on a great river, has always had vital links with the sea. For many centuries the world's shipping has sailed into the Port of London and the Lord Mayor is Admiral of the Port. The world's shipping is still said to sail in, but in fact it motors in or steams in. This phenomenon is the reason for the existence of the Institute, and it is very fitting that its headquarters should be situated in the City of London. I imagine that the Institute is the largest, although perhaps the youngest, of the learned societies within the City's famous square mile.

It gives the Institute special pleasure to welcome London's chief citizen to its memorial building. I thank the Lord Mayor sincerely and warmly on behalf of all the members of the Institute and delegates for his kindness and for the honour he has done us in opening the Conference.

The Chairman then declared the end of the proceedings at the official opening ceremony.

After the opening ceremony, the ladies attending the Conference were taken by coach to the Houses of Parliament and were escorted on a tour of the buildings.

The first technical meeting of the Conference opened at 10.30 a.m. when a paper entitled "Canberra" by T. W. Bunyan, B.Sc. (Member), P. D. Morris, M.I.Mech.E. and D. D. Stephen, B.Sc., A.M.I.Mech.E., A.M.I.E.E., was presented and discussed. (A full report of this meeting and other technical proceedings of the Conference, will appear in the October issue of the TRANSACTIONS.) This meeting closed at 12.30 p.m., when members proceeded to the Mansion House to meet their ladies for luncheon.

At the Mansion House they were received by the Lord Mayor and Lady Mayoress, Mr. and Mrs. Calderwood and Vice-Admiral Sir Frank and Lady Mason together with Mr. Sheriff C. S. P. Rawson and Mrs. Rawson. The luncheon, which was presided over by Mr. Calderwood was graced by the Right Honourable The Lord Mayor as the principal guest, and was attended by 330 delegates, members and their ladies.

Receiving guests at the Mansion House. From left to right: The Lord Mayor and Lady Mayoress, Mr. and Mrs. J. Calderwood and Vice-Admiral Sir Frank and Lady Mason

The Loyal Toast, proposed by the Chairman, having been honoured, Mr. B. P. Ingamells, C.B.E. (Chairman of the Conference Committee), rose to propose the toast of "The Right Honourable The Lord Mayor, the Corporation of London and the Sheriffs".

He said: It is with the utmost diffidence that I rise to speak to you, a diffidence deeply rooted in the high regard with which we hold the City of London, and to which I must add a personal reason, which is an awe I have always held for the Lord Mayor himself in his gilded coach. This memory goes back to my childhood days, when I knew a nursery rhyme which went:

"Even a King of England on Temple Bar must beat
For leave to ride up Ludgate, down the hill of Fleet".

Inevitably, I suppose, in proposing a toast like this, one thinks of the City of London as the financial capital of the world; but I am no financier, even though I would like to speak about such prowess. If I were a financier I would undoubtedly be much richer than I am, but I am only an engineer. But I am happier, I feel, in dealing with ships, and it is just as easy to link ships with the City of London as it is with the finance which runs those ships.

After all, it is the international commodity markets in the

City of London, with their world-wide ramifications, their world-wide reputation for integrity, which are a financial pillar of strength to the whole of our country, and with great benefit to it. Many of us here in our younger days were at sea, and we were carrying cargoes, but little did we think of who sold those cargoes. As we grew older we realized that it was the international commodity markets which bought and sold raw material and gave us the work to do.

We put the cargoes in isolated ports, often with shallow coasts, picking up from lines under a hot sun: tin in Malaya, tea in India, wool in Australia, sugar in the West Indies, copper in South America, and so on. And how uncomfortable we found it! And although we never thought of the City of London selling this material, I feel quite sure that the City brokers here, catching the four o'clock home in the afternoon, seldom thought of us either. (*Laughter.*)

It therefore makes it most difficult for me, in my old age, to say thank you to the City brokers for all the good work they did. But in sober judgement one must do this, because it is the buying and selling of raw material in the City which adds greatly to our financial strength in this country, and still gives employment to our ships all over the world. I think we should be grateful, because those were the ships which shaped our careers as young sailors which finally ended up in the Egyptian Room.

Today I will not say that we are surrounded by admirals, because I see so many bonny hats among the audience, but undoubtedly we have a lot of admirals here, some from overseas, some from the United Kingdom, and all of them headed by our Chairman of Council, Admiral Sir Frank Mason. (*Hear, hear and applause.*) There should have been a time-lag before that applause, for I was going to add that Admiral Sir Frank Mason is recognized as one of the best engineers that the Royal Navy has had in this post-war era. (*Applause.*)

But, my Lord Mayor, none of these admirals can hold a candle or an electric bulb, or whatever an admiral holds nowadays—even perhaps a sword—to you; none of them can equal the famous rank that you hold as Admiral of the Port of London, and you are the most famous of them all! (*Applause.*) And, as Admiral of the Port, we would like, in seamanlike fashion, to grapple you to our hearts. Also, Sir, as the only professional and technical body within your precincts, we do feel that we are in the unique position to offer you advice on maritime or engineering matters whenever you should need them; and if ever you should need them, do remember that our services are there for you day and night. (*Hear, hear.*)

My Lord Mayor, you already have many years of loyal and faithful service to your City and country behind you, and we feel sure that, with the help of your Sheriffs, during your present year of office, you will add greatly to the lustre of that wonderful historic title of The Lord Mayor of London. (*Applause.*) It is therefore with great pleasure, as well as with confidence, that I propose the Toast of "The Right Honourable The Lord Mayor, the Corporation of London and the Sheriffs". (*Applause.*)

In responding to the toast the Right Honourable The LORD MAYOR said: I would like first of all to thank Mr. Ingamells, your immediate past-Chairman, on behalf of the Corporation of London, the Sheriffs and myself, for the very warm welcome which he has extended to us today.

I feel that I have an especially close link with your Institute, because first of all the River Thames has brought all the prosperity of London which it has known over the past 2,000 years, and you are exclusively concerned with what happens on the sea and the River Thames, and so many of you have come up the Thames to London again and again. But the second link is because one of the two Sheriffs who look after the Lord Mayor during his year of office is Mr. Christopher Rawson, a member of your own Institute, and I am delighted that it has been possible for him to be here today . . . because otherwise he would have been at the Old Bailey. (*Laughter and applause.*)

At the reception before the luncheon at the Mansion House. The Right Honourable The Lord Mayor, with (left) Mr. Sheriff C. S. P. Rawson and (right) Vice-Admiral Sir Frank Mason, K.C.B.

Now, you mentioned that "Even a King of England on Temple Bar must beat". We in the City of London have been doing our very best to keep alive in the minds of the citizens of London, and also the rest of England, that ancient tradition; but, of course, I have to admit privately in here (and hope no one will quote me) that it is in fact not strictly accurate. When the Queen arrives at Temple Bar it is true that a cord is placed across the Strand apparently barring her entrance. In fact, it is not really to bar her entrance at all; it is just to tell her where the City begins; and there the Lord Mayor surrenders his insignia of office to the sovereign of the day, and if he is regarded as a reasonably good Lord Mayor he gets them back. (*Laughter.*) On one occasion the sovereign of the day chose to keep the sword!

It is a special pleasure to me to know that as recently as the 17th April His Royal Highness Prince Philip accepted the Presidency of your Institute, and I feel that is the most wonderful thing in the history of this Institute, and I do congratulate you. (*Applause.*)

As the Lady Mayoress and I were shaking hands with every one of you today we were delighted to see such a wonderful gathering of people from all over the world, both from the Commonwealth and from overseas, and I do congratulate so many of you in having undertaken the journey to get here today, and I am certain that you will have found it very worth while.

During the past six months since I came into the office of Lord Mayor I have made a great number of speeches; this is, I think, the 430th speech that I have made during that time! Consequently, as I listen to far more speeches than I have made, I do hear words of commendation from time to time which remind me of the Hollywood advertisements which were brought out, as you know, by Sam Goldwyn when he had a new world-beater. I expect some of you will have heard the story of how Sam Goldwyn had just finished one of those mammoth epics and he was completely dissatisfied with the efforts of all his henchmen to suggest a really satisfactory Press hand-out. Finally, one enterprising fellow produced the following: "This fantastic film has the wit of Voltaire, the poetry of Shakespeare and the suspense of Edgar Alan Poe. Greater than the Bible, it will give you a thrill which you will remember for each day for the rest of your life". "Yes", said Sam Goldwyn, "that's much more like it: just a plain statement of facts, with no exaggeration". (*Laughter.*)

Also at the Mansion House, Major General R. J. H. Risson, C.B., C.B.E., D.S.O., E.D., B.E., President, the Institution of Engineers, Australia, with Mrs. Risson

Now you, Mr. Ingamells, referred to your journeys round the world, which must have been done by so many of you here—the great romance attaching to the profession that you have chosen, rather than perhaps in the banking world, where we merely lend the money for the cargoes that you carry all over the world. You yourselves, so many of you, have gone out of the Port of London and travelled far and wide across the world, and very often, as one sits in an office, one envies the people who travel across the world and who have the advantage of an exciting life, with all the romance that the sea has always lent to people in England. And the only touch of it that I shall ever know so long as I work in the City of London is just during this one year of office, when I become the Admiral of the Port of London. I gather that the only reason that I am allowed this wonderfully romantic title is that one Lord Major centuries ago was bold enough to sail out into the Thames Estuary and arrest a band of pirates! (*Laughter.*)

Among the overseas visitors at the luncheon at the Mansion House were: Mr. H. G. Bauer (Member) who presented the fourth paper to be read at the technical meetings, Mr. J. R. Newell, President of the Society of Naval Architects and Marine Engineers, U.S.A. and Mr. A. R. Gatewood (Vice-President for U.S.A.)

I would just thank you all once again very much, on behalf of the Sheriff, Mr. Christopher Rawson, and the Lady Mayoress and myself, for the very delightful luncheon to which you have asked us today. (*Applause.*)

Vice-Admiral SIR FRANK MASON, K.C.B. (Chairman of Council) then rose to say: As Chairman of the Council it falls to my lot to try to thank the Lord Mayor for a good many things, but first of all for offering us the use of his official home for this function. I certainly, speaking personally, always feel a great thrill when I attend any function in this famous building, and I expect everyone else feels much the same, particularly, perhaps, those of our visitors from overseas. Also speaking personally, but no doubt for many others, I always feel that when I am in the City I am on very historic ground,

Delegates from India: Mr. T. M. Sanghavi, B.E. (Secretary, Indian Division) with Mrs. Bose and Rear-Admiral T. B. Bose, B.Sc., I.N. (Vice-President for India)

Three delegates from the U.S.S.R. photographed at the reception before luncheon: Mr. L. T. Lantsov, Senior Engineer, State Committee for Shipbuilding, Mr. V. G. Markasov, Senior Engineer, Register (of Shipping) of the U.S.S.R. and Mr. A. T. Plekhanov, Engineer, State Committee for co-ordination of Scientific Research

and here we are in the heart of it. And, speaking of history, the Lord Mayor was telling me before lunch that he is the tenth generation of his family to have his being in the City of London; and I think I am correct in saying, Sir, that you are the third to hold this office. (*Hear, hear and applause.*) But, even transcending the privilege of lunching in the Mansion House, is the fact that the Lord Mayor and, no less, the Lady Mayoress, have graced this occasion with their presence. As I said in another place this morning, they have so many demands on their time that it seems almost incredible to me that they can make it, so to speak. It is indeed a pleasure and a signal honour for all of us. I recall what one of your predecessors said in this very room in considerable detail and with much warmth of feeling, when he referred to the staggering demands which are made upon the physical, mental, gastronomic and oratorial stamina of a Lord Mayor. (*Laughter.*) I am sure we would all hope that the Lady Mayoress is not subjected to quite such a marathon.

For all these things we are very much in your debt, and we are extremely honoured that you have opened our Conference and have come here today to be with us in your own home. As a token of our appreciation the Council have asked me to invite you to accept Honorary Membership of the Institute. (*Applause.*) Before I actually present this Certificate I would explain that this is the grapnel with which we take you to our hearts. (*Applause.*)

The Right Honourable the LORD MAYOR, in accepting the Certificate of Honorary Membership of the Institute of Marine Engineers, said:

I would first of all like to thank the members of the Institute through you, Vice-Admiral Sir Frank Mason, for the very generous tribute which you have paid to me now at this moment in presenting me with a Certificate of Honorary Membership of your Institute. I regard it in the same spirit as you have presented it—as a grapnel binding me to you by friendship—and I very greatly appreciate this gesture to me.

Guests from Japan: Mr. T. Rinoiye, Past President, Society of Naval Architects of Japan, Mrs. T. Rinoiye, Mrs. M. Yamaguchi and Mr. M. Yamaguchi, Director, Society of Naval Architects of Japan

I realize, from what Mr. Ingamells said earlier, that I now have as of right the very considerable professional knowledge bound up in your Institute available to me, should the Lady Mayoress and I require it at any time on the estuary

Mr. J. Stuart Robinson, M.A. (Secretary of the Institute) (left) at the reception with members from Canada, from left to right, Mr. and Mrs. A. Newland, Mrs. Pallas and Mr. T. M. Pallas, P.Eng. (Secretary, Canadian Division)

Delegates from Belgium with their wives. From left to right: Professor G. Aertssen, Past President, Union Belge des Ingenieurs Navals, Mrs. G. Aertssen, Mrs. J. J. L. van Maanen-Portiejle and Mr. J. J. L. van Maanen, Secretary-Treasurer, Union Belge des Ingenieurs Navals

of the Blackwater where we sometimes venture in a small boat with one rather dicky engine. I can assure you that I shall take it literally. (*Applause.*)

Thank you very much indeed once again for this presentation that you have just made to me, which I very greatly appreciate. (*Applause.*)

Following the luncheon at the Mansion House, members returned to the Memorial Building to hear the paper "Marine Gas Turbines in the Royal Navy" by Captain G. F. A. Trewby, R.N. (Member) presented and discussed. This meeting closed at 5.30 p.m.

At 6.0 p.m., approximately 500 members and their guests were received in the Memorial Building by Mr. and Mrs. J. Calderwood and Vice-Admiral Sir Frank and Lady Mason, at a Cocktail Party, which was much appreciated by all who attended.

Mr. J. Calderwood, M.Sc. (Vice-President) welcoming Mr. Stewart Hogg, O.B.E. (Chairman, Social Events Committee)

Vice-Admiral Sir Frank and Lady Mason, who with Mr. J. Calderwood and Mrs. Calderwood (seen in background) received the guests, greeting Mr. P. Jackson, M.Sc. (Member of Council)

On the morning of Tuesday, 8th May, the ladies were taken on coach tours to Windsor and Hampton Court.

The first technical meeting of that day started at 9.30 a.m. when two papers on "Post-war Developments and Future Trends of Steam Turbine Tanker Machinery"—the first by Cdr. E. H. W. Platt, M.B.E., R.N. (Member) and Mr. G. Strachan, B.Sc. (Member) and the second by Mr. H. G. Bauer (Member)—were presented and discussed.

At the conclusion of this meeting, delegates to the Conference were entertained to luncheon by Lloyd's Register of Shipping. In the afternoon papers entitled "The Doxford

Lady Mason receiving Mr. R. Hunter. Vice-Admiral Sir Frank Mason, K.C.B. (Chairman of Council) is seen centre

Direct Drive Diesel Engine" by Mr. P. Jackson, M.Sc., M.I.Mech.E. (Member of Council) and "Direct Drive Diesel Machinery" by Mr. H. Andresen, were presented and discussed.

In the evening, Mr. C. C. Pounder (Immediate Past President), presiding and Mr. J. Calderwood received members and delegates at a dinner, which was held in the Ballroom at Grosvenor House. After proposing the Loyal Toasts the Chairman, Mr. Pounder, rising to propose the toast of The Guests said: When Methuselah was 900 years old the journalists of the time called upon him with greetings for a happy birthday. Soon the inevitable question was put to him regarding his health. Methuselah replied that, apart from having osteo-arthritis in every limb, apart from being a chronic dyspeptic with lungs that wheezed like a blacksmith's bellows, and apart from the fact that he was stone deaf and almost blind, his health was a source of continual enjoyment to him and life was very pleasant indeed. (*Laughter.*)

Why do I tell you this story? Because of the number of people—strangers to this country—who, especially over the past few days, have expressed surprise at the virility, the alertness and the enterprise exhibited in everything around them. One visitor said he had clearly understood that Britain was going to the dogs. That, of course, is quite correct; Britain *is* going to the dogs. This old country of ours has always been going to the dogs; it has been going to the dogs ever since dogs were created. (*Laughter.*) A perusal of writings and speeches made one hundred, two hundred and even more years ago bears out this assertion. The "demnition bow-wows" of the amiable Dickensian character Alfred Mantalini may always be at our heels; but, let there be no mistake about it, such parts as may have gone to the dogs have always been the unworthy parts. In more respects than many people are apt to think, this nation is still a leader—in my opinion a great leader—in most of the spheres that ultimately matter. (*Hear, hear and applause.*)

To me it is axiomatic that only by meeting people from other countries can one discover the greatness and the littleness of one's own people. Rudyard Kipling crystallized this notion, albeit in a different way, in his graphic phrase: "What should they know of England who only England know?"

In short, what does anybody know about anything unless there is something else to serve as a yardstick? By profession I am a machinery designer (*may God forgive me!*) and I know only too well that, in the process of designing an engine, for example, it is not sufficient to see only one scheme; an experienced man requires to see, and to study, many schemes before a satisfactory decision can be made.

A few weeks ago, in the great dining hall of this hotel, where fifteen hundred men foregathered on the occasion of the Institute's Annual Dinner, when responding to the toast of the Institute, I referred to this International Conference in one brief phrase that came to my lips spontaneously and naturally. I said it was an occasion when, unreservedly, nation could speak peace unto nation. As is usual, the proceedings at the

Some of the delegates at the Dinner at Grosvenor House. (Clockwise starting nearest camera) Mr. J. C. Proudfoot (Chairman, North Midlands Section), Commander H. G. Gillis, R.C.N. (Vancouver Island Section), Mr. W. Kitson, Engineering Institute of Canada, Captain G. I. D. Hutcheson, C.B.E., B.E., R.A.N. (Vice-President, Australia), Rear-Admiral T. B. Bose, B.Sc., I.N. (Vice-President, India), Mr. H. G. Frisk, Secretary, Society for Shipbuilding and Aeronautics, Mr. T. M. Sanghavi, B.E. (Secretary, Indian Division), Mr. J. Stuart Robinson, M.A. (Secretary of the Institute), Mr. J. H. Thomas (Chairman, Eastern U.S.A. Section), Mr. S. N. Dranitsin, Senior Engineer, Ministry of Sea Transport, U.S.S.R., Mr. T. M. Pallas, P.Eng. (Secretary, Canadian Division) and in the foreground, nearest the camera Captain W. S. C. Jenks, O.B.E., R.N. (Chairman, Merseyside and North Western Section) and Mr. G. Kaudern, President, Society for Shipbuilding and Aeronautics, Stockholm

Annual Dinner received reference in many papers and in many periodicals. Some newspapers reported certain parts, other papers gave other details, and so on, after the fashion of journalistic activities having different interests to encompass. But, without exception, every paper reported the simple sentence that I had quoted. To me, at least, this was symptomatic of a widespread, deep, urgent longing for the fulfilment of the ancient prophecy: "nation shall speak peace unto nation and they shall not make war any more".

Granted the validity of my premise, there is surely no greater civilizing influence known to man that the fostering of honest international trade, than the carriage, sale and exchange of merchandise between country and country the world over. The beneficient ramifications of the process are almost limitless.

Our part, as engineers, in this world-wide industry lies in the devising of the mechanisms whereby ships of commerce are propelled across the separating seas. All of which brings us back to this International Conference, at which the views and experiences of many engineers have been and are being expressed and exchanged. From Sunday evening, when the delegates assembled to meet the Conference Committee and the Institution staff, until now, I have been present at all the technical proceedings of the Conference. As a result I, at least, am satisfied that the Conference has fully achieved its purpose. (*Hear, hear and applause.*) It must now be patent to the world that the Institute of Marine Engineers is an authoritative body of high international standing.

The Institute was formed, in London, in the year 1889 and, until about 1948, it remained more or less a London body. The membership was 6,000. Thereafter, under the wise guidance of a succession of able men on the Council, wide expansion took place. Sections were formed in Australia (at Sydney in 1948 and Melbourne in 1953); in India (at Calcutta in 1953 and Bombay in 1954); in Canada (in which six sections now form the Canadian Division); in South Africa (at Capetown in 1955 and Durban in 1956); in Pakistan (at Karachi in 1957); and at Singapore in 1958. Now, with a membership of 15,000, in addition to the overseas Sections mentioned there are seven Sections in the United Kingdom—actually in Great Britain, which is a different entity from the United Kingdom. What makes the difference? Northern Ireland, of course! (*Laughter and applause.*)

Complementary to the Sections, in all the most important seaports of the world the Institute has some kind of organization, often under senior members of the Institute designated Vice-Presidents. In Northern Ireland, where I live, our members are too few for a Section and so we have a Panel,

Mr. Benjamin Rogers, (left) Deputy High Commissioner for Canada, being welcomed at the Dinner by Mr. C. C. Pounder (Immediate Past President, presiding) and Mr. J. Calderwood, M.Sc. (Vice-President)

and a very sound and lively Panel it is.

With us, tonight, amongst the stalwarts from overseas, we have men who laid the foundations of some of the Sections and are still active in them. Although sorely tempted to do so, it would be invidious of me to pick out individual names for mention.

One of the important factors contributing to the usefulness of this Conference has been the generosity of many firms in facilitating visits to their works. We should like them to know how much we appreciate their assistance. Also, one must not lose sight of the hospitality shown by the Shipbuilding Conference and the National Association of Marine Enginebuilders.

A Greek shipowner recently asked me if membership of the Institute was restricted to British Commonwealth citizens. In my reply I made it quite clear that the Institute was a world-wide organization. It knew no bounds of nationality. Its qualifications were technical, not racial.

And now, to give point to everything that has been said,

Mr. W. R. Harvey, O.B.E. (Member of Council), who in the Spring of last year visited Sections in the United States and Canada, is seen here enjoying a reunion with some members of the Eastern United States Section: from left to right, Mr J. H. Thomas (Chairman of Section), Mr. A. R. Gatewood (Vice-President for United States of America) and Mr. G. H. Hodges (Member)

I will ask you to rise and drink with me to the Toast, "Our Guests". (*Applause.*)

In reply to the toast, Mr. Benjamin Rogers, Deputy High Commissioner for Canada, said: I assume that marine engineers do not claim the dubious distinction of being the oldest profession in the world. (*Laughter.*) In fact, I gather that you think (some of you) that your profession started with perhaps the steam engine or the first machines that were put into ships. But I am not going to be deterred by that. I shall draw my inspiration, like you, Mr. Chairman, from the Book of Genesis. I am going to assume that ever since man has been building rafts, boats and ships there have been marine engineers . . . (*Interjection: "Naval Constructors"*) . . . and that therefore your profession is one that has its roots in antiquity. I said that I was going to take my text from the Book of Genesis. I shall refer not to Methuselah but to Noah. When Noah called upon some of your predecessors to build the Ark he gave them specifications that he had received from the Almighty, but I suspect that they also had some practical experience to guide them. After all, they managed without sea trials, without a fitting-out basin, without even a launching. They simply built the Ark on dry land, provisioned her, embarked a very motley collection of passengers and floated off when the waters rose. Their ship survived a great storm that lasted for many months, and the creatures that had gone in, in the words of the old song, "two by two, two by two", emerged with their numbers somewhat increased. (*Laughter.*)

In the long history of mankind, marine engineers—or naval constructors (*Laughter*)—must have taken part in countless projects. I imagine that you had a hand in moving those great blocks of stone to Stonehenge from South Wales, and, of course, in transporting the material for the Pyramids. Your skill enabled the Phoenicians to sail from the eastern Mediterranean to these islands, and even, it is said, as far north as the Arctic Icepack; the Vikings to cross the Atlantic to North America; the Polynesians to range the vast reaches of the Pacific Ocean. Thanks to the Marine Engineers of England, the small, easily-handled, English ships were able to defeat and scatter the great galleons of a country with which England has been at peace for a long time. (*Laughter.*) Indeed, since Alfred the Great founded the Royal Navy, and other people founded other navies, you have been making vital contributions to the national defence of this and other countries. Since the world was young you have been collaborating with fisherman in the winning of food from the sea.

Arks and aircraft carriers; barges, biremes and battleships; coracles and canoes, cruisers and corvettes; destroyers and E-boats; ferry boats, factory ships and frigates; fishing craft of every description—down through the alphabet and down through the ages marine engineers have participated in the design, construction and operation of an infinite variety of boats and ships. I wonder whether your profession should not bear some responsibility also for the ghost ships, like "The Flying Dutchman", the mystery ships like "The Marie Celeste", and even the fictitious ships like "The Walloping Window Blind", of which it was said:

Mr. J. Stuart Robinson (second from the right) with a party of guests from the U.S.A. and the U.S.S.R. at the Dinner at Grosvenor House. From left to right: Mr. J. R. Newell, Mr. H. G. Bauer, Mr. J. H. Thomas, Mr. B. Smetannikov, Technical Engineering Translator, Leningrad Economic Council, Commander I. P. Sakulkin, U.S.S.R.N., Mr. L. T. Lantsov, Senior Engineer, State Committe for Shipbuilding, Mr. N. N. Rodionov, Engineer, State Committee for Shipbuilding, and Mr. A. R. Gatewood

"No gale that blew
Dismayed her crew
Or troubled the Captain's mind.
The man at the wheel
Was taught to feel
Contempt for the wildest blow.
And it often appeared
When the weather had cleared
That he'd been in his bunk below".

I should like to think that fair Helen of Troy was an Honorary Member of the Marine Engineers Guild . . . "the face that launched a thousand ships".

When the Spanish Conquistadores arrived in Peru about

430 years ago they found the extensive and well-ordered empire of the Incas. Though the Incas had no written language they had a remarkable statistical system; they conducted successful trepanning operations on broken skulls; and they were superb stone masons and irrigation engineers—the best in the world of their day. And yet, because of their isolation, they had not heard of the wheel and axle! They had not stumbled on it or invented it themselves. I mention the Incas simply to illustrate the fact that only 400 odd years ago—a mere moment in the history of the world—communications were so bad that distinct civilizations had developed in complete ignorance of one another.

For many thousands of years from the dawn of civilization, man's technological progress was painfully slow. Then, in the 15th century, only 500 years ago, the darkness of the Middle Ages suddenly gave way to the dawn of the Renaissance. In a brief period gunpowder, the printing press, the mariner's compass, were invented; or, if they were not invented, they were borrowed from the Chinese. (*Laughter.*) A new spirit of enquiry moved men to push back the frontiers of knowledge and the frontiers of their physical environment. Suddenly, almost before they knew what was happening, "iron men in wooden ships" were exploring new seas and discovering new lands, making highways of the oceans of the world; establishing contacts, sometimes for good, frequently for ill, between peoples that previously had not known of one another's existence. And it was your predecessors who made it all possible.

Then, some 200 years ago, came the steam engine, which detonated an explosion of technological progress. Beginning about 175 years ago, William Symington, Robert Fulton, and others who certainly deserved to be called Marine Engineers, successfully pioneered the application of steam engines to the propulsion of boats; and ever since then, Mr. Chairman, men of your profession have been enabling people in ever increasing numbers, and goods in ever increasing quantities, to be transported round the world. My ancestors went to Canada the hard way, by sailing ship; but the great waves of migration from Europe to the Americas, to Australia and to New Zealand —movements of people that have transformed the political geography of the world and changed the history of the world, were made possible by steamships. The fish we eat are caught from ships—except those that some of us catch ourselves at great effort and expense. (*Laughter.*) Every day we eat things and use things that in raw or finished form have been transported across the oceans in ships; and the ships, Mr. Chairman, the steamships and the motor ships and the nuclear-powered ships, have been designed and built and operated by marine engineers . . . and naval constructors. (*Laughter.*) We are constantly astonished by your achievements, and we wonder what you will be up to next.

Now, it is quite obvious to you and to all of my listeners that I have been speaking from the point of view of a layman; but I am speaking on behalf of guests, some of whom are laymen and some of whom are marine engineers. On behalf of them all I pay homage to you, to your Institute, and, from a layman, to the members of your profession, for the contributions that you have made and are making to our material progress and to the defence of our way of life. I express our good wishes to you for your Conference, and for the good that will come out of the Conference; and I thank you

Mrs. B. M. Sullivan (Secretarial Assistant, Administrative) with on her left: Mr. E. Abrahamsen, Vice Chairman Den Norske Ingenior Jorening, Mr. A. T. Plekhanov, Capt. R. G. Raper, R.N. (Chairman, West of England Section), Mr. A. R. Gatewood, Rear-Admiral J. B. Caldwell, M.B.E., C.D., R.C.N. (Vice-President for Canada) and Mr. A. H. Wilson (Member of Council). Seated on Mrs. Sullivan's right: Lt. Cdr. (E) J. M. C. Guerreiro de Amorim, P.N., Secretary, Ligados Engenheiros Maquinistas Portugueses and Mr. T. Rinoiye and the Institute of Marine Engineers for good food, good wine, good company; in short, for a delightful evening. (*Applause.*)

Mr. Roger's speech was followed by a pleasantly informal ceremony in which Mr. G. Kaudern, President of the Society of Shipbuilding and Aeronautics, Stockholm, presented a plaque to the Institute. Mr. Kaudern said: I am a guest here, like many others, which I appreciate very much; and, like other guests, I have been appointed by my Institute as a delegate, for which I am still more grateful. I speak as the Chairman of the Shipbuilding, Marine Engineering and Aeronautics Section of the Swedish Association of Engineers.

The Association is composed of all engineers—civil engineers, naval architects, etc.—who have graduated from the technical universities of our country; and the Association is 101 years old.

I would like to take the opportunity to say a few words of thanks to the Institute of Marine Engineers for all the hospitality and the outstanding organization that we have already found to be characteristic of this International Conference. But that was not the main purpose of my speaking. In addition to what our Chairman has already said, I think I can also speak for myself and for many of those here present when I say that at an International Conference like this one, in Spring time, in the middle of London, we all get a very strong feeling of the importance and leading role that British engineering is playing, especially in shipbuilding, marine engineering, and so forth. I think I can say for all of us that we do not envy you this leadership. It has been of the greatest importance to the development of marine engineering technique in all countries all over the world, and we all appreciate that and know it; and therefore, although I understand it is quite unnecessary, I would like to encourage you to maintain this leading position. At least the small countries feel that it is something which is of the greatest importance to them. This is perhaps not always so easy today when competition, no doubt, is growing very severe all over the world; but it is an excellent proof that you are still in the front line when we see that two of the papers presented by British engineers at this Conference deal with future development—those dealing with gas turbines and nuclear propulsion.

As our Chairman has also mentioned, there is another field where the British people are playing an important and leading role. Many many years before words like "United Nations", "E.E.C.", "O.O.C.D.", etc., were invented and covered the front pages of the newspapers, your people had established an international co-operation covering the whole world, especially through your international organizations like the Institute of Marine Engineers. I would again encourage you to keep your leadership in this respect, and I hope it will act as a sign to other countries, too. An excellent proof of what I have just stated is again this Conference itself which we are attending, where Marine Engineers from the whole world can meet and speak of their problems, and we speak in a friendly way, regardless of language or nation.

Mr. C. C. Pounder, who presided at the Dinner, shaking hands with Mr. G. Kaudern after accepting on behalf of the Institute, a plaque, presented by the Shipbuilding, Marine Engineering and Aeronautics Section of the Swedish Association of Engineers

It is with all this in mind that I now have the great pleasure of presenting to the Institute of Marine Engineers a little plaque of honour from my organization. Please receive it as a very minor token of our gratitude and appreciation of what your Institute is doing for us. (*Applause.*)

Mr. C. C. Pounder, in reply to the presentation, said: In the name and on behalf of the Council and members of the Institute I receive from your hands, Mr. Kaudern, this lovely plaque, the gift of the Swedish Society to the Institute of Marine Engineers. (*Applause.*)

I did not intend to say more than that, but you have so effectively touched one or two chords, which in turn have so evoked echoes from the past, that I feel impelled for a moment or two to tune-in to those echoes.

My personal sympathies as an engineer, and my friendliness as a man, go out perhaps more to the small nations than to the large nations. This, to me, is natural. I dislike to talk about my own life, if only because you might think I am another Methuselah. (*Laughter.*) But many of you are interested in the development of heavy oil engines. In Belfast our first love was the Sulzer engine, the offspring of that wonderful little country Switzerland. In 1912 we bought from Winterthur the largest Diesel engine then known to the world. This engine generated power for our works for many years and was retained long after it ceased to be economical to run, because of the excellence of the workmanship, just as we nostalgically retained until ten or fifteen years ago two large horizontal compound drop-valve steam engines made by Sulzer Bros. in 1892. In 1912 also we became associated with the Burmeister and Wain engine, the product of another most remarkable little country, Denmark. With this engine type I have lived for forty years. From Holland there came the Werkspoor engine, which makes me think of my friends G. J. Lugt and his successor and mantle-bearer F. G. van Asperen, whom I had hoped would have been here tonight. In 1913, the firm where I was trained built the Carels engine for the first British Diesel engine propelled cargo vessel *Eavestone*, under licence from Carels Bros. of Ghent in Belgium. Also from Belgium we had the Cockerill gas engines—great horizontal blast furnace gas engines as long as the width of this room. The same firm—Richardsons, Westgarth—had a very successful licence from Brown Boveri of Baden for steam turbines for power stations. And so I could go on. Interestingly enough, Wain was a Rochdale man; Cockerill was a Manchester man; Brown also was British. To press my point a little further, Sir Charles Parsons, the inventor of the marine steam turbine, was an Irishman. The most recent advances in marine heavy oil engines had their origin in the exhaust turbo-charging system invented by Dr. Alfred Büchi, again of Switzerland, whose professional friendship I enjoyed for many years. Also, if you take the United Kingdom—I mention it again because that is where we all are, at the moment, gathered together—where might you expect to find the greatest versatility, the widest variety of marine Diesel engine types, and the most powerful units that have been constructed? It is quite clear that you, gentlemen, are tonight scintillating with brilliant intelligence because you have already guessed it; it is in the smallest constituent part of the United Kingdom, namely, Northern Ireland. (*Laughter and applause.*) Our contribution—I must not forget our natural modesty here—to the development of the heavy marine oil engine has been second to none in this country; and we have been responsible for much progressive steam work also. To sum up: it seems to me that in the great world of engineering it has been to the little countries that one has had to look for technical leadership and to the great countries for the money, for the "drive", and for the organization necessary to make the very best use of the inventions for the good of mankind.

I will end as I began, by asking Mr. G. Kaudern to convey to his colleagues in Svenska Teknologföreningen, Föreningen för Skeppsbyggnadskonst och Flygteknik the genuine thanks of this Institute for the gift of this beautiful plaque, but, more than all, for the kindliness, the thoughtfulness, and the good fellowship that lie behind the gift. (*Applause.*)

On the same evening, some of the ladies attending the Conference dined at Kettners and afterwards attended a performance of "Twelfth Night" at the Old Vic.

Delegates from India at the Dinner. Rear-Admiral T. B. Bose, B.Sc., I.N. (Vice-President for India) and Mr. T. M. Sanghavi, B.E. (Secretary, Indian Division)

Admiral Bose was Local Vice-President for Bombay prior to being elected Vice-President for India in 1962 upon the formation of the Indian Division

The last technical paper of the conference, "Problems of Merchant Ship Nuclear Propulsion" by Mr. B. Hildrew, M.Sc. (Member) was presented and discussed at 9.30 a.m. on Wednesday, 9th May; during this time the ladies visited St. Paul's Cathedral and the Tower of London. Delegates, members and their ladies met at Tower Pier at 11.45 a.m. and there embarked in launches which carried them down the river to Greenwich. Here in the grounds of the National Maritime Museum, they were entertained to luncheon by the Shipbuilding Conference and the National Association of Marine Enginebuilders. Informal speeches of welcome were made by Mr. A. H. White, C.B.E., President of the Shipbuilding Conference and Mr. D. G. Ogilvie, B.Sc. (Member) (Chairman of the National Association of Marine Enginebuilders). Captain G. I. D. Hutcheson, C.B.E. R.A.N. (Vice-President for Australia) thanked the hosts in reply.

The delegates were then taken on a conducted tour of the Royal Naval College, the Queen's House and the Museum, and members spent a pleasant afternoon in a similar fashion. Tea was provided in the large marquee and the party returned to London by coaches at 4.30 p.m.

In the evening Her Majesty's Government held a reception in the River Restaurant of the Savoy Hotel, when the guests were received by The Right Honourable Ernest Marples, M.P., Minister of Transport, and Mrs. Marples.

On Thursday, 10th May, delegates and members and their ladies spent the day on visits to Stratford-on-Avon, Luton Hoo and Woburn Abbey, returning to London in the early evening. On that same evening, a reception was held at Guildhall, when

Coach trips were arranged for delegates who wished to participate in the all-day visits to various engineering works, part of the programme arranged for the Conference. In the photograph on the left: Vice-Admiral Sir Frank Mason, K.C.B. (Chairman of Council) is seen second from left with one of the parties of visitors. The right hand photograph shows another group of interested observers

guests were received by Mr. and Mrs. J. Calderwood, Vice-Admiral Sir Frank and Lady Mason and Mr. Sheriff C. S. P. Rawson and Mrs. Rawson. Those attending were able to visit the Livery Room and also the Crypt.

On Friday, 11th May, the ladies attending the Conference had a free day in which they were able to visit the shopping centres and other places of interest in London. Meanwhile coach trips to the Atomic Energy Research Establishment at Harwell, to Petters Ltd., Staines, and the British Internal Combustion Engine Research Association at Slough, W. H. Allen Sons and Co. Ltd. and Brookhirst Igranic Ltd., at Bedford and Davey Paxman and Co. Ltd., at Colchester were undertaken by members and delegates. The coaches returned to London in time for delegates and members to prepare for the final function of the Conference, a Dinner and Dance held in the Ballroom at Grosvenor House.

A brilliant occasion, this marked the culmination of a week filled with technical interest and enjoyable social events and emphasized the spirit of international friendship and co-operation which had contributed so much to the success of the Conference.

At the reception before the Dinner and Dance at Grosvenor House. From left to right: Mrs. J. J. L. van Maanen-Portiejle, Lt. Cdr.(E) J. M. C. Guerreiro de Amorim, Secretary, Ligados Engenheiros Maquinistas Portugueses, Mr. J. J. L. van Maanen, Secretary Treasurer, Union Belges des Ingenieurs Navals, Mrs. H. J. von Seebach and Mr. H. J. von Seebach

A truly international party at the Dinner and Dance at Grosvenor House, final social event of the Conference. From left to right starting nearest camera: Mrs. M. Yamaguchi, Mr. J. R. Newell, President, Society of Naval Architects and Marine Engineers, U.S.A., Lady Mason, Mr. M. Yamaguchi, Director, Society of Naval Architects of Japan, Captain G. I. D. Hutcheson, C.B.E., B.E., R.A.N. (Vice-President, Australia) Mrs. H. J. von Seebach, Vice-Admiral Sir Frank Mason, K.C.B. (Chairman of Council), Mrs. G. I. D. Hutcheson, Mr. T. L. Lantsov, Senior Engineer, State Committee for Shipbuilding, U.S.S.R. and Mr. H. J. von Seebach, Secretary, Schiffbautechnische Gesellschaft e.V

At another table from left to right: Mrs. E. Morrison, Captain G. F. A. Trewby, R.N. (Member), Mrs. B. M. Sullivan (Secretarial Assistant, Administrative) Mr. Y. Kamenetsky, Senior Engineer, Ukrainian Council of National Economy, U.S.S.R., Mrs. R. Beattie, Mr. Stewart Hogg, O.B.E. (Chairman of the Social Events Committee), Mrs. G. F. A. Trewby, Mr. P. B. Fasham, and Mr. R. Beattie (Chairman, Scottish Section)

Mrs. J. J. L. van Maanen-Portiejle (left) wife of Mr. J. J. L. van Maanen, Secretary-Treasurer: Union Belge des Ingenieurs Navals, talking to Mr. and Mrs. H. G. Frisk. Mr. Frisk is the Secretary for the Society of Shipbuilding and Aeronautics, Stockholm

Mr. T. M. Pallas, P.Eng. (Secretary, Canadian Division) with Mrs. Pallas and Mrs. M. J. Pearce (right) wife of Mr. M. J. Pearce, F.C.A. at the reception before the Dinner and Dance

A party of guests, from left to right: Mr. J. H. Thomas (Chairman, Eastern U.S.A. Section), the Hon. Mrs. Fisher, Mrs. A. E. Franklin, Mr. J. J. L. van Maanen, Miss A. Pinder (Editor, TRANSACTIONS*), Mr. A. T. Plekhanov, Engineer, State Committee for Co-ordination of Scientific Research, U.S.S.R., Mrs. J. J. L. van Maanen-Portiejle, Mr. A. E. Franklin (Assistant Secretary of the Institute), Mrs. J. M. C. Guerreiro de Amorim and Mr. V. G. Markasov, Senior Engineer, Register (of Shipping) of the U.S.S.R. In the foreground are Mrs. J. Stuart Robinson and Mr. H. G. Frisk*

All the papers read at the technical meetings together with the full discussions and authors' replies will be published in the October issue of TRANSACTIONS.