

# HYDRAULIC ENGINEERING

## REPORT OF CONFERENCE HELD AT THE R.N.E.C., MANADON FEBRUARY 1982

BY

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The first Conference on the subject of hydraulic engineering in the Fleet was held at the R.N.E.C., Manadon, in February 1982. Nearly two hundred delegates representing the uniformed and civilian branches of the Service together with many of the MOD contractors involved in hydraulic engineering attended; also present were colleagues from the U.S.A., Canada, Australia, and France, and from the Army and R.A.F.

Twenty-one papers were presented and these and their authors are listed in the Annex.

### Opening

The Conference was opened by Mr. P. W. Jarvis, Director of Ship Design and Engineering who, after welcoming the delegates spoke about the upsurge in hydraulic equipment onboard R.N. ships over recent years, stressing the importance of 'hydraulics' for ship's mobility, steering, stabilization, propeller pitch control, slow-speed drives for hovering, etc.

The wide variety of applications and the large number of designers, operators, and maintainers involved with hydraulic equipment for warships was a major reason for holding the Conference. Equipments were becoming much more complex and the technical problems more difficult to solve, so that cost considerations were becoming ever more critical. Was the increasing complexity justified? There was a pressing need for cheap, reliable, rugged, simple equipments and systems. Clever and sophisticated technology at the limits of engineering capabilities was not wanted. The challenge, therefore, was to give as much up-market performance as possible with down-market engineering and costs.

Mr. Jarvis concluded his address by thanking the Captain and staff of the R.N.E. College for the excellent facilities that had been made available for the Conference.

The Conference was divided into four half-day sessions, each under a sessional chairman.

### The First Session

This session, chaired by Commodore H.L.O. Thompson, Deputy Director Systems Design 1, was devoted to the design and performance of systems. The session included papers by the R.N. and by the U.S.N. on the design of submarine hydraulic systems, from which it was possible to draw interesting comparisons between the equipment philosophies and also to note similarities in the overall design concepts. The R.N. favoured radial-piston and, more recently, internal gear pumps, whilst the U.S.N. employed screw pumps and, for recent design, external systems utilize a simplex dual piston pump arrangement. The U.S.N. has a policy of locating filters downstream of major contamination generators and upstream of critical components, the filters being of the high collapse-pressure, disposable-element type without

by-pass valves. The R.N. fits filters in the supply and return lines near each power plant. The R.N. use an emulsifiable mineral oil (OX30) for nearly all submarine hydraulic applications; the U.S.N. make only limited use of such oil for some of the systems external to the pressure hull.

A paper presented by Vickers Shipbuilding Ltd. traced how mathematical modelling techniques had been used in the design and development of hydraulically-operated weapon equipments. A short film was shown of a chain conveyor for handling missiles in a magazine, indicating how the design had been improved by using the CAD programme.

A contrast to the type of fluid power engineering found in marine systems was provided in a paper by DGA(N) which highlighted the design philosophy and some of the technical features of military aircraft hydraulic systems. Future trends were seen as evolutionary rather than radical; there were, however, tendencies towards higher pressures (perhaps as high as 8000psi), the wider application of microprocessors for the control of fluid power, giving improved monitoring of performance and better storage of system operating parameters both in the short term and for defect identification.

A paper by an officer of C.-in-C. Fleet's staff that analysed hydraulic systems in the Fleet aroused considerable interest and comment, and was constantly referred to by delegates throughout the Conference. Because of the impact this paper had on the Conference, it is reproduced in full in this issue of the *J.N.E.*

### **The Second Session**

This session of the Conference, covering upkeep and maintenance of hydraulic equipment in ships, was chaired by Mr. D. L. Kitch, Superintendent of Naval Mechanical Engineering at NGTE (West Drayton).

The session opened with a paper outlining problems encountered in the refitting of hydraulic machinery in dockyards; this paper by Mr. J. R. Corless of Devonport Dockyard is also reproduced in this issue of the *J.N.E.*

A paper presented by the Fluid Power Centre of Bath University was concerned with condition monitoring of hydraulic pumps. It described various modes of failure in axial-piston pumps, and detailed suitable monitoring methods for detecting such failures. Practical examples were given assessing the relative merits of such monitoring devices.

A paper on hydraulic system monitoring was presented by an officer from the Naval Aircraft Materials Laboratory. This outlined a programme of work conducted by the Fleet Air Arm on specific hydraulic systems that had exhibited high component failure rates. The programme had established acceptable cleanliness levels for these systems, and cleaning routines and methods of assessing contamination levels had consequently been specified. A syllabus for the education of maintenance personnel dealing, in particular, with hydraulic hygiene had been established, and this had led to a marked improvement in the levels of component failure and overall reliability.

Mr. B. Ochiltree of AMTE(HH) presented a paper on the complex and not well understood subject of elastomeric components in hydraulic systems. It shed considerable light on the problems of selection of these materials and their performance in service in hydraulic systems.

The Thermal Control Company has for many years been researching the measurement of contamination in hydraulic systems and its control. A paper on the identification of particles, presented by one of their engineers, outlined future methods of extending the simple comparison microscope technique so that, by examining colours and shapes of particles using special light filters, the operator could identify certain materials and so deduce component

problems. The presentation included some excellent slides of various contaminants found in hydraulic systems, one bizarre example being the leg of an insect!

### **The Third Session**

This session, chaired by Mr. P. R. Prenter, the Managing Director of Mactaggart Scott Ltd, was devoted to the components of hydraulic systems.

A paper on hydraulic filtration presented by the Technical Director of Pall (Europe) Ltd. covered the comparative benefits, selection, and testing of filters. It also embraced courses of contamination, its generation, and its effects upon equipment, ranging from temporary malfunction to catastrophic failure. Data was presented on the performance and efficiency of filters, and the author concluded with a plea for designers to provide the filter manufacturer with *all* the information necessary to select the best filter for a particular application.

The next paper, presented by the Fluid Power Section of the NGTE, West Drayton, dealt with pump and filter testing at the Establishment. It outlined the methods being employed jointly with the NCB's hydraulic laboratory at Bretby for testing filters and gave the filter performance results achieved to date. A large number of hydraulic pumps have undergone functional and endurance testing at West Drayton; the various modes of test and the results of some were given. More recently, several pumps have been tested with an aqueous polyglycol fire-resistant fluid, with which a total of some 25 000 pump-hours running has so far been accrued.

A paper by Birmingham University previously read at the BHRA Fluid Power Symposium at Cambridge in April 1981 was represented at this Conference. This paper examined the effects of centrifugal and frictional forces on the lubrication of slippers in axial piston pumps, and aroused considerable interest. Under normal operating conditions, the slippers tilt: the direction of this tilt, the thickness of the lubrication film between the slipper and swashplate, and the friction between the slipper ball and its cup vary with pressure and swash angle, and cause the piston to rotate in the cylinder bore.

A hydraulic engineering conference would not be complete without reference to hydraulic fluids. This subject was covered quite extensively in the paper presented by NGTE, Cobham. The types of fluid in use and proposed for future use in warships were discussed, particularly in respect of their resistance to fire, their mechanical properties, and their system compatibility. The paper concluded that mineral oils, although they had good lubrication properties and so were excellent hydraulic fluids, created a significant fire hazard. On the other hand, water-based fluids, provided their water concentration is kept to the design level, were fire resistant, but the life of some mechanical components such as bearings were reduced. However, with the correct choice of components, water/glycols are recommended for use with R.N. hydraulic equipments.

Mactaggart Scott Ltd. presented a paper describing the engineering processes involved in the design and development of the aircraft lifts fitted in the INVINCIBLE Class, a completely novel hydraulic equipment for a warship. These lifts cope with working loads of over 18 tons and are one of the largest hydraulically-operated equipments fitted in warships. The pumps are used simply to charge air-loaded accumulators which provide sufficient capacity to raise a fully-laden platform; by this method, the electrical input to the pump motors is kept to a minimum. The reliability, safety, and tests carried out on sub-assemblies and the complete lift were also covered.

The last paper of this session, presented by Strachan and Henshaw & Co.

explained the characteristics and problems associated with leakage from hydraulic valves used in the water-ram torpedo discharge systems of the SSBNs. The paper described a relatively cheap and simple modification to the valve eradicating this undesirable feature. This modification also eliminates silting and sticking of the valve.

#### **The Fourth Session**

This session, chaired by Dr. K. Kent, Head of the Naval Aircraft Material Laboratory, explored future trends in hydraulic engineering. The session opened with a series of three papers presented by the National Engineering Laboratory (NEL), dealing with reduction of noise emanating from hydraulic equipments. The first of these papers by NEL looked at the development of hydraulic pumps and examined the noise characteristics of various pumps used in R.N. equipment. The development of the NEL Phasephlo pump, a variation of the 'Q' pump with each of the three pressure stages divided into three phases to reduce pressure ripple, was explained. In the opinion of NEL, this arrangement with integral silencers and unloading valves offered the best solution.

The second paper by NEL examined improvements to the design of valves to reduce noise. The effect of liquids passing through an orifice may, if liquid pressure falls below vapour pressure of the fluid, cause implosion of the vapour bubbles, significant damage to components, and generate considerable noise. Methods of reducing this problem, including the principles of the NEL helical restrictor valve, were discussed. By mathematical modelling, the flow has been predicted for each position of the spool and resulting velocities are below the speed at which erosion is likely. An analytical redesign of poppet valves to improve stability and reduce valve noise was outlined. An example was given where a valve fitted to a military vehicle system had been redesigned so that the noise, initially greater than that of the vehicle engine itself, had been reduced to an entirely satisfactory level.

The final NEL paper discussed the design and performance of hydraulic silencers. The paper examined the effect of the variation of type and position of the silencer on the pressure ripple and its harmonics and reported both the predicted and the measured values. It concluded that accurate predictions of noise performance could be available but more component data is needed before the prediction technique is widely used.

Bath University have been active in the field of the computer-aided design (CAD) of hydraulic equipment. Their paper outlined the Hydraulic Automatic Simulation Package (HASP) and described how this package can be applied by engineers with no previous knowledge of computer programming or component modelling. Three examples of the application of HASP to system design were outlined.

The final paper of the Conference was presented by Normalair Garrett Ltd. and dealt with the development of an all-hydraulic propeller drive. The paper described research work currently in progress at that firm in examining a hydrostatic propulsion system capable of substantial orders of power. Incorporation of a hydraulic motor in the propeller hub and the elimination of all shafting permits considerable flexibility to machinery layout and improvements to ship manoeuvrability.

#### **Discussion**

Among the many points raised during the discussion periods that terminated each session were:

- (a) The Fleet's obvious concern about inadequacies in maintenance and monitoring facilities.

- (b) The long delays in correcting defects.
- (c) A plea from manufacturers for better consultation between the MOD and the hydraulic industry generally.
- (d) Concern about the effects of shock on hydraulic filters.
- (e) The relative merits of fluoro carbon and nitrile rubber for seals and other components.
- (f) Criticism of the quality of current hydraulic fluids and also their associated fire hazards.

### Conference Closure

The Conference was closed by Commander J. G. Ferrie, Head of CHA(RN). In his opinion, two clear messages emerged from the Conference: firstly, that the system design needed improvement particularly in those areas concerning dynamic performance, tolerance to contamination, and noise; and secondly, safety—the Navy is moving away from mineral oils towards fire-resistant polyglycol fluids, and there was a need for industry to provide equipments that could tolerate this more-demanding hydraulic fluid.

The conference was judged to be a great success, not only because of the quality of the papers and the discussion but also because of the pleasant environment of the R.N.E. College and the warmth of the welcome of the Captain and his staff. Much work was done outside working hours in the more relaxed atmosphere of the wardroom.

## ANNEX—LIST OF PAPERS AND AUTHORS

### First Session—System Design and Performance

- Hydraulic Systems in Submarines by Mr. Pearson, MOD (DPT)
- Computer-aided Design of Weapon Hydraulic Systems by Mr. Lawrence, Vickers Shipbuilding, Ltd.
- Design Trends in Military Aircraft Hydraulic Equipments by Mr. Parker, DGA(N).
- Analysis of Hydraulic Systems in the Fleet by Lt.-Cdr. Wood, Staff of C.-in-C., Fleet.
- Hydraulic Equipment in U.S.N. Submarines by Mr. Wilcox, NAVSEA.

### Second Session—Upkeep and Maintenance

- Refitting of Hydraulic Machinery in Dockyards by Mr. J. R. Corless, H.M. Dockyard, Devonport.
- Machinery Health Monitoring by Dr. Hunt, Bath University.
- System Monitoring in the Fleet Air Arm by Mr. C. Bird, MOD, NAML
- Elastomeric Components by Mr. Ochiltree, MOD, AMTE
- Improved Microscope Methods by Mr. Cooke, Thermal Controls Ltd.

### Third Session—Components

- Hydraulic Filtration by Mr. Way, Pall Europe Ltd.
- Testing of Hydraulic Equipment by Dr. Hargreaves, NGTE, MOD.
- Dynamic Performance of Pumps by Dr. Hooke, Birmingham.
- Hydraulic Fluids by Mr. Easthaugh, MOD, NGTE.
- Aircraft Hydraulic Lifts by Mr. Bird of Mactaggart Scott
- Selector Valves for Submarines Weapons Systems by Mr. Crabtree, Strachan and Henshaw, Ltd.

**Fourth Session—Future Trends**

- Quiet Pumps by Mr. Kane, National Engineering Laboratory.
- Low-noise Valves by Mr. Donaldson, National Engineering Laboratory.
- Hydraulic Silencers by Mr. Whitson, National Engineering Laboratory.
- Computer-aided Design by Mr. Tomlinson, Bath University.
- Hydraulic Propulsion by Mr. Bannister, Normalair Garrett Ltd.

**Papers not Presented**

- Computer-aided Design Hydraulics by Mr. Kakaiya, National Engineering Laboratory.
  - Design of Multi-fluid Pump by Mr. Weeks, Vickers Fluid Power Ltd.
  - Reduction of Fire Hazard by Mr. Jones, MOD, CHA(RN).
  - Hydraulic Training by Lt.-Cdr. Hutchinson, H.M.S. *Sultan*
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