NON-DESTRUCTIVE TESTING TECHNIQUES

AS APPLIED TO THE EXAMINATION OF WARSHIP HULLS, MACHINERY AND SYSTEMS

The Working Party on the Application of Non-destructive Techniques to the Examination of Warship Hulls, Machinery and Systems was established in May 1966, after the original Working Party on similar applications to nuclear submarines had recommended that its terms of reference should be extended to encompass all classes of ships. The composition and the terms of reference of the new Working Party are contained in DCI(RN) 822/66.

In summarizing the achievements of the Working Party, it would be relevant to reconsider here what can be achieved by the use of non-destructive testing techniques. These techniques serve three purposes:

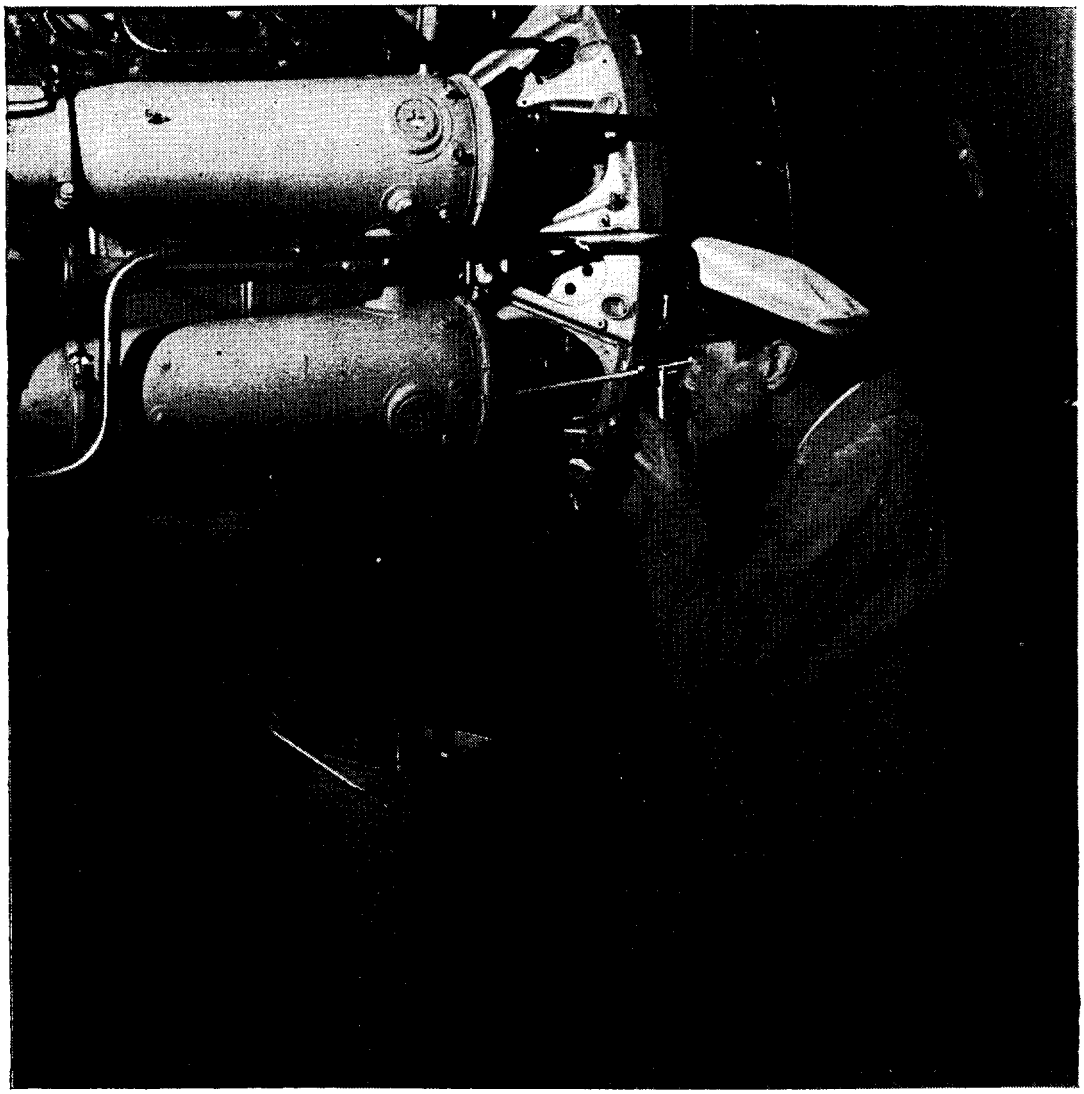

FIG. 1—INSTRUCTOR AT H.M.S. 'SULTAN' DEMONSTRATING USE OF ENDESCOPE

(*a*) They assist in determining the state of structure or equipment

(*b*) They enable quality control to be exercised more efficiently

(*c*) They can assist in determining trends which might help to predict possible service failures.

Purpose (*a*) clearly assists in the more accurate compilation of defect lists. What effect this will have on the total content of a defect list has yet to be determined but initially, particularly where it is necessary to confirm predictions made by NDT techniques, the content will increase. Ultimately, however, defect lists should be more accurate, leading to a possible reduction in refitting load and certainly a more effective refit. In this respect the question of setting up and equipping pre-refit inspection teams in the Home Fleet technical staff organization is one of the issues currently being discussed.

Purpose (*b*) is a fundamental requirement for effective new construction and subsequent refitting. Much attention is being devoted to this aspect, particularly to reducing the effort required to carry out essential quality control, and this is particularly important in nuclear submarines. New techniques and equipments will be recommended for introduction into the quality control organizations in shipyards and dockyards as and when they become available.

Purpose (*c*) is a user function where it is envisaged that the use of new techniques in conjunction with existing maintenance schedules may help to predict possible failures and thereby avert them. Extension of time between routine conventional inspections of equipments is a possible consequence of this aspect.

The efforts of the Working Party have been largely concentrated on seeking information about the range of survey instruments likely to be of value and obtaining those which appear immediately applicable without further development. After limited laboratory evaluation, the next stage has been to place the equipment in the hands of Dockyard, Overseeing or Fleet Maintenance Authorities for evaluation under shipyard or ship conditions. When this second phase is complete, consideration will then be given to recommendations for provision of new equipment on a service basis and for revision of maintenance schedules or other appropriate documentation.

In order to obtain the maximum benefit from the introduction of new equipments, it is necessary that information concerning its potential and use is made generally available. To this end, consideration is currently being given to the production of a BR on non-destructive techniques generally, to which loose-leaf additions can be made as further equipments become available.

Evaluation and acceptance of new techniques is necessarily a lengthy process and, as the new Working Party has been in existence for only a short period, there are, as yet, very few established NDE processes to be reported. The up-to-date situation with each new technique being investigated is summarized below. This shows that many new techniques are extremely promising and should produce positive gains in the near future.

The degree of interest shown by the Home Fleet technical staff and other Fleet and shore establishments has been of great assistance in assessing new techniques.

SUMMARY OF CURRENT ACTIVITIES OF WORKING PARTY

Endescopes

Wear and Waste Tests

The object of endescope examination of boiler tubes is to replace the existing wear and waste tests by a visual examination in new boilers, partially to supplant the wear and waste test in medium age boilers and to supplement it in older boilers.

Tubes in the starboard boiler of H.M.S. *Yarmouth* selected for removal for the wear and waste test were visually examined before being cut out using an endescope made by Messrs. Optec Reactors Ltd. The detailed visual examination assessed the tubes as being in good condition internally and externally. Internally, there was slight pin pitting up to approximately 0·010 in. in depth and mainly in the rolled parts of the tubes. Externally, there was slight wastage in the root areas. The gauged measurements are not yet to hand but an examination of the cut-out tubes confirms the findings of the pre-cut-out visual examination.

It is intended to undertake another '*Yarmouth* type' exercise when a boiler in known poor condition becomes available. Acceptance of the visual examination in place of the wear and waste test will depend on the final comparison of the *Yarmouth* trial and of the further exercise to be undertaken.

H.P. Air Bottles

A viewing system is at present being developed by Messrs. Optec Reactors Ltd. which it is hoped will allow satisfactory visual internal inspection of pressure vessels of this type *in situ*. Concurrently with this development an

FIG. 2—INSTRUCTOR AT H.M.S. 'SULTAN' DEMONSTRATING USE OF ENDESCOPE

alternative bottle closing system is being investigated, which may be removed and replaced with the vessel *in situ*, and so allow use of the viewing system. Some means of cleaning bottles *in situ* will be necessary to allow adequate inspection and it was first thought that a mechanical brush system might be possible but this is now doubtful. Shot blasting/vacuum cleaning or chemical cleaning are possible alternatives being investigated. The past history of proof-testing vessels of this type shows that it should be possible to extend proof tests to something like nine-year intervals, provided that a satisfactory intermediate visual examination can be carried out.

Provision for Visual Examination in New Designs

An internal Ship Department instruction exists stating that where there is a requirement for internal examination of machinery, access points are to be provided to allow the use of viewing instruments. Certain new turbine and heat exchanger specifications already include this requirement. GRM(E)s are being amended accordingly.

Diesel Engines

The uses of the Optec Reactor endescope have been demonstrated to the staff of Flag Officer Submarines, who thought the instrument would be of most use in those circumstances where an engineer officer is required to decide whether

or not to authorize the undertaking of a fixed period maintenance routine, such as a top overhaul.

General

The Optec Reactor instruments are recognized as the standard sets in the high quality field and 11 sets have been distributed to Commands, etc. (DCI(RN) 958/66 refers) with another set held in the Ship Department. A similar set is on order for the A.M.E.E. with a special of the same quality for the N.G.T.E. (NMW). These instruments offer a photographic capability and D.G.A.(N) have ordered the necessary equipment for distribution to photographic personnel.

At the lower end of the viewing instrument range are mirror probes. A set of these instruments made by Messrs. P. W. Allen is presently being patternized with a request for purchase and distribution to the Fleet generally.

There is also a requirement for instruments which fall between the foregoing extremes in capabilities, quality, price, etc., and an evaluation is at present in hand with a view to subsequent recommendations as to what should constitute the range of medium quality instruments to join the already recommended instruments in a complete range. The results of this evaluation will be available to any Command, etc. who may wish to purchase additional instruments.

Interesting Developments

Optec Reactors have recently developed prototypes of:

(*a*) A retroview endescope

(*b*) Photo-flash equipment utilizing normal endescope light guide as the transmitting medium

(*c*) Ultra-violet light utilizing normal endescope light guide as the transmitting medium.

P. W. Allen's have recently developed an extendable endescope, designed to allow rapid visual examination of lined hoses which might also have applications in the inspection of sea tubes.

Spectrographic Oil Analysis

A contract is at present being placed with British Railways to analyse engine lubricating oil spectrographically, samples being taken from a total of 44 Deltic 18-7A engines from CMSs based in this country. Sampling will be monthly and will continue for two years with a review after 18 months to determine whether an extension of the trial is required.

British Railways are currently analysing oil samples from their own locomotives and for each locomotive engine they are establishing a trend. Deviations from this trend, unless explained by oil changes, indicate some physical deterioration within the engine. British Railways are so confident of this system of detecting what can be described as incipient defects long before they become disasters, that locomotive depots are required to take the engines out of service on the advice of the oil laboratory.

In applying this system to the 44 Deltic engines, it is hoped that similar trends for each engine will be established, so that major failures may be avoided by detecting initial small defects. In this way, the repair bills will be greatly reduced, although it is not anticipated that this analysis will lighten the normal maintenance load.

Closed Circuit Television

A thorough investigation into the commercial miniature television camera market has resulted in the selection of an instrument made by Visual Engineers

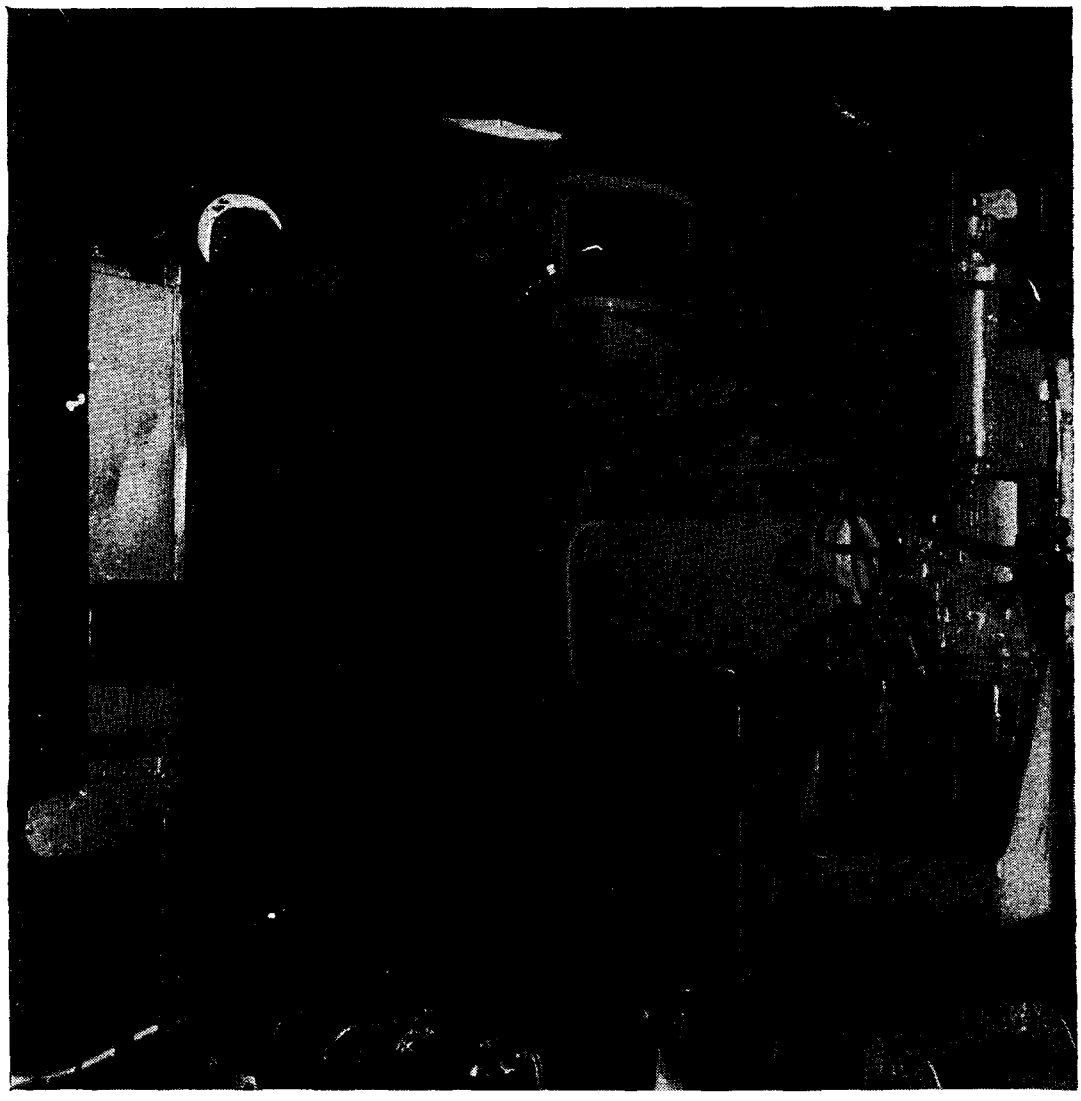

FIG. 3—TRAINEE EXAMINING VALVE SEATS, ETC., INSIDE DIESEL ENGINE CYLINDER

Ltd. as being the most promising available. In its initial form the definition was unsatisfactory but modifications have been incorporated to improve this. It was also necessary to devise suitable centring devices to hold the camera steady in the centre of any pipe or tube, along which it was intended to pull it for inspection purposes. These centring devices have now been obtained. Evaluation trials of the equipment in Portsmouth Dockyard are scheduled to take place in the near future. Problems to be investigated in connection with this instrument include the provision of remote controlled focusing arrangements and a constant requirement to reduce its overall size. It is considered that this equipment still has some way to go before it can be regarded as a reliable maintenance tool.

Ultrasonic Flaw Detectors

Many types of flaw detectors are in widespread use and the techniques involved are in general well proved. Examples of current uses of flaw detectors are plate inspection, thickness gauging, weld inspection, brazed joint assessment, forging inspection, inspection of bars and billets, fatigue crack detection in cylinder head studs, pivot pins, etc. There are many commercial developments in both flaw detectors and transducers and new equipments are assessed and obtained as appropriate.

Hull Weld Auto Scanning Device

This equipment, intended in the first instance for the automatic scanning of large weld areas of nuclear submarine hulls, is now in an advanced state of development and the first prototype trials took place in February. The main purpose of the equipment is to reduce the very large effort required at present to carry out surveys of submarine hulls and also to produce an automatic record of the results of such surveys. Its ultimate potentialities are, of course, much wider than submarines alone and it is possible that it will also be useful for surveying other types of warship hulls and weather decks. A contract for the development of the automatic recording equipment has been placed with Smith Electronics.

Ultrasonic Thickness Indicators

A Budd portable digital thickness indicator, model UT780, is being assessed. This equipment gives a digital print out of thickness of plate material to a very high degree of accuracy and works over a considerable thickness range. It is considered that this item will prove most useful in carrying out surveys of submarine hulls, frigate weather decks, etc., and will lessen the likelihood of small errors due to operator interpretation of the normal ultrasonic picture. After laboratory evaluation, it is anticipated that this first Budd instrument will be evaluated by Portsmouth Dockyard.

Ultrasonic Leak Detectors

These instruments are capable of detecting very small leaks in pressure or vacuum systems and therefore have application in such things as compartment air testing, citadel air testing, steam and air valve leak testing, etc. Three types of leak detectors were selected and evaluated at Barrow and by NAMDU. These were the Sonic Aid, the Dawe and the Delcon. All of these were found to be reliable and robust. It was concluded that experience, practice and considerable care are necessary to guarantee accuracy in interpretation of defects. They are specialist-use equipments and their value relates very closely to operator ability. It is intended to loan one of each of these equipments to the Home Fleet technical staff before the end of the year for practical evaluation. One great advantage of this equipment is that only very low pressures are required, and thus the time spent in preparation for testing is minimized.

Eddy Current Equipment

Eddy current equipment for the detection of surface cracks, flaws, etc. in non-magnetic materials has been available for some time. AML are, however, now developing an eddy current crack detector for ferrous materials. The unit will be battery-operated and will be provided with simple probes suitable for searching plate surfaces and fillet welds for surface cracks. If successful, this equipment could assist or replace the conventional dye-penetrant systems. The prototype equipment will be made available for evaluation in a dockyard, probably Portsmouth. The possibility of using eddy current techniques for inspection of heat exchanger tubes is being considered in conjunction with certain commercial firms.

Noise and Vibration Measurements

This is not a field in which early and sweeping gains can be expected. Measurement of noise and vibration is, and will continue to be, an important area of investigation for the non-destructive assessment of machinery condition.

Machinery vibration monitoring equipment is being fitted in nuclear submarines and in H.M.S. *Penelope*. The experience gained in the use of this equipment will be valuable in relating the change in the mechanical state of a machine with the change in vibration levels.

Brazing Monitors

Preliminary discussions have been held with various commercial concerns on the possibility of developing a rapid direct-reading brazing monitor which will print out the effective percentage of any type of brazed joint. It is too early to predict whether there are likely to be any successful developments in this field.

Non-Destructive Testing Staff

The questions of NDT staff, their status, training requirements, etc., to meet the needs of D.G. Ships and D.G.D. and M. are constantly borne in mind. The nucleus of a Home Fleet NDT team has been formed and similar teams may be required in other areas in the future.

Presentation of Non-Destructive Techniques

With the growing number of new techniques being examined and evaluated, it was considered that presentations should be held to bring these new techniques to the notice of interested staff. The first presentation was held in the Ship Department early in 1966, and a further presentation was held at H.M.S. *Sultan* on the 16th November, attended by a total of 106 personnel from Southern Commands, dockyards and ships.

Contacts with other NDT Organizations

A full exchange of information is maintained with other non-destructive testing Organizations at all levels. In particular representatives of the Working Party have attended two meetings of the British National Committee and it is now proposed that one member of the Working Party should become a member of this Committee. Consideration is also being given to holding a Symposium in the near future, with the CEGB and other interested bodies, to discuss common problems.

Representation by Commonwealth Navies

Both the Royal New Zealand Navy and the Canadian Defence Ministry have expressed interest in the Working Party. Currently, they are being provided with copies of Minutes of meetings but it is probable that in the near future they will be invited to send representatives.