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# SCIENTIFIC AND TECHNICAL PROGRESS REPORT

JUNE 1963

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SCIENTIFIC AND TECHNICAL

PROGRESS REPORT

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ABSTRACT

This report covers the work carried out by this Establishment up to 31st March, 1963, on Sonar Equipment; Weapons and Fire Control; Launching Equipment; Mine Countermeasures and Mining; Instructional Equipment; Research; Operational Research and Assessment; Post Design and Supporting Developments.

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Admiralty Underwater Weapons Establishment  
Portland.

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PROGRESS REPORT - 1962

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## SECTION 1. - SONAR EQUIPMENT

### 1.1 - SUBMARINE SETS

#### Active/Passive Sonar Type 2001 for H.M.S. DREADNOUGHT and H.M.S. VALIANT

##### Sea Trials

Only one major trial of Type 2001X in H.M.S. VERULAM took place in 1962. The aim of this trial was to test the prototype electronics of the Sector Display in both the active and the passive modes of operation and compare its detection capability with that of the other displays. The trial was carried out in May in the Atlantic, North and South of the Canary Islands. The target was H.M.S. SEALION. Climatic and oceanographic data for the time of year indicated that near-surface propagation conditions would be beginning to deteriorate and would depend critically upon the prevailing weather conditions. The trial was therefore planned to start in the north and move south if necessary to take advantage of increased surface mixing in the North-East Trade Wind belt. As foreseen, weather conditions in the north were unfavourable and so the latter part of the trial was carried out to the south of the Canaries.

2. The trial also gave propagation information and considerable echo and background data were recorded on magnetic tape for subsequent study in connection with automation research. As in all previous Type 2001 trials the detection results were augmented by oceanographic, propagation and reverberation measurements.

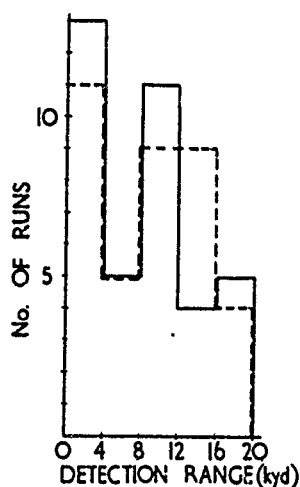


Fig. 1 Histogram for Northern Area.

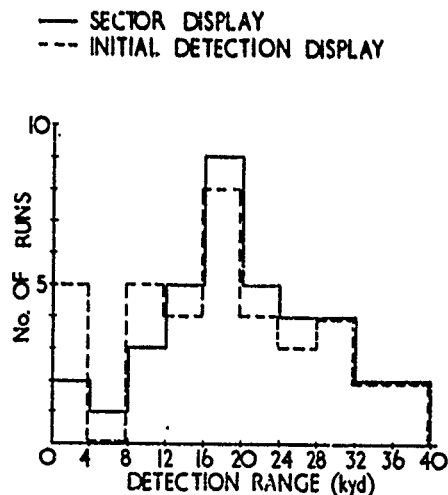


Fig. 2 Histogram for Southern Area.

3. A preliminary report has been issued, and detailed analysis of the results is nearing completion. The main conclusions are:-

- (a) The active initial detection performance of the Sector Display (S.D.) is very similar to that of the Initial Detection Display (I.D.D.). This is shown by the histograms reproduced in Figs 1 and 2.

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- (b) The active and passive bearing accuracies of the S.D. lie well within the required limits. ( $1^{\circ}$  r.m.s.)
- (c) Whilst the 10 Kyd range increment display as fitted in H.M.S. DREADNOUGHT is essential tactically, it does not permit use of the full range discrimination inherent in the system.
- (d) The S.D. provides a useful classification aid and is capable of showing wake echoes from surface targets.

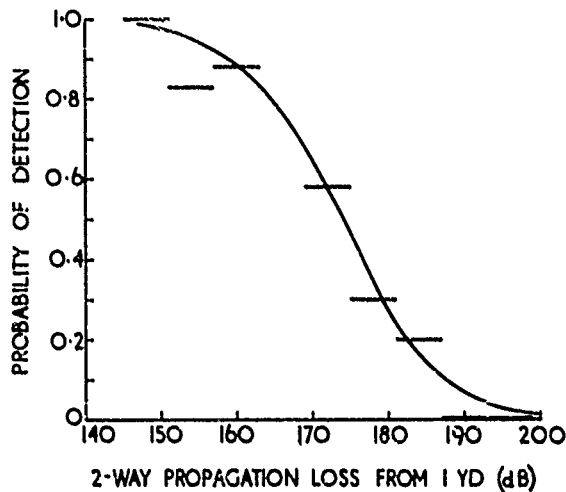


Fig. 3 Detection Transition Curve for one run.

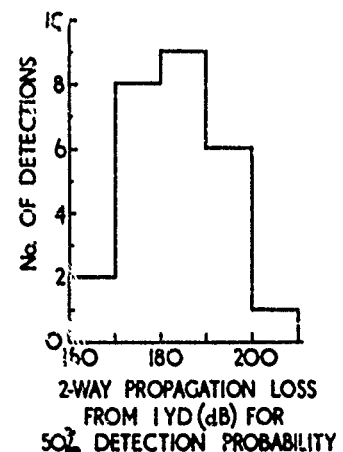


Fig. 4 50% Detection Probability Histogram for 26 runs.

4. Part of the analysis of the results obtained on the I.D.D. during this trial has consisted of a ping by ping comparison of the one-way propagation loss measurements taken on the submarine with the echo levels as shown on the films from the I.L.D. Fig. 3 shows the probability of detection versus the two-way propagation loss for a typical detection run. The cumulative probability curve is the best fit to the data. Fig. 4 has been derived from 26 runs analysed in a similar manner. This figure shows the number of occasions when the two-way propagation loss for 50% probability occurred in a given propagation loss interval. These results apply to "possible" detections since they are obtained by working backwards in time from valid detections to zero detections. The effective detection threshold can be varied by grading the echoes and treating just observable echoes as undetected. The observed wide variation of propagation loss at detection is a consequence of reverberation limiting and the general distribution is in reasonable agreement with that for earlier trials in the same general area. A general view of the I.D.D. is shown in Fig. 5 on the next page.

#### Refurbish of H.M.S. VERULAM's Equipment

5. The experimental Type 2001 has been extensively refurbished during H.M.S. VERULAM's refit and it will be used during the ship's future programme

of trials in connection with Automatic Processing of A/S Data and Classification (page 78) and Propagation Research (page 57).

#### The Sector Display

6. Consequent upon the H.M.S. VERULAM trials the design of the Sector Display for Sonar Type 2001-X1 (to be fitted in H.M.S. DREAENOUGHT) was modified during 1962. The revised parameters are now as follows:-

- (a) Beam width:  $20^{\circ}$  (receive and transmit on any selected bearing from Red  $110^{\circ}$  to Green  $110^{\circ}$ ).
- (b) Pulse length: approximately 612 milliseconds, dependent upon local velocity of sound in the sea (adjusted to 1,000 yd travel time).
- (c) Analysing filters: 30, spaced at 10 c/s intervals.
- (d) Frequency Deviation: Linear 3.8 to 3.5 kc/s.

7. In the active mode of operation the left and right hand channels use identical circuits to process the received signals. The phase differences of the pairs of range filters are measured to give the angular position of the target relative to the line of sight. The output of the left hand filter is rectified to give the display video brightening signal.

8. The display shows a range interval of 10 kiloyards. The centre of the range interval is selected by the operator. The original range interval of 4 kiloyards was discarded after trials in H.M.S. VERULAM.

9. The bearing selector switch selects the beam-forming delay line nearest to the desired bearing and adds the delay needed to centre the phase comparison display on the correct bearing.

10. The bearing selector switch and phase correction network are also used in the passive mode of operation for the determination of accurate bearings of radiated noise. To do this, the left and right outputs are correlated, but a  $90^{\circ}$  phase-shift is inserted in one line so that the amplitude at the centre of the correlogram is zero. When the target is to the left of the beam the output is positive and when it is to the

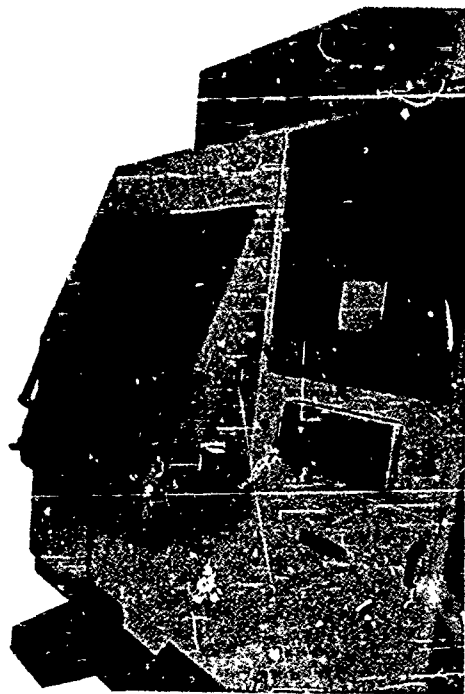


Fig. 5 Initial Detection Display.



right the output is negative. Two centre-zero meters are used to display the outputs of the two received frequency bands 1.5 to 2.3 kc/s and 5.5 to 6.5 kc/s.

11. Another receiver is used to amplify the sum of the left and right hand signals. The received frequency bands, 1.5 to 2.3 kc/s and 5.5 to 6.5 kc/s are both heterodyned to 500 to 1,500 c/s. Either of these channels can be fed to the operator's headset to assist in classification.

#### Type 2001-X1 Equipment for H.M.S. DREADNOUGHT

12. The whole of Sonar Type 2001-X1 has now been installed in H.M.S. DREADNOUGHT. All but one cabinet of electronic equipment was in use during the contractor's sea trials which were completed during February 1963. Since that time the remaining cabinet has been installed, minor difficulties observed during the contractor's sea trials have been resolved and the formal beam pattern trials are planned to take place during May 1963.

13. A series of limited beam pattern trials, to prove the array prior to the contractor's sea trials, were carried out, as planned during January 1963. For this trial H.M.S. DREADNOUGHT was submerged with the top of the transducer array 15 feet below the surface. A 62 ft aluminium boom (see Fig. 6) carrying a calibrated transducer was mounted on the submarine hull above the array and could be trained between Red 150° and Green 150°. Pen recordings were taken of delay line and correlator outputs in reception and of the boom transducer output during transmission.

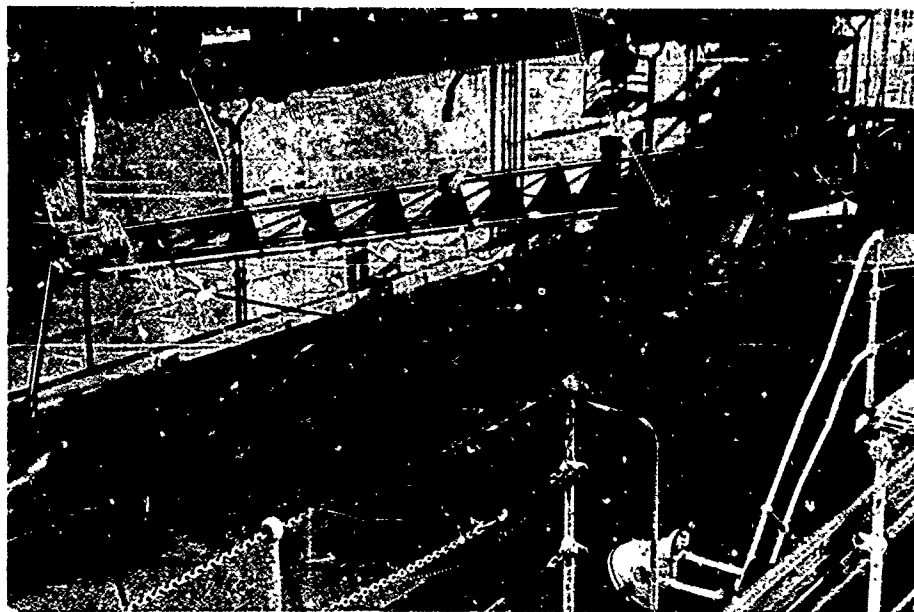


Fig. 6 Boom Arrangement for Beam Pattern Measurements.

14. The beam axes, corrected for errors due to the asymmetry of the boom arrangement, were found to be correct to an accuracy of  $\pm 1\%$ . Near field effects and reflected sound did not seriously affect the main lobe shapes, but minor lobes were distorted by reflections and their positions and amplitudes are of little quantitative value.

15. A complete set of H.F. and L.F. correlograms was recorded, using a noise signal transmitted by a transducer mounted on the end of the boom, confirming that all round passive cover was available. A detailed analysis of these results is still in progress.

#### Theoretical Beam Patterns

16. A programme has been written for a computer to compute beam patterns obtainable with the confozmal arrays in H.M.S. VERULAM and H.M.S. DREADNOUGHT. There is provision for plotting horizontal and vertical beam patterns on transmission or reception at any angle of depression, and for varying the number of staves used, the amplitude shadings, and the phase delays. The programme has also been used to investigate the effect of phase and amplitude errors and possible ways of improving side lobe suppression by empirical means. It is now being extended to cover the near field so that the beam pattern measurements in H.M.S. DREADNOUGHT can be checked against theory.

#### 60-Way Pressure Hull Gland

17. The problem of passing 1176 twin-cores (plus sufficient spares to cover contingencies) through the pressure hull has been solved by the provision of 22 specially designed glands. Each gland accepts 60 twin-cores from the transducers and passes a 30 quad cable through the pressure hull.

18. The glands fitted in H.M.S. DREADNOUGHT have been tested to 1,000 p.s.i. hydraulic pressure.

19. The simultaneous moulding of 64 transducer cables into the gland body gave rise to manufacturing difficulties. A modified design has therefore been produced in collaboration with D.G.S. for use in H.M.S. VALIANT. In the modified design the original 64 moulded entries are replaced by eight screwed units each carrying eight moulded entries.

#### Sonar Intercept Set - Type 197 (Formerly known as "VELOX")

20. The use of the hydrophone element fitted in the Type 719 transducer to replace the original hydrophone is under investigation and preliminary trials show promise. It is hoped to carry out trials with a complete array in mid-1963. This new hydrophone will have a more consistent sensitivity, giving greater bearing accuracy, as well as being less affected by depth. In addition it can be produced with a polythene cable thus obviating the need for the present cable-changing boxes.

#### Submarine Search Hydrophone - Type 186

21. A noise source similar to the foreign device used by A.R.L. has been manufactured by Messrs Hartley Electromotives Limited. This is a 110 volt d.c. motor driver mechanical "rattle", which can be lowered from any suitable vessel and used as a noise source for Type 186 trials. This noise source is now undergoing noise spectrum and mechanical endurance tests.

22. A small expendable noise source is also being developed by the same firm, for use by a submarine as a sonar confidence check whilst on patrol. The first experimental model, driven by a battery operated electric motor, was not satisfactory as regards noise output. A clockwork version is now being considered and preliminary noise output trials are encouraging. This noise maker is intended to be part of a cannister and float assembly which can be fired through the Submerged Signal Ejector.

#### 1.2 - SHIP SETS

##### Scanning Sonar - Type 184

#### Sea Trials

23. During the year the experimental equipment in H.M.S. BROCKLESBY has been used for operational evaluation trials in conjunction with J.A.S.S., Londonderry, under the following circumstances:-

- (a) Varying oceanographic/climatic conditions.
- (b) Against unrestricted, manoeuvring and multiple targets.
- (c) Investigations of operating, tactical, and maintenance procedures.
- (d) Side by side comparisons with Type 177.

24. Three important conclusions have been drawn:-

- (a) The fundamental assumption tacitly implied in the Type 184 concept - that echo detection would generally be made in the presence of self-noise - rarely applies. The dominant background, especially in inshore waters, is reverberation, whose decay rate, as a function of range, is very similar to that of echo level.
- (b) The experimental equipment in H.M.S. BROCKLESBY was not operating as efficiently as it is reasonable to expect the prototype equipment will do. Prototype items and setting up procedures were slowly introduced during the year, and the results became progressively better. For the final evaluation in 1963, the equipment will, in all essential respects, be up to prototype standards. The Doppler Display performance was particularly affected in this respect during the early trials.
- (c) The trials to date have not provided in full the difficult search situation for which Type 184 was designed, so that the compromise between detection potential and search capability has not yet been completely proved, although it would appear to be acceptable in deep water. There is still an urgent need to have high speed submarines available for the assessment of modern sonar systems.

25. The reverberation problem is illustrated in some detail in the table on the next page, which gives the comparative performances of Types 184 and 177 and in which the Portland sea area is used as a reference for reverberation level. For the deep water results, the target is always in the layer. Some of the evaluation figures should be regarded as preliminary, since analysis

is still proceeding. It is obvious from these results, however, that Type 184's disadvantages in shallow water under high reverberation conditions are considerable.

Water Depth (fathoms)	Reverb. Level Ref. Portland sea area (dB)	Layer Depth (ft)	Sea State	Target Aspect	Median Detection Range (yd)	
					Type 184	Type 177
>1000	-20	150	0 - 2	Beam	19800	18000
>1000	-20	150	0 - 2	Random	10000	12000
30	0	-	0 - 2	Random	6300	18000
>1000	-15	150	0 - 3	Random	10000	11000
>1000	-10	300	1 - 4	Random	7100	9400
>1000	-10	450	3 - 5	Random	6000	6000
70	0	-	1 - 3	Random	4900	6700
< 100	+10	-	1 - 3	Random	0	12000
< 100	+5	-	1 - 3	Random	5000	11000
< 150	0 to +10	-	3 - 6	Random	1000	-

26. Some understanding of the reverberation problem may be derived from the basic sonar equation in terms of the detection potential of the equipment parameters which is given by:-

$$(10 \log \frac{100}{\tau} - 10 \log w - J - R_f - M) \text{ dB}$$

where  $\tau$  = pulse length

$w$  = bandwidth

$J$  = Receiver Reverberation Directivity

$R_f$  = Reverberation spectrum level in a 1 c/s band relative to the total reverberation energy in a bandwidth wide compared with the spectrum spread

$M$  = the recognition differential.

27. A practical detection range, however, not only depends on the detection potential but also on actual level of reverberation and propagation loss and may be related to the detection potential as shown in Fig. 7 on the next page. Shallow water reverberation levels associated with the Portland area are assumed together with a 15 dB target at periscope depth in a 150 ft isothermal layer bounded by a thermocline in deep water and by the sea bottom in shallow water. The detection potential value for the Type 184 P.P.I. Display is 8 dB, and for the Doppler Display 13 to 23 dB depending upon the amount of target doppler.

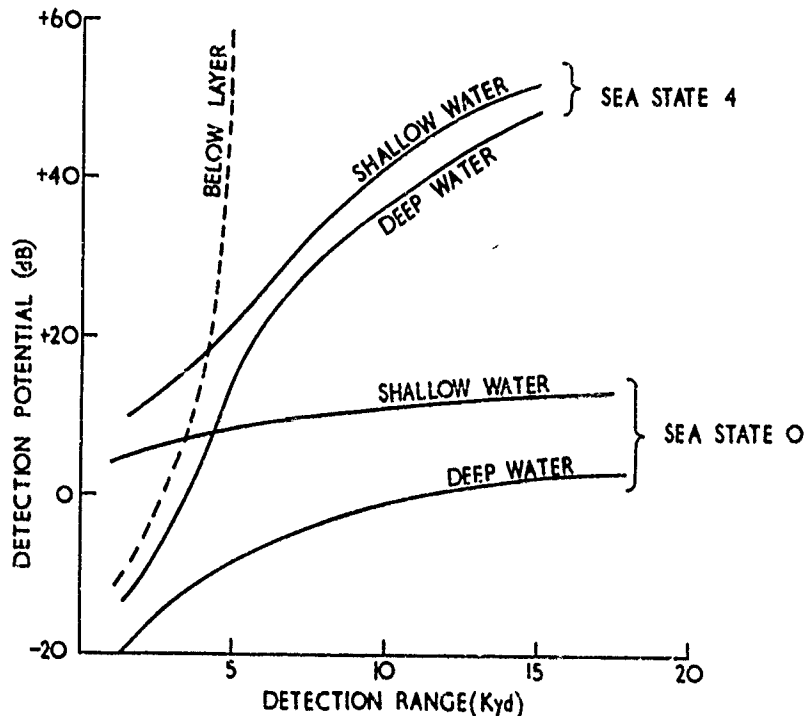


Fig. 7 Theoretical Detection Performance.

28. Means of improving the detection potential of Type 184 within the limits of the present system design are under investigation.

Own Doppler Nullification

29. The own doppler nullifying system, described in detail in the previous report, has been working successfully and has now been incorporated into the final design.

Prototype Manufacture

30. Three prototype Type 184 equipments have now been manufactured, two of which have been fully system tested in the laboratory and at present one is being installed in H.M.S. PENELOPE and the other in H.M.S. EAGLE. The third equipment is undergoing system tests prior to ship installation. Service Acceptance will be carried out in H.M.S. PENELOPE during 1964.

Automatic Handling of Type 184 Data in the D.L.G.'s

31. There is now a firm requirement to handle and display sonar information within the ADA (Action Data Automation) System in the Guided Missile Destroyers D.L.G.05 and 06. This involves:-

- (a) The injection into ADA of range, bearing and doppler information on sonar contacts, by "semi-automatic"-means (i.e. direct from the Sonar Control Room under operator control), together with supplementary information such as instant of transmission and sonar range scale.
- (b) The display of this data, to show past history by presenting the last few echoes in quick succession ("rippling").
- (c) Classification, including correlation with radar and other information.
- (d) The interchange of A.S.W. information over TIDE links.
- (e) Improved MATCH fire control, using the ADA computer to predict target position and calculate orders to the helicopter.
- (f) Calculation and display of recommended manoeuvres for torpedo avoidance.

32. Preliminary demonstrations have shown that the proposed "rippling" technique appears to be adequate for the display and assessment of past and present sonar information, so that an A/S plot can be dispensed with.

33. The equipment modifications and additions required to feed the 184 data into the ADA system are now well in hand.

34. The development of processes (b) to (f) above can be divided into four stages:-

- (i) The writing of detailed "rules" laying down the operational requirements.
- (ii) The translation of these rules into detailed "flow diagrams" showing the operations required with the computer.
- (iii) The further translation of flow diagrams into detailed computer programmes.
- (iv) The testing, evaluation and assembly of these programmes (including the writing of auxiliary programme material for test purposes).

35. Stage (i) (rule writing) is the responsibility of a T.A.S. officer attached to D.U.S.W. and working in close collaboration with A.U.W.E., and some ten draft rules having been written to date. The broad outline of the flow of data within the computer has been laid down, and work on detailed flow diagrams has started. Stages (iii) and (iv) are not yet under way; progress in these will inevitably be slow because of the lack of immediate access to a POSEIDON computer, the only one available at present being at A.S.W.E., Portsmouth.

#### Variable Depth Sonar Type 199

36. The first Canadian equipment was received in May 1962 and set up in A.U.W.E. in order to check the additional modifications required for R.N.

installations and to carry out a System Test of equipment. This set has now been installed at H.M.S. COLLINGWOOD.

37. The second equipment is being installed in H.M.S. LEANDER and a series of joint D.G.S./A.U.W.E. trials of the Handling Equipment and Sonar is planned for September 1963.

#### Sonar Type 170B Depth Determination

38. Further meetings with R.C.N. representative were held in A.U.W.E. in March 1962 and in Ottawa in November. At the latter meeting the Canadian proposals for their future attack sonar system were discussed, and it was learnt that they intend no sweeping changes to Type 170 in existing installations.

39. A trial to check the effect of changes in method of signal processing, with a view to reducing the present errors, was scheduled for February 1963 but has been postponed to late 1963 due to lack of trials vessels.

#### 1.3 - HELICOPTER SET

##### Dipping Sonar - Type 195

##### Shipborne Trials of Experimental Equipment

40. The experimental Sonar Type 195 installed in E.T.V. ICFWHALE in December 1960 continued in use throughout 1962 for circuit development. Another experimental model was fitted in the Wessex helicopter XM329. Delivery of this helicopter was much delayed and it became available at Portland in March 1962. On conclusion of trials, XM329 was returned to Westland Aircraft Limited in August for the fitting of prototype equipment.

41. The investigation into transmitter performance showed that the electrical efficiency could fall below the design value, leading to a current drain in excess of the nominal  $460A \pm 10\%$ , to overloading of the aircraft generator and to risk of transmitter overheating in high ambient temperatures. It was also found that the impedance of a transducer strip could vary over a wider range than was at first supposed, due to manufacturing and other tolerances, as well as the quite large changes of impedance caused by interaction between the units of a multi-element array. In addition, the transistors had to be used beyond their "cut-off frequency" of about 7.5 kc/s, and the resultant circuits are unduly sensitive to changes in transistor characteristics.

42. The transmitter was therefore redesigned for the Prototype model, using a modified circuit less dependent on the value of the load impedance and the transistor characteristics. Consequential redesign of the transmitter protection circuits was necessary, and this led to some delay in the completion of prototype equipment and of the pertinent chapters of the handbook.

43. The individual Doppler AGC amplifiers and rectifiers were redesigned to obviate large-signal overloading by increasing the dynamic range at all background levels. It has also been found that a reduction in the rate of response of the AGC loop to decreasing signal levels can lead to a more uniform, and hence an apparently lower background level, and so to a significant improvement in detectability of low-level echoes.

44. The interference in signal circuits, originating in the redesigned servo training system which uses a mercury-wetted relay, has required a number of changes in submersible body and winch wiring. It was found that the balanced quad layout of conductors in the strain cable must be maintained at every point in the circuit, and in all connectors carrying signal leads.

45. The Strain Cable design was changed to give a further increase of life. All internal screens have been eliminated, the conductors now being arranged symmetrically in six quads and six interstitial wires. It has been established that there is not significant coupling within the cable between the signal leads and the high voltages on power supply and servo leads.

46. Winch and Body trials late in 1961 had demonstrated that the sinking speed of the body was inadequate, and that slack cable could occur on water entry. The action of the winch hydraulic controls remained too abrupt, and the reslection of the control valve at water entry caused an unacceptable delay. A new immersion switch system for the body was developed, using an electrode energised at high frequency and located at the bottom of the body in a redesigned fairing. The winch was fitted with a programmed throttling valve, actuated by a signal from the immersion switch, to control water entry speed. Further weight reductions in the winch were achieved by use of an aluminium brake drum and cotton-base brake linings. Trials showed that the new system gave promise of solving the water-entry problem, but that a number of winch deficiencies still remained.

47. It is hoped that these remaining problems have been overcome in the Prototype design. Efficiency was improved by adoption of chain drives. The brake operation was found to be affected by ingress of sea water and by heat damage to the linings, and the brake was redesigned. Excessively stiff operation of the hydraulic control lever was reduced by incorporation of a servo system into the control-valve linkage. The programmed throttling valve did not give full protection against slack cable, and a new hydraulic sensing system was fitted in its place. Trials of the prototype winch from E.T.V. ICEWHALE have yielded the promising results. Work is in hand to improve the procedures for setting-up the winch controls, and a final check will be made when Wessex XM329 becomes available for prototype trials.

#### Flying Trials of the Complete Experimental Sonar Equipment

48. Following the return of Helicopter XM329 to Portland in March 1962 initial difficulties with the winch, electrical interference, and helicopter engine starting prevented an effective start of the trials until the end of Easter Leave. From then until mid-June, 38 sorties were flown, 32 being for sonar trials purposes. The performance of the experimental equipment was satisfactory, detection ranges being similar to those found during the more extensive trials from E.T.V. ICEWHALE during the previous year. In the shallow waters off Portland, in isothermal conditions, contact was maintained to over 12 Kyd on one occasion, and to over 8 Kyd on several occasions. During the first series of trials off the Lizard a fairly strong thermal layer was present, and there was insufficient depth of water for the submarine to operate below the layer. In spite of these adverse conditions an average range of 6.3 Kyd was achieved.

49. A second deep-water trial series off the Lizard was held in mid-July. Serious difficulties with the helicopter engine curtailed these trials, and only three runs took place in deep water (50 fathoms). There was a surface



isothermal layer down to 70 ft and a deep isothermal region below 90 ft. The detection trials all took place below the thermocline and uniformly good detection was obtained. "Unalerted" detections using a search procedure took place over the range 2 to 8 Kyd, and contact was held out to beyond 12 Kyd. On one occasion, initial detection was made at 12.5 Kyd.

#### Trials of Prototype Equipment

50. The manufacture of six sets of prototype equipment is well in hand. A complete prototype equipment has now been fitted in Wessex helicopter XM329. The prototype trials were commenced in March 1963. These trials are expected to take three months and will be followed by the Naval Acceptance Trial. It is hoped to complete a draft handbook prior to the Naval Acceptance Trial.

#### Special-to-type Test Equipment

51. In addition to the development of the sonar equipment, much effort has been deployed on the development of special-to-type test equipment. The development of an Airborne Monitor Box, a first-line test set, and a full set of equipment for use at second line is expected to be substantially complete within the next six months.

#### 1.4 - HOVERCRAFT

52. Some work has been carried out at A.U.W.E. using Hovercraft SRN-2. To date SRN-2 has been over the noise and magnetic ranges at Portland and during February 1963 a series of trials were carried out to determine whether SRN-2 can be held in a sufficiently stable hover so as to use Helicopter Sonar Type 195. Should this not be the case, a redesign of the Type 195 submersible body mounting arrangements will be required for the hovercraft application.

53. The noise level radiated by SRN-2 appears to be similar to that radiated by a Wessex Mk 1 helicopter. In the 'displacement' condition (i.e. when stationary or at low speed), SRN-2 appears to be slightly noisier at low frequencies and slightly less noisy at frequencies above 10 kc/s than is the case during "passage" running at 25 to 35 knots.

54. In its present commercial form SRN-2 possesses too great a magnetic field for it to be suitable for mine countermeasures work in shallow water. It is calculated that even if fitted with an orthogonal D.G. System with heading control it would be inferior, from a magnetic safety aspect, to a delta-engined Coastal Minesweeper.

#### 1.5 - ANCILLARY EQUIPMENTS

##### Underwater Communications and I.F.F.

55. In January 1963, D.U.S. prepared a draft Staff Requirement for the modification of the existing Underwater Telephone (Type 185) to provide a higher power directional acoustic communication facility compatible with the existing Type 185 for fitting in submarines and A/S frigates. The prime reason for the draft requirement is the urgent need for longer range underwater communications which has arisen with the advent of the nuclear submarine particularly if it is to be used as an A/S escort. An intramural project study is in hand.

56. A separate Staff Target is being raised by D.U.S.W. for an acoustic underwater data link compatible with ADA and TIDE. This is a separate and much longer term subject, still in the early research stage. The basic problem is to eliminate confusion due to multi-path propagation, the effects of which can vary enormously in different sea areas and conditions. Initial consideration suggests the use of a variant of the RAKE technique developed for radio communication. In this system, test signals are interposed between the messages sent by the two ends of the link. These test signals are automatically analysed to determine the optimum coding procedure for the conditions prevailing at the time. By this means, although the mean rate of exchanging messages will vary with acoustic conditions, a high degree of reliability should be maintained.

#### Underwater Detection Equipment Test Outfits (U.D.E.T.O.)

57. Limited effort has been available since June 1962 and work is now in hand to meet the requirements of H.M.S. TRIUMPH with priority given to Types 170, 176 and 177. This will also enable existing requirements for surface ship U.D.E.T.O.'s to be brought up to date. When the information for H.M.S. TRIUMPH is completed, Submarine Depot ships will be considered, followed by Minesweeper Maintenance Vessels and Escort Maintenance Vessels.

#### Ruggedised Bathythermograph

58. Some improvements have been made to the design to facilitate the accurate adjustment of instruments to a standard calibration. The reliability of the depth recording mechanism has been established by tests at twice the maximum pressure and by approximately 2,000 cycles between surface and maximum pressure.

59. The prototype instruments for acceptance trials now being manufactured should be completed by mid-1963.

#### Echo Sounding Equipments

##### Echo Sounder Type 773

60. The installation in H.M.S. WEN was modified during the year to operate in conjunction with the National Institute of Oceanography's Precision Depth Recorder and is giving good service during the current Indian Ocean Survey.

##### Replacement for Echo Sounder Type 765

61. The Echo Sounder Type 765 has been in service since 1944 and now requires modernisation to meet present and future requirements. D.N.D. has raised a draft Staff Requirement for a replacement set, this requirement has been investigated and draft Agreed Characteristics formulated.

62. The proposed replacement will be based on Type 773 but will include an A.U.W.E. designed recorder, in place of the present commercial instrument, and a Bridge Repeater to provide the Command with shallow water information.

##### Precision Depth Recorder

63. In order to provide a Precision Depth Recorder for use in Survey Ships and certain selected general service ships for acquiring deep sea data, D.N.D.

has raised a draft Staff Requirement. This has been investigated and draft Agreed Characteristics formulated; these take account of the recent decisions made by the International Hydrographic Bureau, Monaco.

64. The Precision Depth Recorder will be used with the replacement for the Echo Scunder Type 765.

#### Interference in Submarines

65. The problem of interference on Type 186 in "A" class submarines, caused by the air conditioning and refrigeration plants, is still being investigated. It is realised that the most effective cure would be re-siting and possibly re-mounting the offending machinery, but some improvement may be obtained by short-circuiting the affected hydrophones. A trial on these lines will be carried out in June/July 1963.

#### Low Frequency Triplane Target

66. A version of the standard triplane target, but scaled to suit the frequencies of Sonar Type 177, has been made and moored off Portland. Preliminary sonar trials are promising.

## SECTION 2 - WEAPONS AND FIRE CONTROL

### 2.1 - ONGAR WEAPON SYSTEM

#### Introduction

Increased financial approval for the weapon and control system is being sought.

2. Eight weapons have been assembled and run, though never more than three at any one time. Running is limited both by availability of spares, and trial facilities. Some 100 runs have been carried out in the last 12 months with the loss of one weapon. Modifications as a result of experience to date are being introduced to achieve compatibility, reliability, and reasonable ease of assembly and maintenance.

3. Certain problems have appeared as a result of the trials. For example the radiated noise is greater than anticipated and difficulties have come to light in the secondary battery which fails to hold its charge.

#### Homing

4. Trials with PENTANE vehicles at 16 knots have shown satisfactory homing against a suspended noise target, and (in azimuth only) against H.M.S. SERAPH. Self-noise measurement at 28 knots using a PENTANE vehicle have shown no untoward effect from the flat nose shape.

5. First runs using an ONGAR vehicle at 24 knots brought little useful information owing to trouble with new homing test equipment, but it has been shown that there are no major design errors.

6. Eleven electronic homing units have been completed, the last four incorporating the latest modifications.

7. Four Transducers are available with modified projectors and reverberation sensing elements to give better beam shapes.

#### Reverberation Measurements

8. A series of trials were carried out during November 1961 using an ONGAR homing transducer mounted in the fin of H.M.S. ALCIDE. Most of the trials en route to Gibraltar were in water deeper than 1,000 fathoms and the remainder in a Mediterranean exercise area were in a water depth between 200 and 400 fathoms.

9. The measurements of reverberation level were recorded in four beams of the ONGAR transducer, two upward looking beams (A and C) and two downward looking beams (W and Y). The ONGAR Comparator was also used with beams A and C, and its output recorded. The following transmission parameters were used:-

- (a) 5, 20 and 50 mS pulses of interrupted C.W. centred on 33 kc/s.
- (b) A 20 mS pulse of white noise generated between 32 and 35 kc/s (the same as the ONGAR transmission).

- (c) Transducer depths of 50 ft, 150 ft and 350 ft.
- (d) Transducer tilt angles of  $0^\circ$ ,  $\pm 7.5^\circ$ ,  $\pm 15^\circ$  and  $\pm 30^\circ$ .

10. The records are being analysed and the following provisional conclusions have been reached:-

- (a) The peak reverberation level observed in the ONGAR beams is about 10 to 15 dB less than the echo level expected from a 10 dB target. This is so for ranges between 200 to 1,000 yd. At ranges less than 200 yd the difference decreases.
- (b) The mean reverberation level in each beam is the same when an allowance is made for the respective surface reverberation index.
- (c) The coefficient of variation (standard deviation/mean level) is about 0.4 for the interrupted C.W. transmission and about 0.2 for the noise transmission.
- (d) The dependence of the scattering-strength on the grazing angle  $\theta$  appears to be between  $\sin^{0.1}\theta$  and  $\sin \theta$ .
- (e) No definite trend has been detected in the variation of the reverberation level with course relative to the direction of sea.
- (f) No amplitude correlation exists between beam A (axis  $22.5^\circ$  port) and beam C (axis  $7.5^\circ$  starboard), but some correlation (coefficient 0.3 to 0.4) exists between beams in the same vertical plane, e.g. between beam A (axis  $7.5^\circ$  up) and beam Y (axis  $7.5^\circ$  down).

11. The data processing will be completed in the near future, after which a comparison is to be made between the values of scattering-strength obtained from these trials and the values given in the literature.

#### Weapon Controls

##### Azimuth

12. Direction keeping has been found to be good over the short ranges run to date, but early runs gave some damage at the end of run owing to rapid precession of the gyro as the weapon surfaced nose up. All gyros have since been modified to fit slip-ring pick-offs on the inner gimbal and an anti-spin brake in azimuth.

13. Reliability is lower than anticipated and is being investigated. Delivery of gyros is nine months behind schedule from the manufacturer and is one of the main delays in assembly of weapons.

##### Roll

14. Runs in the water have confirmed simulator prediction. The roll unit has been simplified to reduce backlash and improve operation, and has operated consistently in trials. Roll gyroscopes are also in short supply.

### Depth

15. The three interim depth gears have proved their worth and been taken out of service. The final depth gear in its shallow water form (10 to 230 ft) has run well down to 190 ft to date and satisfactorily executed up and down changes (20 ft steps). The full depth range (50 to 1,150 ft in 100 ft steps) is about to be introduced.

16. This is another holding item in the development programme.

### Propulsion System

#### Batteries

17. The first two silver oxide/zinc secondary batteries delivered to A.U.W.E. were considerably above the specified weight limit and were returned to the firm. Of ten further batteries delivered, three were wetted-up for use in weapon running trials, but a large number of cells failed to hold charge after the first charge/discharge cycle. Single cell tests had indicated a life of about twenty cycles.

18. Extensive tests are being conducted to find the cause of failure of cells when assembled as a battery. Meanwhile silver oxide/zinc batteries, consisting of cells developed for the PENTANE torpedo, are being used for weapon running with a duration limited to 5 minutes at high speed.

#### Motor

19. Eight motors have been built at A.U.W.E. and four more by contract. These motors have been run for the full practice duration at full power without water cooling. The power required for full speed is less than estimated, however dynamometer tests including speed changing (series/parallel on battery) at the calculated full load have given no trouble. No trouble has been experienced with the motor on trials (low speed only to date). A scheme is now being drawn up to fit water cooling into the motor in the weapon.

#### Propeller

20. Adequate stocks of stainless-steel blades are now available. Even blades in this metal have suffered some damage in trials from malhandling and early runs on the noise range at Loch Goil show that cavitation is higher than anticipated.

#### ONGAR - 10 inch Powered Model

21. Trials on a 10 inch diameter powered model with the ONGAR afterbody configuration have been conducted in the 30 inch water tunnel at A.R.L. The aim of the trials is to measure the propulsion and cavitation performance characteristics of the ONGAR propellers. The water tunnel facility enables trials to be conducted over a wide range of front and rear propeller pitch combinations with the aim of obtaining optimum cavitation performance concurrent with an acceptable propulsion performance.

22. Measurements of propulsion performance have been made over a range of propeller pitch combination ranging from about 32 degrees to 45 degrees on each propeller. The analysis of the measurements is completed and in the case where comparison with full scale runs is possible the agreement between model and full scale is good.

23. A preliminary examination on the model of the cavitation performance at the present ONGAR blade settings indicate a cavitation inception depth in excess of 50 ft at 24 knots. However, detailed cavitation measurements is the subject of the last phase of the trials currently taking place.

#### Propeller Shafts

24. Some redesign and change of material of the propeller shafts and coupling shafts is being carried out to withstand the high torques imparted during the launching phase - this torque is developed by the water windmilling the propellers until oil pressure developed by the shaft-driven pump closes the contactor on to the battery and the motor then comes under power. This system has worked very satisfactorily and required about 20 revolutions of the propellers to become self powered.

#### Two-speed Contactor

25. The contactor unit using oil pressure for switching operation has continued to prove satisfactory. The internal mechanism is shown in Fig. 8.

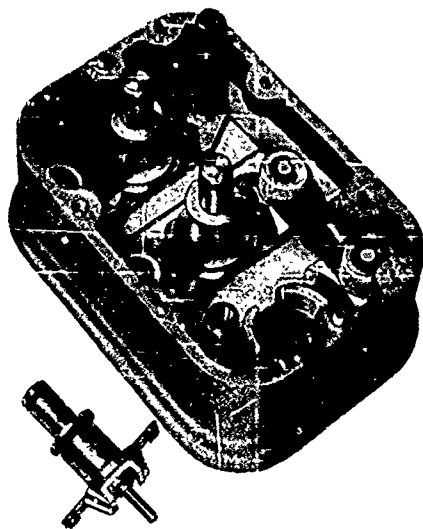


Fig. 8 Two-speed Contactor Unit.

#### Wire Guidance System

26. All 27 guidance electronic units have now been made, but vibration tests have shown that some mechanical stiffening is necessary.

27. Trials have shown that the command signal levels up and down the wire are satisfactory. Runs in which the weapon has been steered in azimuth and depth via the wire and other signals recorded have given no cause for alarm, though there are still some problems associated with the coded 400 c.p.s. pulse. A further pulse is being added to provide a measure of the true speed of the weapon. This has been incorporated in view of the tolerances on the primary battery output now being quoted by the manufacturer.

28. An additional channel is being added to the guidance unit to give command arming and thus increase the safety of the firing submarine.

### Outboard Dispenser

29. The Mk 2 Outboard Dispenser, intended for ONGAR, contains 5,000 yd of wire against 2,000 yd in the dispenser for the Mk 23 torpedo, and is designed for higher towing speeds. The first experimental model was completed in September and subjected to a number of discharges through the Deep Firing Tank to prove compatibility with Water Ram Discharge as fitted in H.M.S. DREADNOUGHT. It has since been employed in a small number of submarine runs with ONGAR at speeds up to 8.2 knots and dispensed satisfactorily. Towing stability has been confirmed up to 10 knots, using a surface craft. Arrangements are in hand for towing an instrumented dispenser from a faster vessel to determine the behaviour at even higher speeds.

### Pistol

30. The pistol provides for contact operation with a sensitivity adjustable between 5 and 15g and for non-contact operation up to a range of 15 ft from the target submarine.

31. The non-contact pistol supplies approximately 150 watts at 1,900 c.p.s. to coils in the tail fins to provide a rotating magnetic field around and at right angles to the axis of the torpedo. In the head there are four coil pockets connected so as to have their axes along the torpedo axis to reduce the direct pick-up from the tail coils to a negligible level. These receiving coils pick up the reflected signal from the target and this is amplified and differentiated to actuate the detonator firing circuit at the point of nearest approach to target.

32. The experimental non-contact pistols have functioned satisfactorily in ONGAR vehicles against submerged static targets; two models, engineered to production standards, are at present undergoing environmental tests prior to releasing the drawings for production.

33. A comprehensive pistol test set has been designed and one model constructed for assessment with the two production pistol models.

### Ancillary Power Supplies

34. The 3-phase inverter has been very reliable in use and the early models of the new design are now to hand.

35. In common with other transistorised equipment, overloads cannot be tolerated and an extensive programme of voltage stabilisation is being progressed. In addition to this many relays are being replaced by semiconductor switches, as relays have been one of the main sources of unreliability in the weapon.

### The Transponder

36. Two experimental models of the transponder were delivered during 1962 and gave very satisfactory performance during sea trials in shallow water. The r.m.s. bearing error, for ranges between 2.5 and 10 kyd using over 4,000 transmissions, was  $0.29^{\circ}$ . No measurement of range accuracy was made; as indicated in earlier trials this is not a problem, i.e. under the worst conditions a standard deviation of 8 yd was obtained at 15,000 yd range.



37. A prototype transponder has since undergone a series of climatic and durability tests followed by a 1,000 hour life test; these were completed without failure. The unit met the requirements of the K114 Test Specification after the 1,000 hour life test had been completed.

38. Twelve prototypes and three pre-production models are to be made. The Test Specification is in draft form and drawings are almost complete.

#### Hull

39. There has been a big demand for ONGAR dummies, space models, etc. and owing to difficulties in achieving crack-free welds the delivery rate of body sections has fallen - present commitments can just be met. The afterbody is being re-modelled internally to allow easy access to the tightly packed assemblies and improve generally the layout of cables, pipes, etc. Weapons 13 to 27 will have these modifications, though in fact most of the components will come from weapons 1 to 12. The modifications are being carried out as material becomes available.

#### Transport Containers

40. Four shock resistant boxes for weapon and head are now in use and have proved satisfactory.

#### Test Gear

41. To avoid a multiplicity of special-to-type test gear, the use of TRACE (Tape-recorded Automatic Check-out Equipment) is being investigated. This will check out most of the assemblies in Armament Depots and Depot Ships merely by inserting a punched tape and setting the machine to work.

42. The general programme of test gear and test specifications is behind schedule and contract action on some components awaits receipt of the increased financial approval. It is proposed to include a 3-axis Stabilised Test Table for thorough performance check out on the depot ship; so far only preliminary design has been possible.

#### Torpedo Guidance Control Unit Mk 2

##### Experimental Equipment

43. The past year has seen the completion of the design of the experimental model of the Torpedo Guidance Control Unit, Mk 2. The lessons learnt with the breadboard equipment have proved of great value and the simplified logic and storage systems used in the experimental model have permitted a very considerable reduction in size. The equipment is housed within one modified standard cabinet, the upper four drawers being associated with the display system, the lower two drawers with the computer and its storage system.

44. The individual electronic units for the equipment started to become available in August 1962 and have been subjected to extensive laboratory testing prior to their assembly into the cabinets. Checking of both the computer and display system as separate entities is now nearing completion and the next step will be to marry the two together. Overall testing can then commence and when this is completed a series of dry land tests of the equipment as a fire control instrument using simulated inputs and outputs will be carried out.

45. A number of additional facilities not specifically called for in the Staff Requirement have been built into the T.G.C.U. Mk 2. Should own ship data from log or compass prove unreliable, these functions can now be set in by hand. Similarly, it will also be possible to hand set target range, course, speed and bearing, and the successful operation of the equipment is not wholly dependent on the sonar, which provides automatic transmission of bearing. Attack data obtained from the periscope or radar can thus be used and this facility would allow the use of the equipment as a fire control computer against surface targets for weapons with an anti-ship capability.

46. Extensive shock and climatic testing of the individual units of the equipment has been carried out during the past year and this testing will eventually extend to a complete T.G.C.U. Mk 2. Weaknesses have thus been discovered at an early stage and remedial action taken.

47. Whilst the main effort over the past few months has been devoted to T.G.C.U. Mk 2 itself, progress has been made on a number of associated instruments:-

- (a) Torpedo Simulator: Requirements for a torpedo simulator which will permit functional checking of T.G.C.U. Mk 2 have now been finalised. The simulator, in effect, replaces the guidance unit of the torpedo and indicates that the "weapon" is responding correctly to the command. The repeat-backs of course and speed from the "weapon" are also provided and, besides providing a check on T.G.C.U. Mk 2, this will also allow realistic dummy attacks, including weapon guidance to be carried out in operational submarines.
- (b) Action Data Recorder: The requirements for the recording system used in conjunction with T.G.C.U. Mk 2 during practice firing of the weapon have recently been finalised and an Action Data Recorder is on order. The recorder will store on tape the wire commands and repeat-backs, the highlights of the digital data on the storage drum, and a voice commentary. When played back through T.G.C.U. Mk 2 the binary data will be decoded by the computer and presented on the Numerical Display. Wire commands and repeat-backs will appear on a multi-channel paper recorder.
- (c) Test Equipment: It now seems probable that the special test equipment needed will primarily be a simple card tester. The monitoring system built into T.G.C.U. Mk 2 itself will allow a fault to be isolated to a group of three cards and by subsequent use of the card tester a defective card can be isolated. A breadboard equipment has been developed. In service, this equipment will initially be used in depot ships, but may be fitted in submarines, depending on its size. Recent experience with T.G.C.U. Mk 2 suggests that the theoretical prediction of one fault per 200 hours is pessimistic and a more likely figure is one fault per 700 hours. This comes about because of the enhanced reliability shown by the encapsulated Combi elements used through the equipment.

#### Prototype Equipment

48. Whilst the experimental equipment already described marks a big advance on the breadboard system discussed in earlier reports, it now seems possible, whilst the design is still fluid, to simplify the equipment still further and

to use a simpler logic system. This will permit a significant reduction in the number of different types of printed cards used and should result in easier maintenance and increased reliability. The drawings for the prototype are, therefore, being based on this simpler system and equipments numbers 2 and 3 will be made to these drawings.

#### T.C.S.S. 8X and 9X

49. These systems, which are developments of T.C.S.S. 6 and 7 in which T.G.C.U. Mk 1 is replaced by T.G.C.U. Mk 2, are being fitted to H.M.S. CACHALOT and H.M.S. OCELOT, respectively for development trials. The minor changes required to the associated instruments of both systems in order to incorporate the requirements for ONGAR have been completed and equipment manufactured.

50. The T.C.S.S. 8X system in H.M.S. CACHALOT is nearing completion and trials should commence in mid-1963. In the first instance, these trials will be designed to prove the computational and display facilities and position-keeping accuracy of the experimental T.G.C.U. Mk 2. When this phase is completed trials of T.G.C.U. Mk 2 in association with the weapon can commence.

51. The T.C.S.S. 9X system for H.M.S. OCELOT is being installed and is roughly one year behind the parallel system in H.M.S. CACHALOT. The system, less T.G.C.U. Mk 2, has undergone system tests at the works of Messrs Barr and Stroud and has proved to be functionally satisfactory.

52. The existence of two torpedo control systems T.C.S.S. 8 and 9 for spindle and cable set torpedoes, respectively, raises serious logistic problems in regard to types of torpedo, torpedo control instruments, spares, etc. It has been proposed therefore, that an attempt should be made to standardise on the more flexible cable set T.C.S.S. 9 system. Although this would take some years to accomplish the fitting in submarines it would eventually show a considerable simplification in the types of weapon, control instruments, etc., required and result in reduced requirements for logistic support.

#### 2.2 - MK 23 TORPEDO AND CONTROL SYSTEMS T.C.S.S. 3, 6 AND 7

##### Torpedo

53. Further trials of the torpedo were carried out during 1962/63 and these are summarised below:-

- (a) Shock Trials: One torpedo was subjected to shocks of 16, 30, 40 and 57g when mounted in a tube in the N.C.R.E. Shock Test Base. The torpedo functioned satisfactorily after the first two shocks, except for a gyro wander beyond the specified limits after the second shock. The torpedo failed to function after the third and fourth shocks, but the depth gear functioned correctly after cleaning the contacts and the azimuth controls operated when tested with an azimuth unit that had not been subjected to shock.
- (b) Vibration Trials: One torpedo is currently being subjected to a series of vibration trials in three mutually perpendicular planes, at room temperature, and at 125°F and -20°F. The azimuth units used on these trials are being returned to R.N.T.F. for examination and testing. Apart from these units, the faults occurring to date have been of a minor nature.

- (c) Climatic Trials: Two torpedoes are currently being subjected to climatic trials. After two months at  $-20^{\circ}\text{F}$ , the torpedoes functioned satisfactorily when brought to the minimum operating temperature of  $20^{\circ}\text{F}$ .
- (d) Three Months Storage Trials in a Submarine: Three torpedoes were stored for three months in a submarine. Two torpedoes were stored in tubes, and one in the racks. One of the torpedoes in the tubes developed a fault which is being investigated. The other two torpedoes ran satisfactorily to maximum range at the end of the storage period.
- (e) Further Acceptance Trial Running: In further trials in July 1962 the torpedo performances were as shown in the table below:-

Aim	Valid Runs	Successful Runs	% Success	
			1962 Trials	1961 Trials
Guidance and Position Keeping	40	40	100	80
Acoustic Contact	33	33	100	57
Homing and Hitting	30	29	97	100

54. Further small torpedo modifications recommended as a result of the July 1962 trials were, in general, incorporated in the torpedoes used in January 1963 trials and appear to be satisfactory.

#### Outboard Dispenser

55. Ninety runs were completed with the prototype dispenser for the 21 inch Mk 23 torpedo (Mk 1 Outboard Dispenser) during the first half of 1962 and following minor modifications, this dispenser was offered for acceptance. In the course of system acceptance trials in July, sixty discharges were carried out and dispensing performance was better than 90%. Since then, satisfactory discharges have been made from both bow and stern tubes of an 'A' Class Submarine, but during trials in H.M.S. OTTEL in January 1963, some trouble was experienced with the operation of the dispenser release mechanism, owing to high discharge velocities.

#### Control Systems

56. Modifications to the prototype T.G.C.U. Mk 1 in H.M.S. WALRUS were completed in May 1962 and their success demonstrated during a subsequent trial. Acceptance trials on the complete system were undertaken in July 1962 and were generally successful, although due to abnormal sound propagation conditions the "acoustic contact" link with the weapon was not as conclusive as on previous trials.

57. The fire control equipment was released for service use although formal acceptance of T.G.C.U. Mk 1 was withheld pending further investigation into the torpedo and continuing weapon trials. The equipment was, however, released from production and is being widely fitted in operational submarines.

58. Prototype installations of the T.C.S.S. 6 and 7 systems have been fitted in H.M.S. OTTER and H.M.S. OLYMPUS and successful control of Mk 23 torpedoes from H.M.S. OTTER has been demonstrated. Similar trials, but using the T.C.S.S. 7 system to control the Mk 23 torpedo, will be carried out in H.M.S. OLYMPUS in July 1963. A proving programme of weapon trials is at present in hand and the final stage of these trials will be a long range operational trial for the complete Mk 23 control system against a realistic target in November 1963.

59. Installation of the T.G.C.U. Mk 1 in both new construction and submarines refitting is proceeding and with the completion of H.M.S. DREADNOUGHT seven submarines will be in service with a Mk 23 control capability.

#### T.C.S.S. 3

60. With the exception of a few "T" class submarines, the T.C.S.S. 3 systems are being replaced by T.C.S.S. 6 as submarines are refitted.

#### T.C.S.S. 6

61. The T.C.S.S. 6X system was fitted in H.M.S. OTTER subsequent to shore testing at Messrs Scott in May 1962. Since the T.G.C.U. Mk 1 guidance control unit for the Mk 23 torpedo was not at that time available, it was not possible to complete setting to work this portion of the system.

62. The harbour acceptance trial was satisfactorily completed in May 1962. The results showed a marked improvement in the computing accuracy of the calculator T.C.C. Mk 16, Mod.3 on its predecessor the Mod.1 version, particularly at short hitting runs and experience since, whilst limited, has shown the calculator to be more stable with respect to time.

63. Certain defects, which came to light during the system testing, have been investigated and appropriate modifications are being introduced.

64. The T.G.C.U. Mk 1 guidance control unit became available in December 1962 and this allows the remainder of the harbour acceptance trials to be completed. The sea acceptance trials of the system were carried out in January 1963 during which Mk 8, Mk 20S and Mk 23 torpedoes were successfully fired and controlled.

65. Four other submarines, H.M.S. ORACLE, NARWHAL, TRUNCHEON and ALLIANCE, have been fitted with production T.C.S.S. 6 systems during the development period allocated to the prototype system in H.M.S. OTTER. Whilst this goes some way to ensuring that the latest equipment gets into service as soon as possible, it does raise considerable difficulties in ensuring that production systems are up to the latest prototype standard.

66. Some further work on the T.C.C. Mk 16 Mod.3 calculator is being carried out and a bearing rate indicator has been developed by Messrs Muirhead. Tests on a laboratory rig have proved satisfactory and the next step will be a trial at sea.

T.C.S.S. 7

67. At the commencement of the development of the prototype T.C.S.S. 7X system it was intended that the system should be installed in H.M.S. OLYMPUS following a shore test at the works of Messrs Barr and Stroud. Furthermore, it was intended that final development and trials of the system would be complete prior to the installation of production equipments. However, due to delays in completion of the submarine, followed by difficulties encountered during testing and tuning whilst the submarine was still in shipbuilders' hands, much of the prototype lead time was lost.

68. During the setting to work of the system on the submarine, trials of the data transmission links between control instruments and tube space showed significant errors. Investigation as to the cause of these errors and subsequent system modification thus had to be made, not only on the prototype equipment but also to three subsequent production systems in parallel. These transmission errors stem from three main causes:-

- (a) The abnormally long cable run of 150 to 200 ft in R.N. submarines.
- (b) The use of a common S3 stator line for five different servo motions.
- (c) The susceptibility of the Mk 5 a.o. servo amplifier and associated Data Set Unit to 400 c/s interference.

69. Investigations of these problems on H.M.S. OLYMPUS proved both difficult and uneconomical and the data transmission system was, therefore, set up at A.U.W.E. to determine the source of error and methods of effecting a cure, prior to implementing modifications to the system itself. The errors were found to be primarily caused by cross talk from core to core in the submarine cabling and were considerably reduced by using cables containing a number of triple twisted cores and dividing the synchro stator lines for each servo motion such that commoning only occurred at the point of entry into the torpedo umbilical B cable at each disconnect switch.

70. Introduction of 400 c/s filters into the signal input stage of the servo amplifiers reduced interference and provided reliable operation of data set units. It was impossible to introduce the improved cabling into H.M.S. OLYMPUS or H.M.S. DREADNOUGHT as main cable runs in both submarines had been completed well before this stage. It was, however, possible to make a comparable improvement in data transmission by core selection in existing cabling, although this naturally involved a considerable rearrangement of existing functions.

71. The result of these modifications is to limit transmission errors to +30 minutes of arc for "coarse only" transmissions and to +15 minutes of arc for coarse/fine systems. Harbour acceptance trials of the T.C.S.S. 7X installation including the prototype T.C.C. 17 calculator were successfully completed in December 1962 in H.M.S. OLYMPUS. A similar trial was completed in H.M.S. DREADNOUGHT in March 1963. Successful firing of the U.K. Mk 8 Mod.4 torpedoes have already been made from H.M.S. OLYMPUS and sea acceptance trials, in which all compatible British torpedoes will be fired, will take place when the submarine can be made available. The DREADNOUGHT system will be subjected to similar trials, which will take place in conjunction with deep discharge tests in August 1963.

72. The draft handbook for the T.C.S.S. 7 system has been completed and vetted and is in process of being converted to the final handbook.

### 2.3 - MK 20C COMBINED ANTI-SUBMARINE/ANTI-ESCORT TORPEDO

73. The design work for the conversion has now been completed and production drawings are available.

74. A decision on whether or not this torpedo is required in service is awaited.

### 2.4 - THREE-DIMENSIONAL TRACKING RANGE

75. The estimated completion date is still the end of January 1964. The basic design is largely completed and the assembly of the units is well advanced. Trials off Portland with an experimental transmitting transducer assembly and the proposed Elliott pulse transmitter gave satisfactory signal strengths out to maximum designed range of 5,000 yd.

76. The design of the instrument containers has been finalised and these should be available for installation on E.T.V. WHIMBREL at Gosport during June 1963.

77. The first of the three hydrophone supporting booms is being installed in H.M.S. GOSSAMER for handling trials. The other two booms should be ready for June 1963.

### 2.5 - ARROCHAR TORPEDO PROOFING RANGE

78. A report on possible methods of instrumenting the Arrochar Torpedo Proofing Range to give the degree of accuracy required for proofing ONGAR has been completed by Elliott Bros (London) Limited under a design study contract. It is shown that adequate accuracy can be achieved and makes recommendations on the techniques to be employed. It is clear that any such system would be very expensive, owing to the number of pressure tight units involved, each requiring communications with the firing point.

79. Consideration is therefore being given to designing a simple 3D Range installation for Arrochar using standard 3D practice heads on the torpedoes, and simple tracking installations on one or more of the target rafts. This may take the form of either tape recording of the pulse from the tracked torpedo, to be analysed later on E.T.V. WHIMBREL 3D range, or a simple analogue computer with its own plotting table.

80. Preliminary trials indicate that the simple 20 kc/s range will be reasonably satisfactory at Arrochar.

### 2.6 - RECORDING EQUIPMENT FOR TORPEDO ATTACK DATA

81. Further development of a small, portable digitizer/decoder with "freeze and read" facilities now includes a simple print-out facility. Prototype units are expected to become available shortly and production versions of these will replace the original unit developed for testing T.S.C.U. Mk 1.

82. The 15-channel data recorder on H.M.S. MAIDSTONE has now been in service some nine months without repetition of the last reported defects on the Underwood typewriter and it would appear that this weakness has been overcome (see page 46).

83. Special-purpose write-out machines are now available and it is intended to use an input/output writer manufactured by International Business Machines in place of a typewriter on subsequent attack teacher recorders.

84. Further details of recording equipment being developed for use in association with T.G.C.U. Mk 2 are given above (see page 22).

#### 2.7 - TORPEDO LOCATION INDICATOR

85. The priority of this item is such that very little work has been possible on it during the last year. A contract is visualised to engineer the electronic equipment into a package suitable for incorporation in the present Holmes Light pocket. However, with the introduction of three dimensional ranging, the use of the torpedo location indicator will presumably not be so pressing.

#### 2.8 - DEEP ACOUSTIC TORPEDO TARGETS

##### Static

86. The adaptation of the Mk 44 target for ONGAR awaits revised global approval.

87. Work is, however, proceeding on the Mk 44 target and limited modifications are in hand as a result of recent trials.

##### Deep Mobile

88. In view of the difficulties of obtaining live targets for the development of anti-submarine acoustic torpedoes, the design of a synthetic mobile target, to carry out manoeuvres similar to those of a submarine, and fitted with transponders and noise generators so that its sonic behaviour will be similar to that of a real submarine, has been considered. A design study contract was placed with The Plessey Company Limited which resulted in proposals being put forward for tailoring the requirements into a converted ONGAR torpedo by the addition of only two relatively small new body sections. The programming and recording system required by the target can utilise apparatus already being developed for the Mk 44 torpedo, thus reducing development costs and the extra expense of small quantity production. Proposals for development are being prepared. Consideration is also being given to the use of such a target for Fleet practice, and a Staff Target is in preparation.

#### 2.9 - Mk 8 MOD.4 TORPEDO

89. Acceptance trials were carried out in early September 1962 but were only partly successful since the azimuth and depth items of the torpedoes were outside the limit specified. This error had not appeared in the prototype torpedoes and an urgent investigation was carried out.

90. The error is now known to be due to unbalance of the air supply to the two sides of the steering engine and changes to the dimensions of the air



passages are being made. Trials of the modified torpedoes were carried out in March 1963 and the modification is now being incorporated in production torpedoes.

#### 2.10 - THE MATCH WEAPON SYSTEM

91. MATCH, as a system, results from the adaptation of existing equipment. The modernisation of Type 177 is the only specific item in A.U.W.E.'s programme requiring additional work for this purpose, but some system study and co-ordination of material problems has also been necessary.

92. The MATCH system is concerned with the application of a wide variety of equipment to exploit the longer range detection potential of sonars such as Types 177 and 184, with the aid of the torpedo carrying helicopter. There are a number of variants of the system for which the equipment can include:-

WASP helicopter	Sonar Type 177
WESSEX helicopter	Sonar Type 184
Radar Type 978	Sonar Type 199
Radar Type 992	Torpedo Mk 44
Radar display Type JUA	True Motion
Radar display Type JYA	Sonar Marker
ADA	Optical Plot Attachment
X-Band transponder system	
MAD	

93. The basic installations are shown in the table below:-

Class of Ship	Helicopter	Control Facilities
TRIBAL's	WASP	177, (199), 978, JUA, JYA
LEANDER's	WASP	177 or 184, (199), 978, JUA, JYA
D.L.G.'s	WESSEX	177, 978, JUA, JYA or 184, 992, ADA
CARRIER	WESSEX/WASP	184, JUA or ADA
BLACKWOOD's	-	177, 978, JUA, JYA
ROTHESAY's	-	177, 978, JUA, JYA
WHITBY's	-	177, 978, JUA, JYA
Post LEANDER's	-	Not decided

94. The main requirements for the system have been settled but implementation continues to be slow. Approval to purchase much of the equipment is still awaited.

95. MATCH system trials were held in H.M.S. ASHANTI in March 1962, utilising experimental models of the main control system developments, with the exception of the improvements to Sonar Type 177 which are reported below.

96. These trials had two purposes. The first was to obtain experience of aircraft handling and operation from the flight deck of a TRIBAL class frigate. This part of the trial, using a P.531-O helicopter, was successful. In spite of bad weather and makeshift arrangements 315 day and night take-offs and landings were made under a variety of conditions. The anti-roll stabilisation of the ship made a major contribution to operation in heavy seas but the need for positive arresting gear on landing was again apparent.

97. The scope of the tactical trial was limited owing to submarine and aircraft availability but successfully demonstrated the potential of the system and the effectiveness of the fire-control arrangements. The A.S.W.E. sonar marker was found to be accurate, but the random jumps in its position, due to the crudity of the sonar data, were found to be disconcerting to the helicopter director. Nevertheless the results of some 120 runs against a submarine target at speeds up to 12 knots and at ranges out to 18,000 yd indicate that, using a salvo of two U.K. Mk 44 torpedoes, the system should have a useful capability against alert evasive submarines at speeds up to 15 knots. The ship must, however, be in sonar contact up to the time of weapon release, and it is a major weakness of the system that the delays in making the attack give the submarine ample time to take advantage of sound propagation conditions and dive to safety.

98. Other facilities contributing to the success of the fire control system were the Decca Optical Plot Attachment which was found to make an important contribution to direction accuracy by enabling the attack graticule to be visually superimposed on the radar display; and sea-stabilisation of this display with the aid of "True-motion". An X-band radar transponder system was found to be essential for following the helicopter through bad sea or rain clutter. Luneberg lens reflectors were not adequate for this purpose.

99. Arrangements for the engineering development and production of these equipments are in hand.

100. The next series of trials, expected in Autumn 1963 in H.M.S. LEANDER, will have production prototypes of the sonar improvements and sonar marker, but for much of the other equipment only experimental models will, as yet, be available. The WASP Mk 1 helicopter will be utilised. Improved operating procedures will be tried to improve fire-control accuracy against faster, deep, and evasive submarines. (Until a torpedo with better search capability is available, however, the probability of acquisition will be low for target speeds over 18 knots.) Better trials instrumentation will be essential and for this purpose a D.M.E. (Distance Measuring Equipment) available commercially in the U.S. has been ordered.

101. The MATCH fire-control problem is not adequately solved by manual methods using the data and facilities available in ships with conventional A.I.O. systems. The better handling of sonar data, tracking and prediction possible with the aid of a computer will be exploited in ADA-fitted ships by the addition of a fire-control programme for MATCH. Orders will be presented on the ADA display for voice transmission to the helicopter by the direction officer.

### Torpedo Dropping Rules

102. The progress of system development has made possible better estimates of system delays and this in turn has lead to a revision of the dropping rules recommended for the Mk 44 torpedo. For the full MATCH system in which prediction is made by the A.S.W.O. at the A/S Plot (JYA) a distance ahead of the target of 36 yards per knot of target speed is now recommended. The proving of the rules is not practicable without a very extensive series of trials with running torpedoes. In the forthcoming trials in H.M.S. LEANDER further data will be obtained, justifying or amending the assumptions made in deriving the rules, and experience will be obtained in their application, but the number of torpedo drops will be too small to prove whether or not the rule is the optimum.

### Adaptation of Type 177 for the MATCH System

103. The completion of a feasibility and design study of possible modifications to Type 177 to make it suitable for use in the MATCH system was completed. The main recommendations are:-

- (a) The Sector and Doppler Displays should be modified to handle targets with dopplers up to  $\pm 40$  knots.
- (b) Additional visual integration to be provided on the Range Recorder.
- (c) Facilities to be provided for the semi-automatic feed out of target information.
- (d) A trial to be carried out to assess the performance of a  $40^\circ$  wide Sector Display beamwidth compared to the existing  $20^\circ$  width.

104. To implement these recommendations a contract was placed with R. B. Pullin and Company in April 1962 to carry out the detailed technical modifications and to assist A.U.W.E. with fitting the equipment into a ship for sea trials.

105. Preliminary sea trials of part of the modified equipment took place in H.M.S. HARDY in October 1962. The equipment under material evaluation was the modified Sector Display which now uses only the 20 mS and 150 mS transmission pulses, but with the facility that both pulses can be used up to the maximum doppler limit of  $\pm 40$  knots, as distinct from  $\pm 5$  knots and  $\pm 1$  knot respectively, in the present Type 177 sets. Reverberation suppression with a rejection characteristic of variable bandwidth was also incorporated in the 150 mS channel for the purpose of the trials. In addition, an electronic strobe of target bearing has been added to the Sector Display. Other components under evaluation were the audio and recorder marking circuits which had been modified to cope with the variations in processing frequencies introduced by the increased doppler coverages, and the receiver beam-forming networks which had been modified to give the dual facility of either a  $20^\circ$  or  $40^\circ$  acoustic beam width of the Sector Display.

106. Shallow water areas visited during the course of the trials were off Portland, south-west of the Scilly Isles and the Londonderry exercise areas. Excellent sonar conditions were encountered in the first two areas whilst severe gales were encountered in the latter, somewhat curtailing the trials.

107. In these trials the Doppler Display was operating with a 5 cycle bandwidth and 10° acoustic beamwidth while the Sector Display had a 400 cycle bandwidth and a choice of either 20° or 40° beamwidth.

108. Results show that the introduction of reverberation suppression in the 150 mS pulse receiving channel of the Sector Display is of assistance in detecting targets showing more than 6 knots of doppler. The targets were either A class or PORPOISE class submarines and generally ranges in excess of 10,000 yd, were obtained with very little difference in detection range with the different bandwidths or beamwidths.

109. The degradation in performance which theory would predict from increasing the bandwidth and beamwidth was not evident and this may be explained by reference to Fig. 7. In the 150 mS pulse and 40° beamwidth mode of operation reverberation limitations are about the same as those for Type 184 and the same generalisations about the change in detection potential due to variations of the parameters apply. It may therefore be predicted from the more comprehensive trials with Type 184 that increasing the beamwidth to 40° would reduce the detection potential of Type 177. Thus it will be seen from Fig. 7 that for the Portland area, low sea state, a change in detection potential of only 4 dB can result in an increase in range from 5 to 15 kyd. Day to day changes in propagation conditions in this area can exceed such values, hence the danger of drawing conclusions from limited trial data.

110. Further trials will be carried out early in 1963 with the Doppler Display modified to provide for +40 knots of doppler and also the addition of visual integration on the Range Recorder will be evaluated.

111. It is planned to complete all trials of this nature by the end of May 1963 to finalise production information by the end of June 1963. A decision on the width of the acoustic beam for the Sector Display information will, however, await the results of later trials and an assessment of comparable features included in the Type 184. In particular the use of a 30 knot target is badly needed in order to assess the operational usefulness of increasing the sector width and the performance of operators.

112. It is planned that incorporation of the modifications in existing Type 177 equipments shall be achieved by substituting modified electronic units for the existing units, the work being undertaken aboard ship by a contractor.

#### 2.11 - FURTHER DEVELOPMENT OF A/S MORTAR MK 10

113. Consideration has been given to various improvements of the A/S Mortar Mk 10 including extension of the range and a "Slimline" double mortar layout.

##### Extension of Range

114. Trials have been successfully carried out at Predannack Down to prove that an extension of range to 1,500 yd is possible without any mechanical modifications to the weapon. No further work is being done in the absence of a firm requirement (see page 92).

"Slimline" Limbo

115. The object of the "Slimline" configuration is to accommodate double mortar mountings in a reduced length of ship, to provide increased stowage and permit a reduced manning.

116. A sketch design for Post LEANDER Frigates has been submitted to D.G.S. for consideration.

2.12 - PROXIMITY FUZE FOR A/S MORTAR MK 10: CANADIAN PROJECT INSIGHT

117. A visit was made by a R.N. team to Canada to discuss the final R.C.N. design proposals. These were found to meet R.N. safety and functioning requirements.

118. As a result of the discussions with the Canadians it became necessary for calculations on the magnitude and pattern of the near field of a typical submarine to be carried out with special reference to the probable range and depth of actuation of the Canadian proximity fuze for A/S Mortar Mk 10 which is to undergo proving trials in the U.K. This study was necessary to guide selection of procedure and equipment for the trials against the target.

119. Financial approval for expenditure to provide facilities for R.C.N. trials has been obtained, and design and contract action has been taken.

120. The facilities being provided are as follows:-

- (a) Setting up a single barrel A/S mortar at St Thomas Head, Weston, in order that the mechanical arming trials can be carried out.
- (b) Setting up a single barrel A/S mortar at Loch Long to fire into the recovery net, in order that the electrical safety and arming depth of the fuze may be determined.
- (c) The magnetic survey of a wooden barge, its purchase and modification for use in trials against a target in Loch Gail.

## SECTION 3 - LAUNCHING EQUIPMENTS

### 3.1 - WATER RAM DISCHARGE FOR NUCLEAR SUBMARINES

#### Prototype Equipment

The trials of the prototype water ram discharge system fitted to the A.U.W.E. Deep Firing Tank were completed in September 1962. During this trial the weapons discharged included:-

Mk 8 <sup>XX</sup>	torpedo	to a depth of 200 ft
Mk 20	torpedo	to a depth of 700 ft
Mk 23	torpedo	to a depth of 700 ft
ONGAR		to a depth of 700 ft
S Mk 6	mine	to a depth of 70 ft

These weapons were discharged at all speeds and accelerations expected in service and under conditions representing all the tube configurations in H.M.S. DREADNOUGHT.

2. The trials of all weapons to be discharged from H.M.S. DREADNOUGHT were fully instrumented and analysed. From the results Test Specifications for "Setting to Work" and "Calibration" were drawn up. These specifications together with others covering pressure testing, gauging, interlocking, indicating and safety mechanisms for use by Admiralty Overseers and Test Teams formed the culmination of the trials programme. This is the first time that a detailed short trials programme on prototype weapon launching equipment has been possible before ship completion and it should result in greater operational and material reliability than previous systems.

#### Fore-End Mock-Up

3. The full scale bow mock-up of H.M.S. DREADNOUGHT at A.U.W.E. has been modified in many respects to simulate the redesign necessary for H.M.S. VALLIANT. This work has been completed for the weapons equipment, but the mock-up is still being utilised by other Departments, e.g. by Director General, Ships, in finding the optimum run of the D.G. cables.

4. It is intended that the mock-up should remain in being until the Barrow mock-ups of H.M.S. VALLIANT are complete.

#### Production Equipment

##### H.M.S. DREADNOUGHT

5. All the equipment for H.M.S. DREADNOUGHT has been installed. A great deal of effort by the Establishment has been put into assisting the Shipyard Overseers with the work of checking test specifications and setting to work. In addition the Installation Inspection and Part Harbour Acceptance Trial (T.A.S.) was carried out during November 1962 at Barrow. In general the equipment was satisfactory with the exception of the "triggering" of the firing air circuit. This failed occasionally due to excessive leakage of the starting air supply from some components. The leakage was traced to the failure of the top stops to return after firing, and the use of Aluminium Bronze pistons in Aluminium Bronze cylinders. This latter material combination has an extremely

high wear rate and gave rise to the leakage. Modifications are in hand to prevent recurrence of these defects.

6. Dummy Mk 20 torpedoes were discharged satisfactorily from all tubes.

#### H.M.S. VALIANT

7. All production information, drawings and test specifications have been issued to D. U.

#### 3.2 - POWER LOADING GEAR FOR NUCLEAR SUBMARINES

8. All the torpedo handling, stowage and loading equipment for H.M.S. DREADNOUGHT has been manufactured and installed. The Advance Installation Inspection (T.A.S.) was carried out on the starboard side loading and traversing gear and the centre line loading gear in May 1962. In general the inspection was satisfactory.

9. This was, however, the first time that the centre line loading gear had been tried as no trials facilities had been available at A.U.W.E. As a result it was decided that the fore and aft support beams needed stiffening to prevent the possibility of an accident when loading short weapons, particularly the Mine M Mk 5. Modifications were put in hand.

10. The Installation Inspection and Part Harbour Acceptance Trial (T.A.S.) was successfully carried out during November. All types of weapons were tried in each tube and every stowage position. Weapon loading and traversing was carried out over the full range of load conditions. Embarkation and disembarkation of all weapons was also accomplished. As a result of the trial a defect list has been passed to Admiralty and the Shipbuilders for correction prior to the Final Harbour Trial.

#### 3.3 - SUBMERGED SIGNAL EJECTORS MK 4 AND MK 5

##### Mk 4

11. The Mk 4 Submerged Signal Ejector is designed to discharge all U.K. and some foreign pyrotechnics and decoys of 3 inch and 4 inch diameter at all depths from the surface to 1,000 ft. The stores are discharged by a water pump system and the whole equipment is designed to full shock standards.

12. During harbour trials of the Mk 4 Mod. 1 ejector in H.M.S. OTTER the noise level of the water pump during discharge was unacceptably high. No reason could be discovered for this in H. S. OTTER and an ejector was mounted on the test tank at A.U.W.E. exactly repeating the configuration of the OTTER installation. Instrumented trials showed that the water pump cavitated during the firing stroke. The collapse of the cavity gave rise to peak pressures of the order of 500 lb per sq. in. and accounted for the noise. The pressure peak decreased as the discharge depth increased and disappeared below 100 ft.

13. Subsequently the same symptoms, although less pronounced, were found when firing the Mk 4 Mod. 0 ejector in H.M.S. DREADNOUGHT.

14. It was found possible by a reduction in firing pressure to eliminate the pressure peaks. A clearance trial was carried out in H.M.S. OTTER in December,

and the ejector accepted for emergency and escape purposes from periscope depth to 500 ft. Similar measures will be taken in H.M.S. DREADNOUGHT and other O class submarines fitted with the Mk 4.

15. A redesign of the water pump assembly is now in hand with the object of eliminating the cavitation. A modification to the ejectors now being fitted to submarines is being prepared for trials, with the aim of cushioning the cavity collapse and reducing the peak pressures.

16. There is no longer a requirement to make special arrangements for discharging foreign stores used in a Submarine Explosive Echo Ranging (SEER) system.

#### Mk 5

17. The Mk 5 Submerged Signal Ejector is designed to fire U.K. pyrotechnics at all depths from the surface to 500 ft. The ejector is designed for escape use only. It will be removed and the hull pads blanked in time of war.

18. As a result of shore trials and trials in H.M.S. OYSTER in December the Mk 5 ejector has been recommended for acceptance from the surface to 350 ft. Clearance for use for emergency and escape purposes has been given from 350 to 500 ft. It is hoped that a full acceptance trial to 500 ft will take place in 1963 when a submarine and surface escort can be made available.

19. Arrangements are in hand to shock test a Mk 5 ejector at the Naval Construction Research Establishment. If the trials are successful there will be no need to remove the ejector in time of war.

#### 3.4 - DISCHARGE FROM NEW DESIGN NUCLEAR SUBMARINES

20. The Staff Requirements for this submarine have not yet been finalised. Work on this project has been limited to sketch designs of varying fore end layouts in collaboration with the Ship Department. This work has been aimed at attaining the best possible layout of torpedo tubes and sonar transducers, with particular emphasis on siting any extraneous noise source, e.g. bow caps, shutters, and torpedo dispenser towing cables, as far aft of the transducers as possible. Preliminary studies of the effect of increased diving depth on the tube equipment have been made.

21. Proposals have been made and approved to provide a new torpedo firing tank to enable development work to be done on discharge systems for deep diving submarines.

#### 3.5 - TORPEDO DISCHARGE FOR PORPOISE AND OBERON CLASS SUBMARINES

##### Constant Impulse Feature

22. Resulting from the experience gained in the trials in H.M.S. RORQUAL, further modifications were carried out on the Impulse Cut-off (I.C.O.) Units and a fully instrumented trial was carried out in H.M.S. GRAMPUS in May 1962, to ascertain the performance of all components of the system.

23. The complete system has now been set up on the deep firing tank at A.U.W.E., but unforeseen delays have prevented trials starting. It is now



expected that trials will commence in May 1963. It is intended to investigate all the problems existing in the firing and venting system and to modify as necessary to make it fully operational. This work will include finding a solution to the run-back problem (see page. 110).

### 3.6 - APPLICATION OF THE ONGAR WEAPON TO CONVENTIONAL SUBMARINES

24. The work of modifying the handling and discharge gear in PORPOISE and OBERON classes of submarines has been planned in two phases, viz:-

#### Phase 1

- (a) Modifications consequent on fitting T.C.S.S. 8 or 9.
- (b) Modifications to the embarking arrangements, stowages and loading gear to minimise shock and abrasive effects on the torpedo during handling and loading.
- (c) Modifications to the tubes to minimise abrasion of the torpedo when loading and corrosion when kept in the tubes.
- (d) Providing stowages for dispensers and spare gear and for the overall functioning test set.

#### Phase 2

- (a) Improvements to the stowages to limit the transmission to the torpedoes of shock due to enemy action.
- (b) Modifications to the upper stowages of OBERON class submarines to make them suitable to carry ONGAR.
- (c) Modifications to the loading gear of OBERON class submarines to enable ONGAR to be loaded into the upper four tubes.

25. Phase 1 modifications, with the exception of those to minimise the abrasive effects in the loading gear and tubes and corrosion in the tubes, have been designed and fitted in H.M.S. CACHALOT. The same modifications are being done in H.M.S. OCELOT with the addition of anti-abrasive features in the loading gear.

26. Admiralty approval is being sought for use of one of the torpedo tubes of H.M.S. ORPHEUS to be bored oversize and fitted with Tufnol or Terylene/resin sections over the strips. This is the proposed technique to provide anti-abrasive and anti-corrosion features in the tubes, and the proposal is to prove the effectiveness of the technique when the modifications are done by dockyards.

27. The modifications to H.M.S. CACHALOT and H.M.S. OCELOT were made to sketches in a very short time to enable H.M.S. CACHALOT refit completion date to be met. Shortcomings are already becoming apparent and depending on the experience gained in these ships further redesign may be necessary.

## SECTION 4 - MINE COUNTERMEASURES AND MINING

### 4.1 - MINEHUNTING

#### Minehunting System (Acoustic) Mk 1

##### Sonar - Type 193

The prototype equipment in H.M.S. SHOULTON has continued to give good results although some components which have been fitted for four years are showing need for replacement.

2. The first production equipment is being fitted in H.M.S. KIRKLISTON due to complete conversion to a minehunter in October 1963 (see page 107).

3. The handbook for the equipment and "Instructions for Installation" have been produced in draft form.

##### Minehunting Plotting Table

4. The first production Mk 20 Plotting Table is to be supplied for fitting in H.M.S. KIRKLISTON due to complete conversion to minehunter by October 1963.

##### Mine Disposal Weapon

5. The redesigned bridge and fittings for towing the charge from the Gemini dinghy was supplied to H.M.S. SHOULTON and proved satisfactorily robust. A requirement was raised for a brake to be fitted to the winch to allow rapid free lowering of the charge instead of hand winding. A brake, designed to give a preset terminal velocity, did not prove satisfactory and a new design of brake with manual control has been made and tested and is being incorporated in the winch design. The stainless steel, screened towing cable has proved to be expensive in manufacture. Approval of the Radio Hazard Committee is being sought for use of a less expensive cable.

6. Ten charge cases suitable for inert filling have been completed. A further twenty cases coated internally for explosive filling are being made. Thirty safety and arming mechanisms have been made for trials. The transfer of a mine destruction charge from ship to dinghy during trials in rough weather is shown in Fig. 9 on the next page.

7. Means of reducing the underwater noise from the outboard motor of the Gemini dinghy have been investigated. Fairly simple modifications to exhaust and cooling water outlets have given a worthwhile reduction. A further four engines are being modified to check the results.

##### The Short Scope Buoy

8. Further trials to measure scope, endurance, visible range by day and night, and radar range, have given satisfactory results. Packaging and environmental and shock trials have been completed, a stronger cruciform support for the radar reflector has been designed by A.S.W.E. to A.U.W.E. requirements. This buoy completed trials in 1962 and was accepted for Service. Arrangements for production are in hand by D.W.U. It now appears that a different type of buoy will be required to meet the Staff Requirements for an



Fig. 9 Transfer of a Mine Destruction Charge from Ship to Dinghy.

Improved Standard Dan Buoy, which requires longer endurance but may have a greater scope than the Short Scoop Buoy (see page 41).

#### Remotely Controlled Vehicle for Mine Disposal

9. A Staff Target has been issued and investigations of possible control systems and propulsion systems have commenced. A Gemini dinghy has been operated under radio control and steered by differential propulsion using lash-up arrangements to provide the initial "feel" of the problems of control.

#### Minehunting System (Magnetic) Mk 1

##### Gradiometer

10. The gradiometer and recording system is in service in H.M.S. BRONINGTON and H.M.S. BRINKLEY.

##### Mine Position Marker

11. After a repeat proving trial carried out in June 1962 the Mine Position Marker was not accepted for service because:-

- (a) marker buoys dipped and dragged in tide speeds less than those specified;
- (b) explosive cutters were not completely reliable;

- (c) conductors broke internally within the armoured cable;
- (d) markers did not always stream correctly.

Action is in hand on defects (a), (b) and (c). Defect (d) has been overcome.

12. Proposals for an alternative design of marker and with different Agreed Characteristics, were investigated but it was decided that first priority should go to clearing outstanding problems on the existing design. The marker requirements are being reconsidered for the 1970 M.C.M. Vessels, and for those Conversion Minehunters which will also be fitted with both the Acoustic and Magnetic Systems, with the possibility in mind of using the Mine Disposal Weapon to attack targets detected with the magnetic system.

#### Mine Splash Simulator

13. The design incorporating self-sinking arrangements was completed and single units were tested satisfactorily. There has been considerable delay in getting sufficient samples from the firm for Acceptance Trials.

#### 4.2 - MINE SWEEPING

##### Unified Acoustic Sweep - OSBORN Phase B<sup>x</sup>

14. Development of electro-hydraulic mechanisms to drive both the Audio Frequency and Low Frequency sound sources has continued.

##### Audio-Frequency System

15. The Dowty Rotol A.F. System was installed in an OSBORN body in mid-1962

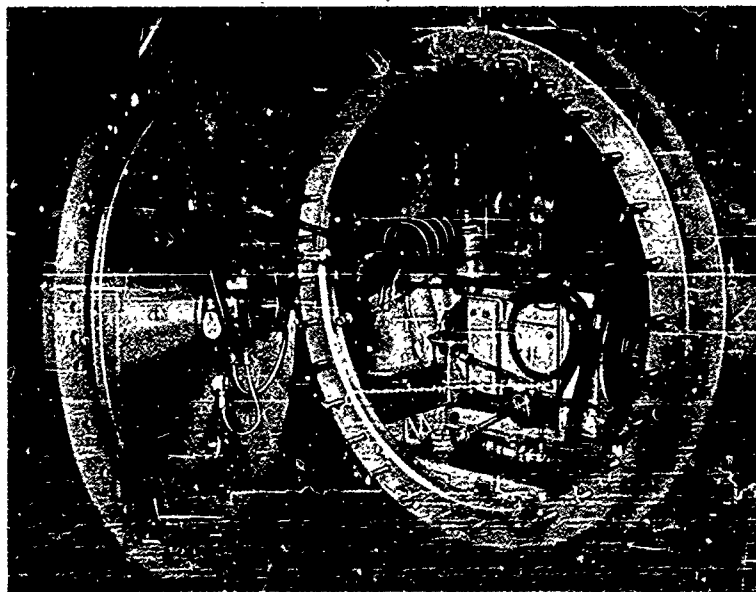


Fig. 10 The A.F. Unit in OSBORN Phase B<sup>x</sup>.

and is shown in Fig. 10 on the previous page. A sound output of 5,000 microbars octave level measured at a distance of 6 ft, was achieved over a frequency range of 40 c/s to 450 c/s. This represents an extension in the upper frequency beyond 240 c/s required by the Agreed Characteristics. Between 40 c/s and 30 c/s, the level fell below the target level to 3,800 microbars approximately, and this is under investigation.

16. The reliability of the experimental system to date is good. Some 150 hours running has been achieved with excellent repeatability of response without adjustment of settings.

#### Low Frequency System

17. An experimental unit has been constructed and installed, as shown in Fig. 11, in the central part of the OSBORN body. Laboratory trials were satisfactory and experiments are in hand to measure the sound output in water over the designed range of 8 c/s to 30 c/s.

#### Electrical Control Panel and Strain Cable

18. An experimental control panel, built at Cottage Laboratories, has been installed in H. I. S. GLASSERTON. This controls the L.F. and A.F. systems, and provides indications of depth and roll of the OSBORN body, and indications of the hydraulic system performance. Trials have been satisfactory and design of a prototype panel is under way.

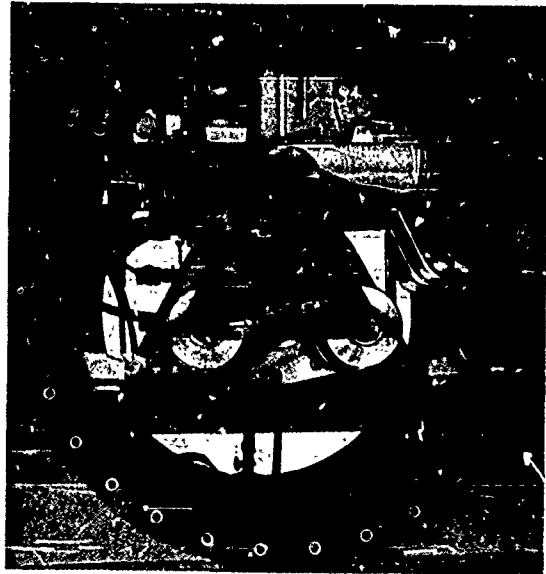


Fig. 11 The L.F. Unit in OSBORN Phase B<sup>x</sup>.

19. The multicore strain cable for towing the OSBORN body also supplies power and control signals to the L.F. and A.F. systems. Improvements have been made in the arrangements for securing the cable to the body. A further improvement in the cable design to increase its endurance is now contemplated.

#### Explosive Shock Trials

20. Two series of explosive shock trials against OSBORN bodies were carried out during the year to provide early data on the shock resistance of the L.F. and A.F. units. Encouraging results were obtained. During these trials a new buoyancy material for inclusion in the tail section was satisfactorily tested.

### Output Indicator

21. In order to distinguish between the sea bed monitor hydrophone, required for predicting acoustic propagation conditions, and the hydrophone to be mounted on the OSBORN body to give a continuous indication of the working of the sweep, the former device has retained the name Acoustic Monitor (see page 75) whilst the latter is now known as the OSBORN Output Indicator.

22. An experimental version of the Output Indicator was built during the year and is being fitted to the OSBORN body for trials.

### Interim Towed Acoustic Sweep

23. Ships of the 2nd Mine-sweeping Squadron fitted with this sweep, including modified Pipe Noisemakers, were ranged at Bexington. The resulting data on sweep performance is being analysed.

### Non-Magnetic Improved Standard Dan Buoy

24. A new development programme for the Improved Standard Dan Buoy has now to be arranged since it is no longer considered possible to use the float of the Short Scope Buoy for the Improved Standard Dan Buoy (see page 37).

### Magnetic Sweep for I.M.S. and C.M.S.

#### Sweep for I.M.S.

25. As the importance of the I.M.S. has declined, it has been agreed that further work should be limited to investigations of increased length of the ribbon tail, and to the fitting of P.N.M.'s on the legs of the sweep.

#### Sweep for C.M.S.

26. A buoyant cable of French manufacture using aluminium conductors completed about 150 hours endurance running but was then damaged by underwater obstruction and is being repaired. A new British aluminium cable using neoprene sheathing has become available. Four sweeps for endurance and handling trials will be made using this cable and incorporating a cadmium copper catenary cable which gave satisfactory results in tests during the year. Investigation of vulcanising techniques for cable joints has continued.

### Shipborne Swell Recorder

27. Acceptance trials on the sea unit, cable, and control unit took place in July and August 1962. Environmental and packaging trials have since been completed. The cable reel manufactured by D.G.S. was not satisfactory and is being modified. The swell recorder, less the cable reel, was accepted for service, and is in production.

### Acoustic Sweep Test Set

28. Production of 40 test sets is continuing. One prototype calibration machine of the new hydraulic type has been made and was satisfactory. Components for five further machines have been made, and are being assembled.

### Mine A Mk 12 Exercise Version

29. The design using a sodium phosphide filling, contained in Kilner Jars, was successfully tested, and has been accepted for service.

### 4.3 - CLEARANCE DIVING AND MINE INVESTIGATION

#### Shaped Charge Cutting Outfit (Explosive)

30. Following successful Inter Service Trials the Mine Cutting Outfit (Explosive) has now been adopted by the Army and R.A.F. and the equipment has been renamed the Shaped Charge Cutting Outfit (Explosive).

31. Trials have now confirmed that 0.25 inch thick steel mine cases of up to 30 inches diameter can be cut using curvilinear charges from this outfit.

#### Suction Clamp

32. Six suction clamps for securing a neutralising point charge on a mine case are being made for trials.

#### Radiographic Equipment for Mine Investigation

33. After further trials during the year the Mine Radiographic Outfit, complete with processing equipment, radiation monitor, etc., has been accepted for service.

#### Magnetic Mine Detector for Clearance Divers

34. The first two instruments have now been manufactured by a contractor, and trials will be carried out early in 1963. The contract has been extended to cover the manufacture of a third experimental model, to be followed by three units to prototype design. A contract has also been placed for the fibre-glass cases which will contain the instruments.

35. A non-magnetic headphone has been designed, and the first experimental model completed. This headphone is of the double-bimorph type, and uses lead titanate/zirconate elements.

#### Underwater Telephone for Clearance Divers

36. The performance of the commercially available AQUAVOX is close to that required and had been considered for R.N. use. The equipment had, however, a number of known failings, mainly the standard to which various parts have been engineered. It is now known that the manufacture of a new version of the Underwater Telephone engineered to service standards is being supported abroad. It is intended to purchase six sets for U.K. evaluation.

## SECTION 5 - INSTRUCTIONAL EQUIPMENT

### 5.1 - INITIAL DETECTION AND CLASSIFICATION TEACHERS

#### Type 177 Teacher A/S 1072

This project has reached the production stage. Two magnetic tape record/playback units were manufactured and one prototype playback unit; the two recorders are being used in conjunction with a Type 177 installation in H.M.S. VERNON, to monitor the recordings obtained from sea trials and to prepare master tapes. The playback unit (see Fig. 12) only will be issued to ships. An additional unit providing a stabilised 60 cycle supply has been found to be necessary as the frequency stability of normal ships' supplies is well outside the acceptable limits for the playback units.

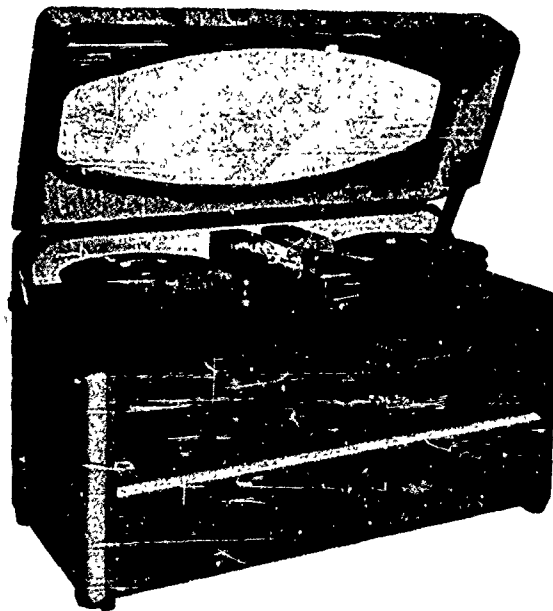


Fig. 12 Ten Channel Playback Unit.

#### Type 184 Teacher A/S 1078

2. It has been decided not to proceed with this Teacher as the provision of a Shipborne Command Trainer for Type 184 (see page 45) would practically satisfy the requirement for an I.D.C.T.

#### Type 195 Teacher A/S 1074

3. Development work has started on this project. It is proposed to use a 14-channel magnetic tape record/playback unit already developed by Messrs Solartron Limited for the Ministry of Aviation. The teacher will probably be shore based and will consist of a cabinet housing the playback unit, the associated electronics, power units and certain parts of Type 195



equipment, together with several Type 195 consoles. Tapes played on the unit will operate the displays and sonar effects at the pupils' positions, the Instructor being able to monitor through a closed intercom system. Recordings from which master tapes will be prepared will have to be made under operational conditions, and this involves siting a recorder in the helicopter in a suitable position and providing plug-in junction boxes and cables to break into the Type 195 circuits at the required points.

#### 5.2 - ANTI-SUBMARINE UNIVERSAL ATTACK TEACHER

4. The commitments of A.U.W.E. are virtually complete, the first A/S 1068E version, which caters for Types 170, 176 and 177, is being installed in trailer vehicles by D.G.W.(U), and will be tested and tuned by A.U.W.E. staff on completion. Production of equipment for the second A/S 1068E is proceeding satisfactorily.

#### 5.3 - TYPE 170 ATTACK TEACHER A/S 1071

5. Production of these teachers is in hand and the first three are being installed in trailer vehicles.

#### 5.4 - TYPE 187 MASS PROCEDURE TEACHER A/S 1073

6. This teacher is now in the production stage. The design is based on a one-pupil unit consisting of the Type 187 Sound Room equipment, and electronics cabinet, in which the synthetic effects are generated and an Instructor's Control Unit. To install a trainer to teach more than one pupil all these units are multiplied by the number concerned. The Instructor sets by hand the target's range, bearing and speed and with two other controls sets an automatic range and bearing rate. Aural effects and operation of the centre bearing meter (with indications of side lobes) are produced on the pupils console, these effects being controlled in strength, revolution count etc., by the settings on the Instructor's Control Unit (see Fig. 13).

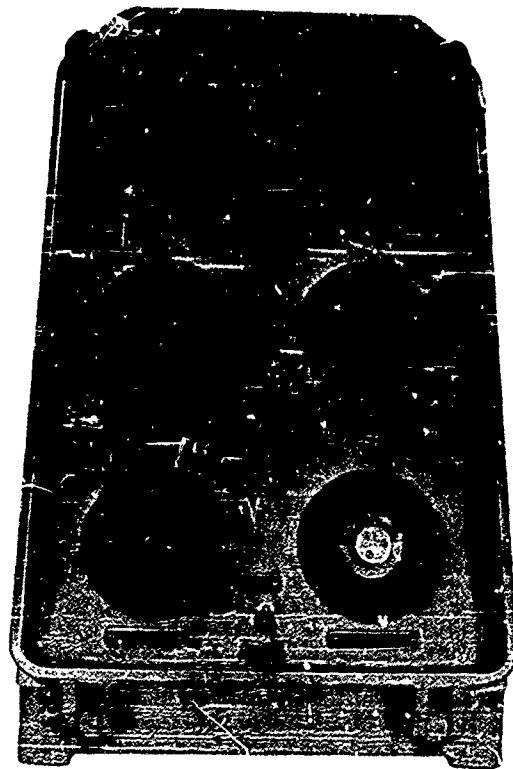


Fig. 13 Instructor's Control Unit.

#### 5.5 - TYPE 193 COMMAND TRAINER A/S 1076

7. A feasibility study has been completed of a Type 193 trainer aimed towards making use of the major components of an existing Radar Simulator. The proposed trainer would include the full Command control of the minehunter, effect of tide on the ship, position keeping on buoy, operation of dinghy and weapon analysis.

#### 5.6 - TYPE 170/177 AND 170/184 SHIPBORNE COMMAND TRAINER A/S 1077

8. A feasibility study has been completed for a Shipborne A/S Command Trainer for ships fitted with sonar Types 170 and 177 or with Types 170 and 184. When at sea a synthetic submarine echo will be injected into the sonar sets while they are working under normal conditions. With the ship in harbour the sonar sets will not be able to transmit, therefore a synthetic background, reverberations etc. will be provided; this condition will also require synthetic ship's motion.

9. Target speed, course, depth and dive angle will be set manually, but it is proposed to employ analogue computing techniques to generate rates of change of vessel co-ordinates in response to external manual settings of ship's speed and helm (from own ship's motion when at sea or synthetic control unit when in harbour). These rates of change would then be converted into pulse frequencies, by means of precision voltage/frequency converters, from which range and bearing information would be derived in digital form by counting pulses. This information would be used to control the sonar effects by a digital computer described in the next section.

10. It is proposed to simulate the aiming and firing of a torpedo (either free running or guided) from the submarine, the control of a simulated MATCH System, and of the Mortar Control System Mk 10, and to incorporate facilities for future weapons, e.g. guided missiles. Analysis of the weapon attack will be available. It is hoped to house the system in one cabinet which will be in the Sonar Control Room, with the addition of two smaller units in the Operations Room to provide remote controls for the submarine, helicopter, etc.

11. More detailed design studies have been made in A.U.W.E. but development contracts for the Trainer cannot yet be placed as financial approval is awaited.

#### 5.7 - TYPE 170/184 SHORE BASED COMMAND TRAINER A/S 1079

12. The requirement is to develop a system which is capable of providing training through several stages, from simple Sonar Control Room operations to the more advanced training for both Operators and Commands using more than one ship. As a result of feasibility studies it would appear to be more economical in development time and production costs to provide a digital computer with sufficient capacity in the single ship trainer already described to allow for the addition of two ships and other advanced requirements.

13. The system proposed would be based on a fast digital computer, with a stored programme, using well established techniques. Information which exists in the sonar sets in analogue form, shaft rotations, etc. would be converted to binary code. The computer would scan the inputs at regular intervals and transfer this information to the store, for use by the programme performing

the calculations when required. Calculations made in the computer would control the sonar displays. Instructor's Console instruments and true motion plot. The sonar effects would be generated in peripheral equipment designed for each type of set.

14. The system would provide for a single-ship or two-ship Command Trainer requirement, the two arrangements differing in the quantity of input/output peripheral equipment required, but all basically common units. Incorporation of new developments in sonar and weapons would mean reprogramming the computer and the addition of new peripheral equipment, the basic units remaining the same.

15. As sonar effects should be as realistic as possible, the inclusion of such features as wake echoes, temperature gradients, tide effects etc. are being considered in the studies.

16. The next phase in this programme is to complete a detailed design/project study for which contracts are being placed.

#### 5.8 - TYPE 195 HELICOPTER A/S TRAINER

17. The proposed system will provide for training on one, two or three helicopters attacking a single submarine target, with weapon simulation and the full search facilities of the Type 195 sonar. Helicopter movements conforming to true flight characteristics and other desirable features are being considered in the project study. The requirements of this trainer are so nearly identical with the A/S 1079 Command Trainer (see page 45) with the exception of the peripheral equipment associated with Type 195, that it is proposed to develop the two trainers in parallel, using the same basic building bricks.

#### 5.9 - SUBMARINE DEPOT SHIP TORPEDO ATTACK TEACHER

18. The submarine depot ship Torpedo Attack Teacher, Mk 2, was installed in H.M.S. MAIDSTONE early in 1962 and harbour acceptance trials carried out in May 1962. With the exception of a few minor defects, which were subsequently rectified, the trial was successful and the equipment accepted for service use. Apart from one minor fault on the 15-channel data recorder, the teacher has functioned satisfactorily during the last nine months (see page 27).

19. The teacher for H.M.S. FORTH will be a similar system to that installed in H.M.S. MAIDSTONE, but will now incorporate T.C.S.S. 6 and 8 training facilities. Manufacture is underway and the system will be assembled, tuned and shore-tested prior to assembly in H.M.S. FORTH in January 1964.

20. The teacher for H.M.S. DOLPHIN will also incorporate T.C.S. 6 and 8 training facilities and, in addition, certain design changes affecting the model ship track and display unit have been incorporated. A target/escort display and control unit with range and bearing attachment will also be provided. Working models are being made to prove the new design arrangements and it is expected that these will be ready for approval in April 1963.

## SECTION 6 -- RESEARCH

### 6.1 - TORPEDO RESEARCH PROGRAMME

#### Introduction

The period under review corresponds roughly to the first year of the joint A.R.L./A.U.W.E. torpedo research programme which has been planned on a five-year basis.

#### Propulsion

##### Propulsion System Development

2. The major effort on propulsion is currently being devoted to an experimental study of one particular torpedo propulsion system which holds out promise of good performance at depth. This is a direct cycle system with isolation of the power plant from the pressure prevailing at the depth of operation. The system is based on the propellants combination H.T.P. and P.P.S. (phosphorus/phosphorus sesquisulphide) the exhaust products of which are in the main either condensable or soluble. Thus the exhaust isolation problem is essentially one of pumping liquids overboard: since this can be achieved without an excessive expenditure of power, propulsive performance can be rendered almost independent of depth.

3. Particular emphasis is being laid on the development of a gas generator to provide the working fluid for prime mover operation. A specimen design of a gas generator is illustrated in Fig. 14. Gas generation has been reliably achieved at full scale. The required propellant flow rates, high combustion efficiency and a good admixture of a water diluent in the combustion product

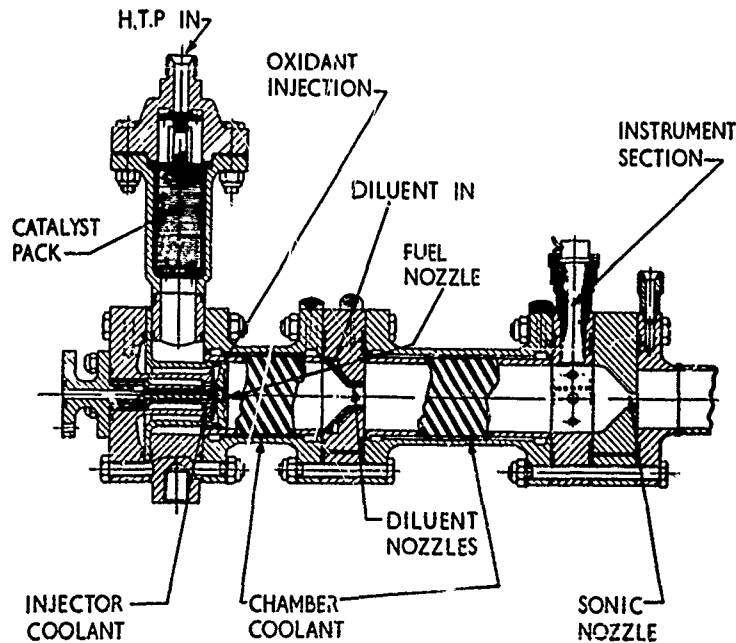


Fig. 14 Working Fluid Generator EX.5.

have all been obtained. The latter is required to provide an acceptable temperature condition for admission to the prime mover.

4. Whilst the mechanics of a gas generator design have been established, the working fluid generation has up to now been accompanied by severe attacks on material from a combination of corrosion and erosion associated, it is believed, with a solid or liquid acid formation from the phosphorus pentoxide component of the combustion product. It has also been observed that parts of the gas generator may be attacked by sulphur but this effect may not be serious in the very short operating times required in the application. Accordingly the test programme is being urgently directed to investigating means of suppressing the acid formation in the working fluid and to seeking materials of construction, particularly for the prime mover, able to withstand the extremely arduous conditions.

5. Two parallel prime mover developments are being pursued for operation with the propellant system. The first is a multiple-lobed cam plate piston engine. Design data on the load transmission structure of this type of engine have been obtained from operation of an experimental unit rated at 30 H.P. On the basis of these data two different full scale engine designs have been completed and manufacture is well advanced. The first of these is intended to provide performance data and to establish the feasibility of operation with H.T.P./P.P.S., having regard to the possible nature of the working fluid. The second is intended to provide confirmation of mechanical design with respect to the power, weight and space requirements of a propulsion system installation in a test vehicle.

6. The second prime mover development is a high speed, single stage impulse turbine engine with speed reduction gear transmission. Detailed design of the power plant is complete, but manufacture is being held awaiting the outcome of the materials evaluation programme which is in hand.

7. Component procurement is in hand for the test facility for development of the exhaust isolation and disposal unit of the propulsion system. Two forms of exhaust disposal have been studied, a high pressure water driven jet ejector unit and a jet condenser with positive displacement pump. The former is thought to be the more promising line of approach because it offers a simplification of the propulsion system and tolerance of transient off-design combustion conditions. Further such a system might be arranged to accommodate a high permanent gas content in the working fluid and so allow greater freedom in the choice of propellants combination. Detailed design is proceeding of a series of water driven jet ejector units for experimental evaluation.

8. Work has commenced on the overall design of the first stage propulsion test vehicle. This is primarily intended to provide early in-water operating experience with the H.T.P./P.P.S. combination. The propulsion system will be of very simple form with pressurisation of the propellants and direct prime mover exhaust discharge.

9. Design studies are proceeding, at present at low priority, of alternative propulsion systems for the attainment of high automobile performance with substantial independence of operating depth. A simple direct cycle system, using a very high pressure piston engine power plant, appears promising and a design development of the multiple-lobed cam plate piston engine referred to above has been put in hand to allow experimental evaluation of the system.

Study of an indirect closed cycle system has now reached the stage where experimental investigation of certain problem areas is necessary and component design to allow this is proceeding.

### Fuels

10. P.P.S. fuel, consisting of 70% phosphorus and 30% phosphorus sesqui-sulphide, has been manufactured in a crude form and some of its physical and chemical properties investigated. As the fuel ignites in air all handling and transfer operations are done under water, and initial difficulties due to the formation of a scum at the interface between the P.P.S. and the water have been overcome by the addition of potassium metabisulphite to the water.

11. Compatibility tests of materials in contact with P.P.S. over a six month period have indicated that stainless steel, titanium alloys, nickel alloys and pure aluminium, are suitably resistant at 60°C. Suitable plastics are P.T.F.E., polythene and polystyrene. No completely suitable elastomer has yet been found.

12. The physical properties which have been investigated are freezing point, density, vapour pressure, specific heat and viscosity.

### Metallurgy

13. In view of the almost complete absence of reliable data on the corrosion resistance of materials to the products of combustion of P.P.S. with H.T.P., a qualitative survey has been carried out using, in particular, a simple tube furnace containing the sample at the test temperature down which mixed acids of appropriate composition were allowed to flow. Corrosion was measured by weight change after a standard time, usually one hour, and by metallographical examination. Temperatures of 60°C, 220°C, 700°C and 1,000°C were used, corresponding roughly to condenser exhaust, condenser inlet, turbine inlet and combustion chamber respectively. In view of the known susceptibility of nickel-base alloys to grain boundary attack by sulphur compounds several nickel-free materials were tested as well as conventional high temperature materials. A selection of the results is given in the table below in which the loss in weight of the various metals is expressed in grams per sq. cm. per hour:-

Metal	60°C	220°C	700°C	1,000°C
Mild Steel	.009	2.3	1.1	0.85
Stainless Steel En 58J	.001	2.0	.19	.21
Aluminium Bronze E.S.1400-AB2	.0008	.4	.02	
Aluminium 25% Si	.3	1.0		
Titanium Alloy 318A	.6	20		
Monel	.0001	.035	.003	3 (estim.)
Corronel B	.003	.02	.002	
Nimonic 90		.07	0.28	
Hastelloy		.002	.04	
Molybdenum				.010
Silicon Nitride (AML245/12)			.006 (gain)	

14. From this work materials were selected for combustion rig construction. It was found that, whilst the combustion chamber conditions were much more severe than in the tube furnace so that metal removal rates of 0.001 inch per second were suffered, the materials were still in the same order of resistance. The tube furnace is now used only for initial assessment of prospective coatings and other new materials.

15. The only material so far tested which showed no attack at all in the tube furnace was vitreous carbon, but this material is not yet in production. Silicon nitride and molybdenum showed most promise of the other materials tested.

#### Fuel Cells

16. A survey of the present state of development of fuel cells has been completed and is being published. Most research on this topic is directed towards applications where relatively low electrical outputs are required over a long period, and under these conditions a high overall conversion efficiency of chemical to electrical energy is achieved. However, increasing the power density of the fuel cell will decrease its efficiency to a level where it is no longer attractive. In addition, the number of fuel and oxidant combinations that can be used is severely limited by the rate of the appropriate reactions at suitable electrodes. The system using hydrogen as fuel with oxygen as the oxidant has shown most promise for long term applications, but the inactive electrodes must have a high porosity to provide a suitably large area for the electrode reaction. This results in a very bulky cell and hence a low power density. An assessment of hydrogen/oxygen fuel cells for torpedo propulsion, allowing for storage of reactants in pressure vessels, shows that for a duration of less than 1 to  $\frac{1}{2}$  hours zinc/silver oxide batteries provide a lighter and more compact source.

17. A more promising approach would be a fuel cell with a consumable anode, and using a cathode depolariser (or oxidant) dissolved in a circulating electrolyte. Advantage can be taken of the extremely rapid electrode reaction of halogens on a film of precious metal to construct duplex electrodes that could then be made into a very compact battery. From initial calculations it would appear that a battery superior to zinc/silver oxide is possible, and further theoretical study of suitable systems is planned.

#### Torpedo Homing Research

##### Torpedo Simulator

18. Much of the available effort during the past year has been devoted to the construction of a three dimensional torpedo simulator. This consists essentially of a general purpose analogue computer and special purpose electronic equipment in which are generated the signals needed in simulating the torpedo homing acoustics. The simulator will be used as a tool for the study of alternative search and homing systems.

19. The proposed method of operation is as follows. The torpedo search pattern and target motion are set up on the computer. Calculations are made continuously of the amplitude and time of arrival of target echo and boundary reverberations and amplitude of volume reverberations. The special purpose equipment, which is under the control of the computer, generates separately signals representing each of these quantities correctly scaled in magnitude.

This combined output is passed to a circuit representing the torpedo signal processing and this circuit is used to determine whether or not the target echo is detectable against the background of noise plus reverberation. When once an echo is detected a circuit representative of the torpedo "logic" checks whether consistent detection occurs in one or two subsequent pings. When satisfied that this is so, the logic circuit informs the computer programme that the torpedo has acquired its target and the search trajectory must cease. The signal processing circuit now extracts target angle information (in azimuth and elevation) from the target echo and feeds it into that part of the computer programme simulating torpedo control and dynamics. Results obtained from a number of runs representing different target courses and speeds and different initial torpedo positions can be used to make a good assessment of the likely performance of the search and homing system under study.

20. A view of the Torpedo Simulator laboratory is shown in Fig. 15. A general purpose analogue computer consisting of two PACE 231R computer units has been installed. The special purpose equipment consists of a number of units known as target echo generators and reverberation generators. One set of such units is required for each transducer beam being simulated.

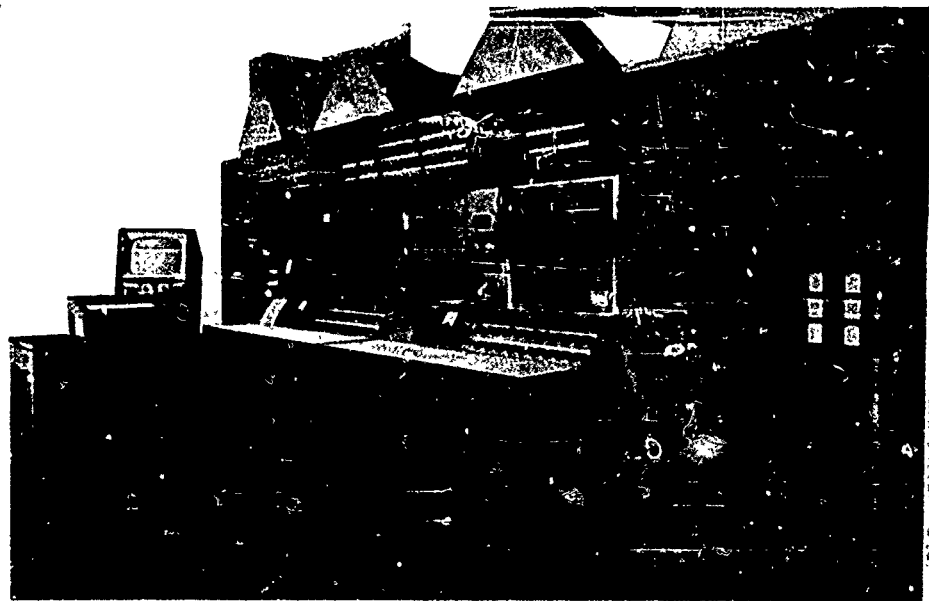


Fig. 15 Torpedo Simulator Laboratory.

21. In the simplest form the target echo generator creates a CW pulse (at any required frequency from 2 to 100 kc/s) suitably delayed in time by an interval equal to the time taken for the sound to travel to the target and back to the torpedo. Pulses in the several beams are phase delayed with respect to one another by an amount appropriate to the target bearing.

22. The reverberation signals are generated by passing white noise through a very narrow band filter ( $Q$  of the order of 5,000) and applying a T.V.G. control to the output amplitude. Three generators are required per beam, one for surface reverberation, one for bottom and one for volume reverberation.



Separate T.V.G. controls are used in order that each reverberation signal level will decay with time in the appropriate manner.

23. Design of the special purpose equipment is nearing completion and a typical C.R.O. trace of the final combination of target echo signal, surface and volume reverberation components is shown in Fig. 16.

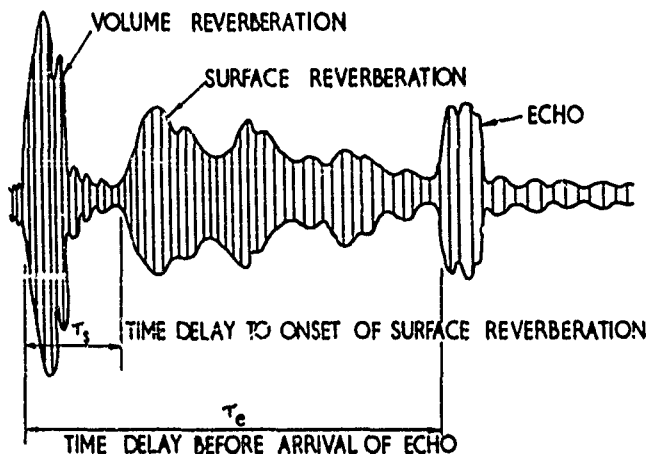


Fig. 16 A Typical Simulated Echo/Reverberation Trace.

24. The task of programming the computer for the investigation of torpedo search procedures is in hand.

#### Transducer Beam Patterns

25. While simulator studies may show that certain transducer beam patterns have special merits, the important problem still remains of achieving them in practice. As a start on this problem measurements have been made of beam patterns of a number of simple combinations of transducer elements on a flat torpedo head. Results have shown a significant disagreement with theoretical predictions of beam patterns using standard prediction methods which assume that the transducers are embedded in a baffle of infinite extent. It is thought that the discrepancy is due, at least in part, to a finite baffle effect.

#### Torpedo Hydrodynamics Noise

##### Flow Noise

26. There is good reason to suppose that, at the speeds required of future homing torpedoes, the noise background against which targets have to be detected in noise limiting conditions will be predominantly flow noise. Considerable effort is being devoted to the design and development of equipment and instrumentation for torpedo flow noise investigations, both in the laboratory and at sea.

27. The design of equipment necessary to investigate, under laboratory conditions, the effects of speed and body surface state on both the direct and

radiated components of flow noise over the frequency range 2 to 70 kc/s is complete. It is proposed to conduct laminar and transitional flow regime studies on a rotating disc assembly and turbulent flow regime studies on this and a rotating cylinder assembly. Manufacture of the first of the engineered equipments, namely the rotating cylinder, is nearing completion. An extensive series of experiments is being planned.

28. An attempt is being made to develop a laboratory technique designed to investigate the effect of different head shapes on the diffraction of noise generated downstream from the head of a torpedo body. Difficulty has been experienced in obtaining a suitable omni-directional source.

29. Considerable progress has been made with the development of a flow noise test vehicle, based on the ONGAR design, which will be used in a full scale check of self noise levels as predicted from the laboratory experiments. A sketch of the proposed test vehicle with the salient features detailed is shown in Fig. 17. The nominal values of all-up weight and displacement will be 1,700 lb and 1,750 lb respectively. The vehicle is to be capable of bursts of speed up to 50 knots. The maximum operating depth will be 600 ft.

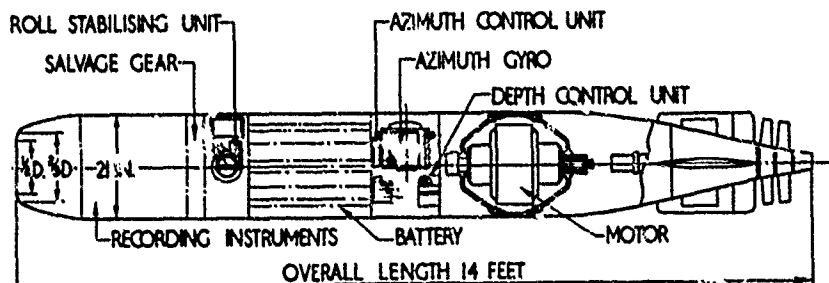


Fig. 17 Sketch of the Flow Noise Test Vehicle.

30. Analogue computer studies on the stability and control of the vehicle are in progress. Fig. 18 on the next page illustrates the response of the vehicle when commanded to dive to a preset depth of 400 ft, control being effected by the current ONGAR control system. In this system the vehicle is under pitch control only when within a preset depth bracket ( $2h_1$ ) of the nominal running depth, the elevators being operated in a "bang-zero-bang" mode. In addition, the pitch angle is limited to  $5^\circ$  when within another depth bracket  $2h_2$  ( $h_2 > h_1$ ) and to  $30^\circ$  outside this bracket, the elevators operating in a "bang-bang" mode when these limits are reached. Examination of the figure shows that sudden changes in depth can occur as the positively buoyant vehicle bounces along the top of the fixed depth bracket  $2h_1$ . This depth variation is not considered to be a desirable feature in a test vehicle designed for noise measurements in level flight and accordingly alternative control systems are being investigated.

31. Special noise measuring transducers of sensitivity  $5\mu V$  per microbar and 3,000 pF electrical capacity are to be used. To match these a broad-band, transistorised low noise amplifier has been developed. Preliminary tests results on the amplifier have indicated the following noise performance:-

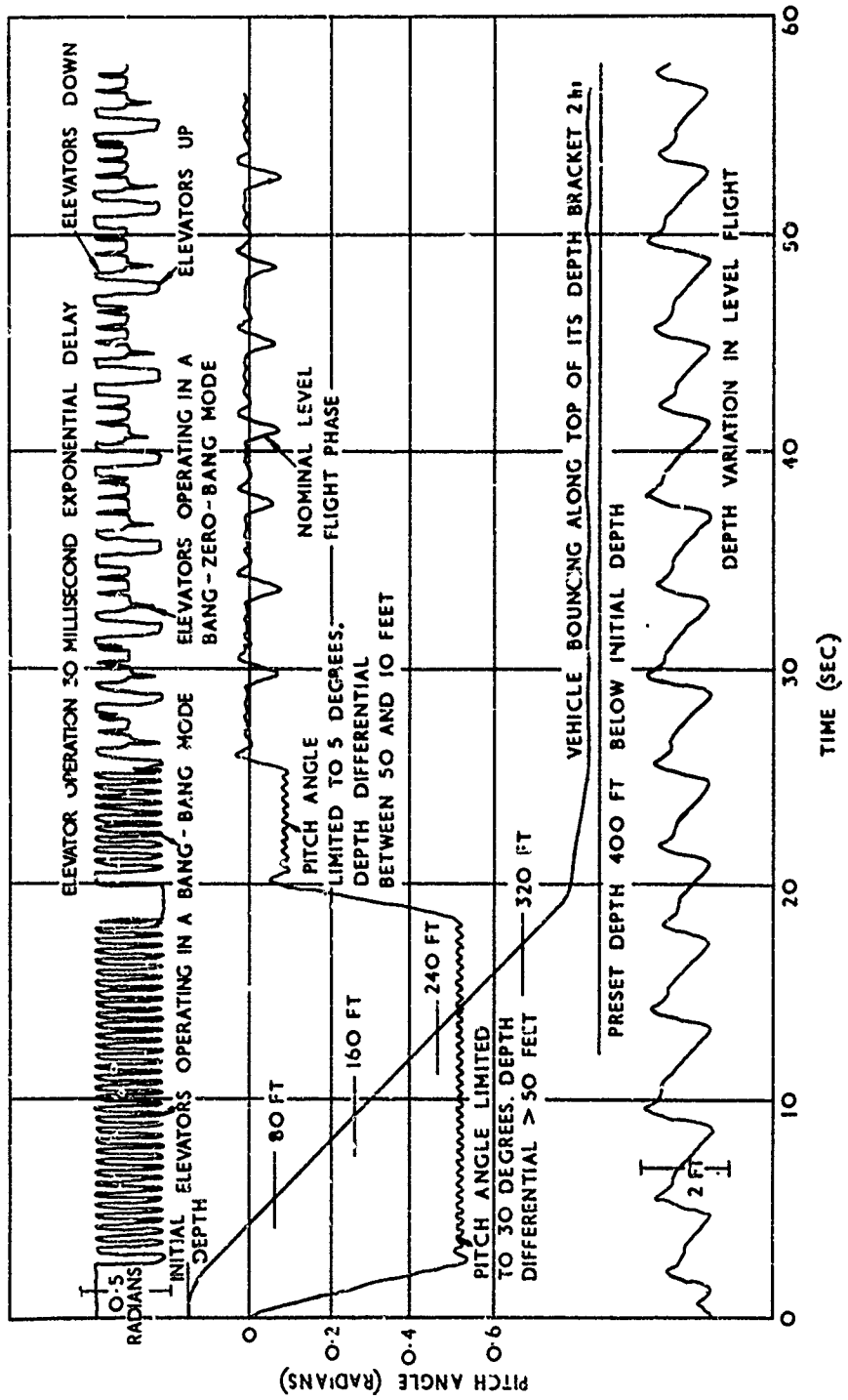


Fig. 18 Dynamic Response of Flow Noise Test Vehicle.

2 to 5 kc/s	3 dB above sea state 2
5 to 50 kc/s	Sea state 2
50 to 80 kc/s	3 dB above sea state 2

This has been achieved mainly by selection of low noise components and component layout.

### Torpedo Dynamics

#### Stability and Control

32. Studies have also been made on the hydrodynamic performance of a torpedo initially describing a vertical trajectory when commanded to pull out and describe level horizontal flight; such investigations are relevant to concept of a "vertical search" torpedo. Fig. 19 illustrates the response of a neutrally buoyant torpedo as a function of its hydrodynamic characteristics, control being effected by using a linear combination of pitch and depth to operate the elevators in a "bang-zero-bang" mode. In this figure, changes in hydrodynamic design are represented by different values of the so-called "margin of stability" which is a function of the hydrodynamic deviations of the torpedo. For normal torpedo configurations it cannot much exceed unity. As the value decreases, the stability of the torpedo decreases and its manoeuvrability increases. The corresponding effect on the pull-out trajectories can be derived from Fig. 19.

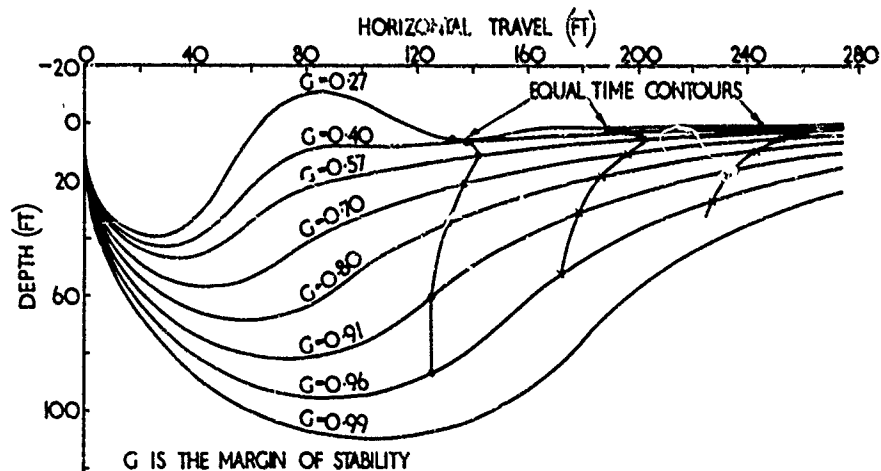


Fig. 19 Torpedo Trajectories.

### 6.2 - RESEARCH IN SUPPORT OF CURRENT TORPEDO DEVELOPMENT

#### Investigation of Silver Oxide/Zinc Couple

33. The rate of decomposition of silver dioxide increases with an increase of temperature. Tests to find the temperature dependence of the rate of decomposition have shown that a steady decomposition rate is not maintained at a fixed temperature, but that the rate of decomposition also increases with length of time in store. The rate of decomposition in the temperature range

30° to 50°C is initially quite slow, so that the increase in rate of decomposition with storage time was not noted in earlier tests of limited duration. At 100°C the rate of decomposition is considerably higher and the complete decomposition curve can be plotted in a relatively short period. Tests at this higher temperature indicate that silver dioxide has a sigmoidal shaped decomposition curve with an initial induction period with very little decomposition followed by a rapid speeding up of decomposition rate. The results available at lower temperatures can be extrapolated to longer periods by comparison with the shape of the decomposition curve at 100°C, and suggest that a loss of about 5 to 10% per annum may occur at 40°C. Further long term tests at lower temperatures are in progress to confirm this value and to find what limitations on storage temperature of silver/zinc batteries are required.

34. The amount of gas evolved when charged silver dioxide battery plates are wetted with KOH electrolyte has been measured, and the discharge characteristics of the plate noted. Long term storage of plates at 30°, 40° and 50°C has shown that the volume of gas evolved on wetting increases with storage time and is higher at the higher temperatures. The effect of an equivalent amount of gas liberated in the confined space of a cell is being investigated using silver dioxide plates that have been heat-treated at 70°C for one week to reproduce conditions equivalent to storage for one to two years at 40°C.

35. An investigation of the anodic dissolution of zinc in alkaline solutions has demonstrated the need to warm the silver oxide/zinc primary cells to prevent passivation of the zinc electrode at low temperatures. The effect of temperature, KOH electrolyte concentration, and zinc in solution on the anodic polarisation of a zinc electrode has been evaluated.

#### Silver/Oxide Zinc Secondary Cells for ONGAR

36. Single cell tests in the laboratory had shown that reservoir type silver oxide/zinc secondary cells gave over twenty charge/discharge cycles at a high rate of discharge and a relatively high charging rate. However, these cells have shown a high failure rate on the second or third cycle when assembled as a battery. The reason for the large difference in cycle life in a battery is being investigated, particularly the effect on cell life of the charging temperature and the pressure on the cell due to swelling of the separators when wetted. Tests at A.U.W.E. and at the firm have demonstrated that the temperature rises very steeply when the battery is overcharged, and with the present interleaved cell connectors it is not feasible to disconnect cells when they reach top of charge condition. It has been found that the time to top of charge varies greatly from cell to cell.

37. Excessive temperature rise of a battery caused by a high rate discharge has resulted in distortion of cell cases and rendered them inoperative. Extensive tests are being carried out to improve the heat dissipation from batteries and to minimise pressure build-up on individual cells.

#### Research on Weapon Hulls in Reinforced Plastics

38. The mechanical testing of the hull sections in glass reinforced plastics has continued. The first of the two hull sections manufactured with glass rovings-reinforced resin skins and rigid polyurethane foam core has been fitted with strain gauges and transducers and preliminary pressure tests carried out. With pressures up to 100 p.s.i. the deflection has been found to be

linear. Experiments on the water absorption of the glass rovings-reinforced resin skins have shown an absorption of 1 mg per sq. cm. after 12 weeks exposure at 43°C.

39. Two hull sections with fluted core construction replacing the polyurethane foam have been manufactured by Bristol Aeroplane Plastics Limited. These sections incorporate a glass reinforced plastics joint ring system and the weight of the first 4 ft long section with integral male joints has been reduced to 81.5 lb. The corresponding section in aluminium alloy weighs 100 lb.

### 6.3 - MEASURES TO IMPROVE SONAR PERFORMANCE

#### Propagation Research

40. The five-year programme of propagation research is now well under way. A body of data has been collected from one-way propagation measurements using simple (omni-directional) equipment and progress has been made in deriving some first-order statistics (principally mean bottom reflection loss) from the data. This introductory experimental study was virtually complete by Spring 1962, and is Phase I of the research programme.

41. Current effort is concentrated on the extension of these one-way propagation measurements to the measurement of second-order statistics (fluctuations, correlation between separated receivers, etc.). For this work more sophisticated equipment (directional line hydrophone arrays, high fidelity tape recorders and correlation analysis equipment) has had to be obtained. Preliminary trials to prove the equipment were started in July 1962; the results are now being evaluated.

42. The continuation of work beyond Phase II will be concerned mainly with topics involving two-way propagation, such as reverberation and target echo studies. This will constitute Phase III.

#### Bottom Reflected Sound

43. Effort has been largely devoted to the development of the line hydrophone array, recording system and correlation processing equipment required for the study of secondary characteristics of sound fields in connection with Phase II. The receiving array, which is 16 ft long and contains 42 hydrophone elements, is shown in Fig. 20. It is pivoted about the centre point so that it can be used in either the vertical or horizontal position.

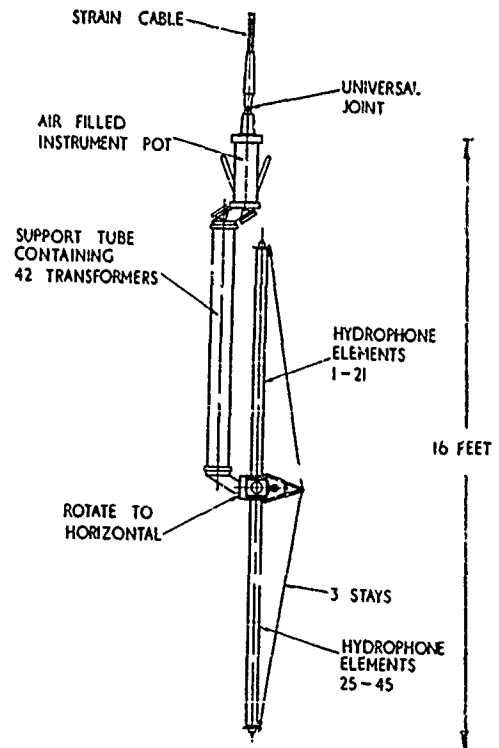


Fig. 20 A Multi-Element Hydrophone Array.

44. Sea trials were conducted in July in the Atlantic and in October in the Mediterranean to evaluate the array and recording system under a variety of environmental conditions. Useful data at a frequency of 3.6 kc/s were obtained on the spatial characteristics of sound transmitted by the surface duct, via the bottom, and along the axis of the deep sound channel. The channel, at a depth of 400 ft in Mediterranean waters, is of easy access and is of interest in that reflections at the sea surface and bottom are not involved.

45. Development is nearly complete of a loop recorder delay unit and correlator for laboratory processing of pairs of recorded outputs from selected elements in the hydrophone array. An example of the signals received by elements in the array from the same transmission is shown in Fig. 21; as the signal amplifier gains were not the same, amplitudes should not be compared, but the variations in shape of the signals from elements spaced only 1.4 wavelengths apart are apparent. In this example, much of the variation is due to interference with the surface reflected wave. To avoid this complication it will be necessary to operate the array at greater depths than the 400 ft available in the trial, and so it is being modified to work at depths of 2,000 ft.

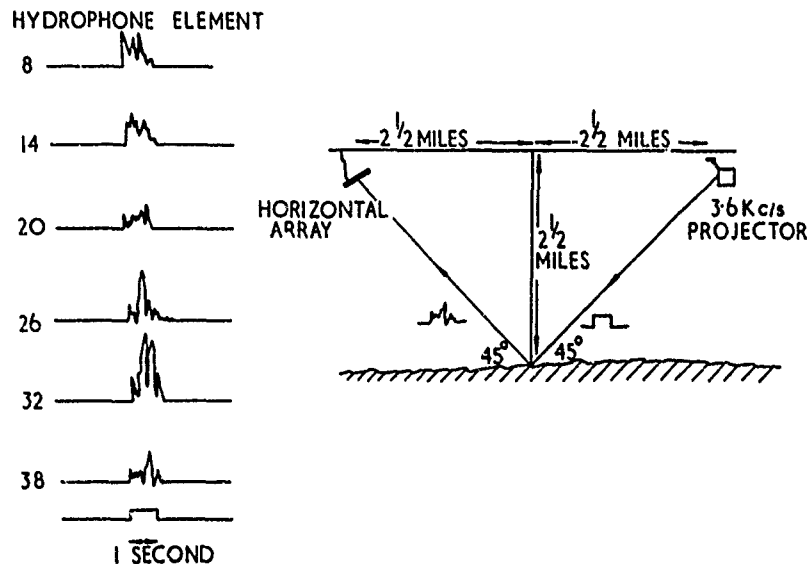


Fig. 21 Envelopes After Bottom Reflection.

Bottom Bounce Study (SUMMIT)

46. While the detailed mechanism of acoustic reflection from the bottom can be studied in particular areas by laboratory-type experiments using two ships and complex equipment, the investigation of the operational aspects of bottom bounce over extended areas require simpler measurements. For this purpose, Hydrographer has made available, full time, a survey ship in 1963 and 1964 to obtain statistical information on bottom loss data over the whole North Atlantic area, with associated oceanographic measurements.

47. This survey (SUMMIT) forms part of the NAVADO cruise (North Atlantic VIDAL and DALRYMPLE Oceanography), H.M.S. VIDAL and H.M.S. DALRYMPLE being the survey ships involved. The provisional track chart for the operation, involving some 70,000 miles of sounding lines, is shown in Fig. 22.

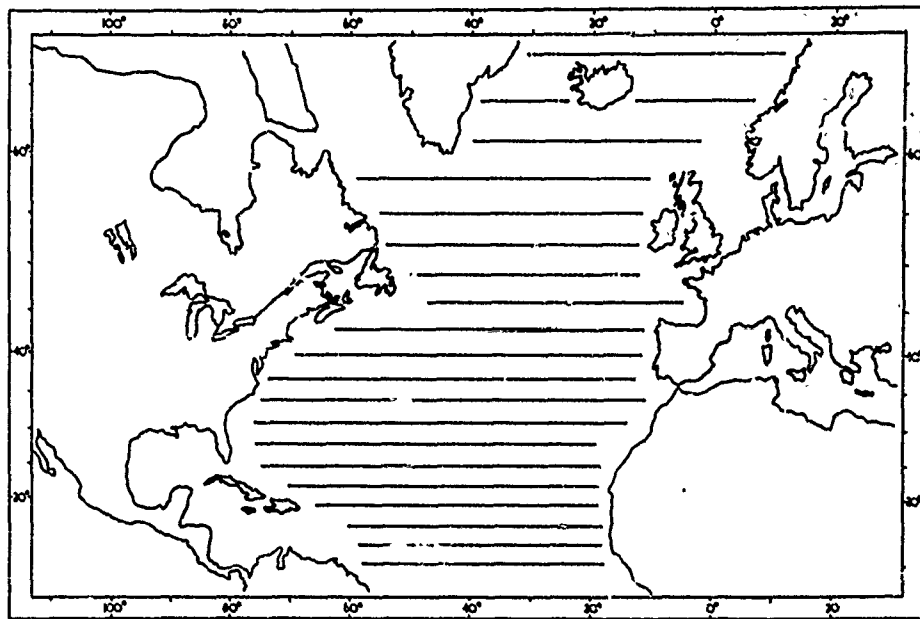


Fig. 22 Provisional Track Chart for NAVADO Cruise.

48. The system of measurement adopted uses a deep Echo Sounder (Type 773) to which is coupled a Precision Depth Recorder. The latter will provide precise depth records with a resolution of approximately 1 fathom for any depth. Associated equipment will measure the energy and peak pressure of the signal echo returns from the bottom.

49. From these measurements, with appropriate ancillary data, estimates for bottom loss at each vertical reflection can be made. In selected areas it is hoped to use a helicopter with explosive charges to supplement the observations by producing data over a range of frequencies and grazing angles as shown schematically in Fig. 23 on the next page.

50. Preparatory trials have been carried out over the last year using a Westrex Precision Graphic Recorder in conjunction with the 10 kc/s Type 773 Echo Sounder. The bottom reflection losses measured in these trials are compared with steep angle losses at 3.5 kc/s as measured by two-ship experiments in the Table below.



Area	Depth (fathoms)	Losses	
		Oblique (3.5 kc/s)	Vertical (10 kc/s)
SWALLOW BANK 14° 15' W 41° 08' N	2920	8 dB	12 dB
GALICIA BANK 11° 20' W 42° 43' N	1000	20 dB	22 dB
SOUTH OF TOULON 6° 30' E 42° 20' N	1500	9 dB	10 dB

51. These values are averages taken from several measurements in the areas tabulated. The correlation between the two sets of measurements is better than might have been expected. An interesting feature of these trials was that in these areas which have been charted in detail by oceanographers, the Precision Graphic Recorder was also used for accurate navigation.

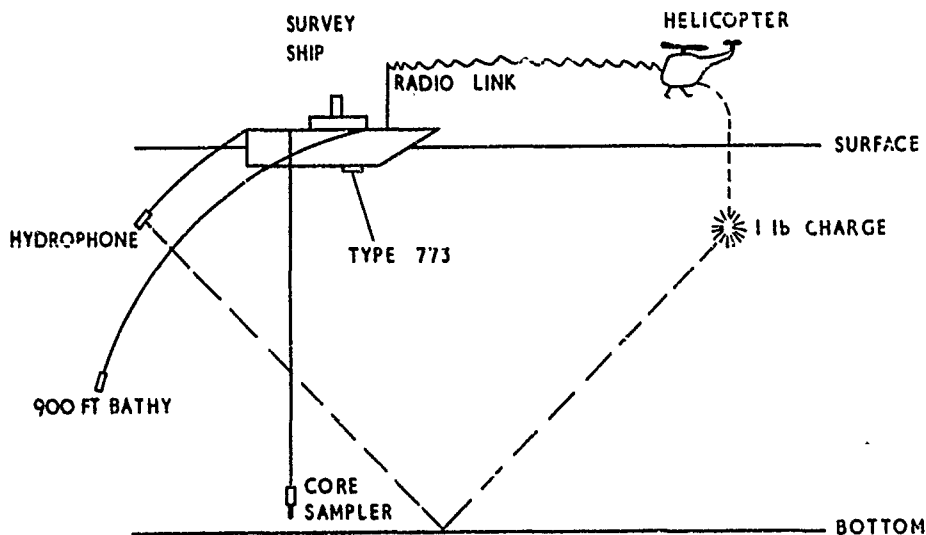


Fig. 23 SUMMIT Measurements with a Helicopter.

52. In the forthcoming survey it is planned to take bottom samples and, it is hoped, photographs of the bottom. Together these will indicate the nature of the bottom reflecting surface.

#### Surface Duct Propagation and Internal Waves

53. The effect of internal waves on surface duct propagation is of interest to the users of sonar equipment, and it has become apparent that insufficient

is known of the frequency of occurrence or of the magnitude of such waves to enable an estimate of the effect on sonar ranges to be made.

54. No effort is available for a full-scale study of this phenomenon, but the example in Fig. 24 shows a 100 ft variation of layer depth over a period of 1 hour. This was noted incidentally during a propagation trial in the South West Approaches.

55. It is of interest that this observation arose by chance during a period when bathy-thermograph dips were being taken at unusually frequent intervals. This emphasises the inadequacy of a single bathy-thermograph dip in a situation varying in both time and space.

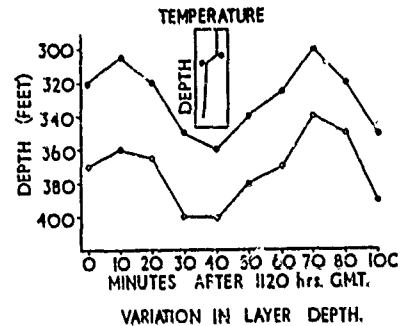


Fig. 24 Internal Waves.

#### Model Experiment in Bottom Reflection

56. The laboratory investigation into reflected sound from acoustically hard surfaces in air is temporarily in abeyance due to concentration of effort on preparations for Phase II of the propagation research programme.

#### Ray Tracing

57. The Ray Calculator has been in use for 18 months and is a valuable laboratory tool for computing and displaying sound refraction paths under specified oceanographic conditions.

58. An improved Ray Calculator, based upon the laboratory design, has been manufactured by R. B. Pullin Limited and is about to be installed as part of the computing facility in A.U.W.E. The main difference in performance between this calculator and its predecessor is that the maximum grazing angle at which rays may be launched has been increased from  $\pm 10^\circ$  to  $\pm 70^\circ$ .

59. Some theoretical work on ray tracing has been carried out. This has cleared up a number of sources of error, and given a basis on which more sophisticated computations may be made. When time permits, it is planned to produce a digital computer ray tracing programme which will include such useful features as calculations of intensity, effect of horizontal variation of velocity structure and effect of imperfect reflecting surfaces.

#### Oceanography in A/S Detection

60. The collection of temperature and salinity data from various international sources has continued, and has been of use in planning propagation trials. During the course of these trials serial observations were made so that the velocity structures computed from them could be used in analysis of the propagation data.

61. The Chief Officer of O.W.S. WEATHER SURVEYOR has been instructed in the use of the oceanographic equipment and observation of salinity, temperature and depth are now being made weekly while on station by the three weather ships

WEATHER ADVISER, WEATHER REPORTER and WEATHER SURVEYOR. It is expected that O.W.S. WEATHER MONITOR will be instructed and her programme of observation started in 1963. The data from these ships are being analysed but there is not yet sufficient for definite conclusions to be reached concerning temporal variations in the deep velocity structure in the Atlantic Ocean.

62. In April 1962, a N.I.O. Thermostat Salinity Meter, loaned by the Fisheries Laboratory, Lowestoft, was installed in A.U.W.E. Since then the salinities of water samples collected during propagation trials and by the Ocean Weather Ships, have been measured. It is hoped that further equipment, suitable for accurate salinity measurement aboard ship, will be available before the next propagation trial.

63. A device has been constructed to measure temperature and depth continuously to a depth of 500 metres, the results being displayed on a paper record. It has five temperature ranges,  $0^{\circ}\text{C}$  to  $10^{\circ}\text{C}$ ,  $0^{\circ}$  to  $20^{\circ}$ ,  $0^{\circ}$  to  $30^{\circ}$ ,  $10^{\circ}$  to  $20^{\circ}$  and  $10^{\circ}$  to  $30^{\circ}$ . No tests have yet been made at sea.

#### Echo Formation

64. In the "image pulse" theory of echo formation discrete echoes are formed whenever there is a mathematical discontinuity in the relation between the projected area of the echoing body and the distance from the source. This theory has been extended from the previously treated case of amplitude - modulated transmissions to deal with a more general form of modulation, embracing F.M. and noise transmissions, to deal with back scattering at small distances and with the bistatic as well as the monostatic case.

65. The same echo-formation process applies in these cases and irrespective of the type of modulation. Each directly backscattered echo component has the same form as the transmission.

#### 6.4 - EXPLOSIVE ECHO RANGING

66. In August 1961, A.U.W.E. in collaboration with Royal Aircraft Establishment, Farnborough, drafted an outline research programme to cover a period of 2½ years with the following terms of reference:-

To carry out acoustic research on Explosive Echo Ranging in shallow waters with the aim of drawing up a specification for an airborne sonobuoy system to meet the requirements of the part of Operational Requirement (OR) 3548 relating to active detection in shallow water, i.e. detection and localisation of a submerged submarine out to a range of 10 miles. In the execution of this task particular attention is to be paid to the problem of distinguishing between submarine and non-submarine echoes.

67. In addition to the facilities to be provided by A.U.W.E., it was foreseen that a sea-going research vessel would be needed for extended trials in areas other than Portland. The vessel was required to have adequate laboratory space, accommodation, equipment handling facilities and a high capacity battery supply for extended silent ship working. To meet this need modifications are being made to A.C.S. BULLFINCH.

68. Subject to Admiralty and D.R.P.C. approval this research programme should commence during 1963.

## 6.5 - TECHNIQUES TO IMPROVE THE DEFOY RESISTANCE OF GUIDED TORPEDOES

### Sea-Return Circuits

69. Work is continuing on the problem of reducing the attenuation of a single core wire with sea-return. Calculations show that there is an optimum amount of copper necessary to achieve minimum attenuation with a fixed overall size of wire. The amount of copper in use at present is well below this optimum, a worthwhile reduction in attenuation could be achieved by increasing the copper diameter from 0.018 inches to 0.022 inches.

70. In order to investigate the production problems associated with the manufacture of long lengths of wire with reduced insulation, Messrs British Insulated Callenders Cables Limited have manufactured a number of experimental lengths of wire with different types of insulation.

### Twin Circuits

71. The results of measurements made on the impedance balance to earth of flat twin wire show that the use of such a wire at frequencies as high as 20 kc/s is not justified if the length is greater than about 10,000 yd, unless a very large dispenser is used. The degree of impedance balance measured is comparable with that predicted by the manufacturers, i.e. of the order of one per cent.

### Dispensers

72. The attenuation of the wire in a fully or partially coiled state is difficult to predict. Measurements show that at high frequencies the attenuation of the present wire in the coiled state is usually less than that of a fully paid out wire. However, with the proposed lower loss wire, the attenuation in the coiled state may predominate if precautions are not taken.

73. The mechanism of attenuation in the coiled state is being investigated theoretically and methods of reducing it are being considered.

### Noise

74. A theoretical investigation of the likely magnitude of electromagnetic background noise induced in the guidance circuit has been made. It is hoped to confirm this theoretical work by measurements at sea.

## 6.6 - NOISE REDUCTION (INCLUDING FLOW NOISE)

### Flow Excited Noise

75. Two further trials with the buoyant body designed to elucidate flow noise problems in ships, have been performed in Loch Linnhe where the water depth is 400 ft. The semi-ellipsoidal nose was permanently bonded to the body for these tests, and there was therefore no possibility of entrapped air. It was found that with this arrangement there was no change of noise level with depth once the terminal velocity had been reached, see Fig. 25 on the next page. It has therefore been concluded that this effect which was shown in earlier trials was due to entrapped air at this joint.

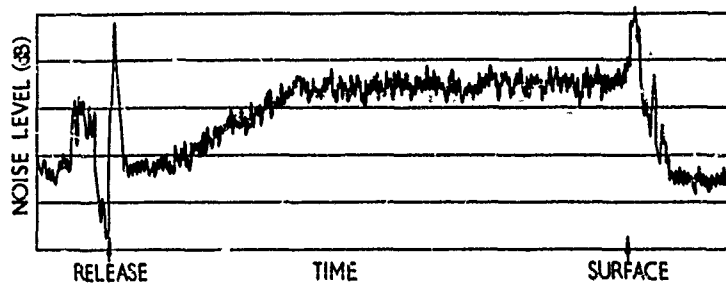


Fig. 25 Noise Pressure Level Versus Time for a Third-Octave Band Centred at 111 c/s.

76. Measurements of the spectrum level of the noise between 100 c/s and 10 kc/s have been made over the speed range 25 to 45 ft/sec. Spectrum level measurements have also been made on the body with its shell coated internally with an Aquapla damping material. Fig. 26 compares the spectrum level measurements on the damped and undamped body and also the wall acceleration levels measured with internal accelerometers. It will be seen that the damping material has a considerable effect on the vibration levels but no effect on the noise measured at the nose hydrophone. This appears to be good evidence for assuming that the wall vibrations do not contribute to the flow noise, but this should be concluded only with caution until more experiments have been made to determine the exact source of the noise. The variation of the noise with speed was found to be close to a power law over the whole frequency range. The values compare with the theoretical values, for pressure level fluctuations, of 9 dB at the lower frequencies and 18 dB at the higher frequencies.

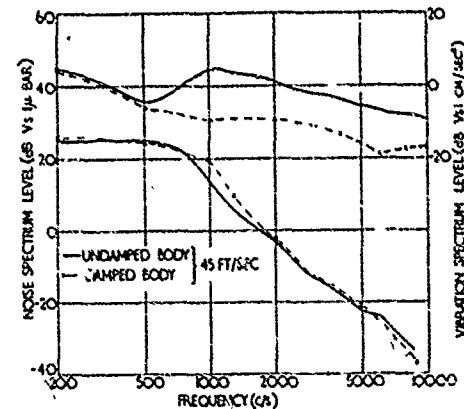


Fig. 26 Noise and Wall Acceleration Spectrum Levels Versus Frequency.

77. When the hydrophone is sited in the apex of the nose it is in a stagnation region and can therefore only receive noise by acoustic radiation from downstream. This means that the hydrophone is in a region of acoustic shadow and will receive noise only by a diffraction process which is frequency dependent.

78. This partially accounts for the very steep slope of the spectrum levels, about 15 dB per octave, above about 800 c/s. Subsidiary measurements were made of this diffraction by using a small noise source on the wall of the body. On the basis of the results of these tests the spectrum can be corrected for diffraction effects; when this is done the slope above about 800 c/s is close to 17 dB per octave.

79. The new buoyant body with an array of hydrophones around the nose and along the length of the cylindrical section is nearing completion. It incorporates multi-channel tape and pen recorders and facilities for boundary layer exploration using pitot-static tubes.

80. The contract work at Southampton University has been completed and a final report issued. Measurements in the 2 inch water tunnel were made of the r.m.s. pressure fluctuations, statistical amplitude distribution, longitudinal spatial correlations and of the effect of a step in the tube wall on the downstream pressure fluctuations. The general conclusion drawn from the work is that the results are in broad agreement with the more extensive measurements on turbulence in air tunnels.

Flow Noise - Amoeba

81. A hose-like cylinder of rubber, 30 ft long, filled with oil, and carrying a number of transducers distributed along its length - Amoeba - has been used for the purpose of obtaining flow noise data. A successful trial has been carried out with a 30 ft long transducer array towed deep in a 1,000 fathom site some 1,500 yd astern of a coastal minesweeper. The data from the trial are being analysed.

Self Noise in Surface Ships

82. A summary of self noise measurements taken in 1962 is shown in the table below.

Ship	Class	Purpose of Trial
H.M.S. ASHANTI	Type 81 A/S Frigate (1st of Class)	To compare self noise levels due to steam and gas propulsion and measure increase of noise from stabilisers in various conditions. Auxiliary machinery noise was examined.
H.M.S. VERULAM	Type 15 A/S Frigate	To measure self noise in a ship a long time out of dock. The Type 2001 Sonar dome was observed to shield the dome forward of it from direct radiated propeller noise.
H.M.S. URCHIN and VENUS	Type 15 A/S Frigates	To compare the degradation of Sonar performance due to self noise, over a period of 2 years out of dock, in two similar hull forms having different underwater finish. (3 trials in H.M.S. VENUS, 2 trials in H.M.S. URCHIN in 1962.)
H.M.S. LOWESTOFT and BERWICK	Type 12 A/S Frigates	To study the contribution to self noise from main and auxiliary machinery and take routine measurements up to 28 knots.
H.M.S. LONDONDEERY	Type 12 A/S Frigate	To measure self noise in double curvature glass-fibre domes fitted to hull outfit 15 and hull outfit 20.
H.M.S. LION	Tiger Class Cruiser	Routine self noise measurements. Change of noise level during evasive action was examined.

## Stabilisers

83. No substantial direct effect of stabilisers on self noise was measured in H.M.S. ASHANTI but consequent modification of the ship's sea-keeping behaviour could conceivably affect self noise in bad weather.

## Machinery Noise in H.M.S. BERWICK and H.M.S. LOWESTOFT

84. H.M.S. BERWICK was found to be exceptionally quiet in the standard sonar bands even though machinery noise was excessive at lower frequencies. Her sister ship H.M.S. LOWESTOFT did not show this excessive L.F. noise.

85. Further trials in H.M.S. BERWICK are desirable in which auxiliary power may be obtained from shore supplies, to carry out "on/off" measurements of the noise contributed by individual machines.

## Relationship between Hull Vibration in Vicinity of Domes and Self Noise

86. During the first-of-class noise trials carried out in H.M.S. ASHANTI, measurements of hull vibration in the vicinity of the domes were made to determine whether, and over what speed range, vibration of the hull is a significant contributor to self noise.

87. Fig. 27 compares the hull vibration levels in the octave 4.8 to 9.6 kc/s near the Hull Outfit 20 dome with self noise levels at 6 kc/s in Hull Outfit 20 for a range of ship speeds. Above a speed of 15 knots a factor other than hull vibration dominates self noise levels. Below 15 knots the form of the curves indicate that it is possible that noise due to vibration of hull plating, both flow and machinery induced, is a significant contributor to self noise.

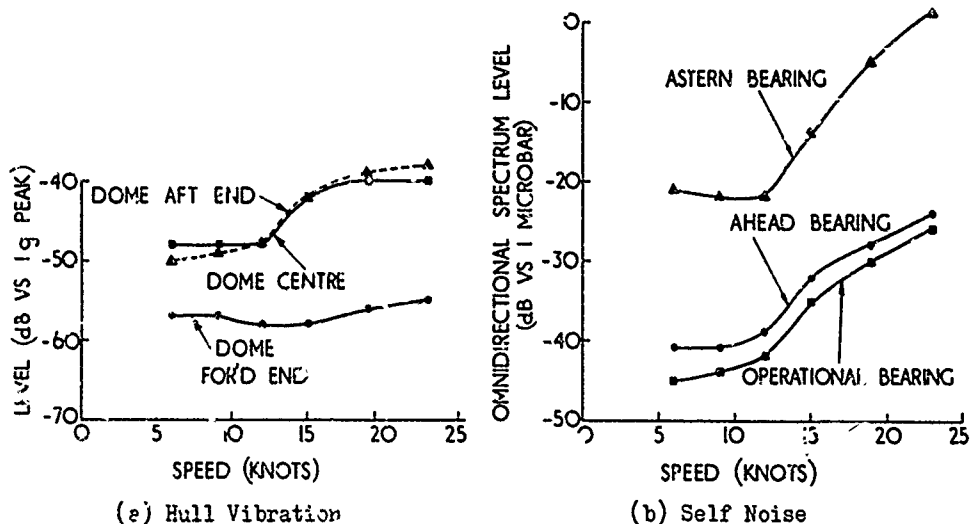


Fig. 27 Comparison of Hull Vibration and Self Noise Levels in H.M.S. ASHANTI.

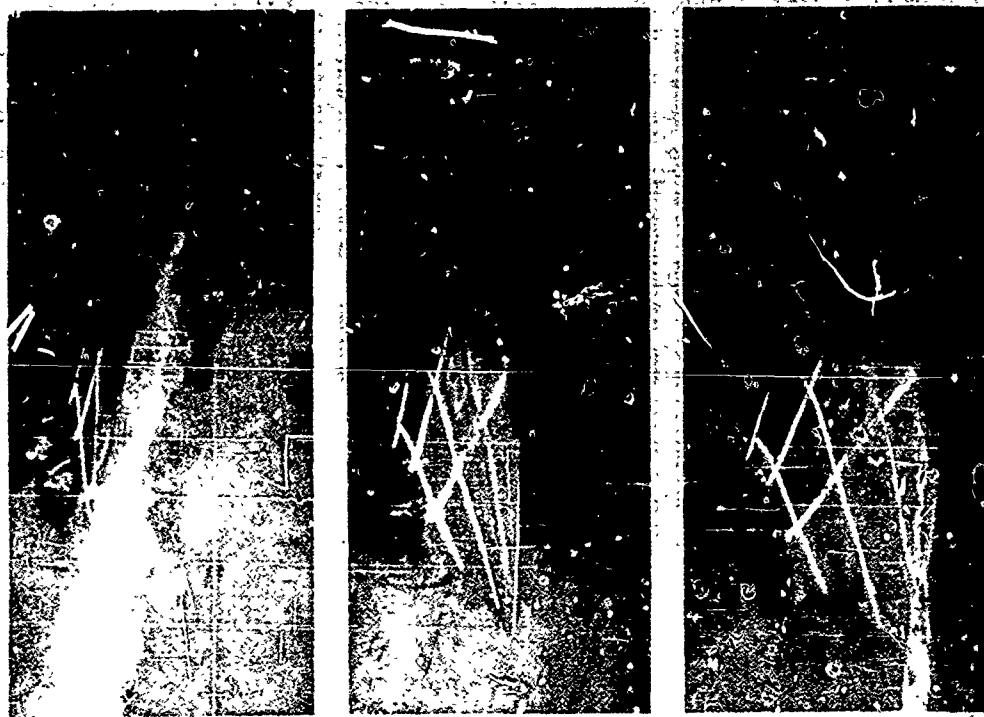
### Hull Finishes

88. Comparison of the effects on self noise of alternative anti-fouling hull treatments in H.M.S. URCHIN and H.M.S. VENUS has not been possible owing to bad weather during all three of the trials so far carried out in H.M.S. URCHIN. The series of trials in H.M.S. URCHIN has accordingly been abandoned but it is proposed to complete the corresponding series for H.M.S. VENUS in the hope of assessing the effect, over a period of two years out of dock, of the special anti-fouling treatment that she received initially, i.e. Vacu-blasting and painting with Composition 161P.

### Effect of Evasive Action

89. H.M.S. LION steamed at 18 knots carrying out Evasion Zig-Zag Steering Plan 25S from "ATP 3 - Anti-Submarine evasive steering". Self noise was recorded in Type 176 position on ahead, abeam and astern bearings and in Type 174 position on R90°. In no instance was any significant increase in self noise recorded.

90. H.M.S. VENUS repeated the procedure at 22 knots when noise was measured in Type 164 position on ahead, abeam and astern bearings and in Type 174 position abeam. Again no significant increase was recorded.



(a) Pitch 10

(b) Pitch 20

(c) Pitch 22

Fig. 28 The Effect of Varying Pitch on Propeller Cavitation.



## Propeller Noise

### AGOUTI

91. Trials were carried out with H.M.S. UNDAUNTED during the period September to December 1962. Using large capacity compressors the effects of variations in air volume and hole patterns have been studied to determine the optimum combination for the reduction of noise radiated from the propeller. Detailed assessment of the trials results is still in hand but initial analysis shows that over the frequency range 75 c/s to 76.8 kc/s the ship at 18 knots with AGOUTI working is no noisier than at 10 knots without AGOUTI.

### H.M.S. YAXHAM - Cavitation Noise Trial

92. A trial with H.M.S. YAXHAM is in progress with the aim of studying the noise significance of different forms of cavitation. By varying the propeller pitch, at constant revolutions (800 r.p.m.), it has been possible to produce either essentially no visible cavitation or strong visible cavitation of the tip vortex alone or strong visible face cavitation alone. This is illustrated in Fig. 28 on the previous page.

93. It is remarkable that whereas the tip vortex and face cavitation are accompanied by substantial increases of radiated noise at low frequencies, little effect is apparent at the higher frequencies. This is illustrated in Fig. 29.

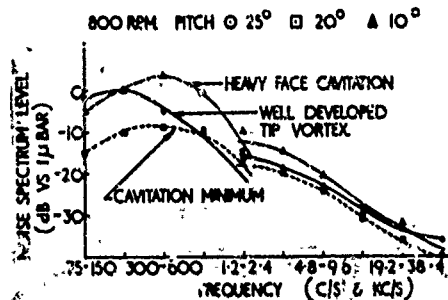


Fig. 29 The Effect of Propeller Cavitation on Noise Level.

### Underwater Viewing Equipment

94. A system for recording the behaviour of submarine propellers is being developed at the request of D.G.S. The system, working at depths of up to 350 ft, will use the pulsed high speed camera equipment developed for the cine/television installation.

### Portland Sound Range

#### Radiated Noise Measurements During 1962

Class	No. of Ships	Range Days
Aircraft carriers	2	2
Fast replenishment tankers	1	1
Submarine base maintenance ships	1	1
Destroyers	4	4
Frigates	17	24
Minesweepers	17	34
Cablesheeps	1	1
Helicopters	1	1
Hovercraft	1	2

95. Rangings of special interest included:-

- (a) The first-of-class trial of the Type-81 frigate H.M.S. ASHANTI, which has both steam and gas turbine propulsion systems. There is evidence to suggest that, with suitable isolation mountings, gas turbine propulsion could be considerably quieter than steam at all frequencies. Trials have shown that careful balancing of the gas turbine is not by itself enough to yield this potentially quieter performance and it is clear that failure to employ isolation mounting carried a heavy penalty.
- (b) The German C.M.S. FULDA, fitted with controllable pitch propellers, some degree of attenuation of airborne noise from the engine room, and vibration mounting of the main machinery.
- (c) The German frigate EMDEN, fitted with controllable pitch propellers a combined Diesel and gas turbine propulsion system.

Machinery Noise (Radiated)

Importance of Spectrum Lines due to Machinery in Type 12 Frigates

96. An analysis has been carried out of the most prominent spectrum lines radiated from Type 12 frigates fitted with the original 3-blade and the later noise-reduction 5-blade propellers. The level of these lines, which originate from machinery, have become of far greater significance with the fitting of modern 5-blade noise-reduction propellers because the underlying level of general noise is markedly less than with the standard propellers.

Effect of Line Components on Range at which Ship may be Detected

97. An examination of the effects of discrete spectrum components on detection ranges and mine actuation widths has been carried out using H.M.S. SCARBOROUGH as an example. The following table shows the calculated effect of suppressing particular lines on detection ranges by Sonar Type 186 in the listening band 300 to 600 c/s and assuming sea state 2. Two situations have been considered in which depths of 100 ft and 300 ft for the surface duct apply.

Speed (kt)	Depth of Surface Duct (ft)	No Suppression (kyd)	Propeller singing lines alone eradicated (kyd)	Gear meshing lines alone eradicated (kyd)
10	100	3.4	2.0	-
	300	130	38	-
14	100	3.0	2.3	-
	300	100	5.4	-
16	100	2.7	-	2.5
	300	76	-	68
18	100	2.4	-	2.3
	300	58	-	54

98. It will be seen that the singing propeller in this case is the dominant source of discrete frequency noise. The effects on mine actuation are similarly important. If the propeller did not sing the relative magnitudes of gear mesh and other machinery lines would become more important. Thus the discrete frequencies tend to control the risk of detection and the mine risk.

#### 6.7 - DOME INVESTIGATIONS (INCLUDING NOISE REDUCTION)

##### Replacement for Dome A/S 26

99. The five double curvature A/S 80X domes have now been in service for periods ranging from 18 months to 2 years without any adverse reports. Further acoustic trials have been carried out with this type of dome to assess the bearing error which might result from phase distortion. Comparative tests, using the phase conscious Type 170 transducer at 21 kc/s, produce the results given in the table below.

Dome	Description	r.m.s. Value of Bearing Error (Comparison of L and R Squares)	Mean Attenuation dB (L and R Squares)
A/S 82	Standard production 0.020 in. stainless steel skin with steel reinforcement.	0.6°	2.3
A/S 80X	Double curvature glass fibre skin 0.25 in. thick. Steel vertical and glass fibre horizontal reinforcement.	1.3°	2.8
A/S 80X modified	As above - with sections of glass fibre horizontals removed.	0.8°	1.3
A/S 80X Shell	As above - skin only	0.2°	0.25

100. The significant improvement obtained by removing certain sections is thought to be in part due to the presence of voids which are formed during the lay up of glass fibre ribs.

101. Work carried out using perspex sheet (to simulate the acoustic problem without the variation in result which arises from voids and inhomogeneity of glass fibre) has however demonstrated the manner in which a single rib may increase the attenuation out of all proportion to its size. The effect is particularly marked when the width of the rib corresponds approximately to one quarter wavelength in perspex.

102. Development is accordingly being directed toward replacing the glass fibre horizontals with steel girder structure secured to the skin but not embedded within it.

### New Dome Configurations

103. An underwater observation sea trial has been carried out in H.M.S. LONDONDERRY. Twelve underwater periscope positions were installed in the ship a view of the bow and both domes. A comparison between onset of cavitation obtained during this trial and results of water tunnel model scale tests is shown in the table below.

Feature	Mean Attack Angle (Estim. for Full Scale)	Rudder Angle	Cavitation Onset Conditions				
			H.M.S. LONDONDERRY Result			Water Tunnel Result	
			Speed of Entry into Turn (kt)	Approx. Speed in Turn (kt)	Critical Cavitation Index (for Keel Line)	Model Scale	Critical Cavitation Index (for Keel Line)
Bow	0°	0°	17	17	3.6	1/6	0.8
	2°	15°	22	16	4.0	1/6	1.25
	6°	25°	20	14	5.3	1/6	2.95
	8°	35°	8 to 12	6 to 8	20	1/6	4.1
A/S 80X 100 in. Dome	0°	0°	-	-	*	1/6	0.55
	0°	15°	-	-	*	1/6	0.55
	2°	25°	-	-	*	1/6	0.6
	3°	35°	-	-	*	1/6	0.65
A/S 74X 157 in. Dome	0°	0°	25 to 26	25 to 26	1.6	1/10	1.35
	1°	15°	24 to 28	20 to 24	2.0	1/10	1.3
	1°	25°	24 to 28	20 to 24	2.0	1/10	1.3
	2°	35°	22	13	6.0	1/10	1.25

\* No cavitation visible up to 28 kt, the maximum speed during trials.

104. Although a reasonable relationship between model and full scale cavitation onset results was obtained for the 157 in. dome, a significant discrepancy was noted in the case of the bow. In part this is considered to be due to the difference in surface finish between ship and model.

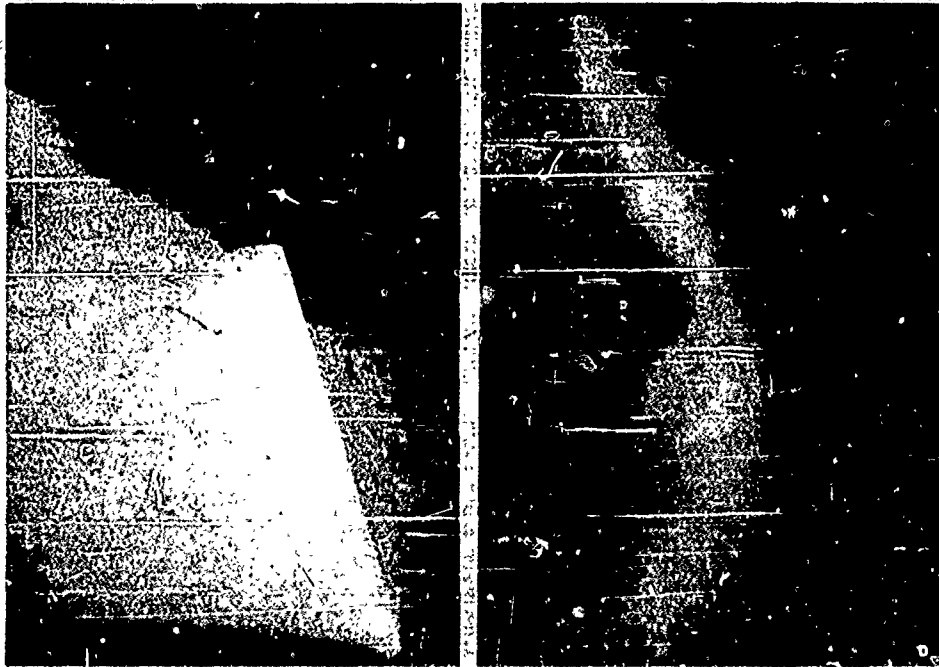
105. Fig. 30 on the next page illustrates the bubbles which are swept down from the bow and envelope both domes during turns executed with 35° rudder in calm weather. The serious effect which the bubbles must have on sonar performance suggests that in order to maintain sonar contact in turns surface escorts should use the minimum rudder angle possible.

106. The results of the trial confirm and strengthen the need to improve the shape of bows of A/S escorts and to install a fairing to defer cavitation at the 157 in. dome/hull junction. A further sea trial, for which equipment is already being made, has been requested; this trial should demonstrate the improvement which may stem from an elliptical bow and faired dome.

### Slamming Trial

107. Equipment has been installed in H.M.S. LONDONDERRY to measure the dynamic pressure loadings on the domes during "slamming". Both 100 in. and

157 in. domes have been fitted with pressure sensitive transducers mounted flush with the external profile. Outputs of these and strain gauges fitted in the domes are fed to two twelve channel recorders. Records will be taken by ship's staff when condition of speed and weather seem likely to cause slamming.



(a) View looking forward past 100 in. dome to forefoot

(b) View looking forward from position forward of 100 in. dome

Fig. 30 Cavitation Shed from the Bow of H.M.S. LONDONDERRY in 35° Rudder Turns.

#### Replacement Dome for Type 187 Sonar

108. To eliminate the operational speed limitation now imposed on conventional submarines, which arises as a result of failures among existing A/S '79 domes on the surface in rough weather, a stronger replacement dome design has been produced and two prototypes are being manufactured.

#### Fin Domes

109. A further design of glass fibre dome is in hand for use with the Type 185GL sonar in nuclear submarines. In view of its location adjacent to the repeating compass in the forward part of the fin the stiffening structure for the dome will be produced in an aluminium bronze of suitably low permeability.

#### Bottom Bounce Sonar Investigations

110. The estimated H.P. requirements, predicted from towing tank trials, of a Type 12 frigate hull fitted with the 100 ft long integral dome form (which had excellent cavitation onset performance) suggest an increase of 150% as

compared with bare hull at 20 knots. This very large increase in power requirement is considered to be largely due to the dome position used during the trials (15% of the ship's length aft of the bow). Further work is needed to determine an optimum position for a large dome on the hull.

111. Consideration is being given to other arrangements for bottom bounce arrays which would minimize such propulsion penalties in frigate sized vessels including the possibility of stowing the array above water.

112. Models are being manufactured for use in water tunnel trials which are programmed for mid-1963, these include bow forms for mounting various large arrays in the new design aircraft carrier.

#### 6.8 - INVESTIGATION OF TORPEDO DISCHARGE FROM SUBMARINES

113. The development of a model for investigating the external hydrodynamic forces on torpedoes during the launching phase has continued. Although a satisfactory method of firing the model torpedo has been developed, some delay has been caused by the need to repair parts damaged by the large number of firings now made.

114. The outstanding problem is still that of measuring the transient forces on the model. Instrumentation has been developed for this. A new firing tube having a bore of improved accuracy has been fitted, but trials in air reveal unexpected forces which are being investigated.

#### 6.9 - MINE COUNTERMEASURES RESEARCH

##### Magnetic Sweeping

115. Tests have been carried out at the Bexington Range using the coastal minesweeper H.M.S. HIGHBURTON to determine the magnetic field levels associated with the closed loop sweep, MM Mk 11(L) and the open loop electrode sweep, MM Mk 11(O). The results of these tests on the range are being compared with the predicted field levels obtained in the laboratory from tests on scale models of the two sweeps. A plot of the field contours obtained from laboratory tests for a depth of 10 fathoms and a plot obtained from the Bexington trial results for the MM Mk 11(O) in a depth of 8.5 fathoms are shown superimposed in Fig. 31 on the next page.

116. In the case of this open loop sweep, the position of the field contours is dependent upon the relative conductivities of the sea and the sea bed. For minesweeping purposes it is convenient to use the parameters  $Q$  (a reflection coefficient) and  $d/H$  (an electrical depth ratio) to describe the conductivity conditions. The laboratory diagram is drawn for values of  $Q = 0.95$  and  $d/H = 1.2$ ; the average values applicable at Bexington are now known to be  $Q = 0.93$  and  $d/H = 1.15$ . It is already clear that there is a very good degree of correlation between the observed and predicted patterns. A set of punched tapes appropriate to the exact values of  $Q$  and  $d/H$  off Bexington are in course of production for use on the laboratory sweep field plotting equipment and electrode field computer to enable a more exact comparison to be made, in respect of swept path, position of mine orientation, and sweeper safety.

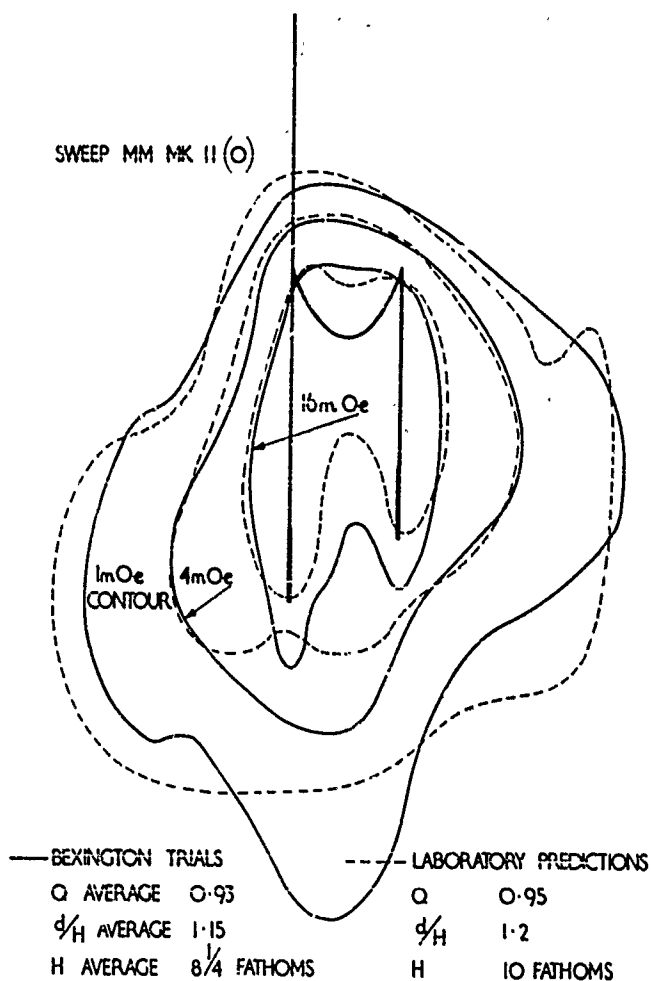


Fig. 31 Comparison of Model Scale  
Predictions of Sweep Field and Observations.

MM Mk 11 and MM Mk 20 Sweeps - Operational Data

117. Minesweeping calculators have been produced for the open loop and closed loop versions of the MM Mk 11 and the MM Mk 20 sweeps. The calculator slides apply to sweeping speeds of 6, 8 and 10 knots and cover all likely types of horizontal component magnetic mines, divided into four groups according to the duration of influence field necessary for the mine circuit to actuate.

118. The calculators give values for the aggregate actuation width averaged over all angles of mine orientation. The use of this value of swept path ( $\bar{w}_e$ ) for calculation of percentage clearance of a mined area will tend to give, in certain cases when high order clearance is required, an over-estimate of the percentage cleared, and for this reason it may be necessary to produce a second

set of slices for statistical minesweeping purposes giving a value of  $W$  based upon the aggregate actuation width for the 10% worst angles. This matter is under consideration.

119. Tables of safe current have been prepared from knowledge of the combined magnetic field of coastal minesweepers and the computed value of the sweep field in the region around the minesweeper. For each minesweeper - sweep combination, two sets of tables have been prepared:- one for sweeping horizontal field component mines and the other for vertical field component mines.

#### Acoustic Sweeping

##### Definition of Acoustic Mine Actuation Levels

120. Experimental work on the actuation level of the British V. circuit to both sweep-like and ship-like noise has shown that the definitions proposed to N.A.T.O. by the U.K. are realistic and the measurement procedures simple. The definitions were fully discussed at the 1962 meeting of the N.A.T.O. M.C.M.W.P. technical panel.

##### Acoustic Propagation Monitor

121. Trials with the prototype production model of the monitor have been successful. A small number of outfits of this equipment are being made for practical evaluation pending a decision from the assessment mentioned below.

##### Prediction of Acoustic Swept Paths

122. A study of L.F. propagation data in shallow water made available through N.A.T.O. has provided some indications of the possible variation of swept path within typical sweeping areas. From this it has been possible to assess the effect on a sweeping task of propagation data obtained theoretically and by use of monitors. A single profile from an expendable monitor is generally preferable to theoretical prediction particularly at the lower frequencies. Multiple monitor profiles spaced along the channel become more necessary as combination mine complexity increases and as minesweeper acoustic safety requirements are raised. A paper which considers the policy that should be adopted in practice in respect of acoustic monitors is in preparation.

##### M.C.M. Range at Bexington

123. Apart from the auto-tracker, the instrumentation is complete and the range fully operational. A number of investigations have already been carried out including a trial with sweepers of the 2nd M.C.M. flotilla. Manufacture of the auto-tracker system is nearly finished and it should be installed shortly.

##### Pressure Mine Countermeasures

##### Introduction

124. A good deal of understanding has accumulated in this field over the years and it is doubtful whether further research investigations would be particularly rewarding. This being so, it was decided to cease active research



in the field of pressure mine countermeasures, at least for the time being; the period under review has been largely devoted to winding up the investigations in progress and documenting the results in report form.

#### Pressure Mine Sweep

125. Model-scale work on the MATTRESS pressure mine sweep has now ceased pending a decision as to whether to pursue the investigation, with special emphasis on engineering aspects, at large scale. The investigation to date indicates that the device would apparently be feasible from the point of view of construction and towing drag, and that there appears to be a very good case for examining such further matters as the towing stability, explosion resistance, handling and seamanship.

#### Safe Speeds for Ships

126. Work aimed at relating pressure signatures of ships to simple geometrical and other parameters has now been completed. Expressions embracing all ships, both warships and merchant ships, are available.

127. Safe speed data have now been extended to cover the case of merchant ships in swell and a technical note is being published.

#### 6.10 - DEGAUSSING FOR C.M.S., I.M.S., CONVERSION HUNTERS, AND FUTURE M.C.M. VESSELS

128. Variable-strength permanent magnets for "dipole" type compensation have been developed: action is in hand by D.G.S. in collaboration with A.U.W.E. to introduce them into service on current C.M.S. for use in conjunction with the normal D.G. coil system to compensate the very large permanent magnetism in their propulsion engines. The design of the magnets permits the magnetic moment to be varied over a wide range to suit the particular requirements of individual sweeper's engines. The technique of deperming the crankshafts of C.M.S. engines has been finalised and has passed into service. The stability of the treatment has been confirmed by re-testing one of the earliest set of three which were depermed and subsequently run for 2,500 hours in an operational sweeper (see page 77).

129. The first phase of D.G. trials on the partially converted minehunter H.M.3. KIRKLISTON has been completed and an interim D.G. coil system design produced. This system will be fitted into the first of class during current refit when further confirmatory trials are proposed. Magnetic measurements on individual consoles of Sonar Type 193 equipment have shown that the ferromagnetic field may not be significant for the Conversion Hunter: further trials to measure the electro-magnetic stray field await the availability of a conversion hunter fitted with an operational set.

130. The relationship between self danger width of a M.C.M. vessel to horizontal magnetic mines of 0.5 mG level and the N.A.T.O. criterion of "the peak of the combined vertical component of magnetic signature" has been investigated on the model scale (see page 103). The results have led to a proposed magnetic specification for the new M.C.M. vessel of 0.6 mG in 5 fathoms (N.A.T.O. criterion) which provides a self danger width in shallow water such that an adequate risk factor of 0.06 in 3.5 fathoms, falling to 0.02 in 5 fathoms and greater is achieved. To each and maintain this magnetic

specification will require R. and D. effort by all Departments concerned with construction, storing and maintenance of these vessels and an outline of the effort involved in doing so has been published.

131. A large amount of non-ferrous substitution of materials will be required for most of the major items in the new M.C.M.; so also will prefitting treatment, involving dipole compensation and demagnetising, will also be necessary. Consequently "Land" D.G. ranges both for R. and D. and for production purposes are considered essential. Considerable effort has been expended in finding suitable magnetically quiet sites for the instrumentation for the first one which will probably be located at D.G.W. (Compass Division), Ditton Park.

#### 6.11 - DEGAUSSING FOR NUCLEAR SUBMARINES

132. Preliminary investigation of pressure/magnetic effects of the pressure hull material under deep diving conditions were made by compressing solid test pieces in a specially designed non-magnetic test rig. These trials have not progressed very far, but the results indicate that the mechanical strain under deep diving conditions may have serious consequences with regard to magnetic mine safety and range of detection by airborne M.A.D.

133. The axial current flash technique of deperming has been explored at full scale and shows promise. This method has the advantage over all existing methods that magnetic fields inside the hull during the process are reduced to a level below that at which they could affect sensitive navigational and recording equipment and the contents of missiles.

134. A report on the distant magnetic field of submarines (that is, at typical M.A.D. ranges) has been issued. This is a theoretical treatment intended as an aid in the calculation of detection ranges when actual magnetic moments of submarines (model or full scale) are known.

#### 6.12 - THE NEW MINE COUNTERMEASURES VESSEL

135. Target levels for the magnitude of pressure, acoustic, and magnetic influence fields in the new construction mine countermeasures vessel have been formulated for inclusion in the Staff Requirement. The target levels are based on the concept of minimum acceptable danger widths, a concept which is operationally more acceptable than the former considerations simply of the maximum field directly beneath the ship (see page 102). It is, however, a complicated procedure to make direct measurement of danger paths and field and model studies are in hand to show the connection between the figures for maximum noise level and D.G. combined code number as recorded during a routine operational ranging, and the required danger path (see page 76).

136. A schedule of R. and D. effort required to ensure a sufficiently low level of magnetic field in the new Mine Countermeasures Vessel have been drawn up for the Admiralty Working Party concerned with the new vessel, and A.U.W.E. has collaborated with D.G.S. in preparing a similar schedule in connection with noise.

#### 6.13 - MINEHUNTING PROBLEMS - MINE BURIAL

137. Acoustic minehunting may be made more difficult if the mines are partly buried and would be ineffective against completely buried mines. It is

therefore important to assess how widespread, in areas of operational interest, are conditions in which mines would probably become buried. An analysis of available information from U.K. and foreign sources has been made and a tentative basis arrived at for some form of prediction based on parameters such as sea bed conditions, tide and swell.

#### 6.14 - ADVANCED MAGNETIC TECHNIQUES

138. Digital methods of recording and processing the data from nuclear and atomic magnetometers have been examined briefly. The new magnetometers are particularly suited to digital methods because the outputs are signals of varying frequency. The standard method of field measurement is by a succession of frequency determinations using a counter-timer. Although the original intention was to assemble apparatus for use in conjunction with magnetometers for submarine magnetic moment measurement, it is now appreciated that these techniques have wider application.

139. A commercially manufactured metastable helium magnetometer was purchased by A.R.L. and has been on loan to A.U.W.E. for laboratory evaluation. The particular virtue of this magnetometer is its theoretical orientation independence. Rotational effects have been examined in detail by comparing the output of the helium magnetometer in various orientations with a nuclear magnetometer. Orientation errors have been found to exist but indications are that these originate in the electronics and not in the magnetometer head.

#### 6.15 - AUTOMATIC PROCESSING OF A/S DATA

140. Studies of the design of a system for automatic detection of sonar targets on the doppler display of sets similar to Types 2001 and 184 have continued.

141. Signals recorded on magnetic tape on trials of the experimental Type 2001 set in H.M.S. VERULAM have been analysed in the laboratory to determine their statistical character and to look for any systematic differences between target echoes and the background signals of noise or reverberation. Because of the very large number of recording channels required if the outputs of the doppler filters were recorded directly, the signals at the inputs of these filters have been recorded. The signals have then been replayed in the laboratory through a bank of doppler filters similar to those used in the Type 2001 set. Because of the relatively small fractional bandwidth of any one doppler filter, the recording and replay apparatus must have exceptional freedom from wow and flutter. A substantial improvement to a commercial tape recorder has been made by using a pilot signal from a stable oscillator recorded on one track to correct the frequency of the signal channels. The correction is electronic and substantially free from time delay.

142. Electronic equipment for measuring the amplitude distribution of the replayed signals has been built. This counts the number of times regularly taken samples exceed a preset threshold level. Fig. 32 on the next page is a typical result obtained on a reverberation background. It will be seen that at low amplitudes the distribution follows the Rayleigh law but that at the largest amplitudes measured (about three times the r.m.s. amplitude) the frequency of occurrence is about four times as great.

143. Measurements of the frequency of simultaneous occurrence of reverberation levels in two adjacent doppler channels or two adjacent beams have shown negligible correlation at low amplitudes but an increasing correlation at high amplitudes.

144. True submarine echoes show a spread in range, bearing and doppler about 50% greater than suggested by elementary calculations based on the system parameters. These echoes do not, however, have any characteristic waveform which distinguishes them from peaks of reverberation or noise. Automatic detection must therefore be based on the comparison of signals received on successive transmissions and the association of those with consistent movement and doppler. Additionally, it may be possible to reject signals which appear simultaneously in many beams or doppler channels and are due to bursts of noise or to echoes from large bottom features.

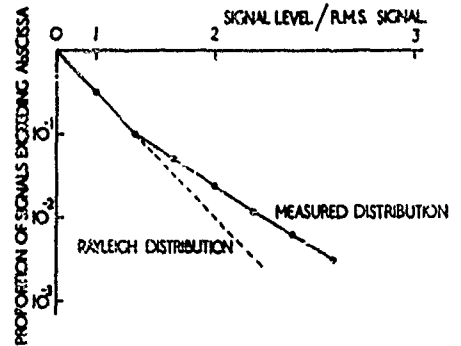


Fig. 32 Comparison of Reverberation Distributions.

145. The estimate of consistency of movement is greatly eased by accurate bearing information. On a set like Type 2001 where the preformed beams are  $10^\circ$  wide there is a possible error of nearly  $5^\circ$  if the bearing is taken as that of the largest signal. It was therefore hoped that a more accurate bearing could be obtained by interpolating between beams according to the relative amplitudes of the signals received in them. It has been found, however, that differences of amplification and over-loading on large signals invalidate interpolation. Comparison of time-bearing plots using bearing interpolation and using merely the bearing of the largest signal show only a two to one improvement in smoothness for the interpolated case.

146. Apparatus is being developed for translating recordings of signals received on sea trials into digitised "words" representing amplitude, bearing, doppler and range. These words will be passed into a POSEIDON computer, sorted and stored. Some of the computer programmes needed for this have been written. It is clear that a great deal of experience is required for the preparation of useful programmes.

147. In view of the likely complexity of any system of completely automatic detection and the risk that the computer might handle large numbers of false targets the possibilities of a special monitoring display are being investigated. This display would show the raw sonar signals, as at present, and would have superimposed markers which show the signals which the computer is handling. Such a display would allow an operator to confirm or supplement the decisions of the computer and it would allow operation to continue in the event of a computer breakdown. It also lends itself to the development of automatic detection by beginning with comparatively simple schemes and proceeding with successive improvements.

## 6.16 - FUTURE TRENDS IN FIRE CONTROL

148. The techniques being followed in the first digital computer under development for torpedo fire control, the T.G.C.U. Mk 2 and the present position with this equipment are given on page 22. The use of a fixed programme, special purpose machine for this task, does show tremendous flexibility as compared to the earlier electro-mechanical analogue systems used hitherto. Furthermore, it is also true that special purpose machines of this type can be tailored to the form of calculation they are required to perform.

149. This evaluation is now being challenged by the availability of small general purpose digital data processing systems for shipborne use. Such systems, because of their general purpose nature, can provide solutions to a very wide range of computational and data handling problems. This flexibility gives them a much greater long term development potential than that which could be achieved with any of the special purpose equipment.

150. The first general purpose digital data handling system to go to sea in the R.N. will be the ADA system developed at A.S.W.E. Whilst originally developed for use in Aircraft Carriers, plans now exist for it to be fitted in smaller ships which have an anti-submarine capability. This has opened up the possibility of utilising spare capacity in these ADA systems for the automatic of anti-submarine warfare. The first ships in which this opportunity can be exploited will be the guided weapon destroyers D.L.G.05 and 06 as described elsewhere in this report in which the fire-control function served is guidance of the MATCH helicopters. The major limitation of this system is the slow data rate imposed by the semi-automatic data link between the Sonar Type 184 and ADA. In later A/S Frigates, it is hoped to overcome this limitation by the development of an automatic link supervised by an operator and by a special display showing both the raw Sonar data and the computer evaluation of it.

151. In these Frigates, it is probable that ADA will be used for the control of the long range weapon IKARA. Looking further ahead to the possibility of A/S vessels fitted with IKARA and a longer-range mortar, it appears logical to control both weapons by the ADA system. The availability of more than one type of weapon, either within the ship or within the force of which the ship forms a part, opens up the possibility of utilising ADA to provide an automatic threat evaluation and weapon assignment.

152. Cost and size considerations may preclude the fitting of the present ADA system in the smaller ships of the R.N. Present thoughts suggest that such ships should be provided with a more limited form of general purpose data handling system and the D.S.C.E.P.S. (Data System Coastal Escorts and Patrol Ships) is one possible solution.

153. The work at A.U.W.E. required to further this programme is primarily concerned with rule writing for the various tactical situations and associated computer programming and with the investigation of special peripheral equipment used for data display and presentation of operational state.

## 6.17 - TRANSDUCER RESEARCH

### Development of Lead-Titanate-Zirconate Piezo Electric Ceramic

154. Early difficulties in polarising this ceramic have now been overcome and most of the work with this material has used samples of composition AM97 supplied by Admiralty Materials Laboratory, electroded and polarised at A.U.W.E. Silver electrodes deposited by vacuum evaporation have been shown to make satisfactory acoustic joints in transducers driven at high amplitudes (up to 0.014% r.m.s. mechanical strain). Tensile strength of 1.5 to 2 tons per sq. inch have been obtained for epoxide resin joints between vacuum silvered AM97 test discs, compared with 0.5 to 1.6 tons per sq. inch for fired silver electrodes, and 0.3 to 0.6 tons per sq. inch for electrodes using a commercial cold silvering solution. The advantage of depositing electrodes by cold silvering or vacuum evaporation rather than by a firing process is the elimination of contamination of the ceramic by the electrode material diffusing into it.

155. AM97 has been tested with mechanical and electrical stresses applied simultaneously. The table below shows that the changes in power factor and capacitance are greater than the sum of those which occur when the stresses are applied separately.

Stress		Power Factor at 1 kc/s	Capacitance at 1 kc/s (relative values)
Electrical	Mechanical		
0*	0	0.0023	100
2 kV/cm	0	0.001	108
0*	10,000 lb/in <sup>2</sup>	0.0031	122
2 kV/cm	10,000 lb/in <sup>2</sup>	0.021	141

\* Measured at low electrical field.

156. In this case the mechanical stress is applied along the direction of polarisation and there is a rise in capacitance. If the stress is applied at right angles to the polarisation the capacitance decreases. This effect has been observed in a commercial grade of similar material tested as a spherical shell under hydraulic pressure. The capacitance decreased by 53% at 9,000 lb per sq. inch when the sum of the principal stresses in the ceramic was 55,000 lb per sq. inch.

157. Alternative ceramic compositions are being investigated. Small additions of Uranium or Chromium appear to reduce the change of capacitance with stress without seriously affecting the other properties.

### Acoustic Joints

158. Good acoustic joints have been made using the soft metal Indium as a joint filler. Rings of indium foil 0.005 inch thick are placed between the ceramic rings and gauze electrodes of the normal type of transducer stack and a pressure of 3 tons per sq. inch is applied by tensioning the centre bolt. Experimental transducers have been driven successfully at high amplitudes for short times, although the tensile strength of sample joints has been found to

be comparatively low at 0.3 tons per sq. inch. The advantage of this technique is that it eliminates the resin glues used at present.

#### Materials for Transducer Pistons

159. The vibrating piston of a high power, broad band transducer needs to be light to keep the Q-factor low and rigid to prevent flexural resonances occurring in the operating frequency band. It has been shown that for these criteria the best piston materials have the highest ratios of velocity of sound ( $c$ ) to density ( $\rho$ ): this ratio is shown in the following table for several materials.

Material	$c/\rho$ (cgs units)	Remarks
Silicone Nitride	$2.4 \times 10^5$	Promising new ceramic
Glass	$2.08 \times 10^5$	Brittle
Aluminium	$1.9 \times 10^5$	Precautions needed against corrosion
Titanium	$1.3 \times 10^5$	Resists corrosion well
Steel	$0.65 \times 10^5$	Corrodes
Aluminium Bronze	$0.5 \times 10^5$	Resists corrosion fairly well

160. Aluminium is used at present wherever the risk of corrosion can be made small, usually in transducers where all the other parts are of Aluminium, for example in torpedo and helicopter transducers. In most other cases Aluminium Bronze is used despite its low  $c/\rho$  ratio. Titanium pistons are being used on experimental transducers. Silicon Nitride not only has a high  $c/\rho$  but is easy to machine before final firing and dimensional changes during firing are negligible. The thermal expansion coefficient is about the same as the piezoelectric ceramic (4 to 5 parts in  $10^6$  per  $^{\circ}\text{C}$ ) and this should minimise stresses converted joints caused by differential expansion. Experimental transducers with Silicon Nitride pistons are being tested.

#### Variations in Transducer Characteristics

161. It is often important that the transducer elements forming an array should be alike and should not change under pressure or temperature or with time. Initial differences due to the spread of manufacturing tolerances may complicate the associated electrical circuits and make it necessary to tune each element separately. Variations due to environmental changes have a similar effect but it is not normally possible to adjust the equipment to compensate for these changes.

162. Several Barium Titanate transducers have been tested at different temperatures and pressures and the results are summarised in the table below together with a summary of an analysis of manufacturing variations of 800 Barium Titanate transducers.

Manufacturing Variations	Range which includes 50% of samples	Range which includes 95% of samples
Capacitance ( $C_o$ )	$\pm 1\%$	$\pm 6\%$
Resonance Frequency ( $f_r$ )	$\pm 1\%$	$\pm 2\%$
Coupling Coefficient (k)	$\pm 3\%$	$\pm 10\%$
Resistance at resonance from $C_o, f_r, k$	$\pm 6\%$	$\pm 25\%$
<u>IMPEDANCE CHANGES DUE TO:-</u>		
Temperature + 30% : 0° to 30°C		
Pressure + 4%* : 0 to 500 lb/in <sup>2</sup>		
Ageing + 10% : 100 to 1000 days		
Array Interaction $\pm 30\%$ possibly, depends on array parameters.		
*For Type 2001 transducer designed for operation at 700 ft depth		

163. Although changes in individual parameters are quite small the total effect is large. Thus, taking all the changes into account there is a possible variation in impedance at resonance of 5:1.

#### Leak Detection and Watertight Joints

164. A theoretical study of the problems of transducer leak detection and prevention has been carried out. This indicates the necessity of very sensitive methods if a moderate testing time is to establish the practicability of, say, five years service exposure to high hydrostatic pressure.

165. A mass spectrometer using helium as a tracer gas has been used to test for leaks in two transducers. The evolution of gases from the transducer components and the long time-constant of small leaks made the method more difficult than had been expected. The sensitivity obtained, about  $10^{-4}$  lusec, was just adequate but much inferior to the figure,  $10^{-8}$  lusec, obtainable in ideal conditions.

#### Cavitation

166. Some experiments have been made to extend work done some years ago on the limitation of the power output of transducers due to cavitation. The older results established this limit as:-

$$\text{Maximum average intensity at transducer face} = 0.3 \left( \frac{h}{32} + 1.7 \right)^2 \text{ watt/cm}^2$$

where h is the depth of immersion of the transducer in feet.

This limit was established for frequencies down to 20 kc/s and pulse durations up to 20 milliseconds. In modern transducers operating at lower frequencies modifications to the cavitation limit may occur because of the lower frequency and longer pulse duration and because of the lower proportion of the total



transducer area that is vibrating. (The last cause is consequent on the use of different methods of construction and of circular rather than rectangular pistons.)

167. Experiments at 10 kc/s and 100 milliseconds with the Type 195 transducer have shown that the 0.3 multiplier in the above formula becomes 0.23 if the total area of the transducer is taken.

168. Experiments at 3.5 kc/s using a single small element (diameter one sixth of a wave length) have given values of about 0.1 for the above multiplier. These experiments were, however, carried out with CW signals. An unexpected result was a reduction in the diameter of the motional impedance circle during cavitation, i.e. the effective radiation resistance is increased by cavitation.

#### Array Interaction

169. Advantage is being taken of an existing A.R.L. computer programme to make a theoretical investigation of the effects of various element and array parameters on the performance of piezo-electric elements within an array. The A.R.L. programme, designed for the Ferranti Pegasus computer, can only deal with plane arrays having quadrantal symmetry, but can provide very full information on the acoustic and electrical characteristics within such an array. All elements are assumed fed in parallel, and "steering" is not considered.

170. Scaling laws have been ascertained in order to present the results in a more generalised form, and initial calculations have been made for arrays containing very small elements, where interaction effects are expected to be most pronounced. An example of curves obtained for a particular array is shown in Fig. 33, in which the abscissa is the generalised frequency parameter  $2Q(f-f_0)/f_0$ , corresponding to that usually employed in studies of tuned circuits. ( $Q$  is the Q-factor,  $f_0$  the resonant frequency of an isolated element in water, and  $f$  the frequency.) It has been established that, over a limited range, this parameter can be used to give approximate results in the presence of changes of Q-factor. The ordinates are normalised to an input of 1 volt, an electrical to mechanical transform coefficient of 1 newton/volt, and to  $f_0 = 1$  kc/s. The elements are assumed to have a mechanical acoustic efficiency of 90%, coupling coefficient of 0.28 and a Q value of 19.6. On each diagram on Fig. 33 a curve is also shown of the behaviour of a completely isolated element, and this brings out clearly the changes of performance within the array due to the presence of neighbouring elements. The maximum value of the velocity of the centre element is 30 times greater than that of a mid-side element at the same frequency, although only about  $1\frac{1}{2}$  times as great as the maximum velocity of an isolated element. It can also be seen that over a certain frequency range, only the corner elements of the array are acting as radiators; the other elements are then absorbing power. The peak rate of absorption for the centre element is in fact about twice the peak rate of emission for an isolated element. Considerable variations also occur in the electrical input impedance.

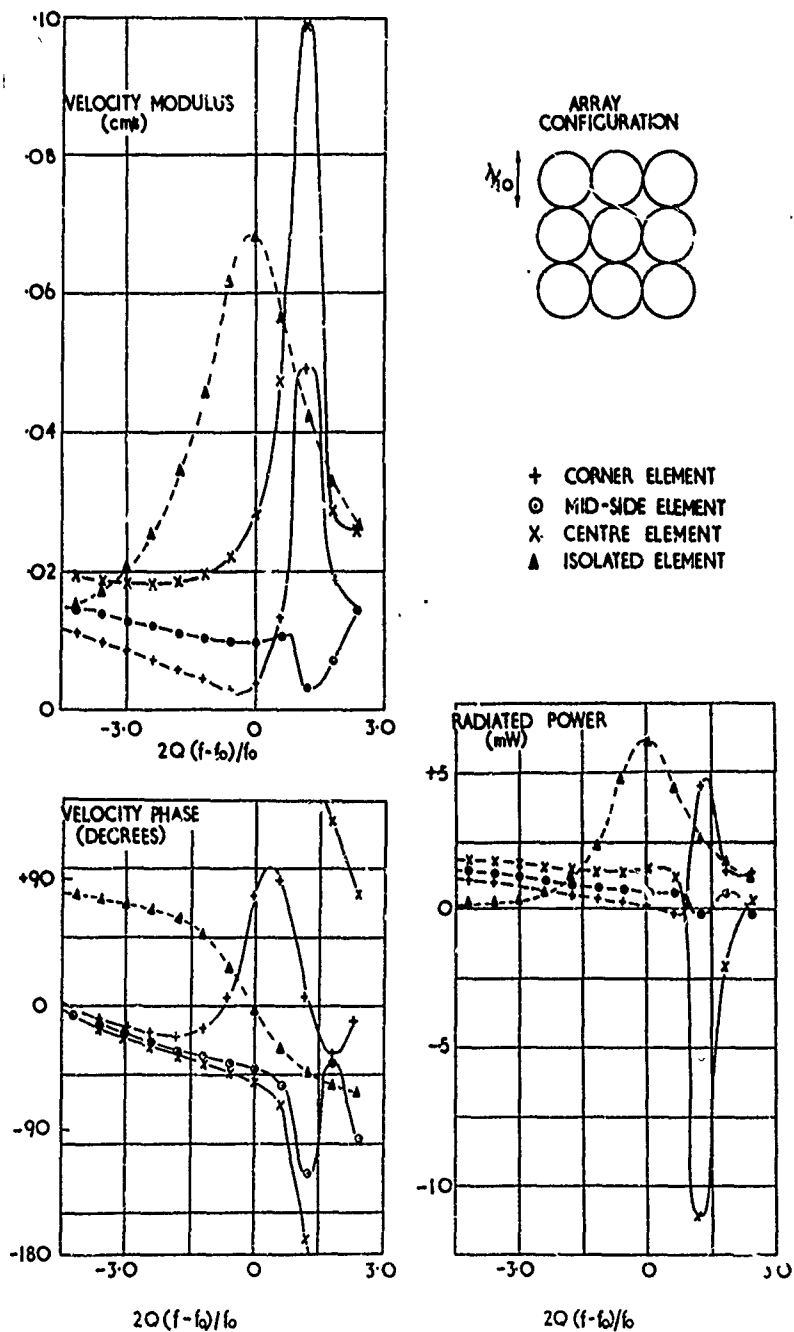


Fig. 33 Influence of Interaction on the Performance of Elements.

SECTION 7 - OPERATIONAL RESEARCH AND ASSESSMENT

7.1 - SHIPBORNE ANTI-SUBMARINE WEAPON SYSTEM (SASS)

The Joint Admiralty/Ministry of Aviation Working Party set up in August 1961 under the chairmanship of a member of A.U.W.E. to advise the Director General of Weapons, Admiralty, and the Director General of Guided Weapons, Ministry of Aviation, on the provision of a long range A/S. Weapon system for new ships has now completed its work. A report was published in May 1962 recommending the adoption of the Australian IKARA with the Mk 46 torpedo as payload.

2. Since the publication of the report the Working Party have continued their studies of the technical details, procurement and costing of the chosen system. A mission was sent to Australia in July and August 1962. A full submission to the Board of Admiralty and Defence Research Policy Committee, including a Staff Requirement, detailed Operational Requirement and Limited Through Costing, has been prepared and was submitted to the Naval Staff in January 1963. Approval to go ahead on the Project Study is awaited.

Comparison of Sonars

3. A study has been made of the potential fire-control performance of

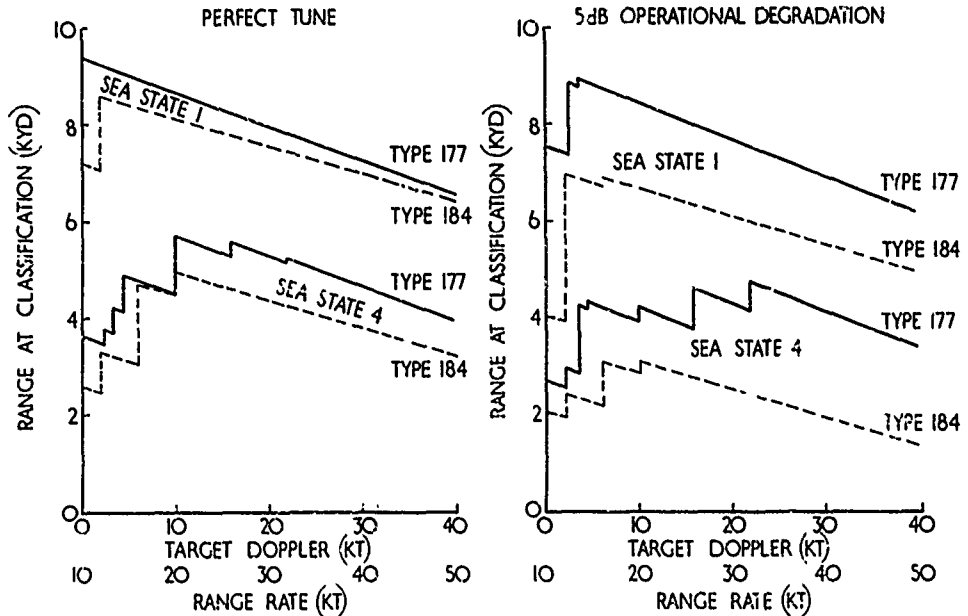


Fig. 34 Classification Ranges of Sonars Type 177 and 184.

available British and foreign sonars. The latter offer no clear advantages over R.N. equipment. At moderate ranges where signal/background ratios are high, instrumental errors are the main source of error; trials of Type 177 with the MATCH system have indicated sonar accuracies better than 1 in

bearing and  $\frac{1}{2}$  in range. At ranges near the limit of detectability, bearing errors are dominated by the signal/background ratio. The study showed that, for a given performance, Type 177 can accept a propagation loss 9 dB greater each way than can Type 184.

4. An analytical study has been made of the performance of Sonars Type 177 and 184 for detection and classification in the presence of noise and reverberation taking into account also the time factor involved in sweeping, detection and classification. Fig. 34 shows a result for typical conditions, with a ship's speed of 15 knots, operating at a frequency of 7.5 kc/s against a 15 dB target in a 150 ft isothermal layer. The target range after these time delays have elapsed is plotted against range rate and target doppler. The extension to 40 knot doppler assumes the planned modernisation of Type 177 (see page 30). It is seen that, above 15 knot target doppler, the effect of the above delays is serious in both sonars. The findings for a moderate ship and target speed, in calm and rough seas, with the target both in and below the isothermal layer, are summarised in the table below for an operational degradation of 5 dB.

Sea State	Target Depth	Potential Detection Range (yd)		Typical Range after Classification (yd)	
		Type 177	Type 184	Type 177	Type 184
1	In Layer	10000*	7800	3100	6400
	Below Layer	3500	3500	1600	2100
4	In Layer	5400	4000	3500	2600
	Below Layer	3500	3500	1600	2100
Notes:- * Using extended range scale this would be 11600 yd.					
Layer depth 150 ft Ship speed 15 kt. Transmission interval 15 sec.			Target strength 15 dB Target doppler 7 kt Own doppler 10 kt		

5. It is concluded that these sonars fall short of the aim to attack submarines at ranges out to 20,000 yd.

#### Attack Times for Sonar and Weapon

6. The above study has revealed that the information rate of the present generation of sonars is, without exception, too low to meet the needs for attacking nuclear targets which may transit the swept area at high speed and may exploit shadow zones to provide only fleeting opportunities for detection and attack. The table on the next page shows an estimate of the median time lapses during detection and attack by Type 177 using a transmission interval of 15 sec on the 10,000 yd range scale.

7. The total time of approximately 4.5 min. allows considerable relative movement between escort and target, e.g. 7,200 yd for a relative speed of 48 knots, a movement so large as to permit at best a single hasty attack. Using a range scale of 20,000 yd these figures become 9 min. and 14,400 yd.

Contributions to total attack time	Seconds
Median sweeping delay*	90
Detection in 3 pings	45
Target classification, 4 pings†	60
Weapon loading and firing delay	45
Guided air flight	48
<b>TOTAL</b>	<b>288</b>
Notes: * Sweeping delay reduced by half in Type 184. † Type 184 may require a minimum of 180 sec for classification.	

8. While the development of bottom-bounce sonars may permit detection of targets unhampered by shadow zones it is concluded that a substantial increase of data rate is required for a sonar to meet the target for the shipborne A/S weapon system.

#### Submarine Vulnerability to A/S Weapons

9. In order to obtain guidance for weapon design, assessments have been made of the vulnerability of submarines to both high explosive weapons and nuclear weapons. Both lethal hull rupture and internal shock damage sufficient to force the submarine to the surface were considered for a wide range of H.E. and nuclear warhead yields.

10. Fig. 35 shows, for illustration, the estimated stand-offs required

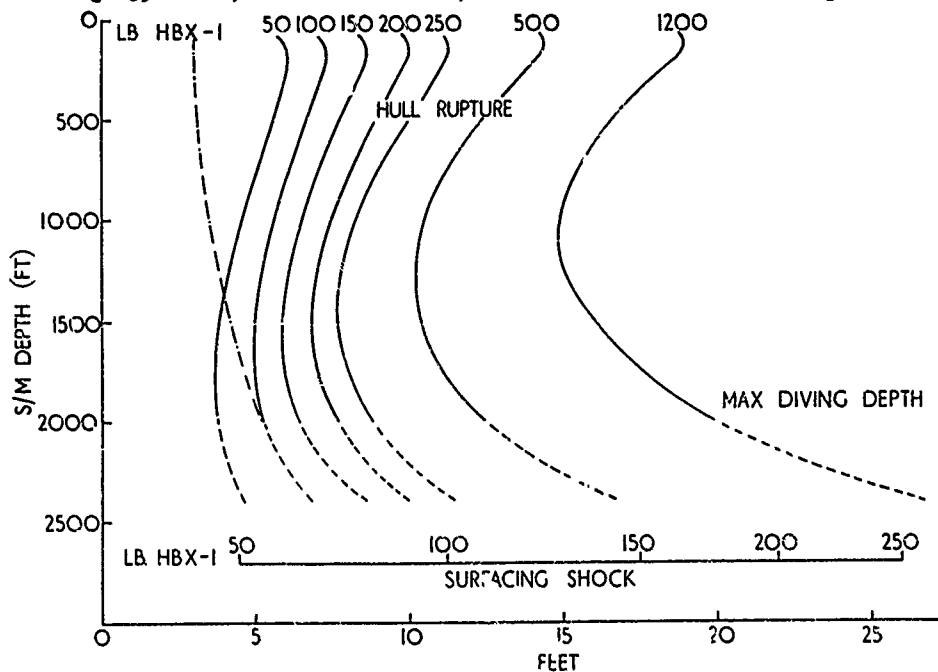


Fig. 35 Stand-off from pressure hull for hull rupture and surfacing shock.

between the warhead and the pressure hull of a hypothetical submarine with a 2,000 ft diving depth, for a range of high explosive warhead weights. The curves include crudely estimated effects of the explosion gas bubble and apply therefore only to stationary or slow targets. The effects against fast targets are more doubtful and are still being discussed. It is possible that they would give a behaviour as shown dotted in Fig. 35 for the case of a 100 lb warhead.

11. The stand-offs for surfacing shock damage (which are independent of depth) are also shown at the bottom of Fig. 35 and it can be seen that surfacing damage can be much more readily achieved against such a tough target.

12. The information on nuclear weapons has also been applied to the case of the IKARA system with a view to determining the optimum depth of burst and desirable sinking speed of the weapon. An increased burst depth improves the warhead effectiveness itself but also increases the dead time in the fire-control system. It was found that a relatively shallow depth of burst gave the best compromise.

#### Prediction of Position of an Evasive Submarine from Sonar Fixes

13. The investigation of the method of estimating the position of an evading submarine from sonar fixes has been continued. Evasive steering about a mean line of advance is assumed to result in a short-leg zig-zag containing a mixture of simple harmonic components. The most unfavourable situation for the use of the method arises when one such component is predominant at a particular frequency. Study has therefore been made of the variation of r.m.s. prediction error with frequency of 'enemy' situation, when the fire-control calculation is matched to:-

- (a) true situation frequency (ideal);
- (b) worst frequency (minimax);
- (c) zero frequency (linear).

The variation of predicted error with situation frequency is plotted in Fig. 36

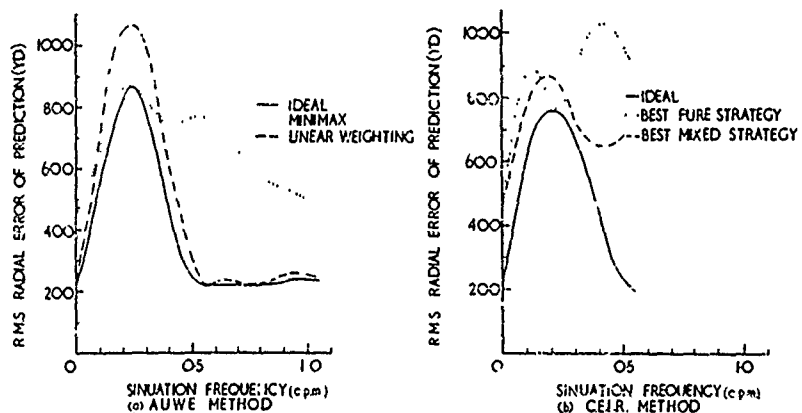


Fig. 36 Variation of Predicted Error with Situation Frequency.

for a 30 knot target and for particular values of the fire-control variables, namely, 11 fixes each with an error having an r.m.s. value of 200 yd at 12 second intervals. The prediction time is 72 seconds. Choice (a) is an ideal which it is impossible to attain because the true situation frequency is unknown. Choice (b) minimises the maximum r.m.s. prediction error which evasion can produce, provided that the number of independent fixes is not much greater than 10, and corresponds to a game theory solution of saddle-point type. Choice (c) reduces the r.m.s. error against a non-evading enemy but increases the peak error at the worst frequency. For numbers of fixes greatly exceeding 10, the game theory solution tends to produce mixed strategies, and there is then no single frequency of situation for which the fire-control computation can be optimised.

14. An alternative method of prediction has been investigated under contract by Messrs C.E.I.R. (U.K.) Limited, in which seven parameters specifying a sinuous target track are evaluated by least squares from the observed fixes. This is a non-linear estimation problem which has been solved iteratively on the LHM7090 Computer using various numbers of fixes, the errors in predicted position being averaged over all phases of situation cycle and over several sets of observational error. No investigation has been possible within the scope of the contract of the effect on prediction accuracy when the evasive manoeuvre comprises more than one frequency.

15. This study indicates that, for a pure situation, a refined game theory approach can reduce the r.m.s. prediction error below the level of the above A.U.W.E. method, particularly when the available number of independent fixes exceeds 10. With 11 fixes on a high speed target the C.E.I.R. solution is of mixed strategy type. Fig. 36 illustrates the variation of r.m.s. prediction error with situation frequency for the same operating variables. Three separate curves represent the following modes of optimisation:-

- (d) ideal;
- (e) best pure strategy (not a true minimax);
- (f) best mixed strategy.

Choice (f) must be compared with choice (b) of the A.U.W.E. method. Allowing for difference of detail in the underlying assumptions, it is fair to conclude that there is no significant difference in prediction accuracy between the two methods when fewer than about 10 independent fixes are available.

16. Work to date has not included data on target doppler which can be obtained from an active sonar, an omission which it is hoped to remedy in the future.

#### Close-Range A/S Weapons

17. Assessment of the future Shipborne A/S Weapon System has included a study of the role and effectiveness of close-range weapons; in particular the performance to be expected from A/S Mortar Mk 10, firing salvos of 3 or 6 projectiles, fitted with fuses of various types, contact, time, or proximity, to ranges extending beyond the present maximum of 1,000 yd.

18. System errors taken into account were errors in prediction of target plan position caused by sonar errors and target evasion, depth errors, and

delivery errors. It was assumed that the fire-control system could be treated as an ideal one, in which best use would be made of all available data given by the range and bearing records of Type 170, and that the enemy would be in a position to choose the most effective frequency of sinuous evasive steering throughout the tracking and prediction time. In practice both sides will fall short of these ideals.

19. In size and vulnerability the target was taken to be equivalent to H.U.S. DREADNOUGHT, and the probability was calculated of inflicting either surfacing or sinking damage with one or more salvos, at various ranges, speeds, and depths, assuming optimum pattern spacing and orientation, and perfect fuze operation. The effect of delivery errors in causing sympathetic premature detonation of proximity-fuzed charges was investigated, and found to be negligible. In the final analysis, salvo patterns of proximity-fuzed charges were taken to be in the form of a single line, aimed to fall across the submarine, a spacing of 32 yd being chosen to maximise probability of surfacing damage.

20. Typical results are indicated in Fig. 37 for 3-charge and 6-charge line salvos with proximity fuzes against a submarine at 500 ft. The horizontal lines are for the case of non-sinuating targets. A r.m.s. radial delivery error of 2% of range is assumed.

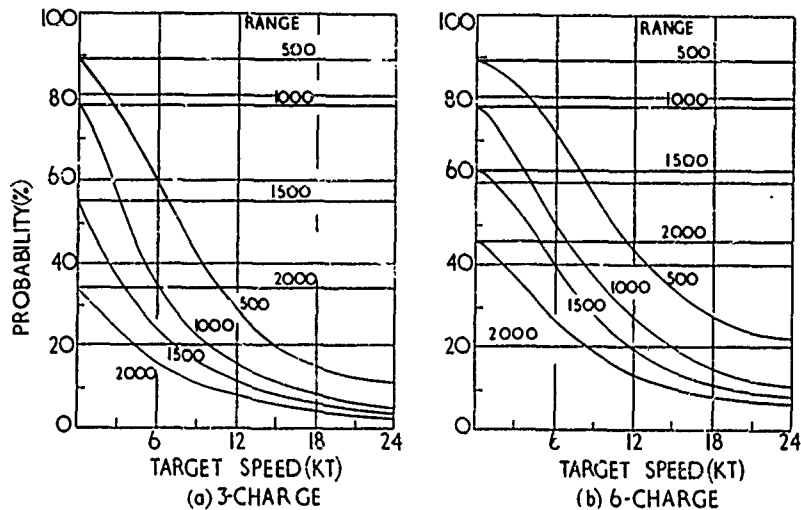


Fig. 37 Overall Probability of Surfacing Damage with a Proximity-Fuzed Line Salvo.

21. It was concluded that the 3-charge pattern fired from single-mounting A/S Mortar Mk 10 can give 80% probability of causing surfacing damage to a 15 knot non-evading submarine at 500 ft depth, provided that proximity fuzes are fitted. Maximum target evasion during tracking and prediction times can reduce this value to 10%. Retention of the present time fuze would halve these probabilities.

22. The 6-charge salvo can give substantially twice the probability of kill against high-speed evading targets at long range. When probabilities are



higher, however, the improvement is less marked and there is little difference between the two salvo sizes for non-evading or low-speed targets.

23. An increase of range from 1,000 yd to 1,500 yd would reduce surfacing damage probability by about one third. In general 3 salvos would be required at 1,500 yd to achieve the same results as 2 salvos at 1,000 yd.

24. The studies have included investigation of available close-range A/S weapons of foreign origin, some of which can provide ranges in excess of 1,000 yd. In general the ship itself has adequate speed and manoeuvrability to close to a range of less than 1,000 yd targets which are vulnerable to such unguided weapons; the need for greater range capability does not at first sight seem great. It is, however, the threat to own ship from the submarine's anti-escort weapons that makes a longer range desirable, albeit with reduced effectiveness and greater expenditure of ammunition.

25. Further studies have been carried on the material aspects of the Mortar Mk 10 and foreign weapons. It has been concluded that none of the foreign weapons should be adopted and that the R.N. should continue with the Mortar Mk 10. A revised layout of the double mortar installation occupying a reduced length of ship, with increased stowage and reduced manning has been recommended for future classes of frigate. It has been proposed that the mortar range be extended to 1,500 yd in those ships in which digital computing facilities are available. Progress on the proximity fuze is reported on page 32 and on the extension of the mortar range on page 31.

#### Salvo Firing of IKARA Missiles

26. A study has been made of the readiness and salvo intervals possible with the IKARA vehicle handling, launching and guidance system and a Working Party paper has been published. The present Australian system is expected not to meet the current requirement that the system should pass from Standby State to Action State (ready to fire) in 30 seconds. Some improvement in this would be possible by the introduction of receiver preheating arrangements prior to the launcher, but the design difficulties and ordnance risks argue against its adoption. Further gain is obtainable if the missile is tracked by the CF299 radar rather than by the Australian tracker, as the missile transponder with its slow warm-up can be eliminated. Similar differences in salvo interval are obtained and both cases are summarised in the table below.

System	Delay from alert to order "fire" (sec)	Total delay till missile leaves (sec)	Minimum salvo Interval (sec)	Max. range at which this is achieved (yd)	Salvo interval at 100,000 yd (sec)
Present R.A.N.	35	45	50	6800	66
R.A.N. plus preheat on trolley	26	36	41	5000	66
R.N. with CF299 TIR for tracking	20	30	35	7000	50

27. These salvo intervals have assumed that only one missile can be guided in flight at one time, and it does not seem worthwhile to demand more. This is particularly true while torpedo mutual interference is such a limiting factor. When and if it is solved the aim would generally be to make it difficult for the target to evade successive torpedoes independently; this it probably cannot do when the interval is of the order of only one minute.

## 7.2 - TORPEDO ASSESSMENTS

### Anti-Escort Torpedo

28. It is likely that the efficacy of passive torpedoes such as the Mk 20(C) and ONGAR (in the passive mode) will be greatly reduced when used in the anti-escort role by the almost certain use of decoys by the enemy. Operation of ONGAR in the active mode is not likely to be satisfactory either because of the poor echo/reverberation ratios obtained against such a surface target. Apart from this, wire guidance does not appear to be the appropriate technique for this weapon because of the restrictions placed on the firing submarine.

29. Alternative techniques such as wake homing and sonar seeking seem more attractive for mid-course guidance and/or homing. Each has its own particular characteristics. Wake homing provides continuous information; it is difficult to reduce the wake of a ship and the method does not appear to be troubled by high torpedo speed. However, the effect of high sea state is uncertain, false triggers may be likely, the effect of target weaves or loops is likely to be deleterious and little experience is available in this country of the fundamental physics of the problem.

30. Sufficient effort is not available to examine the guidance and homing techniques themselves, but a study contract has been placed with the de Havilland Aircraft Company to examine the kinematical, guidance and stability aspects of the homing system premised on the existence of reliable triggering signals.

31. In addition the contract calls for a comprehensive study of the hit probabilities of salvos of pattern-running torpedoes so that a definitive treatment may be available of the potentialities, and performance of this type of weapon. This latter analysis would enable a decision to be made not only on the effectiveness of pattern running per se, but also as a preliminary to a terminal homing phase based, for example, on wake homing.

32. The wake homing problem has been set up on the contractor's analogue computer and various torpedo steering programmes are being simulated to determine the torpedo trajectory, hit probability etc. against a constant velocity target producing an ideal wake.

33. Initially a simple cosine law for torpedo angular velocity is being used and the effect of system lags, etc. on the torpedo pattern stability is being determined. A programme selector has been devised to produce five steps of variable amplitude and duration for the torpedo angular velocity so that more complex and realistic torpedo steering programmes can be investigated. Also a finite width wake model is being introduced by using a conducting strip with probes, as an electric analogue.

34. A programme has been written for the digital computer studies of the pattern running torpedo hit probabilities as a function, inter alia, of the number of torpedoes in the salvo and the errors in target course, speed and range estimation. It appears that a twelve computer running time will be required to analyse the effect of a four torpedo salvo against one particular target track.

#### Universal Wire-Guided Torpedo

35. The logistics problem which will be encountered in supplying, servicing, carrying and loading the three very similar torpedoes Mk 20(S), Mk 20(C) and Mk 23, has led to a proposal by F.O.S.H. that they should be superseded by a Universal Wire-Guided Torpedo, designated Mk 23(U), the simplest and cheapest version of which would be obtained by giving the Mk 23 an up-homing capability as for the Mk 20(C) but leaving it otherwise unchanged (e.g. in speed).

36. A study has been made of the effectiveness in A/S and anti-escort roles of the proposed Mk 23(U), together with an assessment of the effectiveness in these roles of current torpedoes, Mk 20(S), Mk 20(C), Mk 23 and Mk 8. The main conclusions reached are:-

- (a) the proposed Mk 23(U) should be developed;
- (b) the importance of attacking submarines transitting on the surface must be decided before the policy on the development of the Mk 20(C) can be confirmed;
- (c) if the development of the Mk 20(C) is confirmed then the Mk 20(S) should be dropped;
- (d) the present Mk 23 gives the best performance against submarines which may be snorkeling or fully submerged;
- (e) the Mk 8 may be the best torpedo to use in the anti-escort role, though if the restrictions of wire-guidance are acceptable, the unmodified Mk 23 run shallow to hit directly may give a useful capability against one escort at a time.

#### Mutual Interference between Mk 20(S) Torpedoes

37. An investigation of results obtained in a trial with Mk 20(S) torpedoes showed that the variation in speed between torpedoes is as important as gyro angle and firing interval in determining whether or not mutual acoustic interference would occur.

#### Use of Automatic Computer in Analysis of ONGAR Runs

38. A digital computer programme has been developed for use in analysis of ONGAR homing runs. The torpedo internal film record is placed on a film reader, the Benson-Lehner Data Reduction System OSCAR, which punches the data on tape for input to an Elliott 803 Digital Computer. The output tape from the digital computer is run on an Electronic Associates, Inc. Digital Data Plotter to obtain tracks of submarine and torpedo, and torpedo depth, pitch and roll during the course of the attack.

39. The torpedo track is computed from the continuous record of torpedo heading error as the torpedo follows ordered changes in course. The digital computer output tape will also give a tabulated numerical print-out including both ordered and actual torpedo headings, at all data instants during the attack.

### 7.3 - SONAR TECHNIQUES AND PERFORMANCE

#### Variable Depth Sonar

40. A limited number of the R.C.N. AN/SQS 504 Sonars has been bought for fitting in earlier ships of the present construction A/S Frigates of the LEANDER and TRIBAL classes to gain experience of the operational value of variable depth sonar; the first ship so fitted is scheduled to commission early in 1963. This equipment is subject, however, to the limitations in search rate inherent in a searchlight sonar and consideration is being given to the substitution, in later ships of these classes and in new construction, of a variable depth scanning sonar system.

41. A study has been made to assess the probable effectiveness of a variable depth sonar (V.D.S.) to supplement the A/S detection capability already afforded by a medium-range hull-mounted sonar in a ship with a world-wide employment and to make recommendations for suitable fitting. The conclusions of the study are summarised:-

- (a) When considered on a world-wide area basis a V.D.S. can provide a supplementary detection capability for approximately 31% of the time.
- (b) Although there will be large ocean areas, distributed mainly in the equatorial belt, where V.D.S. is of little potential value, the advantages offered by V.D.S. when operating in higher latitudes, together with supplementary facilities which this type of equipment can provide, justify the continued fitting of a V.D.S. equipment.
- (c) In the majority of conditions V.D.S. detection ranges against evasive targets will be refraction-limited to less than 5,000 yd. The V.D.S. equipment should therefore aim to provide optimum search performance at the restricted ranges of deep targets and should be operated independently of the longer range hull-mounted duct sonar.

#### New Passive Sonar for Operational Submarine

42. Although Sonar Type 186 consistently achieves detection ranges of some 60 to 80 miles in trials and exercises against snorkeling submarines of the later types ('A' and 'T' conversion) its detection range against 'P' and 'O' Classes is only some 10 miles. Moreover the long time to carry out an all-round sweep and the existence of only a single narrow detection beam are technically inefficient and tactically restricting. The two latter handicaps could be removed by improvements to the signal processing. One possibility would be to retain the array in its present position and by means of a series of closely-packed preformed beams provide a time-bearing plot. Passive ranging facilities could also be provided by dividing the array in three sections and by determining the target bearing from each of the two array pairs so formed.

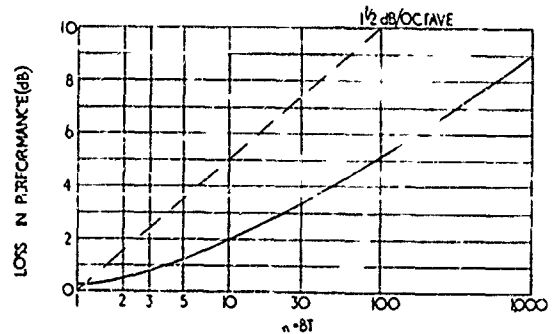
A development programme has been proposed by A.R.L. using the Type 186 array to provide these facilities using a parallel digital processing system based on the use of shift-register delays.

43. Though this system would provide the improved facilities, the performance and characteristics of the Type 186 array leave much to be desired when used for forming beams at a large angle to the normal of the array and its restricted length gives a very short base line for passive ranging. A preliminary design based on the use of three topside arrays has been outlined which could be free of the reflection difficulties of the Type 186 array and would provide a much longer base line. Moreover such a set could probably be designed to provide all the integrated facilities of search, fire-control, torpedo warning and passive ranging etc. and so reduce the total volume of equipment as opposed to the present configuration which requires a separate set for each facility with consequent large space demands. The signal processing system being developed by A.R.L. could, in principle, of course, be made compatible with any new array spacing.

44. A more complete assessment will be made later in the year in collaboration with A.R.L. of the likely performance of the sets using the two different approaches and, additionally, of the performance to be achieved by a passive ranging system based on Type 186 compared with foreign passive ranging systems.

#### Theoretical Analysis of Sonar Detection

45. Theoretical studies have been carried out of the signal-to-noise performance of sonar receivers. A particular point of investigation has been the relative performance of pre-detector and post-detector integration against a white gaussian noise background. It is shown that in practical cases there is relatively little difference between them for bandwidth ratios up to about ten, but that beyond this post-detector integration is inferior.



46. Fig. 38 shows the loss in decibels of a receiver with a bandwidth  $B$  c/s in the detection of a pulse of duration  $T$  seconds compared with a receiver employing a number  $n$  ( $= BT$ ) of optimally designed doppler filters. It was possible to carry out the calculation rigorously in the difficult intermediate region providing the detector was of square-law type. The curve is valid for 50% detection probability with a false alarm probability in each range element between  $10^{-2}$  and  $10^{-5}$ .

Fig. 38 Relative Performance of Post-Detector and Pre-Detector Integration.

47. The detector and bearing accuracy of a phase comparison sonar against white background noise has also been studied and it was shown that signals strong enough on average to meet the statistical criterion for detection would give a good bearing accuracy. For example, with unshaded adjacent transducer arrays, with 50% detection probability and a false alarm probability as high as  $10^{-4}$  per range element, a r.m.s. bearing error of some 4% of the beamwidth

can be obtained. The effect of overlapping the transducers, i.e. by using common staves, or alternatively the effect of a correlated background is capable of degrading the bearing accuracy seriously.

#### Properties of Reverberation

48. A theoretical study has been made of the power spectrum of reverberation in shipborne sonars; the agreement with the rather sparse experimental data available is satisfactory. It was used in the comparison of sonar performances referred to above (see page 86).

49. From a moving ship, the reverberation spectrum shape is not only a function of pulse length but is also spread by the effect of sonar beamwidth. A particular point of interest is that the improvement of echo/reverberation ratio obtained from doppler filters is greatly reduced.

#### Sonar Prediction

50. The experimental Range Prediction Manual for sonar equipments described in the previous S. and T. Report has been in use in the Fleet for a year. During this time approximately 60 reports of detection incidents by medium-range Sonar Type 177 have been received for analysis of which nearly 40 took place in deep ocean waters and the remainder in coastal areas.

51. Preliminary examination of these data suggests that the method will provide operationally useful predictions for deep water areas. A plot of these results is given in Fig. 39; it will be seen that for deep water areas 60% of the actual ranges of detection achieved fell within  $\pm 25\%$  of the predicted range, but coastal waters show a gross over-prediction with the actual ranges of detection apparently limited to approximately 6,000 yd, presumably due to reverberation. It must be borne in mind, however, that the two sets of data were obtained mainly during two exercises in comparatively limited areas and do not represent an adequate sample of the environmental conditions that might be encountered.

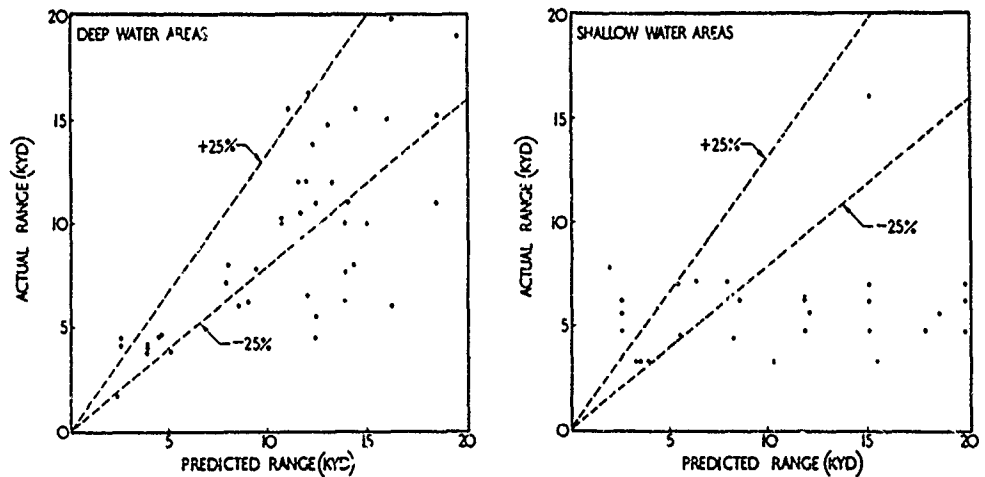


Fig. 39 Comparison of Achieved and Predicted Sonar Ranges.

52. It is believed that refinement of the method generally, and particularly in comparatively shallow water will require in situ measurement of the sonar performance figure versus range using the actual masking background signal, whether this be predominantly reverberation or self noise. The provision of such facilities for measuring the background for Type 177 is in hand.

53. The study of Type 177 detection data for which corresponding reverberation data were available is being extended to initial detection data derived during the development trials of Sonars Type 184 and Type 2001, for which ping-by-ping reverberation records at or near the time of detection were available. As with Type 177 the results indicate that detection of fine aspect, low speed targets is made against reverberation background.

54. The aim of the work is to see if measurement in situ of reverberation level with range can provide data on sonar propagation and performance which might provide a basis for sonar prediction. Since detections are in the majority of cases against a reverberation rather than a noise background, the method used in the manual referred to above, which is based on noise-limited detection, may well need elaboration.

55. To date, the work has been confined almost entirely to analysis of past trials data. A specification has been prepared for the construction of a display for use in conjunction with the background measuring equipment referred to above in order that predictions may be carried out at sea.

#### 7.4 - HELICOPTER/HYDROFOIL CRAFT/HOVERCRAFT STUDIES

56. A general theoretical investigation is being made into the A/S requirements for the new joint R.N./R.A.F. helicopter which is being planned as a successor to the Wessex. At the same time the study is being extended to include the potentialities of hydrofoil craft and hovercraft as A/S platforms since in many ways their operating characteristics are similar to those of a helicopter when running in their foil-borne or air-cushion modes respectively.

57. Although the size and speed of the Wessex successor are likely to be determined by other considerations such as suitability for the commando-carrying and close logistic support role, it is desirable to know the aircraft and sonar parameters which are most appropriate to attacking the fast submarine target of the 1970s (up to 40 knots).

58. The present helicopter set, Type 195, is now undergoing evaluation and no operational experience is yet available. However, it is obvious that two ways in which the set could be improved would be in increased arc of cover per transmission and by increased range. Both these improvements incur extra all-up weight of the sonar and it is likely that if a 5,000 lb limit is imposed for the weight of the sonar set the range of the set would be restricted to some 10,000 yd for an all-round looking set, even under good sonar conditions, i.e. the target in a thick isothermal duct.

59. When the requirements of the helicopter in the datum search role are examined it is evident that the most important A/S factor, apart from time late at the datum, is the maximum range of the set. Thus a 14 minute time late at the datum would require a 10,000 yd range sonar to ensure a 50% first dip detection probability against a randomly evading 30 knot target. However, it is not in general possible to ensure such a long detection range against

targets making use of thermal layers for concealment and it is probably necessary to use rather more detection units of more moderate range capability.

60. Equally in the screening role, maximum range is of greatest importance in increasing the width of the front covered, but the exigencies of sonar performance are again likely to force the use of rather more units with smaller range.

61. In both cases it is considered of little value to design for maximum ranges beyond 7,000 yd or so. Improvements in arc of cover per ping, hoist speed, etc., can be introduced to make somewhat better use of the ranges obtained.

62. In the tracking and closing phase of an attack these latter factors become more important since the helicopter now spends a greater proportion of its time in the hover. However, it appears that none of the single helicopter weapon systems or techniques such as "on-top" drops, unguided or guided fore-run, self-vectored attacks etc. are satisfactory and the best solution would be to use a double-helicopter system. The weapon dropping helicopter would be either a similar helicopter or a MATCH helicopter, which type is likely to be present in sufficient numbers and has sufficient range to make the concept viable. An alternative solution would be to close the target with the helicopter in continuous contact by towing the sonar at a greater speed than the target. However, the tow bar pull required of the helicopter at say 45 knots is well over 10,000 lb, without taking into account the snatch (transient) load factor, and is beyond the capacity of even a future large helicopter.

63. A hydrofoil craft has performance characteristics intermediate between those of a ship and an aircraft, though like the helicopter it must use its sonar in the "grasshopper" mode since a towed sonar would cause a prohibitive drag increase. Its major gain over the helicopter is in load carrying capacity and endurance but its inferiority in maximum speed and acceleration make it inferior in the datum search role unless its delay time can be made much shorter than that of a helicopter by keeping it continuously on station. Equally its comparatively sluggish performance between dips makes the use of a double vehicle weapon system essential. These comments apply generally to hovercraft as well, though maximum speed may not be so restricted.

64. A very important factor in both hydrofoil and hovercraft cases is the self-noise of the vehicle when the sonar is in operation. Unlike the helicopter both vehicles can be run in the displacement mode with main engines switched off and a specially designed transducer suspension system would minimise the effect of heave. Thus it is likely that lower background self-noise can be achieved than with a helicopter. However, the effect of such a main engine switch off on the time to reach maximum speed and the maximum sea state in which the craft can be operated may be undesirable.

#### 7.5 - BEARINGS ONLY ANALYSIS

##### Results Achieved by an Automatic Method

65. During the last year the automatic solution to the B.O.A. problem has been further developed and evaluated on the computing facilities at Portland. Results show that within the assumption of the study, i.e. zero navigational



error, no correlation between bearing errors, no degradation of sonar performance due to the tracking submarine manoeuvre, and a constant velocity target, there is a 90% chance of achieving a solution within 10 minutes. These solutions are accurate to within 5% of range and speed and 5° of target course. They reach out to initial target ranges of:-

- (a) 10 miles when the standard deviation of bearing error is 0.25°;
- (b) 5 miles when the standard deviation of bearing error is 0.5°.

66. The automatic method represents a substantial advance of the hand-plotting method currently in use, see below. In its present form it is limited mainly by the inability to introduce estimates of, or constraints on, the solutions for course and speed. It also suffers from the deficiency, inherent in all existing methods, of being severely disturbed by a well chosen target zig-zag. For these reasons, and because of the uncertain position occupied by B.O.A., among the competing and supplementary techniques in the passive ranging field, no early sea trials are contemplated. A further study contract has been placed with Messrs Elliott Bros to examine the extent to which these deficiencies can be removed or reduced.

#### Results Achieved by Current Hand-Plot Methods

67. An analysis has been made of the results achieved by a variety of teams in bearing-tracking exercises conducted at the Submarine Attack Teacher, Rothesay. Over 100 complete solutions have been analysed to find the accuracy with which each team estimated the range, course and speed of the target. It has not been possible to assess the mean time taken to reach a solution because the necessary data are not contained in the attack teacher records.

68. The analysis shows that the distributions of error in estimation of target course and speed are comparatively normal with standard deviations of 32° and 1.8 knots respectively.

69. In the light of the magnitude of the standard deviations and the size of sample, the estimates were unbiased. It may be noted that standard deviations little larger than these would be obtained from reasonable a priori guesses of target course and starting speed.

70. The distribution of error in estimation of target range is much less normal and shows a wide spread of error. The estimated ranges, grouped in 1,000 yd bands of true range, and averaged within each band are shown in Fig. 40. This reveals that the estimated range tends towards 2,000 yd whatever the true value of range, short ranges being over-estimated, long range being under-estimated. The bias towards 2,000 yd is explicable by the fact that the records are of the firing solutions and that the available torpedo is not effective beyond a maximum of 4,000 yd.

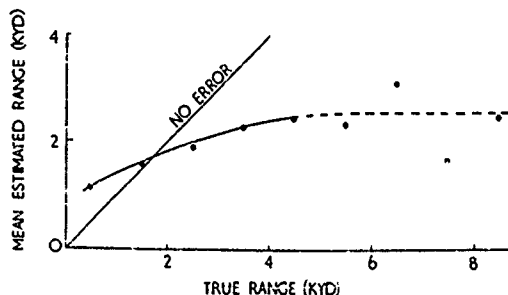


Fig. 40 Mean Estimated Range versus True Range.

Tracking is normally continued till the estimated range approaches about 2,000 yd. The results show, however, that at this instant there is a very large spread in the true range. Contrary to common belief, no appreciable difference was detected between the four types of personnel of differing experience and seniority who acted as operators.

#### 7.6 - ELECTRONIC AND SONIC WARFARE AFTER 1970

71. Because of the increasing importance of electronic warfare in military radar and radio systems the Director of the Signal Division has called for a forward-looking study that would result in a recommended research and development programme for future equipment and a recommended philosophy of usage. Because of the similarity of many of the technical problems and tactical situations in the underwater equivalent of Electronic Warfare (EW), which has been termed Sonic Warfare (SW) it was obvious that a co-ordinated study of the problems would be beneficial not only in the evaluation of techniques but also in their joint employment in Naval Operations. Accordingly in early 1962 a study group of three members, including one from A.U.W.E. was appointed with A.S.W.E. as the co-ordinating authority. The terms of reference of the study call for an appraisal of the likely requirements over the next decade based on an assessment of probable design trends in enemy equipment, priorities for supplementation of the various SW (and EW) tasks and the likely equipment time scale. An important outcome is hoped to be a cross-fertilisation of ideas from the two related fields of EW and SW to ensure that no techniques and concepts are being neglected.

72. It may be seen that the use of sonic warfare has lagged behind that of electronic warfare, e.g. techniques such as jamming, reciprocal intercept and radar silence have not yet been applied in this country in the sonar field. However, one A/S vehicle in particular, a submarine, lives almost entirely in a sonic warfare environment, making detections by passive means, being very conscious of own radiated noise output, exploiting any favourable propagation characteristics of the medium to reduce detectability and being conscious that its homing weapon may be rendered ineffective by the target countermeasures. However, it is still likely that SW techniques can be adopted from the EW field, possibly chiefly in the field of intercept and I.F.F. systems.

73. Apart from the consideration of specific devices to perform essential SW tasks, an important by-product of a study of this nature is the making aware of the designers of our own weapon systems of the potentialities and techniques of SW so that these weapon systems can be made more resistant to enemy countermeasures. Moreover to devise effective SW systems which can be available to the Fleet in time phase with corresponding enemy equipment it is necessary to make an early assessment of the most probable design trends of enemy equipment including the possibility of his using techniques not yet developed for the R.N. With the present 6 to 8 year minimum evolutionary period from research to production it is usually much too late to wait until the characteristics of any enemy equipment are known before starting the design of a corresponding EW equipment. Thus solutions effective against only one design of enemy system should be avoided as being vulnerable to enemy design changes. Instead solutions should be broad-based with a capability to meet a number of possible designs available to the enemy for the accomplishment of his objective. Such solutions represent the best defence investment by having the best prospects of a long operational life.

74. A list of 5<sup>c</sup> tasks has been derived in relation to probable naval operation after 1970, the threats to naval forces in limited and global war, and the assessed degree of sophistication of enemy equipment. A short list of these tasks has been selected on the basis of tactical value, technical feasibility and cost-effectiveness. The next step is to develop the optimum scientific method of realising the required characteristics. Although there is a large number of sonic warfare tasks, the majority of them are already being pursued in some form or other. The outstanding items are in the field of jammers, mobile decoys, communications and I.F.F. though here too the R.N. is closely watching the development of suitable foreign systems which may be purchased or anglicised, or jointly developed.

#### 7.7 - MINE COUNTERMEASURES ASSESSMENTS

##### New Mine Countermeasures Vessel

75. To aid an Admiralty working party in the planning and design of a new mine countermeasures vessel which is expected to enter service in 1970, a study was completed of the characteristics required by this vessel to combat the likely mining threat in the 1970 era and the techniques to achieve them (see page 77). It was assumed that the vessels would have to operate in a limited war setting with equipment very similar to that which is at present in service; the ground mines which would be met would rely on conventional influences - magnetic, acoustic and pressure - with sensitivities high enough to make the safety to the vessels very difficult to achieve; provision would also be required for dealing with moored mines.

76. In this context, the study showed that it would be necessary to maintain both hunting (acoustic) and sweeping capabilities. The question of whether a vessel was required which could both hunt and sweep, or whether separate hunters and sweepers were more suitable, was left open pending further investigations. If separate vessels were required, then at least half of them should be hunters.

77. To achieve a reasonable degree of safety for the M.C.M. vessel, it was concluded that, for sweepers, self-danger widths against magnetic and acoustic mines of seven and twelve yards, respectively, were desirable, although a relaxation of these widths to 20 and 36 yards, respectively, would be just acceptable. The sweepers should not be endangered by pressure mines. For minehunters, a self-danger width not exceeding five yards was desirable, but an upper limit of 15 yards could be accepted. Detailed technical assessments of the prospects of achieving these magnetic, acoustic and pressure signatures, were included in the study.

78. It was also concluded that a worthwhile gain could be achieved in increasing the sweeping speed from 8 to 12 knots, providing the safety requirements could be met at this speed. Any increase in the operational speed of minehunters which did not increase the hunting efficiency would be of direct benefit.

79. Present sweeper navigational accuracies were concluded to be adequate, but an increase in the accuracy of navigation of acoustic minehunters was desirable, to give errors of not more than 20 yards.

### Application of Game Theory to M.C.M. Tactics

80. Other M.C.M. assessment studies have continued in association with the Technical Panel of the N.A.T.O. Mine Countermeasures Working Party. An interim report was prepared for the Panel on estimating the maximum amount of sweeping required to reduce the risk to the ships subsequently using the channel to an acceptable figure. The method, using two limiting sweeping conditions, applied Game Theory to the problem, and overcame the imperfections of the method that had been submitted previously. The work is now continuing to cover practical values of the sweeping parameters.

81. The extended study of an M.C.M. assault operation using the Theory of Games, has been completed and the general results of the study were used in the new M.C.M. vessel assessment described above.

82. During the year the possibility was examined of extending the computer programmes used for the assault setting to study a situation in which more than one minelaying and countermeasures operation occurred. It was concluded that the programmes could be extended to give the ship losses in any specified situation, but that the study of a completely general situation was not possible as the pay-off matrices would be too large for the available computer store to accommodate. Nevertheless it is thought that a study under restricted conditions should be possible and might lead to a solution close to that for the general problem. A general description of a possible tactical setting has been circulated to N.A.T.O. operational commands.

### Navigational Accuracy of Merchant Ships

83. Work has just commenced to obtain accurate information on the navigational error of merchant ships, and how this is affected by different methods of navigation and dan-laying. A.U.W.E. has accepted custodianship of this problem on behalf of the N.A.T.O. Working Party. As a start R.N. trials have been carried out on the Bexington range, using the two shore-based theodolite stations to track R.F.A. vessels transiting a buoyed channel.

### Reduction of Mine Sweeper Risk

84. The paper on a method for reducing minesweeper risk, which had been submitted to the Panel in 1961, was sent to N.A.T.O. operational commands asking them to comment on the method and the presentation. The replies that were received suggested that simplification in the presentation was desirable. A method for achieving some simplification has been tried, and it is now necessary to prepare a shortened paper for operational use.

### Assessment of Recording Mines

85. A trial was carried out to test certain foreign recording mines and assess their value for R.N. use. The trial formed part of a combined naval M.C.M. exercise under the command of the Captain, Mine Countermeasures (Home). In the trial, sweepers from both countries passed in line astern at right angles through a line of recording mines. The track-time chart for each sweeper was accurately determined by two shore-based theodolite stations on their final approach to the mine line. The results were subsequently analysed in detail by A.U.W.E. They showed that the mine clocks were of a high order of accuracy, enabling the distance of the sweeper from a mine at the time of

actuation to be determined with a standard deviation of error of about 10 yards. The performance of the magnetic sweep appeared to give approximately the expected actuation widths. Anomalous results were obtained on the acoustic circuits, however. There appeared to be large differences in the swept paths from different low-frequency sweeps which were nominally the same, some actuation ranges being in excess of 1,000 yd from the sweep. The audio-frequency circuits of the mine also seemed to be activated by the low frequency source, either due to the harmonics of this source or to interference between audio and low-frequency circuits in the mine.

86. It was concluded that, whilst such recording mines cannot offer such good facilities for testing sweeps as the Bexington range, they could fulfil a useful function in operational commands, particularly those based abroad.

## SECTION 8 - POST DESIGN

### 8.1 - SONAR EQUIPMENTS

#### Divers Aid Mk 1 - Type 151D

As a result of trials to compare the performance of the Divers Aid Mk 1 and a foreign equipment it was clear that the latter equipment was to be preferred. A new Staff Requirement has been raised and a transistorised version of the foreign equipment has been proposed as the best means of fulfilling the requirements.

#### Attack Sonar Type 170

2. A limited trial of the pre-amplifiers for use when Type 170 is fitted in conjunction with Type 182, was carried out early in 1962 at one frequency only (22 kc/s). An improvement in initial detection range, compared with present pre-amplifiers, was obtained. A further trial of tests at the remaining frequencies is in hand and includes an assessment of the effect of these pre-amplifiers in reducing self and mutual interference from Sonars Type 177 and 184.

3. Post design work continues satisfactorily at Messrs Hartley Electromotives Limited. The Type 170 Reference Equipment has been installed by the post design contractor and testing and tuning is in hand.

#### H.E. Warning Set - Sonar Type 176

4. The post design contract has been transferred to Messrs R. B. Pullin and Company Limited, and the installation of the Reference Equipment is proceeding.

#### Search Sonar - Type 177

5. During 1962 seventy-four defect reports were received and are under investigation. The Reference Equipment is now being installed by the Post Design Contractor, Messrs Cottage Laboratories Limited.

#### T.A.R.T. - Type 181

6. During the past year only four defect reports have been received and none of these was considered to require further action.

#### Towed Torpedo Decoy - Type 182

7. A further series of trials, lasting approximately four weeks, was carried out in H.M.S. AGINCOURT in July/September 1962. Towed bodies used in the previous trials, together with bodies incorporating a number of further modifications, were used in conjunction with two types of towing cables. One type of cable had a four layer armour construction, generally similar to that used during the experimental trials of the equipment, the other was of two layer armoured construction and was a development of the two layer cable used in the trials in H.M.S. BLAKE and H.M.S. UNDAUNTED during 1961.

8. The results of the trials showed that both types of cable were unsatisfactory, as at no time was it possible to achieve stable results with

the two layer cable and although the four layer cable gave repeatability it eventually failed mechanically and electrically. The limitations imposed by the cables only enabled limited investigations into the alternative body arrangements to be carried out.

9. In view of the results obtained from this trial A.U.W.E. reported that although some progress had been made there was no possibility of releasing Type 182 to the Fleet for at least 12 to 18 months.

10. A further study of the hydrodynamics of the towed body was carried out as a result of this trial and it was shown that the stability could be increased by repositioning the Transducer Casing.

11. Two quarter scale model bodies have been manufactured, one to this arrangement and one as those used in the AGINCOURT trial, and were subjected to towing trials in the Ship Tank at Feltham in February 1963.

12. A new series of sea trials is planned for 1963, starting in H.M.S. ASHANTEE. The object of these trials will be to investigate the alternative body/transducer configuration together with a new design of two layer armour cable.

#### Emergency Underwater Telephone Type 183

13. A failure in the modulator of this set is being experienced and is thought to be due to a limited shelf life of the copper oxide rectifier when potted. A survey of the units in store and held as spares is being undertaken as a matter of urgency.

#### Underwater Telephone Type 185

14. It has been found impossible to make an effective redesign of the pressure hull gland to overcome the large number of failures reported by the Fleet and the only satisfactory solution is the fitting of polythene hull glands with the appropriate transducers. A programme for the fitting of such installations is in hand.

15. Further investigation of the bow installation of four narrow beam transducers in H.M.S. VALIANT showed that the arrangement would not provide the required coverage and an alternative scheme has been produced. This new arrangement, Type 185GL, consists of two synchronously rotating transducers, one in the after end and one in the fore end of the fin structure. This scheme will provide complete all-round coverage. The control unit and synchronous drive unit to control the two scanners is being designed and made in A.U.W.E.

16. Post design work continues at the Post Design Contractors, Messrs R. B. Pullin. The design of the modified Receiver/Transmitter for use in ships with long cable runs has been completed and the first production unit to this design will be completed in mid-1963.

#### Submarine Search Hydrophone Type 186

17. Post design work is still handicapped by the lack of a Reference Equipment but this is now beginning to become available and is being installed

by the Post Design Contractor, Messrs Cottage Laboratories Limited. Some work has however been accomplished by working on equipment installed in the Fleet.

#### Submarine Search Sonar - Type 187

18. Redesign of the transducer, to eliminate interference caused by the relative movement of certain parts of its structure during rotation, has been completed and passed for production.

19. A trial was carried out during 1962 to determine the effect of depth on the present transducer and showed impaired performance at both  $2\frac{1}{2}$  and 10 kc/s. The sensitivity of the transducer decreased with depth, whereas the back response increased. The loss at  $2\frac{1}{2}$  kc/s was greater than that at 10 kc/s and the maximum operational depth was observed to be only 300 ft. The transducer recovered as the pressure was reduced and the recovery time, which was dependent on depth and duration of the dive, was of the order of 30 minutes. To overcome this defect a new transducer of the barium titanate type is being developed.

20. A requirement has arisen for use of Type 187 in the active role for range determination during the later stages of an attack. This is being met by lengthening the existing 2.5 millisecond mine detection transmission pulse to 25 milliseconds and by use of the new barium titanate transducer referred to above, which will have a greatly increased transmitting efficiency over that of the existing scroll type transducer.

21. A Reference Equipment has been installed at the post design contractor's works. This will speed up the introduction of modifications shown as necessary in service.

22. A new version of Type 187 is needed for submarines carrying ONGAR. This version will incorporate a Signal Discriminator to assist in the determination of the range and bearing of the ONGAR torpedo relative to the parent submarine.

23. Experimental and prototype models of this equipment have been made and fitted in H.M.S. CACHALOT and H.M.S. OCELOT respectively. Trials in H.M.S. CACHALOT will take place in the Autumn 1963. Monitoring facilities, to enable the ONGAR attachment to Type 187 to be tested without firing the torpedo, have been included. Provisional test specifications and temporary handbooks will be available later this year. The preparation of the drawings is proceeding satisfactorily.

#### Cavitation Indicator - Type 189

24. The first production unit is scheduled for September 1963 and a post design contract is being placed with Messrs Hartley Electromotives who are the present production contractors.

#### Sonar Type 193

25. The first production equipment completed system test early in 1963 and other production equipment is following. Post design work, mainly associated with problems arising during production and system test, is continuing at the Post Design Contractors, Messrs R. B. Pullin.



#### Helicopter Sonar - Type 194

26. The cast aluminium dome to facilitate production has been accepted into service and is now in production.

27. The elimination of the corrosion of magnesium cable reels due to sea water continues to absorb a considerable amount of post design effort and money. A number of palliatives have been introduced and others are scheduled for incorporation at an early date. In view of the expected 10 years of further life for this equipment serious consideration is being given to the design of an aluminium cable reel.

28. The volume of post design work on this equipment continues to increase; this is mainly due to the special problems arising from its installation in the Wessex helicopter. A continuation contract, covering post design work up to 1964, has been placed with Messrs R. B. Pullin by the Ministry of Aviation.

#### Sound Range - Type 720

29. Production under D.W.U. contracts has been subject to delays and difficulties primarily because production proceeded direct from an experimental model without benefit of a fully and accurately documented production prototype as only a limited number of sets was required. Significant effort has been provided to help overcome these difficulties, including the introduction of modified components.

#### Submarine Scanning Hydrophone - Type 719

30. The replacement units for the 5 inch synchronous link and D.C. motor has been delayed by lack of Reference Equipment, but the new components are now available and tests will be starting shortly

31. Post design work is proceeding satisfactorily at the post design contractors, Messrs E.M.I. Limited, and the installation of the Reference Equipment was completed in March 1963 and will considerably assist post design work.

#### Sonar Directing Gears

32. A post design contract has been placed with Messrs Lawrence Scott and Electromotors Limited, who are at present investigating mechanical defects in the Type 187 directing gear, and simulating working conditions to ascertain possible noise sources.

#### Echo Sounders Types 771 and 772

33. Action is in hand to provide time-interval marking on the recorders.

#### Echo Sounder Type 773

34. The post design contractor for this equipment is Messrs R. B. Pullin; work is in hand to redesign the output stage and provide a receiver test jack in the receiver-transmitter. A redesign of the transducer is in hand to overcome corrosion trouble.

### Echo Sounder Type 776

35. This is a modified commercial equipment and Messrs Kelvin & Hughes have a contract to maintain the drawings. The transducer housing has been modified to accept polythene cable for submarine fitting.

### Submarine Bathythermograph AN/BQH-1B

36. The ship installation drawings have been prepared for fitting this equipment in H.M.S. VALLIANT and 'O' and 'P' class submarines.

37. The first equipment has been received and is being examined with a view to conversion to polythene cables and for trials in a mock-up of the proposed installation.

### Submarine Bathythermograph AN/BSH-2

38. The only failures reported with this equipment have been due to the ingress of water into the salinity-temperature elements. Arrangements are being made for pressure test equipment to be supplied to Portsmouth Dockyard.

## 8.2 - WEAPON EQUIPMENTS

### Torpedo Discharge

#### Torpedo Tubes for 'A' and 'T' Class Submarines

39. The decision to fit the new Impulse Cut-Off Units in A and T Class Submarines has been deferred until trials in the deep firing tank are complete (see page 33).

#### 21 inch Mk 20 Self Discharge

40. Two sets of redesigned torpedo starting gear have been sent to Chatham Dockyard for fitting in H.M.S. OCELOT. The new gear has been designed to obviate the following defects:-

- (a) Seizure owing to inadequacy of lubrication arrangements.
- (b) A torpedo could slide out of the stern torpedo tube prematurely when the top stop was clear and the boat trimmed bow up.
- (c) No remote operation as is desirable in the case of a T.C.S.S. 7 or 9 fitted boat.

41. A layout of the redesigned equipment, as "mocked-up" by Chatham Dockyard, has been generally accepted with minor modifications. These are being incorporated mainly by the Dockyard. The outstanding requirement is the provision of a firing circuit from the Control Room.

## Dual Pressure Firing Gear

### Internal Preservation of H.P. Air Systems

42. The torpedo tube H.P. air cylinders, treated with Araldite, and fitted in H.M.S. TRUMP, have completed a full commission and have been returned to A.U.W.E. for examination.

### Water Non-return Valve

43. The new design has satisfactorily completed trials and drawings have been issued for fitting in all classes of submarine. The final report has not yet been received from H.M.S. TRUNCHEON and hastening action has been taken.

### Large Firing Valve

44. Production drawings for retrospective fitting of a modified valve to ease maintenance in PORPOISE and OBERON Class submarines have been prepared and will be issued when satisfactory trials have been completed. Since the time required to modify large firing valves is estimated to be very much less than the present refit time it is proposed to apply the modification to 'A' and 'T' class submarines.

45. Difficulties have been found in making an airtight seal between the non-ferrous sleeve and the ferrous motor cylinder casting. It is thought that a solution has now been found, but this remains to be proved.

### Auxiliary Small Firing Valve

46. Recent trials of Dual Pressure Air Firing Gear have shown that a torpedo runback could be caused by delayed opening of the Auxiliary Small Firing Valve. This delay starts the Automatic Inboard Venting System too early in the firing cycle.

47. A simple modification to the calibration equipment has been designed to detect this fault and drawings are being prepared.

48. The Auxiliary Small Firing Valve has been modified to cure its delayed opening.

### Top Stop and Spring Catch

49. Modifications have been carried out in PORPOISE and OBERON Class submarines to reduce the excessive friction which caused stiffness of operation.

### Drum for Recording Torpedo Velocity

50. Recent submarine discharge trials in Mk 20 torpedoes have shown that the present velocity drum is unsuitable because of the effects of its large inertia.

51. A lightweight velocity recorder has been designed which uses a separate line storage and measuring drums. The line storage is a fixed spool which can carry up to 300 ft of line and the measuring drum is a lightweight alloy disc of negligible moment of inertia. The line is Nylon monofilament of 80 lb breaking strain.

52. Satisfactory trials of experimental models have been carried out and prototypes are now being manufactured.

#### Power Loading Equipment for PORPOISE Class

##### Rammer Chain

53. The trial of Voler Compound 200R as an anti-corrosion measure has been terminated in H.M.S. PORPOISE after a total period of 16 months. The trial as judged on 'the boats' bi-monthly reports was satisfactory. Admiralty Oil Laboratory has been notified of the result of the trial and has been asked to comment before further action is taken to patternise Voler Compound.

##### Trolley Paths

54. Although it is considered that the only complete solution to corrosion of the Trolley Paths is to machine the support beams and insert stainless steel strips, alternative processes are being tried to obtain a cheaper solution, viz:

- (a) Voler Compound 200R has been tried in H.M.S. PORPOISE; the ship's bi-monthly reports so far indicate that this is satisfactory.
- (b) Laboratory trials were done using a stainless steel strip stuck to the trolley path with Araldite; the adhesion was inadequate.
- (c) Trials are in hand on two trolley paths treated with a nickel-copper-nickel coating applied by the Dalic Plating method.

##### Traversing Noise

55. As an aid for accepting officers of new construction and refitted submarines, an attempt is being made to lay down a standard acceptable noise level for the various working parts of the traversing gear.

##### Refitting Specification

56. A specification for refitting PORPOISE class submarines is almost complete and a similar specification for 'O' class is being prepared. Travcrsing and ramming speeds are to be more closely spccified.

##### A/S Mortar Mk 10

57. The fibre-glass breech cover and the projectile retaining device are approved for production.

58. Difficulty is being experienced, owing to radio frequency explosive hazards, in the development of a line charge for de-icing the exhaust annulus. Two proposals are being forwarded for consideration of the Naval Ordnance Inspection Division.

59. In order to overcome the corrosion and scoring of link bosses on the barrels it is proposed to build up the bosses by the Dalic process of electrolytic deposition which can be carried out in situ. Trials will take place during 1963.

60. A requirement has been received from the Fleet to increase the number of projectiles carried on board each class of A/S frigate and schemes for doing this have been forwarded to D.W.U.

61. A new design of hoist guides for mortar loading equipment has been submitted to D.W.U. because of reports from the Fleet of failures of existing guides and a contract for one experimental set of guides has been placed.

62. The further development of an assessment projectile has now been completed. This has the same ballistic characteristics as a live bomb and is capable of being fired against a submarine at a safe depth. The object is to facilitate the assessment of system accuracy against a realistic target. Trials have been carried out and drawings are being issued for production.

63. The first stage helicopter safety switch which restricts firing of the A/S Mortar Mk 10 on astern bearings, has been fitted in TRIBAL class frigates. Proposals for the second stage have been forwarded to D.W.U. This scheme permits firing on ahead bearings, prohibits firing from just forward to aft of the beam and allows permissive firing, under the control of the Landing Control Officer over the stern.

64. A prototype panel 59 has been tried successfully on a mounting at the Royal Naval Weapon Equipment Depot. This panel enables the mortar barrels to be placed in a new, lower stow position in order that the muzzles of the barrels have the minimum protrusion above the helicopter deck in LEANDER class frigates.

#### 21 inch Mk 20 Torpedo

##### Lead Acid Secondary Batteries

65. Batteries types 22TFA27 for Mk 20(S) and 28TFA21 for Mk 20(E) torpedoes give acid specific gravity higher than the specified value of 1.280 when filled initially with S.G. 1.270 acid recommended by the manufacturers. Tests at A.U.W.E. and by the firm have established that the correct final specific gravity is obtained if the cells are filled initially with acid of S.G. 1.210, and recommendations to this effect have been made.

##### E.D.P. Primary Batteries

66. Recent trials have shown several cases where EDP 4 batteries fail to give a high rate discharge when the battery is primed some time before firing. A preliminary investigation has shown that the inhibitor added to the perchloric acid electrolyte to ensure a reasonable safe stand period will passivate the electrodes and prevent a high rate discharge if an early priming is used. Tests on the rate of passivation of the electrodes at various temperatures are proceeding to find what restrictions need to be placed on firing procedure.

##### Improved Homing Unit for Mk 20/23/30

67. A contract was placed with Messrs G.E.C. in 1960 to redesign the homing unit to meet the Environmental Specification and to improve the stability of the electronic circuits. Eighteen prototype units have been manufactured. Homing trials were successfully carried out on the first four in Mk 20

vehicles and four more have passed environmental tests to appropriate sections of K114. It is intended to issue three units to Captain SM3 for Fleet handling trials in Mk 20 torpedoes and three to R.A.F. Coastal Command for similar trials in Mk 30 torpedoes. All drawings have been approved and issued to D.A.S. and D.G.W.(I).

#### Gyroscopes for Mk 20 and Mk 23 Torpedoes

68. The present designs of gyros have proved difficult to manufacture to the specification and are inaccurate at long ranges. A contract has therefore been placed with Messrs S. G. Brown to improve the designs and supply six gyroscopes to the improved design.

#### Tube-held Hot Run Device

69. A new tube-held hot run device which will be common to the Mk 20 and Mk 23 torpedoes has been designed and two prototype units manufactured. A Mk 20 hull and a Mk 23 hull are being modified to take these units and trials will commence about mid-1963.

### 8.3 - MINE COUNTERMEASURES AND MINING EQUIPMENT

#### Sweep AH Mk 4

70. To achieve increased endurance complete helical spring units have now been made with an interference fit between spring and mandrel, using normal manufacturing tolerances. Arrangements have been made for the issue of these units to the Fleet for evaluation.

#### Sweep AD Mk 3

71. Drawings and specifications have now been issued for minor amendments to the present AD Mk 3's, to improve endurance. To effect a further improvement in endurance with minimum cost, spare connecting rods supplied to the Fleet in future will be of an improved material.

72. Endurance trials of the long stroke version of the sweep AD Mk 3 revealed shortcomings, modifications were introduced and drawings have been issued. The handbook has been amended to incorporate revised frequency calibration figures.

#### T Mk 8 Cutters

73. A further trial on these cutters was unsatisfactory due to failure of ancillary equipment. Cutters are being assembled for a new trial.

#### Sag of W Mk 3 Mod.2 Sweep

74. A set of new sag tables has now been compiled, and has been issued to the Fleet.

#### Pipe Noise Maker Type Q (Admiralty Pattern 9019)

75. Production of P.N.M.'s with rubber mountings to give a longer life is in hand. Trials to effect a further improvement in life of the sweep, by rotating the bars are in hand.

MM Mk 17 Sweep

76. From the few trials completed to date there is an indication that the cadmium copper catenary cable will give the sweep an increased endurance. Further trials are in hand.

77. Sweeps incorporating buoyant cable to an amended specification have given improved endurance in trials. Trials have shown that the replacement of the present elbow former in the sweep, by the bar and stocking device is successful, and arrangements have been made for Fleet use.

Non-Magnetic Minesweeping Equipment

78. An evaluation of existing foreign non-magnetic equipment has been made. A submission of a possible programme with suggested cost for converting U.K. Minesweepers to non-magnetic sweeping gear has been made to Admiralty for the raising of a Staff Requirement.

"Talurit" Mk 5 Swaging Press

79. Some post design modifications are being carried out by the manufacture. These include the provision of cover and lifting lugs for the whole unit, cable guide and cable clamp, improved die location, and a dirt exclusion system between ram and yoke.

## SECTION 9 - SUPPORTING DEVELOPMENTS

### 9.1 - ELECTRONIC COMPONENT DEVELOPMENT

#### General

Most of the work of this section has been on the design and development of electrical filters and delay lines. New designs covering about 250 coils have been produced during the year and an average of eight of each manufactured.

#### Low Frequency Work

2. The measuring facilities have been extended for the accurate measurement and adjustment of filters and coils down to 5 c/s and a new coil design enables band-pass filters operating down to 10 c/s to be constructed.

#### Flat Response from a Resonant Transducer

3. The efficient use of a hydrophone requires that it should be resonant in the middle of the frequency band of interest. However, the associated variation in sensitivity with frequency is then often an embarrassment. This can be overcome either by a compensating equaliser or by associating the transducer with loss free inductors and capacitors so as to form a band-pass filter. The second solution makes the best use of the transducer but the use is limited to a relatively narrow bandwidth. The first solution merely attenuates the transducer output where this is greatest. It is difficult to design an equaliser to work directly connected to the transducer so the equaliser is usually placed at the output of a preamplifier. In a particular case, it was necessary to connect the equaliser to the transducer without an intervening amplifier and the bandwidth required (6 to 16 kc/s) was too great to permit the transducer equivalent circuit being absorbed in a classical band-pass filter. Fig. 41 on the next page illustrates the technique employed. A band-pass filter covering the whole band required was designed so as to incorporate within its structure as much of the transducer equivalent circuit as possible and so that the filter input impedance was as high as possible. The remainder of the transducer equivalent circuit was a simple tuned circuit. The filter was terminated in a conventional "constant resistance" equaliser. The input impedance to the filter was nearly a fixed resistance so the equaliser only had to correct for the response of the circuit  $L_1 C_1$ . The coil  $L_2$  could be wound as a transformer so that a twin balanced cable to the transducer could be used, thus reducing liability to interference pick up. In a particular case a variation in response of 20 dB over the range 6-16 kc/s was reduced to 3 dB.

#### Radio Components Standardisation Committee

4. The A.U.W.E. representative on sub-committee H (Transformers) of the R.C.S.C. has had a large share in preparing DEF.5195 Bobbins for use with laminated or ferrite cores and DEF.5194-A Cores, magnetic ferrite.



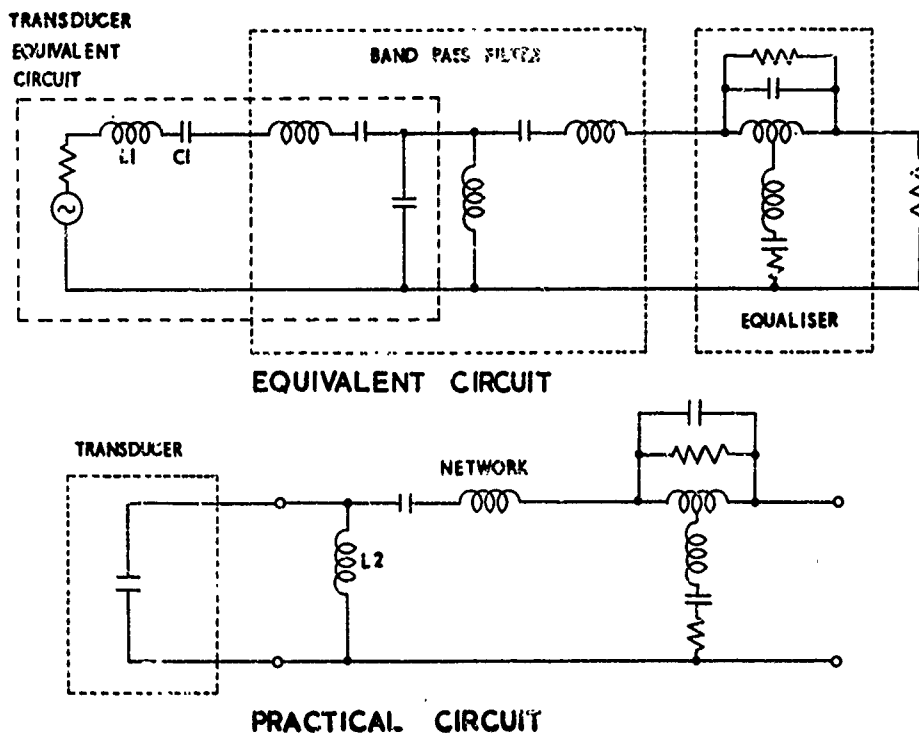


Fig. 41 Flat Response from a Resonant Transducer.

## 9.2 - HULL OUTFIT DEVELOPMENT

### Hull Outfit 8 (For Type 193 Sonar)

5. First production units have now been successfully installed in two Australian minesweepers.
6. To provide castings for this equipment having an adequate low permeability to keep down the magnetic field, a special aluminium bronze (akin to BSS 1400 AB1) has been introduced. The castings for later production units will be made in either heat treated Superston or the new alloy, which should ensure that the maximum magnetic permeability on all items is less than 1.05.

### Hull Outfits 18 and 20

7. Among minor improvements being introduced for this basic design of hull outfit to carry the 157 inch dome, a set of detachable glass fibre fairing blocks has been made. This type of fairing material should ease some of the problems involved in exchange of dome by diver.

### Hull Outfit 21

8. The monitor hydrophone for Type 184 has successfully completed retraction testing under load and has been installed in H.M.S. EAGLE for sea trials. Production information has been forwarded to D.W.U.

### 9.3 - DOME EXCHANGE OUTFITS

9. Development of the improved D.E.O. Type 2 with increased lifting capacity is proceeding at the contractor's works and further trials are expected in mid-1963. In addition to larger buoyancy tanks, to ease the work of the divers the outfit has now finger-operated push valves instead of screw-down valves. The D.E.O. Type 3 was offered for acceptance at Malta in June 1962 and considered satisfactory. The manufacturing drawings are being cleaned up prior to issue for production.

10. An A.F.O. dealing with the standardisation of dome fairing plates and fixing screws will be issued shortly.

### 9.4 - STRUCTURAL MATERIALS DEVELOPMENT

#### Metallurgy

11. The assistance of this section given to the projects and research items is reported under the appropriate heading. A number of items of more general interest has also been studied:-

- (a) Work at R.N.T.F. and A.U.W.E. has shown that crack-free welds can be made in the aluminium alloy sheet used for ONGAR hulls. Current production is limited by porosity rather than by cracks and work is in hand to eliminate this defect.
- (b) A study of the sea water corrosion of aluminium bronze lead to the development at C.D.L. of an aluminium-silicon-iron bronze. Small scale production quantities of this alloy in the wrought form have been received from a contractor, and it has been shown that the alloy has excellent mechanical properties. Welding and hot and cold working trials are in hand.
- (c) Considerable difficulty in obtaining pressure-tight copper alloy castings has been reported. Trials of a range of alloys showed that the newly introduced leaded gunmetal LG4 or BS 1400 was capable of giving pressure tight castings consistently and its general use has been recommended.

#### Plastics

12. It has been common practice to use a gel coat on the outside surface of glass reinforced plastic laminate when these were made by the hand lay-up process. This gel coat gives an improved surface finish and could reduce the rate of deterioration in contact with water but it has recently been suggested that it could also reduce the strength of the laminate. To examine this suggestion and to provide design data for an ONGAR contactor cover, a series of flat panels were laid up with polyester resin and chopped strand glass fibre mat laminate.

13. Simple bond tests were carried out on samples from the laminate panels. A load-deflector curve, in the specified time of about 15 seconds for carrying out such tests is shown in Fig. 42 on the next page.

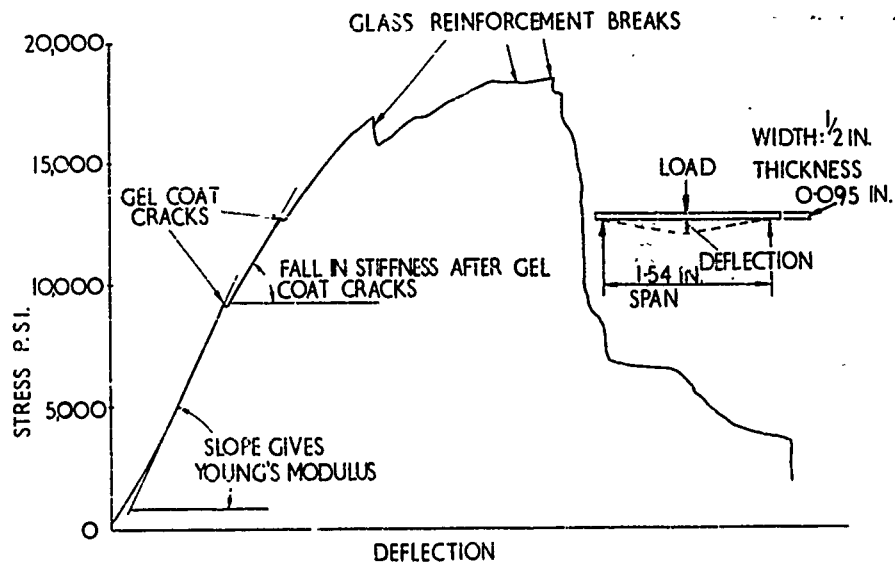


Fig. 42 Stress-deflection Curve of a Bend Test on a Glass-Reinforced Plastic.

14. With the gel coat extension, cracks occurred at about half the ultimate load and resulted in general breakage of the glass rovings at about 90% of the ultimate load. With the gel coat in compression there were no premature cracks.

15. Comparison of sections through the samples after test showed that with the gel coat in compression failure was by general delamination (see Fig. 43 on the next page), whereas with the gel coat in tension the cracks are propagated through the section and cause a reduction in strength from 23,600 p.s.i. to 18,200 p.s.i.

#### Propeller Blades in Reinforced Plastics

16. Two samples of a propeller blade moulded in glass-fibre-reinforced epoxide resin have been produced. Measurements of the blade dimensions are being made to determine the degree of shrinkage obtained during the moulding process.

#### 9.5 - SHOCK MOUNTINGS FOR SONAR ELECTRONIC CABINETS

17. The mild steel yielding strap section of the shock mounting previously reported on has been redesigned in order to increase the amount of free travel before bottoming occurs. Static tests have shown the new design to be an improvement on the old.

18. Manufacture of a mould for the steel-rubber-steel sandwich sub-assemblies has been completed and sample mouldings have been produced by A.M.L. It is proposed to conduct resonance search tests on complete assemblies using varying grades of rubber to determine the optimum hardness value for the rubber mix.



(a) Gel Coat in Compression



(b) Gel Coat in Tension

Fig. 43 Fracture of Polyester/Glass Mat Laminate.

#### 9.6 - SHIP INSTALLATION

##### Sonar Equipments

19. The basic fitting information for each sonar set, hull outfit or echo sounding equipment is contained in the Instructions for Installing (I for I) and the Equipment List (E List) from which the Establishment List for Sonar stores is prepared and published by the Director of Storcs. The new and revised I for I and E Lists completed in the last year, or in the course of preparation, are given below.

Equipment	I for I	E List
Sonar Type 162	Revision in hand	-
Sonar Type 170 EC/GC/GF	In hand	Issued
Sonar Type 176	Revision complete	
Sonar Type 177	Revision complete	
Sonar Type 181	Revision complete	Issued
Sonar Type 183	Revision complete	Issued
Sonar Type 184	Preliminary issue complete	2nd Revision issued
Sonar Type 185	Revision complete	Issued
Sonar Type 187	Revision in hand	Revision in hand
Sonar Type 189	Revision in hand	Issued

Equipment	I for I	E List
Sonar Type 193	Preliminary issue complete	Revision issued
Sonar Type-199		Issued
Patt. 204674 Cable Jointing Set	In hand	
Sonar Hull Outfit 5 and Monitor Hydrophone	Revision complete	
Sonar Hull Outfit 15		Revision in hand
Sonar Hull Outfit 18		Revision issued
Sonar Hull Outfit 19		Revision in hand
Sonar Hull Outfit 20		Revision issued
Sonar Hull Outfit 21 and Monitor Hydrophone		Issued
Dome Exchange Outfit 3		Revision issued
Sound Range Type 720		Revision issued
Echo Sounder Type 773		Issued
Echo Sounder Type 776		Issued
Torpedo Guidance Control Unit Mk 2		Issued
Standard Electronic Cabinet	Revision complete	
Teacher A/S 1068E		Issued
Teacher A/S 1071	in hand	3rd Revision issued
Teacher A/S 1072	In hand	In hand
Teacher A/S 1073	In hand	In hand

20. Layout drawings and wiring diagrams of sonar equipment in various types of ship have been prepared to meet the requirements for new construction, modernisation and experimental trials and are shown in the following tables.

Ship or Class	Equipment	Remarks
G.M. Destroyers	Sonar Type 184 and 182 Hull Outfits 18 and 21	Complete
LEANDER Class	Sonar Type 162, 170, 184, 182 and 199 Hull Outfits 18, 19 and 5	Complete
Type 81 Frigates	Sonar Type 162, 170, 176, 177, 182 and 199 Hull Outfits 19 and 18 or 20	Complete

Ship or Class	Equipment	Remarks
H.M.S. EASTBOURNE	Sonar Type 177 in E.O.16	In hand
H.M.S. GRAFTON	Sonar Type 177 in H.O.16	In hand
H.M.S. BROCKLESBY	Sonar Type 184 and 185	Continuing Commitment
H.M.S. VERULAM	Sonar Type 2001	Continuing Commitment
H.M.S. UNDAUNTED	Replacing Sonar Type 177X2 and H.O.10X by production equipment	In hand
Assault Ship	Sonar Type 182	Complete
H.M.S. HERMES	Sonar Type 184 and 182 Hull Outfits 18 and 21	In hand
H.M.S. PENELOPE	Conversion to Trials Frigate and revised bow form	In hand
H.M.S. LONDONDERRY	Viewing ports and U/W periscopes	For dome fairing and dome slamming trials
H.M.S. RELENTLESS	Sonar Type 182	Complete
1968 Frigate	Sonar Type 184, 182, 162, 185, 170 AN/SQS35 Hull Outfits 18, 19 and 5	Space requirement drawings complete
H.M.S. BULWARK	Sonar Type 182	Complete
A.C.S. ST MARGARETS ) A.C.S. BULLFINCH )	Conversion to trials vessels for Propagation Research	In hand
H.M.S. CACHALOT	T.C.S.S. 8 and ONGAR System	In hand
H.M.S. OCELOT	T.C.S.S. 9, ONGAR System, Sonar Type 187AC	In hand
H.M.S. KIRKLISTON	Sonar Type 193, Minehunting System Mk 1	In hand
H.M.S. CHEDISTON	Hull Outfits 8 and 22	Complete
H.M.S. FORTH	Maintenance for ONGAR, T.C.S.S. Sonar Training Facilities	In hand
R.F.A. TIDESPRING	Sonar Type 182	Complete
H.M.S. SEALION	Exp. equipment for Type 2001 Trials	Complete
H.M.S. MAIDSTONE	Maintenance for T.C.S.S., Sonar Trainers	Complete
H.M.S. VIDAL	E/S Type 773 and expl. equipment	In hand
PORPOISE and OBERON Class Submarines	DUUX-2 and AN/BQH-1	In hand
Ocean Weather Ships	Oceanographic equipment	Continuing Commitment

Weapon and Mine Countermeasures Equipment

21. The installation of experimental equipment for weapon and countermeasures projects is continuing. Details are given in the table below.

Equipment	I for I	Remarks
<u>Project OSBORN</u> <u>Phase B<sup>x</sup></u>  Modification to Loop Cable reel to form two separate drums	AUWE Spec. 22800/73	Prototype equipment fitted in H.M.S. GLASSERTON, trials satisfactory. Proposals forwarded to D.W.U. Dimensional requirements awaiting confirmatory trials in H.M.S. LALESTON in March 1963.
<u>C.M.S. Minesweeper/Minehunter Conversion</u>  Minehunting System Mk 1(A)  Minehunting System Mk 1(M)	AUWE Spec. 19837/9  AUWE Spec. 19837/3 (being written)	Layout approved. Details prepared. H.M.S. KIRKLISTON has started conversion at Portsmouth.
Eddy Current Compensation Equipment, Ship rolling outfit	To be written	Further trials in H.M.S. GAVINTON in No. 9 dock Portsmouth gave 5 $\frac{1}{2}$ <sup>0</sup> roll. Trials in open water to be arranged.
<u>Swell Recorder</u>  Prototype deck unit	AUWE Spec. 22758	Prototype being manufactured at Messrs Clark-Chapman's. Anticipate complete end January 1963.
<u>Magnetic Sweep Leading-on Gear</u>  Production Equipment	To be written	Tenders for writing I for I from three firms have been forwarded to D.W.U.
<u>Mobile Tracking Range</u>  Equipment for E.T.V. WHIMBREL	To be written	One set of boom gear is being made for handling trials in H.M.S. GOSSAMER. Layout of gear in E.T.V. WHIMBREL forwarded to D.W.U.

### A.U.W.E. Civilian Manned Tenders

22. R.D.V. J. FARLEY was refitted during the year and has been in constant service since.
23. R.D.V. SAREPTA II was converted to a vehicle for Dome Exchange Outfit trials and a training platform for use by H.M.S. VERNON's diving teams.
24. R.D.V. DUCHESS OF ARGYLL has been given an adverse survey report and all plans for fitting a 20 ton transducer testing station have been postponed pending the result of a major hull survey to be carried out by Portsmouth Dockyard about mid-1963.
25. E.T.V. SAREPTA, based on the Clyde and administered by CAPIC, Clyde, completed a refit in the last quarter of 1962 and as she is the only Trials vessel with underwater torpedo discharge tubes she is engaged in a heavy programme of ONGAR development trials.
26. E.T.V. WHIMBREL, based on the Clyde and administered by CAPIC has just completed a routine refit and is due to report to Portsmouth and Chatham Dockyards for the installation of 3-D Ranging facilities and associated acceptance trials.

### 9.7 - REVIEW OF BOOK WRITING

27. In the last year the installation of an off-set litho machine has been completed at A.U.W.E. and four books were reproduced for the Fleet. With increased experience it is hoped to quadruple this during 1963.
28. The appointment of a full time editor has, to some extent, made A.U.W.E. self contained; books are now written, processed, printed and bound within the Establishment. Such an arrangement saves both time and money.
29. The number of books in hand now exceeds 200; details are given in A.U.W.E.'s Annual Review of Handbook Production dated October 1962. Despite the fact that the permitted complement of 13 authors has now been recruited, some 70% of the total book writing commitment must still be put out to contract. The standard of authorship with the contractors is not always as good as could be desired, so inevitably a proportion of A.U.W.E.'s author complement must be expended on monitoring the contractor's work.



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TN 41/61	Trials of the Experimental Asdic Type 195 Winch and Submersible Body in a Wessex Helicopter	September 1961	Confidential
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TN 45/61	Design considerations for a passive asdic set for use in battery-powered submarines	August 1961	Secret-Discreet
TN 46/61	Model scale effect on ship's pressure fields	October 1961	Confidential
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TN 52/62	Modernisation of Type 177 and adaption for fire control purposes	January 1962	Secret
TN 53/62	Asdic range prediction using the decay curve of reverberation	January 1962	Secret

<u>Report No.</u>	<u>Title</u>	<u>Date</u>	<u>Security Classification</u>
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