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FROM: secret
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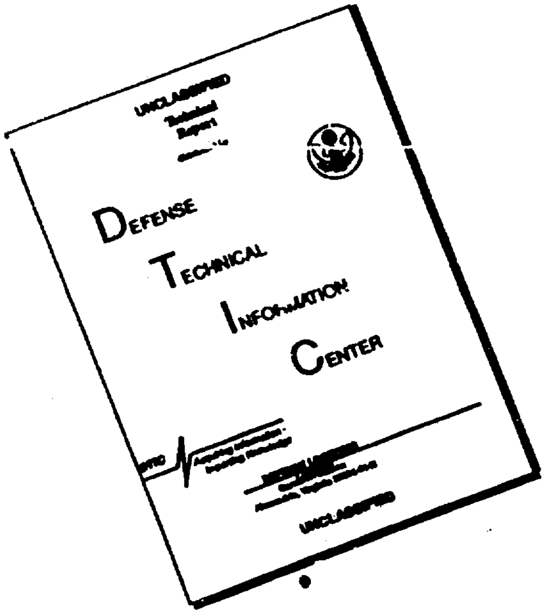

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SONAR SELF NOISE IN SUBMARINES

BY

J.A. STACEY.

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ADMIRALTY UNDERWATER WEAPONS ESTABLISHMENT

PORTLAND

SECRET DISCREET

U.D.C. No. 534.88(204.1):
623.827

A.U.W.E. Technical Note 105/62
December 1962

SONAR SELF NOISE IN SUBMARINES

by

J. A. Stacey

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PRÉCIS

1. Measurements of Sonar Self-Noise in domes and in hydrophone arrays in submarines have been carried out over a period of several years. The results of such trials received in A.U.W.E. before the end of 1961 have been collated and summarised in this report.

2. The array results (Type 186) are most conveniently grouped as follows:-

(a) 'A' class, modernised.

(b) PORPOISE and OBERON classes.

The measurements are presented in tabular form as a comparison of the level in the noisiest octave in the noisiest half-array with the Admiralty noise target level. The interference due to machines individually and in groups is discussed in detail.

3. It has been found that the results in conventional sets in the various classes of submarine, some with several sub-classes according to stage of modernisation, can be reduced to three "divisions", namely:-

I "Old, unmodernised submarines" including old 'A','S' and 'T' class vessels.

II Modernised submarines including 'A', 'T' class modernised submarines and 'T' conversions.

III PORPOISE class.

4. This grouping is based on a natural division according to the levels of the results themselves apart from any tactical grouping. The measurements have therefore been averaged into these divisions and plotted as functions of speed, except for the static measurements which are plotted against frequency. Comparisons between the divisions are presented to show the reductions in self-noise achieved in later submarines and the difference between levels in topside and keelside positions. The variation in noise with operating depth, speed and frequency is discussed in an attempt to establish the major component of self-noise under various conditions of operation including the snort condition. Comparison is also made with results from special trials in R.N. submarines and with submarines of other Navies, R.N. escorts, and an estimated limiting level of flow noise.

5. An overall summary of the self-noise status of modern R.N. submarines is given in Figure 11 and discussed in the conclusions below.

CONCLUSIONS

6. In only one submarine so far measured has the Admiralty self-noise target level for Type 186 operation (namely Sea State 1 between 300 and 1200 c/s) been achieved in every half-array when underway. This limitation is primarily due to auxiliary machinery noise; however, even in the absence

of such machinery noise the flow noise produced by the submarine underway even at slow speed is often above the target level. PORPOISE and OBERON class vessels are quieter than 'A' class and those recently refitted are the quietest.

7. While continued research and development effort directed to noise reduction appears to be necessary in order to ensure that all submarines can achieve and stay below the Admiralty noise target level (when sea conditions permit) detailed attention to the individual submarines which were, at the time of the trial noisier (e.g. H.M. Ships ARTFUL, AURIGA and ORPHEUS) should make it possible to reduce their self-noise level more nearly to that of the quieter ones (e.g. H.M. Ships PORPOISE, OBERON and ALDERNEY) which achieve the target level when in their quietest condition (Type 186 Group I, static). It is stressed that these conclusions apply strictly to measurements in uncorrelated half-arrays and are not necessarily an absolute measure of the performance of the complete set.

8. For Type 187 Search State ($2\frac{1}{2}$ kc/s) the Admiralty noise target level is also Sea State 1 and both PORPOISE class and modernised submarines fail to achieve this by a small margin under static conditions. The noise level when underway increases as the speed is increased above 3 or 4 knots but the further reduction of this noise in PORPOISE Class is dependent upon research into the mechanism of flow noise and its control.

9. For Type 187 snort state (10 kc/s) the noise target level is Sea State 6 and this is achieved in the slow snort condition by modernised submarines (just) and by PORPOISE Class (easily). The failure to meet the target under fast snort conditions is due to propeller cavitation and not to machinery noise.

10. R.N. Submarines compare closely with U.S.N. Submarines as far as self-noise is concerned.

RECOMMENDATIONS

11. It is considered that regular self-noise trials should be continued for the following reasons:-

(a) To monitor the results of the continued work on noise reduction in submarines.

(b) To check that the best results obtainable in the present state of knowledge continue to be maintained and extended in the Fleet.

(c) To provide up-to-date information on submarine self-noise for use in tactical studies and technical assessments.

12. It is suggested that a proportion of production Type 187 transducers should have full acoustic calibration at A.U.W.E. so that absolute levels can be attached to recent Type 187 measurements.

13. Vessels for which a Type 187 transducer calibration is available should be allowed running time in more open and deeper water, independent of radiated noise measurement, in which to exploit their speed and depth

capability for self-noise measurement.

14. Attention should be given to the self-noise correlation between two halves of the Type 186. Without this the present Type 186 measurements can give only general guidance.

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INTRODUCTION

15. The aim of this report is to summarise the information obtained from a number of sonar self-noise measurements carried out as part of the routine noise trials of submarines. These trials have been conducted by the Officer-in-Charge, H.M. Establishment, Loch Goil, originally in accordance with Reference 1 and currently Reference 2.

16. A second aim is to provide as much basic information as possible to those concerned with problems involving self-noise in submarine sonars. To this end results of trials not strictly of a routine nature have also been included. Copies of the original reports which have a limited distribution are held by S.A.R.L., O.in C. H.M.E., Loch Goil, and C.S.A.U.W.E. only and as this Technical Note presents a digest of the information, references to the original reports are not included.

17. Measurements of noise in conventional sonar positions have been carried out in the following H.M. submarines:-

(a)	PORPOISE Class (4)	PORPOISE RORQUAL NARWHAL GRAMPUS*	(* actual Type 187 Transducer used)
(b)	'A' Class Modernised (6)	ALLIANCE AMBUSH ALDERNEY ARTEMIS ASTUTE AENEAS✓	(✓ topside dome abaft fin)
(c)	'T' Class Conversion (6)	TURPIN TIPTOE THERMOPYLAE TRUNCHEON TABARD TACITURN	
(d)	'T' Class Modernised (3)	TAPIR TALENT TIRELESS	
(e)	Old 'T' Class (1)	TACTICIAN	
(f)	Old 'A' Class (2)	ACHERON ALARIC ‡	(‡ before modernisation)
(g)	Old 'S' Class (3)	SCYTHIAN SEA SCOUT SENESCHAL	
(h)	'E' Class (2)	EXPLORER EXCALIBUR	
(j)	Special Trials	SCOTSMAN	(dome development).

Measurements in Type 186 half arrays are available for the following 'A' Class Modernisations:-

AURIGA (3 trials)
ARTFUL
AMPHION
ALARIC
ASTUTE
ALDERNEY

and for four submarines of the PORPOISE and the OBERON Classes

ORPHEUS
WALRUS
OBERON
PORPOISE

Measurements using individual Type 186 hydrophones specially placed in H.M.S. CACHALOT, one of the PORPOISE Class, from which theoretical results in half-arrays were computed, have also been included for comparison.

EXPERIMENTAL TECHNIQUES

General Procedure

18. The procedures and equipment for routine measurement of self-noise levels in submarines (as in other vessels) are described fully in Reference 3. In particular, the measurements are normally carried out with a 15-inch barium titanate hydrophone substituted for the operational sonar transducer (or transducers) normally fitted in the boat. The advantage of this (apart from accurate knowledge of transducer calibration) is that measurements can be taken at frequencies distributed through the full sonar spectrum and not merely at the frequencies of the set or sets which happen to be fitted in the boat at the time of the trial. Thus measurements of self-noise in a 1 kc/s bandwidth centred on 1, 2.5, 5 and 10 kc/s are normally taken in all the standard sonar positions in the boat, and then are reduced to equivalent omnidirectional self-noise spectrum levels by the standard bandwidth correction and directivity corrections as in Table 1.

19. This procedure cannot be retained for measurements with Type 187 nor for the Type 186 array, since neither type of transducer can readily be removed. While the frequency range of measurements is more restricted if the special transducer cannot be used, in two respects replacing the Type 187 transducer would be undesirable. One is that the old type transducer and training shaft, not being designed for use at low frequencies, are more susceptible than is the Type 187 equipment to mechanically-conducted noise. The other is that the highly directive Type 187 transducer discriminates more strongly against noise sources off its acoustic axis, e.g. rattles in the casing, than does the 15-inch transducer, and by more than the difference in the correction for the two directivity indices. Both of these circumstances could result in a pessimistic value for the self-noise level. For Types 186 and 187, measurements therefore are made with the operational transducer in situ. However, for purposes of comparison, the resultant figures have been reduced to equivalent omnidirectional spectrum level,

using factors as given in Table 2 for Type 187 and Table 3 for Type 186.

20. For Type 187 results are given in this report only for cases in which the transducer calibration was known from A.U.W.E. measurements available. Thus a number of more recent trials have had to be ignored. For the Type 186 transducers, a general sensitivity figure of 10 microvolts per microbar for individual elements has been accepted. This figure has been quadrupled for the arrangement of four hydrophones in series and doubled again for the baffle effect of the pressure hull as suggested in Reference 4. Subsequent corrections for bandwidth (25 and 28 dB) and directivity (-12 and -15 dB) bring the overall conversion factor to 51 dB for both channels. In order to compare the results in this report with Type 186 measurements which may appear later, and only as levels in dB Reference 1 microvolt, 51 dB should be subtracted from the microvolt level to convert it to equivalent omnidirectional spectrum level of pressure. It is stressed that these measurements take no account of the correlation between half-arrays.

Electronic Background Noise

21. Present day sonars such as Type 186, 187 etc., were designed for use in a submarine as a silent listening platform and for this purpose very slow speed of advance and the running of only a very few items of auxiliary machinery were acceptable in order to attain the Admiralty Noise Target Level of approximately Sea State 1 - Knudsen curves (Reference 8). If conditions prevailing at the time of the trial should be considerably rougher than Sea State 1, it would not be possible to determine whether the submarine would meet the target under calmer conditions. This is inevitable. However, one of the limitations of making measurements of noise with a broadly-resonant transducer is that its sensitivity at any one frequency is much less than that of a sharply resonant transducer on resonance and the level of electronic bakcground noise is relatively much higher. With the 15-inch transducer in use for the conventional sonar positions and the present matching arrangement (matched at 10 kc/s) the equipment background noise is approximately equivalent to Sea State 2 at 10 kc/s, though rather lower at the lower frequencies. Some of the earlier trials were carried out using a transformer matching at a lower frequency with a result that background levels at 1 and 2.5 kc/s are below Sea State 1 but the level at 10 kc/s is even higher (around Sea State 4). It is thus never possible with this experimental equipment to state the exact level of sonar interference if this is below Sea State 2. Calculations based on the sensitivity of the transducer and the measured background noise in the amplifier (which approaches theoretical thermal noise) suggest that it should, in fact, just be possible to obtain Sea State 1 equivalent but this has not been realised in practice, possibly owing to a certain amount of residual electrical pick-up. In all the relevant plots actual measured levels are quoted, uncorrected for this background which has therefore been sketched in, in the plots. This enables the reader to make his own estimate of the true level and also of the probable accuracy of any correction.

22. Two or three recent measurements have been made using actual Type 187 transducers. For some of these units acoustic calibrations are available in A.U.W.E. and calculations suggest that an acoustic background of Sea

State 1 should be easily measurable above equipment noise. In neither of the two vessels where the noise levels in Type 187 could be converted to absolute acoustic levels did this minimum measured level in fact turn out to be appreciably below Sea State 2 or the best measured with a 15-inch diameter transducer. However, as the background noise in Loch Goil is often not below Sea State 1 to 2 even when conditions appear calmer it is not clear whether this background in Type 187 is due to ambient sea noise or to minimum auxiliary machinery. Measurements in H.M.S. THERMOPYLAE during the development of Type 187 have shown that levels at least down to Sea State 1 can be obtained by the set.

23. As regard Type 186, no difficulty has been experienced with electronic background noise interfering up to the Admiralty Noise Target Level of Sea State 1.

Electrical Interference

24. Some of the early measurements in this series of trials where parts of the Type 138 or 129 installations were used were completely invalidated by electrical interference in the submarine. The original technique was to take measurements from the Sound Room where the transducer cable could easily be tapped, and training of the hydrophone was most convenient. It was readily apparent in some vessels that certain machines produced undue interference, and replacement of the transducer by a dummy one proved this interference to be electrical. The low sensitivity of the special transducer increased the ratio of electrical to acoustic signal and listening in an untuned audio band made the effect even more noticeable. While encountering this difficulty was salutary from the service point-of-view in that it spotlighted a growing problem in submarines at the time, and resulted in the institution of an electrical interference trial of submarine sonar, the original purpose of the self-noise trial was purely acoustic. It was therefore decided that any subsequent electrical interference problems would be as far as possible avoided by working close to the sonar hydrophone position, and independently of cable runs fitted in the boat. This has the additional advantage of reducing capacitive "padding" of the transducer which lowers the effective sensitivity and relatively increases the electronic background noise. This has since been done, but is not, of course, possible, nor necessary for Type 187 itself where the signal cable has been designed to run outboard in the casing and to be of low impedance to minimise electrical interference at the outset.

25. At the beginning of the changeover in the fleet to Type 187 an attempt was made in one or two vessels at direct comparison between 15-inch and 5-foot transducers by mounting the smaller one behind the larger, pick-a-back fashion. This necessitated running a cable aft in the casing to a suitable socket such as the "N.U.C." light in the fin. Whilst this could be done without great difficulty and the restriction on continuous training accepted for a brief trial, the extent of electrical pick-up in the comparatively short but unscreened down lead from the fin to the first point where it could be tapped inside the submarine resulted in no real comparisons being obtained between the two measurements. It may be possible to obtain a useful estimate of the sensitivity of uncalibrated Type 187 transducers by this method if a screened lead can be provided to an external watertight socket (the Type 187 monitor lead could perhaps be used for this

purpose) but for the time being these pick-a-back trials have been discontinued.

26. Severe electrical interference was experienced in Type 187 on one or two occasions when the 400 c/s motor-generator was run and also from some other machines, depending on the cable routeing in individual submarines. As none of these machines was essential to Type 186 search state, the simplest solution has been to switch them off.

EXPERIMENTAL RESULTS

Type 186 Arrays

27. When considering self-noise levels in relation to Type 186 the procedure has been to compare the adjusted noise levels in each half-array (as calculated in paragraph 17) with the Knudsen curve for Sea State 1, which approximates to the Admiralty Noise Target Level for Type 186 operation. The amount by which the adjusted level in the noisiest octave exceeds the Knudsen curve for Sea State 1 is taken as the criterion of noisiness, whether of an individual machine or group of machines, or of the submarine as a whole while underway. The bulk of the noise measurements for Type 186 consist of static trials of individual machines. There are, in general, eight measurements on each machine; that is, measurements on each half-array at each of the two frequencies - 450 and 900 c/s (arithmetic mean frequencies of octaves). The amount by which the noisiest octave exceeds the Knudsen curve for Sea State 1 is set out for each machine in each submarine in Table 4 for 'A' Class and in Table 6 for 'O' Class. Included in Table 4 are measurements carried out in H.M.S. AURIGA by the Project Team and published as Appendix A to Reference 4, and corresponding figures derived from measurements by S.A.R.L. (Reference 5).

28. Comparison of the three measurements in H.M.S. AURIGA taken at different times by different staffs show, in the main, reasonable agreement. Some machines such as Telemotor pumps and the ballast pump seem to show steady increase in noise with time while others have either had attention between trials or are the subjects of slight anomalies, for example, the mid-line circulator which was quieter in later trials. The agreement is, however, not really any closer than between the different submarines of the same class.

29. Some tentative results in H.M.S. CACHALOT based on the correction of measurements in single hydrophones to probable half-array responses are included in Table 6 for comparison. They are based on Reference 6.

30. The overall acoustic status of submarines in relation to Type 186 operation is summarised in Table 5 for the six 'A' Class submarines, and in Table 7 for the four 'O' and 'P' Class submarines (and H.M.S. CACHALOT). Considering Table 5 ('A' Class) in detail, the first row of figures is the level due to absolute minimum auxiliary machinery, run as a group, as measured during the static part of the trial. The second row is the measurement with the same group of machines running when underway. The third row of figures gives the flow contribution of the submarine underway, estimated from a comparison of rows 1 and 2. The fourth row is a calculation of machinery noise based on static measurements, adding to the

minimum level of row 1 the noise of further machines which would be essential to the submarine in a search over a reasonable period of time. The fifth row is a final estimate of a realistic Type 186 search state underway based on the addition of the flow contribution to the revised list of required machinery.

31. Table 7 ('O' and 'P' Class) gives the noise level produced by two states of machinery operation, first under static conditions and second underway. The figures for H.M.S. CACHALOT and all the figures under the heading "Group II (Underway)" are estimates based on combinations of measurements, as direct measurement was not made at the time of the trial.

32. A rough check has been provided of the acoustic calibration of the Type 186 arrays by simultaneous measurements of both background noise and of flow noise in the Type 186 transducer and an A.R.L. Type 1 hydrophone. In only one of the six measurements does the average difference (without account of sign) between the Type 186 and the Type 1 measurement exceed 3 dB, though individual channels differ by as much as 10 dB.

33. The "Underway" figures from Tables 5 and 7 are plotted for machinery "States" 1 and 2 in Figure 11 as part of a summary of the Acoustic Status of the Modern Submarine.

Conventional Sonar Positions

34. The long list of submarines in which some measurements have been carried out would suggest that a normal statistical approach should be possible. However, because of the weather and other conditions, vessels often fail to complete a full programme of self-noise runs; moreover, as a result of changes in standard operating depths over a period of several years, the number of measurements available for any particular condition of depth, speed, and frequency is considerably less than the total number of vessels in the class which have been made available for trials. The method of averaging has therefore been graphical. Taking the submarines class by class, a mean curve has been derived for noise level against frequency for each machinery group in the case of the static trial, and against speed for each frequency and operating depth in the case of underway runs. These class average curves have then been compared and fall very reasonably into three natural submarine divisions. These are:-

(a) Old submarines - 'A', 'S', 'T' Classes (unmodernised).

(b) Modernised submarines - 'A' modernised, 'T' conversions and 'T' modernised classes.

(c) New submarines - PORPOISE Class.

Weighted mean curves have therefore been produced for each of these three divisions.

35. The group machinery noise for each of these divisions is plotted as a function of frequency in Figure 1 for both topside and keelside transducer positions. The appropriate target levels and also the limiting background level in the equipment are shown as shaded areas. The measurements have not

been corrected for background noise, neither sea state nor electronic. If the sea state noise is too high (Sea State 2) the static trial is postponed or abandoned. With the exception of the Group 4 runs, which are under the snorting condition, all these measurements were carried out at approximately 100 feet keel depth. The machinery groups are the conventional ones specified by Flag Officer Submarines in Reference 7.

36. One class of submarine stands apart, viz the 'E' Class. The self-noise measured on the astern bearing at 2½ kc/s in H.M.S. EXPLORER (topside set only fitted) is given especially in Figure 2b. A careful analysis of the noise versus sequence of event has been made in this submarine (see paragraph 121) in an attempt to isolate the causes of the high self (and radiated) noise levels in this class of vessel.

37. In Figures 3, 4 and 5 self-noise in underway runs is plotted as a function of speed, comparing different operating depths for each submarine division in both topside (forward) and keelside positions. In constructing these curves a certain amount of discretion has been used in ignoring certain results clearly due to abnormal circumstances, as for instance, when severe casing rattles were complained of in the text of the original report. Even so certain slight anomalies appear in the three figures, largely due to the fact that the class samples tend to be both small and changing. These plots of self-noise against speed at constant frequency for the divisions form the basic information from which the plots and comparisons discussed later are obtained.

38. Figures 6 and 7 are comparisons, for topside and keelside positions respectively, of the noise of the different submarine divisions. The "deep" curves are obtained by taking a mean lower level of the quieter running depths; the underway snorting runs (where these are available) have been added. Admiralty Noise Target Levels of Sea State 1 for "deep", and Sea State 6 for "snort" conditions have been included.

39. In Figure 8 all the information of Figures 3, 4 and 5 is replotted in families of curves of constant frequency and depth to give a comparison of levels in topside and keelside positions.

40. Figure 9 compares, for topside position and 300 feet depth only, PORPOISE Class submarines with two experimental submarines, viz H.M.S. SCOTSMAN with a small (A/S 59) glass-fibre dome and H.M.S. EXPLORER with a streamlined steel dome.

41. Figure 10 compares PORPOISE Class with U.S. submarines, and also with average R.N. escort vessels. At the same time it gives an indication of the lowest levels of self-noise that have been achieved in surface ships and submarines, levels of noise which can be attributed with some confidence to the basic flow noise. Because of the different ranges of frequencies at which all these measurements were made 5 kc/s has been found to be the only frequency at which they can all be compared.

An Operational Summary

42. Figure 11 consists of a summary of the Acoustic Status of the Modern Submarine. The first plot gives the position for Type 186, the second for a Topside Set, e.g. Type 187 searching at 2½ kc/s when deep on motors, the third for a topside set keeping watch at 10 kc/s when charging batteries.

DISCUSSION OF RESULTS FOR SONAR TYPE 186

Self-Noise Target Level

43. In this report the Admiralty Noise Target Level for Type 186 operation has invariably been used. This closely approximates to Sea State 1. This target level would be taken to mean the target level of noise for the submarine as a whole in its status as a silent, but none the less fully operational, platform. This causes a difficulty in discussion of the noise level of individual machines since if it is required to reach the Admiralty Target Level of Sea State 1, with a certain essential group of machines of similar noise level running, then very possibly individual machines in the group must needs have a noise level significantly below the Sea State 1 figures. S.A.R.L. has suggested (Reference 5) that the target for individual machines should be the Admiralty Target Level for the boat less 5 dB. This matter is still the subject of general consideration and for this reason the noise levels of individual machines, and also the noise levels for the boat with specified groups of machines running, have all been quoted (e.g. in Tables 4 and 6 and Tables 5 and 7) as relative to Sea State 1.

44. It may be noted that in some of the original reports issued by S.A.R.L. (References 5 and 6) noise levels for individual machines have been related to a target level of S.S.2 less 5 dB. As a result figures in this report and in S.A.R.L. reports will be seen to differ by 1 dB (SS2 = SS1+6dB).

Machinery Noise in 'A' Class Submarines

(a) Essential Machines

45. 230 Volt A/C Machines: While both 230-volt alternators have not been measured in every submarine, at least one has been run in each vessel and only the No. 2 machine in H.M.S. ARTFUL required any reduction (about 8 dB in the 600 to 1200 c/s channel). It is not thought that these machines will be a general problem, but some attention may be required to individual ones from time to time to avoid interference in Sea State 1.

46. Gyro Alternators: Those in H.M.S. AMPHION, H.M.S. ALARIC and H.M.S. ALDERNEY were acceptable. Those in H.M.S. ARTFUL, H.M.S. AURIGA and H.M.S. ASTUTE required some noise reduction to meet the target in the high-frequency channel.

47. L.P. Generators: While those in H.M.S. AMPHION, H.M.S. AURIGA, H.M.S. ALARIC and H.M.S. ALDERNEY were satisfactory, those in H.M.S. ARTFUL and H.M.S. ASTUTE required some reduction.

48. Main Motor Cooling Fans: No interference was experienced from any of these when run at slow speed in any of the six submarines, though only the starboard one was run in the case of H.M.S. ARTFUL.

49. One Main Motor at 110 or 120 rev/min (not underway): Some interference was experienced in H.M.S. ARTFUL and also, on one of the occasions, in H.M.S. AURIGA. In this respect conclusion (c) of Reference 4 (that one main motor can be run at 110 rev/min without interference in Type 186) has not been maintained. No difficulty has been experienced, however, in recent trials.

50. Hydrogen Clearance Fans: When all these were run, overall reductions of 10 dB (H.M.S. AMPHION) to 20 dB (H.M.S. ARTFUL) were required. This was due to one or two fans only, and others could be run without interference. By careful selection two or three can usually be used with only 4 or 5 dB interference.

51. After-Services Circulators: These mostly appeared to require about 15 dB reduction, though in the port unit in H.M.S. ARTFUL nearer 30 dB was required. In the two most recent trials it was possible to select a circulator requiring less than 10 dB noise reduction.

52. Telemotor Pumps: Numbers 1 and 2 IMO pumps are invariably excessively noisy, reductions of from 13 to over 30 dB being required. In vessels in which a No. 3 IMO was run only 2 or 3 dB reduction (H.M.S. AMPHION and H.M.S. ASTUTE) or even none (H.M.S. ALARIC) was required in this pump.

(b) Machines which must be run at least intermittently

53. Trim Pump: These were all noisy and reductions ranging from upwards of 10 dB in H.M.S. AURIGA to 24 dB in H.M.S. ARTFUL were required.

54. Ballast Pump: In three 'A' Class vessels measurements showed a consistent 25 dB reduction to be required. Earlier measurements in H.M.S. AURIGA suggested that the necessary reduction was less than this. No measurement was made on this machine in the last three trials.

55. Refrigerators: These caused interference in all six submarines. The required reductions range from 4 dB in the most recent trial (H.M.S. ALDERNEY) to around 20 dB in the early trials.

(c) Additional Machines

56. Ship's Ventilation Fans: Reductions of the order of 10 dB appeared to be necessary even with the fans running only at slow speed.

57. Battery Ventilation Fans: The effect of running these was measured in only two vessels, H.M.S. AMPHION and H.M.S. ASTUTE, and reductions of the order of 10 dB were found to be necessary.

58. Air Conditioning Plant: These were very noisy in all six vessels; reductions of from 13 to 30 dB being required.

59. Distillers: The 5-gallon unit required about 20 dB reduction in the three vessels in which it was measured, while the 15-gallon unit was quieter (15 dB too noisy), except in H.M.S. AURIGA where the figure was nearer 30 dB.

60. CO_2 Absorption Units: These have only been run in the four most recent trials when no reduction in noise was required.

61. Reducers: These were run in H.M.S. AMPHION, H.M.S. AURIGA and H.M.S. ALARIC and no reduction was required.

62. Sub-Pressure Pumps: These were run in H.M.S. AMPHION, H.M.S. ALARIC and H.M.S. ASTUTE and 10 to 25 dB reduction was required.

63. Sound Room Fans: The sound room table fan was run in H.M.S. ALARIC and 3 dB reduction was required. The Vent Axia, however, required no reduction.

64. 400 c/s Motor-Generator: This machine was run in H.M.S. ASTUTE and no reduction was found to be required.

65. Auxiliary Trim Pump: This pump was run only in H.M.S. ALDERNEY when 43 dB reduction was found to be required.

Machinery Noise in 'O' and 'P' Class Submarines

(a) "Group I" Machines

66. 115 Volt A.C. Machines: No significant noise was experienced in any 115 volt motor-generator except in the No. 2 machine in H.M.S. ORPHEUS.

67. Gyros: Those in all vessels except H.M.S. ORPHEUS were acceptable but that in H.M.S. ORPHEUS appeared to require some 8 dB reduction and this on the wheel itself rather than the motor-generator.

68. L.P. Generators: These appeared to be satisfactory in all vessels.

69. Hydrogen Clearance Fans: All vessels had at least one fan on which some noise reduction was required but H.M.S. WALRUS and H.M.S. PORPOISE (and probably H.M.S. CACHALOT) could run most fans with little or no interference. In H.M.S. ORPHEUS and H.M.S. OBERON about 10 dB reduction was required.

70. Main Motor Cooling Fans: As in 'A'Class these were run without causing noise interference.

71. Hovering Gear: This has been run separately only in H.M.S. ORPHEUS and H.M.S. OBERON. With the actuator pump only running little or no reduction was required, but under the pumping condition (not specified for Type 186 operation) up to 15 dB reduction was required.

72. A.R.L. Plotting Table: Again this was run separately only in H.M.S. ORPHEUS and a marginal reduction (3 dB) appeared to be required.

73. Wardroom Record Player (Phone Sets): This was run in H.M.S. ORPHEUS only and with negligible interference.

74. After-Services Circulators: In vessels where these were run separately (H.M.S. OBERON, H.M.S. PORPOISE and H.M.S. CACHALOT) no reduction was required and as H.M.S. WALRUS only required a small reduction with all Group I machines running it is unlikely that the circulators require much noise reduction in this vessel either. This represents a considerable improvement on the state of affairs in 'A' Class where 15 dB reduction was required on most units.

(b) Group II Machines

75. "Vent Axia" Fans: These fans in the E.M.R. and wardroom were run in H.M.S. ORPHEUS only and only a marginal reduction, if any, was required.

76. Sound Room Fan: This was run in H.M.S. ORPHEUS, H.M.S. WALRUS and H.M.S. PORPOISE but only that in H.M.S. ORPHEUS required any reduction.

77. Main Refrigerator: Measurements in H.M.S. CACHALOT suggested that moderate reductions (8 dB) might be required. In H.M.S. WALRUS, H.M.S. OBERON and H.M.S. PORPOISE no reduction was required and in H.M.S. ORPHEUS little or none. A great improvement on 'A' Class.

78. Domestic Refrigerator: This was acceptable, where run.

79. 400 c/s 205V Machines: These were run in H.M.S. ORPHEUS, H.M.S. WALRUS and H.M.S. PORPOISE and no reduction was required.

80. A.T.M.C.8: This was run separately in H.M.S. ORPHEUS only, but no reduction was required.

(c) Additional Machines

81. Steering: This was run separately in H.M.S. ORPHEUS only, when 6 dB reduction was found to be necessary.

82. Telemotor Pumps: As in 'A' Class Nos. 1 and 2 IMO Pumps were noisy; up to 20 dB reduction being required. The McTaggart-Scott Pumps in H.M.S. CACHALOT and H.M.S. PORPOISE were calculated to require 14 dB reduction and the N.E.R.L. pump in H.M.S. ORPHEUS was no quieter. The N.E.R.L. pump in H.M.S. WALRUS, however, was noted as being fitted with flexible piping and this pump was 10 dB quieter than the otherwise similar pump in H.M.S. ORPHEUS. If this is general in subsequent members of the class only 4 dB further reduction will be required. No. 3 IMO in H.M.S. OBERON required no noise reduction, again similar to 'A' Class.

83. C.P. Generators: About 12 dB reduction was required in both units in H.M.S. ORPHEUS but none in H.M.S. OBERON or H.M.S. PORPOISE. No measurements were made in the other two vessels. These generators are included as Group I machines in the H.M.S. OBERON and H.M.S. PORPOISE reports, but as they are quiet in these vessels it does not confuse the issue.

84. Wardroom Heater: This required little or no reduction in the only submarine in which it was measured.

85. 10 x 6 inch and 10 x 3 inch Ventilation Fans: Each of these in H.M.S. ORPHEUS required up to 6 dB reduction but was acceptable in H.M.S. WALRUS, H.M.S. OBERON and H.M.S. PORPOISE; measurements in H.M.S. CACHALOT suggested need for about 10 dB reduction. 10 x 3 inch radar and galley exhaust fans were run in H.M.S. PORPOISE and no reduction was required.

86. Air Conditioning Plants: About 6 dB reduction was required in H.M.S. ORPHEUS and in one of the units in H.M.S. OBERON, but none in H.M.S. WALRUS or H.M.S. PORPOISE. A marginal reduction was required in H.M.S. CACHALOT.

87. 100 kW Generators: No reduction was required in H.M.S. WALRUS, the only vessel in which measurement was made.

88. Trim Pump: This was measured in H.M.S. CACHALOT when 14 dB reduction appeared to be required. In H.M.S. PORPOISE only 4 dB was required, and that only when pumping from forward to aft.

89. Ballast Pump: Measurement has been made only in H.M.S. CACHALOT when 10 dB reduction was required.

90. Both Sub-pressure Pumps, Distillers and CO_2 Absorption Units were run in both H.M.S. OBERON and H.M.S. PORPOISE (only) and no reduction was required.

91. 500 c/s Motor-Generators: These were run in H.M.S. PORPOISE only, but no reduction was required.

92. 180V Machines: These were run in H.M.S. OBERON only and no reduction was required.

93. Battery Cooling Pump: These required 16 dB reduction in H.M.S. PORPOISE and about 6 dB in H.M.S. OBERON. No others were run.

94. Acid Agitation: This required 3 dB reduction in H.M.S. PORPOISE but none in H.M.S. OBERON. No others were run.

95. Battery Ventilation Fans: These were run in H.M.S. OBERON and H.M.S. PORPOISE when up to 16 dB reduction was required, according to which fan was run and to whether it was run in the "slow" or "group up" condition.

96. Lubricating Oil Priming Pump: This was run only in H.M.S. PORPOISE and no reduction was required.

97. Engine Turning Gear: This was run only in H.M.S. PORPOISE and while the starboard gear was quiet, 4 dB reduction was required on the port gear.

98. Crypto Machine: This was run only in H.M.S. PORPOISE and no reduction was required.

Type 186 Search State

99. During the trials, practice has varied in what was deemed essential machinery for Type 186 operation, not only between 'A' and 'O' Classes, but even within the same class of vessel. For this reason, the two classes will, in the first place, be considered separately. Clearly, the comparison between two vessels in the same class would not be a fair one if a particularly noisy machine were omitted from the list of machines required in one particular vessel. In overcoming this second difficulty let us first consider the 'A' class trials.

100. The following five machines were invariably* run in the search state:

One 230V a.c. machine
Gyro Motor-Generator
L.P. generator
One main motor cooling fan (at slow speed)
One main motor (120 rev/min - 2 to 3 knots)

101. In addition the following three machines will be essential for periods of more than a few minutes listening:-

at least one hydrogen clearance fan
one after-services circulator
one telemotor pump

All those eight items have been termed in this report "Essential Machines" and comprise list (a) for 'A' class.

102. The noise outputs for "Type 186 Search State" and "Total Type 186 Machinery" from the original 'A' class reports have therefore been amended to include all eight machines in each case. These are the "Revised" Type 186 levels in Table 5. This also agrees with the grouping suggested in the report of the trials in H.M.S. CACHALOT (Reference 6). The use of the other machines such as the ballast and trim pumps and the main refrigerator would clearly be desirable from the operating point of view, at least at intervals, but it is intended to be fairly ruthless at this stage so they have been excluded. These three items form list (b) of "Machines which must be run at least intermittently". There are no measurements of list (b) machines as a group or of lists (a) and (b) together. Other machines which are not necessary in Type 186 search, but the effect of which on Type 186 self-noise has been measured, form list (c) - "Additional Machines".

103. Turning to the 'O' and 'P' classes, which include the provisional measurements in H.M.S. CACHALOT, the machines were grouped at the time of the trial as those which form an absolute minimum necessary to operate the submarine, and additional machines which are necessary for a normal Type 186 Search State. Usage has come to call these "Type 186 Group I" and Type 186 Group II" respectively, but they must not be confused with the Groups 1, 2, 3 and 4 of auxiliary machinery allocated when dealing with conventional sets. This usage is deplored, but to avoid confusion in this report the Type 186 machinery groups are printed with Roman figures, and the groups for conventional sets with Arabic numerals.

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* In the trial most recently conducted (H.M.S. ALDERNEY) even the main motor and main motor cooling fan were omitted from this group (static) but as neither was noisy the results are not affected by this simplification.

104. The groups are:-

Type 186 "Group I" 'O' and 'P' Classes	one 115V a.c. machine Gyro L.P. generator one main motor cooling fan Hovering gear (actuator pump only - boat at virtually zero speed) A.R.L. plotting table Wardroom record-player on phone sets <u>or</u> one after services circulator (practice varied) All hydrogen clearance fans (not spares)
"Group II" (add)	All "Vent Axia" fans all table fans main refrigerator and cool room fan domestic refrigerator 7½-inch exhaust sound room fan 400 c/s 205V motor-generator A.T.M.C.8

105. Comparing these two lists with the two previously given for 'A' class, it will be seen that all the machines in the full "(a)" list for 'A' class are included in "Group I" for 'O' and 'P' Classes except the requirement for a telemotor pump which does not appear in either list for 'O' Class. The addition of "Group II" machines in 'O' Class represents less stringent living conditions than the full (a) list in 'A' Class where, for example, the refrigerator is excluded. Although even among 'O' Class, practice varied, this did not normally involve the inclusion or omission of <u>noisy</u> machines.

106. Considering the summary table for 'A' Class (Table 5) it will be seen that there is a gradual improvement in noise level with the passage of time which is undoubtedly due to progressive application of experience in noise-reduction work. Thus the total underway noise level has dropped from 22 dB in the third H.M.S. AURIGA trial in 1959 to 13 dB in the H.M.S. ASTUTE trial in 1961, an improvement of 9 dB. Unfortunately, no underway results are available for the most recent trial, (H.M.S. ALDERNEY), but on this occasion, for the first time, <u>no reduction</u> was estimated to be required in the noise level due to the minimum group of machinery when run under static conditions.

107. In the summary for 'O' and 'P' Classes (Table 7) an even greater improvement can be seen and within a shorter time (that is if one ignors the H.M.S. CACHALOT results which were estimates based on single hydrophone measurements). There is a fall in noise level from 20 dB in H.M.S. ORPHEUS reported in January 1961 to only 1 dB in H.M.S. PORPOISE in September 1961. Both H.M.S. PORPOISE and H.M.S. OBERON require no reduction under Group I, static conditions. Of the total noise, not only the machinery noise contribution, but also the flow noise contribution in the Type 186 Search State appears to have been reduced in vessels more recently available for trials; and this applies to 'A', 'O' and 'P' Class boats equally. The improvement ranges from a 15 dB reduction necessary in H.M.S. ARTFUL and H.M.S. ORPHEUS

to 0 dB in the most recent - in which underway trials were carried out - H.M.S. PORPOISE. While it may not now be necessary to keep the submarine underway in order to carry out a search with Type 186, to be able to search when underway without incurring an additional self-noise penalty clearly increases the operational flexibility of the vessel.

108. The speed at which the vessel may proceed without curtailing detection range is thought to be of the order of 5 knots for the most modern vessels.

109. There is no information on the dependence of self-noise with depth for Type 186, though no dependence would be expected.

Comparison of Frequency Channels

110. From the average noise levels in the Type 186 half-arrays (which are not published here), the background in three 'A' Class submarines with the absolute minimum of auxiliaries running is 2 dB above Sea State 1 in both octaves (300 to 600 and 600 to 1200 c/s). Underway, this becomes 7 and 6 dB in low and high-frequency channels respectively. The implication of this is that the general background noise in Type 186, except when particular machines with very strong discrete frequencies are present, has a similar spectral distribution to sea state noise i.e. -5 or -6 dB per octave.

111. When machinery is the dominant contributor to noise in Type 186 arrays, it sometimes happens that the contribution in the lower octave (300 to 600 c/s) is consistently more significant than in the higher octave (600 to 1200 c/s) (e.g. H.M.S. AURIGA - Reference 5). Broadly speaking, this tends to be the general rule. At the same time the general survey of this report indicates that it is not necessarily true; there are frequent examples in which machinery noise as a whole, or the noise of individual members is of greater significance in the higher octave. It follows that it is not enough to base requirements for maximum reduction on machines simply on measurements in the L.F. octave only.

Comparison with U.S. Results

112. Available comparison with results in submarines of other Navies is rather sparse. Some early measurements in U.S.S. BAYA (Reference 9) taken on the 50-element "LORAD" receiving system at 700 c/s gave the minimum level in individual hydrophones under "patrol quiet" and "ultra quiet" conditions at around Sea State 2 (the maximum was in excess of Sea State 6), levels comparable with those recorded in single hydrophones in H.M.S. ACHERON (Reference 10). In the array, allowing 17 dB for directivity effect, a level between Sea State 3 and Sea State 6 has reported. As this is 10 to 15 dB above Sea State 1 it compares with Type 186 in the early 'A' Class and is some 10 to 15 dB noisier than the most recent 'A' and 'O' boats.

113. Measurements on a single hydrophone in the superstructure space at frame 58 in U.S.S. NAUTILUS under "Reactor Creep" conditions are never below Sea State 6 even with the feed pump, a noisy machine, secured. With the full "Ultra quiet" machinery running, the levels are at least 10 dB higher still at Type 186 frequencies (Reference 11).

DISCUSSION OF RESULTS FOR CONVENTIONAL SONAR POSITIONS

Machinery Noise - General

114. In addition to radiated noise and sonar interference in Type 186 half-arrays (where fitted) measurement was usually made, during the static trial, of machinery noise interference in both topside (Types 168, 138, and occasionally 187) and keelside (Type 169 and 129) positions. During the earlier trials measurements were often made of noise from individual machines, but only the average in the different submarine divisions of 'Group' machinery noise is included in this report (Figure 1). In recent trials measurement on individual machines in conventional sonar positions has been omitted altogether because of the time involved in measuring the individual contribution of the large number of machines fitted in modern submarines. This is one of the sacrifices which had to be made to keep the time taken by the complete noise trials of a modern submarine within the 5 days allocated, and it has proved to be justified for the following reasons:-

(a) Speaking generally, machinery noise is not too serious a problem in conventional sonar positions.

(b) Any machine which causes interference in a conventional sonar is normally even more noticeable in radiated noise or in Type 186 self-noise, and attention is therefore drawn to it in any case. Although measurements have been made (both static and underway) of noise in the keelside positions over the whole frequency range 1 to 10 kc/s as for the topside position, this is largely for comparative purposes as it is unlikely that a set operating at frequencies below 10 kc/s would ever be used in this precise position. At this frequency the noise level due to machinery in a modern submarine either approaches the target closely or is affected by background noise in the equipment, so that, again, auxiliary machinery does not appear to be a serious problem, and any machine causing interference in Types 129, 169, or 719 would be expected to be a serious problem from other noise aspects.

115. On examination of the plots of group machinery noise against frequency in Figure 1 several points are readily apparent. One is that with Group I or II machinery running the noise levels at 5 and 10 kc/s (and occasionally even at 2½ kc/s in a quiet submarine are limited by background noise in the measuring equipment. This can be true at 10 kc/s even with Group 4 machinery running. A second point is that the Group I machinery target level is approached very closely by modern submarines at 2½ kc/s (and presumably at frequencies above this, too, if the background had been low enough to allow this to be checked). Groups 2 and 3 require possibly 6 dB reduction to achieve their targets, while with Group 4 machinery running, under which conditions the target is relaxed to Sea State 6, and the frequency of interest is 10 kc/s, the target is achieved for the PORPOISE Class and almost achieved by modernised submarines. (Snorting runs underway are slightly quieter.)

116. The curves for old submarines are not of great interest except, perhaps, to indicate what progress has been made in the resilient mounting, and noise reduction of submarine machinery. In making this comparison a further point, which is indicated in the key, must be borne in mind. It is that the practice on the very early trials was to train both hydrophones astern during the static trial to give the maximum chance of detecting, as was thought, individual machines. When comparing group machinery noise with a target level it is probably fairer to train the hydrophone on an operational bearing, and this has since been done. For this reason the "Old submarine" measurements topside are, no doubt, pessimistic and the keelside ones probably optimistic as the astern bearing of the normal keel-side set (Type 129/169) is blanketted by the keel.

Individual Machines

117. Occasionally, individual machines are noted in reports as causing excessive noise in a conventional sonar position. In the case of H.M.S. RORQUAL five such items were mentioned. Thus 'bangs' occurred at the end of each hydroplane movement. Four items in the torpedo control gear caused excessive noise. Except in the topside position at 10 kc/s, the G.A.P.S.U's gave rise to levels 10 dB above all other Group 3 machinery when measured in either position and at any frequency, and upwards of 20 dB noiser in the keelside position at frequencies of 5 kc/s and below. D.P.S.U.'s, Torpedo ramming gear and TCSS3, were also shown to be noisy. Independently, all G.A.P.S.U's, D.P.S.U.'s and ramming gear were found to be excessive contributors to radiated noise, the G.A.P.S.U. being detectable at an estimated 9000 yards in Sea State 1 (Reference 12).

118. While in H.M.S. PORPOISE and H.M.S. GRAMPUS no specific machines were cited, H.M.S. NARWHAL had a similar list to H.M.S. RORQUAL's. Hydroplanes and torpedo control and manipulation again appeared, but T.C.S.S.3 was omitted and a ballast pump cited. Again, these items were generally bad from the radiated noise viewpoint.

119. In 'A' class, noisy machines included the main motors in H.M.S. ARTEMIS and the forward high-pressure air compressor in H.M.S. ASTUTE.

Turbine Machinery - 'E' Class Submarines

120. It has been known for some time from tactical exercises that the submarines H.M.S. EXPLORER and H.M.S. EXCALIBUR, when under turbine propulsion are excessively noisy from the radiated noise viewpoint. Because existing noise-ranging facilities did not allow the level to be measured directly when at high speed a self-noise trial was undertaken with the cause of the high radiated noise level in mind as much as the level of self-noise alone.

121. A major difficulty is always encountered in trying to seperate flow, machinery, and cavitation noise, as the machinery cannot be run and made to dissipate power except by driving the vessel. This results in flow and cavitation noise in addition, though some variation in the latter component can be obtained by varying the depth of operation. However, certain auxiliary machines connected with turbine propulsion can be run separately and in order to isolate, where possible, such items as appreciable contributors to total noise the sequence of running-up turbine machinery was

followed carefully with the hydrophone trained astern. The turbine was then clutched in, and when the vessel had gathered way, all the machinery was stopped and a "glide" run obtained. The noise associated with each of these steps is depicted in Figure 2b for a frequency band of 2 to 3 kc/s.

122. When commencing to run on turbines three pumps concerned with cooling and removing the steam from the condenser are started first. These are normally run together and while the total noise level was fairly high it is not known which pump was largely responsible. Next the "Triple Pump" is started, so called because the three pumps supplying fuel, H.T.P., and water are ganged in order to keep the proportions correct. In the first position, however, the 3-cam valve allows only H.T.P. to the catalyst chamber. The fuel and water injection being by-passed at this stage. Initially, there is only the mechanical noise of the pump, which again is high, but after a few seconds decomposition builds up and steam is ejected outboard. Subjectively, both on the sonar and when running turbines alongside for trial, this sounds like a locomotive letting off steam. The next stage, when the combustion chamber has reached the appropriate temperature, is to inject the fuel and water. The fuel burns in the released oxygen producing CO_2 and more steam at a very high temperature. The water injection results in a further very much larger volume of steam but reduces the temperature. All this steam is still ejected overside at this stage and results in a further increase in noise of over 15 dB - now reaching a spectrum level of 1 dyne/cm^2. This is entirely steam noise as the vessel is still proceeding at only 3½ knots on main motors. The character of the noise is similar to previously, i.e. unpitched; but much more intense.

123. The next step, "Steam to Turbine" reduces the flow of steam outboard in order to run up the turbine. It will be seen that the noise dropped considerably according to how much steam was being ejected, and the drop in noise suggests that the turbine itself was not an unduly noisy machine, certainly when compared to the steam noise. The turbine was then clutched in and the vessel gathered way until a speed of about 15 knots was attained. There was no steam overside, but the noise of the vessel had almost regained the "steam overside" level. This was now apparently due to propeller and local cavitation (the vessel was "crabbing" and intense "spitting" noises could be heard under these conditions). While no steam was going overside, exhaust CO_2 from the condenser was having to be compressed and ejected overside and it is thought that this must also be noisy.

124. When the turbine was stopped, (by stopping the triple pump) the noise dropped sharply by over 10 dB before the vessel lost way at all or the turbine could run down. It is thought that removing the drive from the propeller caused this sudden drop in noise as the cavitation on the "back" of the badly slipping propeller would also stop suddenly. This manoeuvre may on the other hand throw some cavitation onto the normal thrust face, but it is certain to be much less and is, in any case, better shielded from the sonar dome. The position is complicated by the fact that the vessel stops crabbing immediately the drive is removed and so local cavitation is also reduced; moreover, the quantity of CO_2 "overside" is reduced quickly.

125. Instantaneous log readings of speed were taken as the vessel lost way until the speed dropped to 4 knots, when the noise level was consistent with that obtained when deep under motors. In fact, the noise at all speeds when

gliding was consistent with flow noise in the casing of a fairly modern submarine.

126. While some of the turbine machinery, particularly the triple pump, is undoubtedly noisy, the noise output does not compare with the non-machinery sources of self-noise present when underway turbining. These other noise levels, as will be seen, are very high, though it must be remembered that there is no experience of operating 'conventional' submarines in this speed range from which a so-called "reasonable" noise level could be estimated.

Underway Runs

127. Because time was not allowed for independent running for self-noise measurements in more open and deeper water all runs had to be carried out at the same time as the noise ranging in Loch Fyne. Hence no very deep runs at high speed could be included. Thus in older submarines, speeds up to 9 knots were employed and in the later ones speeds up to 17 knots at shallower depths only. It is unfortunate that these high-speed runs deep could not be carried out as it is at high speed that the greatest change in noise with change in operating depth is expected. The auxiliary machinery operated was normally confined to Group I, though on some occasions some even of the Group I machines were not required and were therefore omitted. Considering the basic plots of noise against speed for the different divisions of submarines, Figures 3, 4 and 5 are arranged to show the effect of depth at the different frequencies. It will be seen that there is a general decrease in noise as the depth of operation is increased from periscope to the maximum in both topside and keelside positions. Since there is no reason to expect a change in machinery noise with change of depth, and the evidence is that flow noise is not dependent on depth, this noise reduction can only be due to a reduction in the propeller cavitation component. The fact that the reduction in total self-noise with increase in depth is generally greater in the keelside position therefore suggests that a relatively greater proportion of total self-noise in the keelside position is due to propeller noise than in the topside position. In Figures 6 and 7 the different divisions of submarine have been compared for the two tactically most important conditions; namely, the snort and deep conditions. The snort runs are confined to PORPOISE and T Classes because runs under the snorting condition were not part of the normal self-noise programme at the time most of the old vessels were ranged, and to date only one A modernisation has snorted for self-noise runs. This was left out of the averages as the topside dome was abaft the fin and the excessive machinery contribution would have been misleading. Under snorting conditions the Admiralty Noise Target Level is Sea State 6 for frequencies between 1 and 10 kc/s. This target is met at 5 and 10 kc/s for both topside and keelside positions but in the slow snort condition only. All the fast snort runs and the slow snort runs at the lower frequencies are considerably above the Admiralty Noise Target Level in both topside and keelside positions.

128. Comparing the snort runs for PORPOISE Class with the battery driven runs for the Class as shown in Figure 5 the snorting condition is seen to be only about 2 dB noisier, showing that the failure to meet the target under the fast snort condition is due largely to the increase in propeller

and not to engine noise. In fact, the same is true for the T Class when a similar strict comparison is made. This, however, is not directly apparent by comparison of Figures 4, 6 and 7 because the plots of Figure 4 include a number of A Class submarines which are quieter than T Class under these conditions. There are no measurements of A Class snorting to compare with the results from battery runs. There is, however, some machinery contribution to self-noise under the snorting condition. This is particularly noticeable in the T Conversions at 1 and 2½ kc/s in the keelside position where the noise is very much greater than in either the keelside position during battery runs or in the topside position snorting; this may be due to mechanically-conducted noise. In the second place, while PORPOISE Class meet the Admiralty Noise Target at 10 kc/s, when snorting at slow speed, speed for speed, the battery runs are considerably quieter, showing that although the fast snort condition is not machinery noise dominated, the slow snort condition is.

129. The overall reduction that would be necessary to achieve the target is about 10 dB for the T Conversion and 5 dB for PORPOISE Class. This applies at the higher frequencies and the amounts would be even greater at the lower frequencies. The component to be tackled is the propeller noise component at the higher snort speed and the higher frequencies, while some reduction in machinery noise will be necessary to achieve the target at the lower frequencies.

130. Comparing the different submarine "divisions" on batteries, deep, it is immediately apparent that the old submarines are very noisy when at any speed at all. This is due to old, unfaired domes and casings (possibly rattling) and to old, noisy designs of propeller with low cavitation inception speeds even at depth. It is also apparent that the gap between PORPOISE Class and the modernised submarines tends to widen as the speed is increased. This appears to be due to quieter propellers in PORPOISE Class and this conclusion is supported by the fact that a greater reduction in noise is achieved by going deep in a modernised submarine than in PORPOISE Class.

131. Even so, if the old search-state target of Sea State 1 is to be approached at the higher speeds considerable further reduction is required even in the quietest submarines - for instance, 15 dB at 10 knots in PORPOISE Class. The source, when deep, appears to be largely, if not wholly, flow noise, although reduction in propeller noise would allow results no worse to be obtained at shallower depths.

132. Comparison of topside and keelside results at identical speeds and frequencies in Figure 8 shows the topside set to be noisier than the keelside in each of the three divisions of submarines; (old, modernised, and PORPOISE Classes) except for PORPOISE Class at the lower frequencies. For old A, S, and T Classes the difference averages about 5 dB, increasing slightly with depth, but largely independent of speed and frequency, while for the modern submarines the difference is 2 to 4 dB at 5 and 10 kc/s and less at the lower frequencies, particularly in PORPOISE Class. This smaller difference between topside and keelside positions in modern submarines tends to confirm that old topside domes were unduly noisy. This was, in fact, partly due to the casing. Flow noise is still, however, a relatively important contributor to noise in the newer vessels, and often

the major one because the propeller performance has been simultaneously improved.

133. When assessing the tactical advance in noise performance it should be borne in mind that in older vessels the keelside set (Type 129) was regarded as the primary set whereas now it is the topside (Type 187) on which first attention is focused. The improvement is, therefore, represented by the difference between keelside in old submarines and topside in new vessels and is thus, rather less than the absolute reduction obtained in the topside position.

Comparison of PORPOISE Class with H.M.S. SCOTSMAN and 'E' Class

134. Special trials concerned with dome development were carried out in H.M.S. SCOTSMAN over a period of several years. The results obtained with an experimental stainless steel dome spheroidal in shape were used in obtaining the smooth dome flow noise levels published in Reference 13.

135. Further trials were attempted with a dome of similar shape but constructed of resin-bonded glass fibre. This, however, broke up during a high-speed run, though the scanty results already obtained were broadly comparable with the earlier measurements with the steel dome. Both these trials had been conducted using a large rectangular transducer similar to that used in Type 187. The next trials, reported in Reference 14, were of a prototype glass fibre dome, again a body of revolution but this time for use with existing 15-inch diameter transducers. These are the results plotted in Figure 9. It will be seen that the levels are considerably higher than either PORPOISE Class or the earlier H.M.S. SCOTSMAN results. This is thought to be due to a combination of two reasons.

136. In the PORPOISE Class the dome seating is in an extreme bow position and is therefore well away from, and relatively insensitive to the localised disturbed flow (and possibly rattling) of the casing of the submarine. In all the trials with H.M.S. SCOTSMAN the dome lay much further aft and was subject to such localised noises, though in earlier trials the transducer used had a much higher directivity and discriminated better against such sources well off the transducer axis. This enabled lower levels to be obtained even after making the larger correction for directivity. Furthermore, the object of the earlier analysis was somewhat different, for, whereas it is the aim of this report to give average total self-noise levels on operational bearings, and this had been done for the later H.M.S. SCOTSMAN work and for the routine trials, the most urgent requirement at the time of the earlier H.M.S. SCOTSMAN trial was to establish a mean level of the flow noise component and its dependence on speed and frequency. To this end the noisier bearings were ignored as being due to sources other than flow noise on the dome skin and the mean of quieter bearings were plotted as true flow noise.

137. The sonar equipment in 'E' Class employs a 15-inch diameter transducer but in a dome intermediate in size between that normally used for Types 138/168 and that for Type 187. It is similar in form to the 100-inch frigate dome, and of streamlining superior to the early submarine domes. Its location is well forward on the casing but not quite so far forward as on the modern submarine.

138. From the plots in Figure 9 it will be seen that the 'E' Class on main motors are considerably noisier than H.M.S. SCOTSMAN and therefore much noiser than H.M.S. PORPOISE. The levels from the battery runs at shallow depths (which are not published here) were much quieter and were comparable with, say, a T conversion under similar conditions. This increase in noise on going deep, which occurred in both submarines, has not been explained. No such anomaly was, however, apparent when under turbines, and this was the condition on which major interest was centred. The minimum speed obtainable under turbines is about 18 knots, though speeds between 14 and 18 knots may be obtained by running on one shaft only. Because of functioning difficulties only single-shaft running was, in fact, possible in H.M.S. EXCALIBUR but these results confirmed closely the corresponding results from the H.M.S. EXPLORER trial.

139. As would be expected, single-shaft runs are considerably noisier than two-shaft runs at the same forward speed since, in the case of the single-shaft drive, the propeller is slipping and therefore cavitating excessively and the vessel is "crabbing" somewhat, resulting in more turbulent flow and a greater extent of non-propeller cavitation. These effects would all produce an increase in noise.

140. Levels on two shafts increased steadily with increase in speed up to 24 knots but the faster run at "$\frac{7}{8}$ throughput" (the normal maximum power) produced a sharp rise in self noise for a small increase in forward speed ($1\frac{1}{2}$ knots) and a marked increase in vibration throughout the vessel.

141. The fall-off in noise with increasing frequency is less for one than for two-shaft runs. This would tend to confirm the existence of a greater extent of cavitation noise when under one-shaft drive and suggest possibly flow or machinery noise domination over certain ranges of speed and frequency when driven by two shafts, especially as the slope is generally steeper than -6 dB per octave.

142. The fall-off in noise for increasing depth (which is not shown here) is, however, also less for one than for two-shaft runs. This would not have been expected and has not been explained.

Comparison of PORPOISE Class, U.S.Submarines and other vessels

143. From Figure 10 it will be seen that the PORPOISE Class submarine, within its speed range, closely approaches the lowest self-noise levels attainable in our present state of knowledge. This is represented by the firm line curve of "flow noise in smooth domes" which has been generally confirmed by a number of different investigators under widely differing conditions. A level based on three U.S.Submarines, also follows this flow-noise line closely (Reference 15). Because of the number of results which achieved this level and the fact that none was ever found to be below this, it is considered up to now that a "break-through" in the manipulation of the boundary layer and hence of the mechanism of flow noise would have to be achieved in order to reach substantially lower levels. Certain experiements in U.S.S. ALBACORE obtained during some noise reduction experiments (Reference 16) appear, however, to yield results of a considerably lower level. Either these U.S.S. ALBACORE results achieve this breakthrough or there is some factor which has not been allowed for in presenting the results. It is thought that it is the latter.

144. The technique of R.N. and U.S.N. measurements of flow noise differs in the following important respect; whereas the measurements summarised in this report have been obtained with a directional hydrophone and converted to an omni-directional level as described in paragraphs 18 to 20, the U.S.N. technique has normally been to use an omni-directional hydrophone. If, now, large solid angles of the hydrophone's "view" are blanked by absorbent material the sound field will no longer be isotropic and the measured level of noise in the omni-directional hydrophone will be less in proportion to the angle blanked. A directional hydrophone in the same position trained on an unblanked bearing would initially show a still lower level, but the correction for directivity, which would bring the noise up to the level expected in an omni-directional hydrophone, would assume not only an omni-directional hydrophone, but also an isotropic sound field. The resulting level would then be higher than the omni-directional measurement in the non-isotropic field, and it is thought, more nearly the figure required since a sonar equipment of this sort is almost certain to be directive. It seems likely then, that the U.S.S. ALBACORE results are relatively low for this reason.

145. Below 10 or 12 knots PORPOISE Class are quieter than average R.N. escorts (Reference 17) but the rate of increase of noise with speed seems to be less for the escort.

146. Until a "break-through" is achieved in the reduction of flow noise, and unless deterioration in dome, hull and propeller conditions is allowed to occur in individual submarine, PORPOISE Class appear to be as quiet as it is likely they can be as far as Type 187 is concerned.

ACKNOWLEDGEMENT

147. It is readily acknowledged that the great bulk of the trials work which has provided results for this report has been carried out by the staff of the Officer-in-Charge, H.M.E. Loch Goil. The author is grateful for his co-operation and particularly to the regular trials team - Mr. D.H. Cameron (Experimental Officer) and Mr. R.C. Scott (Scientific Assistant) for their untiring efforts.

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* 1962 Classification.

TABLE 1

DIRECTIVITY INDEX OF 15-INCH DIAMETER TRANSDUCER

f (kc/s)	1	2.5	5	10
D (dB)	-4	-8	-12	-18

TABLE 2

DIRECTIVITY INDEX OF TYPE 187 TRANSDUCER

f (kc/s)	2.5	10
D (dB)	-14	-26

TABLE 3

DIRECTIVITY INDEX OF TYPE 186 HALF-ARRAY

f (c/s)	300/600	600/1200
D (dB)	-12	-15

TABLE 4

NOISE LEVELS IN TYPE 186 HALF-ARRAYS IN "A" CL

(dB vs SS1)

Type 186 Group Machine Operating	H.M.S. AURIGA(1) U.D.E. Spring 1958 Reference 4	H.M.S. AURIGA(2) A.R.L. September 1958 Reference 5	H.M.S. AURIGA(3) Loch Goil September 1959	H.M.S. ART October 19
230 volt a.c. machine (No. 1	0	-	0	-
230 volt a.c. machine (No. 2	0	-	-	8
Gyro - Motor Generator	-	-	8	4
L.P. Generator	-	-	0	8
Main motor cooling fans (port	0	0	-	-
Main motor cooling fans (stb'd	0	0	0	0
Main motor 110 or 120 rev/min (port	0	0	-	-
Main motor 110 or 120 rev/min (stb'd	0	0	6	8
Hydrogen clearance fans (No. 1 port	15	-	-	-
Hydrogen clearance fans (No. 2 port	0	-	-	-
Hydrogen clearance fans (No. 1 stb'd	0	-	-	-
Hydrogen clearance fans (No. 2 stb'd	0	-	-	-
No. 2 Port + No. 1 stb'd	-	-	-	18(3)
(All	-	12	14	20
After-services circulators (port	-	-	-	29
After-services circulators (stb'd	-	-	13	15
After-services circulators (mid-line	16	16	18	-
Telemotor pumps (IMO No. 1	18	23	32	18
Telemotor pumps No. 2	16	19	22	17
Telemotor pumps No. 3	-	-	-	-

0 (zero) means "not above SS1" or "no reduction require

\- (dash) means "no measurement"

(1) "slow or full"

(2) "110 or 150 rev/min"

(3) "All except forward"

(4) "All except No. 2 stb'd"

1

TABLE 4

LEVELS IN TYPE 186 HALF-ARRAYS IN "A" CLASS (NOISIEST CHANNEL)

(dB vs SS1)

AURIGA(2) R.L. ber 1958 ence 5	H.M.S. AURIGA(3) Loch Goil September 1959	H.M.S. ARTFUL October 1959	H.M.S. AMPHION April 1960	H.M.S. ALARIC February 1961	H.M.S. ASTUTE July 1961	H.M.S. ALDERNEY September 1961
- -	0 -	- 8	0 -	0 -	0 0	- 0
-	8	4	0	0	7	0
-	0	8	0	0	2	0
0 0	- 0	- 0	0 0	0(1) 0(1)	0 0	0 0
0 0	- 6	- 8	0 0	0(2) 0(2)	0 0	0 0
- - - - - 12	- - - - - 14	- - - - 18(3) 20	7 0 0 10 4 10	6 4 4 14 5 -	11 12 5 - - 12(4)	3 8 2 - - -
- - 16	- 13 18	29 15 -	- - 13	16 15 14	20 18 8	10 5 11
23 19 -	32 22 -	18 17 -	30 14 3	24 16 0	13 14 2	21 22 -

s "not above SS1" or "no reduction required"

s "no measurement"

ll"

v/min"

rward"

. 2 stb'd"

2

TABLE 4 (Contd.)

NOISE LEVELS IN TYPE 186 HALF-ARRAYS IN "A" CLASS (N

(dB vs 881)

Additional Machines	H.M.S. AURIGA(1) U.D.E. Spring 1958 Reference 4	H.M.S. AURIGA(2) A.R.L. September 1958 Reference 5	H.M.S. AURIGA(3) Loch Goil September 1959	H.M.S. ARTFUL October 1959
Refrigerator	19	23	17	17
Trim pump (aft - for'd (for'd - aft)	13	17	10	24
Ballast pump	8	14	23	25
Air conditioning plant (port	-	-	-	28
(stb'd	-	-	-	26
(both	26	29	30	-
Ships ventilation fans (slow)	15	15(1)	10	12
Battery ventilation fans	-	-	-	-
Sub-pressure pump (for'd	-	-	-	-
(aft	-	-	-	-
CO_2 absorption unit (for'd	-	-	-	-
(aft	-	-	-	-
Sound room table fan	-	-	-	-
Sound room "Vent Axia"	-	-	-	-
400 c/s ~~attenuator~~ ALTERNATOR	-	-	-	-
Auxiliary trim pump	-	-	-	-
Reducer	0	-	-	-
Distiller 5 gallon	-	-	20	-
15 gallon	-	-	27	-

(1) full speed

(2) due to 10 x 6 inch fans; 10 x 3 inch fans quiet

1

TABLE 4 (Contd.)

LEVELS IN TYPE 186 HALF-ARRAYS IN "A" CLASS (NOISIEST CHANNEL)

(dB vs SS1)

AURIGA(2) .R.L. ber 1958 ence 5	H.M.S. AURIGA(3) Loch Goil September 1959	H.M.S. ARTFUL October 1959	H.M.S. AMPHION April 1960	H.M.S. ALARIC February 1961	H.M.S. ASTUTE July 1961	H.M.S. AL[illegible] September 1961
23	17	17	10	16	12	4
17	10	24	14	19 20	20 11	12 -
14	23	25	24	-	-	-
- - 29	- - 30	28 26 -	24 13 -	14 14 -	18 19 -	18 16 -
5(1)	10	12	6	7	15	6(2)
-	-	-	14	-	8	-
- -	- -	- -	24 15	18 15	11 -	- -
- -	- -	- -	0 0	0 0	0 0	- 0.
-	-	-	3	-	-	-
-	-	-	0	-	-	-
-	-	-	-	-	0	-
-	-	-	-	-	-	43
-	-	-	0	0	-	-
- -	20 27	- -	17 -	24 14	- 16	- -

; inch fans; 10 x 3 inch fans quiet

2

TABLE 5

REDUCTIONS IN NOISE REQUIRED IN "A" CLASS TO ACHIEVE SEA STATE 1 IN EACH HALF-ARRAY OF TYPE 186 AND AT BOTH FREQUENCIES (dB)

	H.M.S. AURIGA	H.M.S. ARTFUL	H.M.S. AMPHION	H.M.S. ALARIC	H.M.S. ASTUTE	H.M.S. ALDERNEY
Total 186 M/C (Static)	12	12	4	6 (1)	6	0 (2)
186 Search State (underway)	14	17	9	6 (1)	5	-
Flow contribution	10	12 (3)	7	8	-	-
Revised (4) 186 M/C (static)	22 (5)	18	13 (6)	14 (7)	10 (8)	7/21 (9)
Revised 186 SS (underway)	22	19	14	14	13	-

(1) H.C.P.'s dominate; those were not run in other vessels at this stage.

(2) Based on measurements of individual machines only.

(3) Based on published figure; uncertain why this is not equal to the difference between the two figures above it.

(4) Including extra machines, see text paragraph 102.

(5) No. 2 IMO Pump dominates.

(6) Mid-line circulator dominates.

(7) After - services circulator dominates.

(8) Assuming mid-line circulator and No. 3 IMO are added.

(9) Assuming starboard circulator is added and No. 1 IMO is not/is run (no measurement on No. 3 IMO which is usually quieter).

TABLE 6

NOISE LEVELS IN TYPE 186 HALF-ARRAYS IN "O" CLASS (NOISIEST CHANNEL) (dB vs SS1)

"Group I" Machine Operating	H.M.S. CACHALOT(1) Feb. 1960	H.M.S. ORPHEUS Jan. 1961	H.M.S. WALRUS May 1961	H.M.S. OBERON July 1961	H.M.S. PORPOISE Sept. 1961
115V a.c. machine No. 1	0(2)	1	0	0	-
115V a.c. machine No. 2	-	5	0	-	0
Gyro wheel	0	8	0	-	-
Gyro +400 c/s m.a.	0	8	0	0	0
L.P. Generator No. 1	0	0	0	0	0
L.P. Generator No. 2	-	0	0	0	0
Hydrogen clearance fans No. 1 stb'd	-	} 10	} 2		9
Hydrogen clearance fans No. 1 port	-	}	}	} 10	0
Hydrogen clearance fans No. 1 mid	-	-	-	}	0
Hydrogen clearance fans No. 2 stb'd	-	} 9	} 0	}	0
Hydrogen clearance fans No. 2 port	-	}	}	} 0	0
Hydrogen clearance fans No. 2 mid	-	-	-	}	0
Hydrogen clearance fans All	1	10	0	10	-
Main motor cooling fans (port	0	< 2	0	0	0
Main motor cooling fans (stb'd	0	< 2	0	0	0
Hovering gear (actuator pump only)	-	< 2	-	0	-
A.R.L. plotting table	-	3	-	-	-
W.R. record player (phone sets)	-	< 2	-	-	-
After services circulator (port	-	-	-	0	0
After services circulator (stb'd	0	-	-	0	0

0 (zero) means "not above SS1" or "no reduction required".

- (dash) means "no measurement".

(1) Estimated from single hydrophone measurements (Reference 5).

(2) 230V a.c. machine.

TABLE 6 (Contd.)

(dB vs SS1)

Group II Machine Operating	H.M.S. CACHALOT Feb. 1960	H.M.S. ORPHEUS Jan. 1961	H.M.S. WALRUS May 1961	H.M.S. OBERON July 1961	H.M.S. PORPOISE Sept. 1961
E.M.R. "Vent Axia"	-	< 3	-	-	-
W.R. "Vent Axia"	-	< 3	-	-	-
Sound Room Fan	-	5	0	-	0
Main Refrigerator	8	< 3	0	0	0
Domestic Regrigerator	-	< 3	0	-	0 (1)
400 c/s 205V machine (No. 1	-	0	0	-	-
(No. 2	-	0	0	-	0
A.T.M.C.8	-	0	-	-	-
Additional Machines					
Steering	-	6	-	-	-
Hovering gear (off load	-	-	-	0	-
(pumping	-	15	-	6	-
Telemotor pumps (IMO No. 1	22	9	10	3	6
(IMO No. 2	-	8	14	6	11
(IMO No. 3	-	-	-	0	-
(N.E.R.L.pump	-	14	4 (2)	-	-
McTaggart-Scott pump	14	-	-	-	14
C.P. Generator No. 1	-	12	-	0	-
No. 2	-	13	-	0	0
W.R. heater	-	<3	-	-	-
Fans (10 in x 6 in No.1	9 (3)	5	0	0	0
(No.2		3	0	0	0
(10 in x 3 in No.1	13 (3)	3	0	0	-
(No.2		6	0	0	-
Both 10 in x 6 in + both 10 in x 3 in	-	-	-	-	4
Fans 10 in x 3 in radar exhaust	-	-	-	-	0
galley exhaust	-	-	-	-	0

(1) 'either'.

(2) "fitted with flexible piping".

(3) "ships ventilating fans".

TABLE 6 (Contd.)

(dB vs SS1)

Additional Machines	H.M.S. CACHALOT Feb. 1960	H.M.S. ORPHEUS Jan. 1961	H.M.S. WALRUS May 1961	H.M.S. OBERON July 1961	H.M.S. PORPOISE Sept.1961
Air conditioning plant (No.1 (No.2	2	6 6	0 0	0 6	0 0
100 kw generator No.1 No.2	- -	- -	0 0	- -	- -
Trim pump (for'd aft (aft for'd	14	- -	- -	- -	4 0
Ballast pump	10	-	-	-	-
500 c/s motor generator No.1 No.2	- -	- -	- -	- -	0 0
Sub-pressure pump No.1 No.2	- -	- -	- -	0 0	0 0
Distiller No.1 No.2	- -	- -	- -	0 0	0 0
180V machine No.1 No.2	- -	- -	- -	0 0	- -
CO_2 absorption unit for'd aft	- -	- -	- -	0 0	0 0
Battery cooling pump No.1 No.2	- -	- -	- -	7 5	16 16
Acid agitation	-	-	-	0	3
Battery ventilation fan(slow) No.1 No.2 "All"	- - -	- - -	- - -	7/16 [1] 0/8 [1] -/16 [1]	11 1 -
Lub. oil priming pump	-	-	-	-	0
Engine turning gear (stb'd (port	- -	- -	- -	- -	0 4
Crypto machine	-	-	-	-	0

(1) "Group up".

TABLE 7

REDUCTION IN NOISE REQUIRED IN "O" CLASS TO ACHIEVE SEA STATE 1 IN EACH HALF-ARRAY OF TYPE 186 AND AT BOTH FREQUENCIES (dB)

	H.M.S. CACHALOT	H.M.S. ORPHEUS	H.M.S. WALRUS	H.M.S. OBERON	H.M.S. PORPOISE
Group I (Static)	0	14	3	0/9 (1)	0 (2)
Group I (Underway) (3)	8	14	5	5	0 (2)
Group II (Static)	8	20	9	2/9 (1)	1 (4)
Group II (Underway)	11	20	10+	5/9 (1)	1 (4)

(1) 9 dB reduction required when all H.C.F.'s run; No. 2 set could be run without interference

(2) excluding H.C.F.'s.

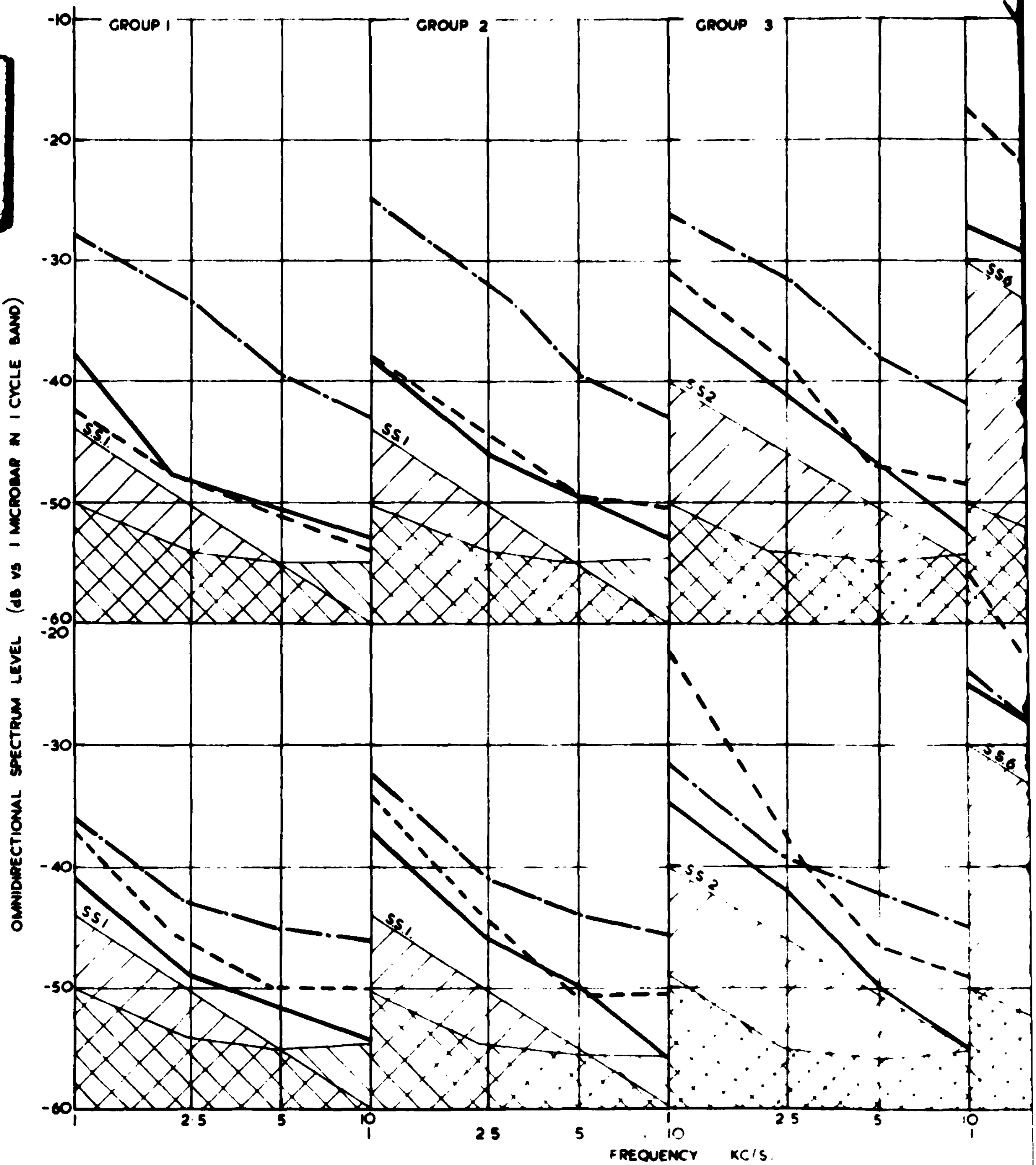
(3) 50 rev/min both shafts.

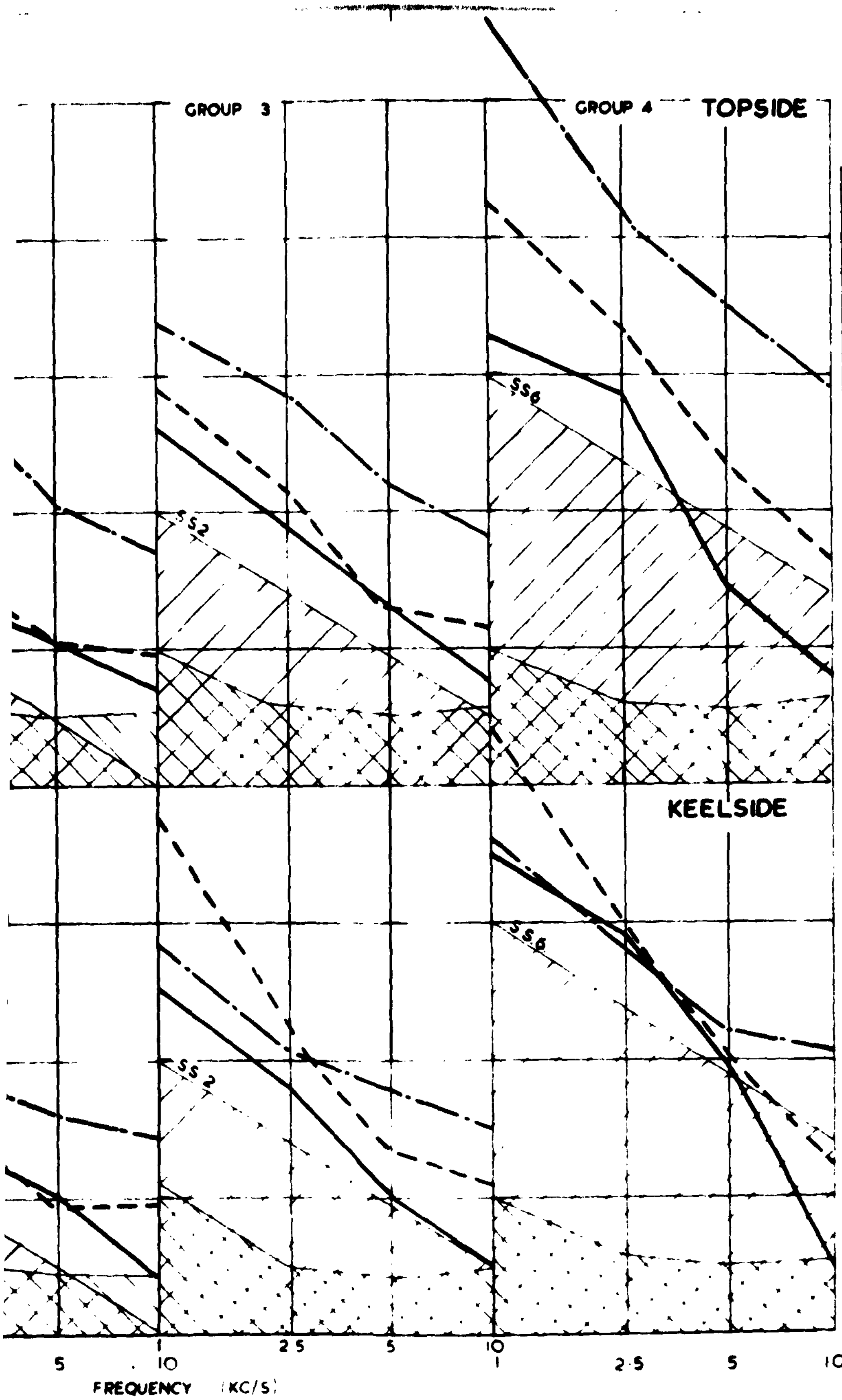
(4) excluding (Main and domestic refrigerators (though not noisy)
(A.T.M.C.8 (not measured)
but including some H.C.F.'s.

NOTE:

H.M.S. OBERON and H.M.S. PORPOISE up to 95 rev/min both (and H.M.S. PORPOISE 110 starboard) with no increase in noise.

1


GROUP 1
GROUP 2
GROUP 3
OMNIDIRECTIONAL SPECTRUM LEVEL (dB vs 1 MICROBAR IN 1 CYCLE BAND)
-10
-20
-30
-40
-50
-60
SS1
SS2
SS6
1
2.5
5
10
FREQUENCY KC/S.



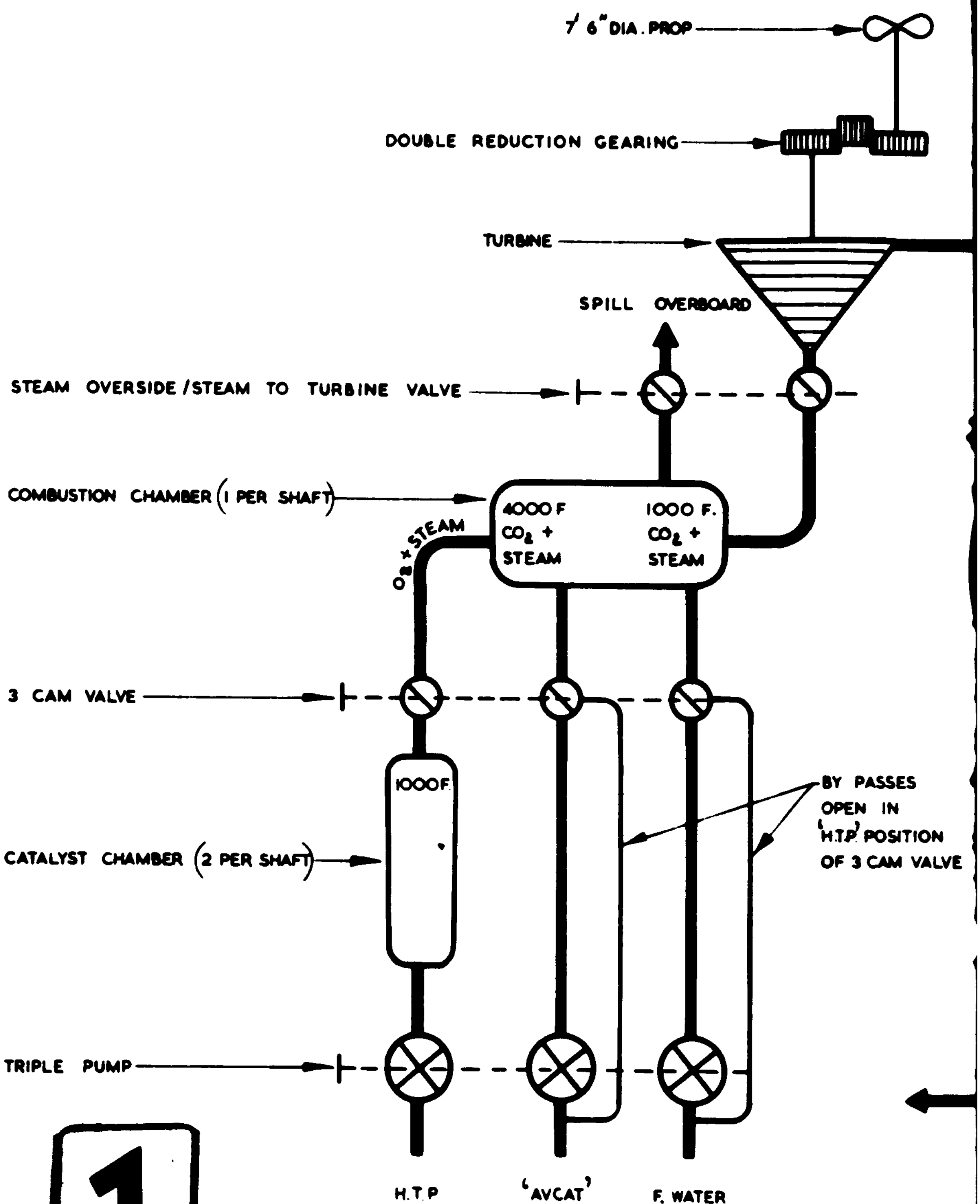
KEY

	CLASS OF S/M	No. OF SHIPS	BEARING
———	PORPOISE	1 - 3	TRAINED AHEAD
—·—·—	OLD, A, S & T CLASSES	5 - 6	TRAINED ASTERN
– – –	T CONVERSION	2 - 4	VARIOUS
– – –	A T STREAMLINE	3 - 4	TRAINED AHEAD
TTTT	BELOW EQUIPMENT BACKGROUND LEVEL		
////	BELOW ADMIRALTY NOISE TARGET LEVEL		

2

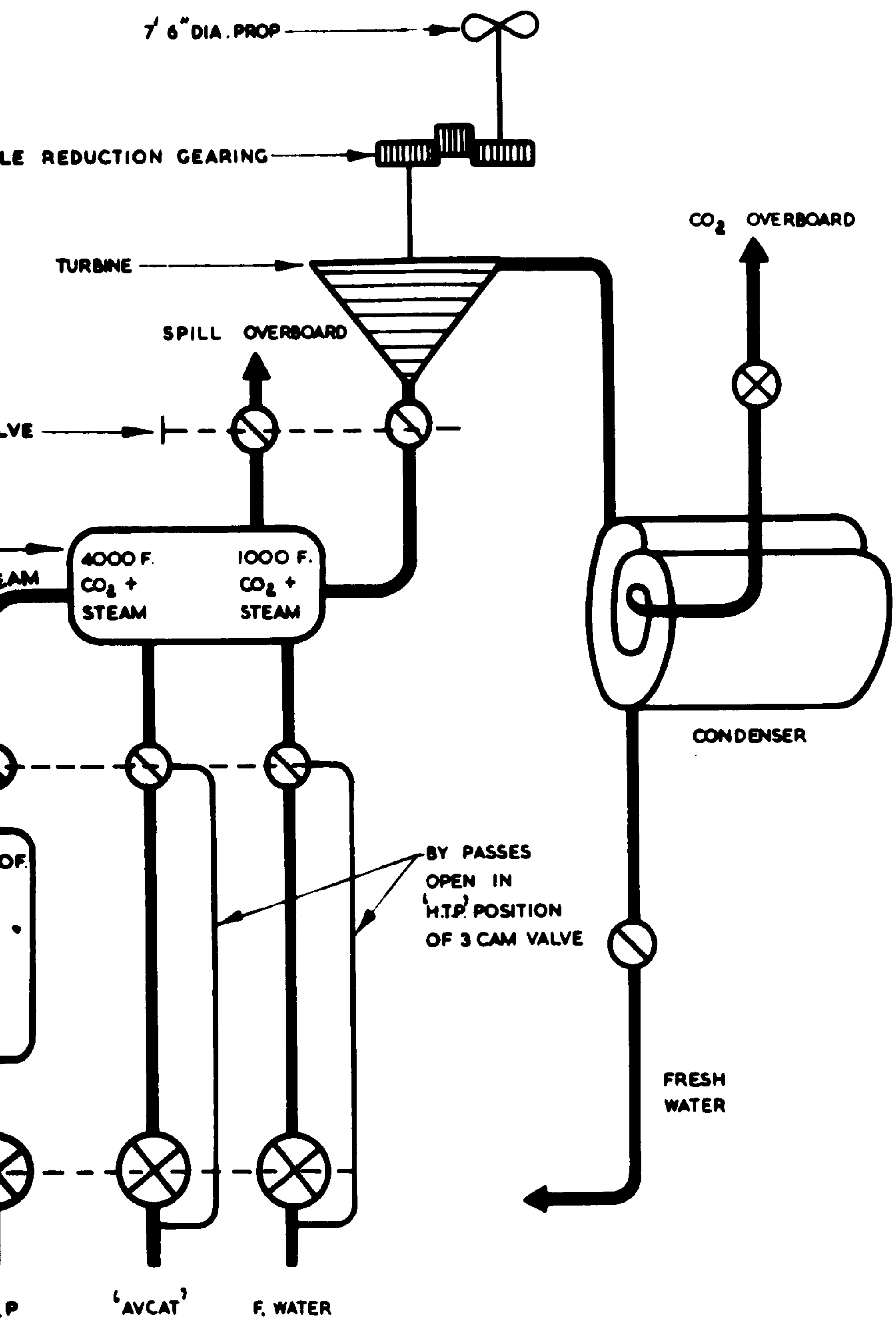
FIG. 1.

'GROUP' MACHINERY NOISE IN CONVENTIONAL SONAR POSITIONS (STATIC TRIAL)


7' 6" DIA. PROP
DOUBLE REDUCTION GEARING
TURBINE
SPILL OVERBOARD
STEAM OVERSIDE / STEAM TO TURBINE VALVE
COMBUSTION CHAMBER (1 PER SHAFT)
4000 F
CO_2 +
STEAM
1000 F.
CO_2 +
STEAM
O_2 + STEAM
3 CAM VALVE
1000F.
CATALYST CHAMBER (2 PER SHAFT)
BY PASSES
OPEN IN
'H.T.P.' POSITION
OF 3 CAM VALVE
TRIPLE PUMP
H.T.P
'AVCAT'
F. WATER

1

SECRET DISCREET FIG. 2 (a)

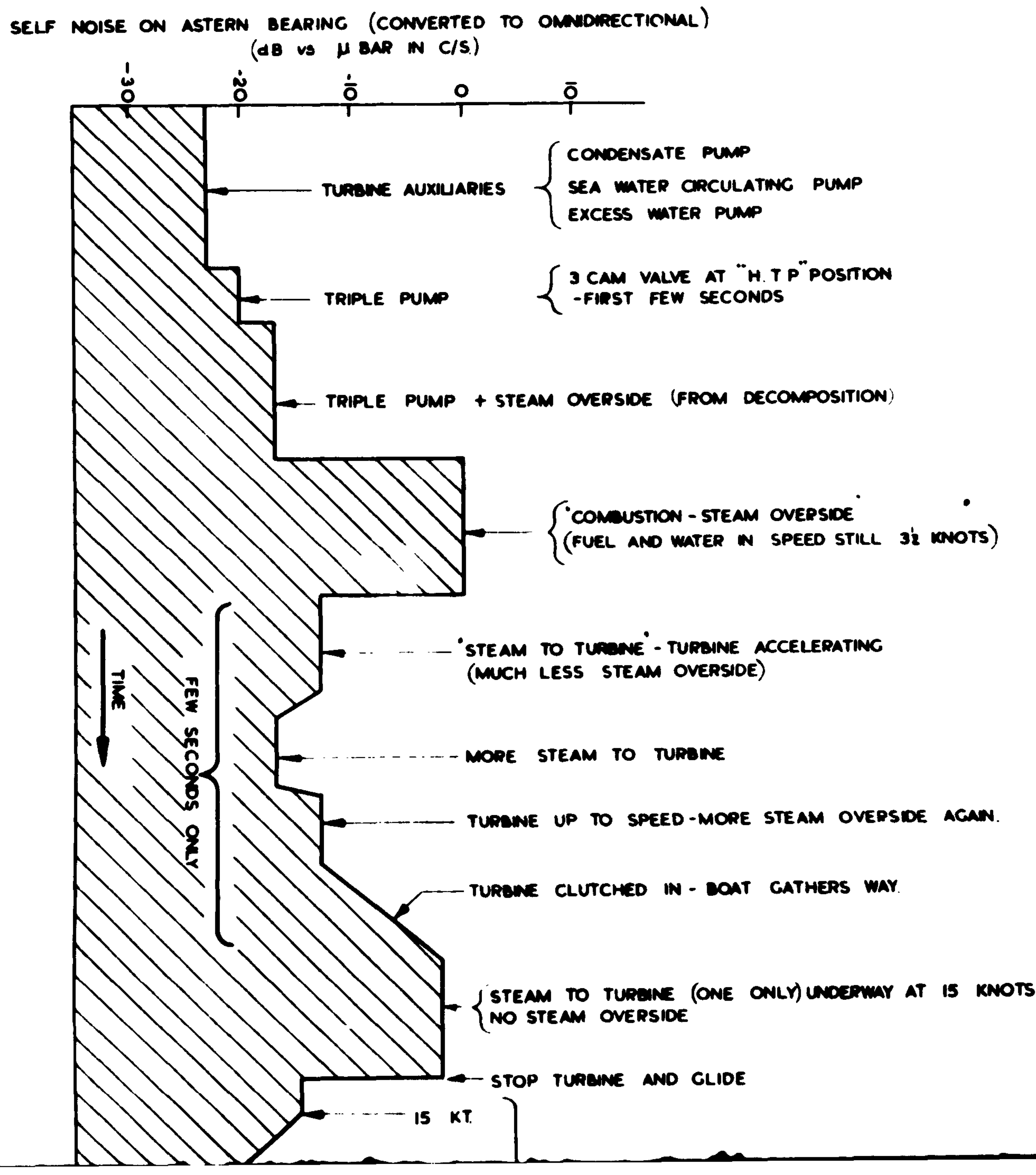


2

FIG.2(a) TURBINE PROPULSION SYSTEM 'E' CLASS

SECRET DISCREET

1



SELF NOISE ON ASTERN BEARING (CONVERTED TO OMNIDIRECTIONAL)
(dB vs μ BAR IN C/S.)
-30
-20
-10
0
10
TURBINE AUXILIARIES
CONDENSATE PUMP
SEA WATER CIRCULATING PUMP
EXCESS WATER PUMP
TRIPLE PUMP
3 CAM VALVE AT "H.T.P" POSITION
-FIRST FEW SECONDS
TRIPLE PUMP + STEAM OVERSIDE (FROM DECOMPOSITION)
COMBUSTION - STEAM OVERSIDE
(FUEL AND WATER IN SPEED STILL 3½ KNOTS)
STEAM TO TURBINE - TURBINE ACCELERATING
(MUCH LESS STEAM OVERSIDE)
MORE STEAM TO TURBINE
TURBINE UP TO SPEED - MORE STEAM OVERSIDE AGAIN.
TURBINE CLUTCHED IN - BOAT GATHERS WAY.
STEAM TO TURBINE (ONE ONLY) UNDERWAY AT 15 KNOTS
NO STEAM OVERSIDE
STOP TURBINE AND GLIDE
15 KT.
FEW SECONDS ONLY
TIME

2

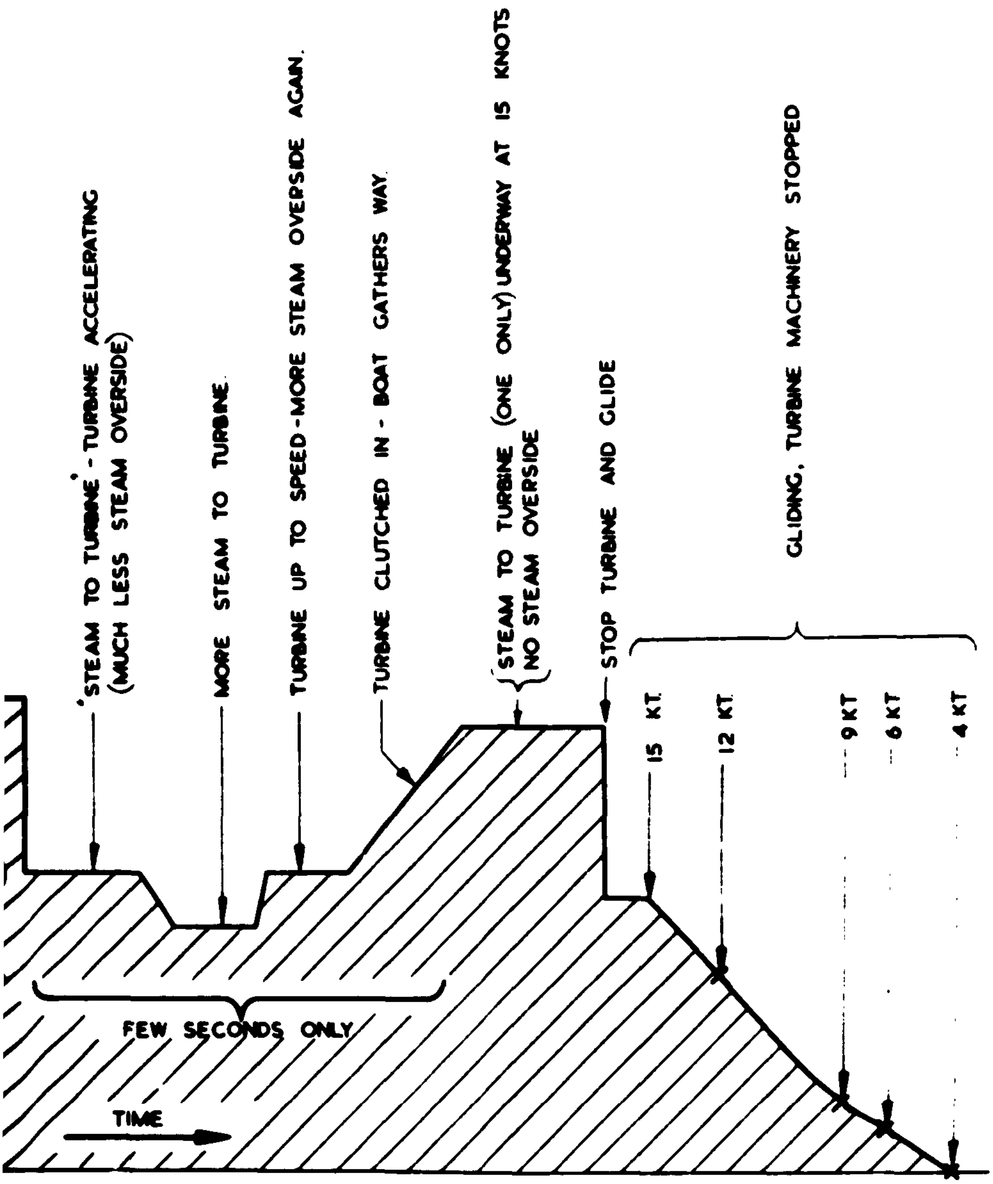
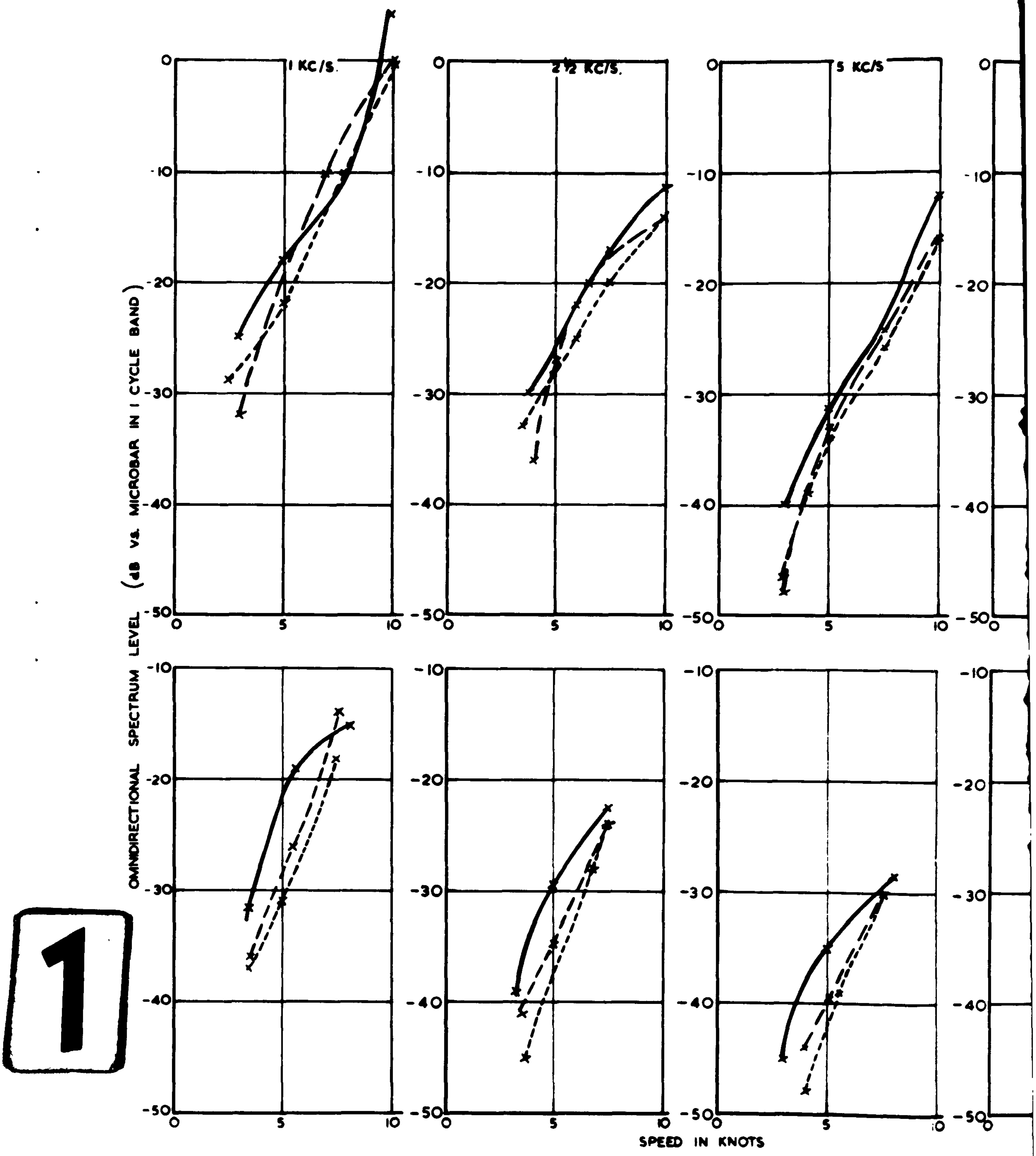
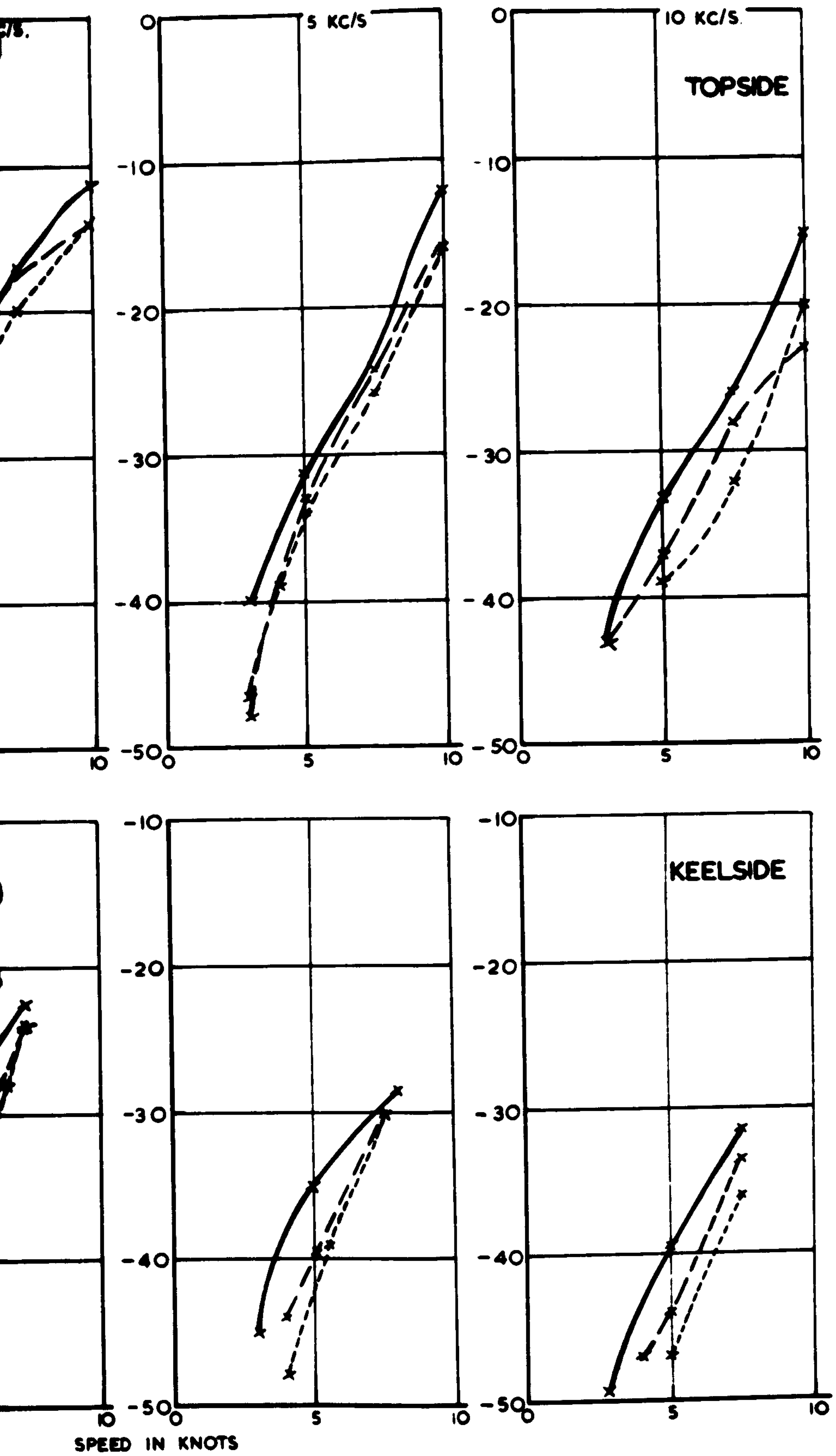


FIG. 2(b) H.M.S. EXPLORER

EFFECT OF TURBINE MACHINERY ON SONAR SELF NOISE AT 2·5 KC/S PLOT OF NOISE ON ASTERN BEARING vs. SEQUENCE OF EVENT.

(WITH DISTORTED TIME SCALE TO SHOW STAGES)


1 KC/S.
2 1/2 KC/S.
5 KC/S
OMNIDIRECTIONAL SPECTRUM LEVEL (dB vs. MICROBAR IN 1 CYCLE BAND)
SPEED IN KNOTS
1



KEY :-

PERISCOPE DEPTH

100 FT.

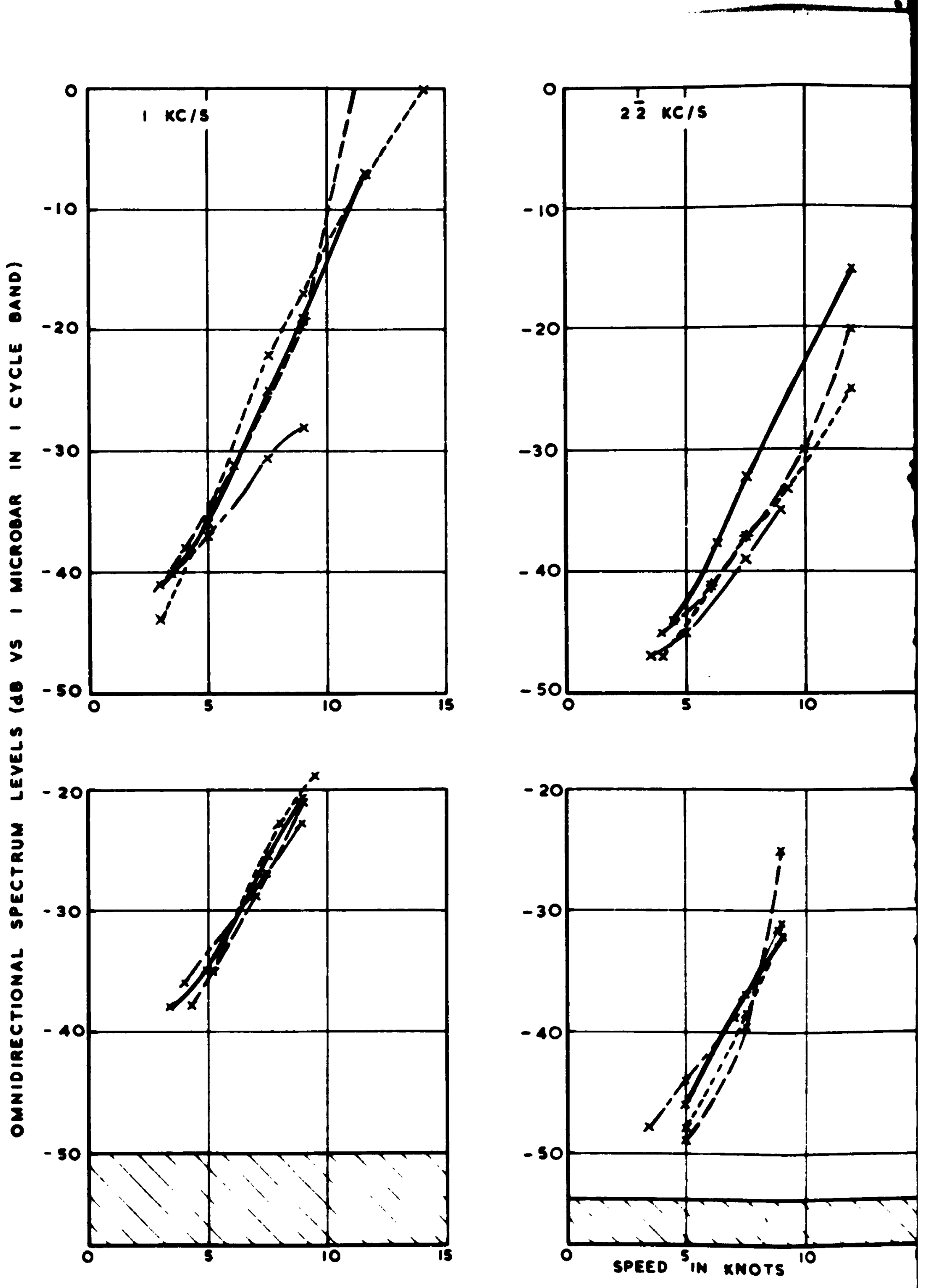
200 FT.

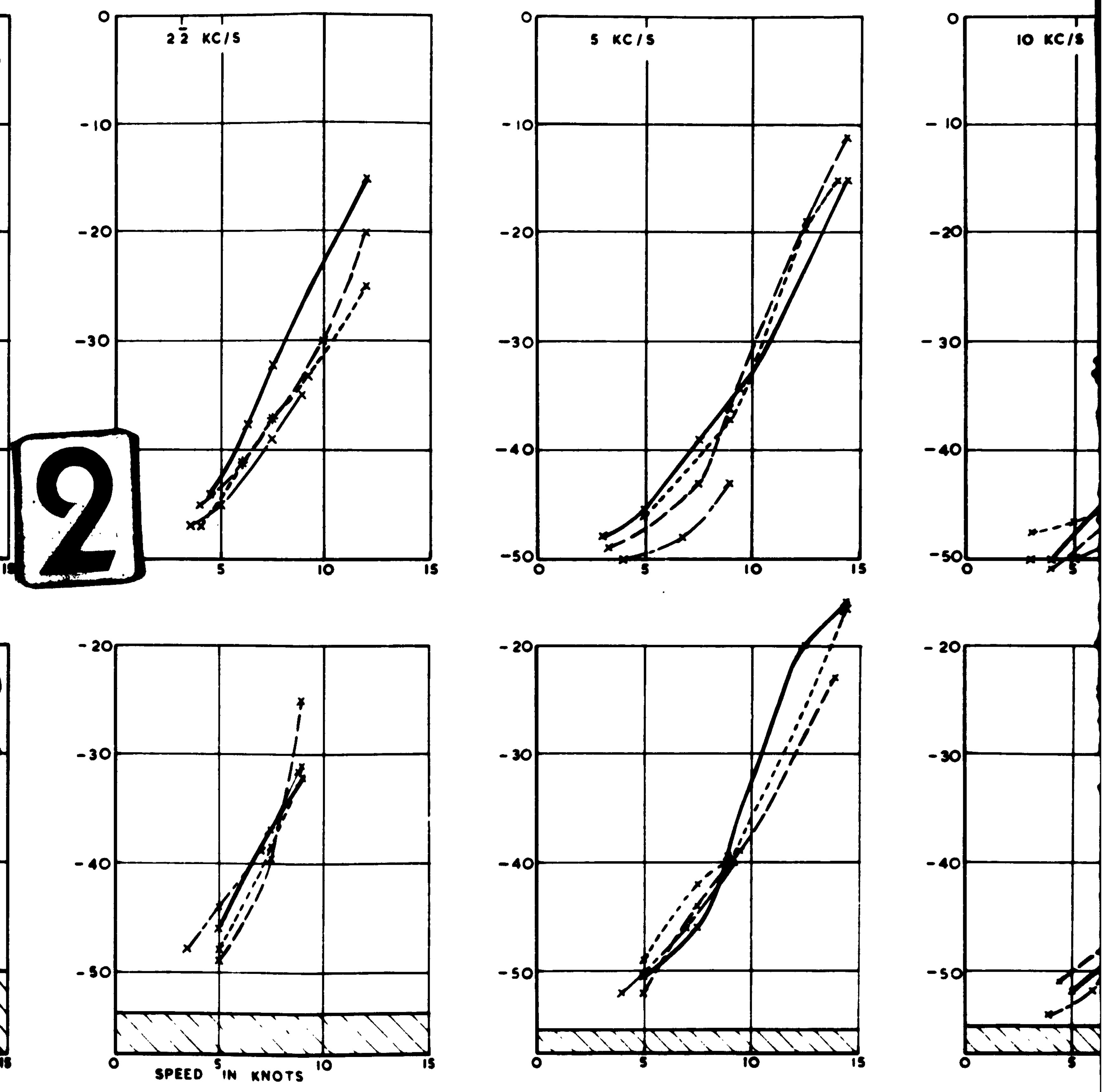
2

FIG. 3 SELF NOISE AS A FUNCTION OF SPEED.

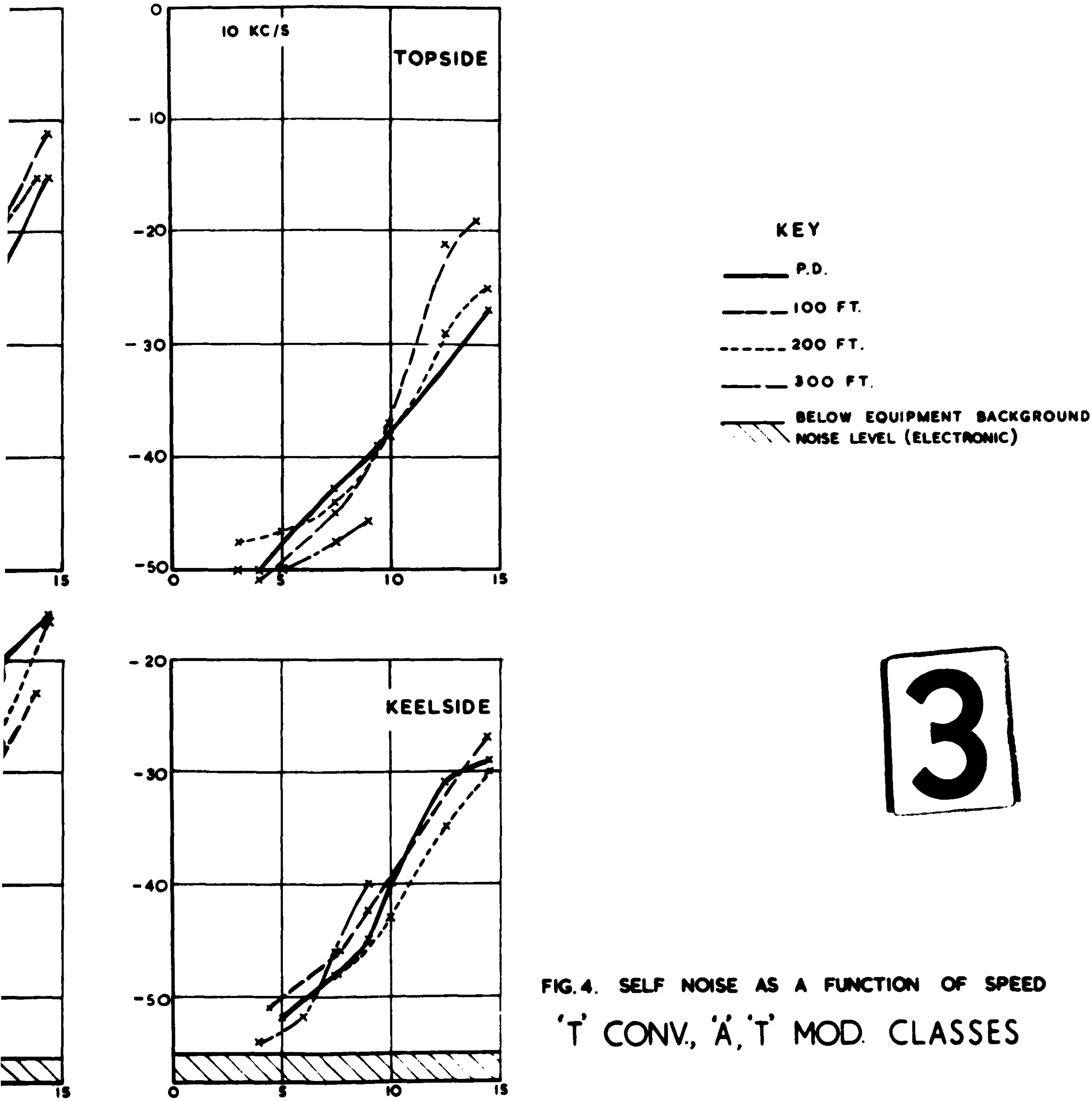
OLD 'A', 'S', 'T' CLASSES

1


OMNIDIRECTIONAL SPECTRUM LEVELS (dB VS 1 MICROBAR IN 1 CYCLE BAND)
1 KC/S
2½ KC/S
SPEED IN KNOTS
0
-10
-20
-30
-40
-50
0
5
10
15



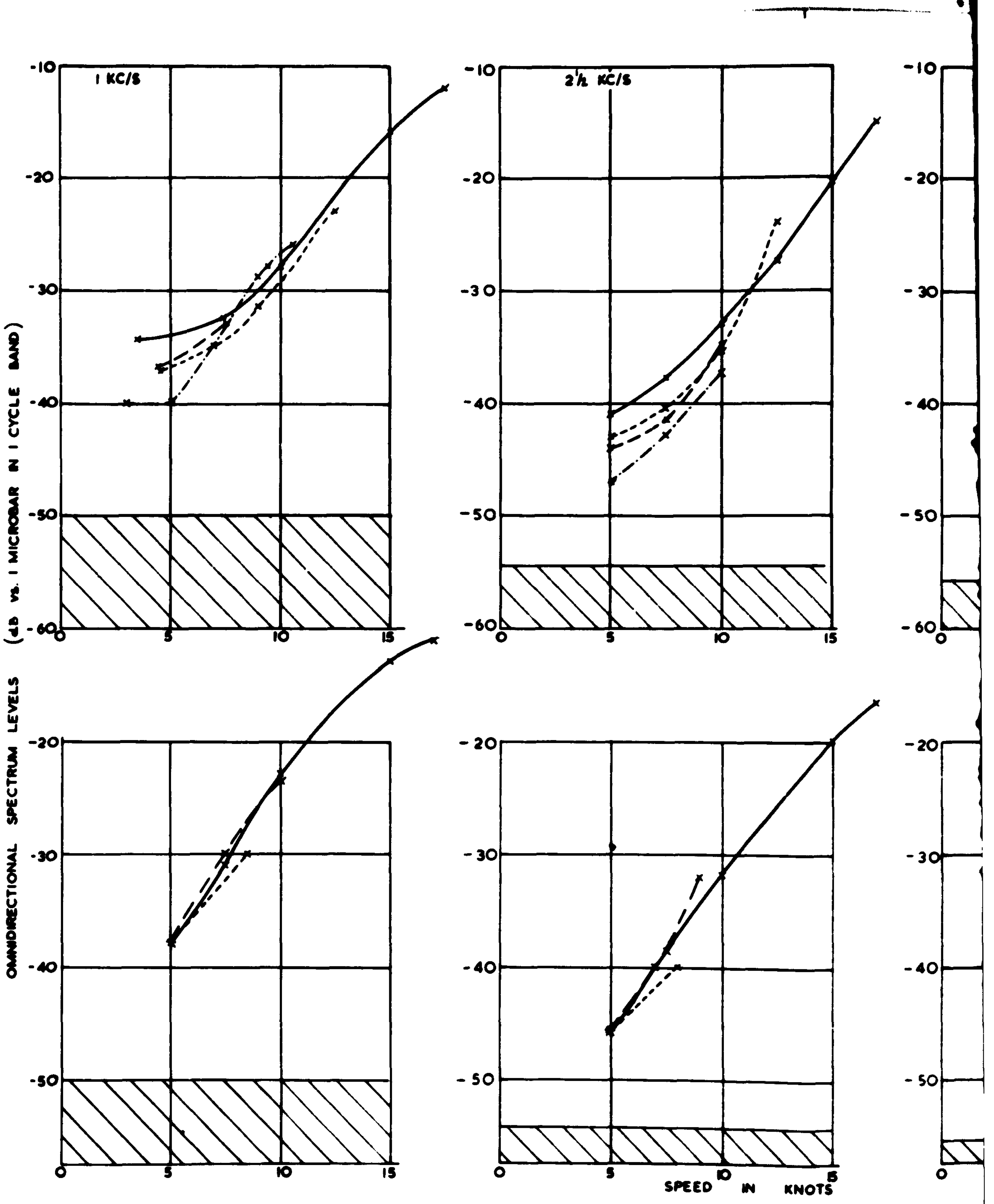
2
2½ KC/S
5 KC/S
10 KC/S
0
-10
-20
-30
-40
-50
0
5
10
15
SPEED IN KNOTS

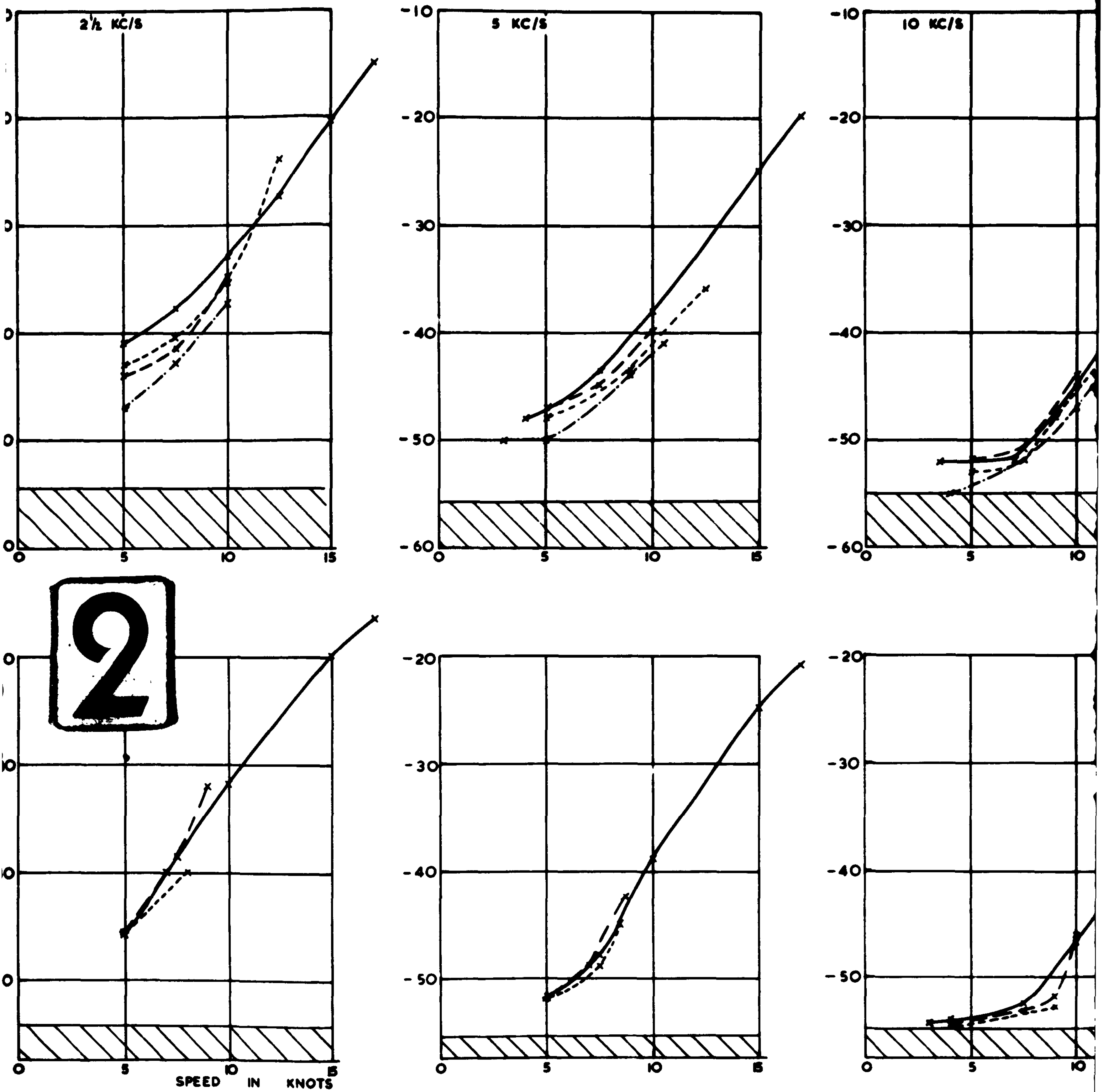


3

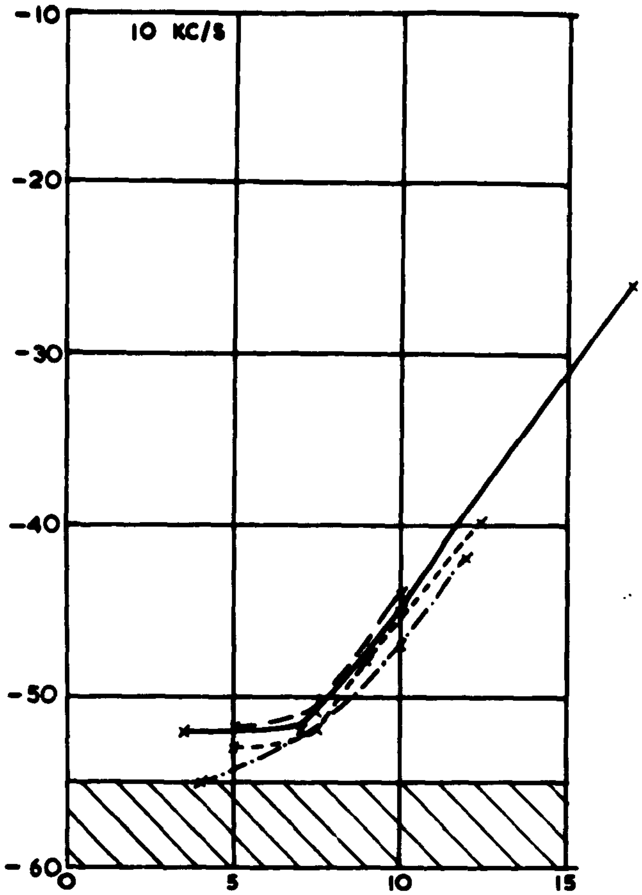
FIG. 4. SELF NOISE AS A FUNCTION OF SPEED
'T' CONV., 'A', 'T' MOD. CLASSES

1


1 KC/S
2½ KC/S
OMNIDIRECTIONAL SPECTRUM LEVELS (dB vs. 1 MICROBAR IN 1 CYCLE BAND)
SPEED IN KNOTS

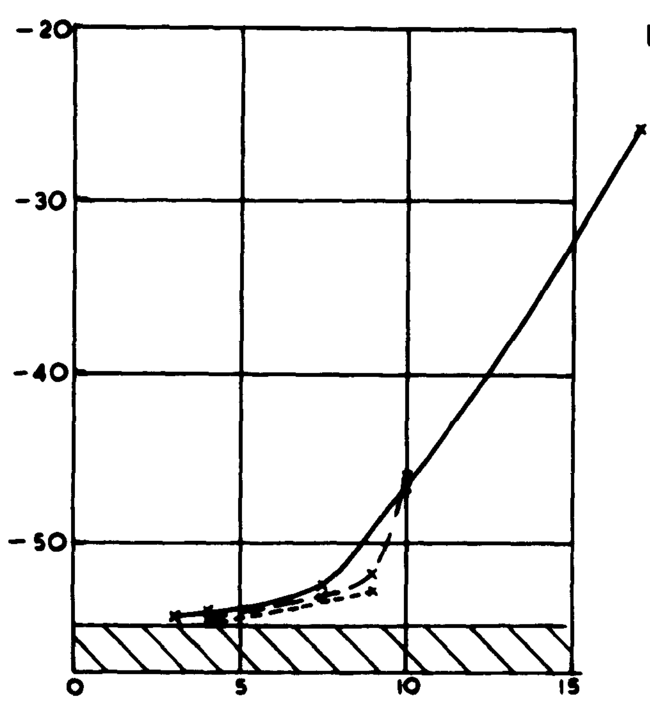


2



KEY.

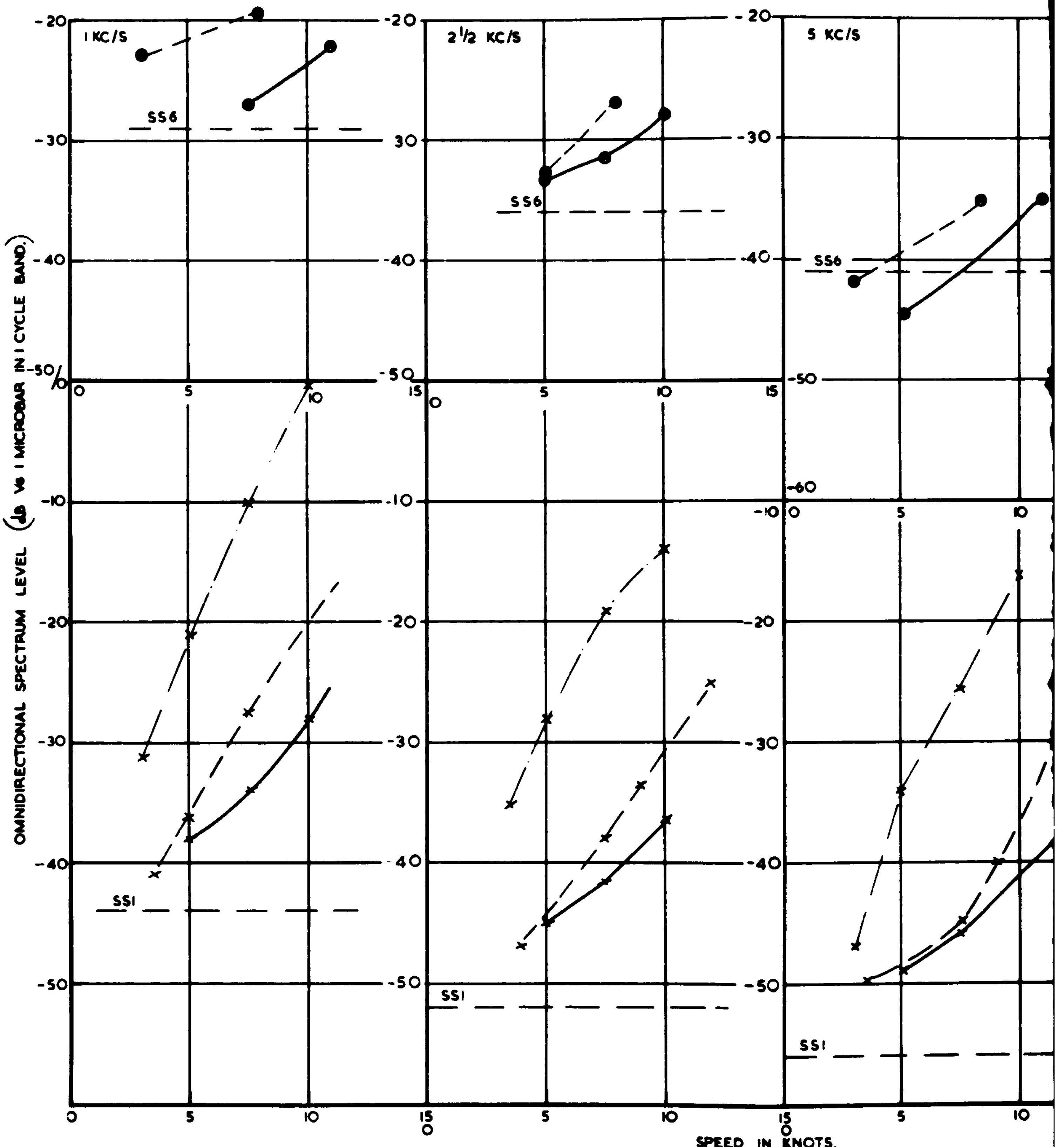
- ——— P.D
- - - - 100 FT.
- ····· 200 FT.
- —·— 300 FT.
- ////// BELOW EQUIPMENT BACKGROUND NOISE LEVEL (ELECTRONIC)



3

FIG. 5. SELF NOISE AS A FUNCTION OF SPEED

PORPOISE CLASS



1 KC/S
2 1/2 KC/S
5 KC/S
SS6
SS1
OMNIDIRECTIONAL SPECTRUM LEVEL (dB vs 1 MICROBAR IN 1 CYCLE BAND.)
SPEED IN KNOTS.

1

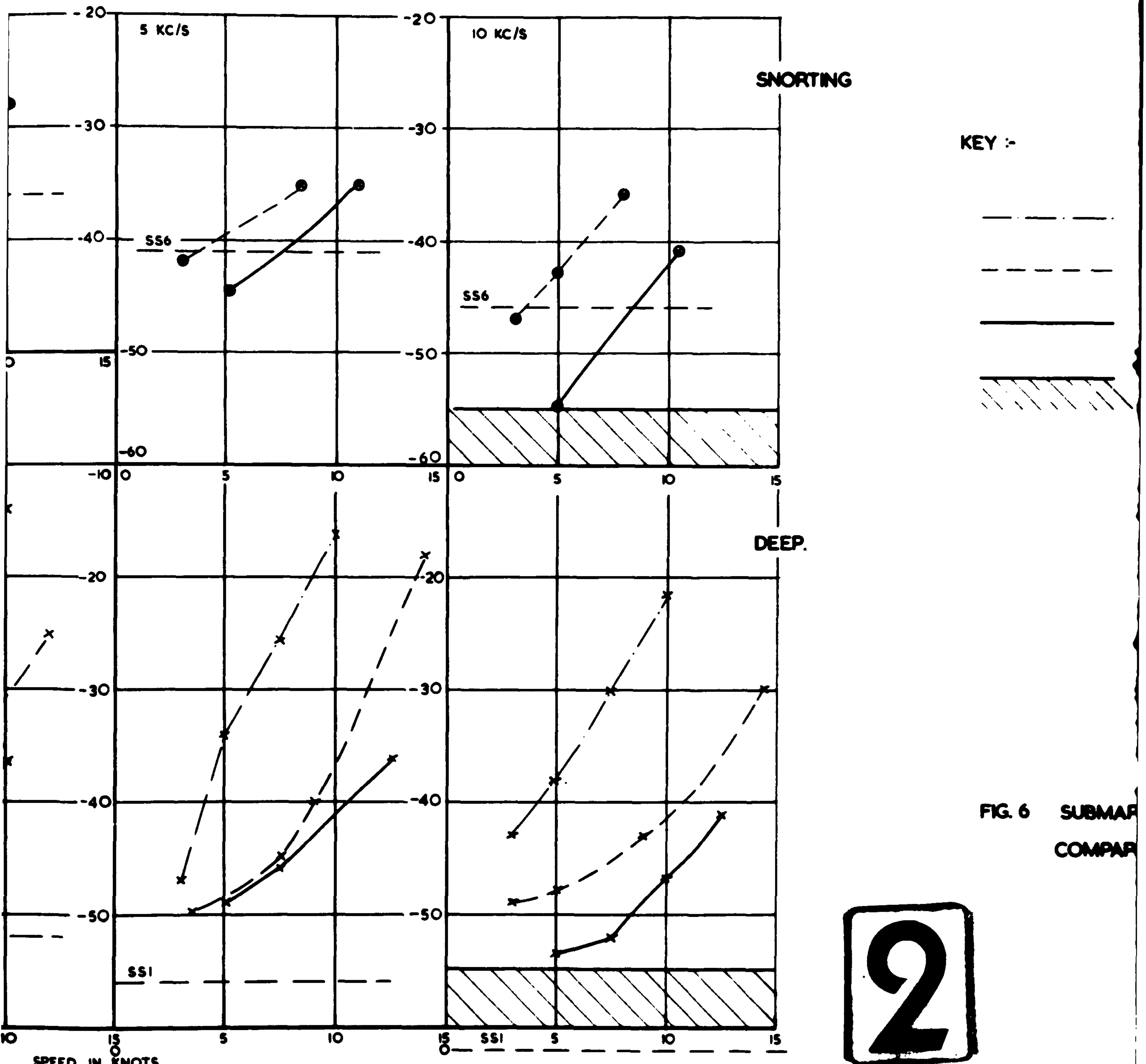
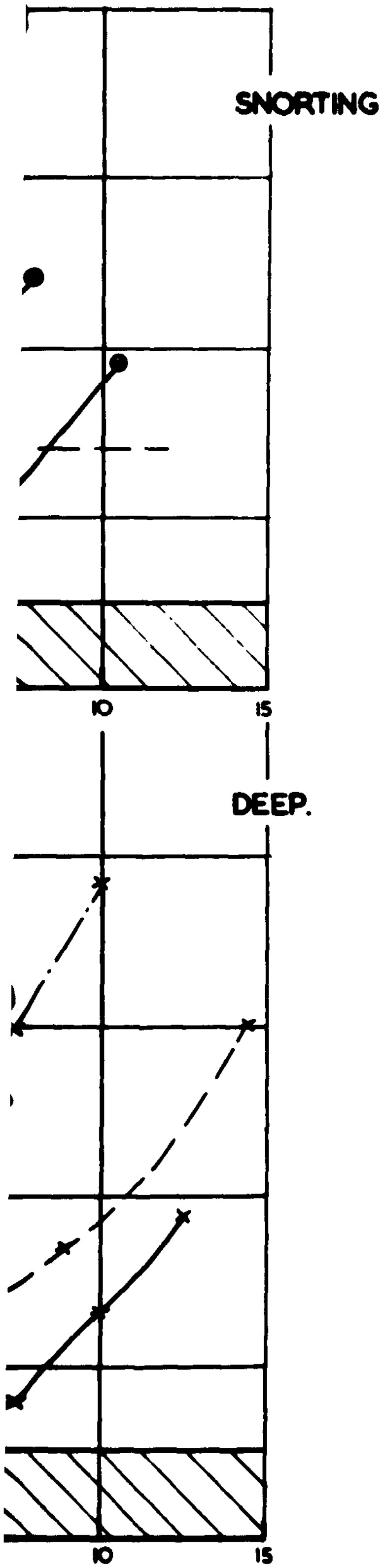


FIG. 6 SUBMAR
COMPAR

TOPSIDE



3

KEY :-

OLD 'A.S.T.' CLASSES.

T. CONV, A.T. MOD

PORPOISE.

BELOW EQUIPMENT BACKGROUND NOISE LEVEL (ELECTRONIC.)

FIG. 6 SUBMARINE SELF NOISE IN TOPSIDE POSITION — COMPARISON OF CLASSES ('SNORTING' AND 'DEEP'.)

1

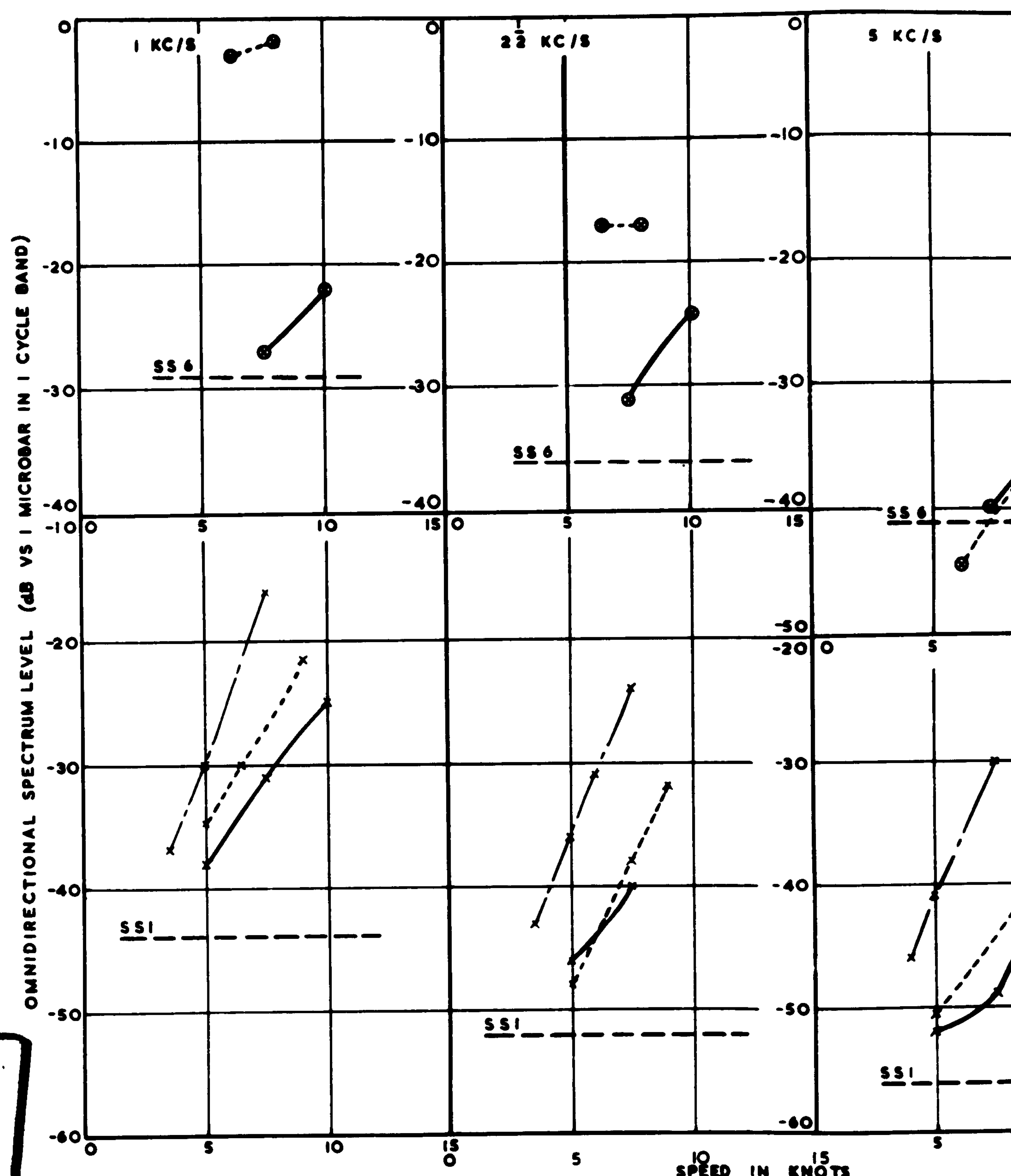
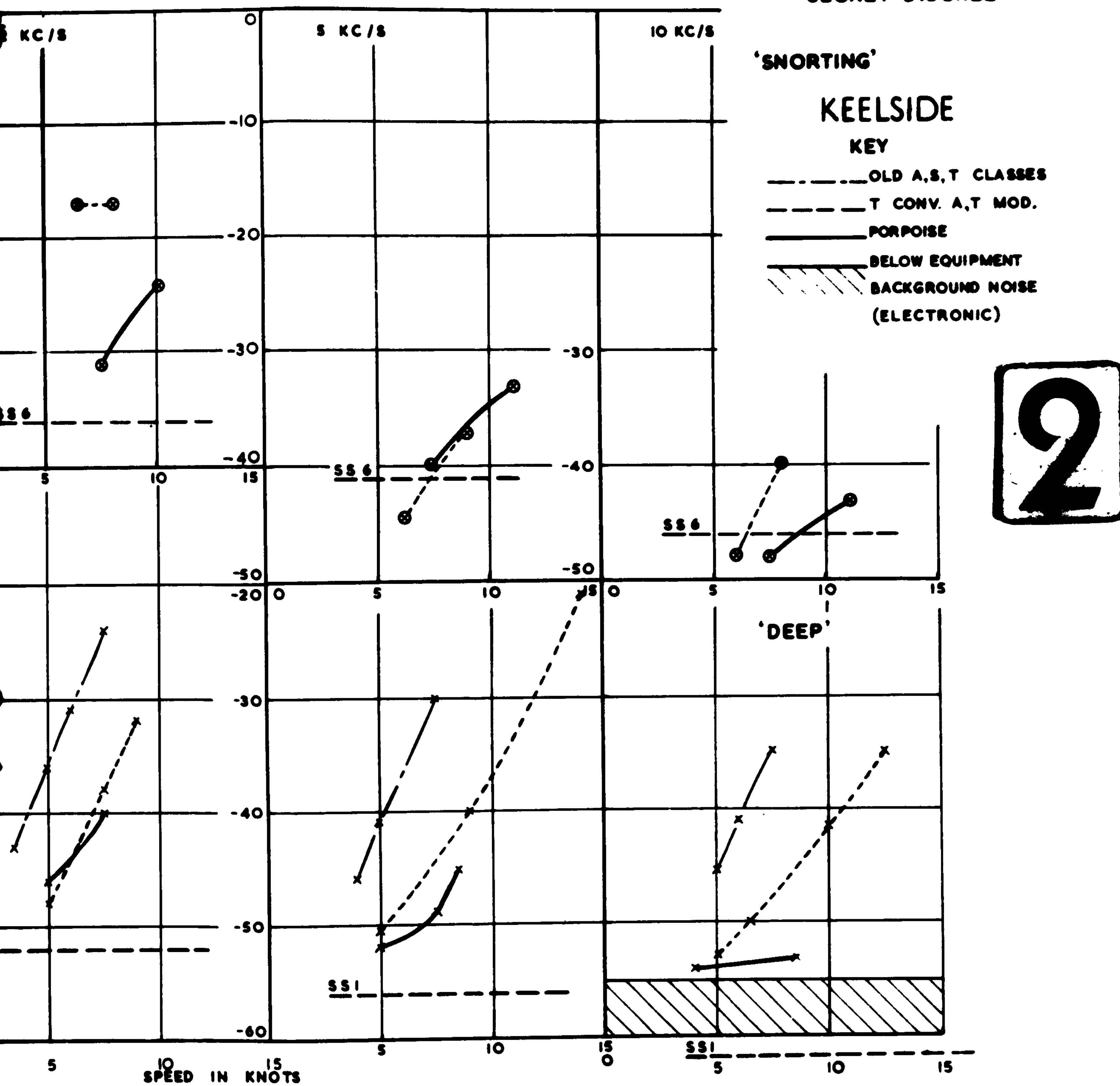


FIG. 7. SUBMARINE SELF NOISE IN KEELSIDE. POSITION — COMPARIS



IN KEELSIDE. POSITION — COMPARISON OF CLASSES. ('SNORTING' AND 'DEEP').

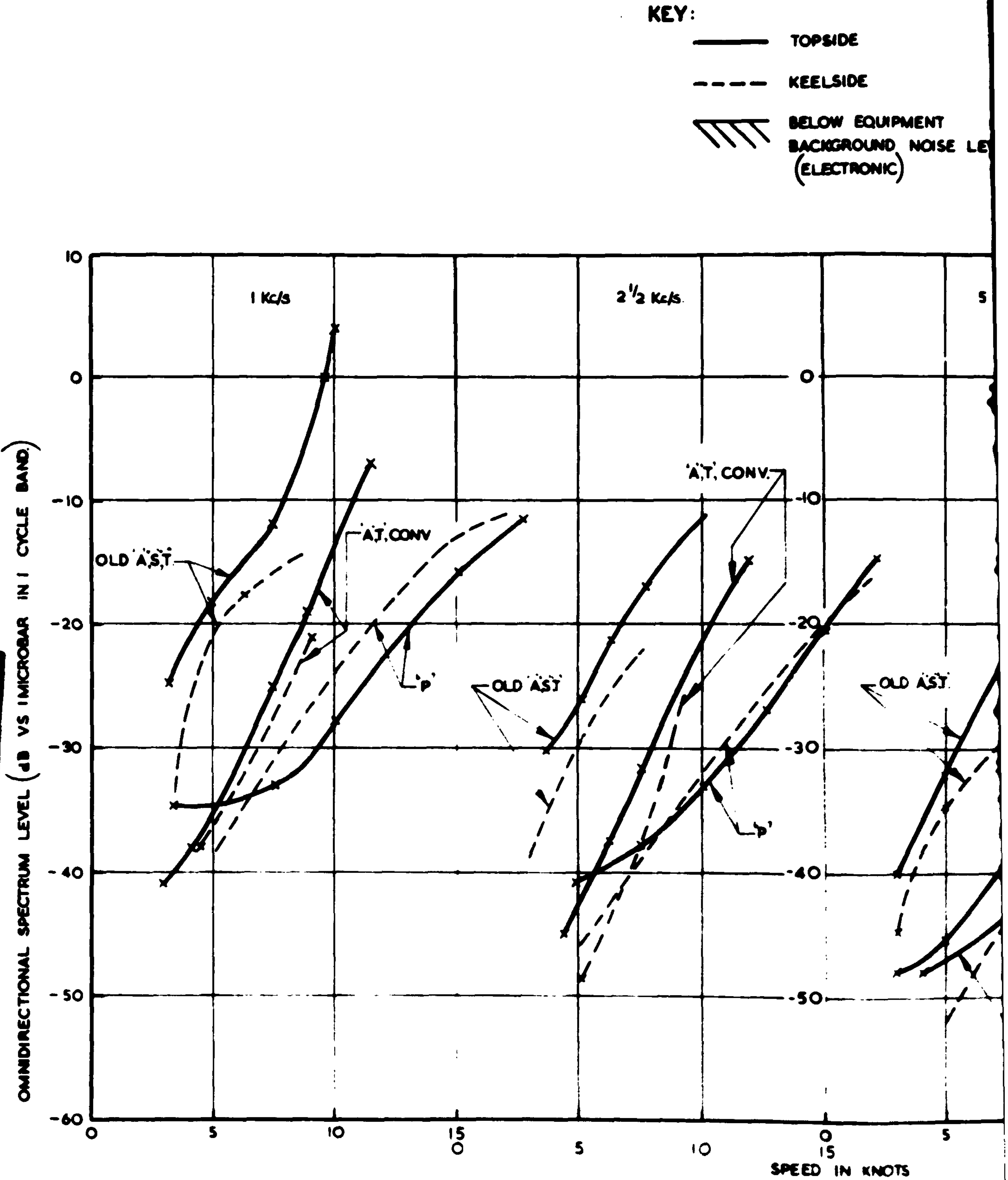


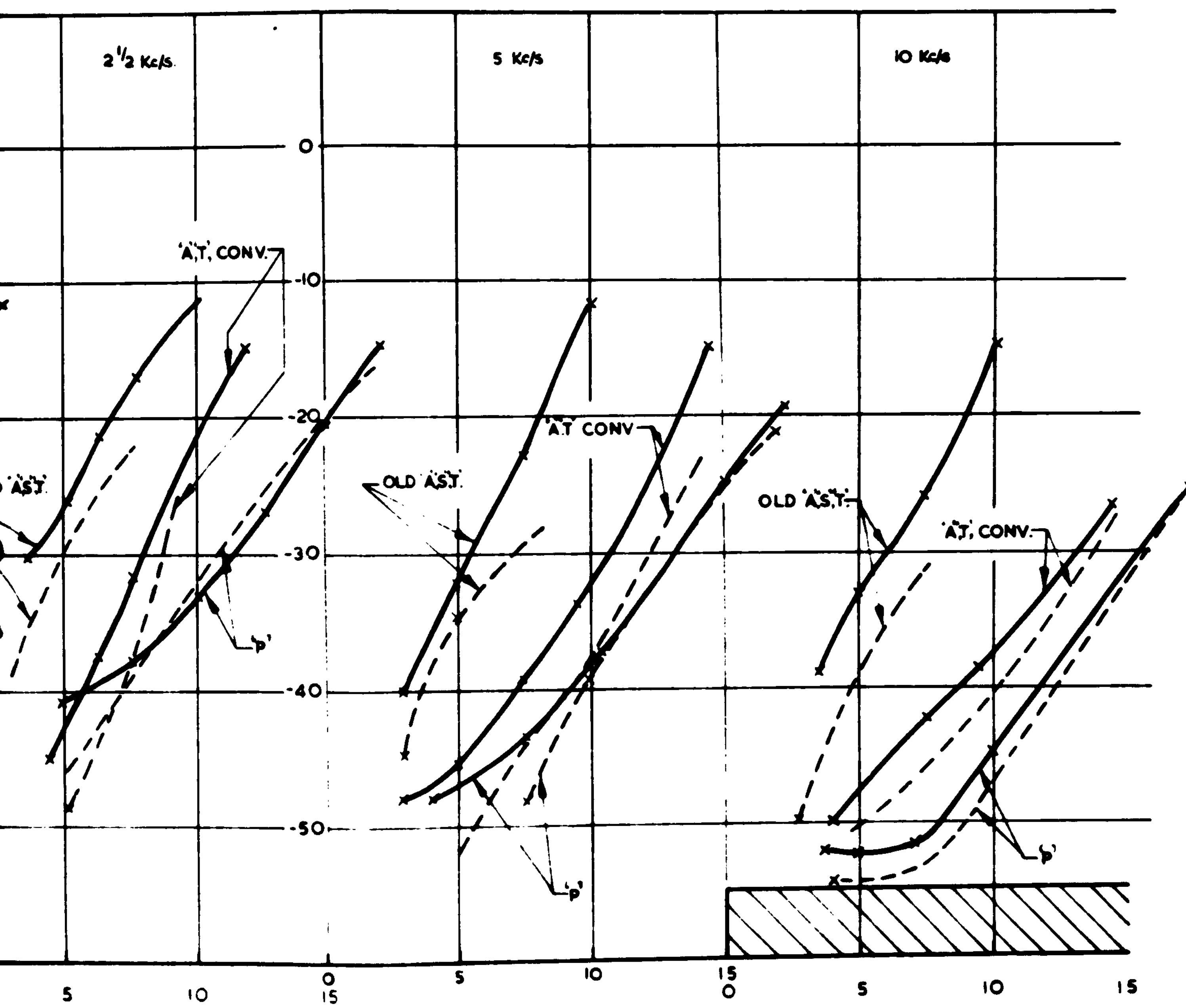
FIG. 8(a) COMPARISON OF TOPSIDE AND KEELS

1

A.U.W.E. TECH. NOTE ·105/62

KEY:
- TOPSIDE (solid line)
- KEELSIDE (dashed line)
- BELOW EQUIPMENT BACKGROUND NOISE LEVEL (ELECTRONIC) (hatched)

PERISCOPE DEPTH



(a) COMPARISON OF TOPSIDE AND KEELSIDE RESULTS-PERISCOPE DEPTH.

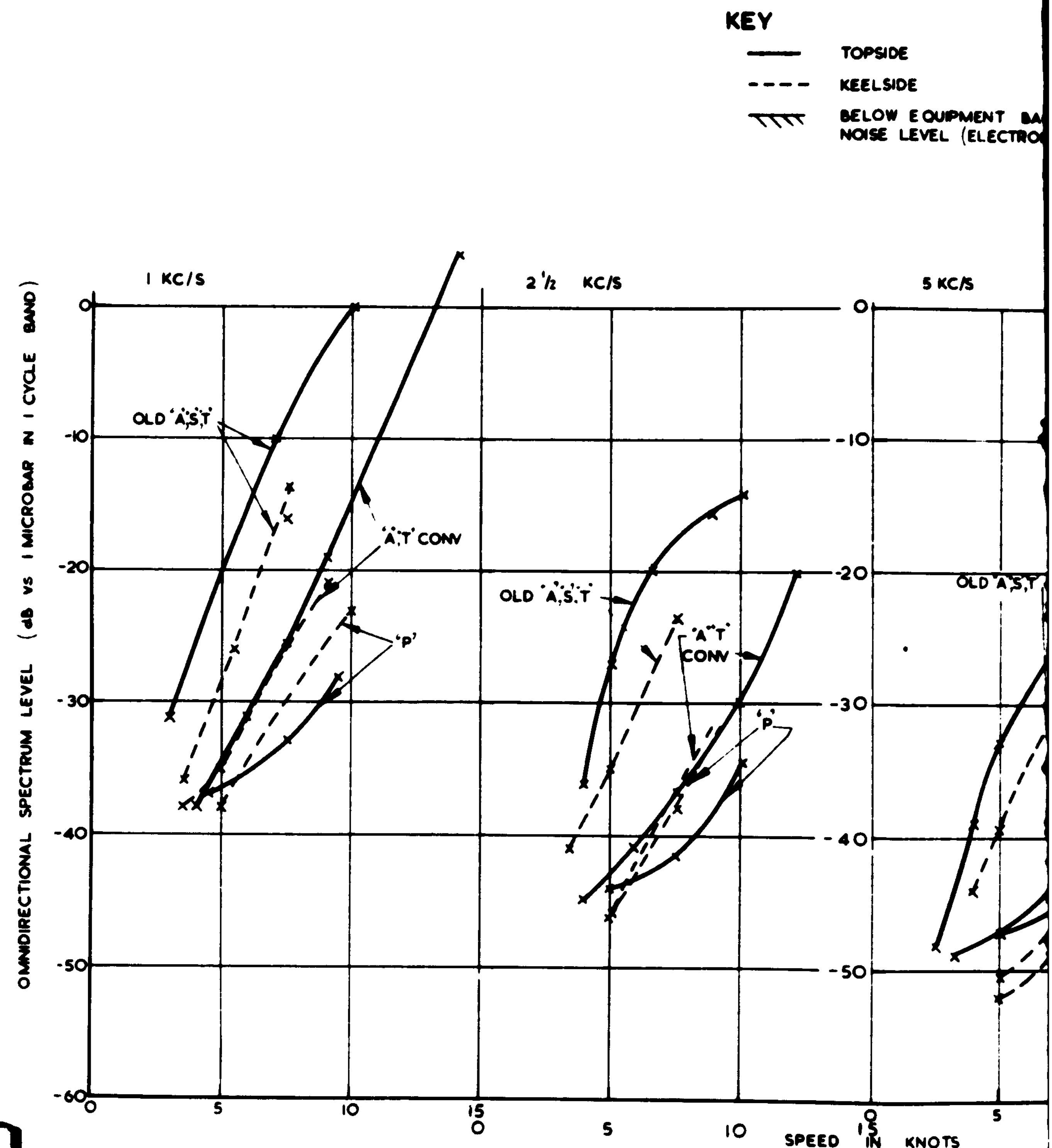


FIG. 8 (b) COMPARISON OF TOPSIDE AND KEE

1

KEY

- —— TOPSIDE
- - - - KEELSIDE
- ⧄ BELOW EQUIPMENT BACKGROUND NOISE LEVEL (ELECTRONIC)

100/120 FEET

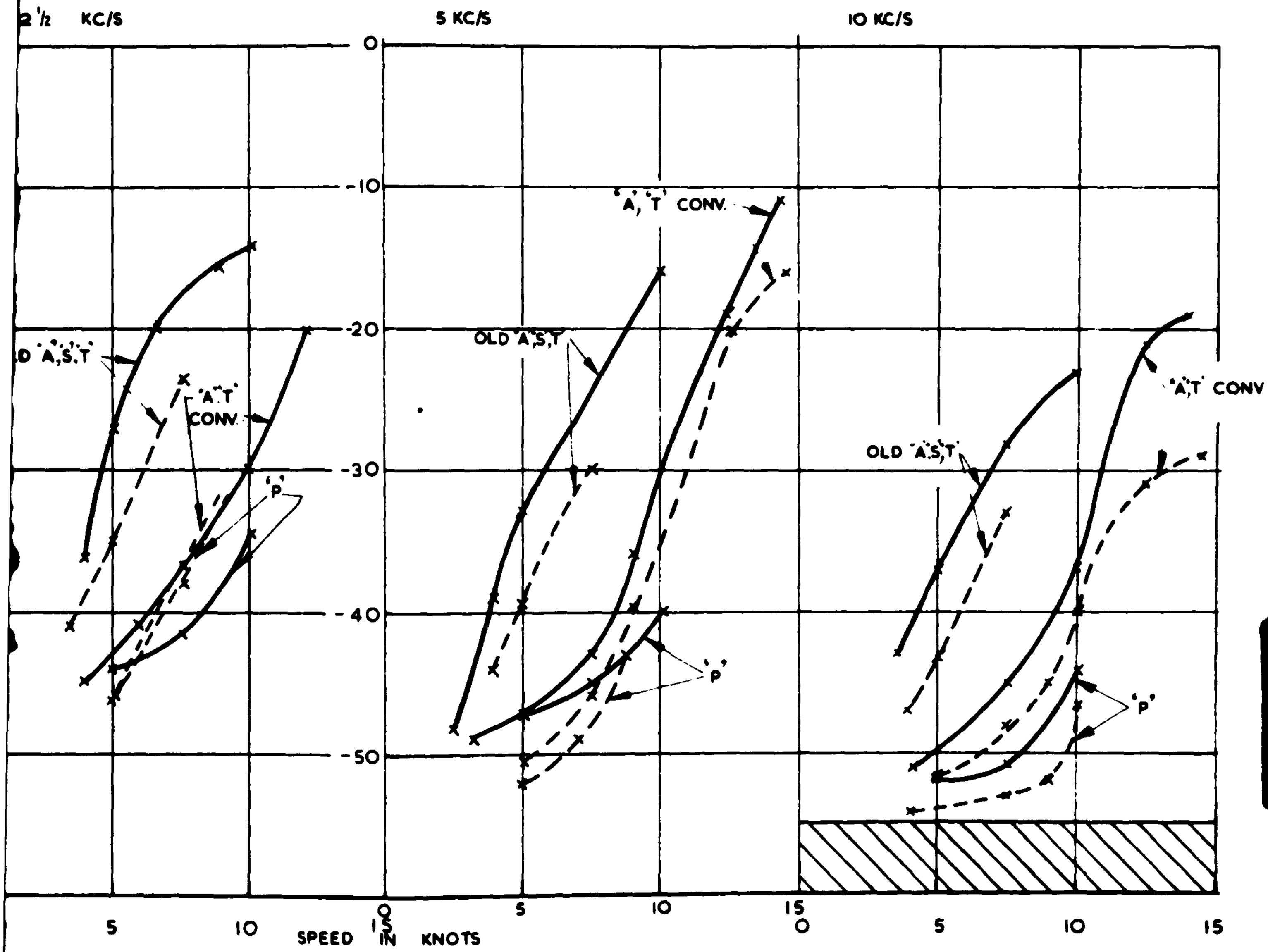


FIG.8 (b) COMPARISON OF TOPSIDE AND KEELSIDE RESULTS 100/120 FEET.

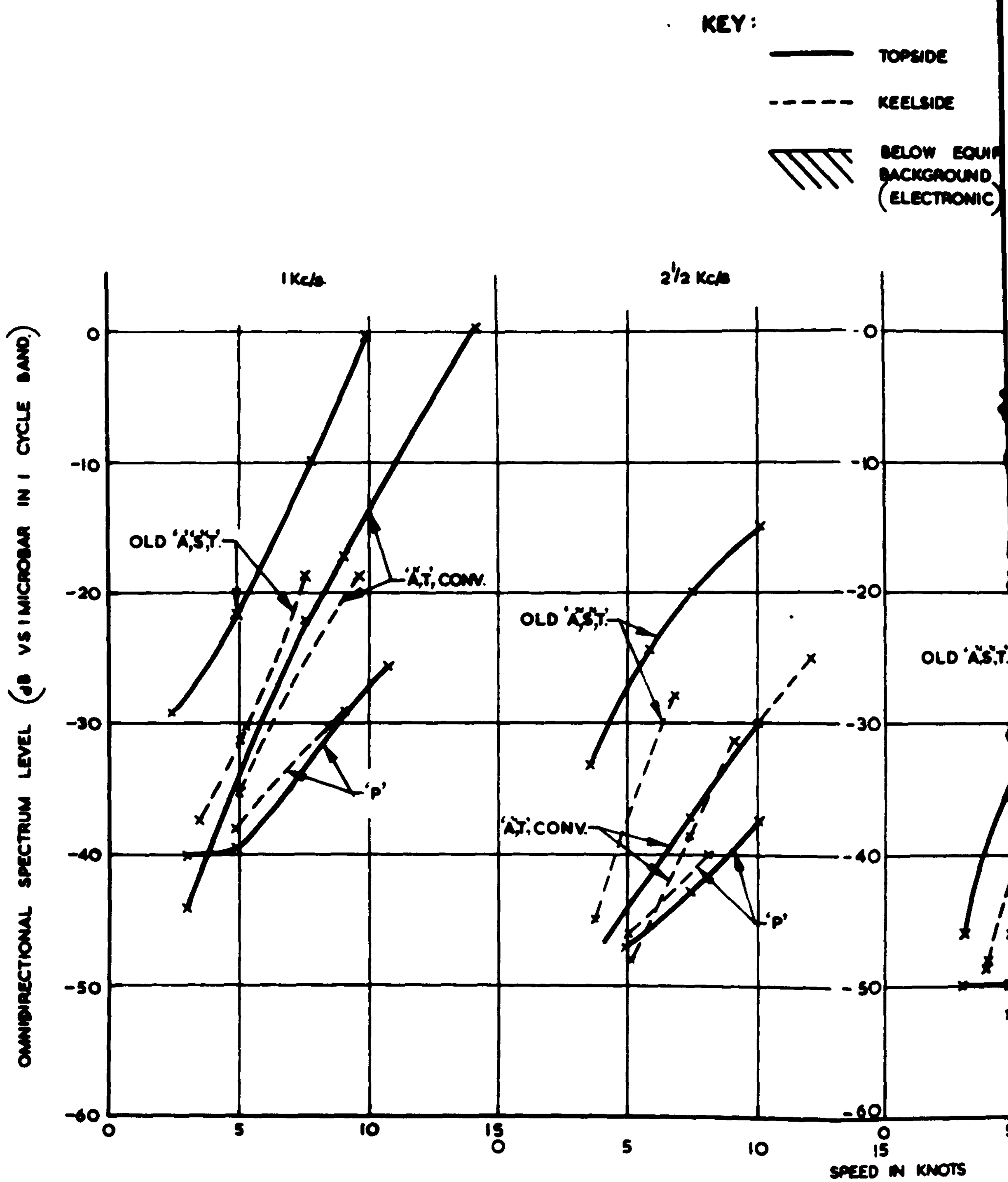


FIG. 8(c) COMPARISON OF TOPSIDE AND

A.U.W.E. TECH NOTE 105/62

1

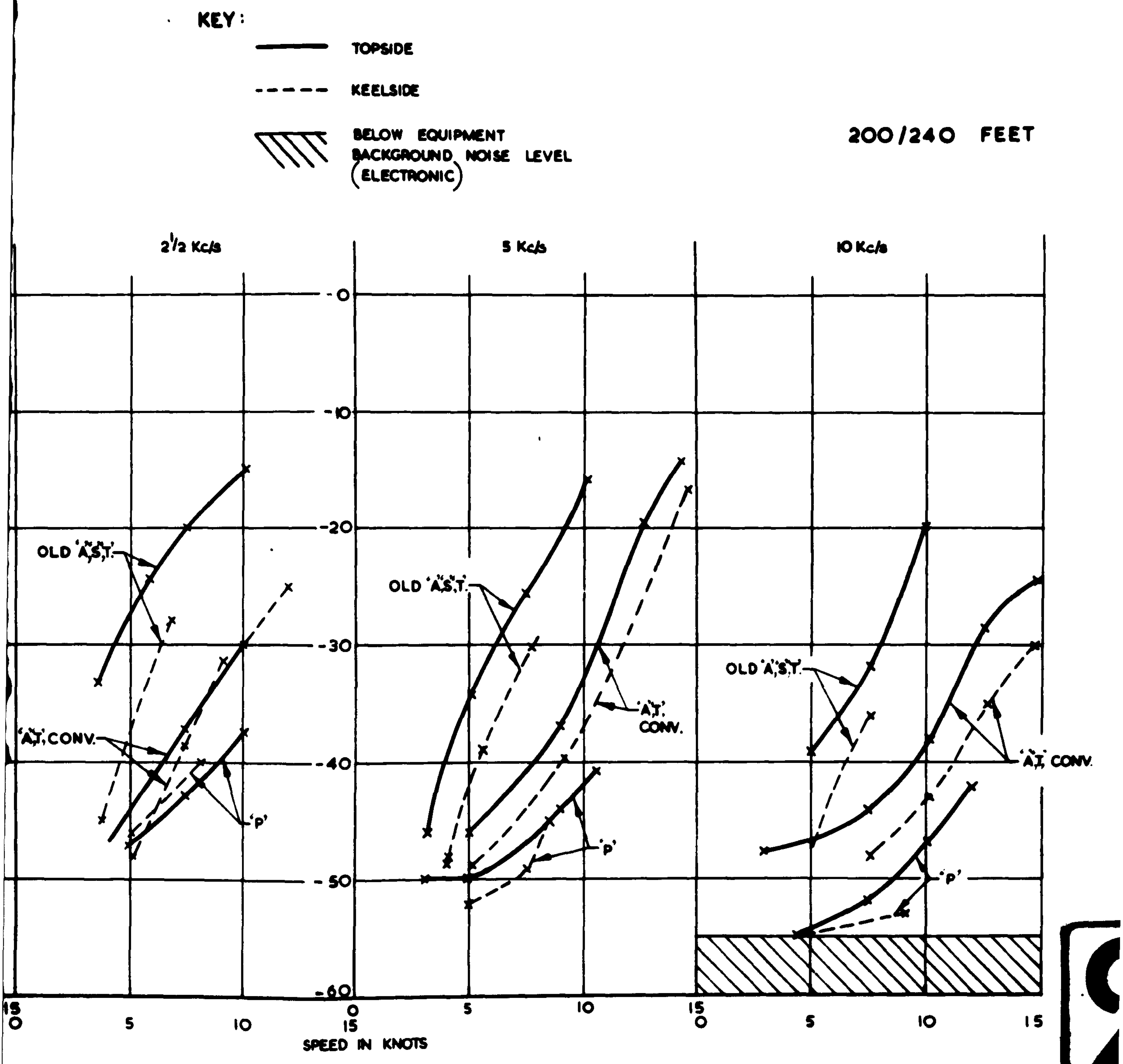
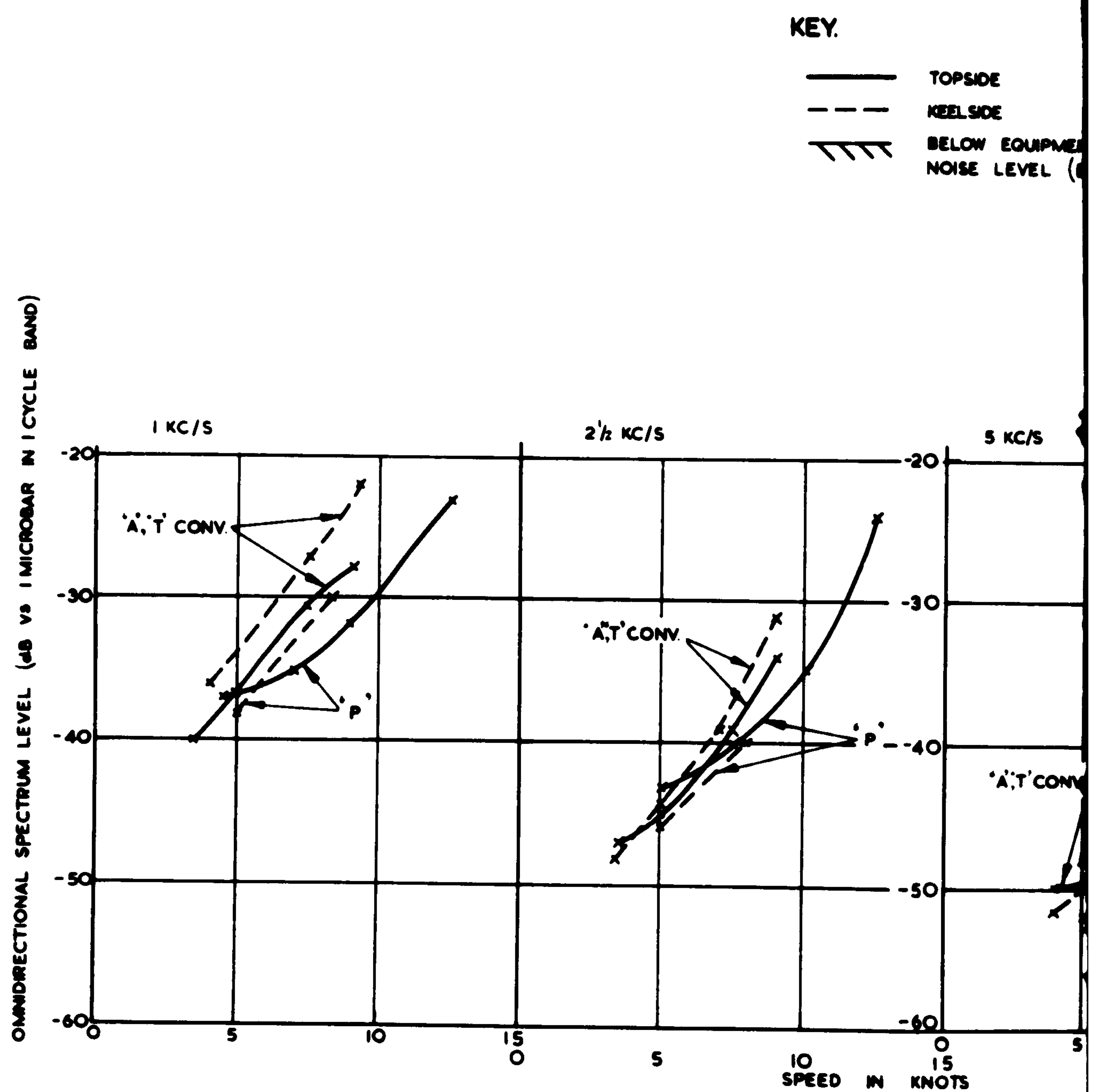


FIG. 8(c) COMPARISON OF TOPSIDE AND KEELSIDE RESULTS 200/240 FEET.



1

FIG. 8 (d) COMPARISON OF TOPSIDE AND KEELS

KEY.

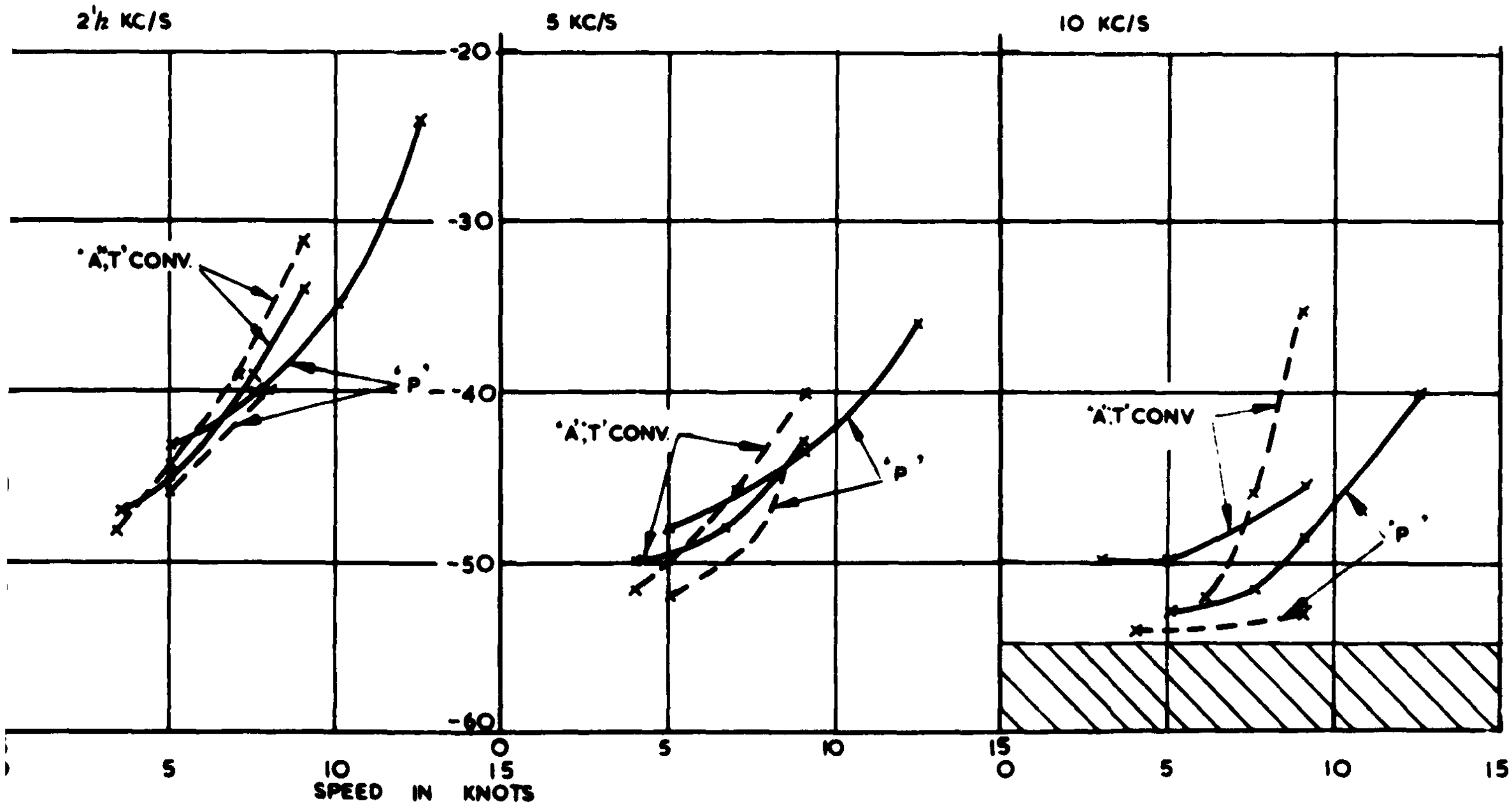
TOPSIDE (solid line)

KEELSIDE (dashed line)

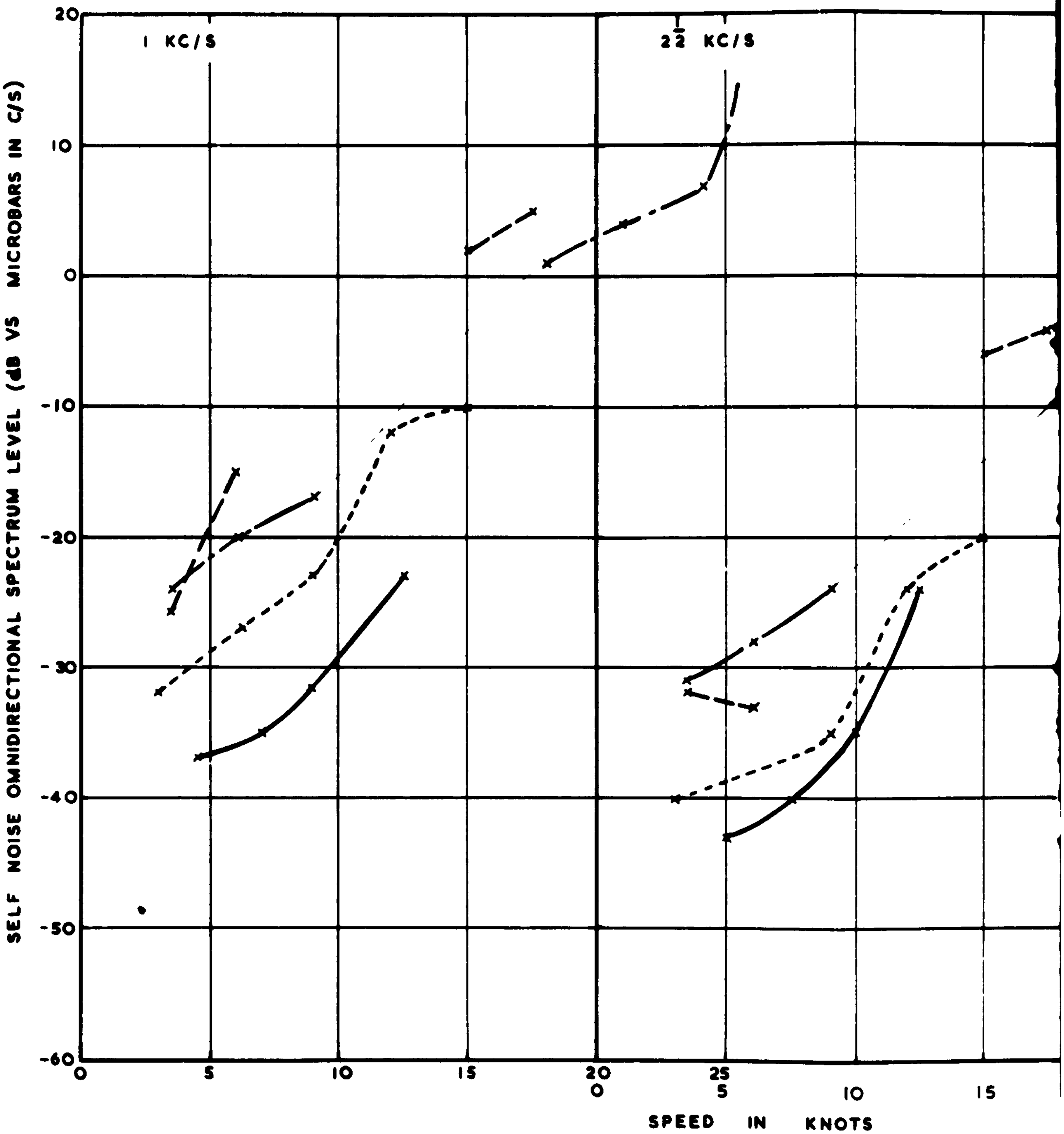
BELOW EQUIPMENT BACKGROUND NOISE LEVEL (ELECTRONIC) (hatched)

300 FEET

2



(d) COMPARISON OF TOPSIDE AND KEELSIDE RESULTS - 300 FEET.



A.U.W.E. TECH. NOTE 105/62

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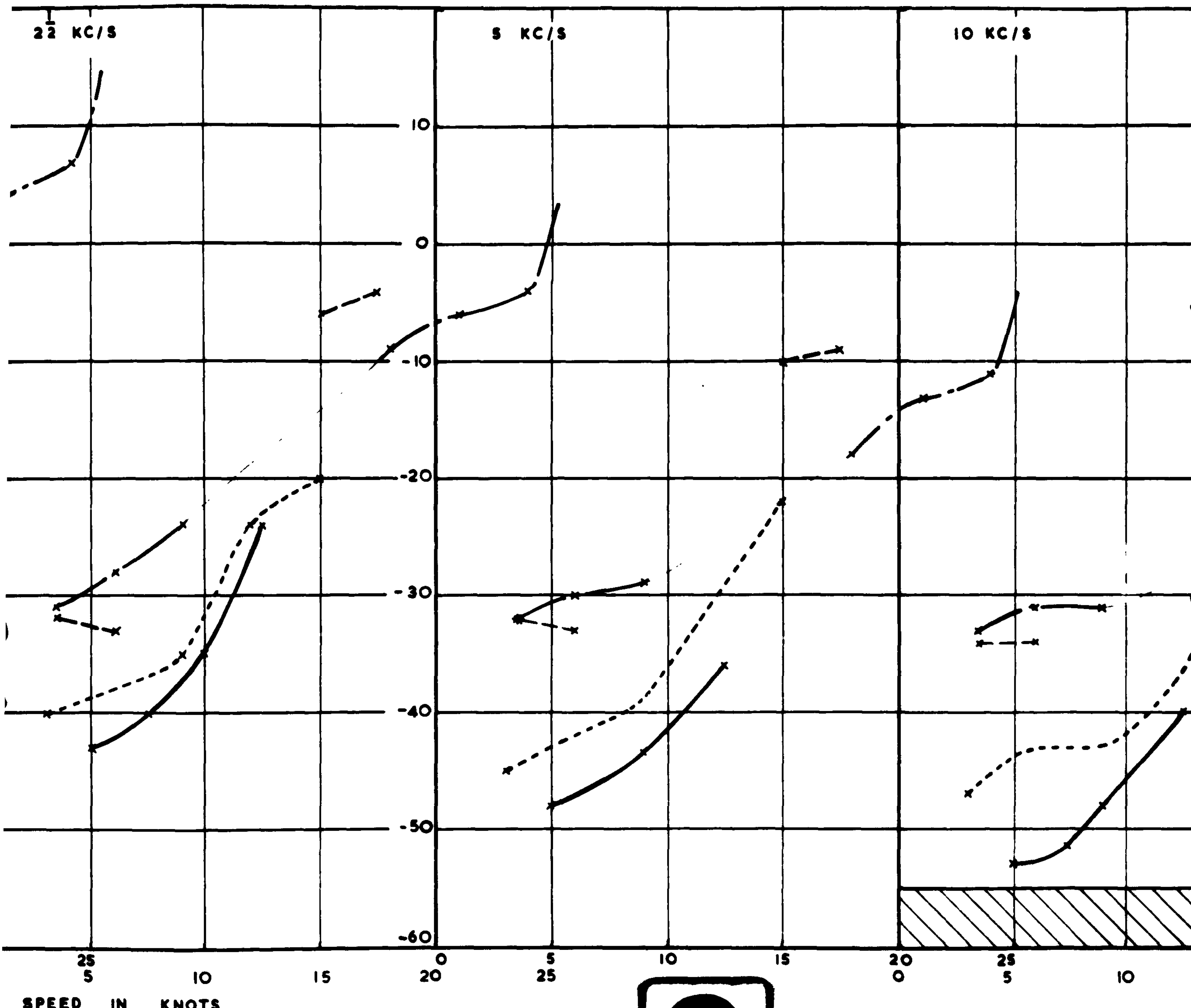
T


2½ KC/S
5 KC/S
10 KC/S
10
0
-10
-20
-30
-40
-50
-60
25 5
10
15
0 20
5 25
10
15
20 0
25 5
10
SPEED IN KNOTS

2

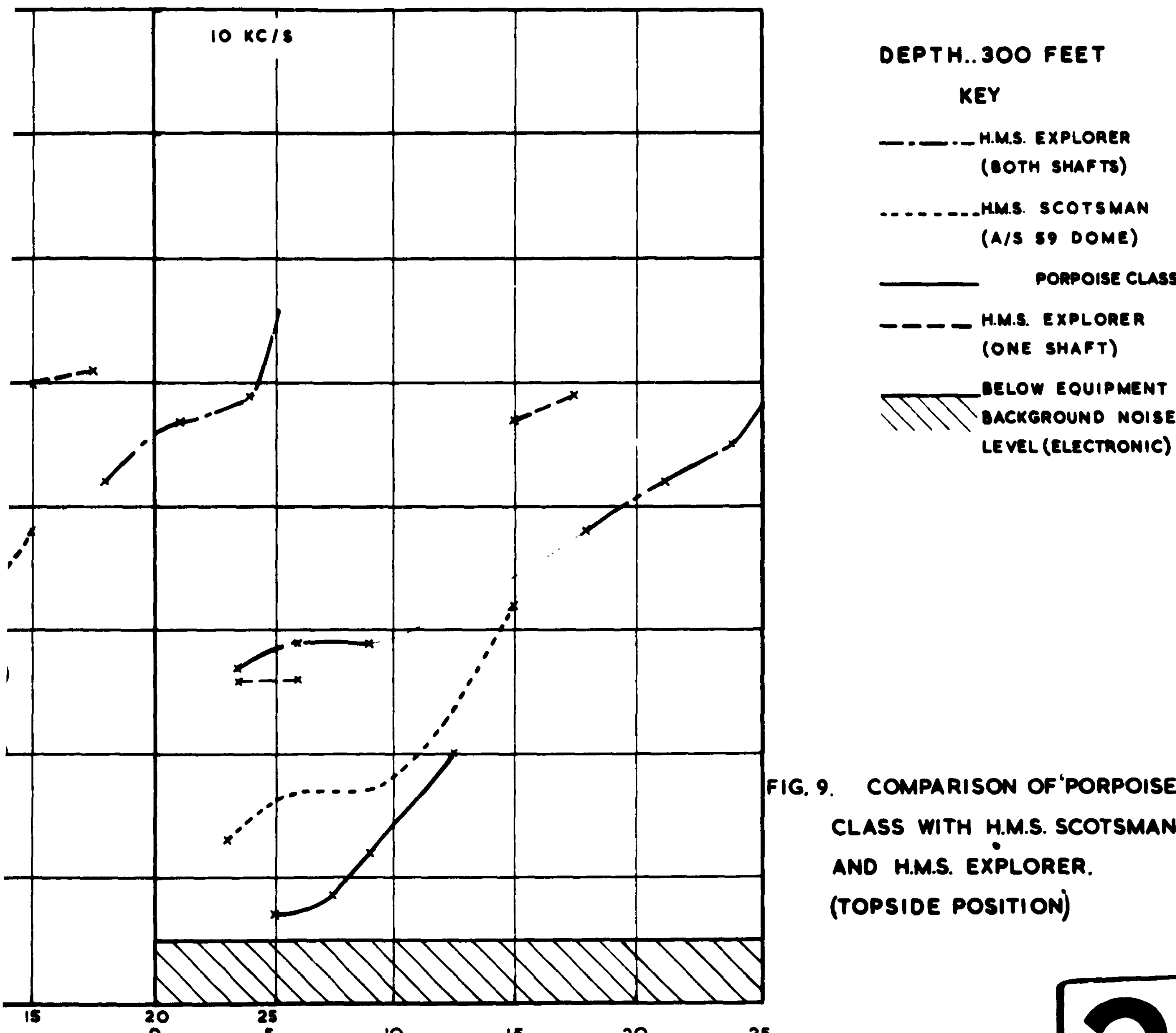
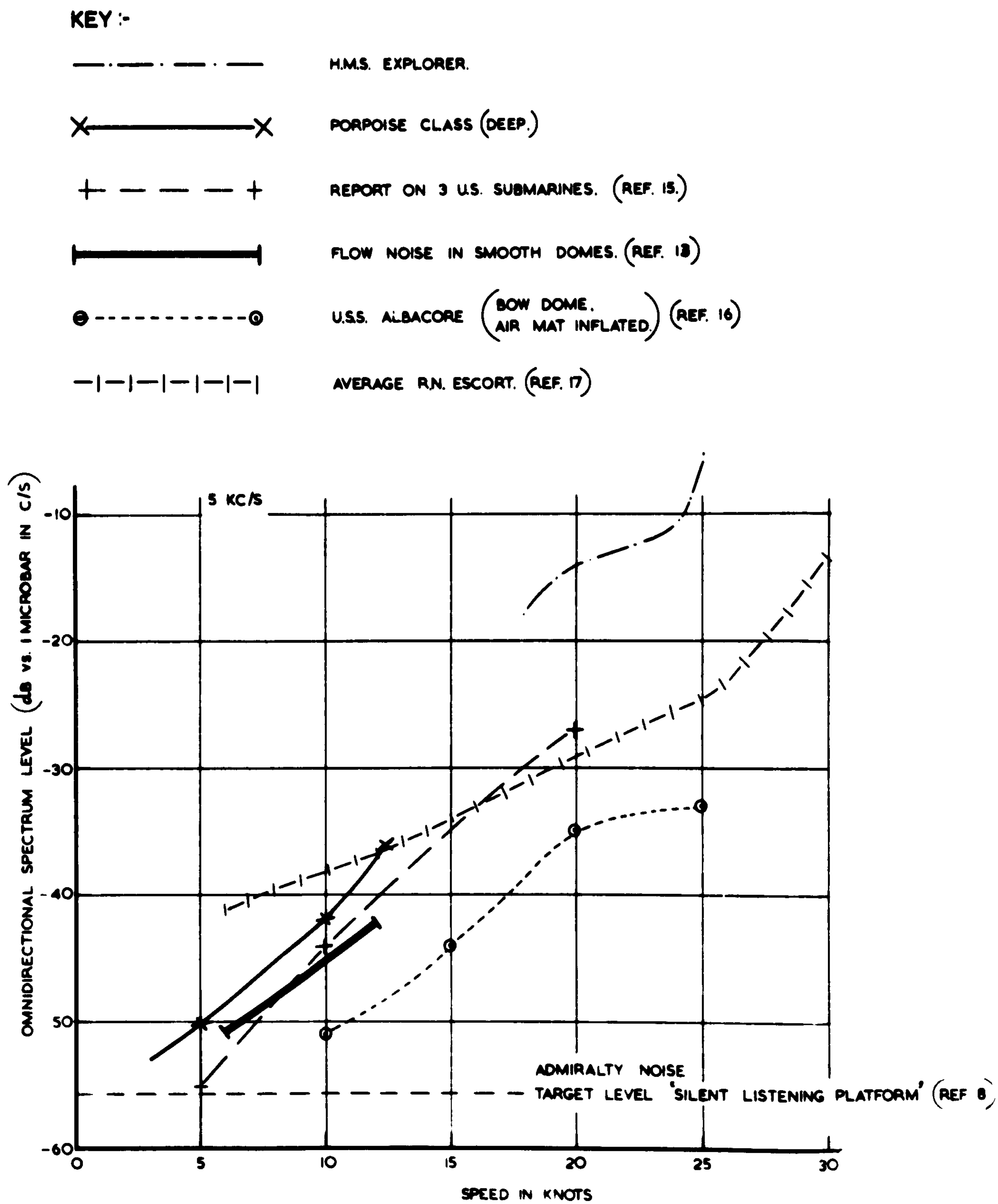


FIG. 9. COMPARISON OF 'PORPOISE' CLASS WITH H.M.S. SCOTSMAN AND H.M.S. EXPLORER. (TOPSIDE POSITION)

3


KEY :-
H.M.S. EXPLORER.
PORPOISE CLASS (DEEP.)
REPORT ON 3 U.S. SUBMARINES. (REF. 15.)
FLOW NOISE IN SMOOTH DOMES. (REF. 13)
U.S.S. ALBACORE (BOW DOME. AIR MAT INFLATED.) (REF. 16)
AVERAGE R.N. ESCORT. (REF. 17)
5 KC/S
OMNIDIRECTIONAL SPECTRUM LEVEL (dB vs. 1 MICROBAR IN C/S)
-10
-20
-30
-40
50
-60
0
5
10
15
20
25
30
ADMIRALTY NOISE TARGET LEVEL 'SILENT LISTENING PLATFORM' (REF 8)
SPEED IN KNOTS

1

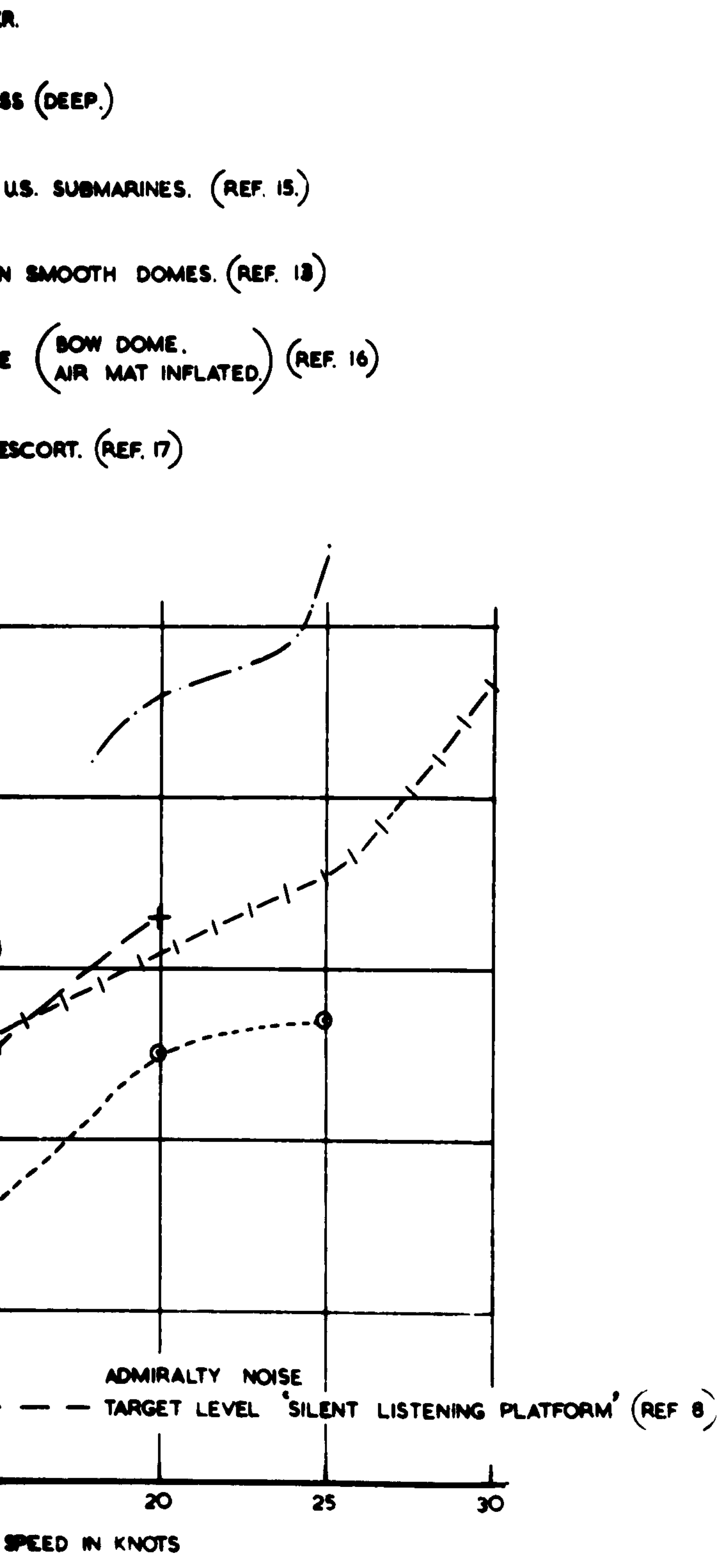


FIG. 10.

COMPARISON OF PORPOISE CLASS, U.S. SUBMARINES AND OTHER VESSELS (5 KC/S., DEEP.)

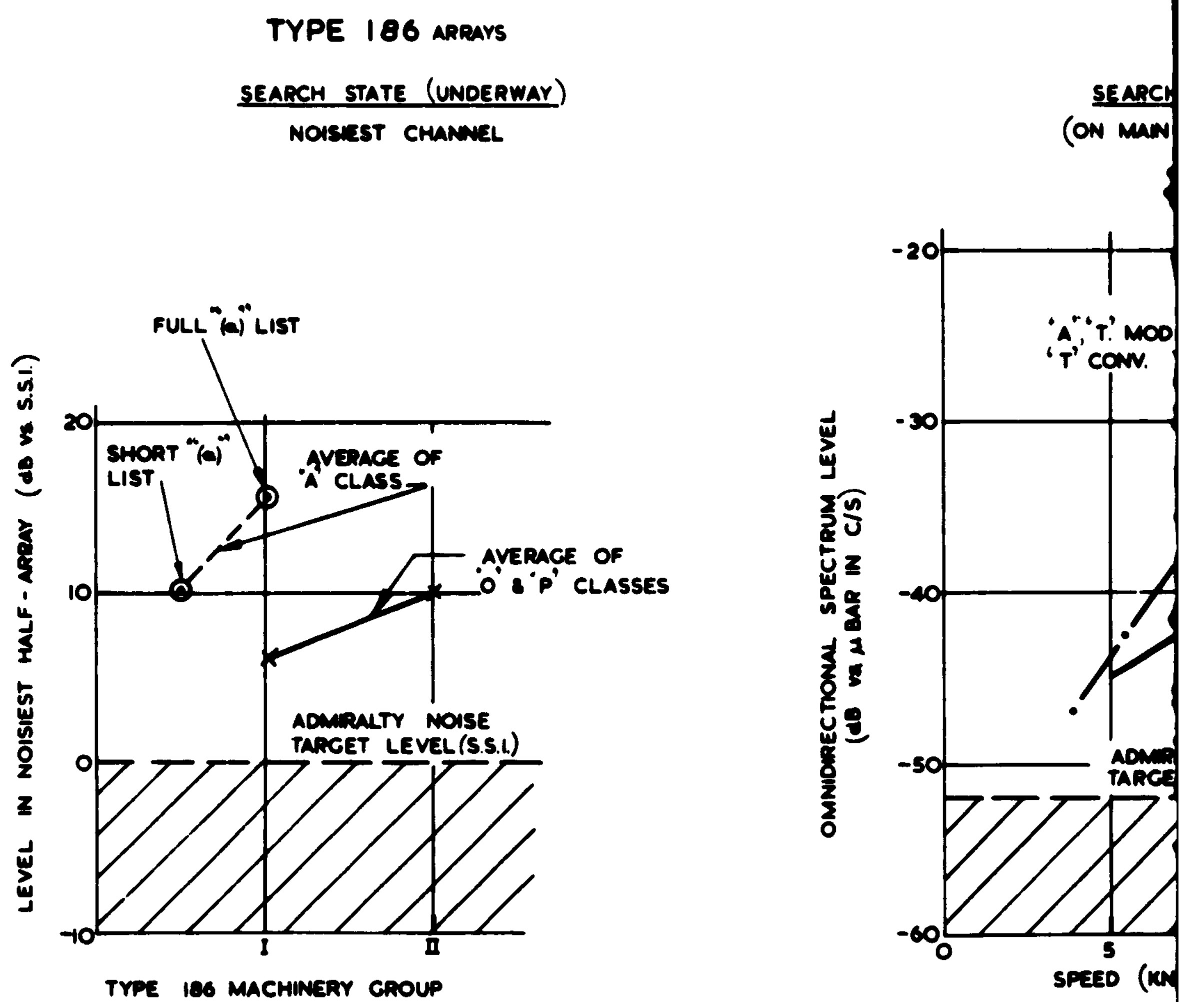
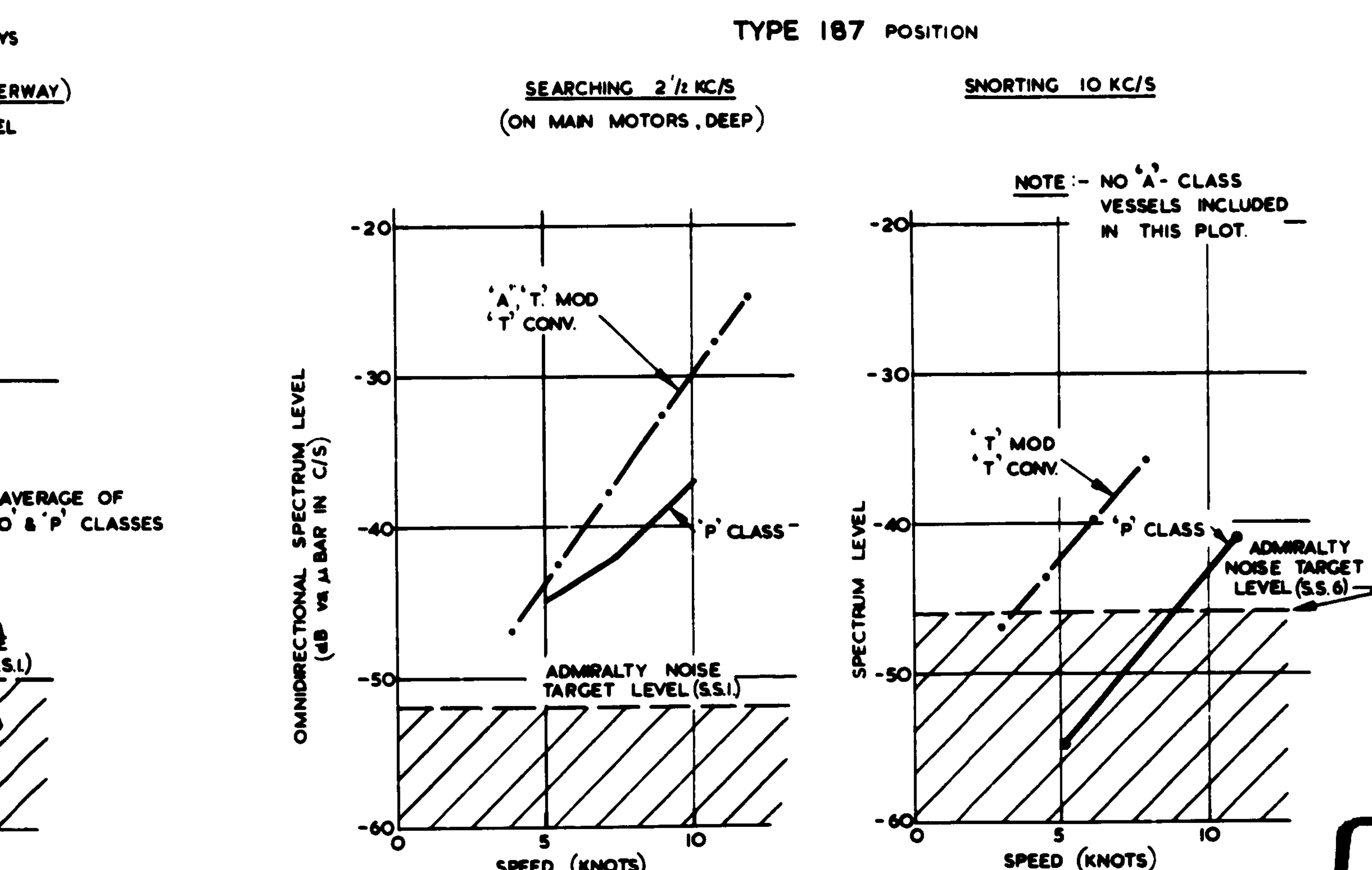


FIG. II. SUMMARY OF THE SELF NOISE STATUS OF T



...MMARY OF THE SELF NOISE STATUS OF THE MODERN SUBMARINE.

U.K. ABSTRACT
NO.

(A)	Country of Origin	UNITED KINGDOM
(B)	Establishment of Origin with short address	Admiralty Underwater Weapons Establishment, Portland.
(C)	Title of Report	Sonar Self-Noise in Submarines
(D)	Author	J. A. Stacey
(E)	Pages and Figures	40 pages ((i) - (iii) (1 - 37)) 11 figures
(F)	Date	December 1962
(G)	Originator's Reference	Technical Note 105/62
(H)	Security Grading	SECRET DISCREET
(J)	Abstract	

From the self-noise standpoint the number of classes of R.N. submarines can be reduced to only three - viz. "Old", "Modernised" and "PORPOISE". Measurements in both conventional (Type 187) and correlation (Type 186) passive listening sets carried out up to late 1961 are summarized and compared with noise measurements in other types of vessel and with submarines of other navies. It is concluded that, except under the snorting condition, the Admiralty Noise Target Levels for self-noise in submarine sonars are generally not achieved, though the margin of failure in some modern vessels is quite small.

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December 1962
J. A. Stacey

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Date of Search: 30 July 2008

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Title: Sonar self-noise in submarines
Availability Open Document, Open Description, Normal Closure before FOI Act: 30 years
Former reference (Department) AUWE Technical Note 105/62
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