NATO STANDARD

APP-33

Standards for Use When Measuring and Reporting Radiated Noise Characteristics of Surface Ships, Submarines, Helicopters, etc. in Relation to Sonar Detection and Torpedo Acquisition Risk

Edition A Version 1

MAY 2022

NORTH ATLANTIC TREATY ORGANIZATION

ALLIED PROCEDURAL PUBLICATION

Published by the
NATO STANDARDIZATION OFFICE (NSO)

INTENTIONALLY BLANK

NORTH ATLANTIC TREATY ORGANIZATION (NATO)

NATO STANDARDIZATION OFFICE (NSO)

NATO LETTER OF PROMULGATION

25 May 2022

1. The enclosed Allied Procedural Publication APP-33, Edition A, Version 1, STANDARDS FOR USE WHEN MEASURING AND REPORTING RADIATED NOISE CHARACTERISTICS OF SURFACE SHIPS, SUBMARINES, HELICOPTERS, ETC. IN RELATION TO SONAR DETECTION AND TORPEDO ACQUISITION RISK that has been approved by the nations in the Military Committee Maritime Standardization Board, is promulgated herewith. The agreement of nations to use this publication is recorded in STANAG 1136.

2. APP-33, Edition A, Version 1 is effective upon receipt.

3. This NATO standardization document is issued by NATO. In case of reproduction, NATO is to be acknowledged. NATO does not charge any fee for its standardization documents at any stage, which are not intended to be sold. They can be retrieved from the NATO Standardization Document Database (https://nso.nato.int/nso/) or through your national standardization authorities.

4. This publication shall be handled in accordance with C-M(2002)60.

Dimitrios SIGOULAKIS
Major General, GRC (A)
Director, NATO Standardization Office

INTENTIONALLY BLANK

RESERVED FOR NATIONAL LETTER OF PROMULGATION

INTENTIONALLY BLANK

RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS

Note: The reservations listed on this page include only those that were recorded at time of promulgation and may not be complete. Refer to the NATO Standardization Document Database for the complete list of existing reservations.

INTENTIONALLY BLANK

RECORD OF SPECIFIC RESERVATIONS

[nation]	[detail of reservation]
HRV	Reservations about ratifying and implementation fall under the fact that the Croatian Navy does not have submarines, antisubmarine warfare helicopters or specialized measuring devices and equipment to conduct measuring of radiated noise pressure level in controlled conditions at hydro acoustic control stations. As a rule, control and measuring starts from the moment of design and construction of ships and submarines, and are performed by scientific research institutions and specialized companies engaged in research of noise reduction of vessels. At the moment, institutions and companies in the Republic of Croatia do not have the capacity to carry out these actions.

Note: The reservations listed on this page include only those that were recorded at time of promulgation and may not be complete. Refer to the NATO Standardization Document Database for the complete list of existing reservations.

INTENTIONALLY BLANK

TABLE OF CONTENTS

INTENTIONALLY BLANK

CHAPTER 1

1.1. TERMINOLOGY, UNITS, AND STANDARDS

1. For this publication, radiated noise characteristics will be described in terms of

   a. Root Mean Square Noise Pressures (p); or

   b. Root Mean Square Noise Pressure Levels (N).

In speaking or writing these quantities it will not be necessary in the normal way to include the qualification “Root Mean Squared” nor any abbreviation for it; a qualification will be needed only if another meaning is to be attached to the figure quoted.

2. The unit of pressure will be taken as the pascal (Pa):

$$1 \text{ Pa} = 1 \text{ newton per square metre } (1 \text{ N/m}^2)$$

It will be convenient in most circumstances to express noise pressures in micropascals (µPa):

$$1 \quad \mu\text{Pa} = 10^{-6} \text{ Pa}$$

3. Strictly, acoustic signal level is an expression of acoustic signal intensity (I) in decibels (dB) referred to some accepted acoustic intensity (I_0) thus:

$$\text{Acoustic Signal Level} = 10 \times \log_{10} (I/I_0) \text{ dB}$$

Provided attention is confined to a single medium in which the specific acoustic impedance (Z) can be taken as having the same value for practical purposes in all circumstances, it is legitimate to write:

$$\text{Acoustic Signal Level} = 10 \times \log_{10} (p^2/p_0^2) \text{ dB}$$

$$= 20 \times \log_{10} (p/p_0) \text{ dB}$$

where p is the root mean square signal pressure, and p_0 is the root mean square pressure consistent with an intensity in the medium of I_0 where $p_0^2 = I_0 Z$. Since the quantity measured (in which the sensors are directly calibrated) is normally acoustic pressure, and not acoustic intensity, it is a convenient and accepted convention to extend this and speak of:

$$\text{Acoustic Pressure Level} \quad = 20 \times \log_{10} (p/p_0) \text{ dB}$$

referring to the referenced pressure p_0 wherein p and p_0 are still regarded as measures of the intensities I and I_0, although these quantities are not now quoted (or even calculated) explicitly. Noise pressure levels N will be so defined and expressed.

4. The reference pressure (p_0) for noise pressure levels will be taken as:

$$p_0 = 1 \text{ µPa} = 10^{-6} \text{ Pa}$$

Thus, with noise pressures expressed in µPa:

$$\text{Noise Pressure Level } N = 20 \times \log_{10}(p) \text{ dB re 1 µPa}$$

5. To avoid confusion with work in airborne acoustics, the reference pressure will be shown whenever a noise pressure level is quoted or presented in tables or graphs.

6. Frequency will be expressed invariably in hertz (Hz).

7. Data analysis and recording should extend over the frequency range 10 Hz (maximum) to 80 kHz (minimum). Ideally, data should be acquired and analyzed at frequencies below 10 Hz and up to 100 kHz, conditions permitting.

8. In quoting noise levels, it is necessary to indicate on all occasions the bandwidth for which such levels apply. Where figures are given for levels over some regular frequency interval, the figures in question will be shown by the notation (e.g.):

'Noise pressure octave level' 'Noise pressure 1/3-octave level' 'Noise pressure 10 Hz band level' 'Noise pressure 6% band level' etc.	$N(f)$

As a matter of convention, such band levels will be associated with the geometric mid-frequency of the band in question. When appropriate, the mid-band frequency will be noted in brackets (as above) in qualification of the general symbol N.

9. For many purposes it is convenient to use the power spectral density per unit of bandwidth or spectrum level. By convention, the spectrum level is expressed in acoustic pressure rather than in power terms. Measurements are usually made in a bandwidth wider than 1 Hz and in pressure rather than in power. The accepted method for making the conversion from pressure level in a finite bandwidth to power spectral density is:

a. By appeal to the fact that for a medium of constant impedance, pressure is proportional to the square root of the power; thus

b. Spectral density can be approximated by dividing the in-band noise pressure (p) by the square root of the bandwidth.

These corrections implicitly assume that the sound energy is uniformly distributed across the measuring band. For the bandwidth commonly used in measurement, this is usually acceptable. Correction of the spectrum level to take account of individual line spectra will not normally be made since broadband sonars typically respond to the received power in their operating bandwidth. If, in an exceptional case, it is necessary to account for line spectra, attention must be drawn to this fact in the report and on the relevant tables and graphs. Hence:

$$\text{Pressure Mean Spectrum Level } N_s(f \text{ Hz}) = 20 \times \log_{10}(p/\sqrt{\Delta f}) \text{ re 1 µPa}$$

$$= N(f) - 10 \times \log_{10}(\Delta f) \text{ dB re 1 µPa}$$

when p is the total noise pressure for the band f_1 to $f_1 + \Delta f$ in µPa. The fact that the quantity N_s relates to unit bandwidth will be taken as implicit in the definition; it will not be shown explicitly in any way in standard texts. Where values for N_s are quoted, the bandwidth of measurement or analysis from which they have been derived should always be stated.

10. The band level $N(f)$ and the spectrum level $N_s(f)$ are to be associated with the geometric mid-frequency of the full band of measurement. This mid-band frequency will be noted in qualification of N (as before) where appropriate. The unit of frequency (Hz or kHz) must always be shown.

11. To indicate the intensity in a clearly discrete component of the noise spectrum, the notation:

Line Pressure Level N_L

will be used. Line pressure levels should be expressed in terms of their absolute values:

$$\text{Line Pressure Level } N_L = 20 \times \log_{10}(p) \text{ dB re 1 µPa}$$

where p is the measured noise pressure in µPa associated with the line component.

12. The relative level of the line may be expressed by reference to the overall level of noise (including the contribution of the discrete component) in a band of prescribed width spanning the line frequency. A formula giving the required result is:

$$\text{Relative Line Pressure Level } \Delta N_L = 20 \times \log_{10}(p/p_1) \text{ dB re (octave) level}$$

where p is the noise pressure associated with the component, and p_1 is the overall noise pressure associated with the 1/3 octave or octave spanning the line. This relative method of expressing line levels should only be used in addition to the absolute level.

13. As a rule, measured noise pressure levels will be adjusted, by application of local propagation factors to equivalent source levels S, e.g.:

Equivalent Source Pressure Levels S (derived from N)

Equivalent Source Pressure Mean Spectrum Levels S_N (derived from N_s)

Equivalent Source Line Pressure Levels S_L (derived from N_L)

14. In free field conditions, when noise intensity is inversely proportional to distance squared and noise pressure is inversely proportional to distance, the adjustment would be:

$$S = N + 20 \times \log_{10}(r/r_0) \text{ dB}$$

where r is the direct distance between hydrophone and source, and r_0 is the selected standard (radius) of reference. To determine the distance from source to hydrophone, the following guidelines should be used:

a. For the track hydrophone (T) the distance *r* is the distance from the hydrophone to the nearest point on the keel; and

b. For the beam hydrophone, the distance *r* is the distance from the hydrophone to the nearest point on the hull. (For most ranges this simple adjustment will not hold; it will be necessary to determine adjustment factors empirically, with due regard to frequency of concern, state of tide, etc.)

15. Steps should be taken at all ranges to ensure that measurement of distance in ranging is sufficiently accurate to precluded errors on this account in excess of ± 1 dB, and that range calibration is sufficiently accurate and detailed to maintain this standard in adjusting measurements to equivalent source levels.

16. Where measured levels cannot be adjusted to equivalent source levels, but are adjusted to an arbitrary distance of reference, they will be indicated by the general symbol *N* and the selected distance of reference will be shown as a bracketed qualification; thus N_s(60 m), etc. The units of range, m (metres), must always be shown in order to prevent confusion with N_s(*f* Hz).

17. The standard distance of reference r_0 is to be taken as 1 metre.

18. On every occasion of ranging, measurements of ambient noise levels should be made frequently and as a matter of routine. With the low radiated noise levels of modern warships and submarines, care must be exercised to assure that measurements are not contaminated by ambient levels. Measurements can be considered free of ambient induced error when at least a 10 dB signal-to-ambient-noise ratio is maintained. Except for line levels (see Chapter 2, paragraph 14) and unless corrected as provided in paragraph 19 below, ambient contaminated data shall not be entered in the range report.

19. Correction of measured signals that fall within 10 dB of the corresponding ambient noise is subject to error because of the variable levels characteristic of radiated and ambient noises. However, in the unusual case that both the measured radiated noise and the ambient noise are judged to be sufficiently stationary and, as a consequence, it is calculated that the corrected data will have a probable error of less than 1 dB due to ambient effects, corrections may be applied. In this circumstance, the data can be included in the report but they must be suitably and clearly identified.

20. Systems used to indicate or compute signal pressures (*p*) or noise pressure levels (*N*) should have the following time characteristics:

a. Analog meters and recorders: time constants between 0.2 and 1 seconds; and

b. Digital computational algorithms: an equivalent time-bandwidth product of at least 5.

Such systems should be calibrated to indicate root mean square levels with an accuracy of ± 0.5 dB for complex signals.

21. Whenever 1/3 (or 1/1) octave analog or digital filters are used in range instrumentation, the composite system characteristic shall conform to IEC 225-199X and/or ANSI S1.11-1986, Order 3 (or Order 7), Type 1-D.

22. Analog-to-digital sampling and processing systems shall include anti-aliasing filters, weighting (windowing) functions and analysis procedures as necessary to preclude false indications of lines due to aliasing and side-lobe effects in narrowband spectra.

INTENTIONALLY BLANK

CHAPTER 2

2.1. THE FORMAT FOR NOISE RANGE REPORTS

1. On the subject of noise range reports the provisions of this publication are not intended to be in any way exclusive. Authorities are invited to include data beyond that called for specifically, or to include additional tabular or graphical presentations of data, whenever this will serve to define noise characteristics, or the effect of noise reduction measures, more clearly.

2. Reports will be divided into four clearly differentiated sections, ordered and titled as follows:

Section 1. Range Officer's Report

Section 2. Noise Status

Section 3. Noise Data

Section 4. Noise Features

SECTION 1 – RANGE OFFICER'S REPORT

3. Section 1 will be confined to a general report in which the Range Officer summarizes and comments on the essential findings of the trial, with due regard to the several different purposes which noise reports are required to serve (see Chapter 1, paragraph 3) and any special interests of the trial. It is recommended that the following checklist be used in preparing this section:

a. Broadband noise;

b. Narrow band noise direct analysis;

c. Narrow band noise demodulation analysis;

d. Localized noise sources;

e. Performance of noise reduction devices

f. Status within the class;

g. Conclusions; and

h. Recommendations.

SECTION 2 – NOISE STATUS

4. Section 2 is intended as a ready reference to the status of the vessel within its class to underline divergences and peculiarities for operational, technical, and noise reduction authorities and, at the discretion of national authorities, the status of the vessel as an operational unit sufficient to allow ready evaluation of detection or torpedo risk in specified operational circumstances.

This information is most conveniently presented in the following graphical form:

a. Graphs of spectrum level for the full frequency range at each speed and operating condition. Class average, the standard deviation and class target levels should be shown on the same graphs if the necessary data are available. Latter comparisons must be presented separately as divergence from class average and/or class target.

b. Graphs showing line pressure levels (N_L) for all lines whose absolute level exceeds the spectrum level of the 1/3 octave (or octave, where octave bands are used) within which it falls. These lines may be shown on the spectrum level graphs when convenient. The analysis bandwidth should be up to 1 Hz or less and must always be shown.

There is a clear advantage in presenting such summary information in an independent and well-defined section. Not all ranging will call for entries in Section 2. However, where no entries are made, the section heading should be included in the report, followed by a suitable phrase of explanation (e.g. ‘not applicable’, etc.).

SECTION 3 – NOISE DATA

5. Section 3 will form the main body of the report, in which the full tabular and graphical record of trial results will be entered.

Trial Information Sheet

6. Section 3 will include, as its first page, a ‘Trial Information Sheet’ as illustrated in Figure 2-1. Where it is helpful, any section may be expanded to give additional information on the vessel, sea conditions, hydrophone locations, ship’s course etc. Additional pages may then be required. Authorities may wish to retain some discretion in the detailed layout of this sheet but it should include at least the headings listed, and provide a record of ship and range status at least as detailed as that in Figure 2-1.

Notes:
1. Where more than one range exists at the same place, some distinction should be made between them.
2. For fleet auxiliaries and merchantmen, add to any class name information on tonnage (displacement), length, beam, and draft. Use symbols, thus:

T 8600 : L 130 oa : b 15 : d 7a : m

Indicate broad character of ship and machinery configuration, e.g. twin triple reduction steam turbines – all machinery aft, etc.

3. e.g. Routine Ranging or routine following long refit, or first of class documentation, or the effect of balance in main turbines, etc.
4. To enable ready cross reference to trial authority, ship trial programmes and similar administrative matters.
5. Include number of propulsors, number of blades/propulsor, qualitative or formal description of propulsors, noise reduction devices on propulsors, etc.
6. Give specific identification numbers or codes: identify details on non-standard treatments, e.g. drawing references for special profile treatment, etc.: include a note on shaft revolutions per knot.
7. List noise reduction (NR) features which are not standard in the class or sub-class named at head of the sheet. It may be necessary in certain special cases to mark this entry and add a supplementary Trial Data page with full noise reduction list.
8. State of paint, degree of fouling, known damage to plating, mechanical state of cathodic protection system electrodes, etc. If information comes from special diver's report prior to ranging, this should be noted (e.g. by symbol '(diver's rep)'). Time out of dock at time of ranging should be noted specifically.
9. Mechanical state of sonar domes, intake and effluent edges and grids, rope guards, torpedo bow cups, 'A' brackets, etc. with particular reference to rattling, vibration, cavitation, etc. Include symbol '(diver's rep)' if it applies.
10. Damage to blades, abnormal or ad hoc treatment of leading edge or profile, state of agouti or air emission holes, wear or erosion on tail cones, damage or erosion on shrouds, slackness in stern glands, etc. Include symbol '(diver's rep)' if it applies.
11. Defects or failures in machinery or mountings, significant defects in maintenance, etc.
12. If not standard, note special features such as active rudders, bow thruster units, stabilizers (included type and location), additional or distinctly modified domes, special internal air-borne noise treatment, significant and unique changes in machinery layout or substitution of new type machines; abnormal trim in warships; load conditions and trim to be specifically stated for fleet auxiliaries and merchantmen.
13. Depth of water (not depth of hydrophone): show here also the 'warning speed' v_w, the speed at which a divergence between deep water and shallow water behaviour of the propeller (and therefore noise) might just begin to be apparent. v_w is defined as 0.6 of critical or wave making speed:

$$v_w = 0.6\ v_c \text{ (kn)}$$

where there critical speed is given by:

14. $$v_c = \sqrt{(gh)} * 1.944 \text{ (kn)}$$

where g is acceleration due to gravity (in metres/second^2) and h is water depth (in metres); v_w should be quoted in knots

14. Give depth of hydrophones used, or state on 'bottom', indicate type(s) and give identifying code(s).
15. Wind force, swell conditions, sea state, etc.
16. Examples:
    background level abnormally high – interference at low speeds; or
    ship navigation below standard – excessive use of rudder; or
    with large ships, speed may still be increasing within ranging sector, etc.

7. It will be found of great value in ranging to make use of a 'Supplementary Information Sheet' (or sheets) as illustrated in Figure 2-2, providing a detailed record of the conduct of the trial and conditions maintained in different runs. The use of such a supplementary sheet, adjusted in layout to meet the convenience of individual ranges, is strongly recommended, and consideration should be given to the inclusion of completed sheets in range reports, immediate behind the Trials Information Sheet in Section 3.

Data Presentation

8. Recommended methods of data presentation are:

a. Spectrum level versus frequency for each speed and condition which has been measured;

b. Comparison of spectrum levels with class averages, standard deviations, and target levels. This may be presented as part of a above or as deviations from average target levels;

c. Performance of noise reduction devices which may be shown on the spectrum level graphs or a noise reduction (or increase) versus frequency for the conditions of measurement;

d. Performance of noise level versus speed dependence for frequency bands of special interest or showing unusual features; or

e. Presentation of dependence of noise level on speed for localized noise sources such as bilge keels, stabilizer fins, etc. Graphical data should be supported by full tabular presentation of all the relevant data.

SECTION 4 – NOISE FEATURES

9. Section 4 will be reserved for data and comment in detail on unusual noise features or features of particular current interest. Similarly, it will provide a place for tabular or graphical illustrations or comparisons of non-formal nature where this may serve to underline noise characteristics of noise trends in vessel or class for the benefit of operational, technical, or noise reduction authorities.

Where there is no matter of importance to enter, this section may simply be omitted.

Narrowband Frequency Analysis/Reporting Guidelines

10. Noise signals between 1 Hz and not less than 5 kHz should be analyzed using a narrow band analyzer. The intrinsic bandwidth of lines in radiated noise spectra will be a function of the inherent stability or quality factor (Q) of the generating machine or resonant structure. The line width will be further modified by characteristics of the sound range such as Doppler and amplitude modulation effects arising out of the ship's speed interacting with directional radiation patterns, the ship/hydrophone geometry and the duration (averaging time) and position of the signal samples. The preferred bandwidth is 1 Hz or less where permitted by above limitations, a factor which favours shorter averaging periods and larger hydrophone to ship distances (which can be increased with speed where radiated noise increases with speed).

11. In all instances, authorities shall insure that apparent line amplitudes are not reduced as a result of choosing an analysis bandwidth which is narrower than the intrinsic bandwidth of the line as received at the hydrophone(s). Through power summation, corrections can be made for lines broadened in frequency and reduced in amplitude due to Doppler or other effects over the signal averaging/sampling period. Corrected line amplitudes must be so indicated in the report.

12. The maximum acceptable bandwidths are:

a. 1 Hz for frequencies up to 50 Hz; and

b. 3% of frequency for between 50 Hz and at least 5 kHz.

13. The analysis bandwidth must always be clearly shown on graphs and tables and appropriate care taken in interpreting the results.

14. A line level is to be reported whenever its narrowband level exceeds the neighbouring narrowband levels by an amount which renders the line identifiable. The line level will not be corrected for ambient contributions and, with the exception of the circumstances of paragraphs 10 and 11 above, will indicate the maximum possible bound on the line level at the moment of measurement. Wherever possible, line levels shall be reported as equivalent source line pressure levels, S_L.

15. A table showing line frequency, level, measuring bandwidth, and source of the noise, if identified, should be given. In addition, an independent graphical presentation of narrow band data may be given.

Band (1/3 Octave or other) Analysis/Reporting Guidelines

16. For the frequency range 10 Hz (max) to 80 kHz (min) the equivalent source mean spectrum level will be calculated for bands not exceed 1 octave in width. The preferred measurement bandwidth is 1/3 octave.

17. The plots for equivalent source mean spectrum level will be presented as sample of Figure 2-3A, Note A (in the insert of Figure 2-3A) is to be taken as mandatory, and each sheet presented in a report is to be annotated at least to the extent indicated in the right hand margin of Figure 2-3A (and in notes B to E in the insert).

Surface Reflections

18. This publication does not require that levels, line or band, be corrected for surface reflection (Lloyd's mirror) effects. Where levels have been so corrected, this shall be noted prominently in the report.

Security Classification (Template is classified when filled out)

TRIAL INFORMATION SHEET

Name of Ship	See paragraph 6, Note 1 Range
See paragraph 6, Note 2 Class of Ship	Date of Ranging

See paragraph 6, Note 3
Purpose of Trial

See paragraph 6, Note 4
Trial Reference

PROPULSORS	See paragraph 6, Note 5
IDENTIFICATION	See paragraph 6, Note 6
NR FEATURES	See paragraph 6, Note 7
SHIP REPORT	
HULL	See paragraph 6, Note 8
HULL FITTINGS	See paragraph 6, Note 9
PROPULSORS	See paragraph 6, Note 10
MACHINERY	See paragraph 6, Note 11
OTHER FACTORS OF POSSIBLE INTEREST	See paragraph 6, Note 12
RANGE CONDITIONS	
WATER DEPTH	See paragraph 6, Note 13, v_w
HYDROPHONE(S)	See paragraph 6, Note 14
WEATHER AND SEA	See paragraph 6, Note 15
SPECIAL FACTOR	See paragraph 6, Note 16

Figure 2-1. Trial Information Sheet Template (NU)

Security Classification (Template is classified when filled out)

SUPPLEMENTARY INFORMATION SHEET

Run number or designation		(1)	
For submarines – depth of run (m)		(2)	
Nominal speed (knots)		(3)	
Shafts turning (if applicable)		(4)	
Shaft rpm (each shaft as applicable)		(5)	
Ship condition if applicable		(6)	
Aspect of measurement		(7)	
Requested distance of nearest approach to hydrophone(s)		(8)	
Measured distance of nearest approach (m)		(9)	
MACHINERY INFORMATION			
Identification Number	Machinery Item		
(10)	(11)	(12)	

Figure 2-2. Supplementary Information Sheet Template (NU)

Notes:

1. Need not reflect order in which runs were accomplished
2. SUR for surface, PD for periscope depth
3. To the nearest ½ knot
4. No 1 or No 2 or No 1 and 2 ((1) (1) (2))
5. For the shafts given in (4) – (180 or 180/160)
6. If special quiet machinery bill designations established for ship fill in. UQ for Ultra Quiet, PQ for Patrol Quiet, or 'Normal'….
7. Pt (port), Std (starboard), 'Bow', 'Stern' as appropriate
8. As specified in the agenda
9. As measured to provide 1 dB Source Level accuracy
10. Use identification number assigned for static trials of auxiliary machinery if available
11. Identify which unit of same type if more than one installed. List all main propulsion machinery as well as principal auxiliary machinery
12. R for machine running
    RS for two speed machine running slow
    RF for two speed machine running fast
    V for variable speed operations (indicate rpm)
    S for stopped
    INT for intermittent operations (automatic or manual)
    X if operating condition unknown

(Template is classified, when filled out)

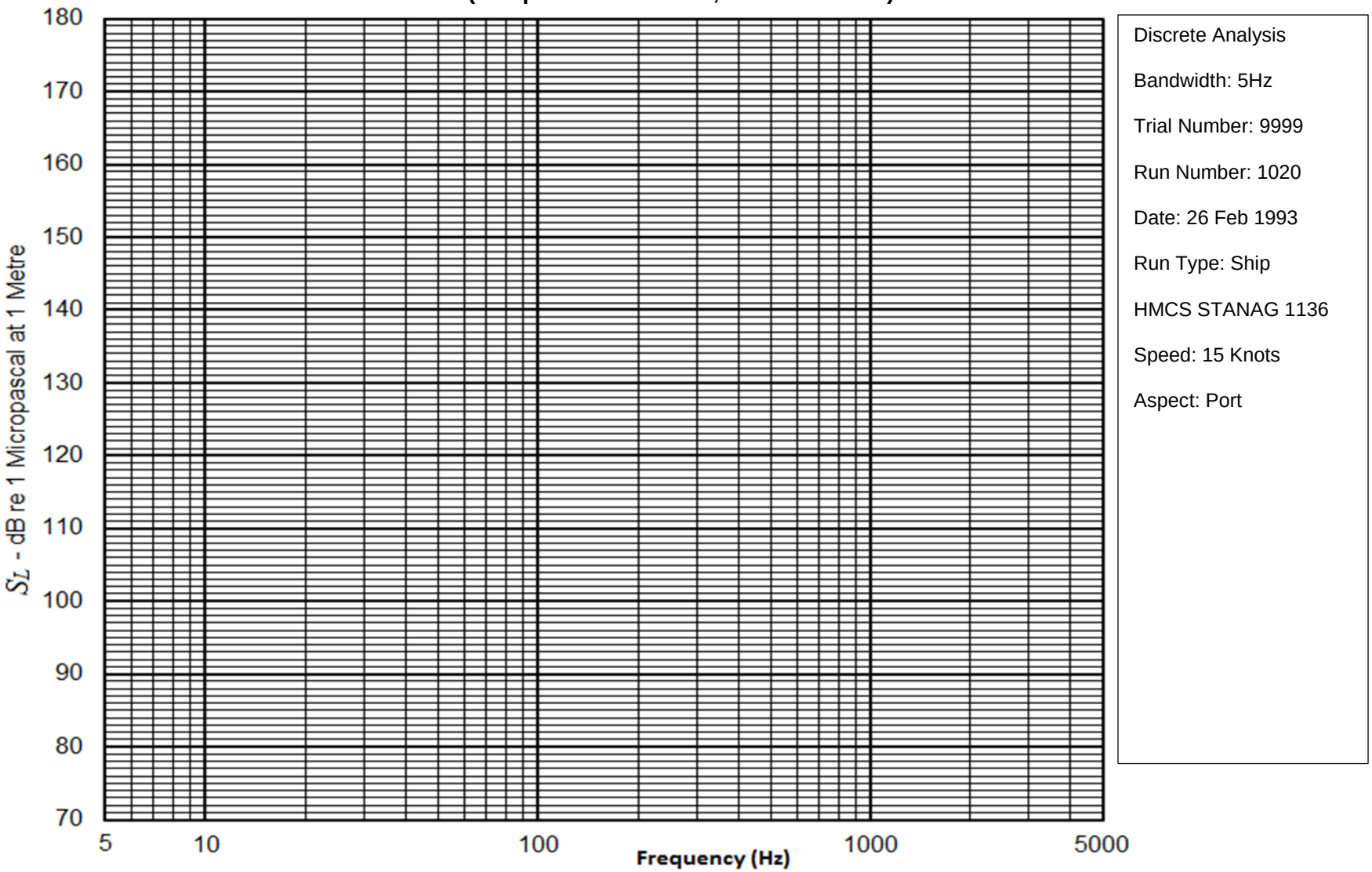

Figure 2-3-A. Template for Equivalent Source Mean Line Level (NU)

(Template is classified, when filled out)

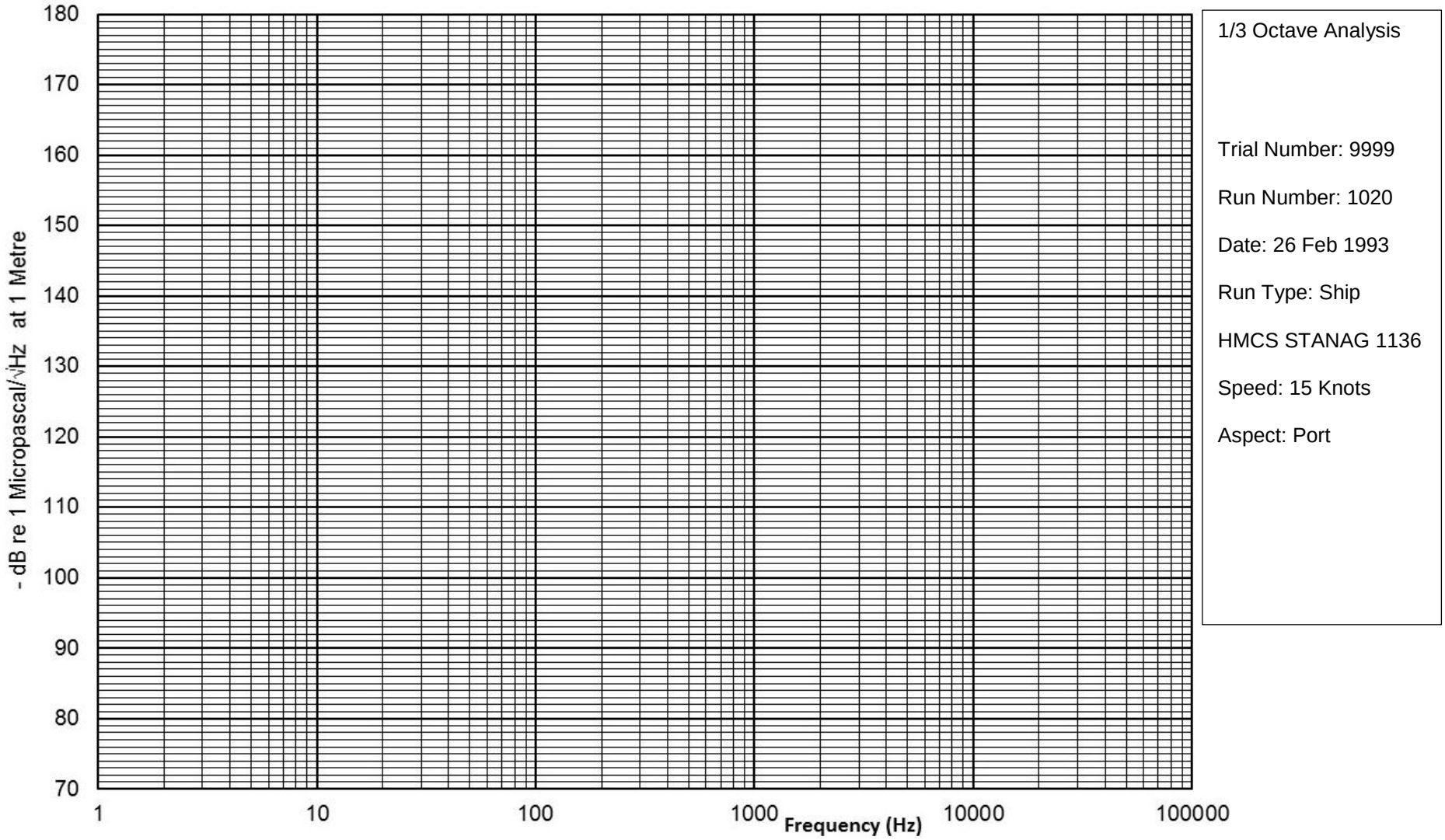

Figure 2-3-B. Template for Equivalent Source Mean Spectrum Level (NU)

RADIATED NOISE REPORT

Notes:

1. Use to be made of the most appropriate of three standard scales to the limits shown, according to the general level of noise signatures. At least the limiting ordinate of all three permitted scales to be printed on the data sheet as shown. Clear indication to be given as to which scale is to be taken to apply to the data presented.
2. E.g. Status in Class or Routine Ranging or Effect of Propeller Pitch.
3. Detailed circumstances which apply for sheet (e.g. Speed 10 knots or RPM/Pitch as indicated)
4. n Hz, 1/3 octave, as appropriate.
5. E.g. Bottom 100 m abeam or below keel at 30 m in 100 m depth.

LIST OF ILLUSTRATIONS

CHAPTER 3

3.1. PROCEDURES FOR RANGING SURFACE SHIPS

THE RANGE

1. When noise ranging, two-way voice radio communication between ship and range is almost indispensable. There is advantage in embarking a technical officer (a permanent member of the range staff) in the ship for the duration of ranging to provide liaison between ship and range, to advise on range procedures, and to collect essential ship data (see paragraph 6).

2. When ranging ships, two hydrophones should be employed:

   a. One directly under the prescribed ranging track (the 'Track hydrophone' or 'T hydrophone').

   b. One at a plan distance from the prescribed track (ideally not less than 100 metres). The maximum distance is to be such that adequate signal to noise ratios are achieved in all bands. (The 'Beam hydrophone' or 'B hydrophone').

The track hydrophone is primarily for the detailed study of noise spectra over the frequency range of 10 to 2500 Hz (see Chapter 2 paragraphs 10-16) and can be used equally for studies related to mine risk in accordance with NATO AMP 15. The track hydrophone directivity pattern should show no more than 3 dB variation at angles within 45° of the vertical over the full working range of frequency or of more than 1 dB within 15° of the same axis. The beam hydrophone is primarily for the study of noise over the frequency range 10 Hz to 80 kHz in connection with general sonar detection and torpedo acquisition risk (Chapter 2 paragraph 5), and must sum the noise from all parts of the ship. When it is desirable to distinguish between the hydrophones the terminology indicated above should be used. The beam hydrophone(s) directivity pattern (unless by specific design) should show no more than 1 dB of total variation in its horizontal plane. Vertical beam patterns shall not deviate from the horizontal sensitivity by more than 2 dB for all angles within 30° above the horizontal.

3. The beam hydrophone should be positioned at a depth in order to provide a depression angle of 30°.

4. The track hydrophone should never be positioned at a depth less than 20 metres. If the local water depth is between 20 and 60 metres the hydrophone should be placed on the bottom; if the local water depth is greater than 60 metres, the depth of the sensor from the surface should be one third of the water depth.

5. When a hydrophone is placed on the sea bed, the sensor itself should stand no more than 1 metre above the bottom.

SHIP RANGING

6. As an essential part of ranging, a report on the ship's status is required from the Commanding Officer. The information needed is best asked for on a prepared (and explanatory) form; this form could well be based on the notes of paragraph 6 in Chapter 2. In this connection, ships should be asked to arrange for a diver's report on the state of the hull, hull fittings, propulsors, etc., at as late as date as possible prior to ranging. Cleaning of the propeller prior to ranging shall be requested.

7. Whenever possible measurements and recordings should be made on board ship, prior to and throughout the course of ranging (see paragraph 1):

a. To check propeller shaft rpm (if possible, by direct reading from shafts) during range runs. Accurate data on shaft rates is important. Figures reported from ships' standard data sources are seldom reliable, and in particular will often not reveal even considerable divergences between shafts; and

b. To obtain a record of the frequencies of vibration (especially the frequencies of fundamental rotation or reciprocation of at least the more important of main and auxiliary items of machinery.

8. It is recommended that close and frequent liaison be maintained with the authorities responsible for investigating and measuring all aspects of surface ship self-noise. Both radiated and self-noise work can benefit by exchanging data on noise sources and experiences.

9. In warships and fleet auxiliaries, runs should be made at shaft rates corresponding with speeds as detailed by National Operational Authorities. It would be of the greatest help for purposes of technical exchange if these rates were adjusted to coincide with speeds from the series

3, 6, 9, 12, …… …… knots and 'full speed'.

At least two runs should be made at each of these speeds, one following the other on reciprocal bearing, where possible. Unless there are significant differences in the noise signatures, the two signatures should be taken together as representative for the speed in question.

10. The ship should be asked to keep a record for each run of nominal speed, actual speed (through the water), shaft rates (rpm), main engine rates (rpm machinery), and propeller pitch (when appropriate). An independent check on shaft rates is desirable (see paragraph 7.a). It is desirable that a track plot be kept in the range, enabling speed over ground to be calculated and hence a check made on speeds through the water; for reciprocal runs mean ground speed is also mean speed through the water; for single runs ground speeds can be corrected from knowledge of local tide streams. The track plot also provides an essential check on lateral running error relative to the location of the hydrophones.

11. Approach to the range should be made from sufficient distance to ensure that speed through the water remains constant without change in engine or propeller settings, and ship's track remains straight without recourse to helm (other than the minimum to maintain ship's head) when within 300 metres of the closest point of approach (CPA) to track and beam hydrophones at low speeds (6 knots), increasing to within 800 metres of the point of CPA at speeds over 20 knots. These distances are absolute minima. Where navigational restrictions permit or where measurements are required at greater distances from CPA, the distances should be increased appropriately (tracking via DGPS is recommended).

12. In routine ranging the status of main and auxiliary machinery should conform throughout to standard operational schedules. It is important that no change in machinery state should be made at any time after the start of ranging (whatever the initial state) without consideration and (if any effect on radiated noise is at all likely) consultation between the ship and the range officer. In ships fitted with Controllable Pitch propellers, pitch/rev settings should include standard operational settings, speed by speed. Stabilisers should be locked, normal at an angle of 0°, but at other suitable angles when so required for special trials. Measurements with the stabilisers operating normally should only be made when the measuring interval extends over several periods of their operation in all relevant influences affecting them (sea state, swell, control settings, etc.). Sonar sets should be in the stand-by state (electrically and mechanically); where retractable domes are employed they should be locked in the extended position at all speeds where this is permitted, and fully retracted and secured at speeds beyond this; dome position should be reported run by run; sonar and radar sets should not be used at all during ranging (e.g. for exercise or maintenance) unless approval has been given by the range authorities.

13. For merchantmen, paragraphs 10 through 12 above should be followed, except that runs should be made at nominal speeds of 10 knots and design cruising speed, or 10 and 15 knots and design cruising speed, as appropriate.

14. For merchantmen and fleet auxiliaries, loading and state of trim are matters of considerable importance. In general such ships should be ranged deep laden, or in deep loading ballast, and with trim normalized; in any circumstances loading and trim should be recorded in some detail (Chapter 2 paragraph 6, note M).

15. When noise reduction devices are fitted, with the possibility of running with them in or out of operation, runs at appropriate speeds should be duplicated to cover the two possible states.

16. Where alternative or supplementary methods of propulsion are available, runs should be made using both alternatives, or a balance of propulsion effort according to standard operational practice at the various speeds.

OVERSIDE MEASUREMENTS

17. It is recommended that, as an additional measure, or as a primary measure where full range facilities cannot be provided, overside measurements should be taken with the ship moored fore and aft between buoys or alongside a pier head.

Trial Site

18. The trial site must be such that acoustic background levels are well below the likely levels of the quietest machinery to be checked; in particular the site must be sufficiently distant from industrial clanging and hammering, such as may transmit noise tones and noise pulses into the water.

Ship Routine

19. Items of auxiliary machinery should be run individually, as far as possible, or in such grouping and sequence as to provide the best chance of noting individual characteristics. If shore power can be provided in place of the ship's own supply it will be much easier to operation machines individually. Where a machine has more than one operating state (of speed, loading, etc.) it should be checked in each such state. It is important that machines be run sufficiently long for them to reach their steady noise state.

20. Measurements should be taken through a hydrophone suspended vertically immediately over the side of the ship at the fore and aft location (± 1 metre) of, and on the same side as the machine to be checked; as a standard practice the hydrophone depth should be half the keel depth (± 1 metre). One moveable hydrophone can be used to take all the necessary measurements in these tests. But these data are generated in the near field and are not suitable as source level.

RANGE REPORTS

21. The range officer's report should include specifically:

a. Cavitation inception speeds on propulsors;

b. Details of the speed range and severity of propeller signing whenever it occurs; and

c. Details of the incidence and severity of propeller blade rate signals, and where possible, the incidence and depth of blade rate modulation of broadband noise (e.g. 100 Hz to 80 kHz).

22. Detailed analysis should be applied in the track hydrophone channel as described in Chapter 2 paragraphs 10 through 18. A graphical presentation should be given of equivalent source mean spectrum level 10 Hz to 2500 Hz, with line spectrum pattern superimposed (Chapter 2 paragraph 17), for the speed of 6 knots (noise almost exclusively of machinery origin) (for merchantmen, 10 knots) and for the ranging speed nearest normal duty cruising speed (the significance of discrete frequencies in the most important operational state). A table showing line frequency, level, and measuring bandwidth and source of the noise, if identified, should be given. In addition, an independent graphical presentation of the narrowband data may be given.

23. Analysis should be applied in the beam hydrophone channel as described in Chapter 2 paragraph 16. A graphical presentation should be given of equivalent source mean spectrum level (10 Hz to 80 kHz), with signatures for ranging speeds according to paragraph 9, included on the same plotting sheet, to enable variations of level with speed to be seen generally.

A plot should also be included (in Section 2 of the report – see Chapter 2 paragraph 4) showing the signature for the particular ship superimposed upon the signature for the class as a whole, for as many speeds as can be accommodated conveniently on the single sheet. The class signature should be shown as a band of width ± 1 standard deviation about the average signature for the class. (This will only be possible for merchantmen in special cases, e.g. single company tanker fleets).

24. On plotting sheets carrying multiple signatures, signature speed will be indicated by a figure imposed on the signature. This will always indicate true speed through the water in knots, and the unit of speed should be given explicitly. If there is reason to indicate also shaft rate (e.g. unusual speed/rpm relation, CP propeller, etc.) signature should be marked x/y, x always indicating speed in knots, y shaft rate in rpm.

25. Analysis in the beam hydrophone channel should be extended, at least to the extent of a spot check, to cover the interval during which the hydrophone is within the interval from bow to stern plus 5° for ships lengths up to 150 metres and from midship to stern plus 5° for ships with lengths over 150 metres. If there is evidence of appreciable directivity on radiated noise.

a. Levels should be averaged over the interval mentioned and the maximum level should also be given. It is recommended to use the procedure from ISO 17208-1 as averaging procedure over time;

b. The pattern should be commented by the range officer; and

c. Steps should be taken to explore the peculiarity in the class as a whole.

INTENTIONALLY BLANK

CHAPTER 4

4.1. PROCEDURES FOR RANGING SUBMARINES

UNDERWAY TRIALS

The Range

1. When noise ranging, the facility of local two-way (direct voice) radio communication between submarine and range is almost indispensable. There is advantage also in sending a technical boarding officer into the submarine (a permanent member of the range staff) for the duration of ranging to provide moment to moment liaison between boat and range, to advise on range procedures, and to collect essential ship data (see paragraph 5).

2. It is desirable that the depth of water at the range should be sufficient for the submarine to run at depth down to some 70 metres, with fully adequate sea room to allow operation at maximum speed. At least it must be possible for boats to run at maximum operational speeds at periscope and snorkel depths.

3. A hydrophone, or hydrophones, should be located at a plan distance from the prescribed ranging track of not less than 100 metres. When ranging is restricted to snorkel and periscope modes a single beam hydrophone, planted at a depth between 20 metres and 60 metres will serve, whether suspended or set on the sea bed. Where deep running is possible, it will be necessary to plant a number of beam hydrophones in a vertical string, or arrange for adjustment in depth of a single hydrophone, so that, at all running depths, a measuring hydrophone will be located at approximately the depth of the submarine (within a subtended angle of ± 15°). Hydrophone directivity patterns should show no more than 1 dB of total variation in the horizontal plane (unless specifically directional) and no more than 2 dB total variation within angles of 30° to that plane

4. In cases where submarine noise cannot be measured at 100 metres, and the beam hydrophone must of necessity be brought very much closer to the submarine, recorded noise levels should not be reported in terms of source strength. Levels should be adjusted for minor variations of distance to a selected reference distance (x metres) and reported simply as noise spectrum levels N(x metres). It is recommended that several hydrophones at different depths be used in order to assess or eliminate the effects of multipath interference and to improve repeatability of measurements

SUBMARINE ROUTINE

5. As an essential part of ranging, a report on the submarine's status is required from the Commanding Officer. The information needed is best asked for on a prepared form. This form could well be based on the notes of paragraph 6 in Chapter 2. Similarly, it will be necessary to prepare a Supplementary Information Sheet as described in Chapter 2. In this connection, submarines should be asked to arrange for a diver's report on the state of the hull, hull fittings, propulsors, etc., at as late as date as possible prior to ranging.

6. Whenever possible measurements and recordings should be made on board the submarine, prior to and throughout the course of ranging (see paragraph 1):

a. To establish cavitation inception speed on each of the submarine's propulsors;

b. To check propeller shaft rates in rpm during range runs, where possible by direct reading from shafts; (Accurate shaft rate information is important. Data reported from submarines' standard data sources are seldom reliable, and in particular will often not reveal even considerable divergences between shafts).

7. Runs are to be defined for the class by national authorities, for example:

a. At snorkel depth on diesels, at 5 knots and at operational 'Snorkel Cruising Speed' for the class;

b. At snorkel depth on diesels, at snorkel cruising speed and snorkel transit speed charging batteries;

c. At periscope depth, on main motors, at operational 'quiet speed' for the class; and

d. Submerged, on main motors, at quiet patrol, sonar attack, and full speeds, at keel depth of 30, 60, …... metres.

At least two runs should be made at each of the speeds mentioned, one following the other on reciprocal bearing. Unless there are significant differences in the noise signatures, the two signatures should be taken together as representative for the speed in question.

8. The approach to the range should be made from sufficient distance to ensure that speed remains constant without change in engine or motor settings, and a straight track and uniform depth are maintained without recourse to rudder or hydroplanes (other than the minimum preserve heading and trim) from 300 metres short of to 300 metres beyond the range hydrophones at low speeds (6 knots), increasing to 800 metres beyond at the highest transit speeds. These distances are absolute minima. Where navigational restrictions permit or where measurements are required at greater distances from CPA, the distances should be increased appropriately.

9. In all runs, the status of main and auxiliary machinery should conform to standard operational schedules. It is important that no changes be made in machinery state during a run. Any change should be notified in the trial status report prepared for the range officer. Sonar sets should be in the stand-by state (electrically and mechanically); where retractable domes or sensors are employed, they should be locked in the extended position, or fully retracted and secured, according to the state in which they would normally be set for the condition of the run. Sonar sets should not be used for any purpose (e.g. maintenance or training) during the ranging. During runs at 'quiet speed', full contributory 'quiet regime' should be maintained throughout the boat.

RANGE REPORTS

10. The range officer's report should include specifically:

a. Figures for cavitation inception speeds on propulsors at each range depth, (as a table, indicating both inception speeds and inception shaft rates);

b. Details of the speed range and severity of propeller signing whenever it occurs; and

c. Details of the incidence and severity of propeller blade rate signals, and where possible, the incidence and depth of blade rate modulation of broadband noise (e.g. 100 Hz to 80 kHz).

11. Detailed narrowband signal analysis should be applied in the beam hydrophone channel (or channels) as described in Chapter 2. A graphical presentation should be given of equivalent source mean spectrum level (10 Hz to 2500 Hz) for the runs described in paragraph 7.b. and 7.c. A table showing line frequency, level, measuring bandwidth and source of the noise, if identified, should be given. In addition, an independent graphical presentation of the narrowband data may be given.

12. One third octave analysis should be applied in the beam hydrophone(s) as described in Chapter 2. A graphical presentation should be given of equivalent source mean spectrum level (10 Hz to 80 kHz) for the runs described in paragraph 7.a. and 7.c superimposed on corresponding signatures for the class as a whole. Class signatures should be shown as bands of width ± 1 standard deviation about the average signatures for the class. When submerged runs are possible (paragraph 7.d.) a data sheet should also be included showing the signatures for all the several ranging speeds for non-cavitating conditions using data from all ranging depths as appropriate.

13. On data sheets carrying multiple signatures, signature speed will be indicated by a figure imposed on the signature. This will always indicate true speed through the water in knots, and the unit of speed need not be given explicitly. If there is reason to indicate also shaft rate signatures should be marked x/y, x always indicating speed in knots, and y shaft rate in rpm.

14. Analysis should be extended, at least to the extent of a spot check to cover the interval during which the hydrophone is within the interval from bow to stern plus 5°. If there is evidence of appreciable directivity of radiated noise:

a. Levels should be averaged over the interval mentioned and the maximum level should also be given. It is recommended to use the procedure from ISO 17208-1 as averaging procedure over time;

b. The pattern should be commented by the range officer; and

c. Steps should be taken to explore the peculiarity in the class as a whole.

STATIC RANGES

15. The static range should be located in sheltered water where suspension of the submarine is possible and background noise does not normally exceed the level associated with sea state 1.

16. Buoys are required to enable submarines to be moored fore and aft while suspended at periscope depth. A telephone link between boat and range is essential.

17. The range hydrophone should be suspended at the same depth as the submarine at a beam distance of 100 metres. It is mentioned that modern submarines usually cannot be measured at 100 metres in silent operation. Consider to lower hydrophone distances to sufficient values if necessary.

Submarine Routine

18. Machinery and equipment will be run as needed to further the purposes of the trial but should include the standard operational conditions appropriate to the class.

Range reports

19. In each case, the resulting radiated noise should be analyzed in narrowband detail as described in Chapter 2. A graphical presentation should be given of equivalent source mean spectrum level (1 Hz to 5000 Hz). A table showing line frequency, level, measurement bandwidth and source of noise if identified, should be given. In addition, an independent graphical presentation of the narrowband data may be given.

20. The noise should also be analyzed in 1/3 octave bands as described in Chapter 2. A graphical presentation should be given of equivalent source mean spectrum level (10 Hz to 80 kHz) with signatures for all the conditions of paragraph 7 included on the same data sheet.

OVERSIDE MEASUREMENTS

21. It is recommended that, as an additional measure, or as a primary measure where full range facilities cannot be provided, overside measurements should be taken with the submarine on the surface, moored fore and aft between buoys or alongside a pier head.

Trial Site

22. The trial site must be such that acoustic background levels are well below the likely levels of the quietest machinery to be checked. In particular the site must be sufficiently distant from industrial activity such as may transmit noise tones and noise pulses into the water.

Submarine Routine

23. The submarine should be trimmed down to maximum draft consistent with safety to cause the largest volume of the hull to be submerged. Items of auxiliary machinery should be run, so far as possible individually, alternatively in such grouping and sequence as to provide the best chance of noting individual characteristics. Check on machines individually will be facilitated if shore power can be provided as a substitute for the boat's own plant. Where a

machine may operate at different times in different states (of speed, loading, etc.) it should be checked in each of such states. It is important that machines should be run for sufficient length of time to ensure that they reach steady noise state.

24. Noise measurements should be taken through a hydrophone suspended vertically immediately over the side of the ship at the fore and aft location (within 1 metre), and on the same side as the machine to be checked; as a standard practice the hydrophone should be lowered to the depth of the submarine's hull (within 1 metre). One moveable hydrophone can be used quite conveniently to take all the necessary measurements in these tests.

Range Reports

25. The noise from individual machines, and machinery groups should be analyzed in narrowbands as described in Chapter 2. A graphical presentation should be given of equivalent source mean spectrum level (10 Hz to 2500 Hz) for the machines and machinery states which will clearly control the radiated noise of the submarine. There is a case for including a complementary graphical or tabular record of spectrum structure for all the machines and machinery states tested.

26. If at all possible (and full range facilities are not available), an additional hydrophone should be located on the beam at a distance of 100 metres and at a depth of 15 metres to 20 metres. Signals should be analyzed, and results presented, as in paragraph 25 above, and in addition the analyses should be extended to include 1/3 octave bands as in Chapter 2.

INTENTIONALLY BLANK

CHAPTER 5

5.1. PROCEDURES FOR RANGING HELICOPTERS, HYDROFOILS, GROUND EFFECT MACHINES, AND FAST PATROL BOATS

THE RANGE

1. When noise ranging craft of this section the facility of local two-way (direct voice) radio communication between craft and range is indispensable.

2. The range should conform to the pattern of Chapter 3 paragraphs 2 through 5 with the additional requirement that, by appropriate aids, helicopters and GEMs be enabled to hover within a radius of half the hydrophone depth over both track and beam hydrophone while measurements are taken over the full frequency range covered by the publication. (This may mean that an additional track hydrophone will be needed where the track hydrophone is restricted to the lower frequency range.)

CRAFT ROUTINE

3. As an essential part of ranging a report on craft status is required from the Commanding Officer. The information needed is best asked for in prepared (and explanatory) questionnaire. This should be designed as to enable production of a detailed 'Trial Information Sheet' as allowed for in Chapter 2

4. For all craft, the procedure of Chapter 3 paragraphs 10 through 12 should be followed, in so far as it may be applicable and with due translation of terms.

5. For hydrofoils and FPBs, runs should be made at speeds in the series 6, 9, 12, …knots. Helicopters and GEMs should be loaded to maximum gross operational weight. They should be guided to hover at normal operational altitude and maximum hover height respectively (as possible sonar vehicles) over the measuring hydrophone(s).

RANGE REPORTS

6. Detailed narrowband signal analysis should be applied in the track hydrophone channel as described in Chapter 2, and graphical presentation, with line structure superimposed on the plot of mean spectrum level as in Chapter 2, should be given for helicopters and GEMs, and for FPBs and hydrofoils at one speed of ranging.

7. Signal analysis should be applied in, and data presented for, the beam hydrophone channel as described in Chapter 2, for all ranging conditions, data for runs and at different speeds with hydrofoils and FPBs being entered on the same data sheet.

8. For hydrofoils and FPBs the practices described in Chapter 3 paragraphs 20 and 21 should be followed with appropriate adaptation

INTENTIONALLY BLANK

ANNEX A TO APP-33

SYMBOLS AND ABBREVIATIONS

1. The following symbols and abbreviations have been used in this publication. In implementing the publication, authorities should make use of the symbols and abbreviations listed, rather than introduce alternatives which could lead to confusion

/	Per
Δf	incremental bands of frequencies (hertz)
µPa	micropascal
a	aft
b	ship's beam (metres)
BTM	on the Bottom (sea bed)
cm	centimetre
cm^2	square centimetre
CP	Controllable Pitch (propeller)
CPA	Closest Point of Approach
d	ship's draught (metres)
dB	decibel
f	frequency (hertz)
FP	Fixed Pitch (propeller)
FPB	Fast Patrol Boat
g	acceleration due to gravity (metres/second^2)
GEM	Ground Effect Machine
h	water depth (metres)
Hz	Hertz (cycles per second)
I	Acoustic Signal Intensity
I_0	Standard Reference Acoustic Signal Intensity
kn	Knot

L	ship’s length (metres)
m	metre
m^2	square metre
N	Root Mean Square Noise Pressure Level
N(*f* Hz)	Noise Pressure Band Level for Band Centered on Frequency *f*
N_L	Line Pressure Level
NR	Noise Reduction
N_S(*f* Hz)	Pressure Mean Spectrum Level for the Band Centered on Frequency *f*
N_S(*r* m)	Pressure Mean Level Adjusted to Arbitrary range of *r* metres
oa	overall
p	root mean square noise pressure (µPa)
p_0	standard reference root mean square pressure (µPa)
Pa	pascal
Pt	Port
Q	quality factor
r	Direct Distance Between Hydrophone and Source (m)
r_0	Standard Reference Distance (usually 1 m)
re	With reference to, referred to
rpm	Revolutions per Minute
s	second
S	Equivalent Source Pressure Level
S_L	Equivalent Source Line Pressure Level
S_N	Equivalent Source Pressure Mean Spectrum Level

Std	Starboard
T	Ship's Tonnage (metric tonnes)
v	Ship's Speed (knots)
v_c	Critical (wave making) speed = $\sqrt{(gh)}$*1.944 (knots)
v_w	Warning Speed = 0.6 v_c (knots)
Z	Specific Acoustic Impedance

HYDROPHONES

B	Beam Hydrophone
T	Track Hydrophone

SUBMARINE QUIET STATES

UQ	Ultra Quiet
PQ	Patrol Quiet
PD	Periscope Depth
SUR	On the Surface

MACHINERY STATES

R	Machinery Running
RS	Two Speed Machinery Running Slowly
RF	Two Speed Machinery Running Fast
V	Variable Speed Machinery (rpm should be stated)
S	Machinery Stopped
INT	Intermittent in Operation
X	Condition Unknown

INTENTIONALLY BLANK

LIST OF EFFECTIVE PAGES

I (RB)
III (RB)
V (RB)
VII (RB)
1-1 to 1-5 (RB)
2-1 to 2-10
3-1 to 3-5 (RB)
4-1 to 4-5 (RB)
5-1 (RB)
A-1 to A-3 (RB)
LEP-1 (RB)

INTENTIONALLY BLANK

APP-33 (A) (1)