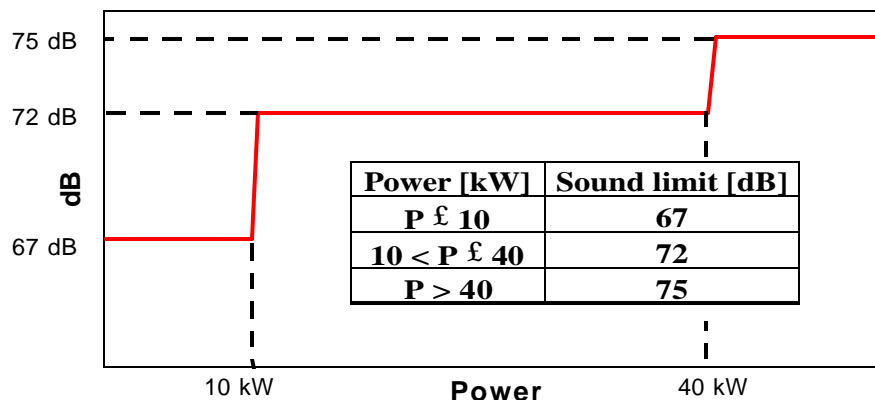


22 November 2004

ICOMIA TECHNICAL GUIDE SOUND TESTING OF RECREATIONAL CRAFT TODAY

Introduction

From 1 January 2006 every CI and 4 stroke internal combustion engined recreational craft, including sailing boats with auxiliary engines, that are placed on the market and/or put into service within the European Union must comply with the sound regulations set out in EU Directive 2003/44/EC¹. It is also compulsory for 2 stroke engines from 1 January 2007. The limits are as follows:



For twin-engine and multiple-engine units of all types an allowance of 3 dB may be applied.

The following propulsion engines and craft are **not** required to comply with these sound emission requirements:

- propulsion engines installed or specifically intended for installation on the following:
 - craft intended solely for racing and labelled as such by the manufacturer,
 - experimental craft, provided that they are not subsequently placed on the Community market,
 - craft specifically intended to be crewed and to carry passengers for commercial purposes, in particular those defined in Directive 82/714/EEC, regardless of the number of passengers,
 - submersibles,
 - air cushion vehicles,
 - hydrofoils;
- original and individual replicas of historical propulsion engines, which are based on a pre-1950 design, not produced in series and fitted on original historical craft and individual replicas thereof designed before 1950, built predominantly with the original materials and labelled as such by the manufacturer or craft built for own use, provided that they are not subsequently placed on the Community market during a period of five years

¹ Optional from 1 January 2005.

- propulsion engines built for own use provided that they are not subsequently placed on the Community market during a period of five years;
- craft built for own use, provided that they are not subsequently placed on the Community market during a period of five years.

Section 1-Requirement by Engine Type

Outboard engines and stern drive engines with integral exhaust²

Compliance with the sound emission limits for outboard engines and stern drive engines with integral exhaust are the responsibility of the engine manufacturer. These engines are tested by them using prescribed “standard” boats and are then delivered to the boat manufacturer with a CE mark which certifies them as being compliant for both sound and exhaust emissions. Their sound testing will not be discussed further in this technical guide.

Inboard engines and stern drive engines without integral exhaust

Compliance with the sound emission limits for inboard engines and stern drive engines without integral exhausts are the responsibility of the boatbuilder. The remainder of this technical guide will be concerned with how boat-builders may demonstrate compliance with the sound requirements of the directive *today*.

Section 2-Demonstration of compliance by boatbuilders fitting craft with inboard engines and stern drive engines without integral exhaust

The physical sound testing of boats in reality will be limited to planing and some semi-displacement boats. However, the first step for the boatbuilder is to carry out a relatively simple calculation which assesses both the power to displacement ratio and Froude number of the boat. This is known as the pd/f method. The result of this assessment will decide whether actual sound testing will be required or not. The calculation of these two values is described in the box below:

The pd/f Method

The ‘Froude number’ (Fn) is calculated as follows:

$$Fn = \frac{v}{\sqrt{(g \cdot L_{WL})}}$$

Whereas:

- v: maximum boat speed in metres per second
 L_{wl}: waterline length measured in accordance with EN ISO 8666
 g : gravitational constant g = 9,8 m/s²

The ‘Power displacement ratio’ (P/D) is calculated as follows

$$P/D = \frac{P}{D}$$

Whereas:

- P : Declared Power in kW in accordance with ISO 8665
 D : Displacement in tonnes at performance test mass conditions in accordance with EN ISO 8666

² any stern drive powered boat where the exhaust gases are expelled through the transmission/drive

Worked examples of these calculations are available at Appendix 1, together with graphs for easy calculation. In addition there is an automatic pd/f calculator on the ICOMIA website homepage at www.icomia.org.

Boats with a power/displacement ratio greater than 40 kW/t and/or a Froude number greater than 1.1 must be sound tested. The only method of sound testing specified in the Directive uses the EN ISO 14509. The requirements of this test are described in Section 3:

Section 3-Sound Testing

EN ISO 14509-Summary

- Series of runs past a fixed microphone – at least two on each side of the craft
- Speed of 70km/h, or maximum speed if this is not achievable
- Distance from microphone between 25m and 27m
- Wave height = 100mm for planing boats, =200mm for non planing boats
- Wind speed = 5m/s for planing boats, =7m/s for non planing boats

Copies of this standard are available from national standards institutes. The specific sound limits are shown in the diagram on Page 1.

Some 70 boats have been tested over the past 15 months using this method and the following are lessons learnt so far:

EN ISO 14509 – Lessons from recent testing

- Spend time finding some sites protected from prevailing local winds
- Seek local advice
- Site the microphone on a fixed point or a small craft – do not try and use a large power boat
- Large boat builders should consider erecting a permanent platform in the test area
- A diagram for easy positioning of the 25m marker buoy is shown at Appendix 2

Section 4-Role of Notified Bodies

Notified bodies have to be notified for the amending directive 2003/44/EC. Those organisations notified as at 31 October 2004 are listed on the following web page:

http://europa.eu.int/comm/enterprise/maritime/maritime_regulatory/rc_switchboard.htm#amend

Most notified bodies are currently in the accreditation process. As further organisations are notified their details will appear on this web page.

The pd/f method

For boats deemed to comply using the pd/f method, the directive allows the following modules to be applied by the boat manufacturer or his authorised representative established in the Community:

“either the internal production control (module A), or the internal production control plus tests (module Aa), or unit verification (module G), or full quality assurance (module H) may be used.” It

is expected that most boat builders will use Module A where no notified body is required. However the pd/f numbers derived must be stated in the boat's technical documentation.

EN ISO 14509 Method

For boats using EN ISO 14509 (the pass-by sound test) to demonstrate compliance, the directive allows the following modules to be applied by the boat manufacturer or his authorised representative established in the Community:

“either internal production control plus tests (module Aa), or unit verification (module G), or full quality assurance (module H) may be used”. It is expected that most boat builders will use Module Aa.

The role of the notified body in Module Aa for assessing the conformity with noise emissions is described in Annex VI.B of the directive as:

“For recreational craft fitted with inboard engines or stern drive engines without integral exhaust (and for personal watercraft): on one or several craft representing the production of the craft manufacturer, the sound emission tests defined in Annex I.C shall be carried out by the manufacturer, or on his behalf, under the responsibility of a notified body chosen by the manufacturer”

This is explained in more detail in the relevant EU guide³ as:

“these noise emission measurement tests must be conducted under the responsibility of a notified body. The noise emission measurement tests may be carried out by the craft manufacturer and witnessed and/or checked by the notified body. Alternatively the tests may be conducted by another party appointed by the manufacturer and witnessed and/or checked by the notified body, or conducted by the notified body itself.”

Section 5-Development of Boat Families

Builders of fast inboard production craft usually offer multiple choices of hull and engine but hold no stock. Consequently a particular hull/engine combination may only occasionally be built yet will still require sound certification. With so many boat engine combinations, there are significant cost implications together with delivery schedules possibly competing with adverse weather conditions. Directive 2003/44/EC at Annex VI B states the following:

“Noise Emissions:

For recreational craft fitted with inboard or stern drive engines without integral exhaust and for personal watercraft:

On one or several craft representing the production of the craft manufacturer, the sound emission tests defined in Annex I.C shall be carried out by the craft manufacturer, or on his behalf, under the responsibility of a notified body chosen by the manufacturer.”

It should be noted the European Commission's Application Guide to Directive 94/25/EC specifies in relation to Module Aa assessment that “in discussions with the manufacturer, the notified body should agree on the type, number and scope of the tests to be carried out”.

³ Directive 2003/44/EC amending the Recreational Craft Directive and Comments to the Directive Combined (First Draft p47)

Since Module Aa recognises that not all craft will have to be tested if the builder can establish a selection of craft representing the production, ICOMIA recommends the following: boat builders should consider establishing “Master Boats” against which other boats could be assessed. Such Master Boats must have taken and passed the “pass-by” test (EN ISO 14509).

The specifics of building specific boat families **must be discussed with your notified body at an early stage**, but the Group of Notified Bodies⁴ has agreed the following guidelines:

Building a Boat Family

- Boats are grouped into Families using the Hull parameters set out in the Reference Boat Standard (DIS 14509-2)
- The “Master Boats” must be tested and pass the EN ISO 14509 pass-by sound test. In addition simple on-board sound measurements should be taken simultaneously with this test using at least a Class 2 sound meter.
- Family boats will be tested using only on-board sound measurements conducted at 70km/h or the maximum speed if this cannot be achieved.
- A comparison of on-board sound measurement between the master-boat and family boats is then made
- The hull parameters, method of on-board sound measurement and other tolerances necessary to build a boat family are set out in Appendix 3

Section 6-Future Developments

There are a number of developments underway which may bring some relief in the future. **However none of this realistically could be available at the earliest until late in 2005.** These developments are described in Appendix 4

Conclusion

The advice to all boat builders is:

- **Step 1 – make a pd/f calculation to see whether your craft will require sound testing. (see Section 2)**

If it does

- **Step 2 - speak now to your notified body or expected notified body to discuss your specific requirements and challenges including the development of boat families**
- **Step 3 - start sound testing now, especially if you have multiple hull/engine combinations. This critically must include the on-board sound measurement described in Appendix 3**

AND

- **Contact your MIA for support – they may be able to coordinate testing programmes with other boatbuilders and have the latest advice on testing**

MOST IMPORTANTLY

- **Do not leave it until too late – regulations are mandatory from 1 January 2006**

⁴ Recreational Craft Sectoral Group (RSG) of Notified Bodies

Worked examples for calculating p/d ratio and Froude Numbers

1. A typical motor cruiser could be as follows: -

Water line length $lwl = 7,8$ metres
 Displacement $D = 4$ tonnes
 Engine power $P = 35hp = 26$ kW
 Speed $V = 8knots = 4,1$ metres per second

The 'Froude number' would be calculated from: - $F_n = \frac{4,1}{\sqrt{9,8 \times 7,8}} = \underline{\underline{0,47}}$

The Power Displacement ratio would be:- $P/D = \frac{26}{4} = \underline{\underline{6,5}}$

As the 'Froude number' is less than 1,1 and the Power displacement ratio is less than 40 this boat complies with the noise emissions.

2. A sailing yacht could be as follows:-

Water line length $lwl = 11,13$ metres
 Displacement $D = 12,56$ tonnes
 Engine power $P = 56hp = 42$ kW
 Speed $V = 9knots = 4,6$ metres per second

The 'Froude number' would be calculated from: - $F_n = \frac{4,6}{\sqrt{9,8 \times 11,13}} = \underline{\underline{0,44}}$

The Power Displacement ratio would be:- $P/D = \frac{42}{12,56} = \underline{\underline{3,34}}$

As the 'Froude number' is less than 1,1 and the Power displacement ratio is less than 40 this boat complies with the noise emissions.

3. A semi-displacement power boat could be as follows:-

Water line length $lwl = 10,44$ metres
 Displacement $D = 9$ tonnes
 Engine power $P = 430hp = 320$ kW
 Speed $V = 22knots = 11,32$ metres per second

The 'Froude number' would be calculated from: - $F_n = \frac{11,32}{\sqrt{9,8 \times 10,44}} = \underline{\underline{1,1^*}}$

The Power Displacement ratio would be:- $P/D = \frac{320}{9} = \underline{\underline{35,5}}$

As the 'Froude number' is equal to 1,1 and the Power displacement ratio is less than 40 this boat complies with the noise emissions. * Since the 'Froude number' is exactly on the limit, care should be exercised in the specification and calculations to ensure accuracy.

4. A small inboard engine speed boat could be as follows:-

Water line length $lwl = 4,9$ metres

Displacement $D = 0,9$ tonnes

Engine power $P = 150hp = 112kW$

Speed $V = 30knots = 15$ metres per second

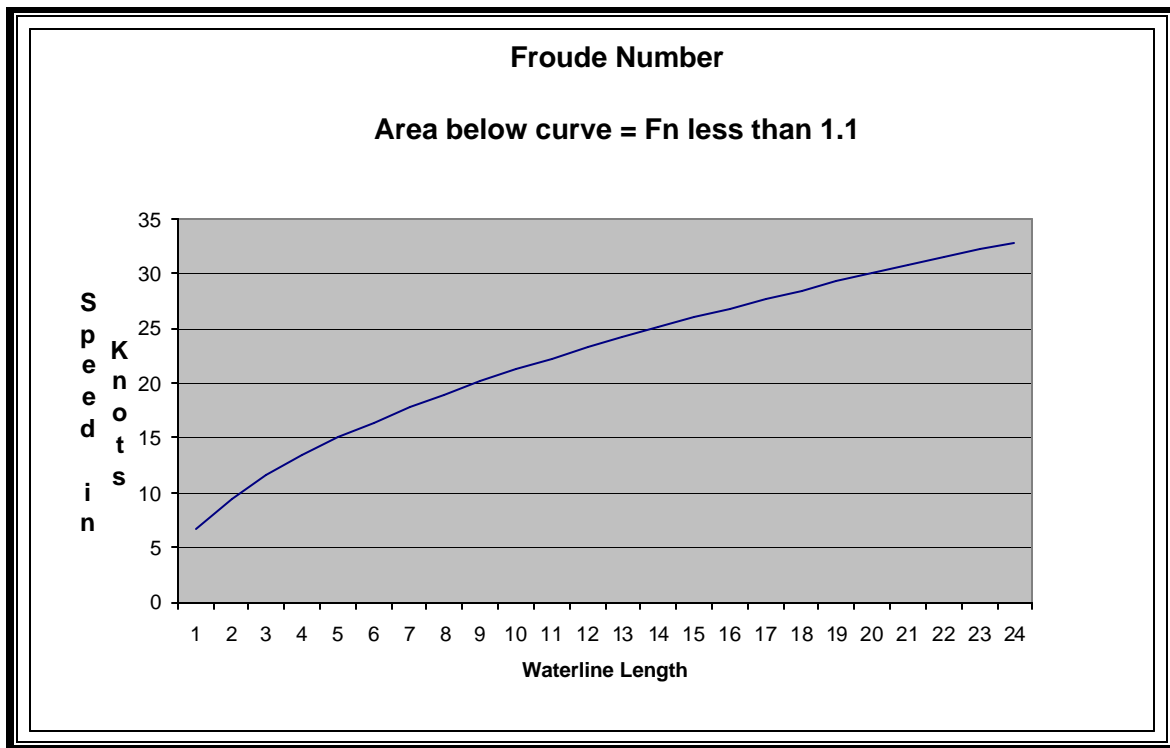
The 'Froude number' would be calculated from: - $F_n = \frac{15}{\sqrt{0,8 \times 4,9}} = \underline{\underline{2,16}}$

The Power Displacement ratio would be:- $P/D = \frac{0,112}{0,9} = \underline{\underline{124,4}}$

As this craft exceeds at least one of the calculation limits a full pass-by test using EN ISO 14509 will have to be undertaken

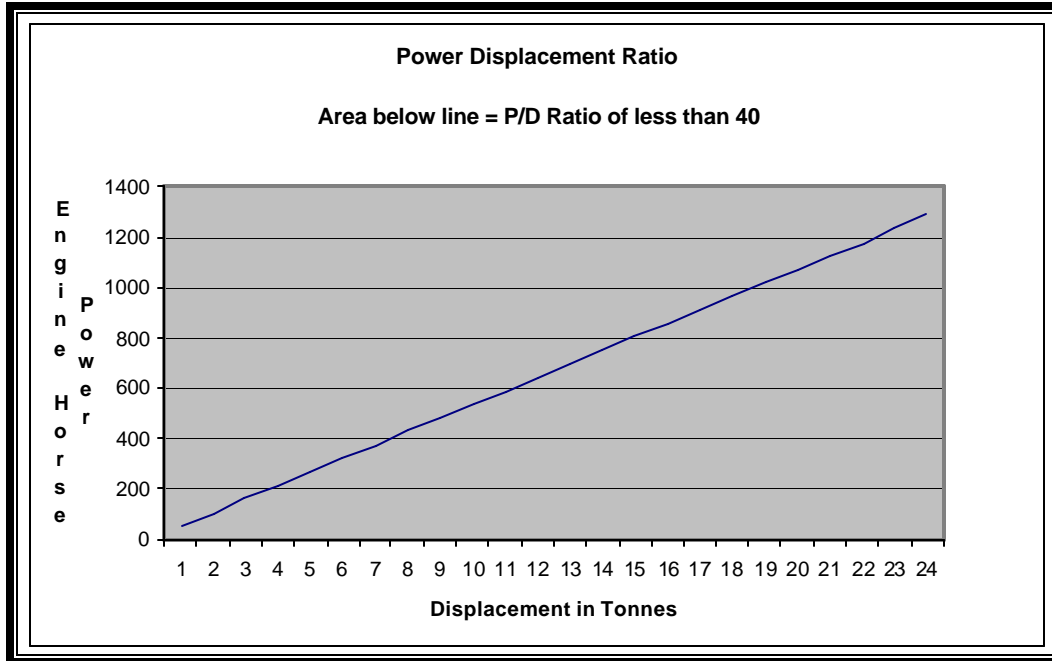
Charts for calculating Froude number and Power /Displacement ratio

Chart for Froude Number



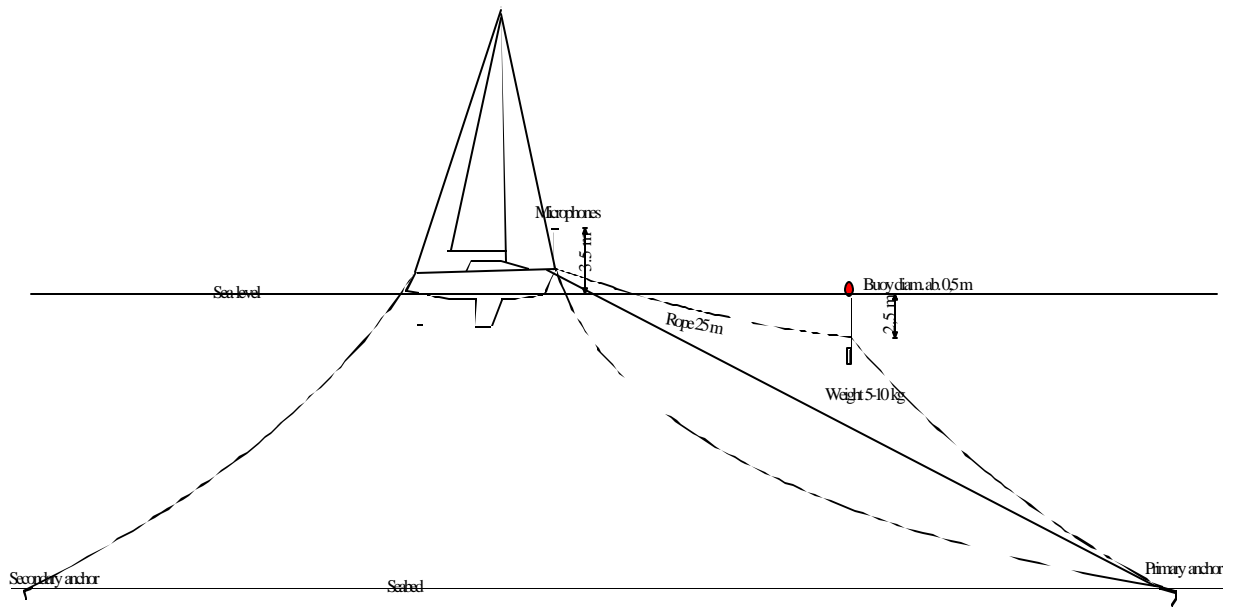
*Waterline length in metres.

Chart for Power Displacement Ratio



*Engine power is shown as Horse Power. For kilowatt rating convert hp x .75

In order to demonstrate compliance both calculations have to be satisfied and the engine(s) must be installed in accordance with the manufacturer's specifications.



CRITERIA TO DEVELOP BOAT FAMILIES

1. Selection of Master Boat.

- Selection of Master Boats should be made in coordination with the Notified Body.
- Master Boats must record a sound level in the EN ISO 14509 pass by test equal to or less than the following⁵:

- a. Single Engined Craft – 72 dB(A)
- b. Multiple Engined Craft - 75 dB(A)

This is because of the current tolerance between pass-by sound measurements and on-board sound measurements. (It is hoped that this tolerance may be revised down slightly following further evaluation from the Soundboat project)

2. Hull Parameters for Building a Boat Family:

	Key Parameters	Units	Master Boat	Family Boat	Tolerance Level vs Master Boat	Within Tolerance? Yes/no
1	Length of the waterline L_{WL} as defined in ISO 8666	m			± 10 %	
2	Beam at the waterline B_{WL} as defined in ISO 8666	m			± 10 %	
3	Bottom type configuration (hard-chine, multi-chine, flat, round)				Same	
4	Performance test mass, mp as defined in EN ISO 8666	kg			± 25 %	
5	stern shape (plan view)				Same	
6	stern shape (elevation)				Same	
7	stern swim platform yes or no				Same	
8	stern swim platform construction (solid or open)				Same	
9	On-board sound level. Enter Master Boat's Maximum Allowable Sound and Family Boat's recorded on-board sound	dB(A)			Equal to or less than Master Boat's Maximum Allowable Sound	

3. Operating and Test Conditions for on-board sound measurement

- The boat speed shall be 70kph or maximum speed whichever is the smaller
- Equipment Specification: The sound measurement equipment including the windshield recommended by the manufacturer shall meet the requirements for a Class 2 instrument according to IEC 61672-1. A sound calibrator, which meets the requirements of IEC 60942 shall be used. The overall acoustic performance of the measurement equipment shall be checked with the sound calibrator according to the instructions of its manufacturer at the beginning and at the end of each series of measurements, and at least at the beginning and end of each measurement day. The sound calibrator used for calibration of the sound level meter shall undergo laboratory verification every year with traceability to a primary standards laboratory. The microphone shield shall not show any evidence of moisture.

4. Measurement of on-board Sound

- Measurements shall be made at the seven microphone positions given in the figure in paragraph 5 below.

⁵ These tolerances are for engines >40kw. For lower power settings, Table 2, Annex 1 of Directive 2003/44/EC must be used. The same tolerance of 3 dB(A) must be applied.

- The microphone is best fitted to the end of a pole which is held manually in turn at each of the positions indicated in paragraph 5 for the time specified
- Each on-board sound level measurement shall be recorded over a 10 s period.
- At all times the microphone windshield must remain dry.
- The average of these seven sound level measurements shall be the arithmetic average of the value measured at each of the seven microphone positions.
- **Master Boats.** The sound level recorded on the sound pass-by test shall be subtracted from the allowable maximum in paragraph 1a or 1b above as applicable. This should be added to the actual recorded on-board sound. This total will be known as the Master Boat's Maximum Allowable Sound.
- **Family Boats.** The family boat's on-board sound measurement must be equal to or less than the Master Boat's Maximum Allowable Sound.
- The family boat's average sound level measurement is the on-board sound level to be inserted at Item 9 in the Key Parameters Table in paragraph 1 above.

Example:

The **Master Boat** with a single engine records the following sound emissions:

- EN ISO 14509 Test: 69dB(A)
- On-board sound: 80dB(A)

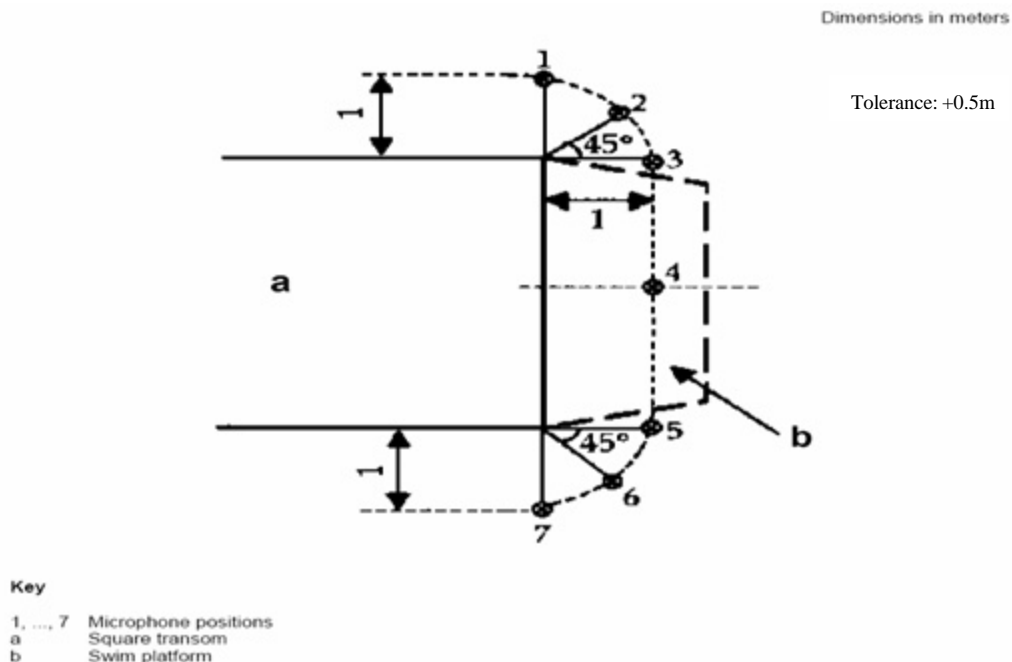
The **Family Boat** on-board sound measurement is made

Calculation of Maximum Allowable Sound

- Allowed sound level (single engine) (a) 72dB(A)
- Recorded EN ISO 14509 sound (b) 69dB(A)
- Difference (a) minus (b) = (c) 3dB(A)
- Maximum Allowable Sound: Recorded on-board sound (80dB(A)) + Difference at (c) 3dB(A) = 83dB(A). This must be entered at Serial 9 in the table in paragraph 2.
- Recorded On-Board Sound of family boat was 82dB(A), which is less than the Master Boat's Maximum Allowable Sound of 83dB(A). The 82dB(A) must be entered at Serial 9 in the table in paragraph 2.

5. **On-board Sound Measurement.**

Microphone Positions. Measurements shall be made at the seven microphone positions shown below:



NB. Microphones shall be located not less than 1m from the hull and not more than 1.5m from the hull. Similarly they shall be located not less than 1m from the water surface and not more than 1.5m from the water surface.

NEXT STEPS

Work is currently being completed in the ISO Working Group for Sound on the following amendments to EN ISO 14509:

Part 1. This will incorporate the existing pass-by test standard but hopefully with a relaxation of some of the atmospheric and weather related criteria.

Part 2. This will incorporate the Reference Boat method described in the directive. This should allow a boat to be assessed by comparison with data derived from other craft that have successfully passed the test in Part 1 and whose information is available in a published database.

Sound Boat. An EU funded project to seek alternative methods of sound assessment is progressing well and much experience gained from the project is already being incorporated into current practise. A predictive methodology incorporating on-board sound measurement and certain hull parameters is to be developed as EN ISO 14509-3, but is unlikely to be available until late in 2005. However it is only now being considered as a New Work Item by ISO, so a harmonised standard using this method is unlikely to be available until late in 2005.

News of these developments will become available through MIAs, Notified Bodies and the ICOMIA website.

This guide will be updated regularly to incorporate developments.