Underwater Radiated Noise (URN)

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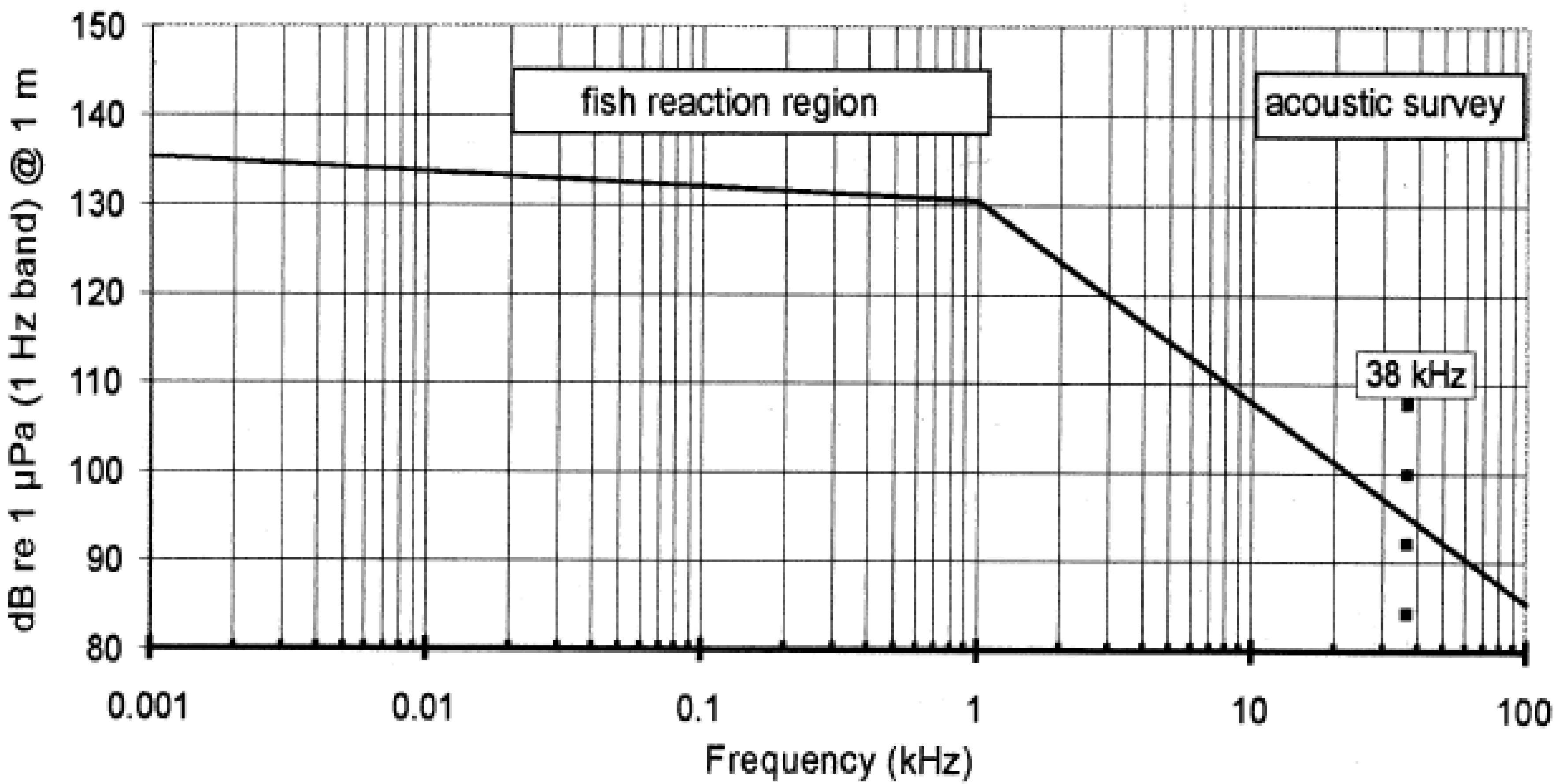
Requirements and standards

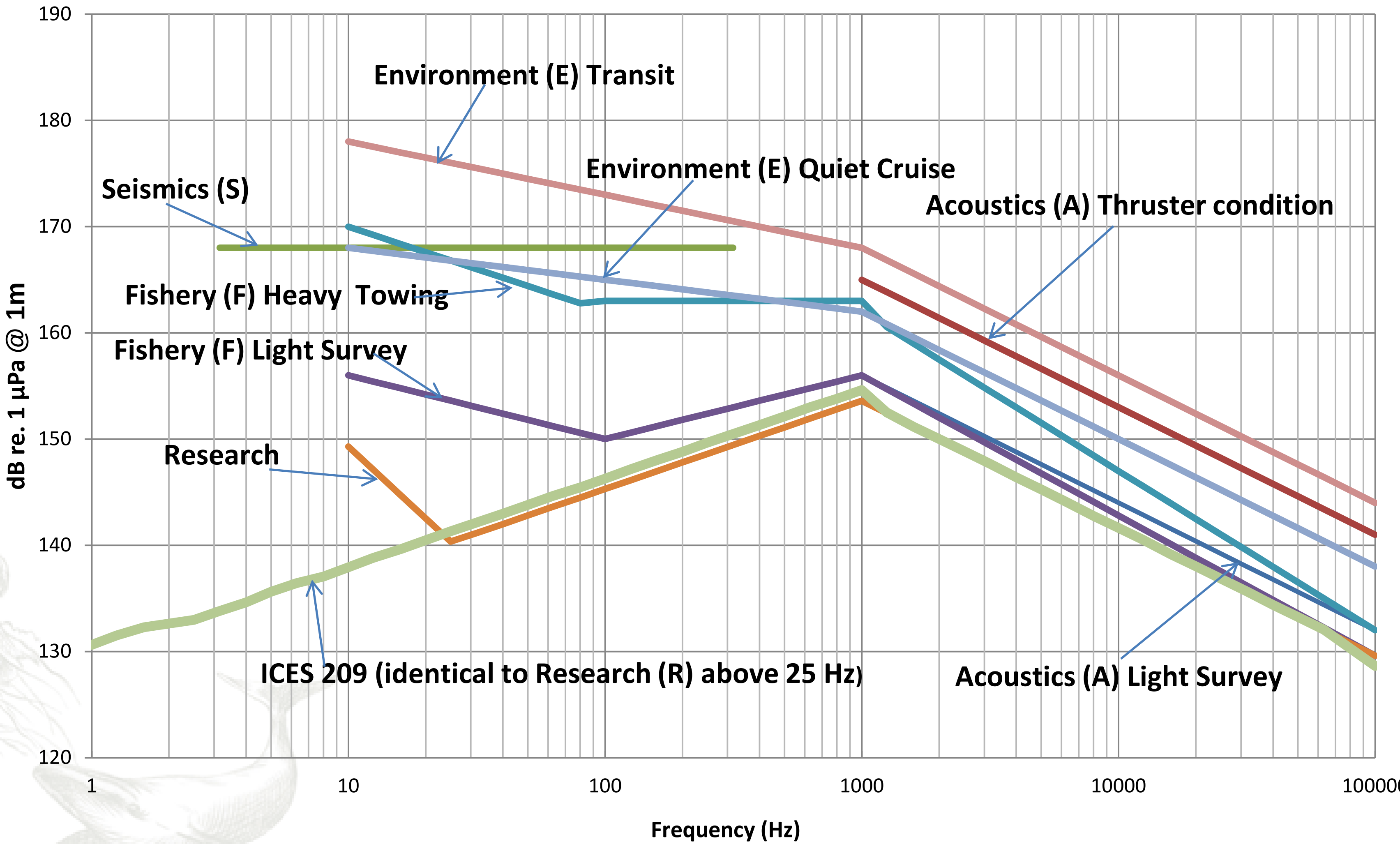
- Reduce risk for fish avoidance (1Hz – 1KHz)
- Improve signal-to-noise ratios (1KHz – 100KHz)
- Above 100KHz the URN is regarded to be so low that is it not disturbing the hydroacoustic systems
- Different standards:
  - ICES 209 CRR
  - DnV Silent
  - Other?

ICES 209 CRR



Proposed underwater radiated noise specification at 11 knots free-running for all vessels used in fisheries research.

DnV Silent notations, Summary of criteria, Band levels vs ICES 209



Hydroacoustic system frequencies

- Fisheries echo sounders:
  18, 38, 70, 120, 200 and 333 kHz
- ADCP: 38, 75 and 150 kHz
- Sonars: 10 – 120 kHz
- Multibeam echo sounders: 12 – 400kHz
- Sub Bottom Profilers: 0,5 - 100kHz

10-20Hz frequency range (1)

- The frequency range from 10 – 20 Hz is the area where peaks in the vessels noise signatures is detected. These peaks are is normally caused by the propeller blades (or slots between the blades) passing the closest section of the hull.
- The frequency of this noise will then be :

Number of blades (slots) x propeller shaft rpm /60

10-20Hz frequency range (2)

- Q: How important is the <20Hz frequency band?
  A: Regarding fish avoidance is it extremly important.
- Q: To what depth is the URN a factor regarding fish avoidance?
  A: We know that is has an impact on pelagic fish, but we do not know the effect on fish on depths larger than 200-300m since it has not been done any controlled studies.
  On the other hand, even if the URN does not scare away the fish on depths beyond 2-300m, it is still necessary to have a low URN >1kHZ in order to have good hydroacoustic performance (S/N) in order to detect fish on larger depths!

URN sources

1. Propeller noise (cavitation)
   (Propeller design & hull shape - Propeller supplier)
2. Electrical motor foundation vibrations
   (Engine vibration levels – Engine supplier and foundation stiffness – Ship designer & Yard)
3. Generator set foundation vibrations
   (Engine vibration levels – Engine supplier and foundation stiffness – Ship designer & Yard)
4. All other vibration sources such as pumps, pipes, compressors etc
   (Yard, Suppliers and Shipdesigner during detailed design and outfitting)

URN sources and measures

- Propeller
  - Propeller cavitation (Number of blades, RPM, fixed vs variable pitch)
  - Propeller exitation of hull (1Hz – 1KHz)
    - Propeller shaft vibrations and pressure pulses from propeller blade tips.
    - Good clearance between hull and propeller, and steady waterflow
  - Gearbox. Avoid gearbox!
- Rotating machinery (Use flexible mounts and stiff foundation)
  - Diesel engines (cylinder firing freq. and harmonics)
  - Generator sets
  - Fans
  - Pumps
  - Pipes

  Worst case: Diesel/gearbox/Controllable Pitch Propeller!

  Best case: Diesel Electric (AC or DC?) and fixed pitch propeller?
- Holes in hull and any other ”irregularities” in the hull creates turbulence. Therefore smoothen the hull as much as possible!

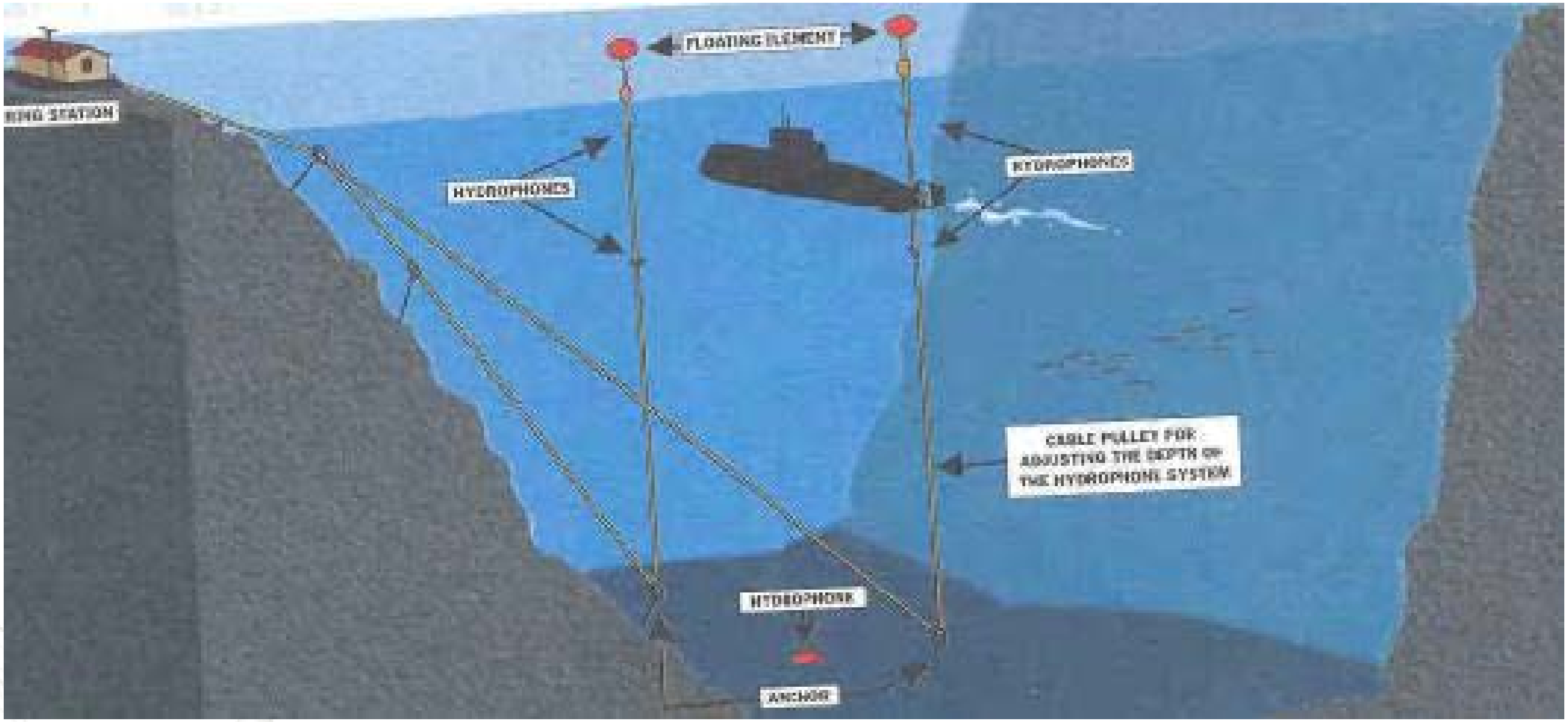
Measurement methods

- DNV Silent
- ANSI/ASA S12.64-2009 (ISO version ?)
- NATO STANAG 1136
- Q: Can we compare URN data collected with the different measurement methods described in the different standards?
  A: To our knowledge (IMR and DnV), the answer is yes, but few tests have been done

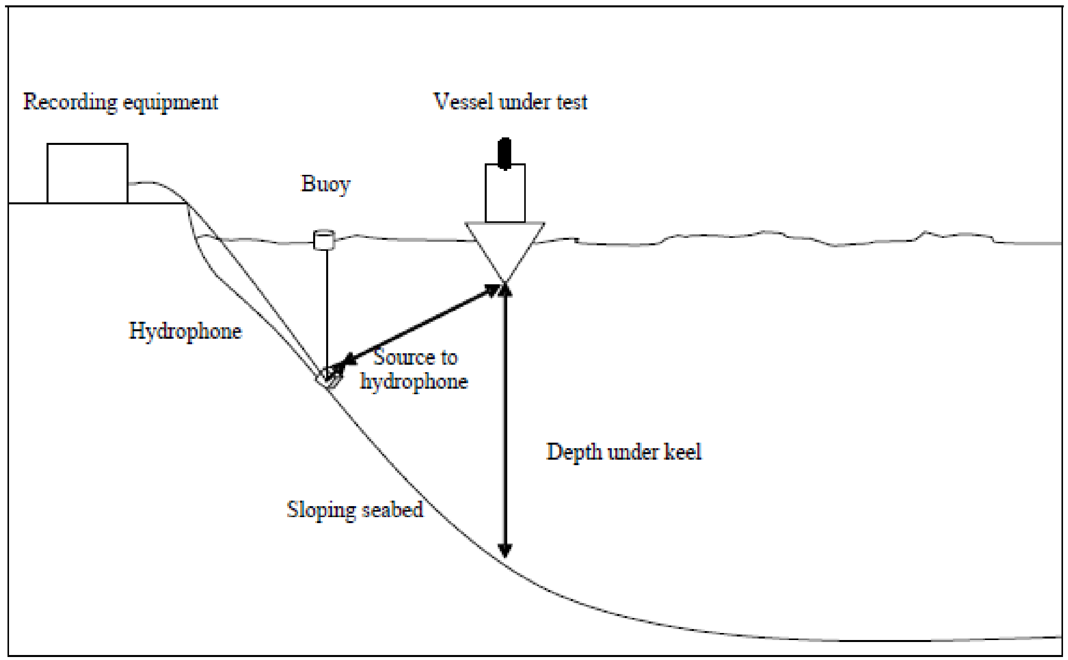
Heggernes – Static test (STANAG 1136)

- Three mooring buoys are located in a triangular pattern separated by approximately 150 m.
- Two hydrophones are mounted on the seabed, one on each side of the moored ship.
- The moored ship typically shuts down as much of the machinery as possible, and then individual potential noise sources (rotating machinery etc) are turned on and measured individually.

Heggernes hydrophones



DnV Silent measurements (1)

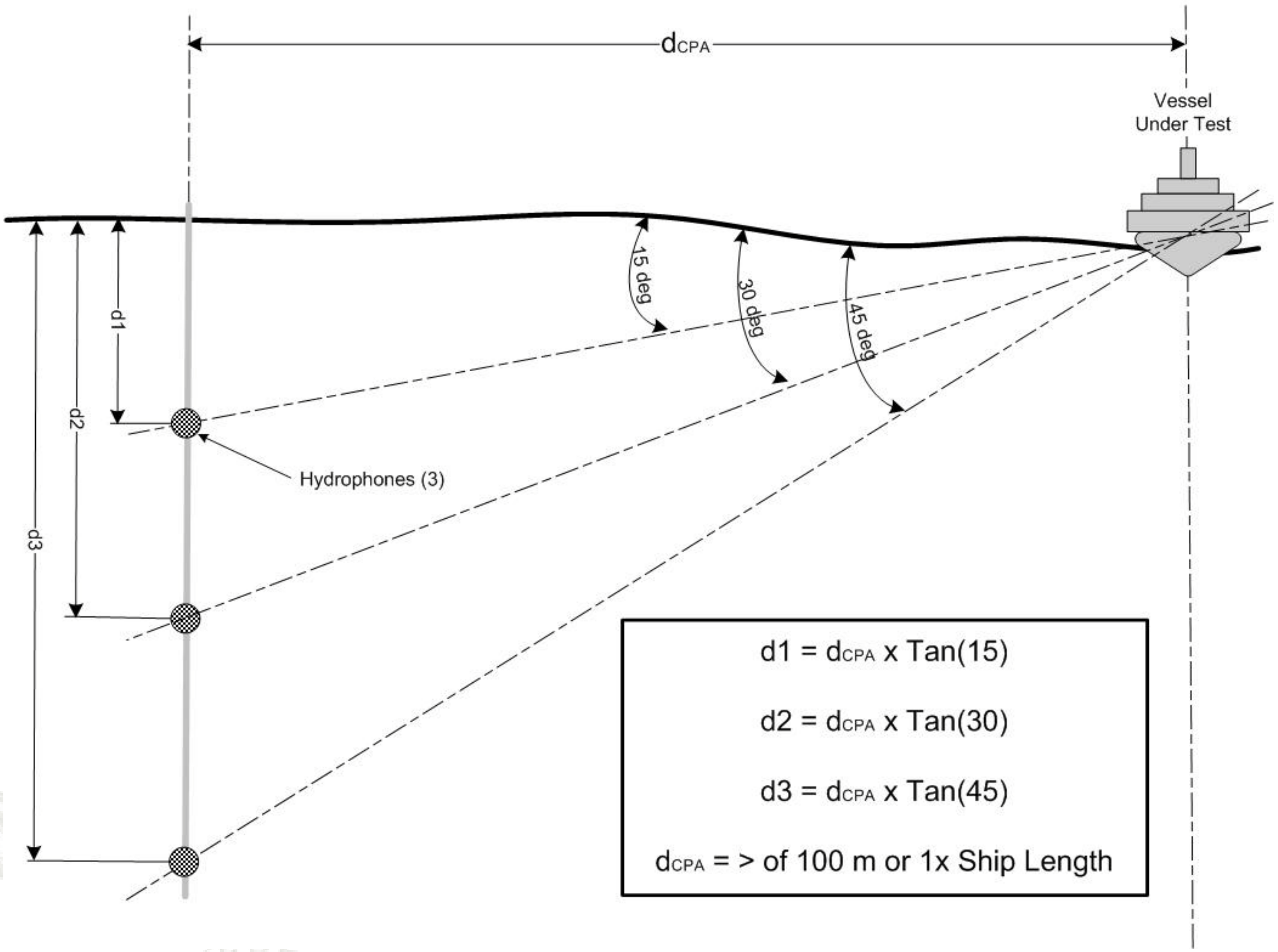


Bottom mounted hydrophone (max 0,2m above seabed), CPA 150 – 250m, Depth > 30m, Fjord/bay width >500m, sand/firm clay/stone bottom

ANSI/ANSA S12.64-2009 grades

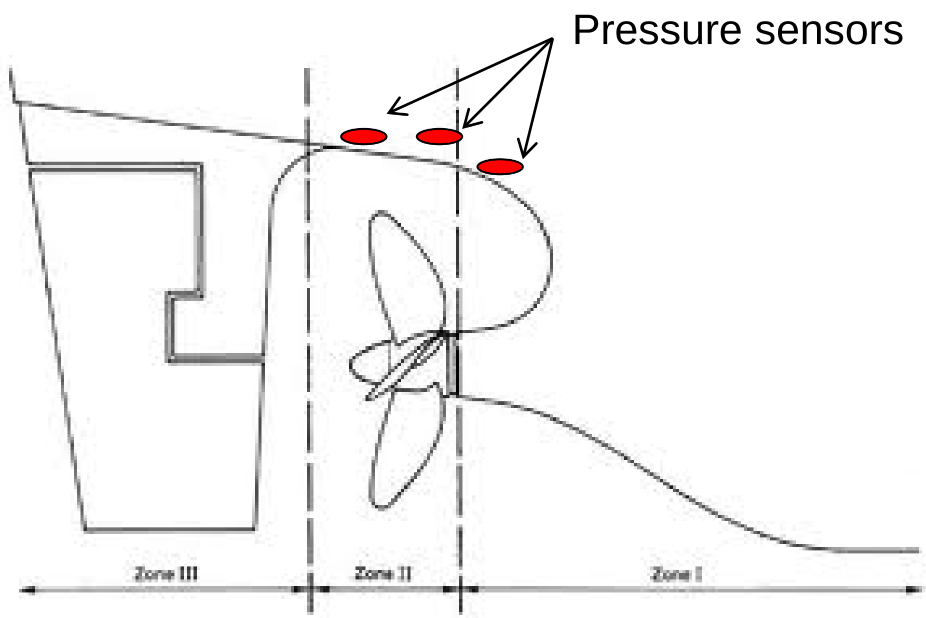
Grade	A	B	C
Grade name	**Precision method**	**Engineering method**	**Survey method**
Measurement uncertainty	1.5 dB	3.0 dB	4.0 dB
Measurement repeatability	± 1.0 dB	± 2.0 dB	± 3.0 dB
Bandwidth	One-third octave band		
Frequency range (one-third octave bands)	10 to 50,000 Hz	20 to 25,000 Hz	50 to 10,000 Hz
Narrowband measurements	Required	Required	As Needed
Number of hydrophones	Three	Three	One
Hydrophone geometry	Figure 1	Figure 1	Figure 2
Nominal hydrophone depth(s)	15°, 30°, 45° angle	15°, 30°, 45° angle	20° ± 5° angle (see 5.4)
Minimum water depth	Greater of 300 m or 3x overall ship length	Greater of 150 m or 1.5x overall ship length	Greater of 75 m or 1x overall ship length
Minimum distance at closest point of approach (CPA)	Greater of 100 m or 1x overall ship length		

ANSI/ASA S12.64-2009 measurements Grade A and B



How to measure below 20Hz?

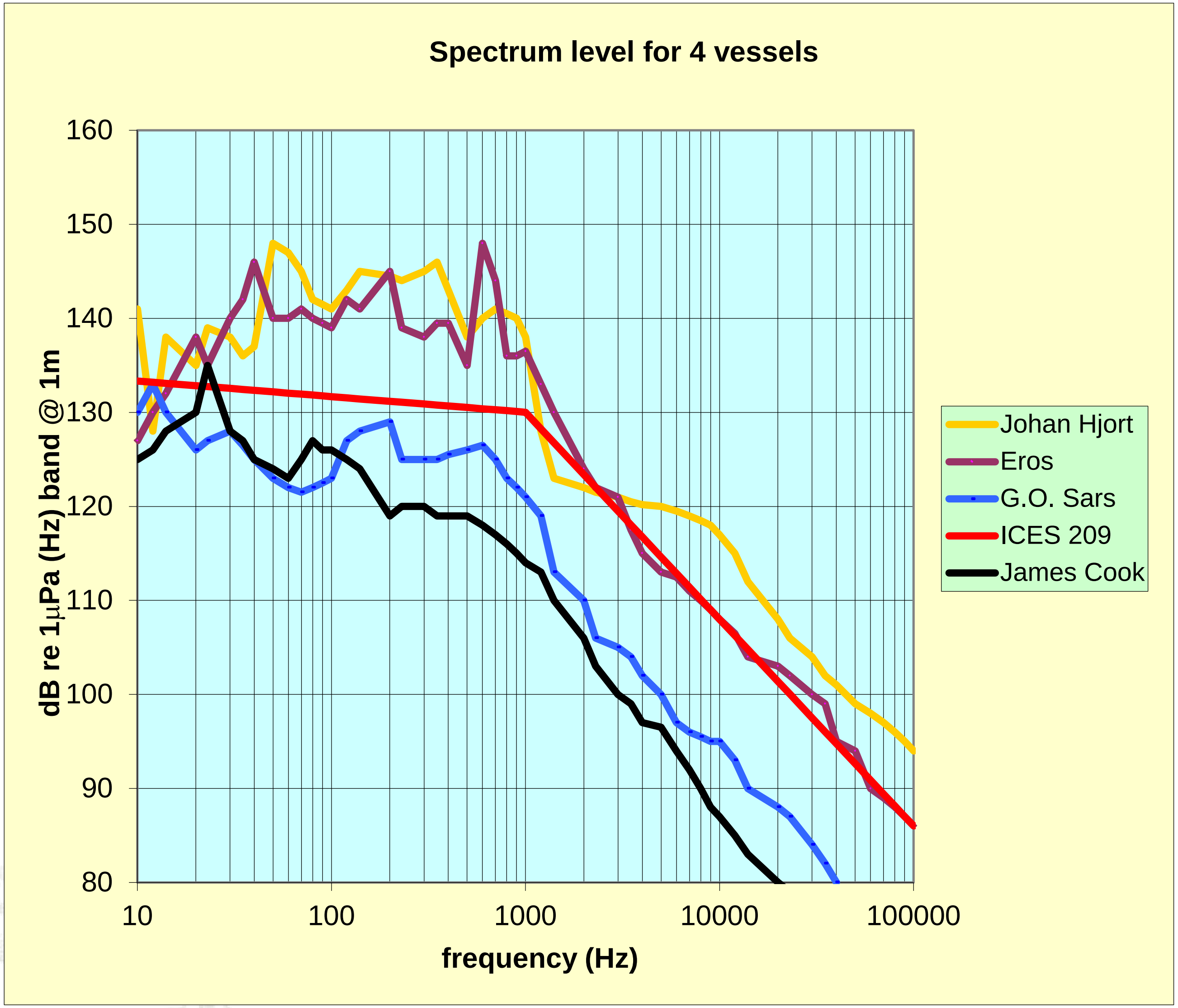
- Normal test set up does not work well for frequencies below 20Hz
- A possible ”work around” is to measure propeller pressure on the hull above the propeller area



What is an acceptable URN level?

- How much can a vessel exceed the ”requirements” set in ICES 209, Silent-R or other standards before the collected data is regarded as ”sub-standard” or has to be rejected, e.g. in ICES working groups developing recommendations regarding fish stocks, catch quotas etc?
- Is there a standard method for ”weighting” the collected data depending on the URN curve for the vessel who collected the data?

Comparison between ”Johan Hjort”, ”Eros” ”James Cook” and ”G.O. Sars”



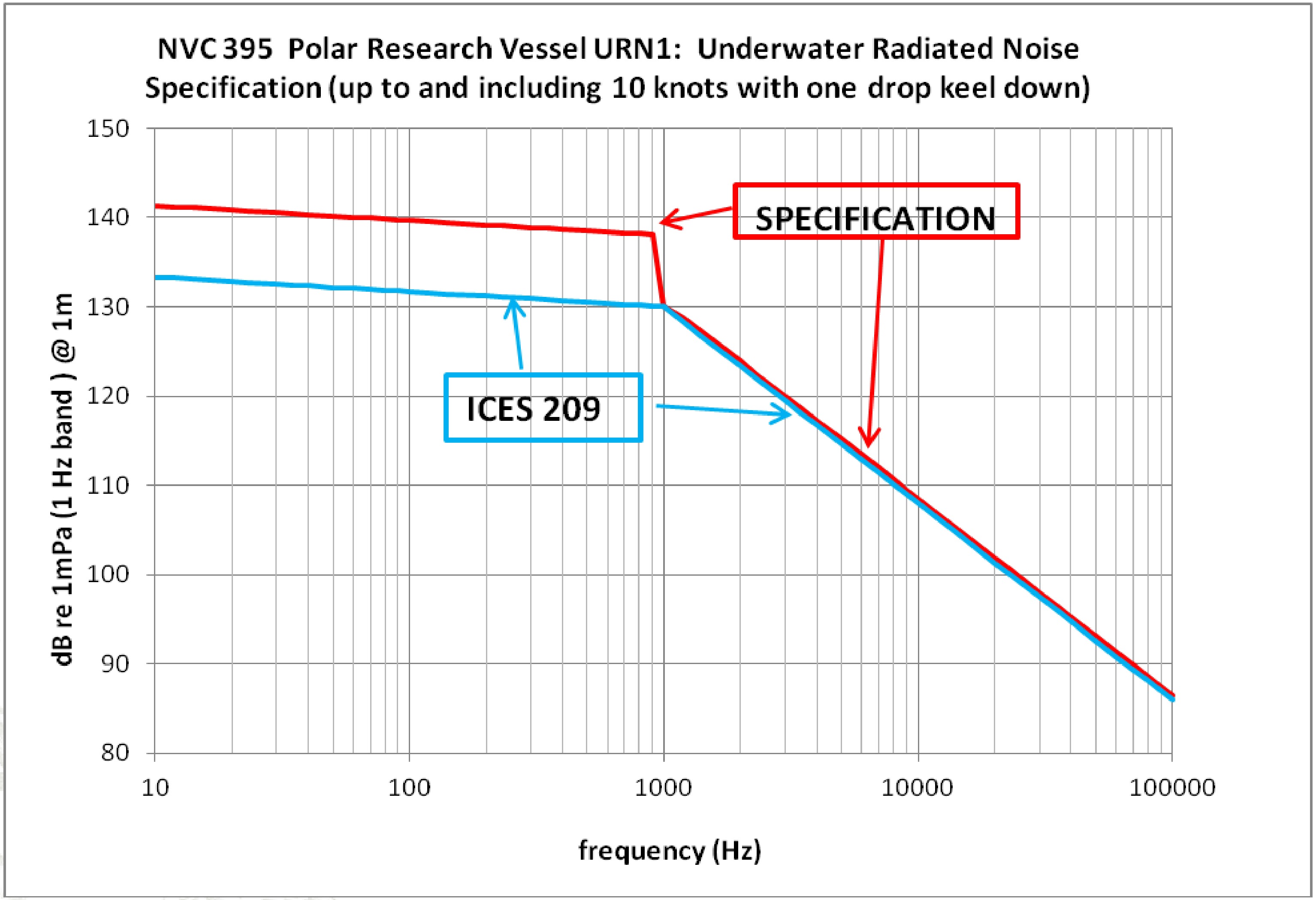
”Standard” propulsion system

- Generator sets (diesels and generators) resiliently mounted on a single or double flexible dampened ”raft” fixed to the hull with extra strength in the foundation to avoid transmission of vibrations in the hull
- DC propulsion motors connected to the propeller shaft(s)
- Fixed pitch large, 5-7 bladed, slow rotating propeller(s)

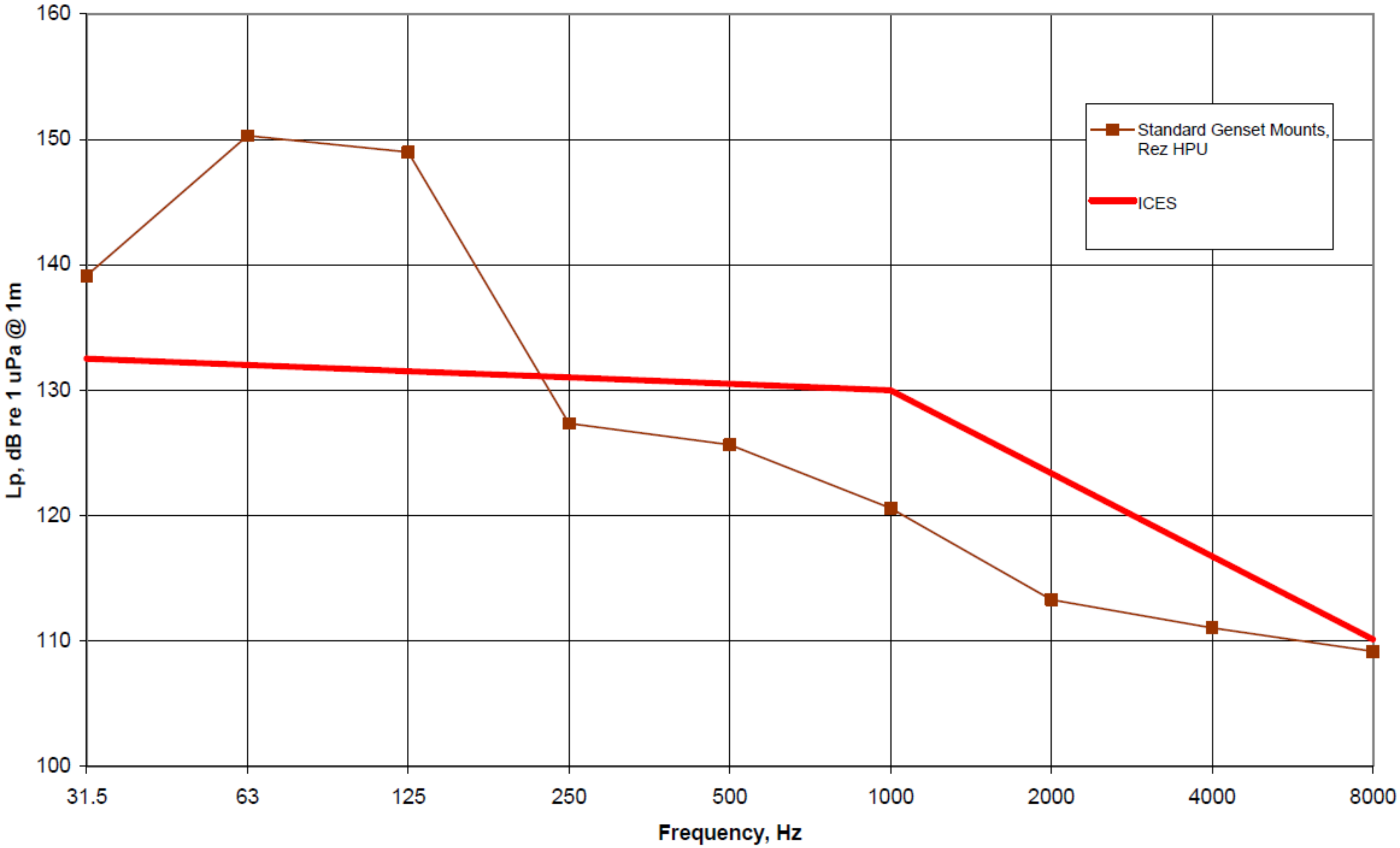
Use of AC motors and/or ”pods”

- RRS Discovery is fitted with AC motors and 2 x Azimuth Thrusters with 5-bladed, fixed pitch, 3.6m diameter. (Not noise tested yet. Own defined URN curve)
- ARRV Sikuliaq is fitted with AC motors and Z-drives. (Not noise tested yet. Very modified ICES 209 curve)
- Maria S. Merian is fitted with AC motors and azipods. (Claims to meet ICES 209. No data available)
- Simon Stevin is fitted with AC motors and FP propellers. (Claims to meet ICES 209. No data available)
- Investigator is fitted with AC motors and shaft/propellers. (Designed to Silent-R. Not tested yet)

New Norwegian Polar Research Vessel (AC el.motors and Z-drives)



Predicted URN signature for ARRV Sikuliaq (8 knots)



R/V Investigator – Why AC? (1)

- DC motors have some disadvantages
  - Brushes require maintenance and replacement
  - Thyristor power converters introduce undesired electrical harmonics into the electrical system (require harmonic filters unless a 24 or more pulse system is used)
  - Large phase shifting transformers are required
- AC motor technology has matured significantly and is now the main choice for electric propulsion
  - Motors are smaller and lighter
  - Power conversion equipment is heavier than DC
  - Overall an AC system is lighter and usually less expensive
  - Saves space in the ship
  - Less maintenance overall

R/V Investigator – Why AC? (2)

- AC drives require two power conversions
  - AC to DC and DC back to AC which creates torque pulses in the motor
- Creates structureborne vibration
- Creates unsteady forces on the propeller
  - Introduction of pulse width modulation (PWM) and indirect power conversion reduces noise (active front end)
  - Use of simpler induction motors with an active front end and a sine wave filter at the input to the motor show promise for quiet ships
- Based on existing vessel data and manufacturer predictions it appears possible that AC propulsion can support ICES 209 or Silent R
- Drive system must use an active front end and sine wave filter
- Motors must meet a structureborne noise requirement

R/V Investigator – Why AC? (3)

- Motors must incorporate quieting technology:
  - Electromagnetic Design (stator arrangement, slot ratio)
  - Shaft Design (balance, stiffness, fundamental frequencies)
  - Bearing Design (high quality sleeve bearings, concentricity)
  - Frame Design (interface to stator, stiffness, and fundamental frequencies). Occasionally this can require resilient mounting of stator within the motor frame although this is more normal when there are shock requirements on the motor.
  - Cooler Box Design (Use of anti-vibration mounts between the cooler box and motor frame)
  - Coupling Design and Motor Mounting (selection of resilient mounts)

Sect.	Item	Description	DC Benefit			AC Benefit		
			H	M	L	L	M	H
2	Resilient Mounting	No difference			◄	►		
2.4.1	Rigid Mounting	Slight benefit to DC			◄			
3.1	Electrical System Efficiency	Slight benefit to DC as losses in drive lower			◄			
3.2	Power Factor	Near unity power factor at low speeds mean better generator utilisation by the AC solution				►		
3.2.1	Generator Rating	Possibility to have improved generator rating with AC solution				►		
3.3	Harmonics	Different methods used by each solution. Slight benefit to AC				►		
3.4.1	Dimensions	AC benefits due to lack of transformer requirement				►	►	
3.4.2	Weights	AC benefits due to lack of transformer requirement				►	►	
3.5	Fuel Consumption	AC due to better generator utilisation				►	►	
4.1	Maintenance – Drive System	No difference			◄	►		
4.2	Maintenance – Motor	Clear AC benefit with reduced maintenance				►	►	►
4.3	Maintenance Rigid or Resilient	There is a slight benefit in rigid mounting as the maintenance costs for inspection and replacement would not be present. However, as there will be other significant equipment also requiring resilient mount (e.g. diesel generator sets, pumps, Air conditioning units, etc.), the actual increase in maintenance will be very small.						

AC or DC?

- Many RVs with DC motors have been built, measured and proven to meet the ICES 209 URN curve. Measurement data are published and made available for ”scrutiny”
- No RVs with AC motors have so far been built and measured, published the results and made the data avaialable to the ”world”!
- IMR is therefore planning with DC motors on the ”Dr. Fridtjof Nansen replacement vessel” until someone comes up with results for AC motors on flexible mounts connected to a propeller shaft using a flexible coupling that meets the ICES 209 URN curve from 10 Hz and upwards