**Subject:** **ARRV Underwater Radiated Noise Design Limit**
Date: 29 July, 2008

References:

1. UNOLS Science Mission Requirements – dated 2000/2001
2. ICES Cooperative Research Report No. 209
3. Measurement of the R/V Revelle Underwater Radiated Noise and Implications for ARRV – dated January 14, 2003

Purpose:

The ARRV has been designed to achieve the lowest reasonably possible Underwater Radiated Noise (URN) limit given our current technology and the design constraints of meeting the requirements to be ice capable. This paper discusses the URN design limit being used for ARRV along with a comparison of the ARRV predicted URN to a number of other UNOLS vessels.

Discussion:

The Science Mission Requirement (SMR) in reference 1 required the ARRV to meet the ICES requirement for URN in reference 2 at a speed of 8 kts. The ICES URN standard is actually for 11 kts, but when the requirement was included in the SMR it was recognized that the ice capable requirement for the ARRV would effect what the ARRV could achieve.

The ICES requirement is intended for a fisheries research vessel and not a general oceanographic vessel such as the ARRV. However, since there was no other standard available at the time the SMR was drafted (and there still is no other standard), it was included as a requirement of the SMR because even for a general oceanographic vessel minimal URN provides many desirable benefits. After significant design analysis during the concept design stage of the feasibility of the ARRV meeting ICES, it was determined that the requirement for the ARRV to be ice capable and meet the ICES criteria were not compatible. The ICES limitations were predicted to be achievable above 250Hz, but were not practicable for an ice capable ship below 250Hz. The following factors have significant influence on the ARRV's underwater radiated noise:

- Vessel hull form is not optimized for low noise. It is optimized for combined ice and open water resistance characteristics which can be at odds to low noise optimization.
- Vessel has twin, high power Z-drives with propellers designed for high bollard thrust in order to provide acceptable ice performance. Z-drives were chosen to provide a high degree of maneuverability in ice and open water. The Z-drives and their propellers are not optimal for underwater radiated noise as they must be designed for milling ice without damage.

- Highly flexible (e.g., double raft) mounting of main generator sets as well as resilient mounts for the Z-drives and thruster are not compatible with operating in ice conditions.

Since the ARRV was not intended to be a fisheries research vessel, the Design Oversight Committee made a decision at the 27 July 2001 Concept Review Meeting to delete the requirement to meet ICES noise criteria. It was decided to design the vessel to be as "quiet as practical", given the competing design requirements to be capable of operating in ice.

To help quantify what would be an acceptable level of URN for the ARRV to meet a "quiet as practical" standard, full scale noise tests were done on an existing UNOLS vessel. The R/V REVELLE was chosen for these tests since it has similar horsepower and azimuthing propulsion as the ARRV. The REVELLE was also seen as a good general purpose oceanographic vessel that was considered satisfactory with regard to URN. The testing was carried out in November 2002 by Noise Control Engineering (NCE, the project's noise control consultant) and the results used as a benchmark with which to compare the predicted URN for the ARRV too. It was felt that if the ARRV could achieve an URN level at the point of cavitation inception that was at least as good as REVELLE then it would be acceptable given the ARRV's intended mission.

The resulting URN design limit in the ARRV specification was the end product of the design efforts that had gone into development of the ARRV. The NCE model prediction for the ARRV indicates that below 250Hz the noise from Z-Drives and generators, even with significant noise reduction measures, will exceed ICES at 50 Hz and 125 Hz by 10 to 12 dB respectively. At frequencies higher than 200Hz, the NCE prediction is for noise to be less than the ICES standard when the ARRV is operating at 8kts free running. Accordingly, a practicable design noise limit curve was developed and included in the contract specs issued in 2004. The current design limit is the same one that was developed in 2004 and has been validated during our ongoing Project Refresh as an aggressive, but achievable URN design limit. The same for our propeller design requirements, given the design constraints for an ice capable propeller and the horsepower requirement for the vessel, designing a propeller with cavitation inception greater than 8 kts is an achievable requirement. A major focus of the Project Refresh has been to strengthen the design package requirements and guidance to the shipbuilder to help ensure the delivered vessel will meet the specified URN limit.

<u>Comparison of URN Design Limit</u>

Figure 1 at the end of this paper graphically shows how the ARRV URN design limit and it's predicted URN noise level compares to a number of other vessels as well as the ICES standard. Figure 1 includes the:

- ICES Standard - for all speeds from 0 – 11 knots free running.
- ARRV specified design limit – 0 to 8 kts free running.

- NCE updated noise model results for the ARRV – Prediction at 8 kts free running.
- R/V REVELLE - measured at10.6 kts free running.
- R/V SHARP – measured at 8 kts worst case which was at delivery with a singing propeller
- R/V SHARP – measure at 8 kts best case after correcting the singing propeller

The comparisons with REVELLE and SHARP are intended only to provide a qualitative comparison of the expected ARRV URN with two known UNOLS vessels.

The URN noise for REVELLE is from the testing that was done in November 2002. While URN noise was also measured at 6.5 kts and 0 kts for the REVELLE, we have only shown the results here for 10.6 kts. This speed was chosen as it is the speed that is just below the inception point for propeller cavitation on the REVELLE. This is similar to the ARRV where 8 kts is the point just below the point where cavitation is predicted to start on the ARRV given its propeller design criteria. Both the ARRV and REVELLE are designed as general oceanographic vessels.

The noise for SHARP is shown at 8 kts which is also just below its point of propeller cavitation. In contrast to the ARRV though, the SHARP design was optimized for reducing URN since it did not have the design constraint of having to be ice capable. This allowed additional isolation mounting of the large machinery such as generators and Z-drives along with optimizing the hull and propellers for noise reduction.

How this can be expected to impact science is a function of the type of science being done. The frequency of underwater radiated noise that is of interest to different science disciplines falls into three general frequency bands:

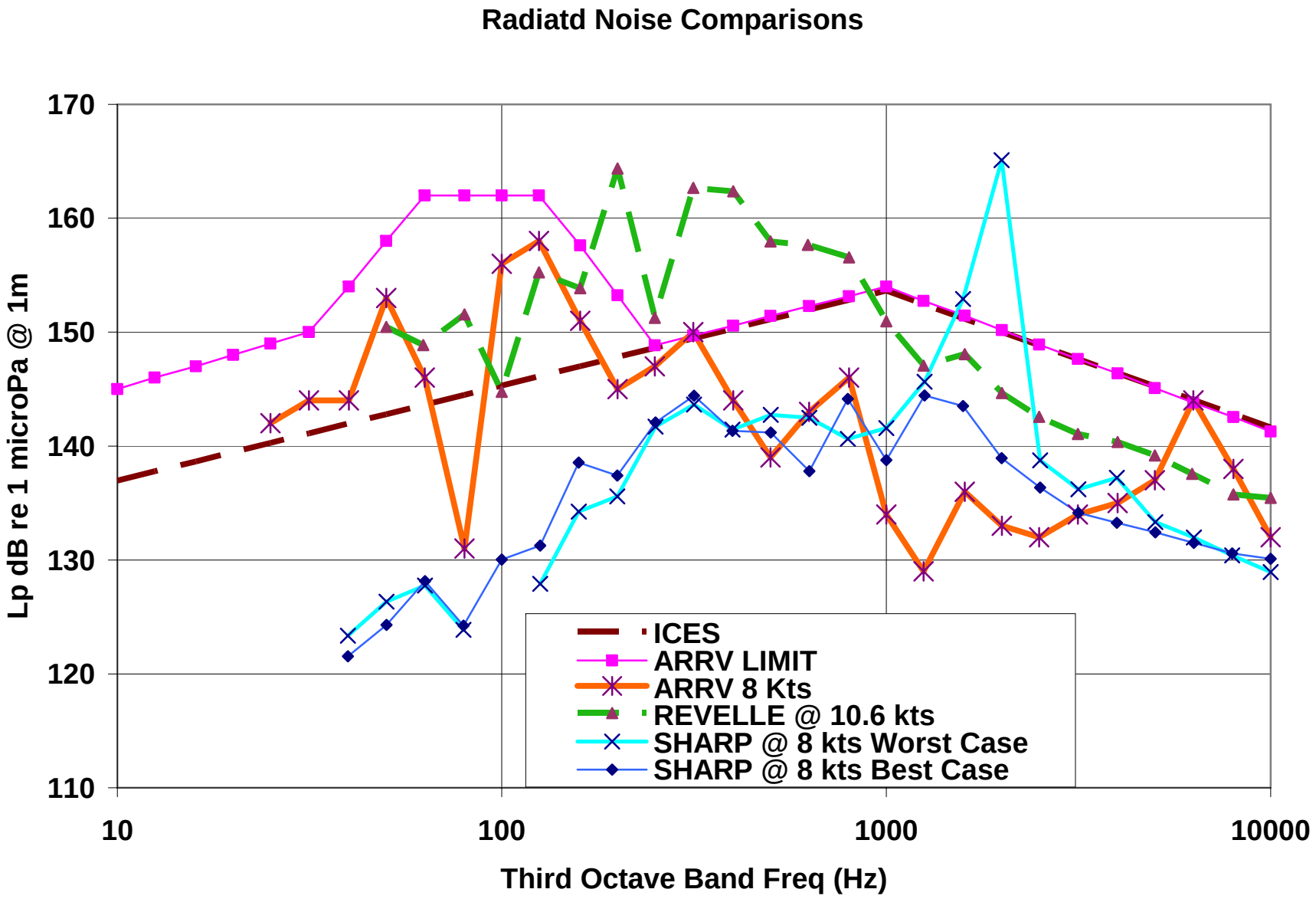
- 0 to 250 Hz – seismic work
- 250 to 1000 Hz – fish stock assessment
- 1000 Hz and above – all who use the various hull and centerboard mounted acoustic systems

For the predicted noise limit on the ARRV this means the biggest impact will be on seismic work. As discussed earlier, the primary noise sources for this range of frequencies are the generators and Z-drives gear noise. Over the course of the ARRV design development, much effort has gone into trying to reduce noise signatures for this equipment while still retaining the robust installations required for an ice capable vessel. This effort, combined with our focus on noise during the design refresh to provide better guidance in the specification/drawings to the shipyard and greater oversight by the UAF inspection team during construction will prove to be an effective combination for minimizing the ARRV's noise signature. A summary of the ARRV design features geared towards reducing noise:

| NOISE SOURCE | ARRV TREATMENT |
|---|---|
| **PROPULSION MACHINERY** | |
| DIESEL GENERATOR ISOLATION | SINGLE MOUNT |
| ELECTRIC MOTOR ISOLATION | HARD MOUNT |
| AUXILIARIES | ISOLATION MOUNTED IF OPEATING IN QUIET MODE |
| PIPING | CRITICAL SYSTEMS TREATED |
| PROPULSION TYPE | HARD MOUNTED, ICE STRENGTHENED (2) Z-DRIVE |
| **TREATMENTS** | |
| HULL DAMPING | UNCONSTRAINED, TREATMENT APPLIED DIRECTLY TO THE HULL PLATE |
| HULL INSULATION | ACOUSTIC TILES |
| BOW THRUSTER | SPECIAL QUIET UNIT |

## Conclusion

The ARRV compares favorably to a modern general purpose oceanographic vessel for underwater radiated noise. Any additional noise treatment could only be done at a significant additional cost and would affect the ice capable ability of the vessel. We believe that given the trade-offs of cost versus noise performance for a vessel designed to operate in the ice, that the ARRV will prove to be an excellent compromise.


Radiatd Noise Comparisons
Lp dB re 1 microPa @ 1m
170
160
150
140
130
120
110
10
100
1000
10000
Third Octave Band Freq (Hz)
ICES
ARRV LIMIT
ARRV 8 Kts
REVELLE @ 10.6 kts
SHARP @ 8 kts Worst Case
SHARP @ 8 kts Best Case