An underwater acoustical trial was conducted on R/V Hugh R. Sharp on 23/24 October 2009 at the Atlantic Undersea Test and Evaluation Center (AUTEC) in the Tongue of the Ocean, Bahamas. The testing used the measurement processes of the Surface Ship Radiated Noise Measurement (SSRNM) program with some modification in line with a draft of Grade B of AMERICAN NATIONAL STANDARD, Quantities and Procedures for Description and Measurement of Underwater Sound from Ships. Thirty two test runs were conducted at speeds from DIW to 9 knots past a vertical string of hydrophones suspended from the stern of the R/V Ranger. Beam aspect data used an integration window covering +/- 30 degrees about CPA of the dominant noise source location. A nominal 180-yard CPA was used for the beam aspect runs. Ship speed was set by using a specified shaft rpm. Data were not corrected for any image interference effects. The attached Testing Information Appendix provides informational characteristics from the testing.

Weather conditions were marginal for measuring a quiet ship. Background noise limited the frequency range to approximately 100 Hz to 32 kHz that ship noise could be extracted from the ambient noise conditions. Wind speed was 6 to 18 knots with seas 2 to 5 feet. Background noise in the 1000 Hz one-third octave band ranged from 82 to 89 dB. The test site was free from shipping interference for most of the evaluation.

Two methods of steering the ship were used to attain a straight line course depending on ship speed. At 6 knots and slower speeds auto heading was used. This method provided satisfactory control at slow speeds. In this mode the Z drive thrust of each unit was angled towards the center line of the ship at various degrees to keep the ship head automatically pointing at the desired angle. Generally at speeds of 6 knots the Z drive thrust was angled inboard on each shaft by 30 degrees while at 4 knots the angle increased to approximately 45 degrees. At higher speeds auto pilot was used. This method kept the Z drive thrust parallel for both units. Propeller cavitation was detected for the entire run when in auto heading mode with cavitation “burst” increases as thrust headings changed, however in auto pilot mode steady state propeller cavitation was lower with significantly evident cavitations bursts when ever there was a course correction to keep the ship on the desired track (embedded recording at 8 knots in auto pilot). Attempts were made to operate the ship in auto pilot at speeds below 7 knots, however steerage was insufficient to maintain the ship on a straight line. Likewise an attempt was made to utilize asynchronous (one Z drive thrusting dead ahead and the other providing steerage) auto pilot or auto heading however the wind and seas prevented this lineup from maintaining a straight line course.

Figures 1 through 10 provide 1/3-octave band measurements of ship radiated noise at the various conditions measured compared to a recommended noise limit derived from that presented in the International Council for the Exploration of the Sea (ICES) report No. 209 of May 1995. Figure 11 is a record of the background noise measurements taken during the acoustic trial. Table 1 provides the tonals detected at the various speeds. Source identification was made based on the character of the tone and mechanical description of the ship machinery. Figures 12 through 14 provide LOFARgram presentations of selected measurement conditions. This presentation shows tones as dark lines at the frequency detected as a function of time. The most significant tonal components were provided by the upper and lower drive train gear mesh. The imbedded recording demonstrates the “whine” at 7 knots.
To convert from levels re 1 μbar to levels re 1 μPa add 100 dB.

R/V HUGH R. SHARP
SSRN M AUTEC
24 October 2009
BEAM ASPECT SIGNATURES
- 4 KNOTS GENERATOR 1
- AUTO HEAD STEERING
- ICES
ONE-THIRD-OCTAVE BAND CENTER FREQUENCIES IN Hertz

1/3-OCTAVE BAND LEVELS IN DECIBELS RELATIVE TO 1 µPa AT 1 YD

R/V HUGH R. SHARP
SSRM AUTEC
24 October 2009
BEAM ASPECT SIGNATURES

- 6 KNOTS GENERATOR 1
- AUTO HEAD STEERING
- ICES

TO CONVERT FROM LEVELS RE 1µBAR TO LEVELS RE 1µPA ADD 100 dB

FIGURE 2
ONE-THIRD-OCTAVE BAND CENTER FREQUENCIES IN HERTZ

1/3-OCTAVE-BAND LEVELS IN DECIBELS RELATIVE TO 1 µPa AT 1 YD

R/V HUGH R. SHARP
SSRNM AUTEC
24 October 2009
BEAM ASPECT SIGNATURES

- 7 KNOTS GENERATOR 1
  AUTO HEAD STEERING
- 7 KNOTS GENERATOR 1
  AUTO PILOT STEERING
- ICES

TO CONVERT FROM LEVELS RE 1 µBAR
TO LEVELS RE 1 µPa ADD 100 dB

FIGURE 3
ONE-THIRD-OCTAVE BAND CENTER FREQUENCIES IN HERTZ

1/3-OCTAVE BAND LEVELS IN DECIBELS RELATIVE TO 1 µPa AT 1 YD

R/V HUGH R. SHARP
SSRNM AUTEC
24 October 2009

BEAM ASPECT SIGNATURES
- 8 KNOTS GENERATOR 1 AND 2 AUTO HEAD STEERING
- 8 KNOTS GENERATOR 1 AND 2 AUTO PILOT STEERING
- ICES

TO CONVERT FROM LEVELS RE 1 µBAR TO LEVELS RE 1 µPA ADD 100 dB

FIGURE 4
1/3-OCtAVE-BAND LEVELS IN DECIBELS RELATIVE TO 1 µPa AT 1 YD

TO CONVERT FROM LEVELS RE 1 µBAR TO LEVELS RE 1 µPA ADD 100 dB

ONE-THIRD-OCtAVE BAND CENTER FREQUENCIES IN Hertz

R/V HUGH R. SHARP
SSRN M AUTEC
24 October 2009
BEAM ASPECT SIGNATURES

8 KNOT GENERATOR 1 AND 2 CENTER BOARD DOWN

8 KNOTS GENERATOR 1 AND 2 ICES

FIGURE 5
1/3-OCTAVE BAND LEVELS IN DECIBELS RELATIVE TO 1 µPa AT 1 YD

R/V HUGH R. SHARP
SSRNM AUTEC
24 October 2009
BEAM ASPECT SIGNATURES

- 8 KNOTS GENERATORS 3 AND 4
- 8 KNOTS GENERATORS 1 AND 2
- ICES

TO CONVERT FROM LEVELS RE 1 µBAR TO LEVELS RE 1 µPA ADD 100 dB

RADIATED NOISE

ONE-THIRD-OCTAVE BAND CENTER FREQUENCIES IN Hertz
ONE-THIRD-OCTAVE BAND LEVELS IN DECIBELS RELATIVE TO 1\(\mu\)Pa AT 1 YD

FIGURE 7

TO CONVERT FROM LEVELS RE 1\(\mu\)BAR TO LEVELS RE 1\(\mu\)PA ADD 100 dB

TO CONVERT FROM LEVELS RE 1\(\mu\)BAR TO LEVELS RE 1\(\mu\)PA ADD 100 dB

ONE-THIRD-OCTAVE BAND CENTER FREQUENCIES IN Hertz

R/V HUGH R. SHARP
SSRNM AUTEC
24 October 2009
BEAM ASPECT SIGNATURES

9 KNOTS GENERATOR 1 AND 2
AUTO PILOT STEERING
ICES
1/3-OCTAVE BAND LEVELS IN DECIBELS RELATIVE TO 1 µPa AT 1 YD

TO CONVERT FROM LEVELS RE 1 µBAR TO LEVELS RE 1 µPA ADD 100 dB

FIGURE 8
R/ V HUGH R. SHARP
SSRN M AUTEC
24 October 2009
BEAM ASPECT SIGNATURES
7 KNOTS GENERATOR 1
8 KNOTS GENERATOR 1 AND 2
9 KNOTS GENERATOR 1 AND 2
ICES
AUTO PILOT STEERING

To convert from levels re 1µbar to levels re 1µPa add 100 dB.
ONE−THIRD−OCTAVE BAND CENTER FREQUENCIES IN Hertz

R/V HUGH R. SHARP
SSRNM AUTEC
24 October 2009
BEAM ASPECT SIGNATURES

FIGURE

TO CONVERT FROM LEVELS RE 1µBAR,
TO LEVELS RE 1µPA ADD 100 dB

ZERO SPEED WITH GENERATOR 1 AND 2 RUN
WAS CONTROLLED BY BACKGROUND NOISE.
LEVEL WAS EQUAL TO OR LESS THAN BACKGROUND 06
PLOT PLUS 50 dB SHOW IN THIS FIGURE.
ONE-THIRD-OCTAVE BAND LEVELS IN DECIBELS RELATIVE TO 1 $\mu$Pa AT 1 YD

TO CONVERT FROM LEVELS RE 1 $\mu$BAR TO LEVELS RE 1 $\mu$PA ADD 100 dB

FIGURE 11

R/V HUGH R. SHARP
SSRM AUTEC
24 October 2009
BACKGROUND SIGNATURES
- BACKGROUND 01
- BACKGROUND 02
- BACKGROUND 03
- BACKGROUND 04
- BACKGROUND 05
- BACKGROUND 06
- BACKGROUND 07

ONE-THIRD-OCTAVE BAND CENTER FREQUENCIES IN HERTZ
<table>
<thead>
<tr>
<th>Possible Sources:</th>
<th>4 KNOTS</th>
<th>6 KNOTS</th>
<th>7 KNOTS</th>
<th>8 KNOTS</th>
<th>9 KNOTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FREQ</td>
<td>LEVEL</td>
<td>FREQ</td>
<td>LEVEL</td>
<td>FREQ</td>
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<tr>
<td>Diesel Generators</td>
<td>30</td>
<td>144</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diesel Generators</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z Drive Lower Gear Mesh</td>
<td>88</td>
<td>146/ -</td>
<td>129</td>
<td>137</td>
<td>157</td>
</tr>
<tr>
<td>Diesel Generators</td>
<td>90</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z Drive Upper Gear Mesh</td>
<td>163</td>
<td>151</td>
<td>215</td>
<td>159</td>
<td>237</td>
</tr>
<tr>
<td>2x Z Drive Lower Gear Mesh</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3x Z Drive Lower Gear Mesh</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2x Z Drive Upper Gear Mesh</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3x Z Drive Upper Gear Mesh</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4x Z Drive Lower Gear Mesh</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Numerous Gear Mesh Harmonics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Port/starboard aspect
3 Hz bandwidth measurement for frequencies below 6400 Hz
R/V HUGH R. SHARP
SSRNM AUTEC
24 October 2009

Figure 14

Frequency in Hz
Testing Information Appendix
<table>
<thead>
<tr>
<th>ID#</th>
<th>INFORMATION TYPE</th>
<th>INFORMATION FROM OWNER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Ship characteristics</td>
<td></td>
</tr>
<tr>
<td>1.1.</td>
<td>Name / classification</td>
<td>R/V SHARP</td>
</tr>
<tr>
<td>1.2.</td>
<td>Reason for the measurements</td>
<td>Periodic recheck</td>
</tr>
<tr>
<td>1.3.</td>
<td>Shipyard and year constructed</td>
<td>Dakota Creek Industries, 2005</td>
</tr>
<tr>
<td>1.4.</td>
<td>Dimensions</td>
<td></td>
</tr>
<tr>
<td>1.4.2.</td>
<td>Length</td>
<td>146 feet</td>
</tr>
<tr>
<td>1.4.3.</td>
<td>Beam</td>
<td>32 feet</td>
</tr>
<tr>
<td>1.4.4.</td>
<td>Draft</td>
<td>8’ 10” (light) to 9’ 8” (heavy)</td>
</tr>
<tr>
<td>1.4.5.</td>
<td>Tonnage</td>
<td>550 long tons</td>
</tr>
<tr>
<td>1.4.6.</td>
<td>Ballast conditions</td>
<td>Not Available</td>
</tr>
<tr>
<td>1.5.</td>
<td>Propulsion characteristics</td>
<td>ASI Robicon Motor with Schottel Z-Drive</td>
</tr>
<tr>
<td>1.5.1.</td>
<td>Power source</td>
<td>Cummins, CMA 455; KTA 19 D(M)</td>
</tr>
<tr>
<td>1.5.2.</td>
<td>Drive train</td>
<td>Diesel Electric; Port &amp; Stbd Z-Drives</td>
</tr>
<tr>
<td>1.5.4.</td>
<td>Number of propulsor blades</td>
<td>5</td>
</tr>
<tr>
<td>1.5.5.</td>
<td>Turns per knot</td>
<td>32 utilized</td>
</tr>
<tr>
<td>1.5.6.</td>
<td>Modifications to propulsion line since the last</td>
<td>New brushes put in both Z-drive motors (May 2009) and new bearing at rear of starboard drive motor (August 2009)</td>
</tr>
<tr>
<td>1.5.7.</td>
<td>Known problems or concerns that may affect</td>
<td>Small cavitation pitting and slight mechanical damage. A 500 Hz tone found in self noise monitor around 2 years ago. The source was never identified.</td>
</tr>
<tr>
<td>1.5.8.</td>
<td>Condition of the hull, last time the hull and</td>
<td>The hull was cleaned at last shipyard period in May 2007.</td>
</tr>
<tr>
<td></td>
<td>propellers were cleaned</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Testing characteristics</td>
<td></td>
</tr>
<tr>
<td>2.1.</td>
<td>ANSI/ASA S12.64 Measurement Grade</td>
<td>Grade B</td>
</tr>
<tr>
<td>2.1.1.</td>
<td>Mitigations / deviations</td>
<td>Less than desired ambient</td>
</tr>
<tr>
<td>2.2.</td>
<td>Location / environment</td>
<td>Atlantic Undersea Test and Evaluation Center (AUTEC) Bahamas Islands</td>
</tr>
<tr>
<td>2.2.1.</td>
<td>Date</td>
<td>23/24 October 2009</td>
</tr>
<tr>
<td>2.2.2.</td>
<td>Latitude / longitude</td>
<td>24 deg 52 Min N / 77 Deg 49Min W</td>
</tr>
<tr>
<td>2.2.3.</td>
<td>Nominal environmental conditions</td>
<td>Winds and seas caused low frequency contamination</td>
</tr>
<tr>
<td>2.2.3.1.</td>
<td>Wave height / sea state / wind / rain</td>
<td>2-5 Feet / State 3/4 Sea / Winds 6-18 Knots</td>
</tr>
<tr>
<td>2.2.3.2.</td>
<td>Vessel traffic</td>
<td>Minimal – one contact during 9 knot runs</td>
</tr>
<tr>
<td>2.2.3.3.</td>
<td>Bottom depth / bottom type</td>
<td>4000 Feet</td>
</tr>
<tr>
<td>2.3.</td>
<td>Measurement system</td>
<td>US Navy Surface Ship Radiated Noise Measurement (SSRNM) FORMS Portable System</td>
</tr>
<tr>
<td>2.3.1.</td>
<td>Suspension system description / diagram</td>
<td>Compliant surface tether</td>
</tr>
<tr>
<td>2.3.2.</td>
<td>Hydrophone depths</td>
<td>324 / 474 / 524 Feet</td>
</tr>
<tr>
<td>2.3.3.</td>
<td>Hydrophone type / model / directionality / nominal</td>
<td>ITC Model 8201 Low Noise Differential Output Hydrophone/ omnidirectional below 40KHz / nominal -158 dB/1V/uPa</td>
</tr>
<tr>
<td>2.3.4.</td>
<td>System component description and diagram</td>
<td>See Attachment</td>
</tr>
<tr>
<td>2.3.5.</td>
<td>Factory calibration details (performed by, dates and</td>
<td>See Attachment</td>
</tr>
<tr>
<td>2.3.6.</td>
<td>Field calibration methods and results</td>
<td>In situ electrical calibration</td>
</tr>
<tr>
<td>2.4.</td>
<td>Testing scenario</td>
<td>US Navy SSRNM Type modified to provide +/- 30 degree horizontal integration window</td>
</tr>
<tr>
<td>2.4.1.</td>
<td>Nominal CPA</td>
<td>180 Yards</td>
</tr>
<tr>
<td>2.4.2.</td>
<td>Selection of center of integration window</td>
<td>Integration about the Acoustical Center</td>
</tr>
<tr>
<td>2.4.3.</td>
<td>Maneuvering geometry</td>
<td>Figure 8 maneuvering</td>
</tr>
</tbody>
</table>
SSRNM System block diagram:
Typical SSRNM Array Hydrophone Characteristics:

**Model ITC-8201**

*Low Noise Differential Output Hydrophone*

The Model ITC-8201 has a differential output with a very low noise preamplifier. Although polyurethane encapsulated, this hydrophone maintains its low frequency roll-off over long-term deployments through an improved internal insulation technique. It can drive cable lengths up to 2,500 feet.

**Specifications (terminal):**

- **Midband OCV**: dB/mV/pa
- **Midband Beam Pattern Shape**: Directional
- **Usable Frequency Range**: 0.1 - 65
- **Preamplifier Type**: Single in/Single out, Voltage
- **Depth**: 900 meters

**Open Circuit Receiving Response**

**Spectral Noise Level**

Directivity Pattern at 50.0 kHz

869 Ward Drive, Santa Barbara, CA 93111
805.683.2575 + 805.967.8199 FAX

www.itc-transducers.com

A-4
SSRNM Array Diagram:

SSRNM Differential Array
Measured June 2008
(not to scale)
Array Cable: 530 x 0.5lb/ft = 265 lbs + 100 + (5 @ 3) = 380 lbs.

Calculated Surface location 519' 6"

Array Bottom 0'

DEPTHS (rounded)

First (Spar Buoy) Grip 20'
Second (Bungee) Grip 525'
Third (Spar Buoy) Grip 600'
Fourth (Bungee) Grip 625'

SSRNM Ch1 Breakout 221' 6"
SSRNM Ch1 Hydrophone RED 225' 6"
Ch1 Hydrophone RED – 324' (CVN 398')
SSRNM Ch2 Breakout 101' 3"
SSRNM Ch2 Hydrophone GRN 105' 3"
Ch2 Hydrophone GRN – 444' (CVN 518')
SSRNM Ch3 Breakout 71' 3"
SSRNM Ch3 Hydrophone PUR 75' 3"
Ch3 Hydrophone PUR – 474' (CVN 548')
SSRNM Ch4 Breakout 21' 6"
SSRNM Ch4 Hydrophone BLU 25' 6"
Ch4 Hydrophone BLU – 524' (CVN 597' 6")

PMS Monitor Phone ORN 185' 6"
PMS Breakout 181' 6"
PMS Hydrophone ORN – 364' (CVN 438')