INTRODUCTION

Gates Acoustic Services was tasked by University of Alaska, Fairbanks, to investigate and quantify acoustic issues associated with operation of the R/V SIKULIAQ. An at-sea investigation was accomplished during ship operations in deep water out of San Juan, Puerto Rico on September 12-18, 2014.

During the at sea test on SIKULIAQ, the primary goal was to determine ship acoustic and bubble sweepdown characteristics and to assess their potential impacts to sonar performance. The Kongsberg EM 302 sonar was the primary focus of this testing with the Kongsberg EM 710 as a secondary priority. Additional goals of this test were to determine propeller cavitation characteristics and to obtain a preliminary snapshot of the expected acoustic background of the sonar region in open water conditions.

The following objectives were accomplished for this testing:

1. The noise levels of the sonar hydrophones were measured using internal Built In Self Test (BIST) routines for the EM 302 and EM 710 sonars.
2. Data was acquired from the internal noise routines of the TOPAS sub bottom profiling sonar.
3. The controlling sources of sonar acoustic levels were investigated.
4. The noise levels of reference hydrophones were measured at selected speeds and vessel conditions.
5. Propeller cavitation characteristics were assessed.
6. The presence of bubble sweepdown was assessed.
7. The noise of the ship bow thruster was measured.
8. Various machinery was measured for vibration levels.
INSTRUMENTATION

In order to successfully accomplish the desired objectives, it was necessary to install a special suite of vibration sensors and monitoring equipment. Two accelerometers were installed in after steering above each propeller to monitor propeller performance and the inception of cavitation. The installed accelerometers were Wilcoxon 752 types with sensitivity of 100 millivolt per g. Additional data was acquired from 6 permanently installed hydrophones located throughout the vessel. These hydrophones were HAP 5050 models with a receive sensitivity of -171 dB per volt relative to one micro pascal. The data from these sensors was processed using a Krohn-Hite Amplifier and a Quattro Signal Analyzer to yield calibrated acoustic levels. Additional data was acquired using the BIST RX Noise Level routine inherent in the EM 302 and EM 710 sonar systems as well as the TOPAS sub bottom profiling sonar.

Figure 1 presents the location of the reference hydrophones and the 2 propeller accelerometers.

TEST CONDITIONS

The following test conditions were evaluated during the underway operations on SIKULIAQ:

- Various vessels speeds were tested from dead in the water to 12 knots
- Eight different vessel headings were measured at a typical survey speed
- Four different bow thruster conditions were measured
- Scientific winch’s were operated and measured

Sea conditions for this trial were relatively calm with a Knudsen Sea State of approximately 1 to 1.5 with winds approximately 5 to 15 knots. The water depth during acoustic data acquisition ranged between 1000 and 5000 meters.

The following table provides vessel speed and shaft rpm for a given vessel percent thrust setting:

<table>
<thead>
<tr>
<th>Percent Thrust (%)</th>
<th>Speed (kts)</th>
<th>Shaft RPM (Average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>30</td>
<td>4.0</td>
<td>104</td>
</tr>
<tr>
<td>40</td>
<td>5.0</td>
<td>136</td>
</tr>
<tr>
<td>50</td>
<td>7.0</td>
<td>170</td>
</tr>
<tr>
<td>60</td>
<td>8.0</td>
<td>205</td>
</tr>
</tbody>
</table>
It should be noted there was a nominal offset of 20 rpm between the port and the starboard shaft rpm for a given thrust setting during a previous test conducted in Lake Erie during July 2014. It was suspected there was an error in the tachometer reading. This issue was investigated and the 20 rpm offset error was determined to be resident in the bridge read out display. Accurate readings were made from the tachometers and display outputs available in Engineering Control.

DATA RESULTS

Baseline Bathymetric Sonar Acoustic Evaluation

Data was acquired from the BIST RX NOISE LEVEL routine inherent to the EM 302 and EM 710 sonar systems. This data represents the sonar background acoustic signature the sonar must operate in. These routines sample data at 30 kHz for each of the 128 hydrophone staves resident in the receive array for the EM 302 and at 70 to 100 kHz for the 128 hydrophone staves resident in the EM 710.

Figure 2 presents a BIST sonar speed series of EM 302 data with a heading into the seas. Each curve in these plots represents an average of 20 samples. This data shows the acoustic profile across the receive array. As vessel speed is increased, levels increase as well. Figure 3 presents similar BIST data from the EM 302 with following sea conditions. This data shows similar results compared to the into the sea heading with slight reductions associated with reduced bubble impacts.

Figure 4 presents a speed versus level comparison of the average EM 302 BIST data collected at all ship speeds for the two different ship headings. This figure shows how the acoustic levels are affected by changing vessel speeds. The acoustic levels presented in this figure, with the exception of the 0 knot data point, are all controlled by hydrodynamic flow noise. An underhull inspection conducted just prior to the test indicated significant bio-fouling was present on and near the transducer arrays. It can also be observed from the data on this figure that following seas resulted in slight reductions of average acoustic noise due to reduced bubble sweepdown effects. Another significant result can be determined from this figure however. The average level of 40 dB at 0 knots indicates that in the absence of speed-related sources, the machinery contributions to the sonar background noise will not interfere with sonar performance.

A coast down run was conducted to assess the significance of flow noise and how much it was contributing to sonar background noise levels. This was accomplished by rapidly pulling back the throttles while the ship was at maximum
speed and acquiring EM 302 data while the ship coasted down in speed through the water. Figure 5 presents a snapshot at each speed. Figure 6 presents an overall summary of the coast down data plotted as a function of vessel speed. This figure indicates that flow noise is dominating the EM 302 background noise levels all the way to a vessel speed of 3 knots. Once again, this is due to the extremely poor underhull condition of SIKULIAQ.

A comparison was made of EM 302 data taken in September to that acquired during shallow water conditions in Lake Erie (from July 2014). Figure 7 presents this data at a vessel speed of 0 knots. The data is very comparable except for the level increases noted on the starboard side of the receive array. Diagnostic testing was conducted to try to determine the cause of these increased levels. Electronic boards were swapped with no impact and machinery conditions were evaluated, with nothing discovered that might be controlling the levels of the starboard receive array hydrophones. It is suspected there is the possibility that living biologic growth located directly on the transducer acoustic window might be making noise that is impacting the sonar levels. Following an underhull cleaning, this data should be reacquired and compared to previous data to determine if this was the source of the slight increase in levels on the starboard side. Figure 8 presents a comparison of current data to that acquired in July 2014 for a vessel condition of 60% thrust. There are also significant increases noted on the starboard side of the array, which is also believed to be associated with bio-fouling of the transducer acoustic window.

Figure 9 presents a BIST sonar speed series of EM 710 data with a heading into the seas. Each curve in these plots represents an average of 20 samples. This data shows the acoustic profile across the receive array. As vessel speed is increased, levels increase as well. Figure 10 presents similar BIST data from the EM 710 with following sea conditions. This data shows similar results compared to the into the sea heading. The data on both of these figures is considered extremely high in level. These high levels are directly associated with the bio-fouling present on the EM 710 sonar array acoustic windows. Figure 11 presents EM 710 data in a speed versus level format. It is typical for EM 710 data to slow relatively little speed dependence due to the inherent high level of electronic noise known to exist in this sonar. The significant speed impacts related to the underhull fouling can be easily seen on this figure.

Data was also acquired from the EM 710 during the coast down evaluation. Figure 12 presents this data in a speed series format to assess the noise levels across the array. Figure 13 presents this data in an overall summary at each speed while coasting. The results are similar to those noted on the EM 302, with underhull fouling causing hydrodynamic flow noise that completely controls the sonar acoustic levels down to a vessel speed of approximately 3 knots.

Figure 14 presents a comparison of the average EM 710 BIST data collected in July and September. This data shows similar results as those obtained for the EM 302, with quiet levels noted while SIKULIAQ is dead in the water. Figure 15
presents EM 710 data in a similar comparison at a vessel condition of 60% thrust. The current data is significantly higher due to the bio-fouling present in September 2014.

During the acoustic test, data was also collected from the TOPAS sub bottom profiler array concurrently with the sonar evaluation. This data was acquired by onboard Kongsberg sonar engineers. It is presented in this report for documentation purposes. Figures 16 through 22 present single samples of TOPAS data for a frequency range of 0 to 15 kHz for each speed tested. Figure 23 presents this data in a speed series format. It is noted that significant 120 Hz harmonics are observed at higher vessels speeds. These harmonics are believed to be associated with propulsion motor tones.

**Underhull Inspection**

Prior to sailing in September 2014, divers conducted a brief underhull inspection. This inspection documented the severity of bio-fouling present on SIKULIAQ. Several figures are included to demonstrate these conditions. Figures 24 and 25 show the condition of ADCP transducers. Figures 26 and 27 show the condition of the EM 710 receive array. Figures 28 and 29 show the condition of the EM 302 receive array. It is very easily seen from these pictures there is significant bio-fouling on the transducer faces, which is the main cause of high sonar levels while SIKULIAQ is operating at speeds above 3 knots.

**Hydrophone Evaluation**

Data was also acquired during the speed runs on SIKULIAQ from the reference hydrophones. This data was acquired in two frequency bands - from 0 to 20 kHz and from 0 to 80 kHz. This data is presented in figures 30 through 41 for each frequency range and hydrophone, respectively. Due to the extreme bio-fouling contamination, this data is only included for completeness. Figure 42 presents data from the forward reference hydrophones in a speed versus level format.

**Propeller Cavitation**

Cavitation measurements were made on both the port and starboard propellers. The measurements were made using an accelerometer mounted on the hull plating located just above each propeller. Cavitation performance was evaluated by monitoring the 2 to 10 kHz band levels of these sensors as speed was slowly increased during straight line course operations.

Figure 43 presents a speed versus level comparison of the port and starboard propellers at a representative frequency of 10 kHz. As seen on this figure, the propellers are remarkably similar in noise level at all tested vessel speeds. This figure also indicates that propeller cavitation is good and was determined to incept at a vessel speed between 9 and 10.5 knots.
Figures 44 and 45 present speed series data from the port and starboard propeller at all tested speeds for a frequency of 0 to 10 kHz. Figures 46 and 47 present similar data for a frequency range of 0 to 20 kHz. The presence of propeller cavitation can be seen in the data on the figures for vessel speeds above 9 knots.

**Bubble Sweepdown**

An assessment was conducted to assess the presence and impact of bubbles associated with bubble sweepdown along the vessel hull. During the at-sea period, numerous bubble transients were detected on SIKULIAQ at vessel speeds above 4.5 knots. The bubble transients were believed to be associated with bubbles passing near the sonar receive arrays, on the outer edges. Typically bubbles are detected aurally when they are near the sonar arrays. On the port and starboard EM 302 array reference hydrophones, they could clearly be heard. The bubble evaluation consisted of eight different ship headings with respect to the prevailing sea conditions while operating at a constant speed of 60% thrust. While sea conditions were minimal (sea state 1.5), they still caused slight vessel motion which generated bubble transients. During this evaluation, video output was monitored from an underwater camera installed on the centerboard as well. Bubbles were easily detected in the camera display. A separate file (edited movie) is provided summarizing the camera output acquired during this test. Figure 48 presents EM 302 BIST data for each heading compared to each other. Bubble transients are noted quite easily on this figure, particularly on the outer edges of the receive array. Figures 49 to 56 present data from the EM 302 BIST routine for each ship heading individually, capturing a significant bubble transient. The interesting thing to note from these figures is that when the seas are on the head or on the stern, bubble noise is detected on each side of the receive array. Of greater interest is the bubble noise tends to be more prevalent on the opposing side of the receive array when seas are nominally coming from beam aspects. Figures 57 to 59 present data from the EM 302 sonar comparing into versus following seas for vessel speeds of 30%, 60% and 90% thrust, respectively. These plots indicate that more significant bubble noise is detected when SIKULIAQ is heading into the seas.

Figure 50 presents similar data from the EM 710 array for all headings. This plot indicates that flow noise was so excessive in the data of this sonar, that impacts from bubble transients were masked. Figures 61 to 63 present data from the EM 710 sonar comparing into versus following seas for vessel speeds of 30%, 60% and 90% thrust respectively. These plots show very little difference in bubble noise at these headings, once again due to the excessive noise associated with bio-fouling.

It is believed that in more significant sea-states, bubble sweepdown impacts will substantially degrade sonar operations. Additionally, when the hull is clean of bio-fouling, the impacts of bubble noise will be much more notable.

**Bow Thruster Operations**
An evaluation of bow thruster noise was performed during this acoustic test. This test was conducted by operating the bow thruster at 25%, 50%, 75% and 100% thrust settings to starboard. Figures 64 to 67 present data from the forward hydrophones for these thrust settings at a frequency range of 0 to 20 kHz. Figures 68 to 71 present similar data for a frequency range of 0 to 80 kHz. Significant noise increases can be seen in the data on these figures, particularly as thrust settings are increased. Figure 72 presents the impact of bow thruster operation on the EM 302 sonar, with significant level increases observed for thrust settings above 50%. Figure 73 presents data from the EM 710 sonar during bow thruster operations, with little impact from this noise source observed in sonar data. Finally, figure 74 presents data from the TOPAS sonar, for bow thruster operations.

Machinery Diagnostics

During the acoustic evaluation onboard SIKULIAQ several machinery items were evaluated. During steady state conditions it was determined that no machinery items were causing sonar degradations.

The ships fathometer was previously evaluated to determine its contribution to acoustic background levels. The results of the system on versus off is presented in Figure 75. As seen in the data on the figure, there are significant levels increases in acoustic data when the fathometer is operational.

During dead in the water testing, data was taken directly on various machinery units. Figures 76 to 78 present data taken directly on the port propulsion motor for frequency ranges of 0 to 5 kHz, 0 to 10 kHz and 0 to 20 kHz, respectively. Data was taken above and below the vibration isolation mounts and significant reductions, as expected, were noted for below mount data.

Figures 79 to 81 compare data taken from the rudder hydraulic pump units for 3 different frequency ranges. Very little difference between these units was noted. Data from the hydrographic winch is presented in figures 82 to 84 for these three frequency ranges comparing above and below mount to document the vibration effects from this system. Data from the traction winch is presented in figures 85 to 87 while various retrieval speeds were performed. Figures 88 to 90 present vibration data collected on the #2 storage drum foundation while cable retrieval operations were being conducted.

CONCLUSIONS

- Bubble sweepdown was detected at vessel speeds above 3 knots
• While SIKULIAQ was dead-in-the-water with propulsion secured, sonar levels were considered acceptable and will yield full sonar performance
• While operating at speeds above 3 knots, all acoustic levels (sonars and hydrophones) were controlled by hydrodynamic flow noise caused by the presence of bio-fouling
• The ships fathometer produces significant acoustic interference at a frequency centered at 50 kHz
• The disparity noted in propeller shaft rpm readings between the port and starboard shaft was determined to be associated with an error on the bridge display

RECOMMENDATIONS

A few recommendations are provided with this report as follows:

• Secure ships fathometer during sonar operations
• Perform thorough underhull cleaning
• Repeat all baseline noise testing in deep water (greater than 1000 meters) to further quantify background acoustic levels following hull cleaning of bio-fouling
• Correct error in shaft rpm resident in bridge display
R/V SIKULIAQ
SENSOR LAYOUT

FIGURE 1
FIGURE 2

R/V SIKULIAQ
EM 302 RX NOISE LEVEL
SPEED SERIES - INTO SEAS
12 SEPTEMBER 2014
R/V SIKULIAQ
EM 302 RX NOISE LEVEL
SPEED SERIES - FOLLOWING SEAS
15 SEPTEMBER 2014

FIGURE 3
R/V SIKULIAQ
EM 302 RX NOISE LEVEL
SPEED VS 30 kHz LEVEL - INTO VS FOLLOWING SEAS
15 SEPTEMBER 2014

FIGURE 4
FIGURE 5

R/V SIKULIAQ
EM 302 RX NOISE LEVEL
SPEED SERIES - COASTDOWN
15 SEPTEMBER 2014
R/V SIKULIAQ
EM 302 RX NOISE LEVEL
0% THRUST - JULY VS SEPTEMBER
15 SEPTEMBER 2014

FIGURE 7
R/V SIKULIAQ
EM 302 RX NOISE LEVEL
60% THRUST - JULY VS SEPTEMBER
15 SEPTEMBER 2014

FIGURE 8
R/V SIKULIAQ
EM 710 RX NOISE LEVEL
SPEED SERIES - INTO SEAS
12 SEPTEMBER 2014
FIGURE 11

R/V SIKULIAQ
EM 710 RX NOISE LEVEL
SPEED VS 70-100 kHz LEVEL - INTO VS FOLLOWING SEAS
15 SEPTEMBER 2014
R/V SIKULIAQ
EM 710 RX NOISE LEVEL
SPEED SERIES - COASTDOWN
15 SEPTEMBER 2014

FIGURE 12
R/V SIKULIAQ
EM 710 RX NOISE LEVEL
COASTDOWN - SPEED VERSUS 70 - 100 kHz LEVEL
15 SEPTEMBER 2014

FIGURE 13
R/V SIKULIAQ
EM 710 RX NOISE LEVEL
0% THRUST - JULY VERSUS SEPTEMBER 2014
15 SEPTEMBER 2014

FIGURE 14
R/V SIKULIAQ
EM 710 RX NOISE LEVEL
60% THRUST - JULY VERSUS SEPTEMBER 2014
15 SEPTEMBER 2014

FIGURE 15
FIGURE 19
R/V SIKULIAQ
TOPAS SUB-BOTTOM
DATA
80% THRUST

Power Spectral Density (Welch)

Baseline noise 80%, raw

FIGURE 21
R/V SIKULIAQ
PORT RX HYDROPHONE
0-20 kHz SPEED SERIES
12 SEPTEMBER 2014

FIGURE 30
R/V SIKULIAQ
TX FORWARD HYDROPHONE
0-20 kHz SPEED SERIES
12 SEPTEMBER 2014

FIGURE 32
R/V SIKULIAQ
AFT SONAR HYDROPHONE
0-20 kHz SPEED SERIES
12 SEPTEMBER 2014

FIGURE 34
R/V SIKULIAQ
AFT PROP HYDROPHONE
0-20 kHz SPEED SERIES
12 SEPTEMBER 2014
R/V SIKULIAQ
PORT RX HYDROPHONE
0-80 kHz SPEED SERIES
12 SEPTEMBER 2014
R/V SIKULIAQ
STARBOARD RX HYDROPHONE
0-80 kHz SPEED SERIES
12 SEPTEMBER 2014

FIGURE 37
R/V SIKULIAQ
TX FORWARD HYDROPHONE
0-80 kHz SPEED SERIES
12 SEPTEMBER 2014
R/V SIKULIAQ
AFT SONAR HYDROPHONE
0-80 kHz SPEED SERIES
12 SEPTEMBER 2014

FIGURE 40
R/V SIKULIAQ
AFT PROP HYDROPHONE
0-80 kHz SPEED SERIES
12 SEPTEMBER 2014

FIGURE 41
R/V SIKULIAQ
SPEED VERSUS 30 kHz LEVEL
15 SEPTEMBER 2014

FIGURE 42
RV SIKULIAQ
PORT/STARBOARD PROPELLER
SPEED VERSUS 10kHz LEVEL
SEPTEMBER 2014

FIGURE 43
RV SIKULIAQ
PORT PROPELLER
0-10 kHz SPEED SERIES
SEPTEMBER 2014

FIGURE 44
RV SIKULIAQ
STARBOARD PROPELLER
0-10 kHz SPEED SERIES
16 JULY 2014

FIGURE 45
RV SIKULIAQ
PORT PROPELLER
0-20 kHz SPEED SERIES
SEPTEMBER 2014

Figure 46
RV SIKULIAQ
STARBOARD PROPELLER
0-20 kHz SPEED SERIES
SEPTEMBER 2014

VIBRATION LEVEL (dB re 1 µg)

FREQUENCY (Hz)

0 KTS
3.4 KTS
5.6 KTS
7.5 KTS
9 KTS
10.5 KTS
11.6 KTS
13 KTS

FIGURE 47
R/V SIKULIAQ
EM 302 RX NOISE LEVEL
HEADING VERSUS SEA-STATE
15 SEPTEMBER 2014
R/V SIKULIAQ
EM 302 RX NOISE LEVEL
7.5 KTS - 60% THRUST - INTO SEAS
17 SEPTEMBER 2014

FIGURE 49
R/V SIKULIAQ
EM 302 RX NOISE LEVEL
7.4 KTS - 60% THRUST - PORT FORE QTR SEAS
17 SEPTEMBER 2014

FIGURE 50
R/V SIKULIAQ
EM 302 RX NOISE LEVEL
7.8 KTS - 60% THRUST - PORT BEAM SEAS
17 SEPTEMBER 2014

FIGURE 51
FIGURE 52

R/V SIKULIAQ
EM 302 RX NOISE LEVEL
8.2 KTS - 60% THRUST - PORT AFT QTR SEAS
17 SEPTEMBER 2014
R/V SIKULIAQ
EM 302 RX NOISE LEVEL
8.4 KTS - 60% THRUST - FOLLOWING SEAS
17 SEPTEMBER 2014

FIGURE 53
R/V SIKULIAQ
EM 302 RX NOISE LEVEL
8.8 KTS - 60% THRUST - STARBOARD AFT QTR SEAS
17 SEPTEMBER 2014

SPECTRUM LEVEL (dB re 1 µPa at 30 kHz)

HYDROPHONE STAVE NUMBER

FIGURE 54
R/V SIKULIAQ
EM 302 RX NOISE LEVEL
8.4 KTS - 60% THRUST - STARBOARD BEAM SEAS
17 SEPTEMBER 2014

FIGURE 55
R/V SIKULIAQ
EM 302 RX NOISE LEVEL
8 KTS - 60% THRUST - STARBOARD FORE QTR SEAS
17 SEPTEMBER 2014

FIGURE 56
R/V SIKULIAQ
EM 302 RX NOISE LEVEL
INTO VERSUS FOLLOWING SEAS - 30% THRUST
15 SEPTEMBER 2014

FIGURE 57
R/V SIKULIAQ
EM 302 RX NOISE LEVEL
INTO VERSUS FOLLOWING SEAS - 60% THRUST
15 SEPTEMBER 2014

FIGURE 58
R/V SIKULIAQ
EM 710 RX NOISE LEVEL
HEADING VERSUS SEA-STATE
15 SEPTEMBER 2014

FIGURE 60
R/V SIKULIAQ
EM 710 RX NOISE LEVEL
INTO VERSUS FOLLOWING SEAS - 30% THRUST
15 SEPTEMBER 2014

FIGURE 61
R/V SIKULIAQ
EM 710 RX NOISE LEVEL
INTO VERSUS FOLLOWING SEAS - 60% THRUST
15 SEPTEMBER 2014
R/V SIKULIAQ
PORT RX HYDROPHONE
0-20 kHz BOW THRUSTER COMPARISON
17 SEPTEMBER 2014

FIGURE 64
R/V SIKULIAQ
STARBOARD RX HYDROPHONE
0-20 kHz BOW THRUSTER COMPARISON
17 SEPTEMBER 2014

FIGURE 65
R/V SIKULIAQ
TX FORWARD HYDROPHONE
0-20 kHz BOW THRUSTER COMPARISON
17 SEPTEMBER 2014
R/V SIKULIAQ
PORT RX HYDROPHONE
0-80 kHz BOW THRUSTER COMPARISON
17 SEPTEMBER 2014

FIGURE 68
R/V SIKULIAQ
STARBOARD RX HYDROPHONE
0-80 kHz BOW THRUSTER COMPARISON
17 SEPTEMBER 2014
R/V SIKULIAQ
TX FORWARD HYDROPHONE
0-80 kHz BOW THRUSTER COMPARISON
17 SEPTEMBER 2014

FIGURE 70
R/V SIKULIAQ
CENTERBOARD HYDROPHONE
0-80 kHz BOW THRUSTER COMPARISON
17 SEPTEMBER 2014

FIGURE 71
R/V SIKULIAQ
EM 302 RX NOISE LEVEL
BOW THRUSTER OPERATION
17 SEPTEMBER 2014

FIGURE 72
R/V SIKULIAQ
EM 710 RX NOISE LEVEL
BOW THRUSTER OPERATION
17 SEPTEMBER 2014

FIGURE 73
R/V SIKULIAQ
STARBOARD RX HYDROPHONE
0-80 kHz FATHOMETER ON VERSUS OFF
16 JULY 2014

FIGURE 75
R/V SIKULIAQ
PORT PROPULSION MOTOR
40% THRUST
17 SEPTEMBER 2014

FIGURE 76
R/V SIKULIAQ
PORT PROPULSION MOTOR
40% THRUST
17 SEPTEMBER 2014

FIGURE 77
R/V SIKULIAQ
PORT PROPULSION MOTOR
40% THRUST
17 SEPTEMBER 2014
R/V SIKULIAQ
RUDDER HPU PUMP COMPARISON
PUMP 1 VERSUS PUMP 2 COMPARISON
17 SEPTEMBER 2014

FIGURE 79
R/V SIKULIAQ
RUDDER HPU PUMP
PUMP 1 VERSUS PUMP 2 COMPARISON
17 SEPTEMBER 2014

FIGURE 81
R/V SIKULIAQ
HYDROGRAPHIC WINCH
ABOVE VERSUS BELOW MOUNT
17 SEPTEMBER 2014

FIGURE 82
R/V SIKULIAQ
HYDROGRAPHIC WINCH
ABOVE VERSUS BELOW MOUNT COMPARISON
17 SEPTEMBER 2014

FIGURE 83
R/V SIKULIAQ
TRACTION WINCH FOUNDATION
RETRIEVAL SPEED COMPARISON
17 SEPTEMBER 2014

FIGURE 85
R/V SIKULIAQ
TRACTION WINCH FOUNDATION
RETRIEVAL COMPARISON
17 SEPTEMBER 2014

VIBRATION LEVEL (dB re 1 μg)

FREQUENCY (Hz)

TRACTION WINCH FOUNDATION - 20m/s RETRIEVE
TRACTION WINCH FOUNDATION - 40m/s RETRIEVE
TRACTION WINCH FOUNDATION - 60m/s RETRIEVE

FIGURE 86
R/V SIKULIAQ
TRACTION WINCH FOUNDATION
RETRIEVAL COMPARISON
17 SEPTEMBER 2014

FIGURE 87
R/V SIKULIAQ
STORAGE DRUM #2 FOUNDATION
RETRIEVAL SPEED COMPARISON
17 SEPTEMBER 2014

FIGURE 88
R/V SIKULIAQ
STORAGE DRUM #2 FOUNDATION
RETRIEVAL COMPARISON
17 SEPTEMBER 2014

FIGURE 89
R/V SIKULIAQ
STORAGE DRUM 2 FOUNDATION
RETRIEVAL COMPARISON
17 SEPTEMBER 2014

VIBRATION LEVEL (dB re 1 µg)

FREQUENCY (Hz)

STORAGE DRUM 2 - 20m/s RETRIEVE
STORAGE DRUM 2 - 40m/s RETRIEVE
STORAGE DRUM 2 - 60m/s RETRIEVE

FIGURE 90