**Weir Canada, Inc.**

# CCGS LIMNOS

## STRUCTURAL MATERIAL LOSS SURVEY

XT6064-R

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# Table of Contents

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# 1 References

A. NETE Task XT6064-R, approved 14 October 2022
B. CCGS LIMNOS, General Arrangement DWG: S010-290-69

# 2 Introduction

Under Reference A, the Canadian Coast Guard (CCG)/Vessel Life Extension (VLE) Office in Halifax, Nova Scotia requested Weir Marine Engineering (WME) to provide Independent Verification and Validation (IV&V) services through Pulsed Eddy Current (PEC) Non-Destructive Examination (NDE) techniques to assess structural material loss.

At the time of the survey, Canadian Coast Guard Ship (CCGS) LIMNOS Mid Shore Science Vessel was docked at the Canada Centre for Inland Waters (CCIW) in Burlington, ON. The work was conducted from October 24th to October 27th 2022. The LIMNOS Crew and the CCG Project Manager provided excellent support to the survey team.

# 3 Pulsed Eddy Current Technology Description

All surveys were conducted using the Lyft PEC system, shown in Figure 1, supplied by Eddyfi Inc.


Figure 1 – Lyft PEC System Processor

The Lyft PEC system is comprised of the following components:

a. Main acquisition unit;
b. Custom small 7-coil array probe (CUS-PECA-7CH-SM-XXXX);
c. Custom medium 7-coil array probe (CUS-PECA-SZ-7CH-C300-GDA-HXXX); and
d. Single element medium G2 probe (PEC-089-G2-XXXX).

It should be noted that the PEC technology is a screening tool, that is to say the technology is not a thickness measurement tool, but rather a method by which to rapidly identify areas of corrosion showing significant changes in steel characteristics. These areas can subsequently be targeted with more invasive measurement techniques such as ultrasonic testing (UT) to accurately measure the remaining steel.

PEC induces a weak magnetic field in the steel and measures the time it takes for that field to decay, this decay rate is compared with the decay rate of a calibration point taken directly on the plate to be measured. This calibration point is assumed to be the nominal thickness of the plate, and all remaining wall thickness (WT) values are determined with respect to this point. Techniques have been developed to ensure this

calibration point is not an area above a stiffener, or an area of corrosion, and recalibration can be completed after the scan during analysis (shown as a light blue square on the scan image).

The calibration must be performed on the piece to be measured as there are factors to the magnetic properties that cannot simply be matched by an equal thickness piece of the same steel grade. Properties that cannot be easily replicated by a calibration plate include the steel's age, temperature, grain orientation, and the ships own unique magnetic signature which changes as the ship travels across magnetic field lines. These properties vary between each plate of the hull, making the use of a standardized calibration plate impractical, and given the success of the calibration techniques developed, unnecessary.

# 4 Interpreting Survey Data and Presentation Format

Interpretation of PEC results shown in this report should be made with the understanding that the PEC is a screening tool not a measurement tool, although the scan images are showing a WT% map (remaining wall thickness), without the associated response curves and exact WT% values for each data point, caution must be exercised when drawing conclusions from the data outside of the comments/conclusions made by the analysis team.

The survey was conducted on two main structure types; decks (D) and hull (HULL). Each structure type is given its own results section within this report.

Within each major structure type, several areas were scanned, as listed below:

a. Deck – Wheel House Top (D-WHTOP);
b. Deck – Wheel House (D-WHOUSE);
c. Deck – Fo'c'sle Deck Passageway (D-FPASS);
d. Deck – Anchor Windlass (D-AWIND);
e. Deck – Mooring Winch (D-WINCH);
f. Deck – Main Deck Washplace (D-MDWP);
g. Deck – Main Deck Forward Port Cabin (D-FWPC);
h. Deck – Main Deck Forward Starboard Cabin (D-FWSC);
i. Deck – Void Space (D-VOID); and
j. Hull – Starboard Hull (HULL-S).

Each of these areas were given a unique numerical indicator as shown in brackets in the above list. For example, the wheel house top deck is given the designation D-WHTOP, where "D" denotes the major structure to be a deck, and "WHTOP" specifies the wheel house top.

Each area surveyed is shown in its own table in the appropriate results section of this report, and may have associated figures consisting of photographs of the compartment with the area of interest marked. An example of a result table is shown in Figure 2.

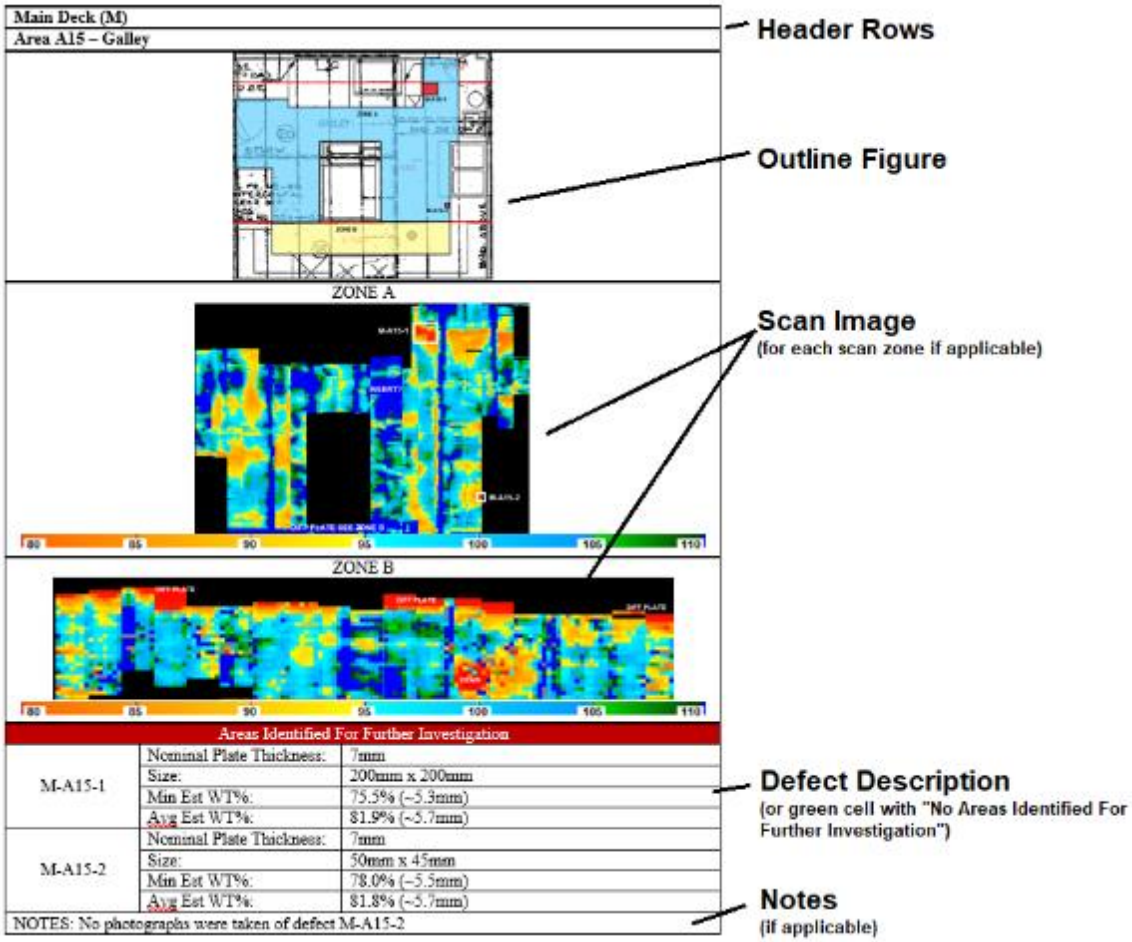



Figure 2 – Example Result Table

The first row of the result table will list the structure type, the specific area scanned, and the letter designation.

Following the header rows will be an outline figure, an example of which is shown in Figure 3. The outline figure shows the General Arrangement (GA), scanned areas (lightly shaded polygons), and defects in approximate location shown by bright red polygons.

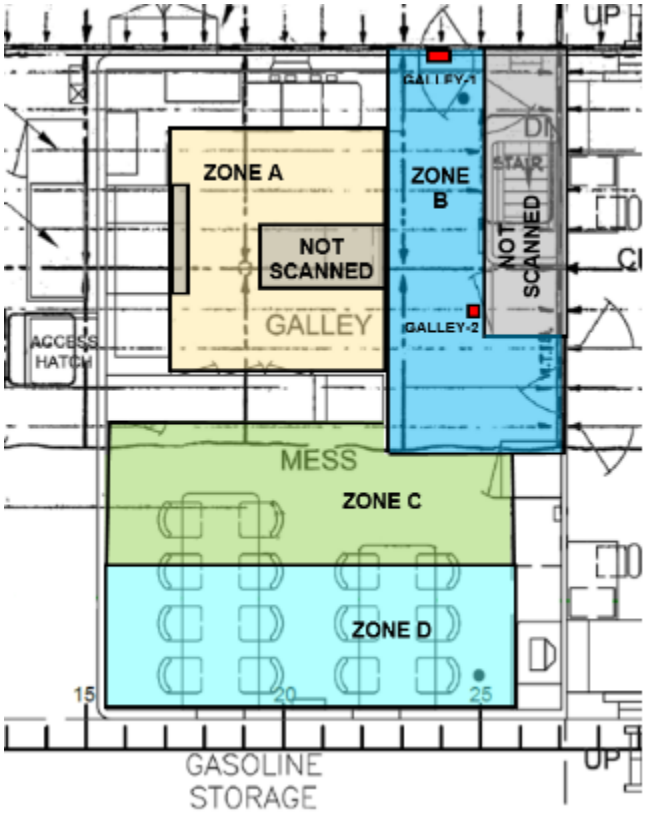



Figure 3 – Example Outline Figure
(Defects Shown As Red Polygons, Scanned Areas as Lightly Shaded and Labelled Polygons)

In several compartments, the differing magnetic properties between plates required a unique calibration for each plate. Therefore, certain compartments require multiple scan images to show the entire area. In these cases differing scan zones are given an alphabetical designation such as “Scan Zone A”; these areas are labelled within the appropriate lightly shaded polygons as shown in Figure 3. If only a single zone exists, the light beige color shown in Zone A will be used and no text label for the scan zone will be shown.

Following the outline figure, a scan image of each scan zone within the compartment is shown. These scans show the WT% relative to the nominal thickness of the plate. The calibration area (outlined in light blue) is assumed to be representative of the nominal thickness, using all the data points contained within the calibration square, the software determines an appropriate set of magnetic response curves. This rectangle does not appear on the scan image if the calibration created on site is kept. With the calibration magnetic response curves set, all WT% values are calculated with algorithms which compare a given data point’s response curve with the calibration response curves. A color bar is provided below the scan image, ranging from 80% (Red) to 110% (dark blue). Nominal steel will show as cyan to light blue (95% to 105%). Structure oriented perpendicular to the scan direction will typically show as dark or light blue linear patterns in the scan, and are easily identified during analysis by the sudden change in magnetic response. Structure oriented parallel to the scan direction are typically displayed as dark blue or grey. Grey points are areas where the WT% exceeds 120% or when there is a signal distortion or the operator moves the probe too quickly to collect data. Black areas are inaccessible areas within the scan, or areas outside the scanned area, and contain no data. An example of a scan image is provided below in Figure 4.

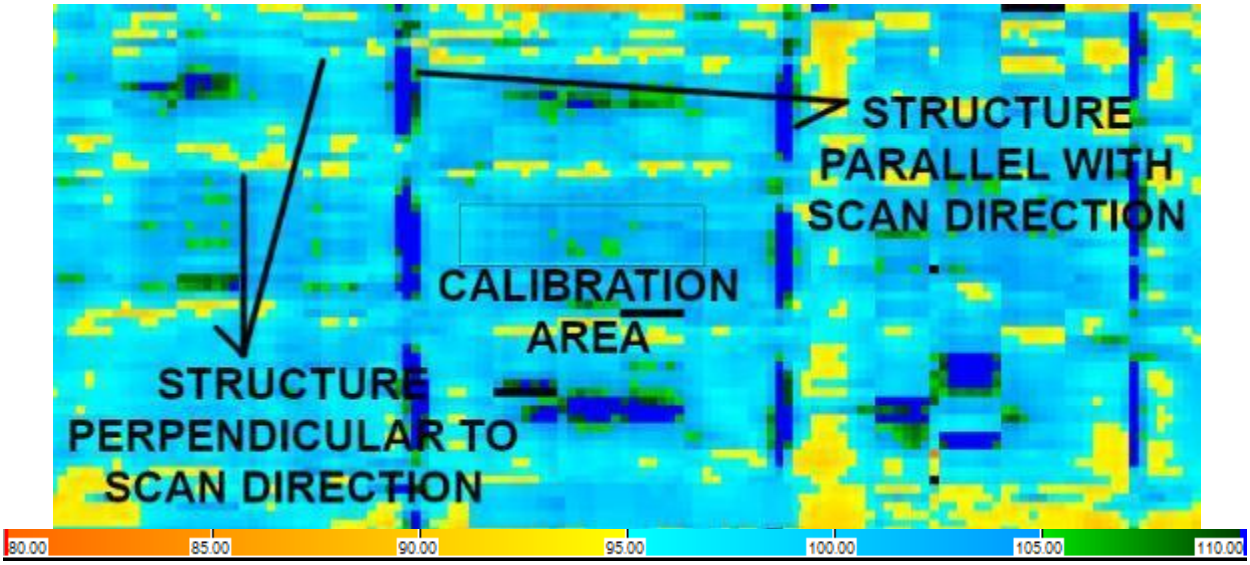



Figure 4 – Example Scan Image with Color Bar

Certain structural features or anomalous readings may appear as defects in the absence of detailed analysis tools available to the data analyzer. To assist the reader, such items are marked on the scan in white text with white leaders or outlines as necessary as shown in Figure 5. These labels are sometimes unique to the particular scan image, in such cases the meaning will be inherent in the name, or explained in the notes. Typical labels to be found on a scan image include:

a. Diff Plate. Denotes a second plate of either differing thickness or different magnetic properties. These areas should not be considered within the scan image and are usually the result of overlap and will be analyzed in subsequent scan zones;
b. Artifact. Denotes the presence of structure or erroneous data which appears as a defect; this phenomenon is further explained in the respective section where it appears;
c. Access Hatch. Denotes the presence of an access hatch bolted to the deck;
d. Drain. Denotes a drain, found in the galley only, these appear as severe defects on the scan image however are easily discernible from true defects due to the response curve;
e. Weld. Denotes the presence of a seam weld, clad weld, or heat affected zone from a weld on the opposite side of the plate, these are identified during analysis by characteristic magnetic response curves; and
f. Structure. Denotes the presence of structure which appears as a defect, this phenomenon is further explained in the respective sections where it appears.

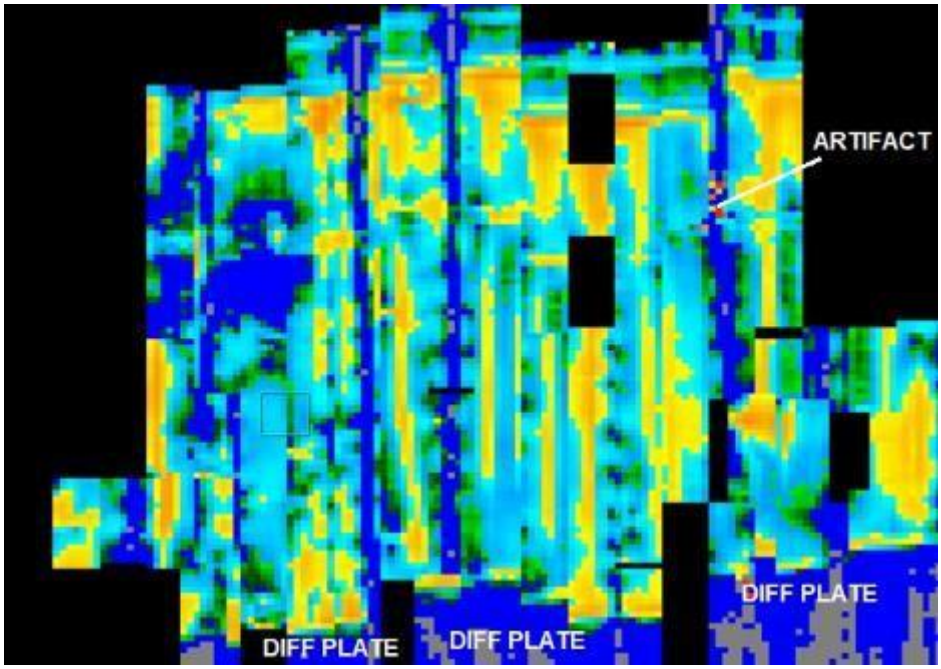



Figure 5 – Example Scan Image Showing Typical Markings in White Text

Defects are deemed as areas below a WT of 80%, which was agreed upon by WME and the client.

Each defect identified is marked on the outline figure, and scan zone image. Each defect is given a unique identifier: first, a designation representing the area scanned (ex: D-WHTOP, identifying the area as the wheel house top deck), and finally a sequential number to differentiate it from any other defects within that area (ex: 1) as shown in Figure 6.

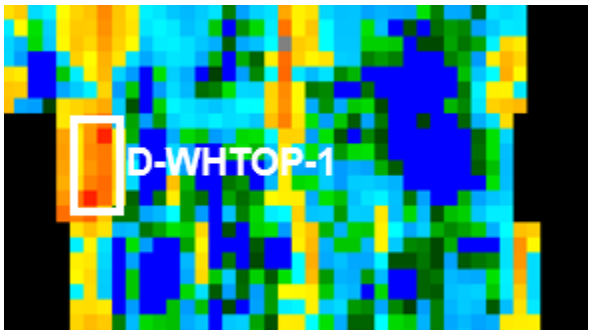



Figure 6 – Example Defect D-WHTOP-1 (Wheel House Top Deck, Defect 1)

If defects are found, a red row in the table with “Areas Identified for Further Investigation” will be shown followed by a description of the defect, including the nominal thickness of the plate it is situated on, the approximate size of the defect, the minimum estimated wall thickness and the average estimated wall thickness within the defect area. If no defects are found a green row will be shown in the table with “No Areas Identified for Further Investigation” as shown in Figure 7.

| Areas Identified For Further Investigation | | |
|---|---|---|
| DEFECT NAME | Nominal Plate Thickness: | Thickness in mm |
| | Size: | [Longitudinal] mm x [Transverse]mm |
| | Min Est WT%: | #% (~#mm) |
| | Avg Est WT%: | #% (~#mm) |

| No Areas Identified For Further Investigation |
|---|

Figure 7 – Example Defect Descriptions (Left – Defects Identified, Right – No Defects Identified)

Finally the results table may contain items of note in the final row of the table.

Following the results tables are figures consisting of edited photographs which show approximate locations of the defects found in the scans and items of note, an example is shown below in Figure 8.

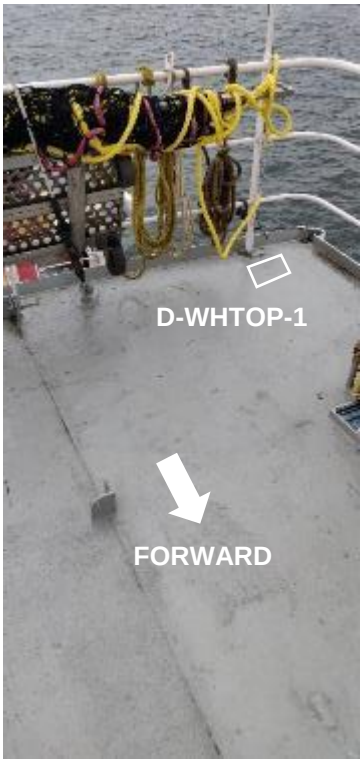



Figure 8 – Example Defect Location Figure (D-WHTOP-1)

# 5 Description of Survey

The survey was conducted on the CCGS LIMNOS Mid Shore Science Vessel (Figure 9), launched in 1968. The vessel particulars are as follows:

a. Length Overall (m): 44.8;
b. Beam (m): 9.8;
c. Draft (m): 2.6; and
d. Gross Tonnage (t): 489.

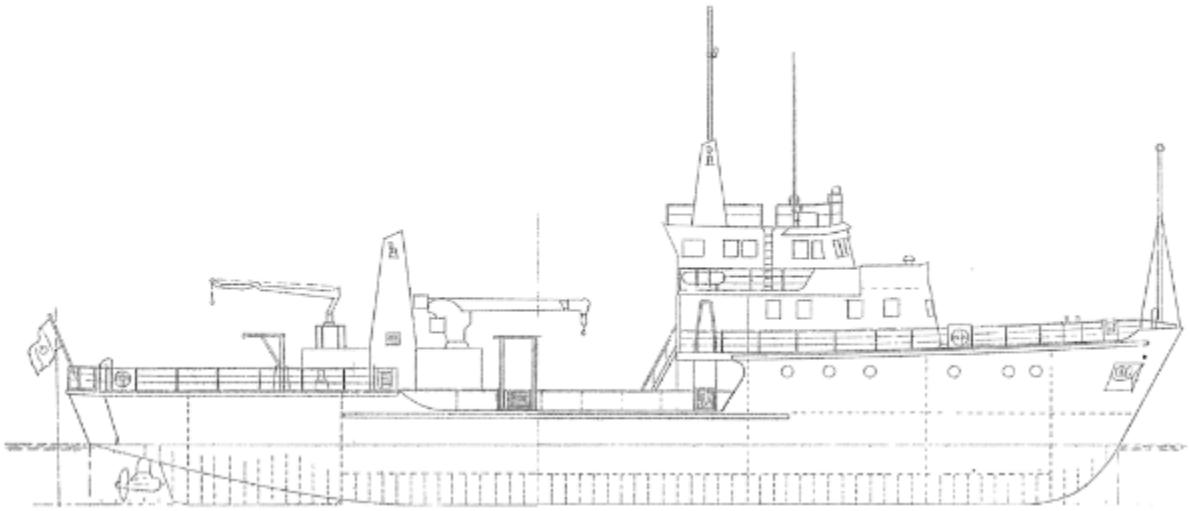


Figure 9 – CCGS LIMNOS Profile (Reference B)

# 6 Survey Results – Decks

Scans of the deck structures of the CCGS LIMNOS indicated six (6) defects below the 80% remaining wall thickness threshold. These defects are summarized in Table 1 and comments for each area scanned are shown in Sections 6.1 through 6.9. Results tables and scan images for all deck structure scan zones are found in Section 6.10.

Table 1 – Decks Defect Summary

| Location | Defect ID | | |
|---|---|---|---|
| Wheel House Top | D-WHTOP-1 See 6.1 | Nominal Plate Thickness: | 6.35mm |
| | | Size: | 75mm x 180mm |
| | | Min Est WT%: | 77.4% (~4.9mm) |
| | | Avg Est WT%: | 84.7% (~5.4mm) |
| | D-WHTOP-2 See 6.1 | Nominal Plate Thickness: | 6.35mm |
| | | Size: | 80mm x 75mm |
| | | Min Est WT%: | 77.6% (~4.9mm) |
| | | Avg Est WT%: | 80.2% (~5.1mm) |
| | D-WHTOP-3 See 6.1 | Nominal Plate Thickness: | 6.35mm |
| | | Size: | 50mm x 75mm |
| | | Min Est WT%: | 79.3% (~5.0mm) |
| | | Avg Est WT%: | 80.6% (~5.1mm) |
| | D-WHTOP-4 See 6.1 | Nominal Plate Thickness: | 6.35mm |
| | | Size: | 65mm x 75mm |
| | | Min Est WT%: | 78.4% (~5.0mm) |
| | | Avg Est WT%: | 79.7% (~5.1mm) |
| Wheel House | D-WHOUSE-1 See 6.2 | Nominal Plate Thickness: | 6.35mm |
| | | Size: | 75mm x 225mm |
| | | Min Est WT%: | 78.1% (~5.0mm) |
| | | Avg Est WT%: | 81.6% (~5.2mm) |
| | D-WHOUSE-2 See 6.2 | Nominal Plate Thickness: | 6.35mm |
| | | Size: | 75mm x 135mm |
| | | Min Est WT%: | 74.4% (~4.7mm) |
| | | Avg Est WT%: | 79.0% (~5.0mm) |

## 6.1 Wheel House Top

Four (4) defects below the 80% reporting threshold were located in this scan.

D-WHTOP-1 is located near a stanchion mount, which can cause interference. Thus, is it is recommended that UT measurements are conducted to verify the state of this area.

## 6.2 Wheel House

Two (2) defects below the 80% reporting threshold were located in this scan.

Both D-WHOUSE-1 and D-WHOUSE-2 are located near the Wheel House entrance on a longitudinal structural member. This area is prone to corrosion as it is in proximity to a wet space (exterior deck) and is a high-traffic zone. However, it is possible this defect is in fact a weld repair or unknown structural feature and therefore it is recommended that the repair records in this area are reviewed and/or UT measurements are conducted to verify the state of this area.

## 6.3 Fo'c'sle Deck Passageway

No defects below the 80% reporting threshold were located in this scan.

## 6.4 Anchor Windlass

No defects below the 80% reporting threshold were located in this scan. The artifacts detected in the scan are likely due to previous hotwork or structural damage. During the survey, the CCGS LIMNOS crew indicated that the anchor windlass was previously actuated while the anchor was in the anchor pocket, causing strain to the structure in the area of the scan. Strain on the steel can cause local magnetic permeability variations, resulting in errant PEC measurements.

## 6.5 Mooring Winch

No defects below the 80% reporting threshold were located in this scan.

## 6.6 Main Deck Washplace

No defects below the 80% reporting threshold were located in this scan. Artifacts present in the scan are due to interference from the sandwich plate beneath the toilet and interference near the bulkheads.

## 6.7 Main Deck Forward Port Cabin

No defects below the 80% reporting threshold were located in this scan. The artifact in this scan is likely due to a weld or unknown structural feature, since magnetic response curves of the PEC data in the area of the artifact indicate that there is no corrosion present.

## 6.8 Main Deck Forward Starboard Cabin

No defects below the 80% reporting threshold were located in this scan.

## 6.9 Void Space

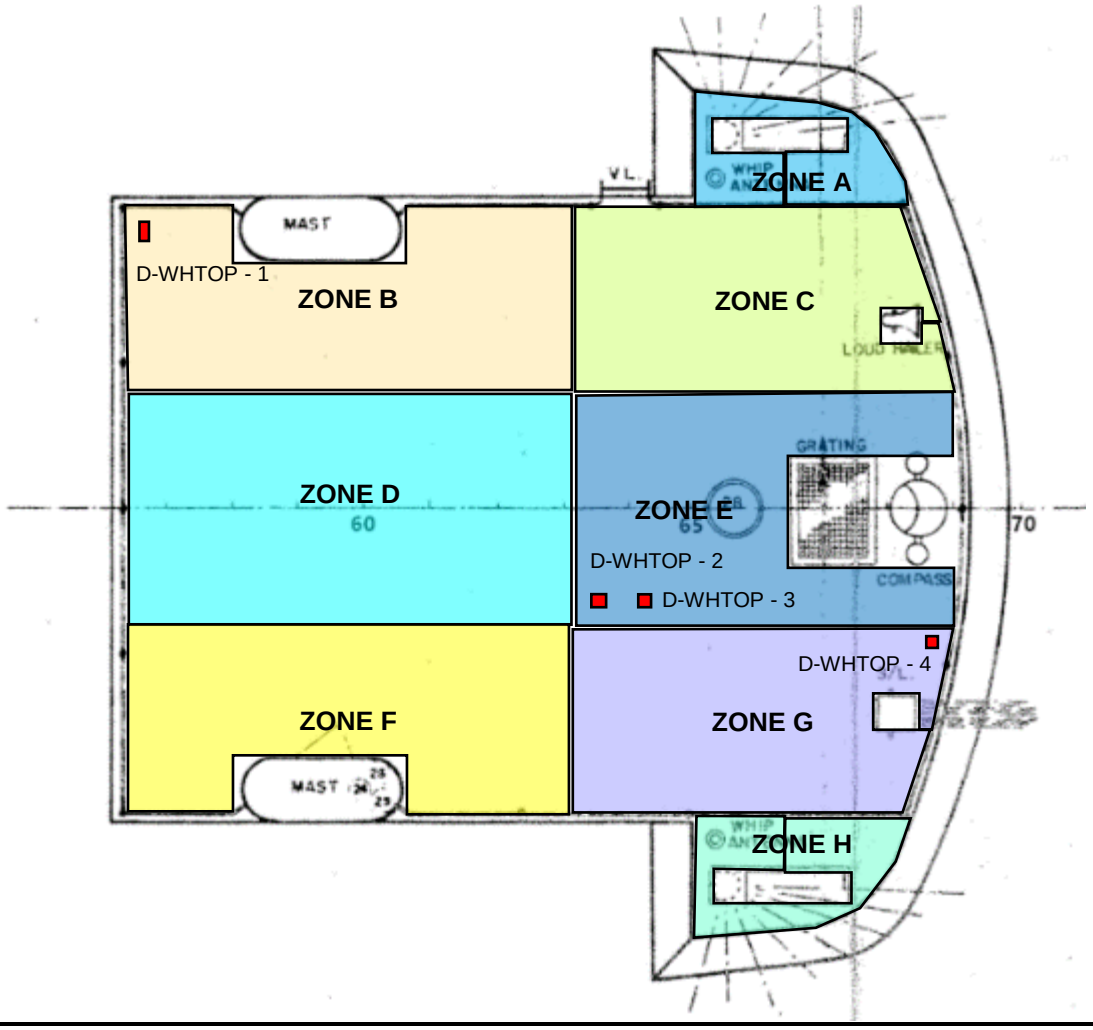
No defects below the 80% reporting threshold were located in this scan

## 6.10 Results Tables

All the results tables of the decks scanned are found within this section.

**Wheel House Top – D-WHTOP**

**Deck Structure**

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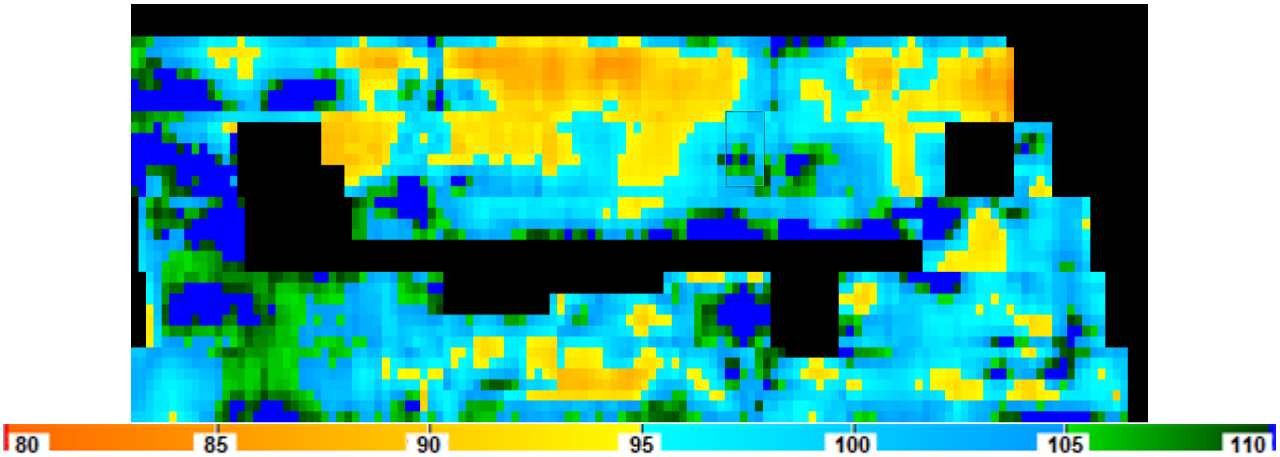

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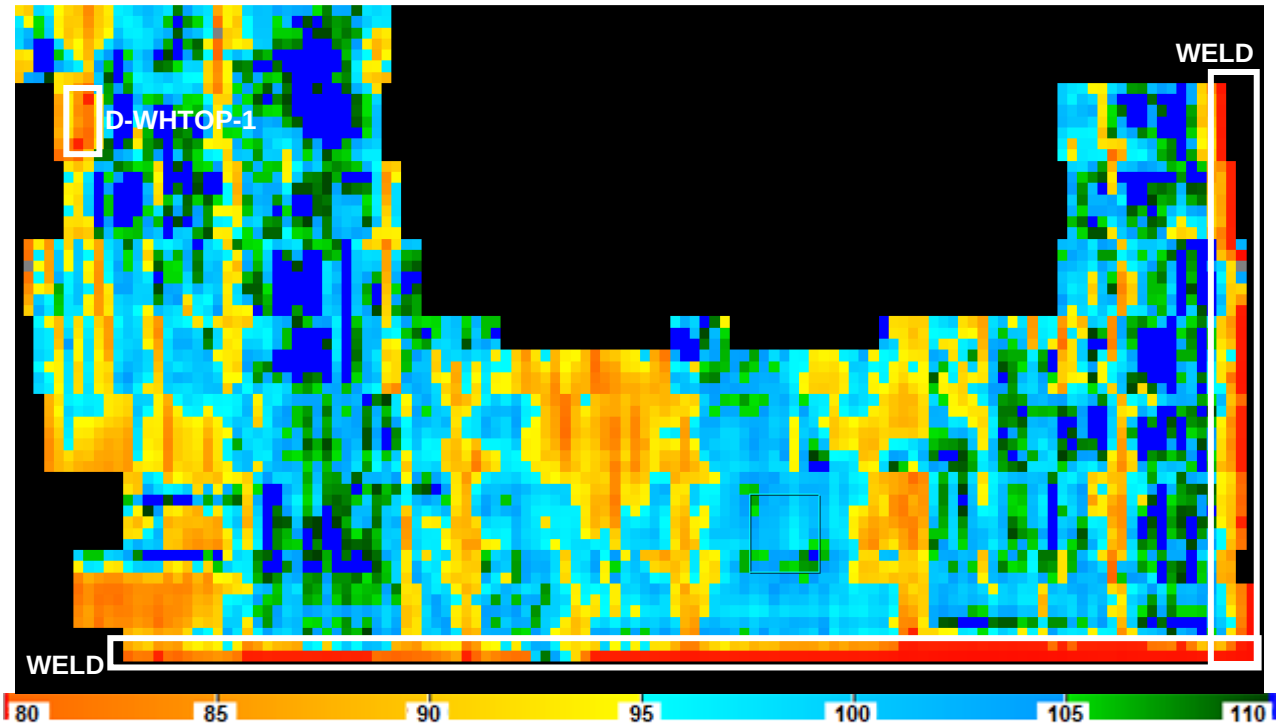
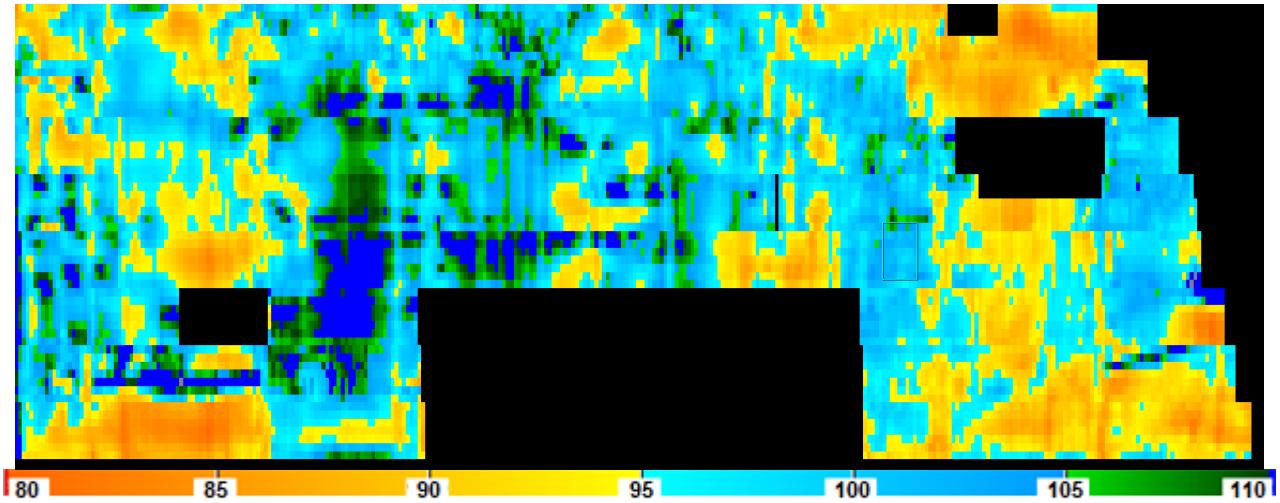



ZONE C



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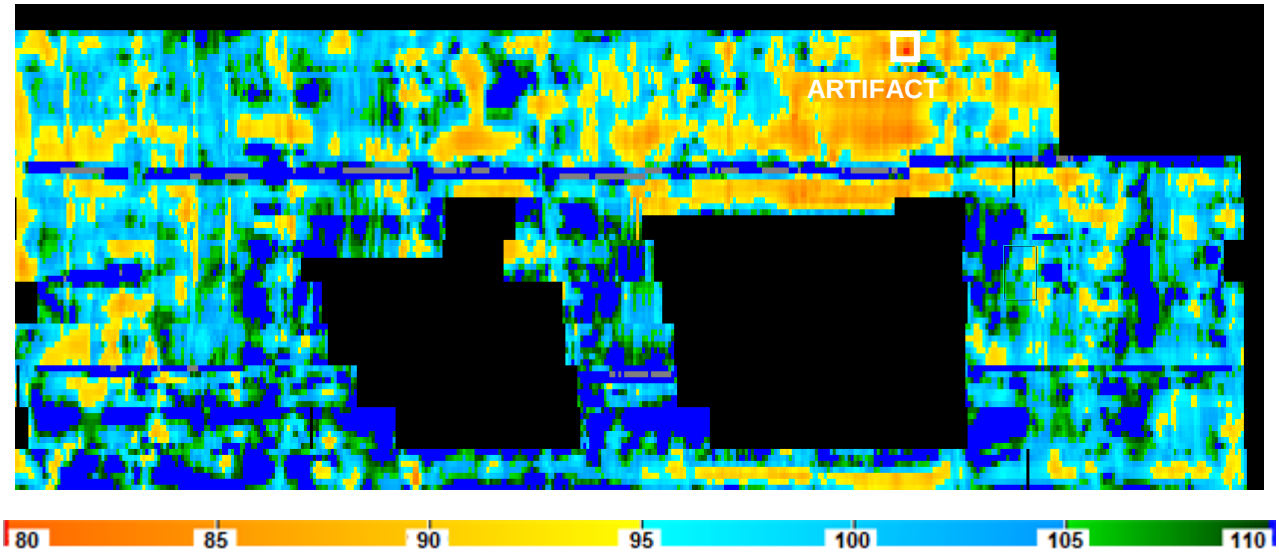
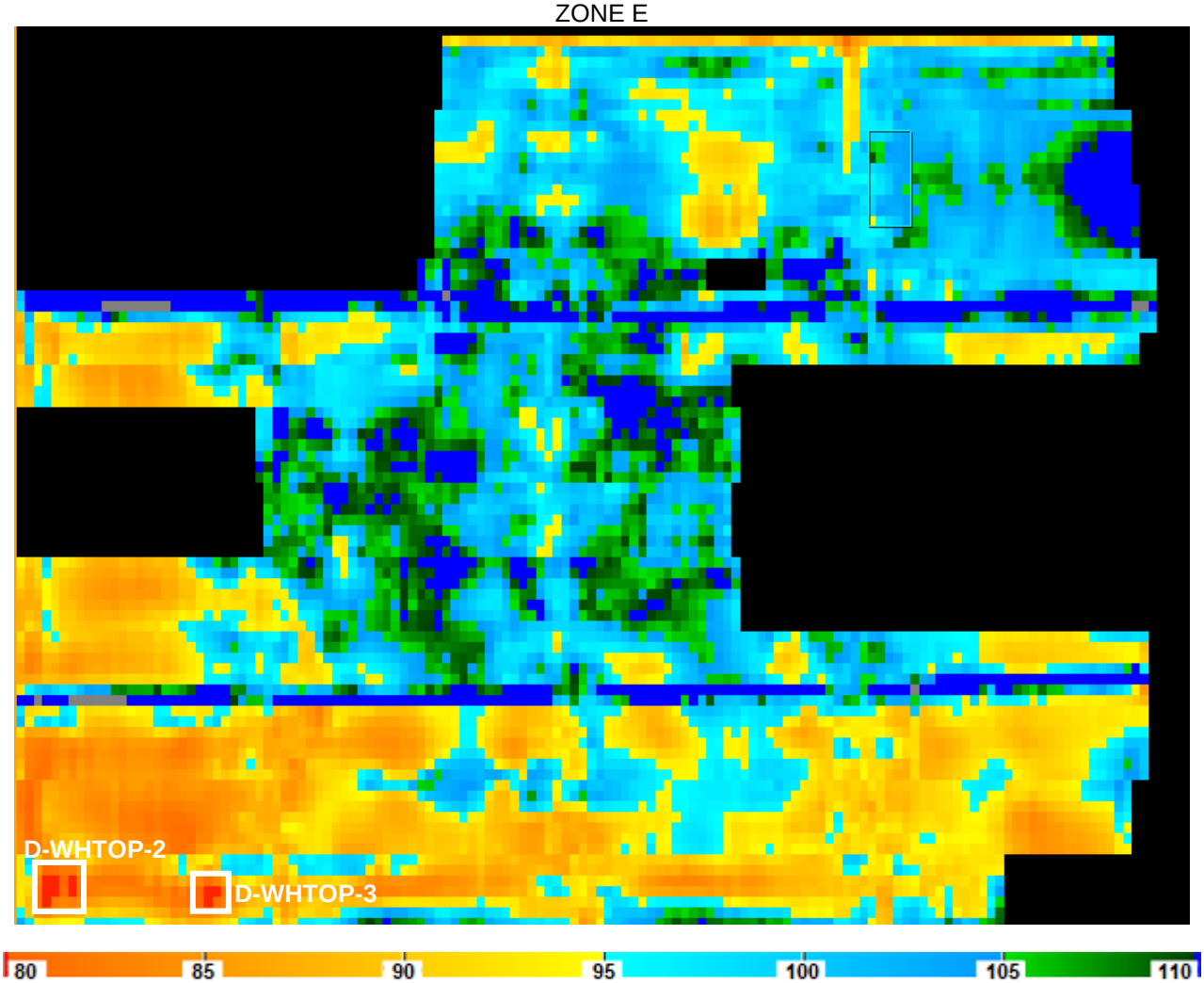
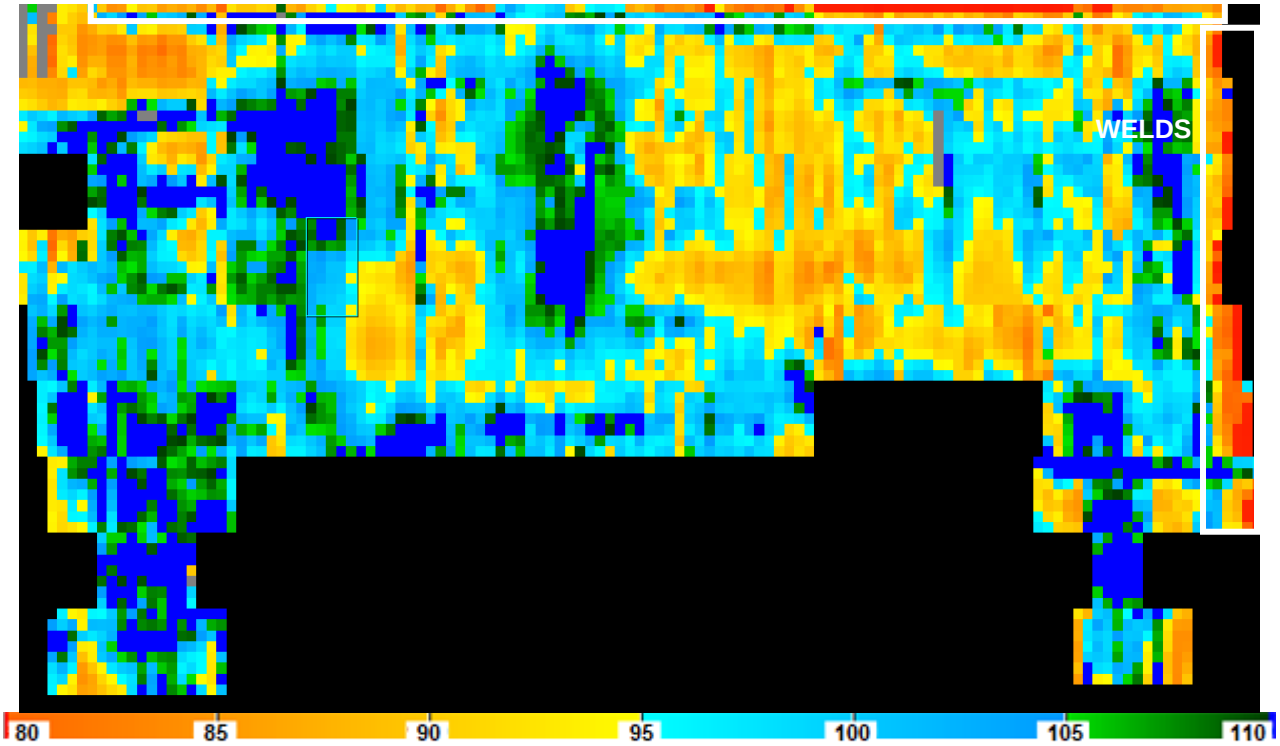

ARTIFACT
80
85
90
95
100
105
110

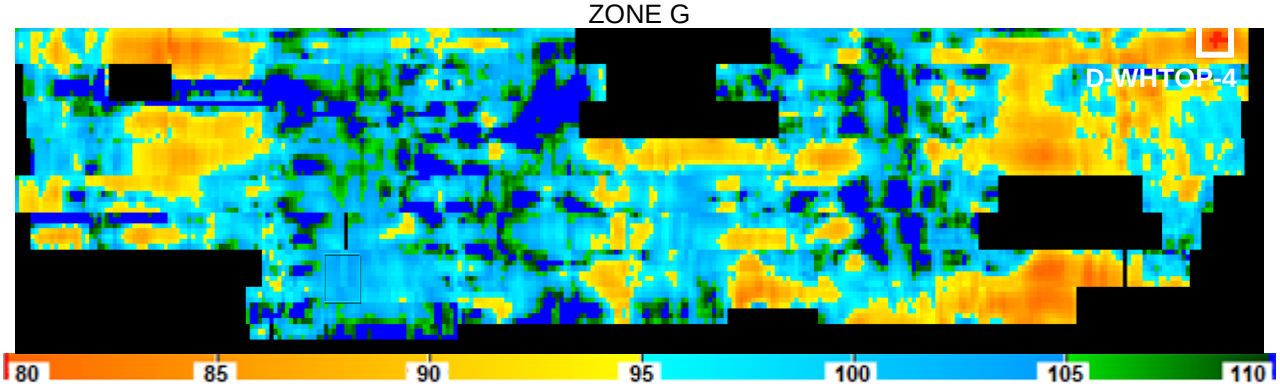
ZONE E


D-WHTOP-2
D-WHTOP-3
80
85
90
95
100
105
110

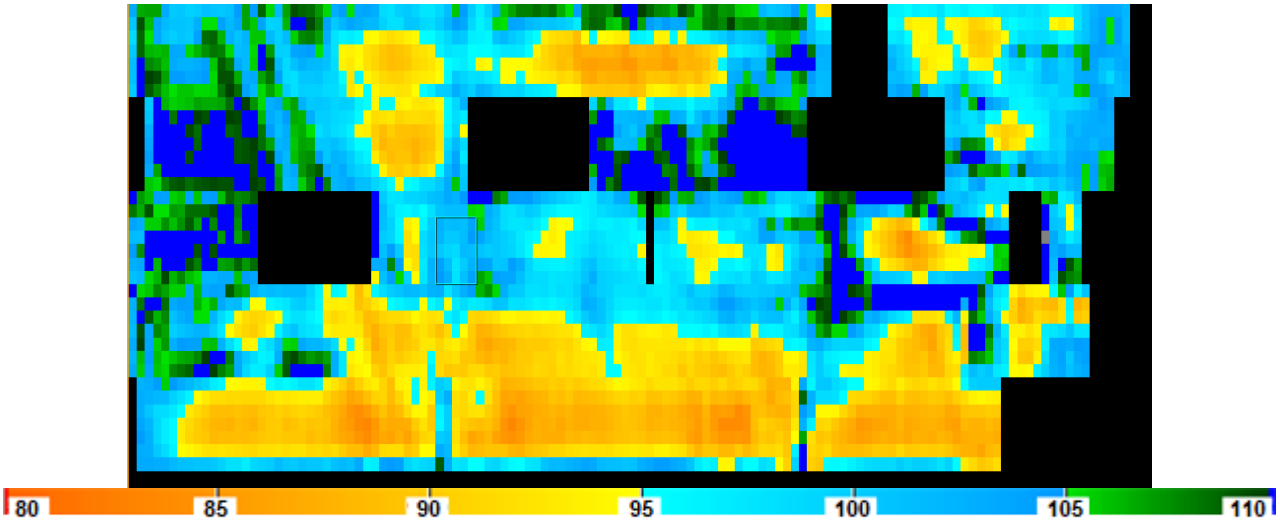
ZONE F




ZONE G




ZONE H



| Areas Identified For Further Investigation | | |
|---|---|---|
| D-WHTOP-1 | Nominal Plate Thickness: | 6.35mm |
| | Size: | 75mm x 180mm |
| | Min Est WT%: | 77.4% (~4.9mm) |
| | Avg Est WT%: | 84.7% (~5.4mm) |
| D-WHTOP-2 | Nominal Plate Thickness: | 6.35mm |
| | Size: | 80mm x 75mm |
| | Min Est WT%: | 77.6% (~4.9mm) |
| | Avg Est WT%: | 80.2% (~5.1mm) |
| D-WHTOP-3 | Nominal Plate Thickness: | 6.35mm |
| | Size: | 50mm x 75mm |
| | Min Est WT%: | 79.3% (~5.0mm) |
| | Avg Est WT%: | 80.6% (~5.1mm) |
| D-WHTOP-4 | Nominal Plate Thickness: | 6.35mm |
| | Size: | 65mm x 75mm |
| | Min Est WT%: | 78.4% (~5.0mm) |
| | Avg Est WT%: | 79.7% (~5.1mm) |
| NOTES:<br>Zone D contains an artifact that is not corrosion, as the magnetic response curves of the PEC data in this area show that the low thickness signals are due to magnetic permeability differences. | | |

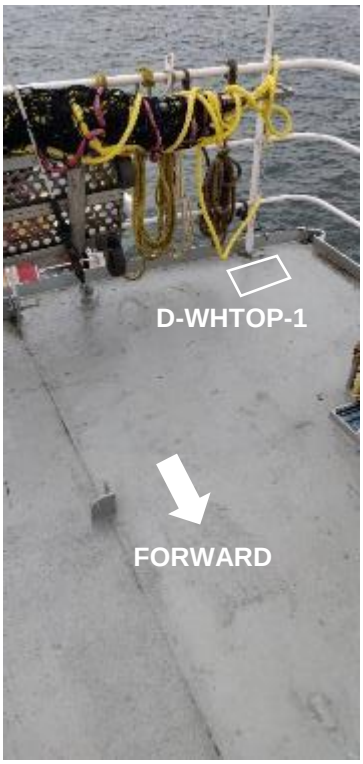



Figure 10 – Defect D-WHTOP-1 on the Aft Portside plate of the Wheel House Top

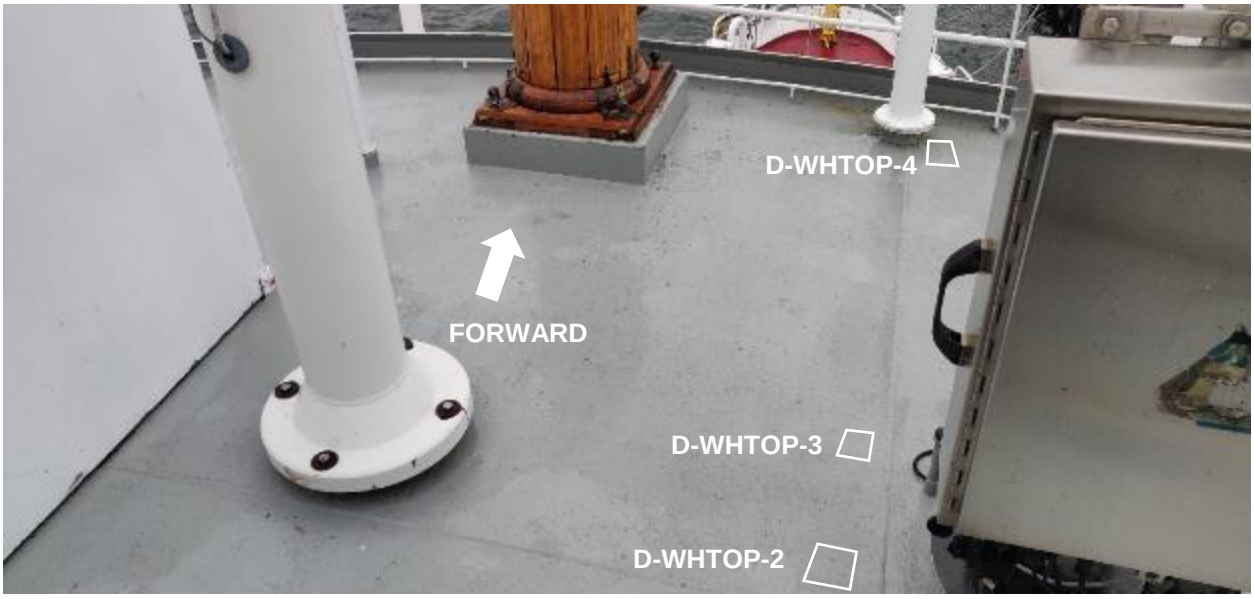
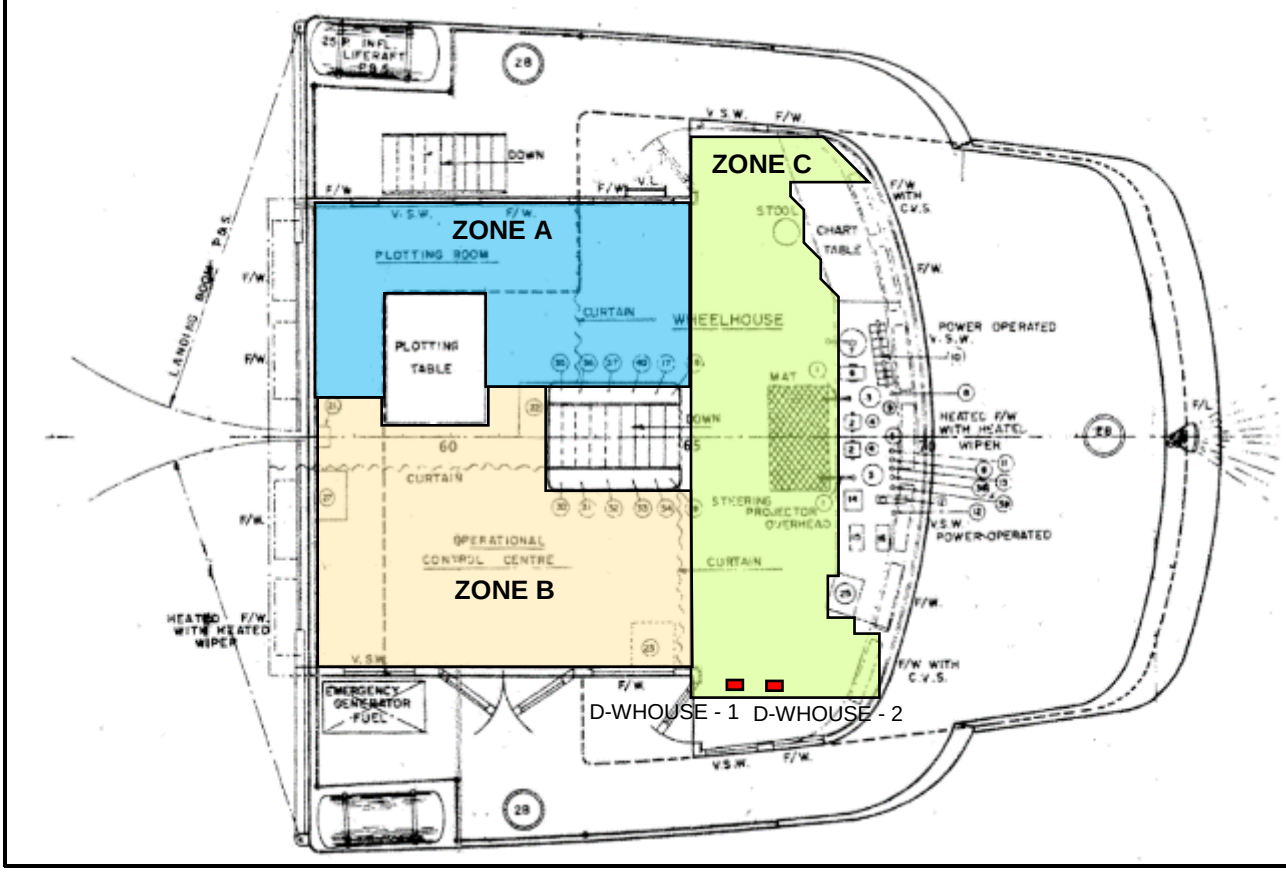


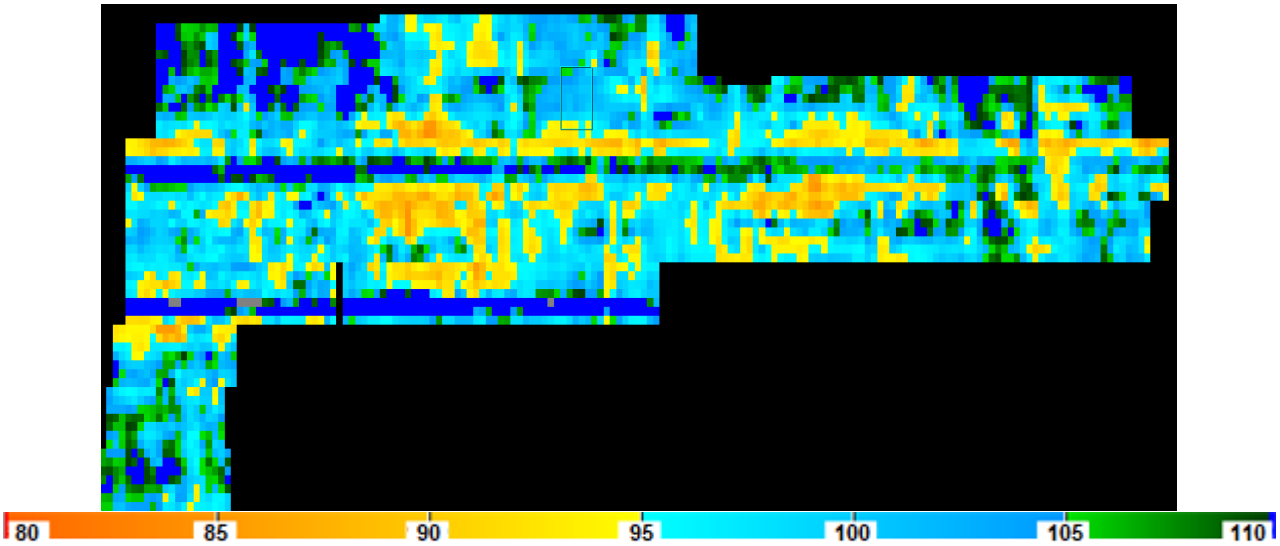

Figure 11 – Defects D-WHTOP-2 and D-WHTOP-3 on the
Forward Middle Plate and D-WHTOP-4 on the Forward Starboard plate of the Wheel House Top

**Wheel House – D-WHOUSE**

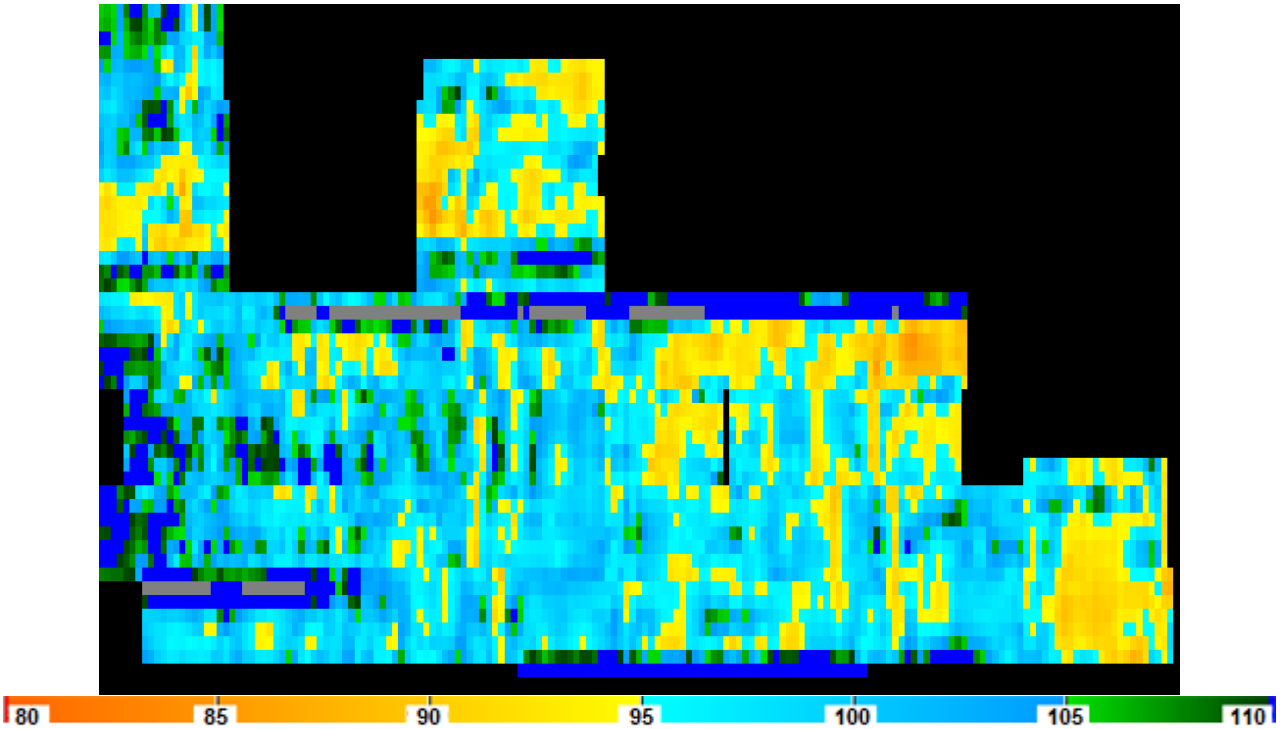
**Deck Structure**



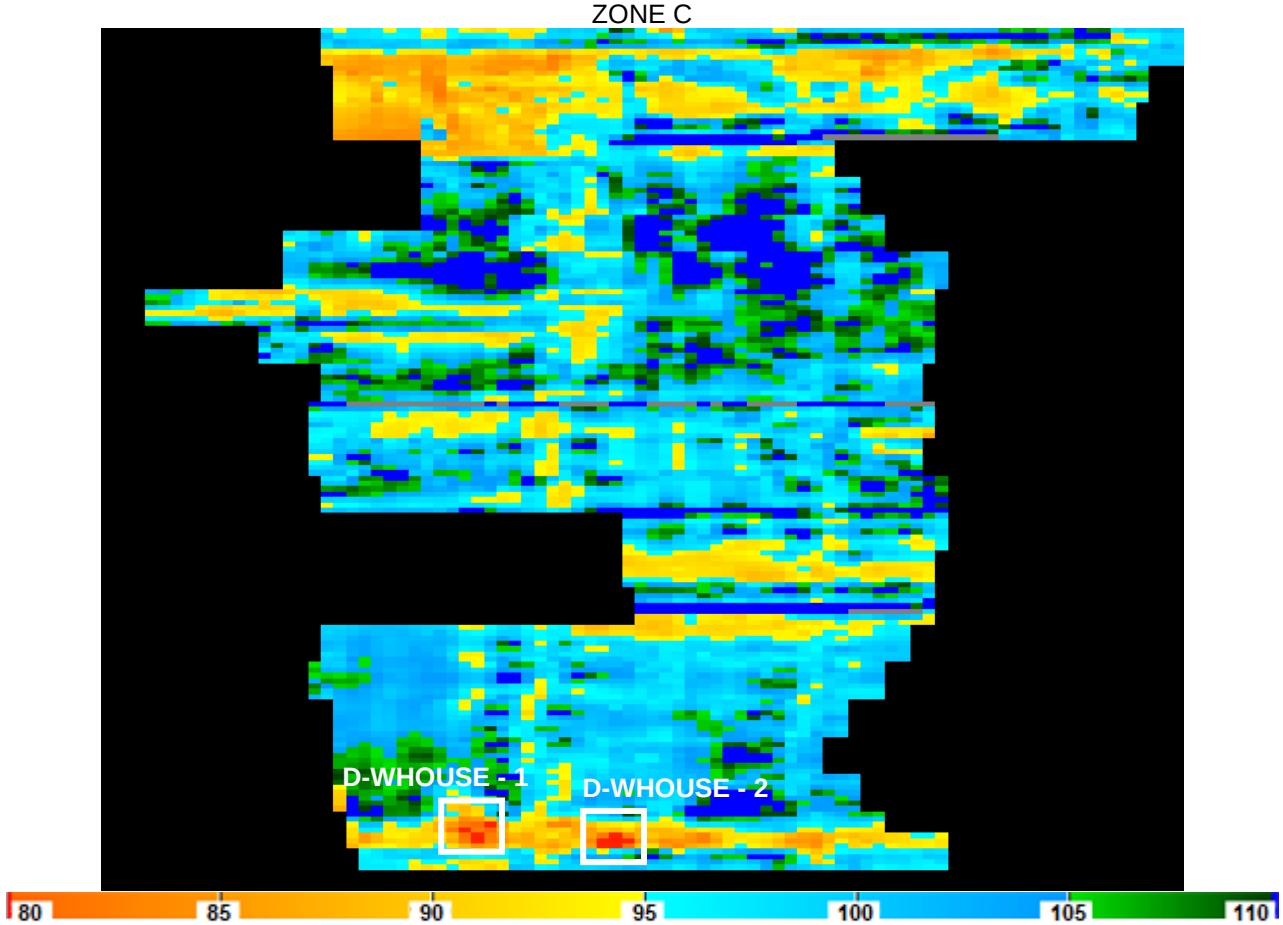
ZONE A




ZONE B



ZONE C



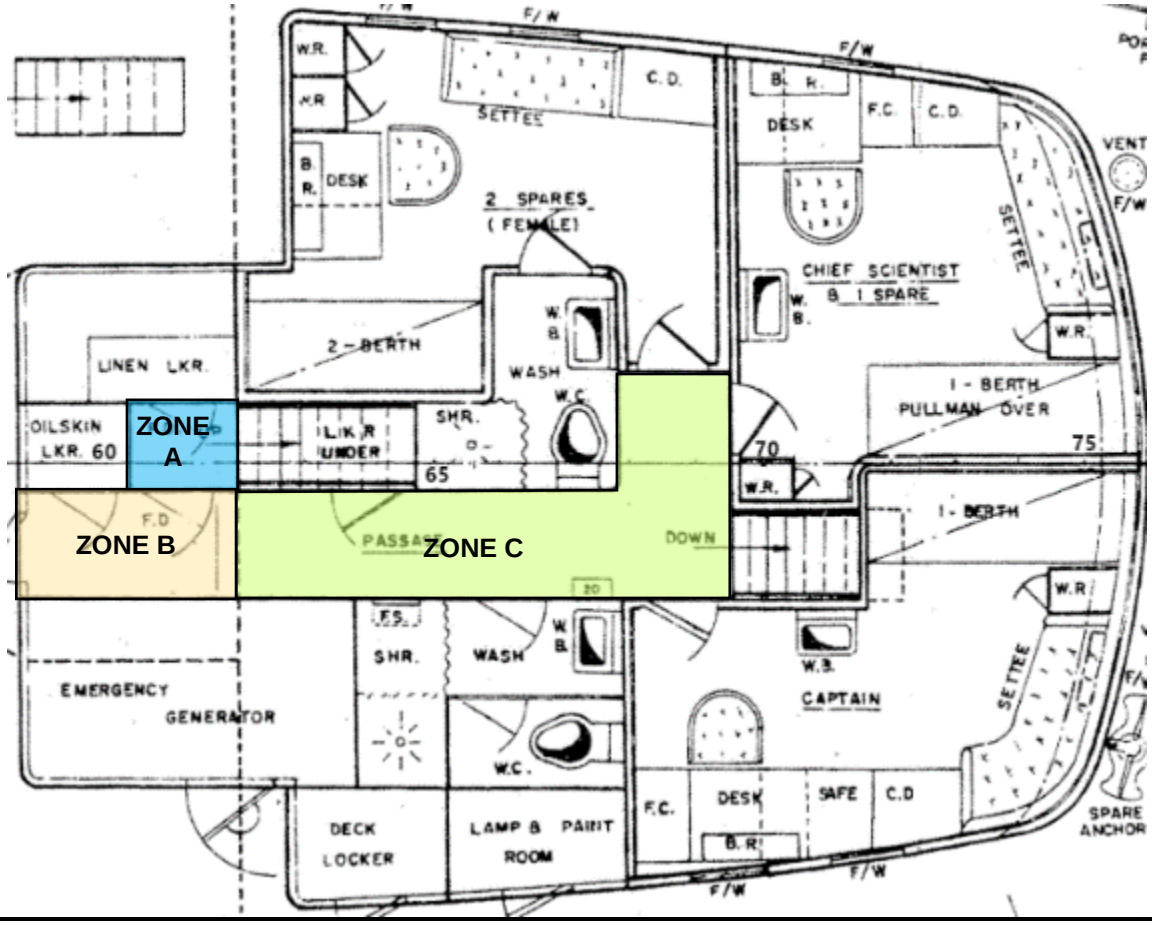

| Areas Identified For Further Investigation | | |
|---|---|---|
| D-WHOUSE-1 | Nominal Plate Thickness: | 6.35mm |
| | Size: | 75mm x 225mm |
| | Min Est WT%: | 78.1% (~5.0mm) |
| | Avg Est WT%: | 81.6% (~5.2mm) |
| D-WHOUSE-2 | Nominal Plate Thickness: | 6.35mm |
| | Size: | 75mm x 135mm |
| | Min Est WT%: | 74.4% (~4.7mm) |
| | Avg Est WT%: | 79.0% (~5.0mm) |

NOTES: As defects in Zone A were found along a longitudinal, these areas could be repair welds. However, complete structural and/or repair details are required to confirm.

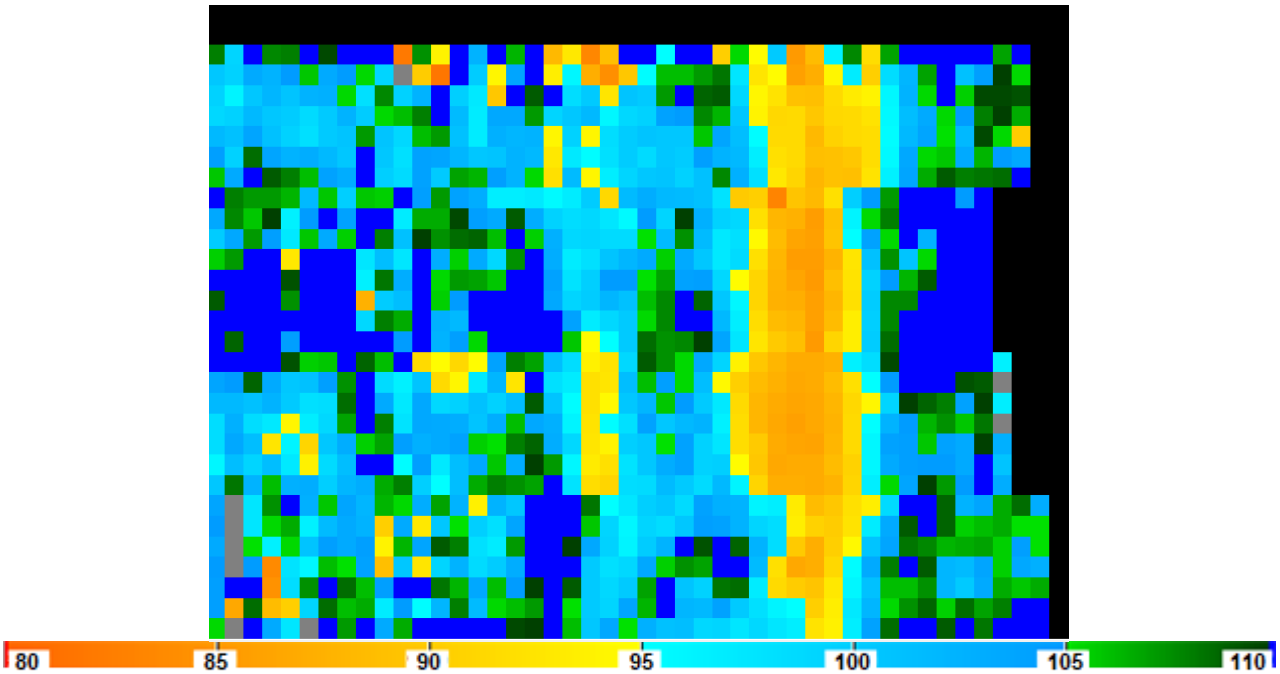

Figure 12 – Defects D-WHOUSE-1 and D-WHOUSE-2 at the Forward Starboard Side of the Wheelhouse

**Fo'c'sle Deck Passageway – D-FPASS**

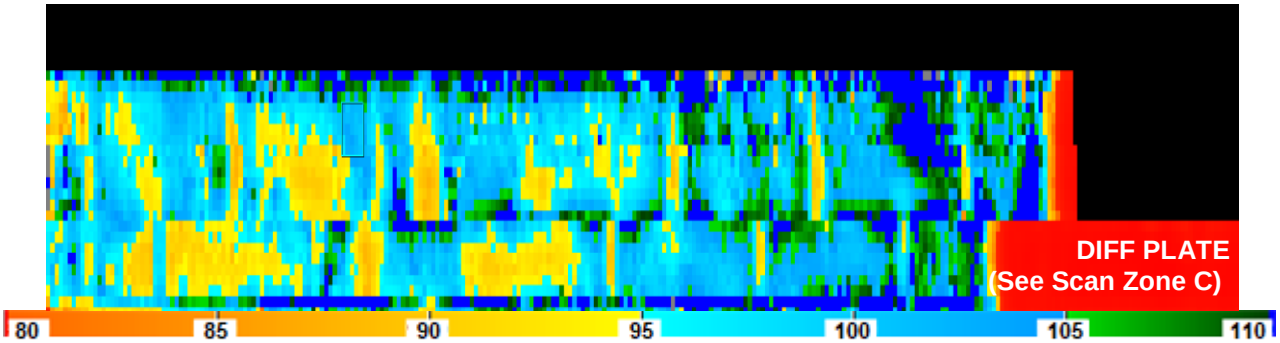
**Deck Structure**



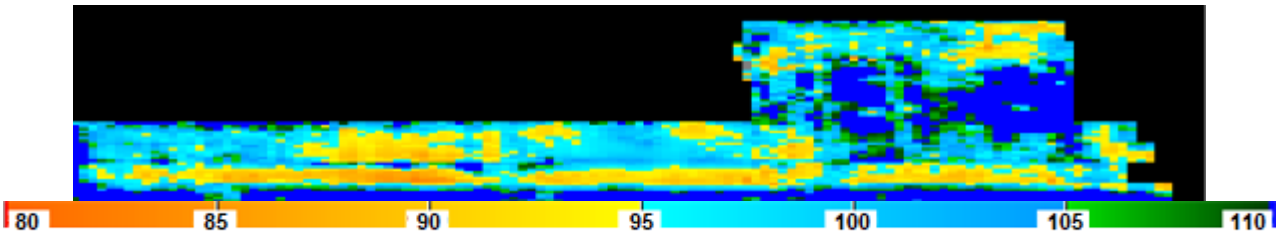

ZONE A



ZONE B



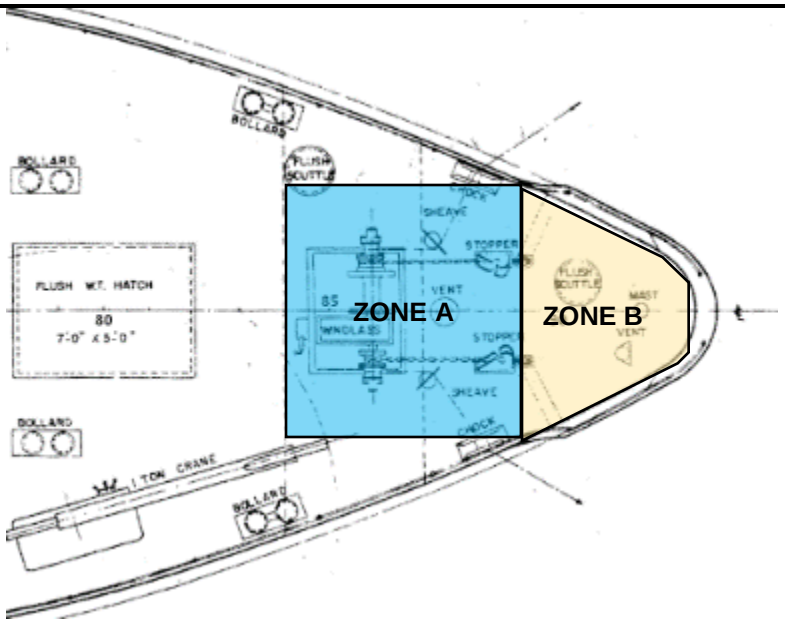

ZONE C



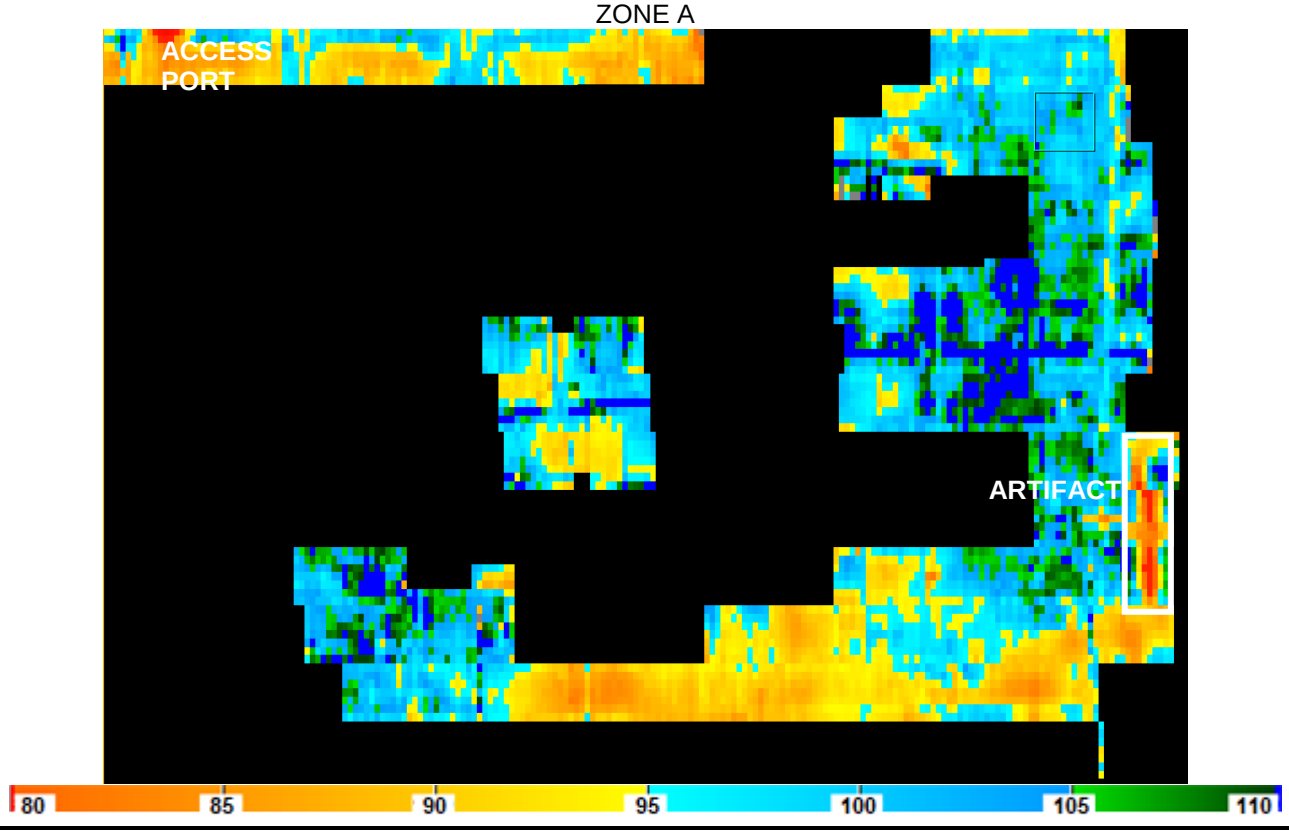

No Areas Identified For Further Investigation

**Anchor Windlass – D-AWIND**

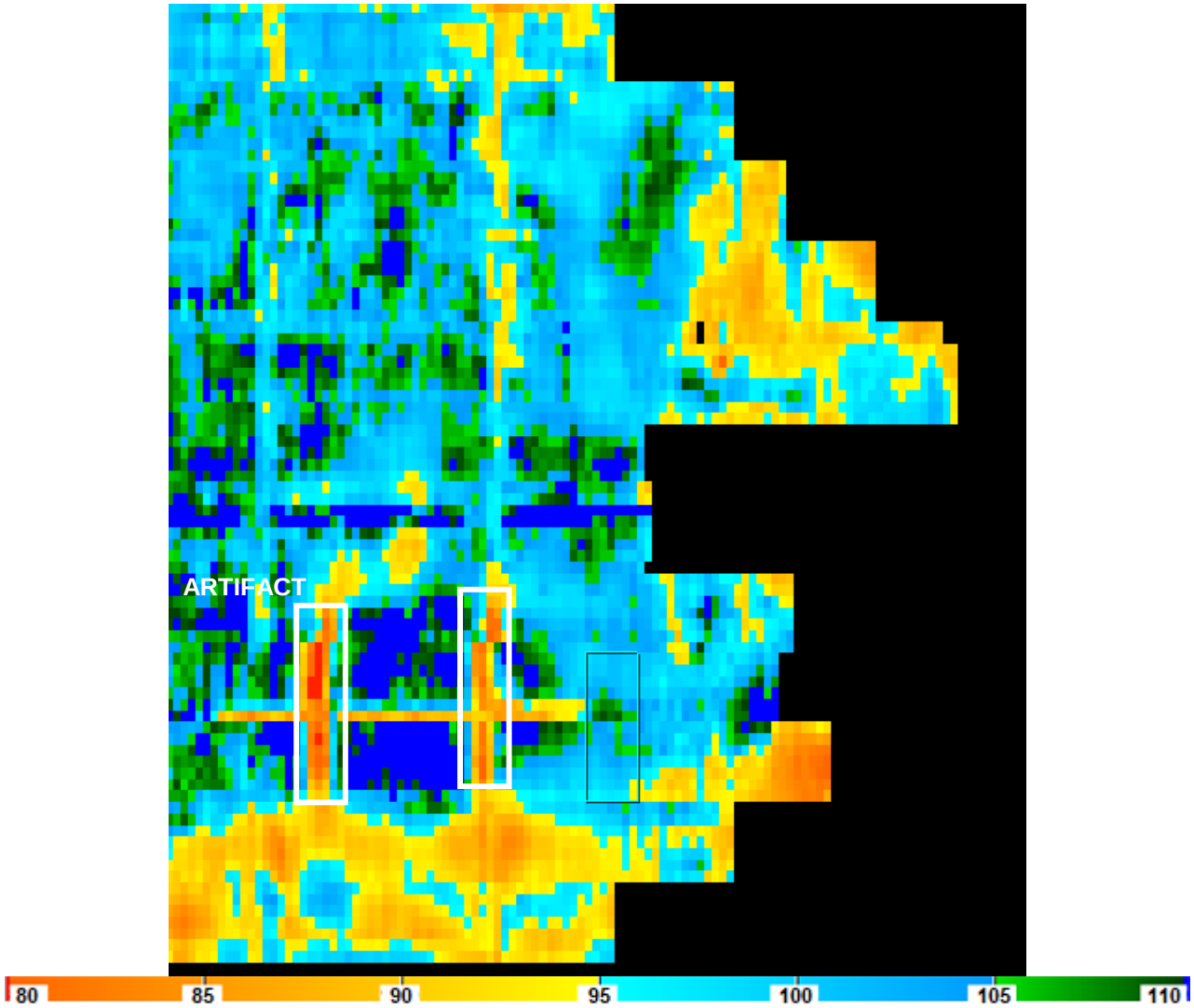
**Deck Structure**




ZONE A



ZONE B

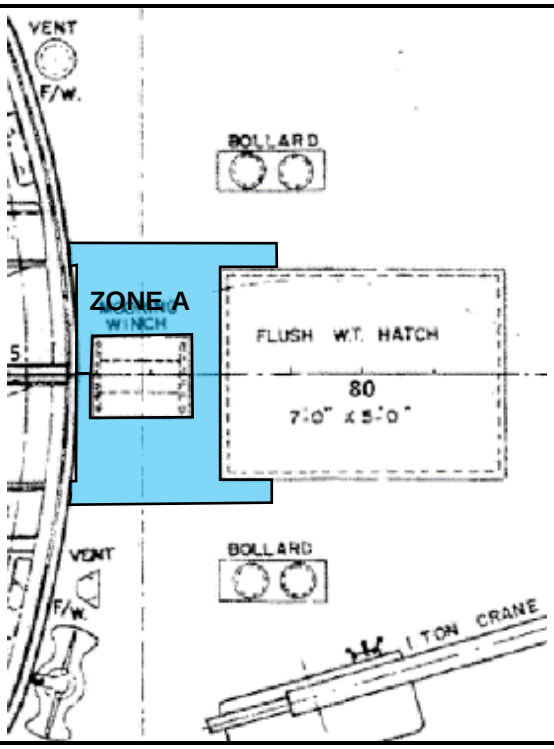



No Areas Identified For Further Investigation

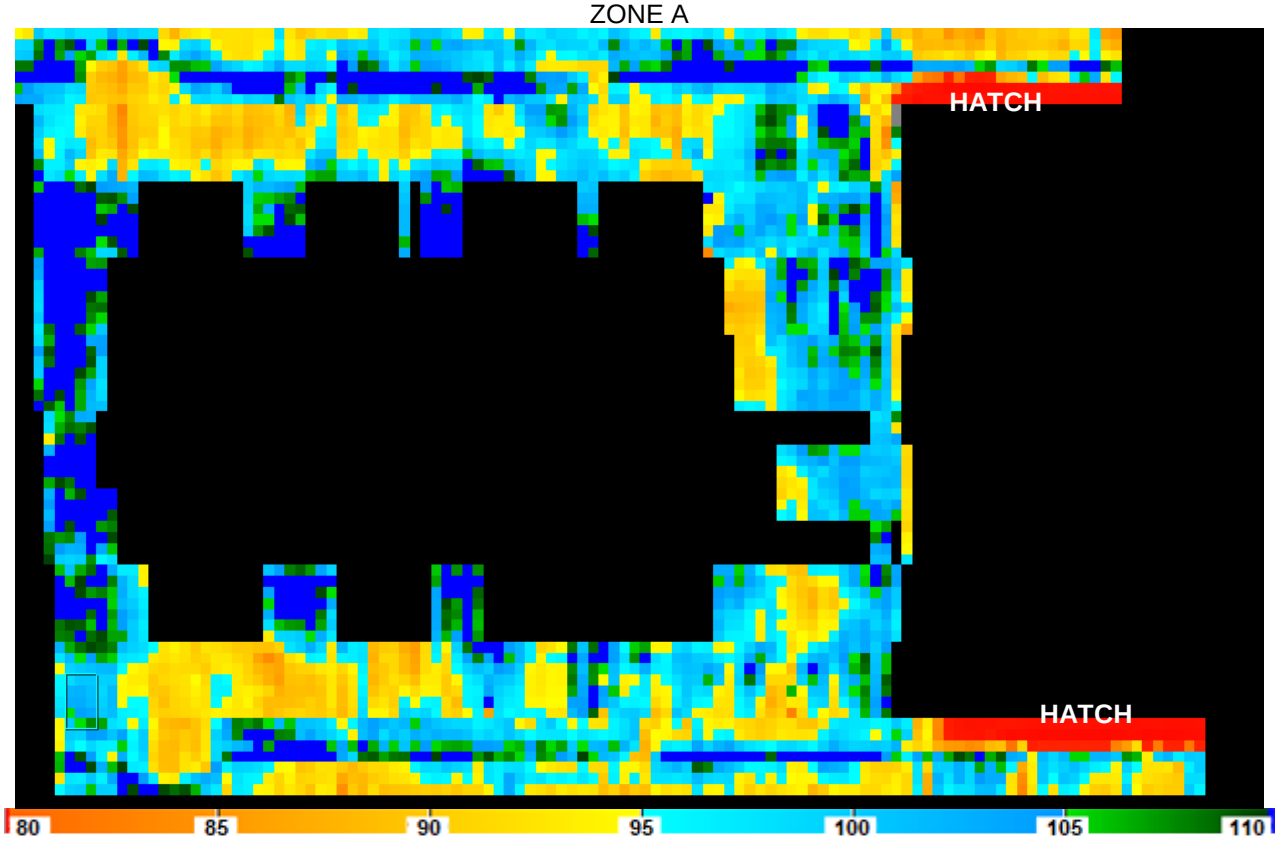
NOTES: Artifacts detected in Zones A and B are likely due to previous hotwork or structural damage. It should be noted that the artifact in Zone A is the same as the Aft-most (left) artifact in Zone B.

**Mooring Winch – D-WINCH**

**Deck Structure**



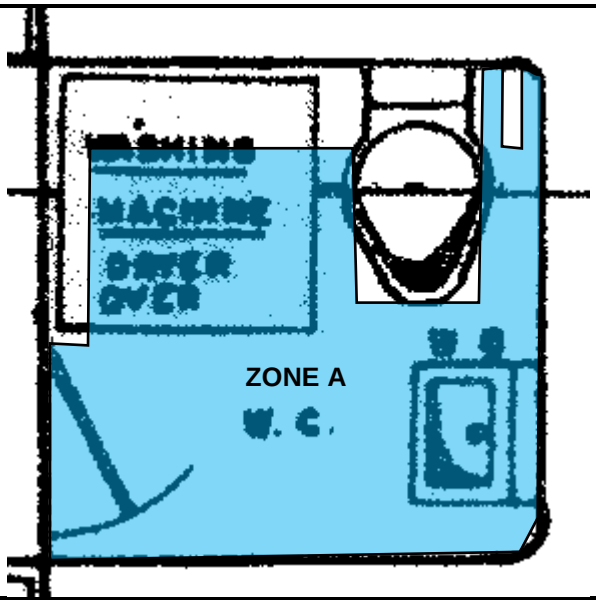

ZONE A



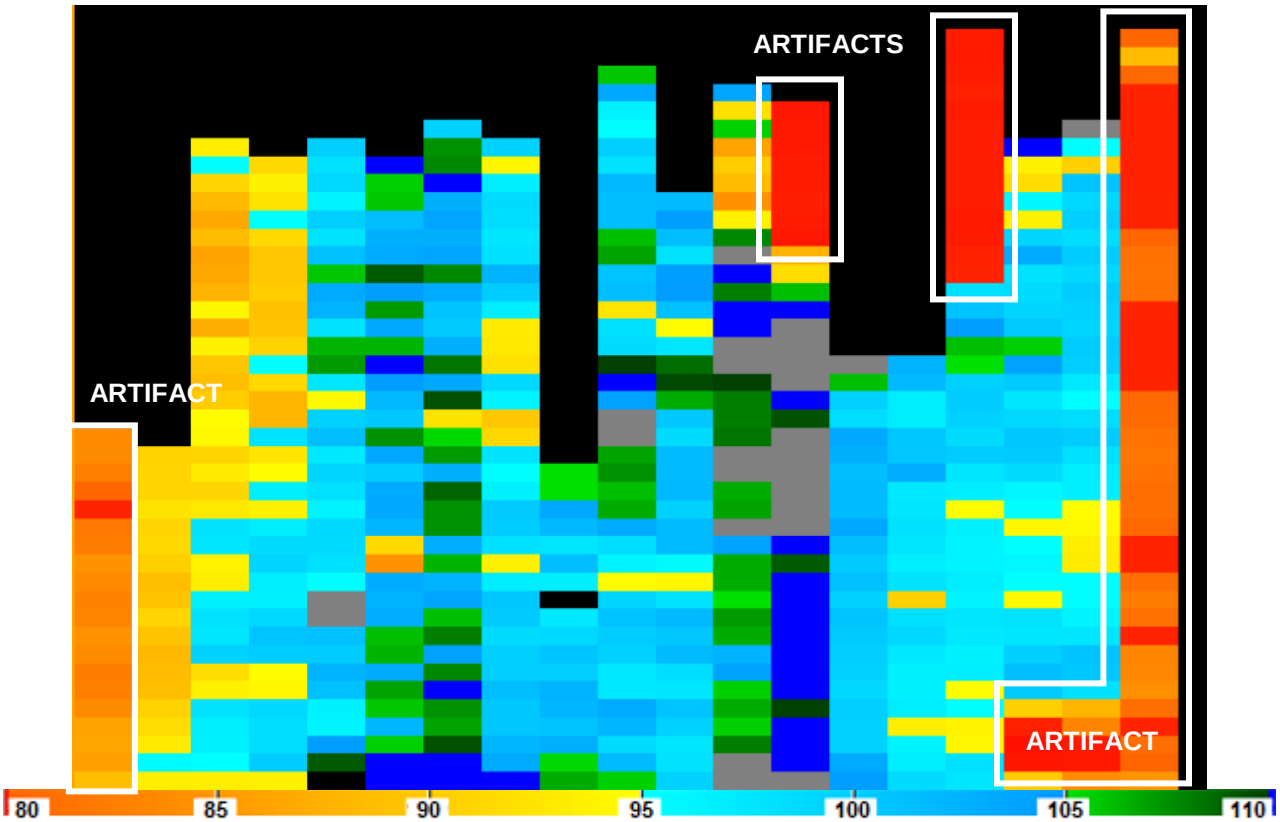

No Areas Identified For Further Investigation

**Main Deck Washplace – D-MDWP**

**Deck Structure**




ZONE A

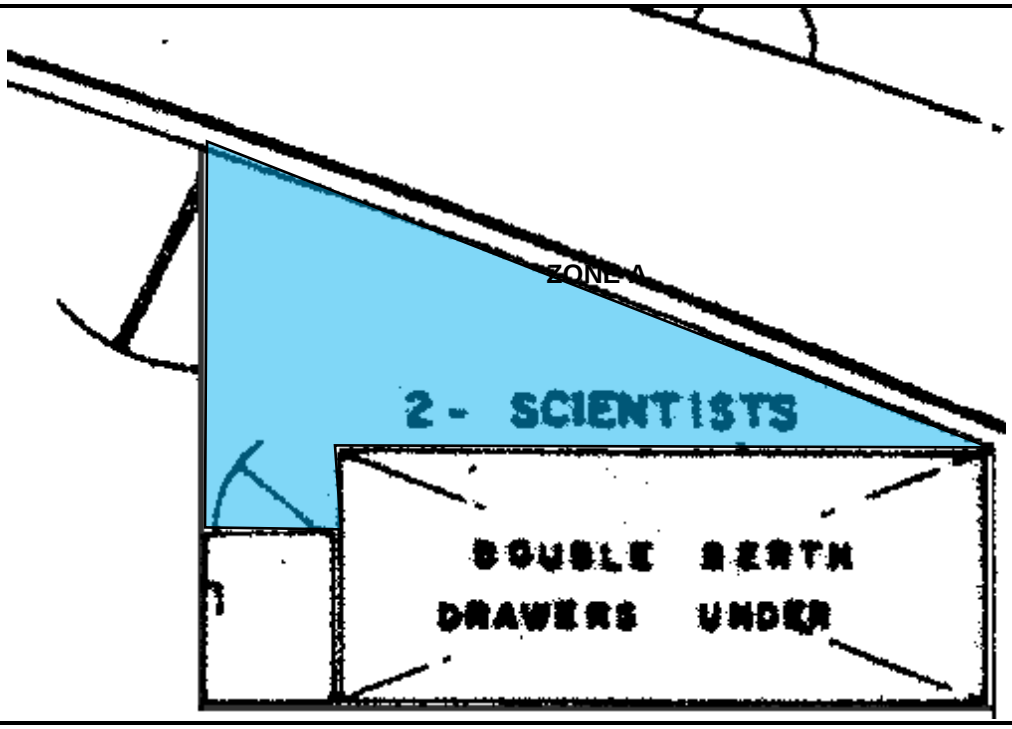



No Areas Identified For Further Investigation

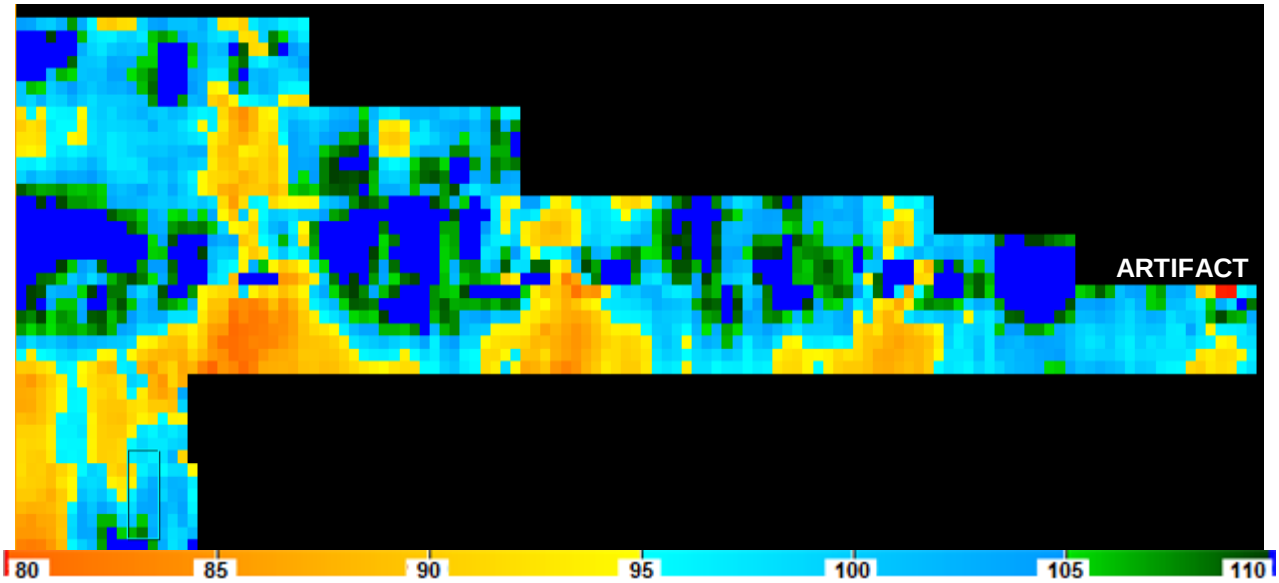
NOTES: Multiple artifacts are found in this scan zone due to interference from the sandwich plate beneath the toilet and interference near the bulkheads.

**Main Deck Forward Port Cabin – D-FWPC**

**Deck Structure**




ZONE A

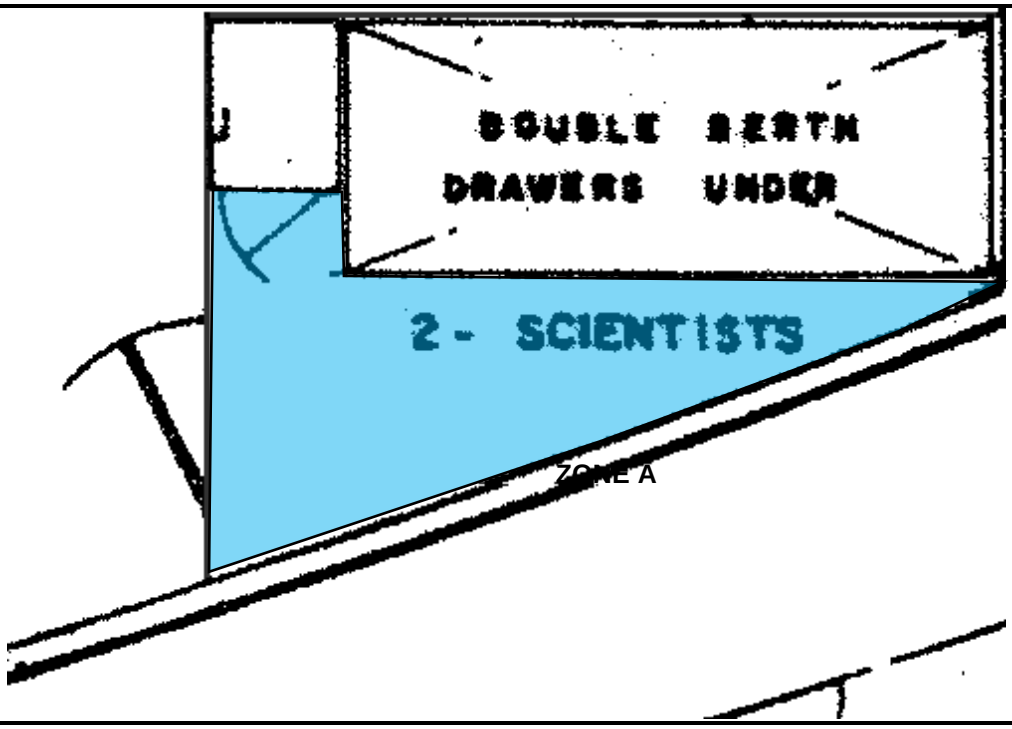



No Areas Identified For Further Investigation

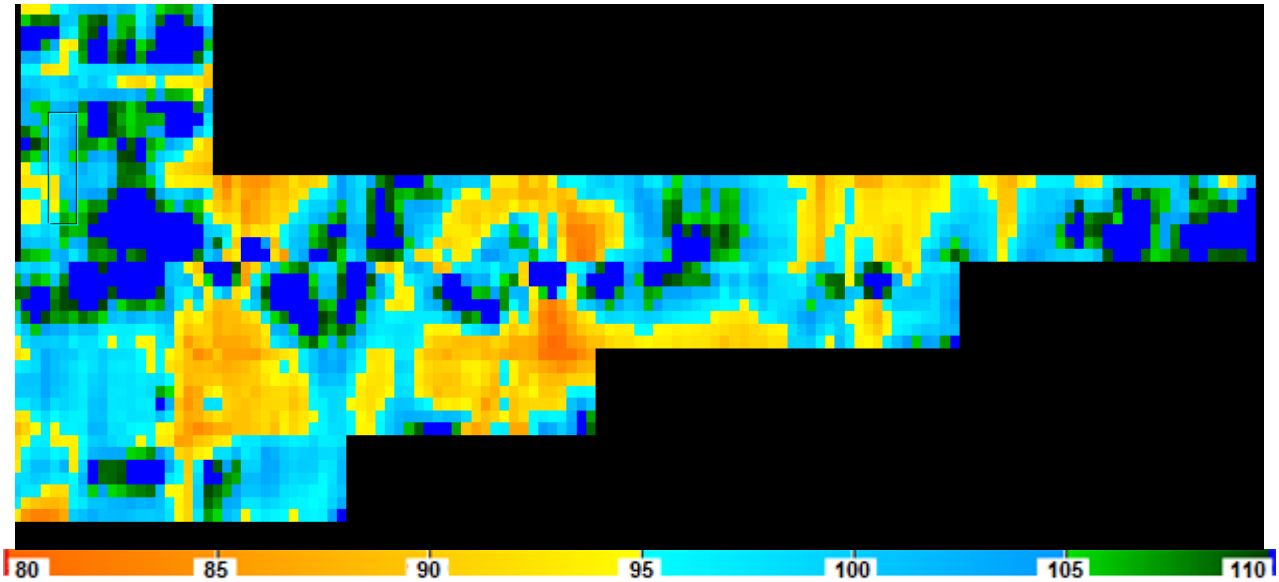
NOTES: The artifact in this zone is likely due to a weld or unknown structural feature, since magnetic response curves of the PEC data in the area of the artifact indicate that there is no corrosion present.

**Main Deck Forward Starboard Cabin – D-FWSC**

**Deck Structure**



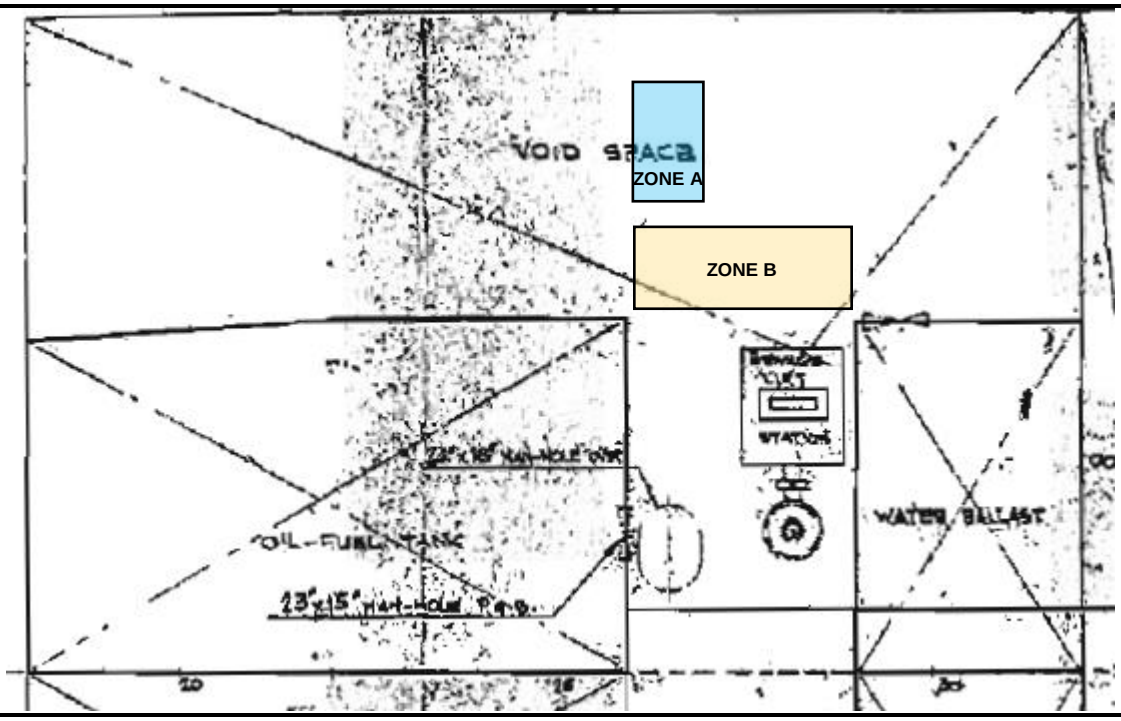

ZONE A



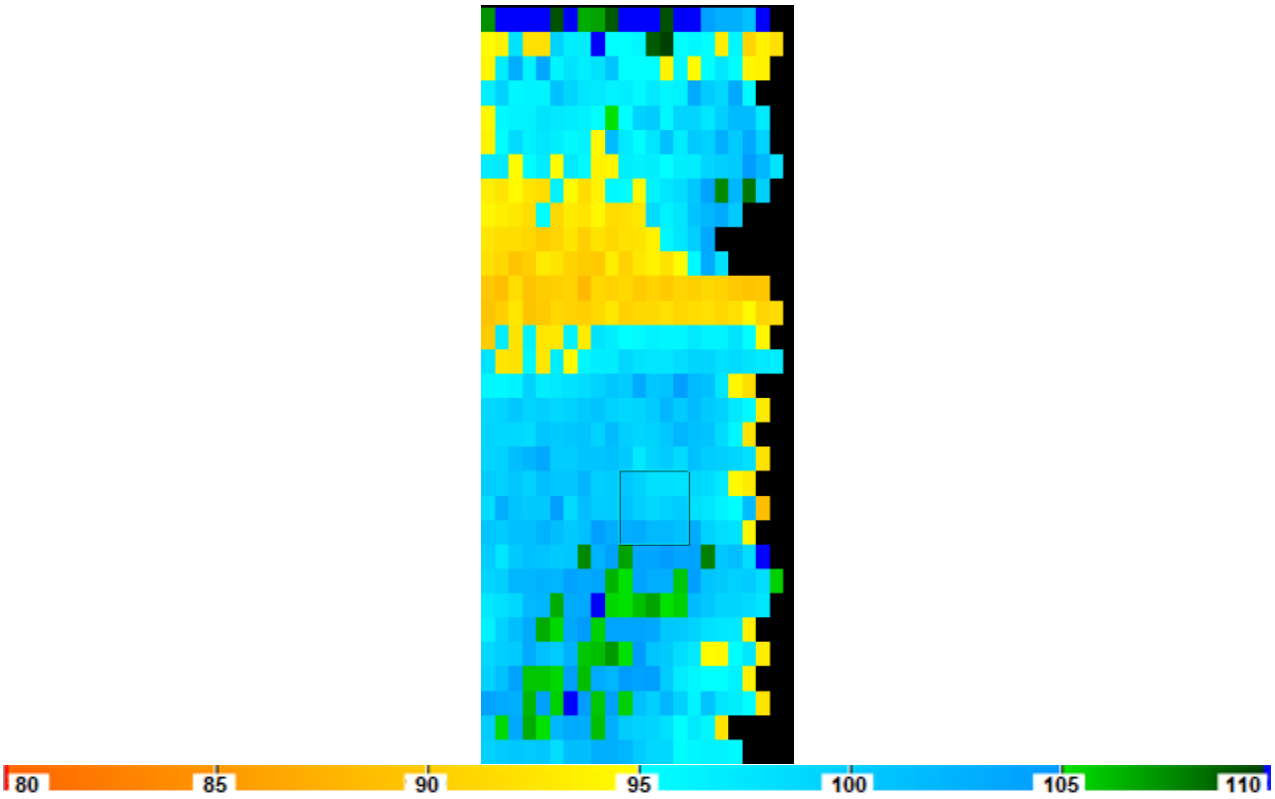

No Areas Identified For Further Investigation

**Void Space – D-VOID**

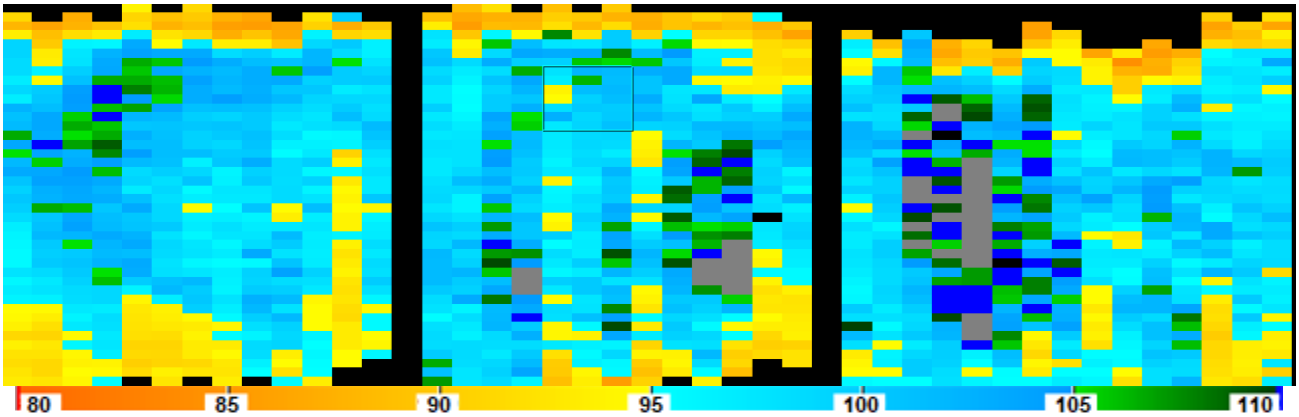
**Deck Structure**




ZONE A



ZONE B




No Areas Identified For Further Investigation

# 7 Survey Results – Hull

Scans of the Hull of the CCGS LIMNOS indicated three (3) defects below the 80% remaining wall thickness threshold. The defects are summarized in Table 2 and comments for this area are shown in Section 7.1. Results tables and scan images for all hull structure scan zones are found in Section 7.2.

Table 2 – Hull Defect Summary

| Location | Defect ID | | |
|---|---|---|---|
| STBD Hull (FR 23.5-45) | HULL-S-1 (See 7.1) | Nominal Plate Thickness: | 14.2875mm |
| | | Size: | 490mm x 135mm |
| | | Min Est WT%: | 78.5% (~11.2mm) |
| | | Avg Est WT%: | 86.3% (~12.3mm) |
| | HULL-S-2 (See 7.1) | Nominal Plate Thickness: | 14.2875mm |
| | | Size: | 225mm x 310mm |
| | | Min Est WT%: | 76.3% (~10.9mm) |
| | | Avg Est WT%: | 89.3% (~12.8mm) |
| | HULL-S-3 (See 7.1) | Nominal Plate Thickness: | 14.2875mm |
| | | Size: | 135mm x 135mm |
| | | Min Est WT%: | 72.7% (~10.4mm) |
| | | Avg Est WT%: | 77.6% (~11.1mm) |

## 7.1 Starboard Side Hull

Three (3) defects below the 80% reporting threshold were located in this zone.

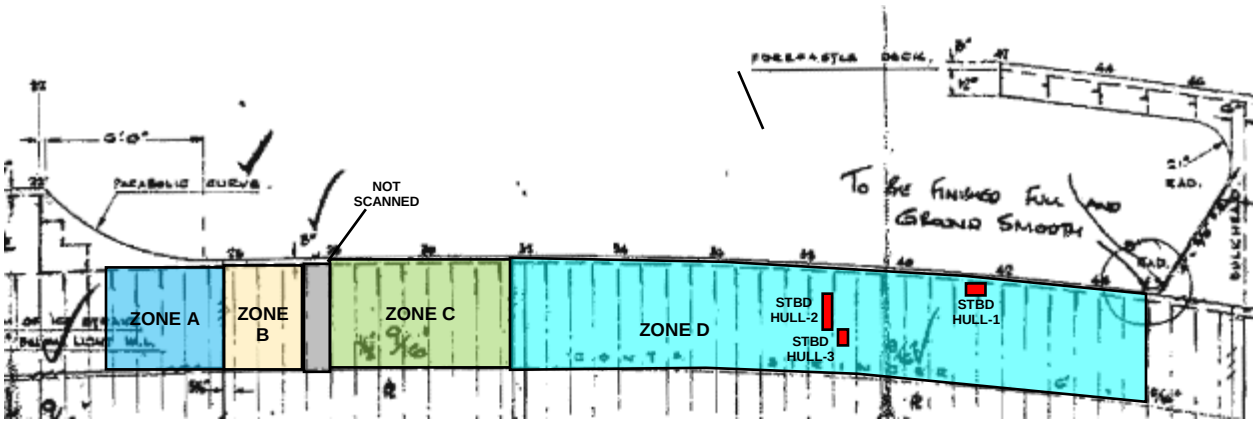
Given the tight frame spacing on the hull and the low resolution given by the probe, there is some uncertainty with the hull data. Therefore, a visual inspection and/or UT measurement of any low thickness measurements in the area is recommended to verify the steel condition.

## 7.2 Results Tables

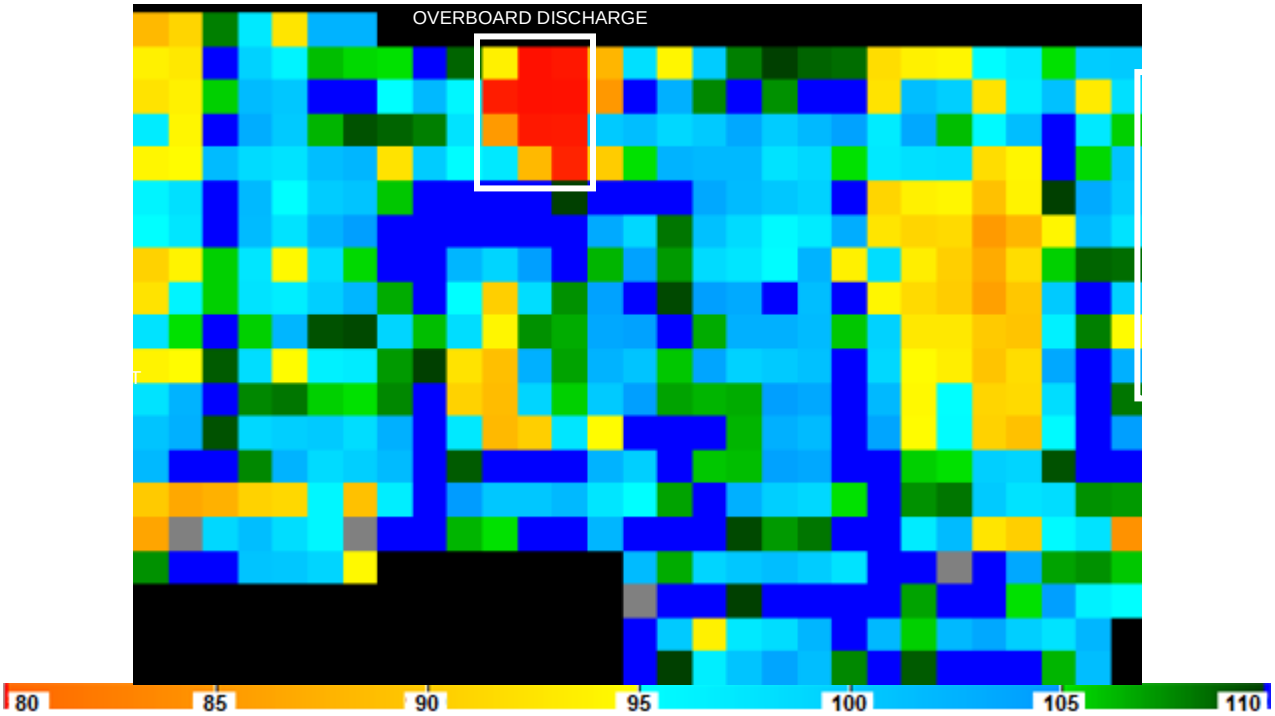
All the results tables of hull areas scanned are found within this section.

**Starboard Side Hull – HULL-S**

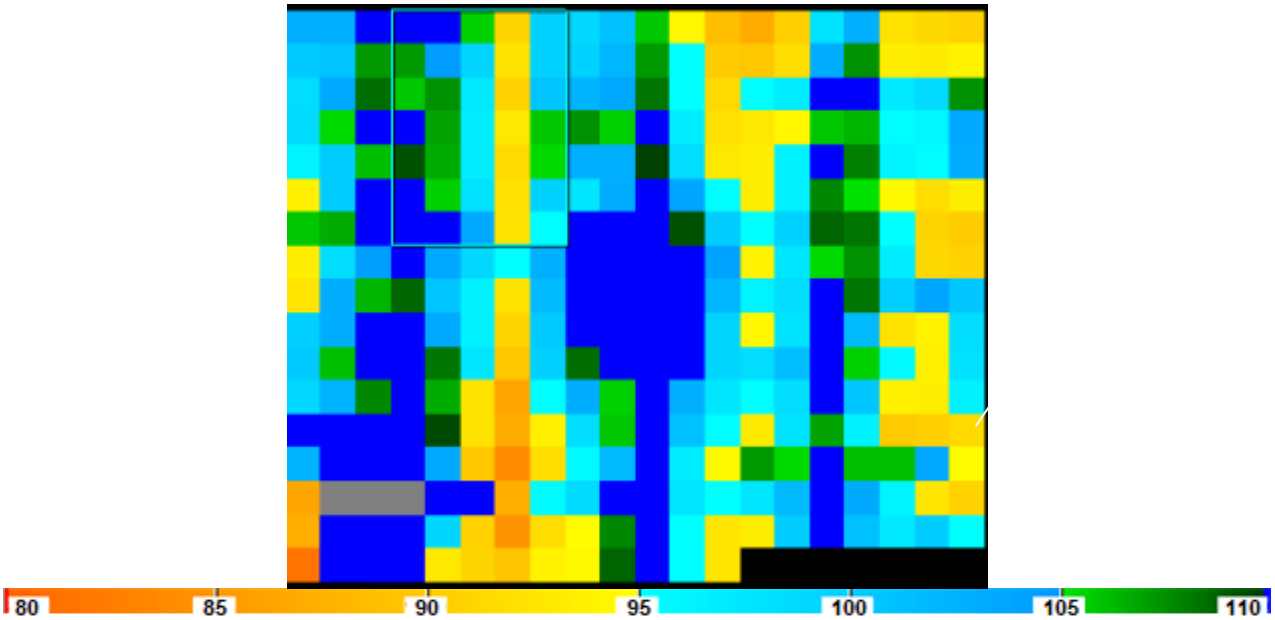
**HULL**



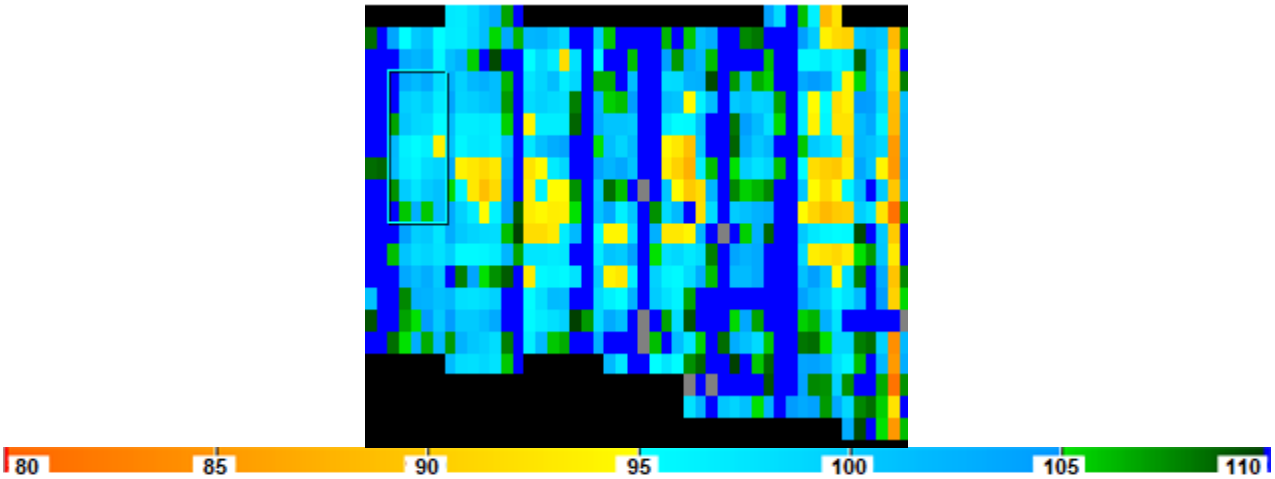

ZONE A



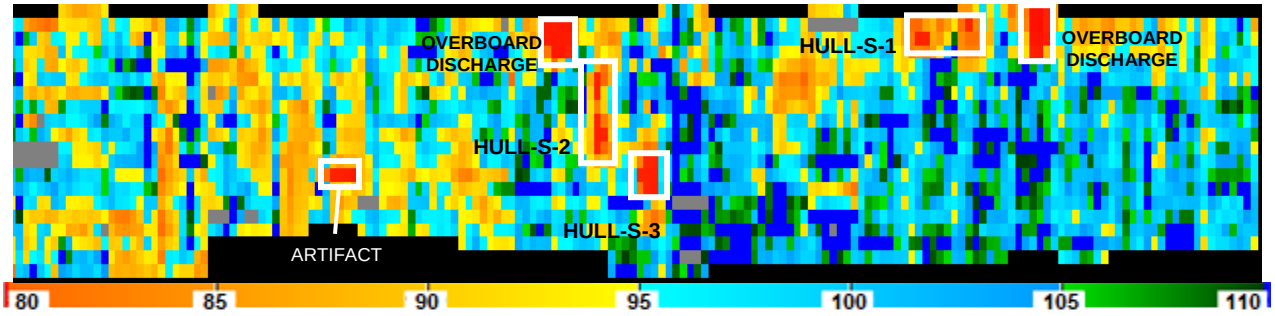
ZONE B




ZONE C




ZONE D




| Areas Identified For Further Investigation | | |
|---|---|---|
| HULL-S-1 | Nominal Plate Thickness: | 14.2875mm |
| | Size: | 490mm x 135mm |
| | Min Est WT%: | 78.5% (~11.2mm) |
| | Avg Est WT%: | 86.3% (~12.3mm) |

| | | |
|---|---|---|
| HULL-S-2 | Nominal Plate Thickness: | 14.2875mm |
| | Size: | 225mm x 310mm |
| | Min Est WT%: | 76.3% (~10.9mm) |
| | Avg Est WT%: | 89.3% (~12.8mm) |
| HULL-S-3 | Nominal Plate Thickness: | 14.2875mm |
| | Size: | 135mm x 135mm |
| | Min Est WT%: | 72.7% (~10.4mm) |
| | Avg Est WT%: | 77.6% (~11.1mm) |

NOTES: Given the tight frame spacing on the hull and the low resolution given by the probe, there is some uncertainty with the hull data. Therefore, a visual inspection and/or UT measurement of any low thickness measurements in the area is recommended to verify the steel conditions.

HULL-S-1 is shown in Figure 13.


Figure 13 – HULL-S-1, HULL-S-2, HULL-S-3 and the HULL-S Artifact

# 8 Conclusions

WME conducted a survey of ten (10) areas of the CCGS LIMNOS Mid Shore Science Vessel using PEC inspection techniques.

Scans of the CCGS LIMNOS indicated nine (9) defects below the 80% remaining wall thickness threshold. Each defect is summarized in Table 11 and Table 22. Further detail on the defects found, scan images and analysis comments for each area scanned can be found in the results sections of this report.

# 9 Recommendations

Since the PEC is a rapid screening tool used to identify corrosion through insulation and not a steel thickness measurement instrument, the defects located in this report should be quantified with more invasive measurement techniques such as UT in support of the PEC's findings.