**NATIONAL TRANSPORTATION SAFETY BOARD**
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

July 5, 2011

# MATERIALS LABORATORY FACTUAL REPORT Report No. 11-063

## A. ACCIDENT INFORMATION

Place : Staten Island, New York
Date : May 8, 2010
Vehicle : Andrew J. Barberi (Staten Island Ferry)
NTSB No. : DCA10MM017
Investigator : Eric Stolzenberg, MS-30

## B. COMPONENTS EXAMINED

1. Europa hydraulic control panel (New York End)
2. Oil samples as follows
    a. Unused Shell Omala 150 oil
    b. Propulsion drive unit sump (New York End)
    c. Right control panel oil filter (New York End—online)
    d. Left control panel oil filter (New York End—offline)

## C. DETAILS OF THE EXAMINATION

On May 8, 2010, the Andrew J. Barberi (Staten Island Ferry) allided with the St. George Staten Island Terminal when the vessel became unresponsive to astern thrust commands as the vessel approached the terminal. The vessel was powered by two propulsion units, one at the New York End and one at the Staten Island End. The thrust for each propulsion unit was controlled by separate hydraulic control panels. Post incident examination of the New York End hydraulic control panel revealed that the propulsion control valve would intermittently stick when the valve was electrically actuated using the pilothouse controls. However, the valve did not stick when actuated using the manual override control button on the side of the valve. In addition, none of the interviewed engineering staff had changed, or heard of someone having changed, the oil filters on the control panel or the position of the oil filter selector valve, meaning the right oil filter had likely been online since the original installation of the control panel. The control panel was removed from the vessel and sent to the Materials Laboratory for further examination along with oil samples as discussed below.

The hydraulic control panel was received by the Materials Laboratory as shown in figure 1. For the purpose of the laboratory investigation, the notable components of the control panel were the propulsion and steering control valves, the oil filter selector valve, and the left and right control panel oil filters.

## 1. Oil Analysis and Examination of the Oil Filtration Components

Also received by the Lab were oil samples, shown in figure 2. The oil samples, from left to right, included an unused aliquot of Shell Omala 150, a sample from the New York End (NYE) propulsion drive unit sump, the contents of the right NYE control panel oil filter, and the contents of the left NYE control panel oil filter. The oil samples from the sump and the right oil filter had a similar color to one another and were darker than the unused oil sample. There appeared to be some particulate debris toward the end of the sample taken from the right oil filter. The left oil filter sample was almost opaque and was a deep red/brown color. At the time of the incident, the oil filter selector valve was set to the right filter position. To the best of the New York City Department of Transportation's (NYDOT) knowledge, the left oil filter had never been online and neither oil filter had been changed since the control panel had been installed in 1981.

According to the NYDOT, the oil for each unit was changed during each shipyard period, approximately every 2.5 years. The oil was last changed in October 2007. The NYDOT monitored the condition of the oil by sending a sample from each unit sump to an independent oil analysis laboratory approximately every three months.

The oil samples received by the Materials Laboratory were sent to another independent test lab for routine oil analysis. The test reports are provided in Appendix A. The samples were checked for wear metals, contaminants, multi-source metals, additives, viscosity, acidity, and particle size distribution. The samples were rated on a five-point scale. 0-1 was rated "normal", 2-3 was rated "abnormal", and 4 was rated "critical". The unused oil sample scored a 0, the sump and right oil filter samples scored a 1, and the left oil filter sample scored a 2. The right oil filter sample was noted for a slightly elevated viscosity. The left oil filter sample was noted for elevated levels of magnesium, calcium, zinc, and phosphorous. The total acidity was also elevated compared to the other samples.

On August 5, 2010, a group exam of the hydraulic control panel was held at the Materials Laboratory in Washington, D.C. In attendance were:

Donald Kramer–Materials Engineer–NTSB
Chief Engineer Brian Curtis–Sr. Marine Investigator–NTSB
Eric Stolzenberg–Sr. Marine Accident Investigator in Charge–NTSB
Ken Olsen–Senior Marine Casualty Analyst–United States Coast Guard
Robert Scamell–Deputy Director of Maintenance/Staten Island Ferry–NYDOT
Brian Walsh–Safety Manager/Staten Island Ferry–NYDOT

The oil filters were examined by eye at the group exam and later in greater detail. The right and left oil filter cartridges and housings are shown in figures 3a and b, respectively. The flow of oil was from the outside of the cartridge, inward through the filter, and out through the top center of the cartridge. The rim around the gasket of the right filter cartridge had occasional patches of a thin-layered dark-green substance consistent with particulate debris, as shown in figure 3a. Similar patches were observed on the interior wall of the right filter housing. There were no indications of particulate debris on the left filter cartridge or in the left filter housing, as shown in figure 3b. Later, the right filter cartridge was disassembled and the filter paper was examined in greater detail. The filter paper had a dark-green color, similar to the color of the particulate debris observed on the filter cartridge, as shown in figure 4a. By contrast, the filter paper from the left filter cartridge had a light-brown color, as shown in figure 4b. There were no apparent perforations in the right oil filter, neither in the folds nor at the glued ends.

## 2. Examination of the Propulsion Control Valve

The propulsion control valve, shown in figure 5a, was disassembled during the group exam, as shown in figure 5b, and its components examined. The unit was a three-position shuttle valve actuated by two solenoids. For convenience, the solenoids were labeled number 2 and number 3. The shuttle valve normally resided in a neutral-center position. When one of the solenoids was electrically energized, an armature would shuttle the valve to one side or the other, and oil would flow through the valve housing. The flow of oil would command a change in pitch of the propulsion drive unit, resulting in an increase or decrease in ahead or astern propulsion, depending on the direction the valve had shuttled. The four-port control valve was manufactured by Rexroth, model number 4WE 5 E 6.1/G24 NZ4, as shown in figure 6a. The number 2 and number 3 solenoids were originally manufactured by Hydronorma, model number GH35-4-S264 24V-DC26W, as shown in figure 6b. Hydronorma solenoids were used by Rexroth in their control valve assembly, but Rexroth did not recognize the GH35 model number on the Hydronorma solenoid.

The number 3 solenoid was disassembled by removing the manual override control button, as shown in figure 7a. The solenoid was filled with oil. The oil was drawn off with a syringe and the number 3 armature was removed from the barrel. At the base of the barrel, there was a copper-colored ring, as shown in figure 7b. The chemical composition of the ring was analyzed using scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS) and found to consist of copper (Cu) and tin (Sn), as shown in figure 7c, consistent with a phosphor bronze. The ring appeared to have been originally fabricated with six tabs extending radially inward. The ring had a circumferential wear pattern on its flat face. One tab and approximately one-quarter of the bronze ring were missing and could not be located. Several of the tabs were bent in the longitudinal direction.

The number 2 solenoid was similarly examined and was also found to be filled with oil. However, two fragments of a similar bronze ring were observed in the cavity between the end of the number 2 armature and the manual override control button, as shown in figure 8a. The number 2 armature was removed from the solenoid housing, revealing one additional fragment of bronze ring. The ring fragments from the number 2 solenoid are shown in figure 8b. Similar to the number 3 solenoid, a fragment (one tab) was missing and could not be located.

The bronze ring fracture surfaces were examined by SEM and had an appearance consistent with post fracture contact damage.

The number 2 and number 3 armatures exhibited wear, as evidenced by the light- and dark gray areas in figures 9 and 10. The composition of the light- and dark-gray areas was identified by SEM and EDS. EDS spectra of the dark-gray regions contained zinc (Zn), phosphorous (P), and iron (Fe), as shown in figure 11a, consistent with a zinc phosphate coating on an iron substrate. EDS spectra in the light-gray areas contained primarily iron, as shown in figure 11b, consistent with the iron substrate where the zinc phosphate coating had worn away. For each armature, the wear was most noticeable near one of the oil flow channels. The opposing channel (180°) showed comparatively little wear of the zinc phosphate coating. Occasional longitudinal groove lines were visible in the oil flow channels and were examined by SEM. No cracking or chipping of the coating was observed associated with the grooves.[1]

Wear debris was found inside the solenoid barrels and at the entrance to the valve housing, as shown in figure 12. Wear debris was flushed from the solenoids and the valve housing onto filter paper and analyzed by EDS. The debris consisted primarily of Fe, with traces of zinc phosphate and phosphor bronze, as shown in figures 13a, b, and c, respectively.

## 3. Examination of the Steering Control Valve

As a point of comparison, the steering control valve, labeled in figure 1, was also disassembled. The steering control valve was located on the same control panel and ran off the same oil filtration system as the propulsion control valve. For convenience, the solenoids on the steering control valve were labeled number 5 and number 6. The control valve was the same Rexroth model number as before. The solenoids were manufactured by Hydronorma but were a different model number: GH35-4-S145 24V-DC26W, as shown in figure 14.

The solenoids were disassembled in the same manner as described above. The bronze ring on the number 5 and number 6 armatures was of a different design, as shown in figure 15. Whereas the bronze ring on the number 2 and number 3 armatures had 6 tabs, the ring on the number 5 and number 6 armatures had 3 tabs. The dimensions of the tabs differed as well. For the six-tab ring, the width at the base of the tab was approximately 0.030 inch, whereas for the three-tab ring, the width at the base of the tab was approximately 0.065 inch. All tabs on the three-tab rings were intact on the number 5 armature and on the number 6 armature.

The composition of the surface layer on the steering control valve armatures differed from the zinc phosphate coating on the propulsion control valve armatures. The number 5 and number 6 armatures are shown in figures 16 and 17, respectively. The EDS spectrum from a dark-gray region on the number 5 armature is shown in figure 18 and consisted primarily of iron (Fe) and oxygen (O), consistent with an iron oxide layer on an iron substrate.

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[1] Cracking or chipping of the coating, if present, would be consistent with scratch damage to the surface in the presence of the coating.

The number 5 and number 6 armatures exhibited wear as shown in figures 16 and 17, respectively. Wear was observed over a greater area on the number 5 armature than any other armature. Partial or complete wear through the oxide was observed around the entire circumference along the longitudinal length indicated in figure 16a. The number 6 armature showed a wear pattern similar to the number 2 and number 3 armatures from the propulsion control valve, as shown in figure 17a and b.

Donald Kramer
Materials Engineer

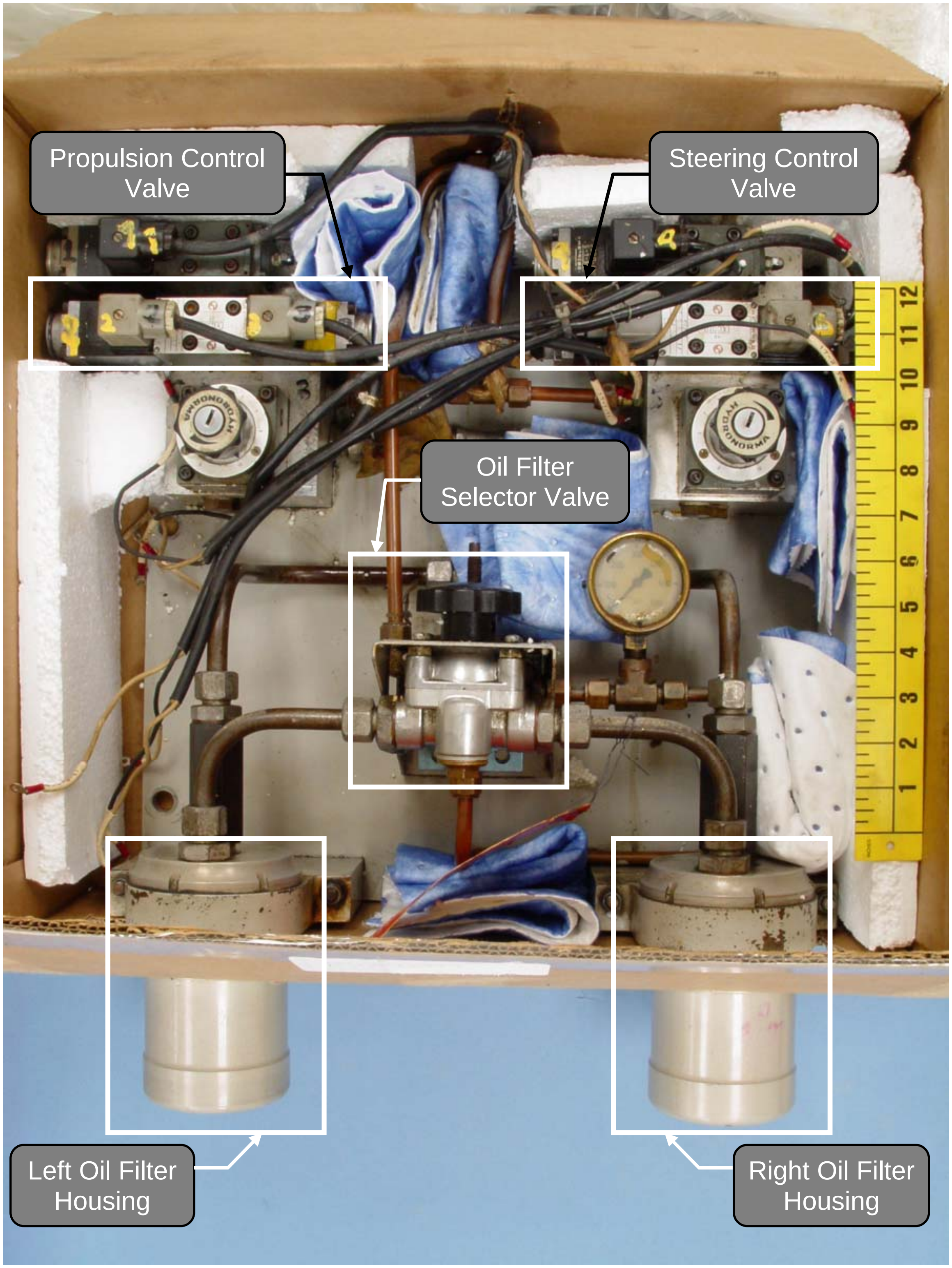


**Figure 1**: Overview of the New York End hydraulic control panel.

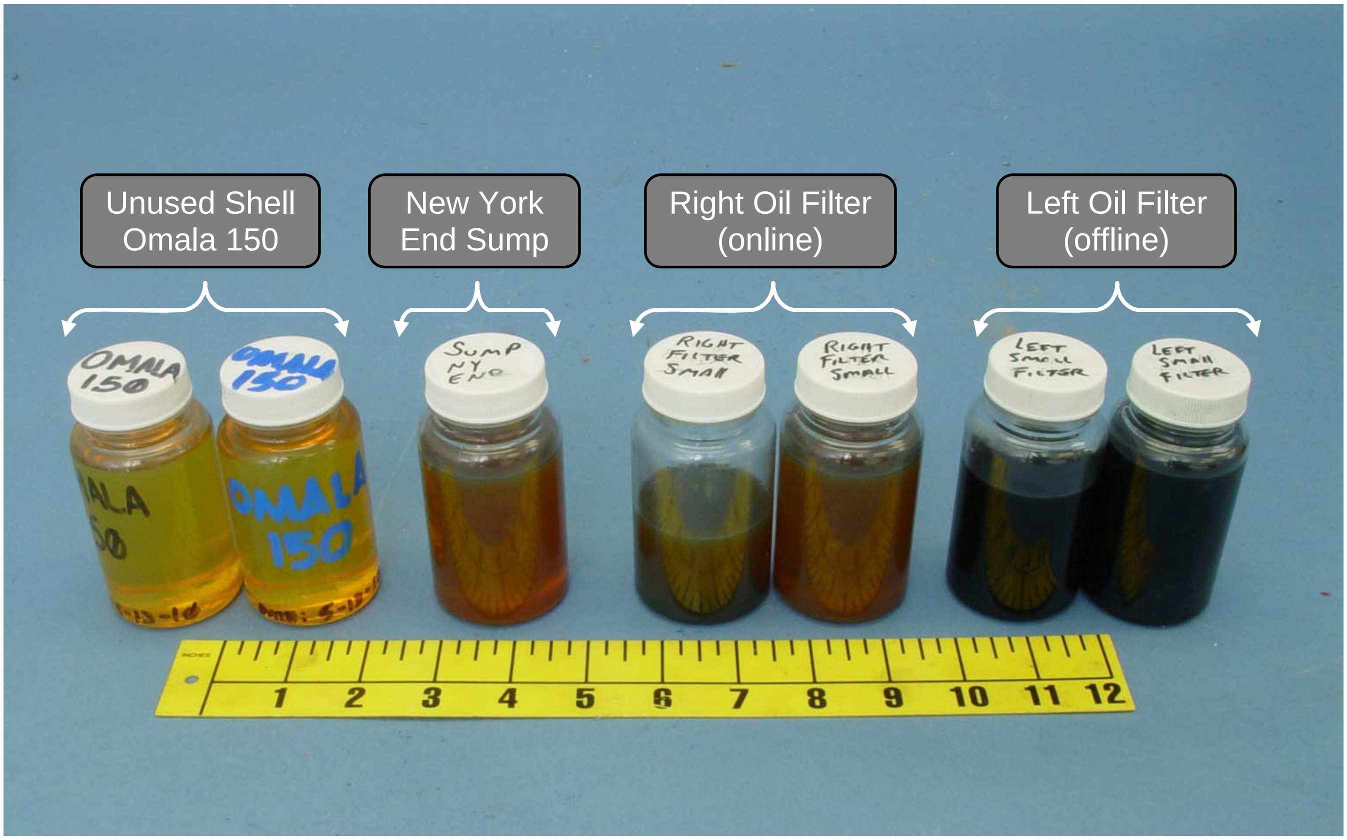


**Figure 2**: Oil samples, from left to right, of unused oil, from the New York End sump, from the right oil filter housing, and from the left oil filter housing.

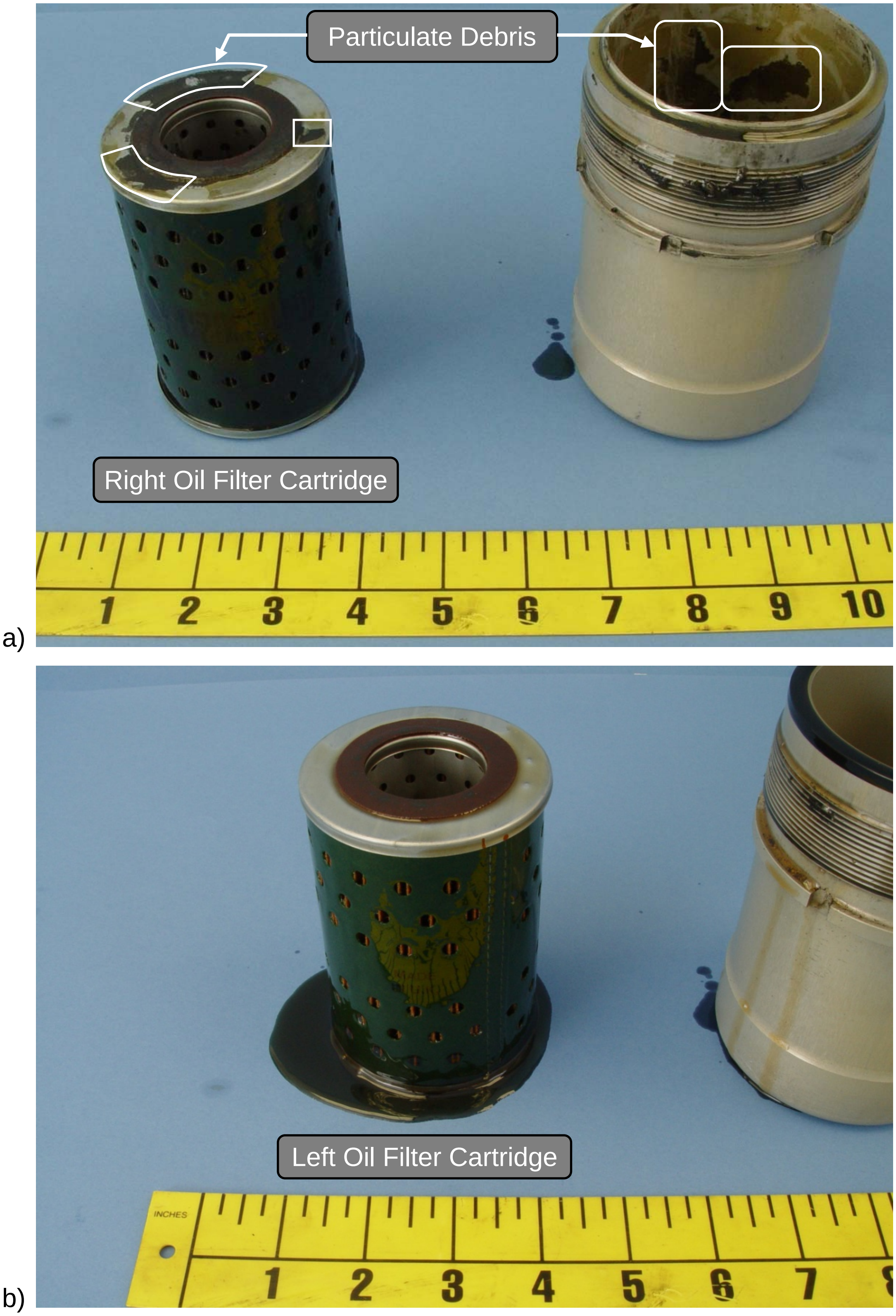


**Figure 3**: Overview of the; a) right (online) oil filter cartridge and housing; b) left (offline) oil filter cartridge and housing.

**Figure 4**: a) Folds of right (online) oil filter after disassembly of the cartridge; b) folds of left (offline) oil filter viewed through a hole cut in the jacket.

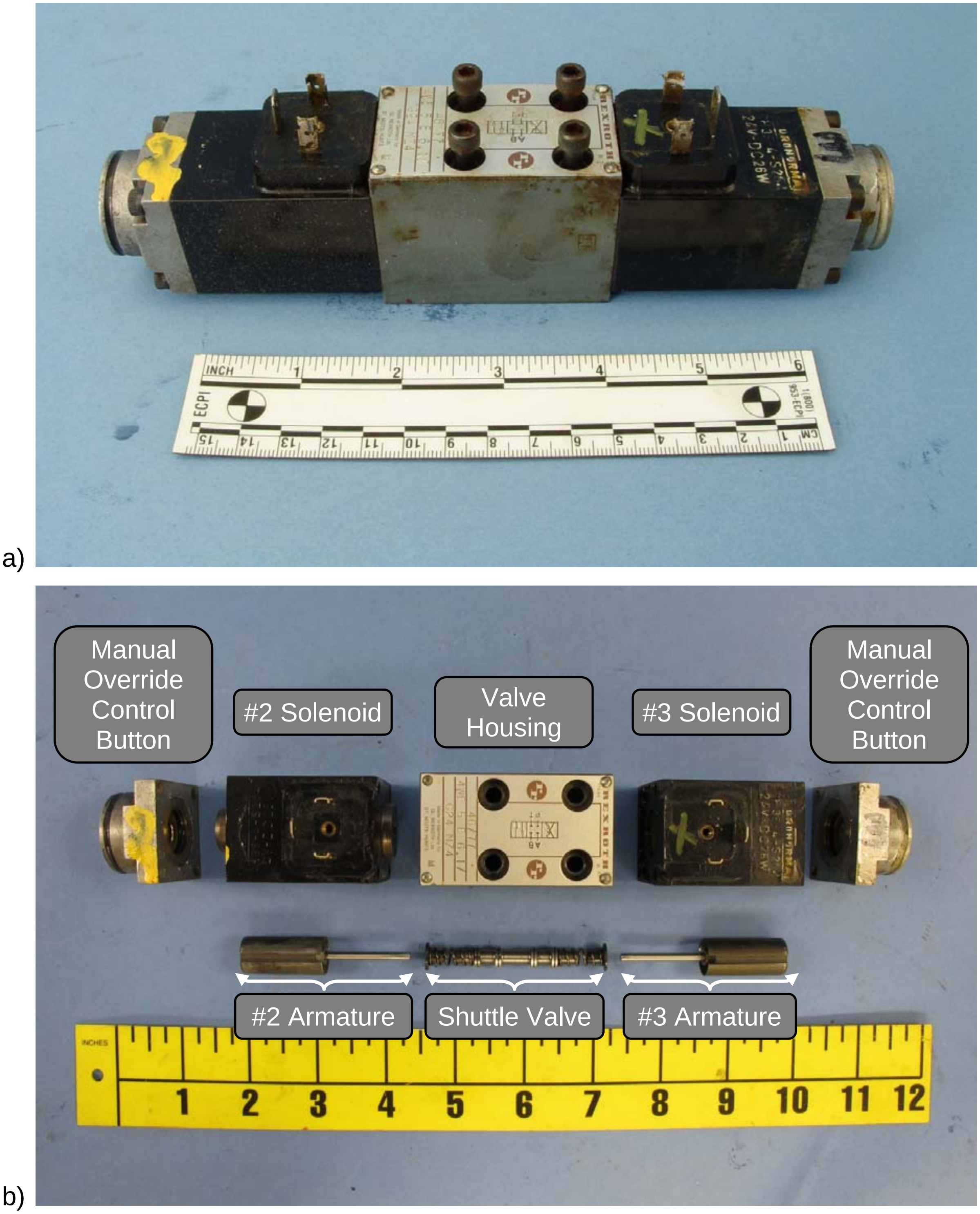


**Figure 5**: New York End propulsion control valve; a) before disassembly; b) after disassembly.

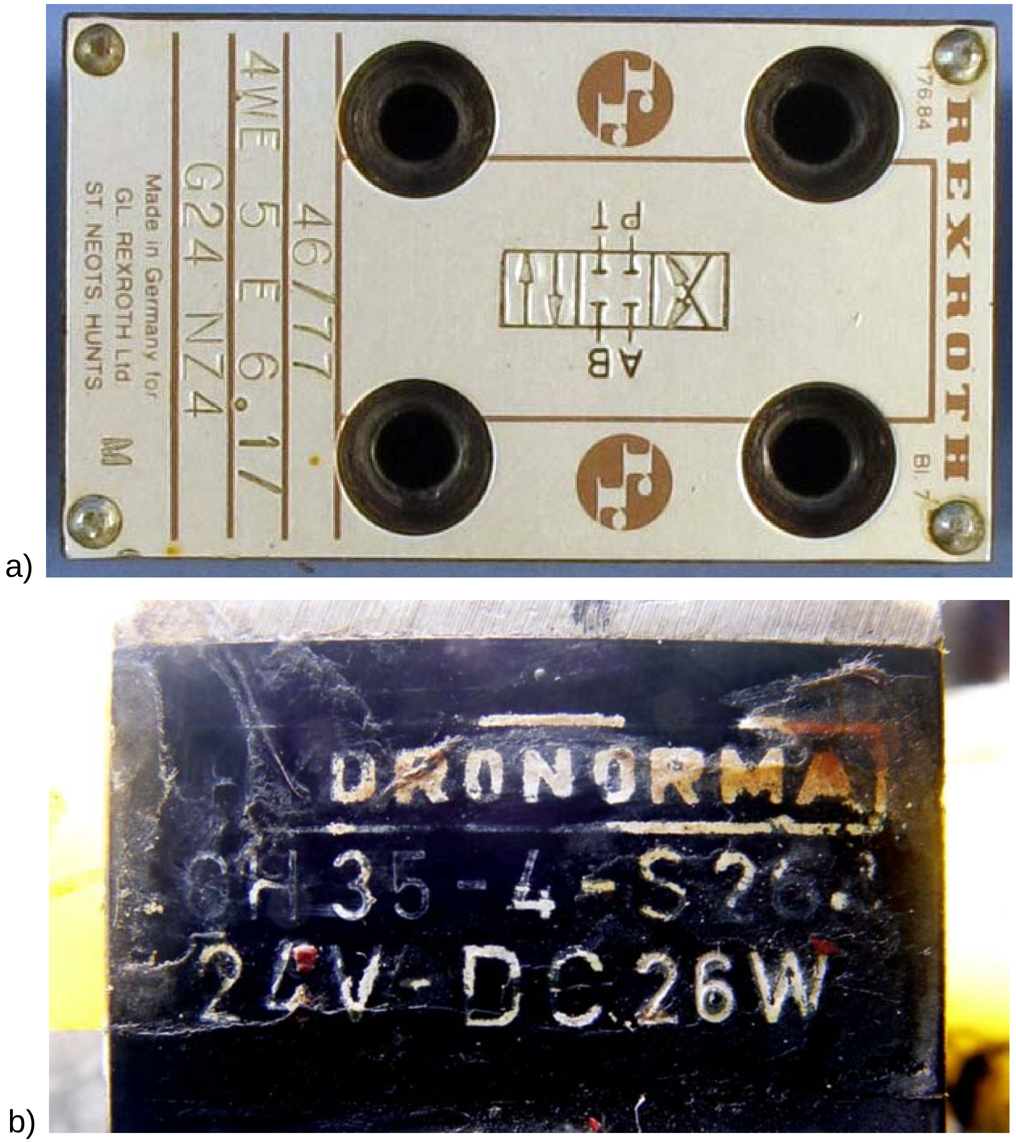


**Figure 6**: a) Rexroth directional control valve model number on the propulsion control valve housing; b) Hydronorma solenoid model number on the propulsion control valve solenoid housing.

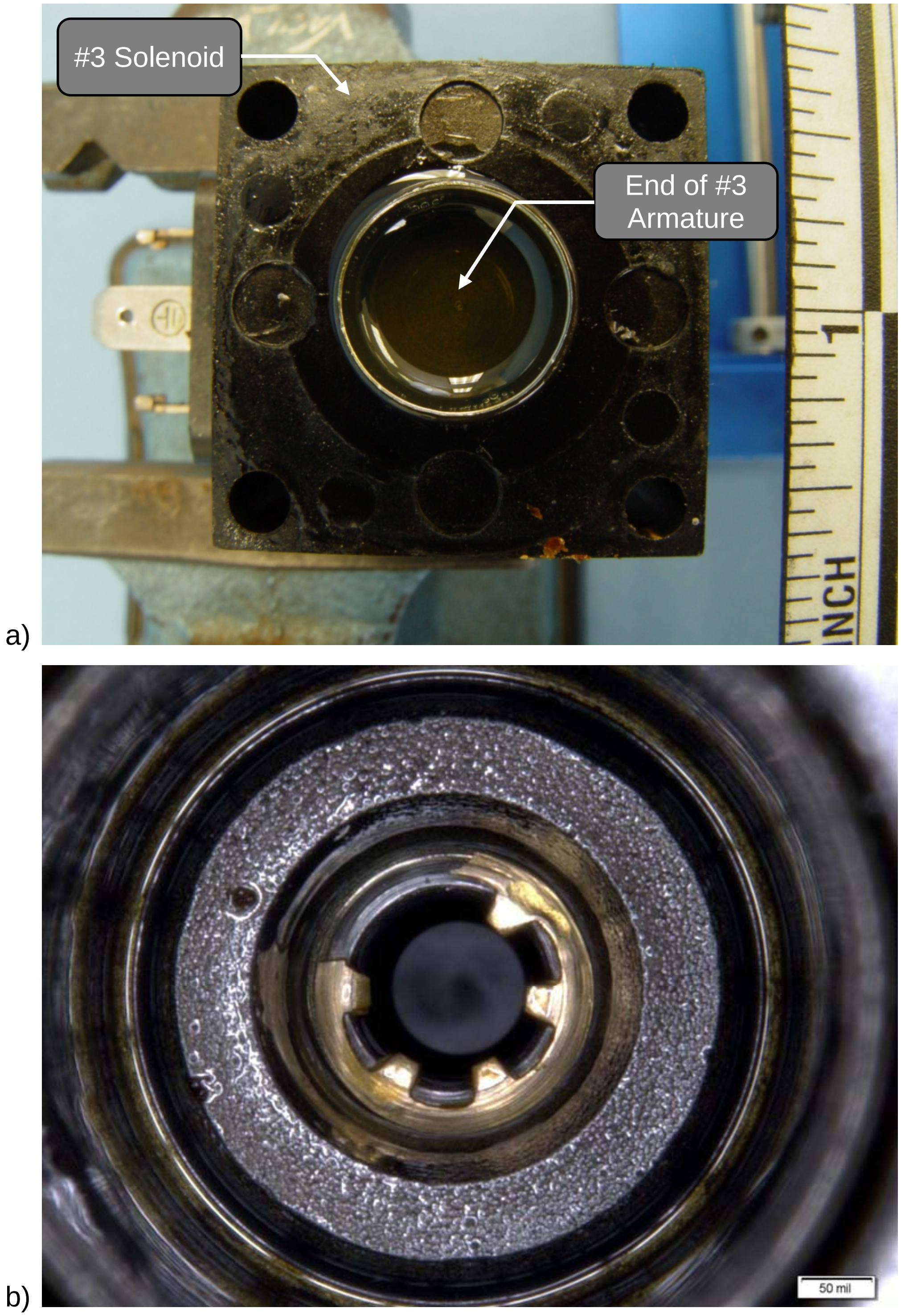


**Figure 7**: Disassembly of the number 3 solenoid from the propulsion control valve; a) end view of the solenoid with the manual override control button removed; b) inside view of the solenoid, drained of oil and with the number 3 armature removed. At the end of the barrel there was a bronze ring. The ring had circumferential wear patterns on the flat face. Approximately one-quarter of the ring was missing.

c)

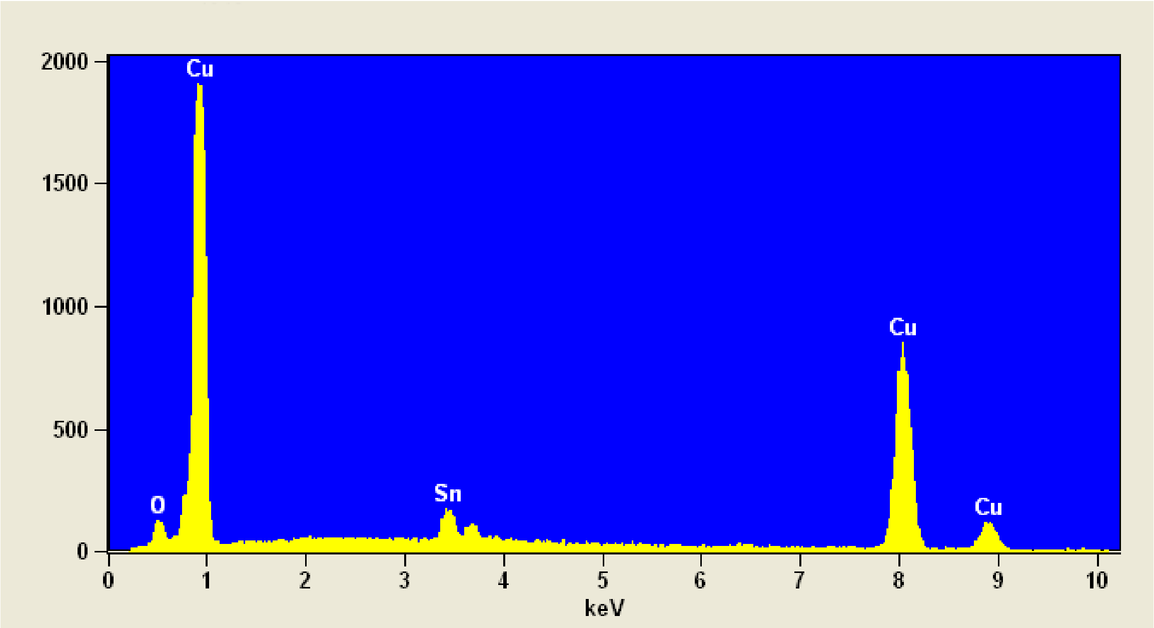
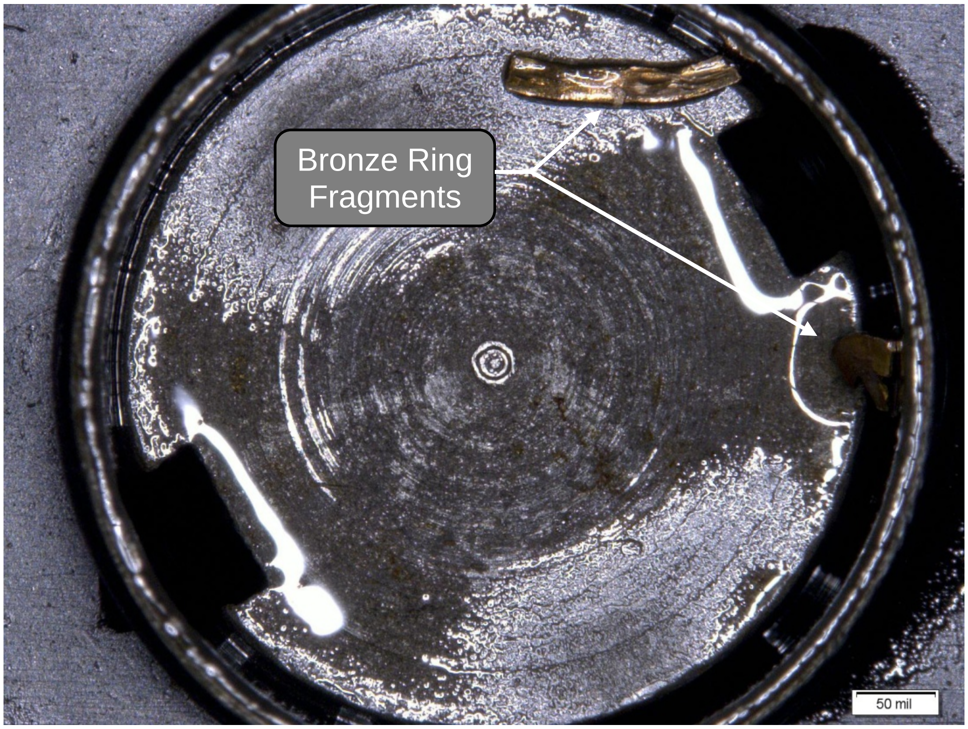


**Figure 7 (cont.)**: c) EDS spectrum of bronze ring containing copper (Cu) and tin (Sn).

a)



b)

**Figure 8**: Disassembly of the number 2 solenoid from the propulsion control valve; a) bronze ring fragments located in the cavity between the number 2 armature and the manual override control button. The excess oil was drawn off with a syringe; b) all recovered bronze ring fragments.

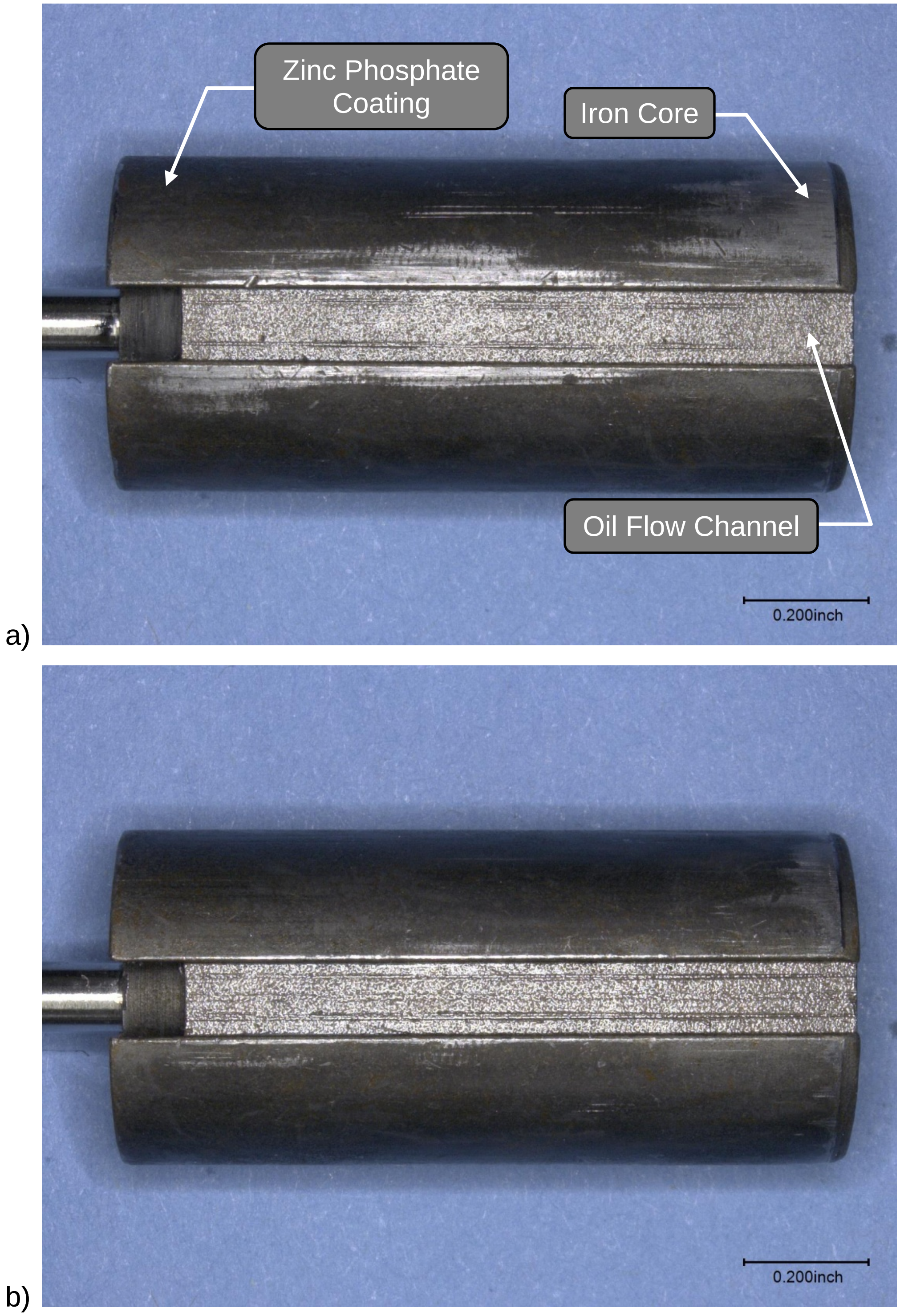


**Figure 9**: Propulsion control valve number 2 armature; a) side of armature with visible wear of zinc phosphate coating around oil flow channel; b) opposite side of armature.

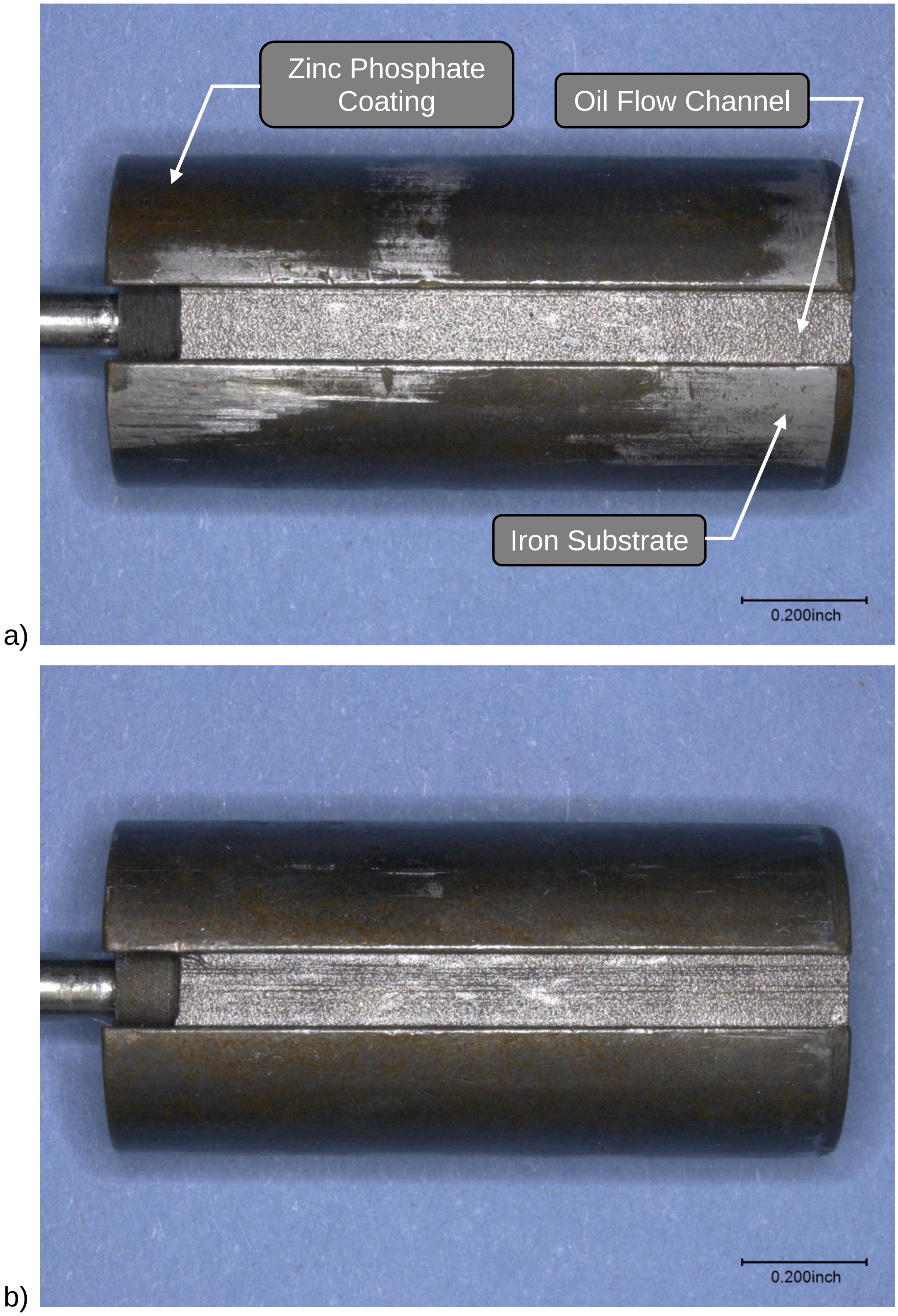


**Figure 10**: Propulsion control valve number 3 armature; a) side of armature with visible wear of zinc phosphate coating around oil flow channel; b) opposite side of armature.

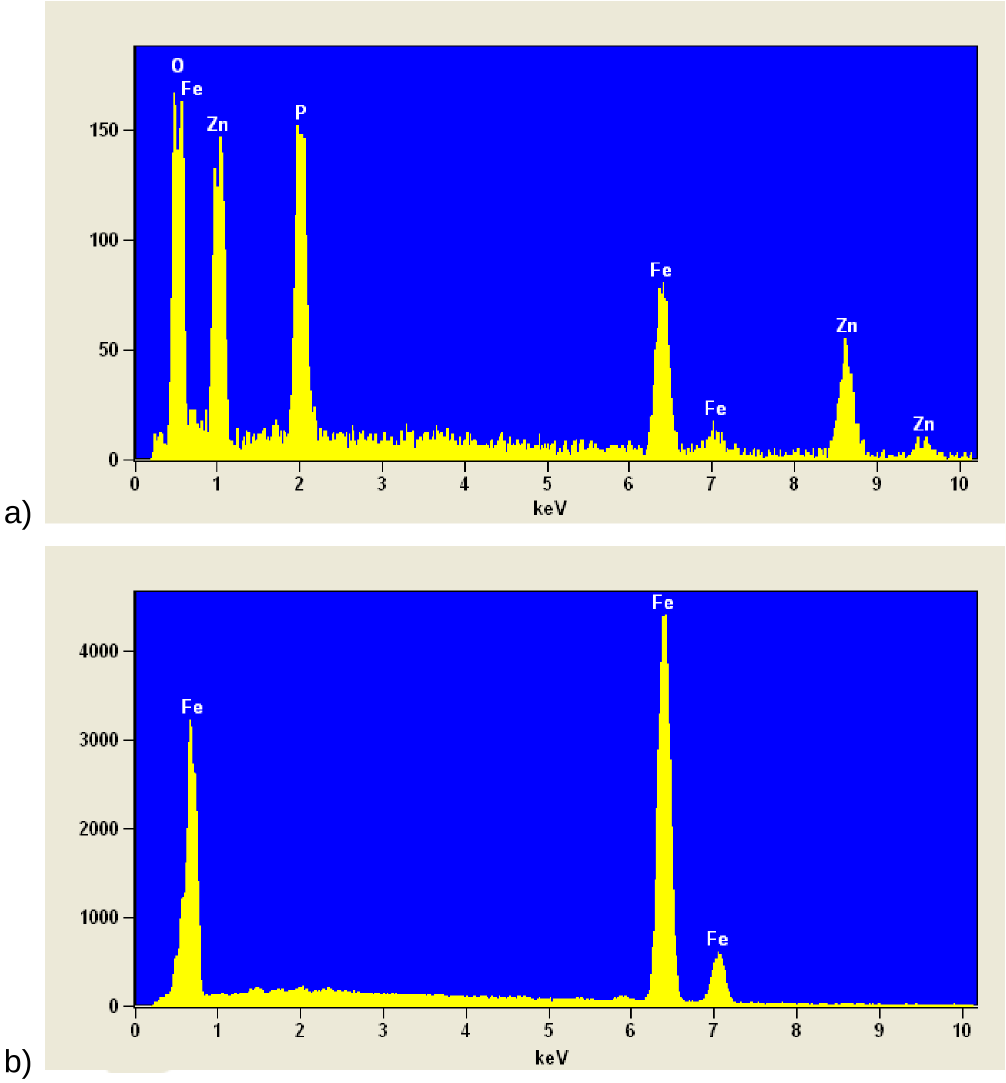


**Figure 11**: EDS spectra from the number 3 armature; a) spectrum from a dark-gray region containing zinc (Zn), phosphorous (P), and iron (Fe), consistent with a zinc phosphate coating on an Fe substrate; b) spectrum from a light-gray region consistent with the Fe substrate where the zinc phosphate coating had worn away.

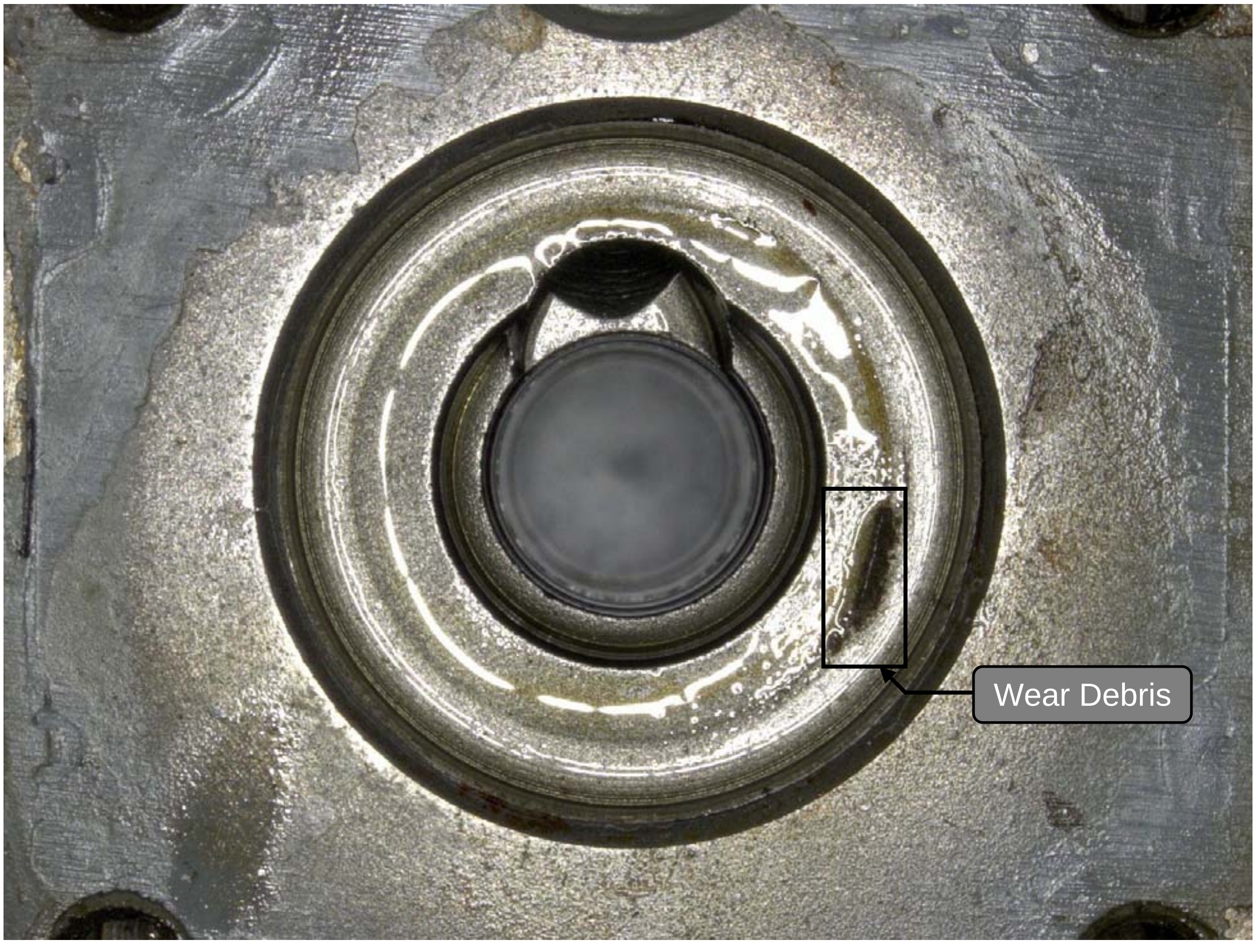


**Figure 12**: Entrance to the propulsion control valve housing on the number 2 solenoid side. Wear debris had accumulated near the entrance.

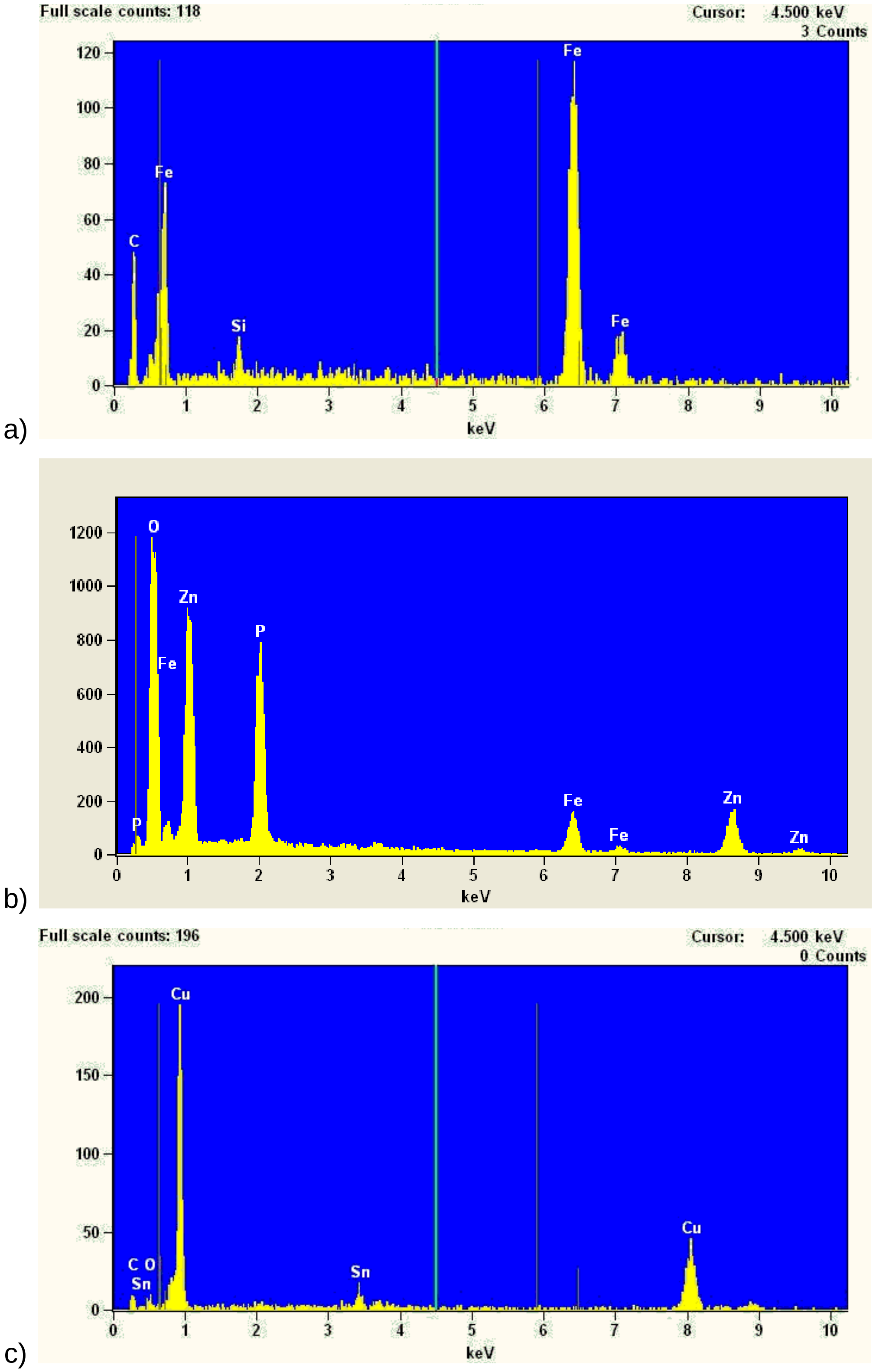


**Figure 13**: EDS spectra of debris collected from the propulsion control valve; a) iron debris consistent with the armature core; b) Zinc phosphate wear debris consistent with the number 2 and 3 armature coating; c) debris consistent with the bronze ring.

**Figure 14**: Hydronorma solenoid model number on the steering control valve solenoid housing.

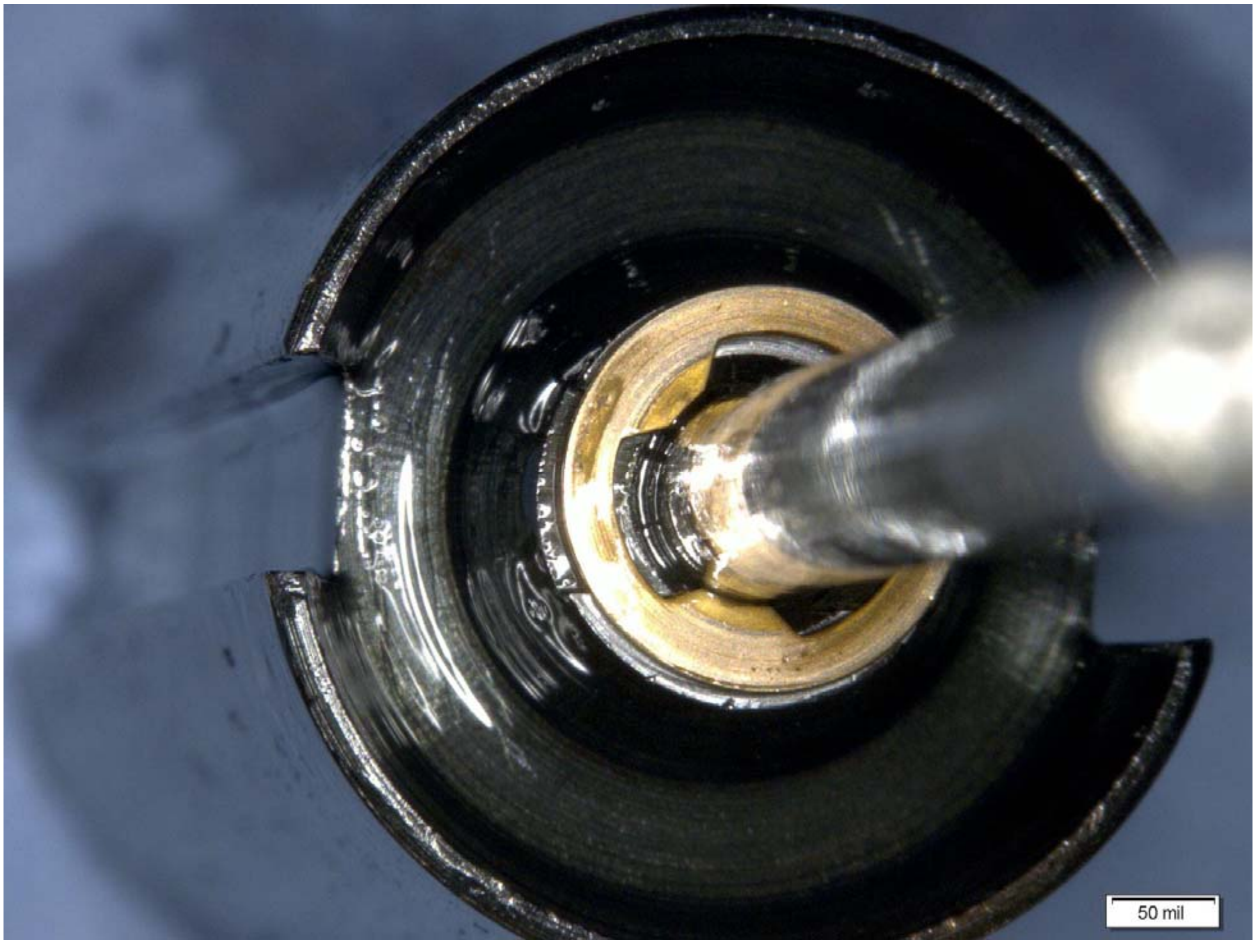


**Figure 15**: The steering control valve number 5 armature, with a bronze ring of different design than that found in the propulsion control valve.

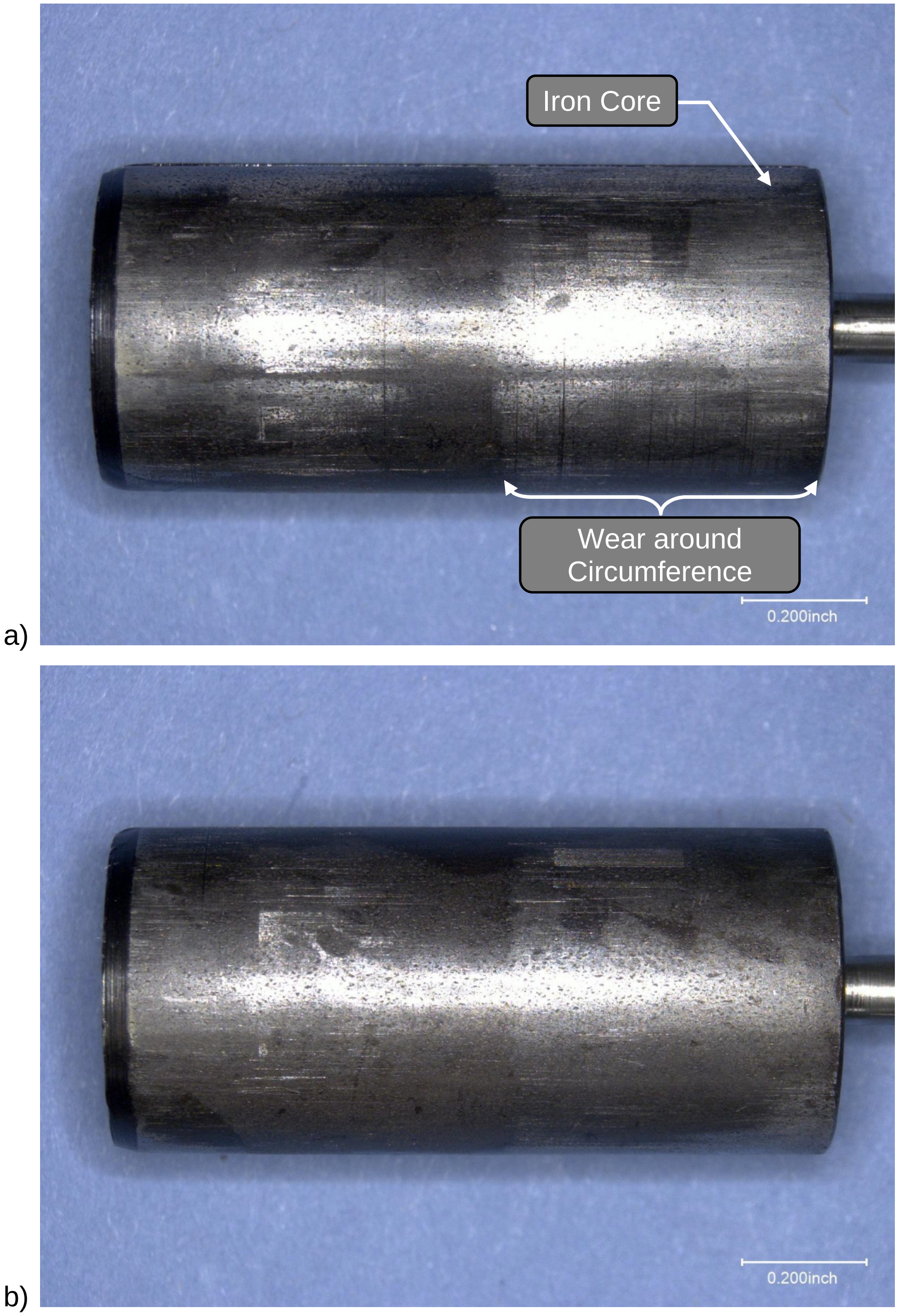


**Figure 16**: Steering control valve number 5 armature; a) and b) opposite sides of the armature showing wear of the oxide layer.

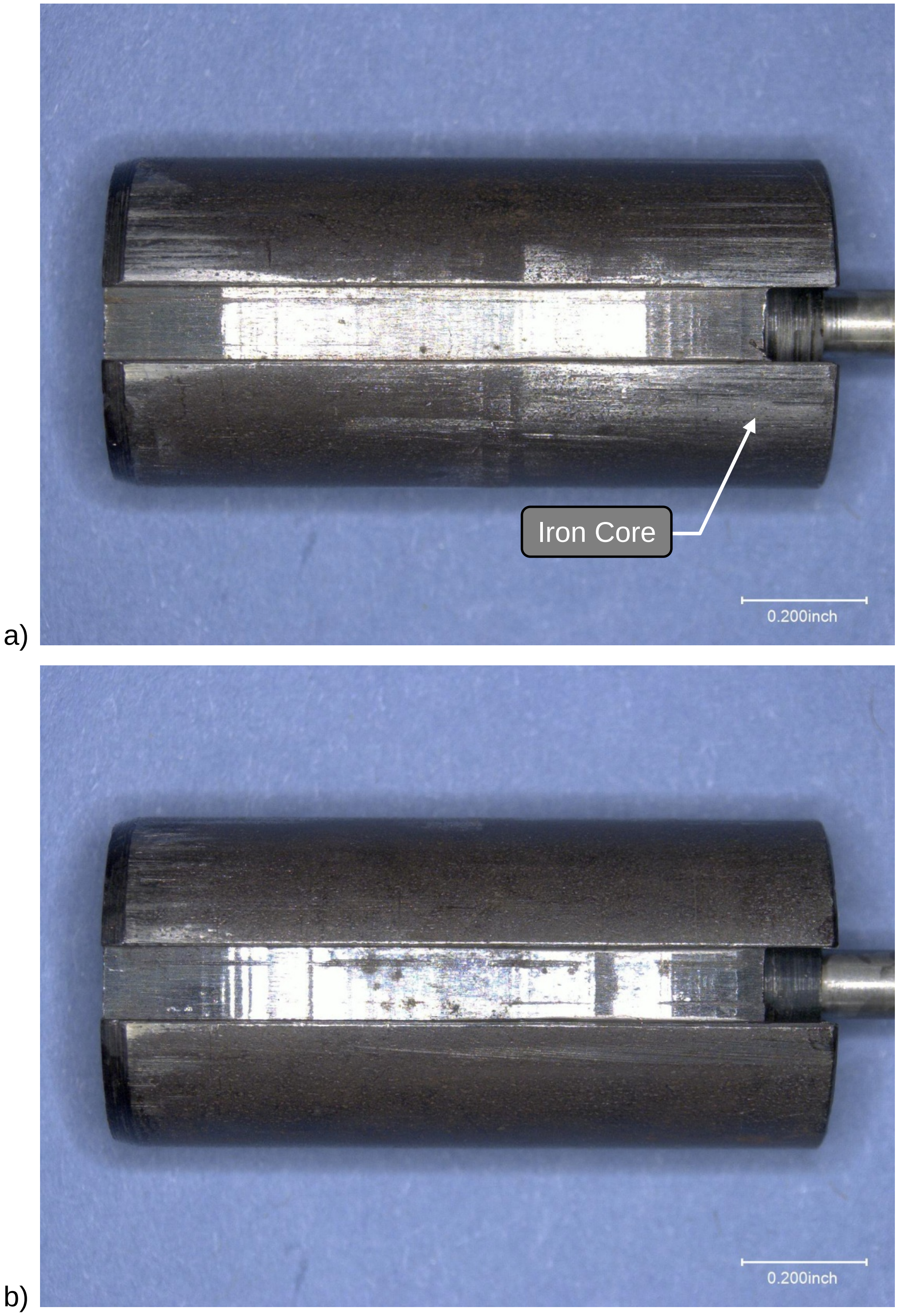


**Figure 17**: Steering control valve number 6 armature; a) side of armature with visible wear of the oxide layer around oil flow channel; b) opposite side of armature.

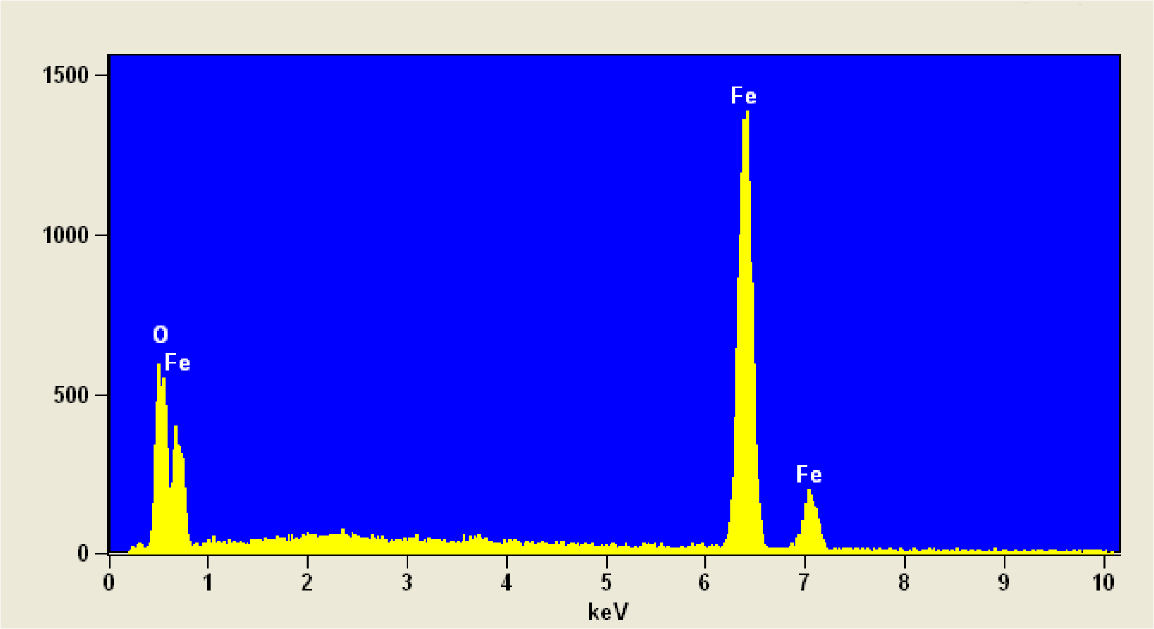


**Figure 18**: EDS spectrum of a dark-gray region on armature number 5 consisting primarily of iron (Fe) and oxygen (O), consistent with an iron oxide layer on an iron substrate.

# APPENDIX A: OIL ANALYSIS RESULTS

**UNIT ID**
CONTROL NL
**SECOND ID** Omala 150 Control

**UNIT TYPE**
NEW LUBE REFERENCE
**APPLICATION**
NEW LUBE REFERENCE

**POLARIS℠ Laboratories**

**COMPANY INFORMATION**
NATIONAL TRANSPORTATION SAFETY
DON KRAMER
(R)

| | |
|---|---|
| **ACCOUNT NUMBER** | (R) |
| **DATE SAMPLED** | 05/08/10 |
| **DATE RECEIVED** | 07/23/10 |
| **DATE COMPLETED** | 07/27/10 |
| **TRACKING #** | 10181Z05023 |
| **MANUFACTURER/MODEL** | |
| **LUBE MFR** | SHELL |
| **LUBE TYPE - GRADE** | OMALA |
| **MICRON RATING** | 0 |
| **FILTER TYPE** | |
| **SUMP CAPACITY** | 0.00 |
| **HYD SYSTEM PRESSURE** | 0 |
| **FLUID ADDED** | |

**OVERALL SEVERITY OF REPORT**
based on comments, not individual flags

| ▼ | | | | |
|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 |
| NORMAL | | ABNORMAL | | CRITICAL |

| LAB # | LOCATION | ANALYST |
|---|---|---|
| 703017 | I | KRM |

**FLUID ANALYSIS REPORT - 877-808-3750**

**COMMENTS** NEW LUBE REFERENCE - Data used for baseline reference only; However; Grade of lubricant required to properly evaluate viscosity;

| | WEAR METALS PPM | | | | | | | | | | CONTAMINANT METALS - PPM | | | MULTI-SOURCE METALS - PPM | | | | | | ADDITIVE METALS PPM | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SAMPLE # | IRON | CHROMIUM | NICKEL | ALUMINUM | COPPER | LEAD | TIN | CADMIUM | SILVER | VANADIUM | SILICON | SODIUM | POTASSIUM | TITANIUM | MOLYBDENUM | ANTIMONY | MANGANESE | LITHIUM | BORON | MAGNESIUM | CALCIUM | BARIUM | PHOSPHOROUS | ZINC |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 236 | 3 |

| SAMPLE # | DATE SAMPLED<br>DATE RECEIVED | UNIT TIME<br>LUBE TIME | LUBE CHG | FILTER CHG | FUEL GC | SOOT Vol. | WATER Hot Plate | VIS 40C CS | VIS 100C CS | TAN Total Acid | TBN Total Base | I-R OXIDA | I-R NITRA | ISO CODE | 4 MICRON | 6 MICRON | 10 MICRON | 14 MICRON | 21 MICRON | 38 MICRON | 70 MICRON | 100 MICRON |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 05/08/10<br>07/23/10 | | U | U | | | <.1 | 143 | | 0.35 | | | | 19/17/14 | 3025 | 973 | 296 | 113 | 44 | 8 | 1 | 0 |

| SAMP # | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | | | |

**UNIT ID**
VOITH UNIT NYE NYE Sump
**SECOND ID**
SUMP FILTER MESHMETALSTRAINER
**UNIT TYPE**
BEVEL GEAR
**APPLICATION**
UNKNOWN

POLARIS™ Laboratories

**COMPANY INFORMATION**
NATIONAL TRANSPORTATION SAFETY
DON KRAMER
(R)

| | |
|---|---|
| **ACCOUNT NUMBER** | (R) |
| **DATE SAMPLED** | 05/08/10 |
| **DATE RECEIVED** | 07/23/10 |
| **DATE COMPLETED** | 07/26/10 |
| **TRACKING #** | 10181Z05024 |
| **MANUFACTURER/MODEL** | VOITH CYCLOIDAL DRIVE |
| **LUBE MFR** | SHELL |
| **LUBE TYPE - GRADE** | OMALA |
| **MICRON RATING** | 0 |
| **FILTER TYPE** | |
| **SUMP CAPACITY** | 2900.00 |
| **HYD SYSTEM PRESSURE** | 0 |
| **FLUID ADDED** | |

**OVERALL SEVERITY OF REPORT**
based on comments, not individual flags

| 0 | ▽<br>1 | 2 | 3 | 4 |
|---|---|---|---|---|
| NORMAL | | ABNORMAL | | CRITICAL |

| LAB # | LOCATION | ANALYST |
|---|---|---|
| 703020 | I | EAD |

**FLUID ANALYSIS REPORT - 877-808-3750**

**COMMENTS** Data flagged for observation only; PHOSPHORUS is SLIGHTLY LOW for the lubricant as identified; Flagged data has been rechecked and confirmed; Grade of lubricant required to properly evaluate viscosity; Unit hours/miles/kilometers not provided for this sample;

| | WEAR METALS PPM | | | | | | | | | | CONTAMINANT METALS - PPM | | | MULTI-SOURCE METALS - PPM | | | | | | ADDITIVE METALS PPM | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SAMPLE # | IRON | CHROMIUM | NICKEL | ALUMINUM | COPPER | LEAD | TIN | CADMIUM | SILVER | VANADIUM | SILICON | SODIUM | POTASSIUM | TITANIUM | MOLYBDENUM | ANTIMONY | MANGANESE | LITHIUM | BORON | MAGNESIUM | CALCIUM | BARIUM | PHOSPHOROUS | ZINC |
| 1 | 5 | 0 | 0 | 0 | 7 | 1 | 1 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 1 | 5 | 0 | 156 | 4 |

| SAMPLE # | DATE SAMPLED<br>DATE RECEIVED | UNIT TIME<br>LUBE TIME | LUBE CHG | FILTER CHG | FUEL GC | SOOT Vol. | WATER Hot Plate | VIS 40C CS | VIS 100C CS | TAN Total Acid | TBN Total Base | I-R OXIDA | I-R NITRA | ISO CODE | 4 MICRON | 6 MICRON | 10 MICRON | 14 MICRON | 21 MICRON | 38 MICRON | 70 MICRON | 100 MICRON |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 05/08/10<br>07/23/10 | 21MO. | U | U | | | <.1 | 146 | | 0.34 | | | | | | | | | | | | |

| SAMP # | PQ | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 13 | | | | | | | | | | | | | | | |

**UNIT ID**
VOITH UNIT NYE
**SECOND ID**
SUMP FILTER MESHMETALSTRAINER
**UNIT TYPE**
BEVEL GEAR
**APPLICATION**
UNKNOWN

# Right Oil Filter

POLARIS℠
Laboratories

**COMPANY INFORMATION**
NATIONAL TRANSPORTATION SAFETY
DON KRAMER
(R)

| | |
|---|---|
| **ACCOUNT NUMBER** | (R) |
| **DATE SAMPLED** | 05/08/10 |
| **DATE RECEIVED** | 07/23/10 |
| **DATE COMPLETED** | 07/27/10 |
| **TRACKING #** | 10181Z05025 |
| **MANUFACTURER/MODEL** | VOITH CYCLOIDAL DRIVE |
| **LUBE MFR** | SHELL |
| **LUBE TYPE - GRADE** | OMALA |
| **MICRON RATING** | 0 |
| **FILTER TYPE** | |
| **SUMP CAPACITY** | 2900.00 |
| **HYD SYSTEM PRESSURE** | 0 |
| **FLUID ADDED** | |

**OVERALL SEVERITY OF REPORT**
based on comments, not individual flags

| 0 | ▽ 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| NORMAL | | ABNORMAL | | CRITICAL |

| LAB # | LOCATION | ANALYST |
|---|---|---|
| 703019 | I | JUK |

## FLUID ANALYSIS REPORT - 877-808-3750

**COMMENTS** Data flagged for observation only; NOTE increase in viscosity; Flagged additive levels are different than what should be present for the lubricant that is identified for this unit. (This does not imply that the lubricant does not meet proper API, SAE, or ISO classifications.); Is the lubricant manufacturer, type and/or grade correctly identified for this unit;

| | WEAR METALS PPM | | | | | | | | | | CONTAMINANT METALS - PPM | | | MULTI-SOURCE METALS - PPM | | | | | | ADDITIVE METALS PPM | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SAMPLE # | IRON | CHROMIUM | NICKEL | ALUMINUM | COPPER | LEAD | TIN | CADMIUM | SILVER | VANADIUM | SILICON | SODIUM | POTASSIUM | TITANIUM | MOLYBDENUM | ANTIMONY | MANGANESE | LITHIUM | BORON | MAGNESIUM | CALCIUM | BARIUM | PHOSPHOROUS | ZINC |
| 1 | 6 | 0 | 0 | 0 | 10 | 1 | 1 | 0 | 0 | 0 | 2 | 11 | 1 | 0 | 0 | 0 | 0 | 0 | 8 | 1 | 23 | 0 | 229 | 6 |

| SAMPLE # | DATE SAMPLED<br>DATE RECEIVED | UNIT TIME<br>LUBE TIME | LUBE CHG | FILTER CHG | FUEL GC | SOOT Vol. | WATER Hot Plate | VIS 40C CS | VIS 100C CS | TAN Total Acid | TBN Total Base | I-R OXIDA | I-R NITRA | ISO CODE | 4 MICRON | 6 MICRON | 10 MICRON | 14 MICRON | 21 MICRON | 38 MICRON | 70 MICRON | 100 MICRON |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 05/08/10<br>07/23/10 | 21MO. | U | U | | | <.1 | 150 | | 0.39 | | | | | | | | | | | | |

| SAMP # | PQ | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 16 | | | | | | | | | | | | | | | |

**UNIT ID**
VOITH UNIT NYE Left Oil Filter
**SECOND ID**
SUMP FILTER MESHMETALSTRAINER
**UNIT TYPE**
BEVEL GEAR
**APPLICATION**
UNKNOWN

POLARIS™ Laboratories

**COMPANY INFORMATION**
NATIONAL TRANSPORTATION SAFETY
DON KRAMER
[redacted]

| | |
|---|---|
| **ACCOUNT NUMBER** | [redacted] |
| **DATE SAMPLED** | 05/08/10 |
| **DATE RECEIVED** | 07/23/10 |
| **DATE COMPLETED** | 07/26/10 |
| **TRACKING #** | 10181Z05026 |
| **MANUFACTURER/MODEL** | VOITH CYCLOIDAL DRIVE |
| **LUBE MFR** | SHELL |
| **LUBE TYPE - GRADE** | OMALA |
| **MICRON RATING** | 0 |
| **FILTER TYPE** | |
| **SUMP CAPACITY** | 2900.00 |
| **HYD SYSTEM PRESSURE** | 0 |
| **FLUID ADDED** | |

**OVERALL SEVERITY OF REPORT**
based on comments, not individual flags

| 0 | 1 | 2 ▼ | 3 | 4 |
|---|---|---|---|---|
| NORMAL | | ABNORMAL | | CRITICAL |

| LAB # | LOCATION | ANALYST |
|---|---|---|
| 703018 | I | EAD |

**FLUID ANALYSIS REPORT - 877-808-3750**

**COMMENTS** Data flagged for observation only; ACID NUMBER is MODERATELY HIGH; Bushing/Thrust metal is at a MINOR LEVEL; CADMIUM sources include ELECTROPLATED COATING, SILVER SOLDER, or as a specialty alloy with a low coefficient of friction; Flagged additive levels are different than what should be present for the lubricant that is identified for this unit. (This does not imply that the lubricant does not meet proper API, SAE, or ISO classifications.); Flagged data has been rechecked and confirmed; Grade of lubricant required to properly evaluate viscosity; Your note was taken into consideration;

| | WEAR METALS PPM | | | | | | | | | | CONTAMINANT METALS - PPM | | | MULTI-SOURCE METALS - PPM | | | | | | ADDITIVE METALS PPM | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SAMPLE # | IRON | CHROMIUM | NICKEL | ALUMINUM | COPPER | LEAD | TIN | CADMIUM | SILVER | VANADIUM | SILICON | SODIUM | POTASSIUM | TITANIUM | MOLYBDENUM | ANTIMONY | MANGANESE | LITHIUM | BORON | MAGNESIUM | CALCIUM | BARIUM | PHOSPHOROUS | ZINC |
| 1 | 5 | 0 | 0 | 0 | 7 | 1 | 1 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 1 | 5 | 0 | 156 | 4 |
| 2 | 7 | 0 | 0 | 2 | 42 | 8 | 0 | 48 | 0 | 0 | 8 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 13 | 4739 | 9 | 849 | 706 |

| SAMPLE # | DATE SAMPLED<br>DATE RECEIVED | UNIT TIME<br>LUBE TIME | LUBE CHG | FILTER CHG | FUEL GC | SOOT Vol. | WATER Hot Plate | VIS 40C CS | VIS 100C CS | TAN Total Acid | TBN Total Base | I-R OXIDA | I-R NITRA | ISO CODE | 4 MICRON | 6 MICRON | 10 MICRON | 14 MICRON | 21 MICRON | 38 MICRON | 70 MICRON | 100 MICRON |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 05/08/10<br>07/23/10 | 21MO. | U | U | | | <.1 | 146 | | 0.34 | | | | | | | | | | | | |
| 2 | 05/08/10<br>07/23/10 | 2MO. | N | N | | | <.1 | 101 | | 1.09 | | | | | | | | | | | | |

| SAMP # | PQ | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 13 | | | | | | | | | | | | | | | |
| 2 | 13 | | | | | | | | | | | | | | | |

Comments are advisory only and are based on the assumption that the sample and data submitted are valid. Missing lube or unit time limits the evaluation. No warranty is expressed or implied.