Advanced methods for sampling and analysis of post-tensioned concrete tendon greases

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ABSTRACT

Post-tensioned concrete tendons in nuclear containment are sometimes ungrouted, relying on a protective coating of grease to prevent corrosion of tendons and other associated components. In these installations, regulations such as ASME Section XI, subsection IWL, and Reg. Guide 1.35 provide guidance for testing this grease to ensure continued protection of the tendon components. Advances in grease sampling and analysis techniques allow for the possibility of obtaining samples without removal of the anchor can cover, significantly reducing the level of effort required to obtain a sample and effectively monitor grease condition. These small sample size methods, utilizing sampling techniques outlined in the ASTM standard D7718, allow for selective sampling from close to the anchor head surface, and without the invasive process of removal of the enclosure can that holds the grease. This means the grease will not need to be partially replenished during sampling, which could subsequently create a non-homogenous grease mixture that could lead to future sampling errors. Additional new analysis methods such as red-oxide quantification, ion-selective chemistry and die extrusion, may enhance the predictive capability of such monitoring, and improve maintenance practices to protect and extend tendon component life of containment applications.

Keywords: Corrosion, Grease, Grease Analysis, Grease Thief, concrete structures, nuclear power, nuclear containment

1. INTRODUCTION

The ungrouted post-tensioning cables in nuclear containment rely on a protective coating of the grease to prevent corrosion of the tendons and other anchor components. When installed these tendons are designed to meet regulations defined in ASME Section XI, subsection IML 25-25 and Reg. Guide 1.35. While these methods provide some data to determine the condition of the tendon, there are new methods and advances in grease analysis technology that allow for more data points to be gathered and provide a more comprehensive condition assessment of the tendon grease. The tools used in gathering the sample are defined in ASTM D7718. The sampling tools are designed to take a small, targeted sample, allowing for improved and precise grease sampling. Reducing the amount of sample required and adding additional tests to the current analysis specifications, allows for improved monitoring and prediction of tendon and anchor component failures. The small and unobtrusive sampling methods enabled with the small volume testing and specially designed sampling tool substantially reduce the time and resources required to get these samples, reducing the cost and increasing the accuracy of safely monitoring these critical assets.

2. SAMPLING CHALLENGE

For ungrouted tendons, ASME Section XI, IWL-2525 Table 1 contains guidance for corrosion protection grease testing. One-hundred twenty-five grams of sample is required to perform the test slate outlined in IWL-2525. This quantity of grease requires disassembly of tendon anchor cans (Figure 1) during sampling and disturbs the anchor area. Harvesting the grease from the anchor cans this way potentially disturbs the position of the cable buttonheads, hiding indications of broken strands. This highly invasive sampling procedure requires costly logistical support, equipment, down time and scaffold building. A tendon failure at a nuclear power plant in the United States prompted the need for a comprehensive analysis project to address concerns about the condition of the remaining tendons. A test slate was developed to address the monitoring parameters outlined in IWL-2525, and evaluate the additional concerns raised by the tendon failure event.

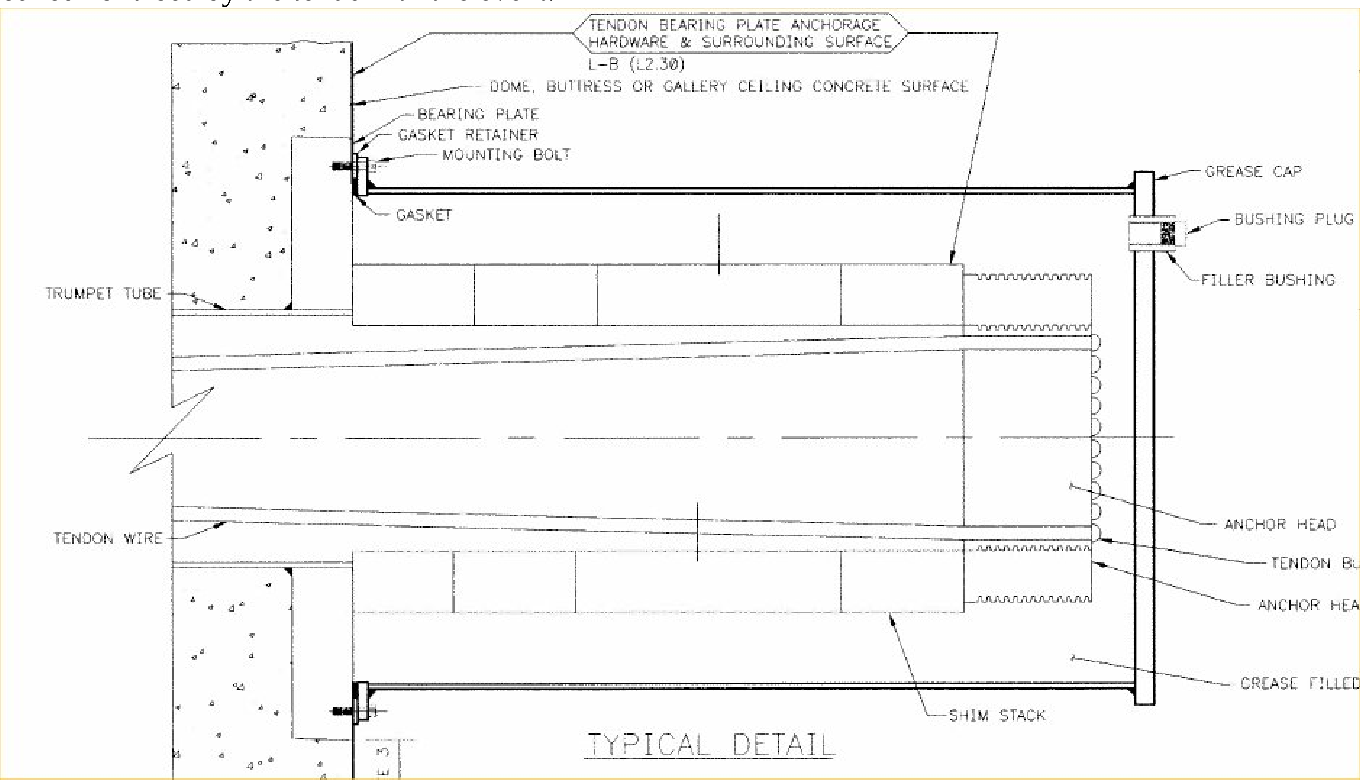

Figure 1 – Cross-section of tendon anchor head and can

The active sampling device (Figure 2) described in ASTM D7718 (Standard Practice for Obtaining In-Service Samples of Lubricating Grease) and a t-handle tool (Figure 3) were used to obtain a small volume of grease near the anchor head without disassembly. The t-handle and the stinger probe on the active sampling device allowed grease samples to be taken from the face of the anchor head. In a pilot program, the new small sampling method was used to take samples of just a few grams, and then traditional large samples were taken by disassembly of the anchor can. The results from the small volume testing correlated to the large volume method, allowing the project to proceed with the small volume method. For this post-failure project, the small volume sampling method saved approximately US$500,000 in sample acquisition costs.

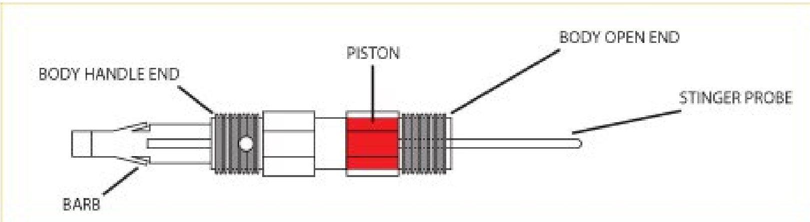

Figure 2 – Active sampling device in ASTM D7718

Figure 3 – T-handle and sampler

3. SMALL VOLUME TEST SLATE

ION CHROMATOGRAPHY

The detection of certain ions is performed to quantify these potential corrosion causing agents.
After careful review of the IWL-2525 test slate, it was found that some of the tests were outdated. In particular, it was discovered that ASTM D992 - Method of Test for Nitrate Ion in Water was withdrawn from use in 1983 and the current version of another test allowed for testing on only two of the required three parameters. A method was needed to support the small quantity of sample available and test for all three ions: chlorides, sulfides and nitrates. Ion chromatography was used to detect the ions in question. The concentrations of ions in the grease were so small, they often fell below the low limit of detection. New methods using ion specific electrodes are under development to improve the detection limit and determine more precise concentrations of ions.

TOTAL ALKALINITY

The Total Alkalinity test was developed to determine the Total Base Number in the anti-corrosion grease. This grease is fortified with basic detergents to neutralize corrosives materials and contaminants that might come in contact with the grease. A modified version of ASTM D4739, a method for measuring alkalinity in formulated oils, was developed to allow for the small volume of grease available to run the test. The method developed uses 0.5 grams grease and a proportionally smaller amount of solvent. The grease is fully dissolved using the acidifcation process outlined in IWL-2525. Colorimetric and Potentiometric titrations were performed and the base number (as a measure of total alkalinity) is reported in mg KOH/mg of grease.

RED OXIDES

The critical load bearing components in the tendons are ferrous steel, and corrosion of these components will form iron oxides. To quantify the extent of corrosion, a method was developed to isolate and count the amount and size of red and dark oxides (Figure 4). The extruded grease film, obtained by using a die extrusion process, was dissolved and the particulate separated using ferrographic analysis. The prepared glass slide was evaluated using visual microscopy, and a method developed to quantify the oxides, as an average count in two defined zones on the glass slide.
A new method has been developed and presented to ASTM to automate the identification and quantification of these oxides using high resolution direct imaging of the extruded grease film and software algorithms for identification and counting.

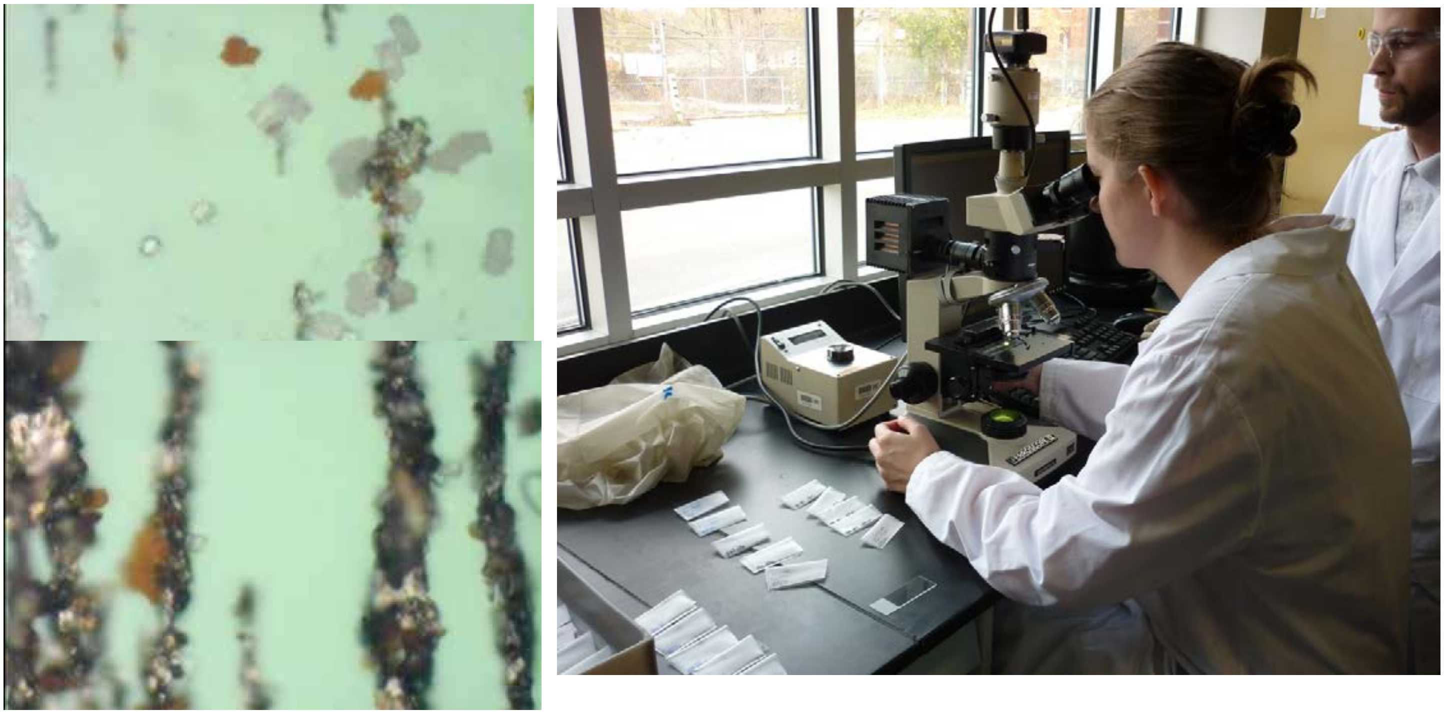

Figure 4 – Microscopic identification of oxides in tendon grease

OTHER TESTING

In order to provide an overall evaluation of the grease and a measure of other potential corrosive failure modes, additional testing was performed to look at microbial content, grease consistency, grease formulation and moisture content.

4. RESULTS

The data was compiled for over 500 tendon locations. The strongest correlations were found between Calcium and Total Base Number (TBN), Red Oxides and Ferrous Debris Level.

Several tendons were identified for further testing that contained high ATP (microbial) content, high red oxides or both high red oxides/low TBN. A majority of the tendons proved to be in good condition. Only a small precentage were candidiates for dissassembly and visual inspection.

Dispersion analysis using standard deviation was applied to the data and the failed tendon. The failed tendon fell 2 sigma outside the mean of the data for ATP, TBN and red oxides. Therefore, those three parameters were focused on when looking at the data set for the 500 tendons.

Dispersion Analysis	Failed Tendon Values	Mean	SD	+/- 1 SD	+/-2 SD
GreaseGT Index	19	75.49	41.944	33.546-117.434	-8.398-159.378
GreaseMoisture	.243	.16493	.041839	.123091-.206769	.081252-.248608
ATPMicro	1216	206.11	188.707	17.403-394.817	-171.304-583.524
TBN	4.8	47.995	15.5876	32.4074-63.5826	16.8198-79.1702
RedOxide	326	33.43	109.854	-76.424-143.284	-186.278-253.138
RDEFE	10.0	8.720	11.3693	-2.6493-20.0893	-14.0186-31.4586
FE	44.0	74.745	186.6510	-111.906-261.396	-298.557-448.047
RDECA	604	2426.51	1100.089	1326.424-3526.599	226.332-4626.688

Figure 2 [1] shows the results of the dispersion analysis of the failed tendon. The failed tendon fell 2sigmas outside the mean in three areas: ATP (microbial), TBN and Red Oxides.

A form of regression analysis was performed using Red Oxides as the dependent variable. Regression analysis demonstrates how the typical value of the dependent variable changes when any one of the independent variables is varied. Weight factors were assigned to each tendon sample scoring 1 – 5. The failed tendon scored a 5, and 12 other tendon samples scored a 4.

Regression Analysis on RedOxide	Beta
RDEFE	.419
FE	.256
GreaseGTIndex	.128
GreaseMoisture	.073
ATPMicro	.064
TBN	-.049
RDECA	-.016

Total Score	% of Tendons
1	49.2%
2	36.9%
3	11.1%
4	2.2%
5	.4%

Figure 3 [1] shows the results from the regression analysis performed on the data set. Less than 10% of the tendons tested required disassembly and further inspection.

5. CONCLUSION

Using the sampling tools outlined in ASTM D7718 new small volume sampling methods were developed to avoid tendon can removal. With the help of a laboratory pilot program a small volume test slate was developed to address the monitoring parameters outlined in IWL-2525, and evaluate the additional concerns raised by a tendon failure event at a US nuclear power plant. Dispersion statistical analysis was first used to determine which testing parameters were most prevalent and meaningful to the analysis. This narrowed the focus and allowed for regression analysis to be applied to the data set to rate and categorize the severity of each sample. The results showed that some tendon areas with non-trivial corrosion (high Red Oxide counts), were not expected since the key IWL-2525 monitoring parameters of moisture, total alkalinity and corrosive ions were not at levels to trigger concern. This raised the issue that the dated methods used in IWL-2525 could benefit from enhanced and updated technologies to better monitor tendon component corrosion in an aging nuclear fleet. The innovative concepts adapted on-site at this nuclear plant for sampling, and in the laboratory to develop small-volume analysis methods resulted in the development of a reliable and cost-effective method for monitoring tendon anchor heads across multiple failure modes.

6. REFERENCES

[1] WURZBACH, RICHARD, "ADVANCED METHODS FOR SAMPLING AND ANALYSIS OF POST-TENSIONED CONCRETE TENDON GREASES", PROCEEDINGS: 10TH INTERNATIONAL CONFERENCE ON NON-DESTRUCTIVE EVALUATION IN RELATION TO STRUCTURAL INTEGRITY FOR NUCLEAR AND PRESSURIZED COMPONENTS, NICE, FRANCE, OCTOBER 3, 2013.

[2] WURZBACH, R., “STREAMLINED GREASE SAMPLING AND ANALYSIS FOR DETECTION OF WEAR, OXIDATION AND MIXED GREASES”, NLGI ANNUAL MEETING, WILLIAMSBURG, VA, USA, JUNE 2008.

[3] WURZBACH, R., WILLIAMS, L., DOHERTY, W., “METHODS FOR TRENDING WEAR LEVELS IN GREASE LUBRICATED EQUIPMENT”, SOCIETY OF TRIBOLOGISTS AND LUBRICATION ENGINEERS (STLE) ANNUAL MEETING, LAS VEGAS, NV, USA, MAY 2010.

[4] ELECTRIC POWER RESEARCH INSTITUTE, “EFFECTIVE GREASE PRACTICES”, REPORT #1020247, PALO ALTO, CA, USA, OCTOBER 2010.

[5] WURZBACH, R., BUPP, E., HART, J., “NEW METHODS OF GREASE SAMPLING AND ANALYSIS FOR MOTOR OPERATED VALVES”, MOTOR OPERATED VALVE USERS GROUP CONFERENCE, SAN ANTONIO, TX, USA, JANUARY 2011.

6] WURZBACH, R., WILLIAMS, L., “STREAMLINED GREASE SAMPLING AND ANALYSIS”, OILDOC CONFERENCE, ROSENHEIM, BAVARIA, GERMANY, JANUARY 2011.