APPLICATION NOTE

Power Plant FAC Inspection Protocol

Using the Niton XL5 Plus XRF Analyzer

What is FAC?

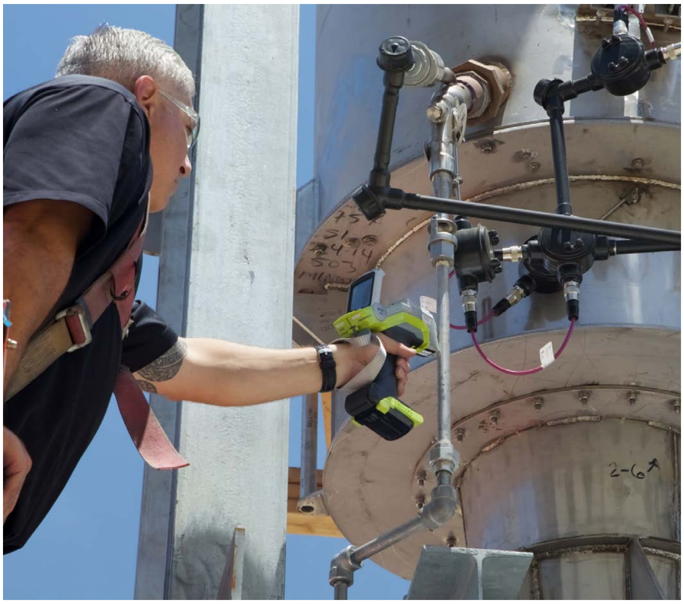
Flow accelerated corrosion, or FAC, is a well-known source of problems in nuclear and fossil fuel power plants. FAC occurs when carbon steel piping and components are degraded in the presence of flowing water or steam water with low-dissolved oxygen.

Flow accelerated corrosion is the dissolution of the normally protective oxide layer on the inside surface of carbon and low alloy steel piping. The iron oxides that naturally form on the exposed surface of the pipe are removed by the de-oxygenated water at elevated temperatures. This results in thinning of the pipe wall, which in turn can lead to leaks and potential catastrophic ruptures that adversely impact both personnel safety and plant reliability.

Highly publicized accidents have attracted the attention of utilities, industry groups such as EPRI, as well as regulatory bodies. In 1996, OSHA issued a hazards bulletin discussing FAC in feed water piping systems. In recent years, the insurance industry has become interested in the economic impact of FAC in terms of plant downtime, equipment loss and personnel hazards. More than 20 years of research has been devoted to understanding the cause and methods of FAC prevention worldwide.

Research conducted through the Electric Power Research Institute (EPRI) has demonstrated that FAC is a complex process influenced by a number of variables, including:

- The composition of the steel – principally the alloying elements of chromium (Cr), copper (Cu), and molybdenum (Mo)
- The water chemistry in use – pH at temperature in the water, dissolved oxygen, and temperature



An inspection is conducted using the handheld Niton XL5 Plus XRF analyzer.

- The water flow variables – fluid velocity, diameter, fitting geometry, and upstream influences

Of the variables presented above, both laboratory testing and plant experience have shown that material composition exerts the most influence on FAC.[1]

FAC Prevention Methods

It has been widely demonstrated that small quantities of alloying elements, chromium in particular, greatly reduce the rate of FAC. Research conducted by Michel Bouchacourt of Electricite de France has shown that at higher levels of trace chromium (above ~0.1%), substitution of chromium creates an oxide structure of

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$FeCr_2O_4$, which is much less soluble than the normal magnetite (Fe_3O_4) oxide layer present in carbon steel piping.[2]

As a result, it has become industry convention when inspecting for FAC to closely monitor trace alloy content. Further, monitoring of trace alloy content helps you facilitate improved planning of inspection protocol. For example, if inspected piping contains sufficient chromium content, it might be possible to omit it from future FAC inspection. The composition data also assists in interpreting the inspection data because it can be entered into EPRI CHECWORKS™ software improving the overall FAC data model.

Traditionally, chemical analysis of carbon steel piping in FAC inspection has been performed by laboratory analysis of filings, or by use of spark-based optical emission spectroscopy due to the need for detection of very low levels of chromium (~0.02%). The Thermo Scientific™ Niton™ XL5 Plus analyzer provides multiple advantages for an FAC prevention program. With its improved detection limits, handheld x-ray fluorescence (XRF) technology has become an ideal method for the FAC analysis application.

Niton XL5 Plus Handheld XRF as Part of the FAC Inspection Protocol

The new Niton XL5 Plus is the smallest and lightest high performance XRF metal analyzer in the market today. The light weight and small size of the Niton XL5 Plus reduce operator fatigue and enable access to more test points. Compact measurement geometry, a powerful 5W X-ray tube, and the latest silicon drift detector technology provide the highest performance and best light element sensitivity for the most demanding applications, such as FAC measurement. Niton XL5 Plus delivers fast, accurate elemental analysis in demanding power generation applications. The analyzer offers the nuclear and fossil power-generation industries the following key benefits:

- Unparalleled chemistry and metal-grade accuracy for confident results every time
- Excellent Cr, Cu and Mo trace element detection for fast and reliable FAC testing
- Small size and light weight improve productivity and testing in tight spots, without operator fatigue
- Flexible user interface enables custom workflow solutions and easy optimization for specific applications such as FAC measurement
- Integrated camera and small spot analysis for accurate sample positioning and image capture
- Splashproof, dustproof and rugged housing for harsh environments

The Niton XL5 Plus is the latest release in our market-leading Niton handheld XRF product line. The Niton XL5 Plus is specifically designed to deliver low detection limits, high accuracy and the fastest analysis time for discovering trace elements, such as Cr, Cu, and Mo. The Niton XL5 Plus is engineered for high performance, reliability, and ease of use, providing further evidence of Thermo Scientific leadership through excellence in innovation.

Test Method and Results

Certified reference standards and samples were analyzed after ensuring the surface was clean and clear of any contaminants. Data quality objectives dictate the sample preparation requirements and the minimum analysis time used.

Typical metal alloys that are at risk of FAC are carbon steels. These alloys will oxidize when exposed to atmospheric conditions. This oxide coating can affect the accuracy of the reading when performing an XRF analysis. It is, therefore, imperative to remove any corrosion in order to ensure an accurate reading.

In addition to oxidation, there can often be paint, oil or grease on the surface. Paint typically contains such metals as titanium, zinc or calcium that can impact the results of analysis. Grease can contain molybdenum and other additives. In order to get the accurate trace element readings, all surface contamination must be removed in the area to be analyzed.

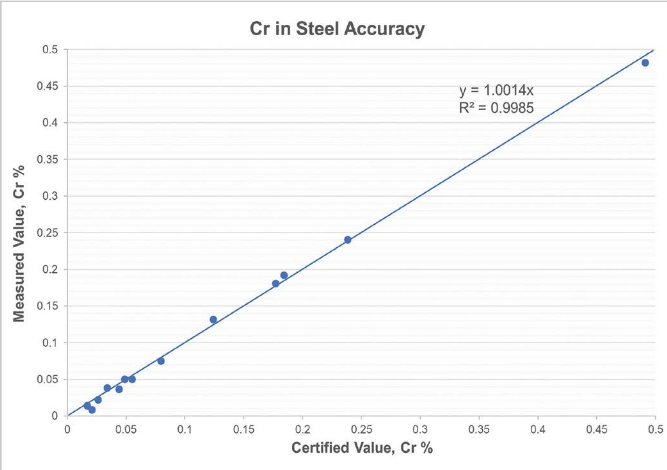

Figure 1: Chromium in steel accuracy using the Niton XL5 Plus analyzer

Figure 1 shows the correlation curve, certified results vs. the Niton XL5 Plus analyzer results. The coefficient of determination (R^2) value is a measure of how closely the data sets correlate with each other, where a perfect correlation would have an R^2 of 1. As can be seen from the data, agreement between laboratory results and Niton XL5 Plus results is very good ($R^2 > 0.99$). The data in Table 1 demonstrates the excellent repeatability for low levels of Cr, Cu and Mo using the Niton XL5 Plus. Total of 15 seconds measurement time was used for this test. Sensitivity and repeatability of Cr measurement can be further improved by using longer measurement time.

Conclusion

The Niton XL5 Plus provides excellent trace element precision and sensitivity for low levels of Cr, Ni and Cu. The results demonstrate excellent agreement with the laboratory results. Given appropriate sample preparation, the new analyzer is able to reliably detect 0.01% Cr levels in steel. Extended measurement time can be used to achieve even better results.

When low detection limits or the highest sample throughput are critical, our combination of hardware, software and direct industry experience provides the ideal solution for the most difficult analytical requirements. The improved analytical capability for trace quantities of Cr, Cu, and Mo and other unique capabilities make the Niton XL5 Plus the ideal tool for fossil or nuclear power plant FAC programs. In addition to FAC measurement, the Niton XL5 Plus can quickly provide full chemical analysis and grade identification for different alloy grades used in the power-generation industry.

Table 1: Accuracy and repeatability for Cr, Cu and Mo in carbon steel (15 second total test time).

Measurement	Cr	Cu	Mo
1	0.079	0.051	0.0040
2	0.078	0.051	0.0047
3	0.071	0.055	0.0037
4	0.078	0.048	0.0044
5	0.081	0.053	0.0055
6	0.073	0.047	0.0040
7	0.072	0.057	0.0046
8	0.076	0.047	0.0042
9	0.083	0.047	0.0048
10	0.074	0.055	0.0044
Average	0.077	0.051	0.0044
Std. Dev.	0.004	0.004	0.0005
Ref Value	0.079	0.050	0.0047

References

1. Chexal, B., Goyette, L.F., Horowitz, J.S., Ruscak, M., *Predicting the Impact of Chromium on Flow Accelerated Corrosion*, PVP-Vol 338, Pressure

2. *Vessels and Piping Codes and Standards*, ASME 1996 Chexal, Goyette, Horowitz, Ruscak, op. cit., loc. cit.

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