

# Use of Handheld XRF in the FAC Inspection Protocol

*Thermo Scientific Niton XL3t GOLDD Alloy Analyzers – Simply Superior XRF*



## 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. As the water flows against the carbon steel material, the stable surface oxide layer (typically  $\text{Fe}_3\text{O}_4$ ) is dissolved into the flowing stream – thinning the walls of piping over time and resulting in catastrophic failures due to rupturing. More than 20 years of research has been devoted to understanding the cause and methods of prevention of FAC 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
- The 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.<sup>1</sup>

## 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

atoms for iron atoms occurs in the oxide layer, creating an oxide structure of  $\text{FeCr}_2\text{O}_4$ , which is much less soluble than the normal magnetite ( $\text{Fe}_3\text{O}_4$ ) oxide layer present in carbon steel piping<sup>2</sup>. As a result, it has become industry convention when inspecting for FAC to closely monitor trace alloy content, because it is the lack of these elements that allows FAC to occur. Further, monitoring of trace alloy content helps you facilitate improved planning of inspection protocol. For example, if you find inspected piping contains sufficient chromium content, then you can omit it from future FAC inspection. The composition data also assists in interpreting the inspection data because it can be entered into CHECWORKS™, improving your overall FAC data model.

Traditionally, chemical analysis of carbon steel piping in FAC inspection has been performed by laboratory analysis of filings, or more recently, by use of spark-based optical emission spectroscopy (OES) instrumentation, due to the need for detection of very low levels of chromium (~0.02%). Although very reliable, OES technology does pose numerous difficulties such as:

- Difficulty of transport – OES instruments tend to be large and unwieldy, posing problems in hard-to-reach locations
- Sample preparation – the OES testing requires careful preparation of the sample by grinding off the oxide layer and eliminating any pitting or inclusions in the test area prior to analysis
- Damage to the sample – the OES test burns and vaporizes a small amount of the sample material, resulting in a heat-affected zone that in some cases must be re-heat treated
- User expertise – OES instrumentation requires a high level of user sophistication to maintain calibration, recognize data anomalies, proper surface preparation, etc.

|               | Niton XL3t 800 | Niton XL3t 900 GOLDD |
|---------------|----------------|----------------------|
| <b>Cr (%)</b> | 0.035          | 0.008                |
| <b>Mo (%)</b> | 0.010          | 0.004                |
| <b>Cu (%)</b> | 0.060          | 0.020                |

Table 1: Comparison of detection limits for trace elements in carbon steel (20 second test)

| Test             | Mo            | Cu            | Cr            |
|------------------|---------------|---------------|---------------|
| 1                | 0.0150        | 0.1080        | 0.1190        |
| 2                | 0.0150        | 0.1110        | 0.1200        |
| 3                | 0.0160        | 0.1060        | 0.1170        |
| 4                | 0.0150        | 0.1180        | 0.1230        |
| 5                | 0.0120        | 0.1090        | 0.1200        |
| 6                | 0.0160        | 0.1040        | 0.1210        |
| 7                | 0.0140        | 0.1110        | 0.1160        |
| 8                | 0.0160        | 0.0980        | 0.1200        |
| 9                | 0.0130        | 0.1180        | 0.1140        |
| 10               | 0.0150        | 0.1030        | 0.1190        |
| <b>Avg.</b>      | <b>0.0150</b> | <b>0.1090</b> | <b>0.1190</b> |
| <b>Std. Dev.</b> | <b>0.0013</b> | <b>0.0063</b> | <b>0.0026</b> |
| <b>Given</b>     | <b>0.0160</b> | <b>0.1090</b> | <b>0.1170</b> |

Table 2: Accuracy and repeatability for Mo, Cu, and Cr in carbon steel

## Advancements in Handheld XRF with

### Niton XL3t 900 GOLDD

With its dramatically improved detection limits, handheld x-ray fluorescence (XRF) technology has become a valid alternative method for the FAC analysis application. The Thermo Scientific Niton XL3t 900 Series with geometrically optimized large area drift detector (GOLDD™) technology is the latest in our market-leading Niton® XL3t Series analyzers, offering vast improvements in sensitivity and speed.

This remarkable instrument is specifically designed to bring you low detection limits, high accuracy, and the fastest analysis time for discovering trace and tramp elements, such as Cr, Cu, and Mo. It is engineered for high performance, reliability, and ease of use, providing further evidence of our leadership through excellence in innovation.

The data in Table 1 details the improvement in detection limits between the Niton XL3t 800 Series analyzer and the Niton XL3t 900 GOLDD instrument. Table 2 shows the impressive repeatability for low levels of Cr, Cu, and Mo in ferrous material using the Niton XL3t 900 GOLDD.

In addition to better detection limits, high accuracy, and excellent repeatability for trace elements, XRF technology provides a number of distinct advantages over the traditional OES analysis method:

- Portability – the handheld Thermo Scientific Niton XL3t 900 GOLDD analyzer weighs approximately 3 lbs. and is transported in a belt holster at the user's side
- Reduced sample prep – XRF technology requires little to no sample preparation
- Completely nondestructive – XRF analysis does not damage the sample in any way, eliminating the need to re-heat treat the sampled area
- Simplicity – XRF technology is much more user-friendly, allowing unskilled operators to participate in the inspection process

### Conclusion

When low detection limits or the highest sample throughput are critical, our combination of hardware, software, and direct industry experience team up to provide you with the ideal solution to your most difficult analytical requirements. The improved analytical capability for trace quantities of Cr, Cu, and Mo in the handheld Thermo Scientific Niton XL3t 900 GOLDD XRF analyzer makes this instrument comparable in performance to OES instrumentation for the FAC application. Given the equivalent performance along with the distinct usability advantages provided by XRF, this powerful instrument is not only a viable alternative to OES for use in the FAC application, but also is rapidly replacing OES in an increasing number of power generation facilities.

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



The Niton XL3t GOLDD analyzers give you the near instantaneous feedback you need for success.

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