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USE OF PORTABLE XRF in the FAC INSPECTION PROTOCOL

What is FAC?

Flow-accelerated corrosion, or FAC is a well-known source of problems in nuclear and fossil-fuel power plants. FAC is a process in which carbon steel piping & 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 Fe_3O_4) is dissolved into the flowing stream - thinning the walls of piping over time and resulting in catastrophic failures due to rupturing. More than twenty 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, copper and molybdenum.
- 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 the material composition, particularly the chromium content, is the most important variable influencing FAC.[1]

FAC Prevention Methods

It has been widely demonstrated that small quantities of alloying elements - particularly chromium - 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 $FeCr_2O_4$, which is much less soluble than the normal magnetite (Fe_3O_4) oxide layer present in carbon steel piping[1]. As a result, it has become industry convention when inspecting for FAC to closely monitor trace alloy content, as it is the lack of these elements that allows the FAC to occur. Monitoring of trace alloy content allows for much better planning of inspection protocol. If inspected piping is found to contain sufficient chromium content, it can be omitted from future FAC inspection. The composition data also assists in the interpretation of inspection data as it can then be entered into CHECKWORKS© to improve the overall FAC data model.

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

	NITON XLt 800SY	NITON XLt 800
Cr (%)	0.019	0.13
Mo (%)	0.004	0.008
Cu (%)	0.05	0.073

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

Test	Cr	Cu	Mo
1	0.085	0.099	0.012
2	0.085	0.137	0.010
3	0.082	0.151	0.008
4	0.084	0.135	0.016
5	0.085	0.123	0.011
6	0.082	0.177	0.012
7	0.085	0.163	0.009
8	0.089	0.162	0.009
9	0.083	0.165	0.010
10	0.087	0.173	0.007
11	0.071	0.146	0.013
AVG	0.083	0.148	0.0106
STD.DEV.	0.0046	0.0235	0.0025
CERT	0.080	0.17	0.011

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

- difficulty of transport - OES instruments tend to be large and unwieldy, posing difficulty in hard-to-reach locations
- sample preparation - the OES test requires careful preparation of the sample by grinding off of the oxide layer and elimination of any pitting or inclusions in the test area prior to analysis
- damage to sample - the OES test burns & 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.

New Developments in Handheld X-ray Fluorescence (XRF)

Advancements in handheld XRF technology have resulted in dramatically improved detection limits, which now make XRF a valid alternative method for the FAC analysis application.Thermo Electron's NITON XLt 800S Series analyzers employ a new "super resolution" solid-state detector that improves the instrument's signal to background ratio, and an improved low-power, miniature x-ray tube fitted with multiple excitation-enhancement filters - resulting in significantly improved detection limits for trace elements. The data in Table 1 details the improvement in detection limits between the multi-filter NITON XLt S Series instruments and the older fixed-filter NITON XLt analyzer. Table 2 shows the impressive repeatability for low levels of chromium, copper and molybdenum in ferrous material using the new S Series NITON XLt.

In addition to better detection limits, accuracy and repeatability for trace amounts of chromium, copper and molybdenum, XRF technology provides a number of distinct advantages over the traditional OES analysis method:

- portability - Thermo's handheld NITON XLt 800S Series 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 less-technical personnel to be utilized for the inspection process

Conclusion

The improved analytical capability for trace quantities of Cr, Cu and Mo in the NITON XLt S Series XRF analyzer make 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, the NITON XLt 800 S Series analyzer is not only a viable alternative to OES for use in the FAC application, it 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

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