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Sensitization and Corrosion in Stainless Steel Filters

RATIONALE

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1. SCOPE:

This document reviews briefly the subject of woven metal screens. Conditions that can promote damaging corrosion in stainless steel filter screens are discussed and recommendations are listed for minimizing corrosion damage. This is a general document only; for specific applications it is suggested that the reader refer to the technical literature, and selected references listed below.

2. REFERENCES:

- 2.1 Metal Handbook, Ninth ed., Vols. 3,4,5 and 6, 1980, 1981, 1982 and 1983, American Society for Metals
- 2.2 Metals Handbook, Eighth ed., Vols. 1,2,3,4,5 and 6. 1961, 1964, 1967, 1970 and 1971. American Society for Metals
- 2.3 1983 Annual Book of ASTM Standards, Section 3, Vol. 03.02, Metal Corrosion, Erosion and Wear, American Society for Testing & Materials
- 2.4 Corrosion and Corrosion Control, An Introduction to the Subject, by J.T.N. Atkinson and H. Van Droffelaar, 1982, National Association of Corrosion Engineers
- 2.5 An Introduction to Metallic Corrosion by Ulick R. Evans, Third ed., 1981 Edward Arnold (publishers) Ltd. and American Society for Metals
- 2.6 Corrosion and Corrosion Control, An Introduction to Corrosion Science and Engineering, by Herbert H. Uhlig, 1963, John Wiley and Sons
- 2.7 A Guide to Corrosion Resistance, 304, 316, 317, "20" and Ni-O-Nel, by J.P. Polar, 1961 Climax-Molybdenum Company, a division of American Metal Climax, Inc.

3. TECHNICAL INFORMATION:

3.1 Summary:

The reliability of stainless steel depends on the reliability of the manufacturer in achieving and maintaining proper metallurgical control over procurement and processing. Sensitization and subsequent intergranular corrosion of fine austenitic stainless steel filter mesh is an important problem which is often unrecognized by the filter user. Recognition of this major corrosion problem and other metallurgical deficiencies often found in filters, followed by appropriate action based on a sound understanding of the required technology, is necessary to achieve adequate control.

3.1 (Continued):

Sensitization is caused by an excessive carbon content in the stainless steel, improper heat treatment including sintering or annealing and welding or brazing operations, or both together. Sensitization can be controlled by applying good metallurgical quality control procedures and manufacturing practices and by specifying low carbon alloys such as AISI type 304L or stabilized alloys such as AISI type 347 stainless steel for filter mesh construction. It should be noted that sensitization can occur in as-woven mesh as well as in subsequently annealed or sintered mesh. If proper quality control procedures are utilized and the material is properly processed, either annealed or sintered mesh is equally resistant to corrosion. If proper quality control procedures or processing steps are not observed, either material can be sensitized. Therefore, procurement documents for filters and other structures made from stainless steel wire mesh should stress the quality control requirements rather than limit the use of annealed or sintered mesh. Other causes of metallurgical or corrosion failure, while less common in occurrence and less important in practice, must also be controlled to achieve reliability. These problems are best solved by filter manufacturers and users working together on a common ground of understanding.

3.2 Woven Metal Screen:

Woven metal screens are produced just as the term implies, by weaving metal wire strands into a mesh or screen with dimensionally controlled opening sizes. Screen can be woven from virtually any metal or alloy that can be drawn into ductile wire. However, filter screens are largely woven from stainless steel wire because of cost considerations and the fact that most filter applications are intended for handling mildly corrosive liquids and solutions. Where greater corrosion resistance is required screens can be woven from more corrosion resistant alloys or even the noble metals, if necessary. Filtration of aggressively corrosive media requires that the filter screen material be selected carefully to assure the desired filter life. The filter body may also require special construction and processing, and non-standard cleansing methods.

Stainless steel filter screens are most frequently produced from 300 series stainless steels. Screen wires may be as small as 13 μm (0.0005 in) diameter and as large as 0.8 mm (0.032 in). There is very little use of ferritic, martensitic or precipitation hardenable SS alloys for this application. Both 304 and 316 SS are widely used for filter screen, however 304L, 316L, 347, 348, and 321 SS alloys may be specified for greater resistance to intergranular corrosion.

From a metallurgical standpoint the quality of screen products, although certified to meet certain requirements, may be subject to considerable and sometimes functionally detrimental variation. For this reason, acceptance sampling for evaluation of screen or wire characteristics considered to be important to filter function should be implemented where appropriate by the filter fabricator. Important fabricator quality provisions other than acceptance sampling should also receive attention; for example, clear and unambiguous marking of each batch of screen and wire as to producer, purchase order number, heat number, process lot number, composition and size characteristics is essential to prevent material mix-ups in the fabrication shop. These same recommendations apply to weld filler metal and brazing alloy material where these processes are used in filter fabrication. Control of ancillary heating operations is also important.

3.2 (Continued):

Generally, filter screens are fabricated from stainless steel wire in the fully annealed or dead soft condition. The screen weaving process necessarily introduces various levels of cold work into the screen wires, depending on the controls and inherent consistency of the weaving process. Filter screens are mostly used in the as-woven condition unless annealing is specified in the purchase order; therefore the wire alloy characteristics are modified from the as-woven condition only by additional forming, welding or brazing cycles that occur as a result of filter fabrication. Without attention to the effects that the various manufacturing operations may have on the corrosion resistance of the alloy from which the screen is produced, the assembled filters may exhibit wide variations in effective service life.

It is recommended that stainless steel filter screens be passivated after weaving by screen manufacturers. Passivation of the 300 series stainless steels is basically accomplished in room temperature nitric acid solutions of 50% concentration sometimes with sodium dichromate added. Special rinses may also be used after passivation. The major purposes of passivation are twofold; first the solutions are designed to dissolve free iron resulting from contact with steel tools or grinding dust from the wetted surfaces. Second, these same solutions are intended to create a blemish free continuous oxide film or passive layer on all wetted surfaces. Even when perfectly accomplished, however, passivation will not provide resistance against destructive corrosive attack in appropriate corroding media. Passivation will minimize rust and stain formation in alloys that are not "sensitized"; it does not help much in "sensitized" areas.

3.3 Corrosion of Stainless Steels:

The 300 series stainless steels can be very resistant to corrosive attack, but they are certainly not immune to corrosion. A mechanism termed "sensitization" is responsible in most instances of intergranular corrosion in these alloys. Whether sensitized or unsensitized, pitting attack and stress corrosion cracking may also be serious, structurally degrading corrosion modes in filter screens. Crevice corrosion and corrosion fatigue may also occur, however the extent to which any of these corrosion mechanisms are responsible for reduced life or outright failure of filter screens is not known. Much has been written in the technical literature on the causes and prevention of corrosion in stainless steels and is not the intent of this report to repeat this. A brief discussion is provided below on this principle mechanisms of corrosion, for continuity in this document:

- 3.3.1 Intergranular Corrosion: This type of corrosive attack is generally confined to grain boundaries. It occurs most severely in metal that has been "sensitized". "Sensitization" is best explained as depletion of chromium at grain boundaries, below the nominal 12% Cr required to attain passivity. This occurs when the carbon dissolved in and normally distributed uniformly in the steel combines with chromium at temperature to form chromium carbides in the regions where carbon diffuses most readily at the grain boundaries. Chromium depletion by this mechanism (carbide precipitation) happens as a result of excessive exposure time at temperatures in the range from 400 °C (750 °F) to as high as 870 °C (1600 °F), the severity of sensitization depends largely on average carbon content, time in the sensitizing range, exposure temperature and alloy composition. The time-temperature relationship for intergranular attack due to sensitization in one alloy is drawn in Figure 1. This characteristic "C" curve shape is typical for 300 series stainless steels.