STRESS CORROSION CRACKING RESISTANCE OF K500 MONEL VS. MONEL 400 IN HYDROFLUORIC ACID UNS #N05500 AND #N04400

Questions have come up recently about the relative resistance of 400 and K-500 Monel® alloys to stress corrosion cracking in HF (hydrofluoric acid) service. In particular, about applications for pressure gauges used in refinery HF alkylation units.

While Monel 400 is reported to be slightly more resistant to SCC (Stress Corrosion Cracking) in aerated acid, the difference is not enough to avoid a failure. Both alloys are subject to vigorous attack in the vapor phase of hydrofluoric acid in the presence of oxygen. The published literature repeatedly emphasizes the need to avoid air (oxygen) in the vapor phase above the acid. Since HF alkylation units are carefully maintained to exclude oxygen, the minor difference between these two alloys should not be a determining factor. It is recommended that gauges intended for direct HF service be ordered to Ashcroft® variations X6A to ensure they are free of residual water. If air cannot be excluded from the process, a diaphragm seal should be used as discussed on page two.

To quote ASME B40.1 Gauges – Pressure Indicating Dial Type – Elastic Element:
"The elastic element [Bourdon tube or bellows] is generally a thin walled member, which of necessity, operates under high stress conditions…"

The full scale pressure of the gauge selected should be approximately two times the intended operating pressure; maximum pressure should not exceed 75% of scale range. Liquid filled and throttled, or Ashcroft® gauges with the ***PLUS!™*** Performance option must be used on pump discharge lines or wherever there is vibration or pulsation.

Since the Bourdon tube of most pressure gauges constitutes a dead-end cavity, and since air (oxygen) promotes SCC, it is important that a newly installed gauge be evacuated and back-filled with an inert gas or liquid. This will avoid trapping air (oxygen) in the highly stressed end of the Bourdon tube. It is understood this step is usually a normal part of repair procedures for HF alkylation units. The step should not be overlooked just because a small amount of air is involved in changing a gauge. Any air trapped in a Bourdon tube will be in a location where it can do the most damage. If the lines cannot be purged and only the gauge is to be changed, it could be evacuated and back-filled with inert gas or liquid, capped or sealed until immediately prior to installation.

A review of the literature on the use of Monel alloys in hydrofluoric acid finds that most articles cite a 1956 paper "Stress Corrosion Cracking of Monel in HF Acid," by Copson and Chung in the NACE (then the National Association of Corrosion Engineer, now NACE International) periodical Corrosion. While they reported a small difference between K Monel and Monel 400 in aerated HF vapors, there was appreciable overlap in the results. Cracks were first observed in four samples of K- Monel in 2 to 6 days, while 25 samples of Monel [400] showed cracks in 4 to 15 days. Both will crack in aerated HF vapors.

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Much of the difference between the two alloys is probably due to the higher hardness of K Monel 500, particularly in the age hardened condition. To quote C.M. Schillmoller in the Nickel Development Institute paper (available on their website) Corrosion Resistance of Nickel Containing Alloys in HF acid, HF and Fluorine,

> "Alloy 400 [Monel 400] may be subject to stress corrosion cracking (SCC) in moist vapors in the presence of oxygen due to accretion of cupric fluorides. Alloy K500 (N05500) with its higher strength, may be even more so."

While correct, Ashcroft® Duragauge® and Type 1259 process gauges with K-Monel Bourdon tubes are not age hardened. They are welded, overpressured and stress relieved. Ashcroft uses age-hardened tubes only for Type 1082 test gauges and 30,000 psi process gauges.

Thousands of pressure gauges with K-Monel Bourdon tubes have been sold to refineries over many decades, presumably for direct use on hydrofluoric acid alkylation units and other corrosive applications. While Ashcroft frequently does not know the service their gauges will be used in, it is probable that refineries only use the more expensive Monel instruments in corrosive applications.

If air cannot be excluded for HF applications, a diaphragm seal should be used. Ashcroft has for several years offered Halar® (ECTFE) clad diaphragm seal components. According to the published corrosion literature, gold and platinum are the only metals fully resistant to aerated and non-aerated HF and its vapors. Ashcroft can offer Monel diaphragms gold plated to ASTM B488, *Electrodeposited Coatings of Gold for Engineering Uses*, and tested to be porosity free to ASTM B735 *Porosity of Gold Coatings on Metal Substrates by Nitric Acid Vapor.* Call Customer Service for price and availability of Halar® or gold cladding.

There are reports in the literature that some of the Hastelloy alloys are more resistant, but they are not immune from SCC, and the test conditions were not always clear. Much of the available corrosion data is about uniform corrosion rather than the more damaging stress corrosion. For those who prefer alternative materials, or who want a second line of protection in addition to the Bourdon tube, Ashcroft offers a full line of diaphragm seals in most corrosion resistant alloys. Many combinations of diaphragm and lower housings are available in the all-welded Type 400 design.

In case of confusion, there is a simple test to determine whether a component is made of Monel 400 or K Monel. The temperature at which Monel 400 becomes magnetic is between +40° and +70°F while that of K Monel is below –150°F. After an hour in a household refrigerator, and sometimes at room temperature, only Monel alloys 400 and 405 will be slightly magnetic. Monel K-500 will not be attracted by a magnet.

The test above chiefly concerns Bourdon tubes, all Ashcroft® Monel gauges have Monel 400 sockets. Monel 405 (UNS #N04405) mentioned above is a free machining grade with added sulfur. This sulfur exists as sulfide stringers in the microstructure which promote chip breakage.

There has been extensive satisfactory experience of sales to refineries with Monel K500 for decades.

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