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WHEN STAINLESS PUMPS
DON'T APPEAR TO BE STAINLESS

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The problem: new cast CF8M (Type 316) austenitic stainless pump casings appear to be rusting from only atmospheric exposure. Without the normal "stainless" aesthetic appeal, the customer rejected the rust-stained pumps. For a new service installation, dirty looking rusting pump casings were not expected. The plant engineer took one look and rejected them as defective. "Those can't be stainless steel pumps; they're rusting!"

After some confusion and several discussions, the cause was determined. The pumps were in fact stainless steel that met the requirements and specifications called out on the purchase order. The casting supplier cleaned the casings through a combination of abrasive blasting and other mechanical means. Residual iron contaminants in the abrasives became embedded in the stainless casing surfaces, and were subject to oxidation to hydrated ferric oxide, which showed up as "ruststains." Exposure to atmospheric moisture caused "rusting" or a "rust bloom." The primary cause of rusting was the inability of the casing to form its continuous protective passivated surface. The cleaning methods used introduced iron-contaminated surfaces.

The Remedy

Clean the surfaces of scale, free-iron and other contamination to permit passivation to occur; or apply a suitable protective barrier coating (paint) over properly cleaned surfaces. Effective cleaning is done by chemical pickling or mechanical means using iron-free cleaning tools. ASTM standard A380-96, "Cleaning and Descaling Stainless Steel Parts, Equipment, and Systems," provides guidelines for proper cleaning of stainless steel.

Lessons Learned

Stainless and other high-alloy steels cannot be processed as though they are carbon or lowalloy steels. Nor does "stainless" mean immune to rusting or corrosion from contamination. Contaminated surfaces are undesirable for developing a uniform passivated oxide film, which will never properly form unless the contamination is removed. While minor contamination generally isn't a serious problem on rough non-machined casting surfaces, there are occasions when surface contamination can seriously affect corrosion resistance and cause rust staining. As shown in the photograph, significant amounts of free-iron can be transferred to otherwise stainless surfaces, which with time, result in rust staining. When the surface of stainless steels have become contaminated with iron, corrosion of the free-iron on the surface may establish corrosion cells resulting in localized pitting. To retain its stainless qualities, stainless steels must be kept clean and free of surface contamination.

Further Discussions

Stainless steels are selected for many services for their corrosion resistance and aesthetic "stainless" appeal. It's desirable to have clean uniformly passivated surfaces. For many services it's mandatory to prevent product or process contamination, and maintain sanitary conditions. Unfortunately, in some instances end users are disappointed to find stainless pumps that are "rusting." Frequently, a legitimate concern arises as to whether the pumps are stainless, or whether the alloy is in its most corrosion resistant condition. Stainless steels do corrode. In fact, it's the formation of a tightly adherent and uniform chromium-rich oxide film (passive corrosion layer) that provides these alloys with their stainless properties and corrosion resistance. Damaging or preventing this "passive" surface film from forming can lead to corrosion and staining. Certain production conditions or handling may make stainless alloys susceptible to localized corrosion, and produce surfaces that appear to be "rusting." Metallurgical changes and mechanical imperfections such as scratches, tooling and grinding marks, heat tint and heat treat scale, or other general surface contamination, can create problems. During various processing operations particles of iron or tool steel can become embedded or smeared into the surfaces. Properly passivated components do not exhibit due to impingement and surface peening. The only way to remove these contaminants and guarantee a thoroughly clean, rust-free surface, is to follow blasting with an acid pickling and passivation treatment.

Pickling and Passivation

Cleaning, pickling, and passivation of stainless steels are widely misunderstood. Pickling removes foreign contaminants, and permits the surface to equilibrate; allowing for the formation of a uniform passivated surface layer which provides corrosion resistance. Acid descaling or cleaning, also known as "pickling," is used to remove surface scale, free-iron and other corrosion products. Pickling effects passivation simultaneously. Stainless steels are self-passivating, due to their high chromium content. A pickled surface passivates spontaneously when exposed to air, water, or other oxidizing environment. For austenitic stainless steels such as CF8M castings, pickling in an aqueous solution containing 6-25 % nitric acid and 1/2-8 % hydrofluoric acid is usually recommended. Sometimes an 8-11 % sulfuric acid solution is first used to remove tight adhering scale. Thorough scrubbing and rinsing to ensure removal of contaminating residues should follow immersion. The surfaces will self-passivate during the rinsing operation. (See ASTM A380-96 Table A1.1 Treatment Codes A and B or Table A2.1 Part I, Treatment Code D). While nitric acid removes free-iron particles, it can not remove residual oxide scale. The nitrichydrofluoric mixture, unlike nitric acid alone, provides a reducing component, which removes iron oxide scale and other metal oxides by chemical reduction. This mixture is not passivating, and corrosion rates are high during exposure, which should be limited to only a few minutes. A uniform passive oxide film forms over the freshly cleaned surfaces once removed from the pickling environment. Passivation is often confused with pickling. Passivation treatments are not designed to remove heat tint, embedded iron, heat treat scale, or other contaminants embedded in the surface, since nitric acid does not readily remove the surface containing these contaminants. Elimination of these contaminants requires removal of the protective oxide layer from the metal by pickling the surface with a reducing component as previously stated. Exposure to air is the primary passivation treatment for stainless steels. This produces a tenacious and durable chromium rich film that forms rapidly on the alloy surface, providing the characteristic "stainless" qualities. The primary function of a "passivation" treatment is to clean lightly contaminated surfaces to ensure the spontaneous formation of the chemically inactive "passive" film. Though stainless steel is naturally passivated by exposure to air or other oxidizers, additional surface treatments often are specified to ensure uniform passivity, and optimum corrosion resistance. Contact with air, water or other oxidizers (e.g., Nitric acid) in the environment are usually sufficient to ensure good formation of the "passive" layer. Passivation treatments following pickling or mechanical cleaning generally are not needed provided thorough cleaning has been performed and maintained, and there is adequate exposure to air or other oxygen-containing environment. While passivation does not improve the resistance normally provided by the alloy, the enhanced passive film is somewhat thicker and more tenacious than that formed naturally. To prevent staining of stainless steel and restore the corrosion resistance, finished parts are often given a passivation treatment, which consists of immersing in a solution of nitric acid. For removal of soluble salts, corrosion products, free iron and other metallic contamination resulting from handling or atmospheric contamination, an aqueous solution containing 20 to 50 vol% nitric acid is recommended for CF8M castings. (See ASTM A 380 Table A2.1 Part II and Part III).

Final Comments

Regardless of treatments used, whether acid pickling, or mechanical cleaning, castings can eventually show signs of rusting if stored outside, due to the settling of ferrous particles or other wind blown contaminants in the environment. For this reason it is important to provide protection and store stainless steel equipment in a dry, iron free environment. An understanding of service conditions and surface cleaning requirements is essential to provide corrosion resistant "stainless" castings. While it may appear confusing to determine which treatments ought to be specified for specific applications, the ASTM A380 document provides an excellent reference which should be reviewed thoroughly by those specifying, as well as those supplying stainless steel equipment.

Selected References: µ
1. Standard Practice ASTM A380-96, "Cleaning and Descaling Stainless Steel Parts, Equipment and Systems;" Annual Book of ASTM Standards, Vol. 01.03, p 145-156 2. "Update on Cleaning Stainless Steels" Staff Report, Metal Progress, June 1973, p 38-60 3. Robert R. Gaugh, "Descaling and Cleaning of Stainless Steel and Heat Resisting Alloys," ASM Metals Handbook Desk Edition, 1985, American Society For Metals, p 29.42 4. C.P.Dillon, "Cleaning, Pickling, and Passivation of Stainless Steels," Materials Performance, May 1994, NACE International, p 62-64 5. Arthur H. Tuthill, and Richard E. Avery, "Specifying Stainless Steel Surface Treatment," NiDi Technical Series