# REGULATORY GUIDE

## OFFICE OF STANDARDS DEVELOPMENT

### REGULATORY GUIDE 3.37

## GUIDANCE FOR AVOIDING INTERGRANULAR CORROSION AND STRESS CORROSION IN AUSTENITIC STAINLESS STEEL COMPONENTS OF FUEL REPROCESSING PLANTS

### A. INTRODUCTION

Section 50.34, "Contents of applications: technical information," of 10 CFR Part 50, "Licensing of Production and Utilization Facilities," requires, among other things, that each application for a construction permit for a fuel reprocessing plant include sufficient information relative to construction materials to provide reasonable assurance that the final design will conform to the design bases with adequate margin for safety. Section 50.34 also requires a discussion of how the applicable requirements of Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50 will be satisfied. As used in Appendix B, "quality assurance" comprises all those planned and systematic actions necessary to provide adequate confidence that safety-related structures, systems, and components will perform satisfactorily in service. Appendix B requires, in part, that measures be established to ensure materials control and control special processes, including welding and heat treating and to ensure the performance of reliable testing programs. These special processes must be accomplished by qualified personnel using qualified procedures.

Austenitic stainless steels are widely used in components of fuel reprocessing plants because of their corrosion resistance to the solutions encountered. However, improper use, fabrication and cleaning could result in corrosion failure of the austenitic stainless steel during fabrication or in service. Many acceptable practices for controlling the use of austenitic stainless steels can be followed to avoid intergranular and stress corrosion. These practices can differ significantly because of insufficient guidance toward standardization. In the interest of standardization, this guide specifies procedures acceptable to the NRC staff for controlling the use and testing of austenitic stainless steels to avoid intergranular corrosion and stress corrosion. The procedures are designed to allow one to detect and control (a) improperly processed or fabricated materials and (b) conditions that could lead to intergranular corrosion and stress corrosion cracking during fabrication or service of austenitic stainless steels. The recommendations of this guide apply to austenitic stainless steel used in safety-related process equipment with its associated vessels and piping, radioactive waste handling and storage systems, metal liners of process cells and waste storage tank vaults, and other safety-related structures, systems, and components of fuel reprocessing plants.

### B. DISCUSSION

The maintenance and decontamination of radiochemical process equipment, structures, and components can be both difficult and hazardous. Cracks, crevices, and discontinuities on the surfaces of radiochemical equipment may retain radioactive solutions or particulates. This complicates decontamination both for decommissioning and for direct repair, maintenance, or inspection. Cracks and defects can also cause equipment leakage by initiating accelerated crevice corrosion from either the operation or decontamination environment. To ensure public health and safety, the defense-in-depth concept dictates that process equipment, structures, and components important to safety be designed, constructed, operated, inspected, and maintained to keep their integrity under all normal and accident conditions.

Welding is used extensively in the fabrication of radiochemical equipment because of the requirement for high quality construction and to minimize discontinuities, crevices, and leakage. Because the austenitic stainless steels, American Iron and Steel Institute (AISI) 3XX series, generally have good resistance to corrosion by nitric acid solutions and other chemically aggressive solutions used in the reprocessing of spent nuclear fuels, these steels are widely used in process equipment,

structures, and components of fuel reprocessing plants. However, unexpected, unpredictable, and unnecessary corrosion failure of austenitic stainless steels can result from their improper application, fabrication, cleaning, and welding. For example, the improper selection and welding of an austenitic stainless steel can leave the material in a sensitized condition susceptible to intergranular corrosion in its service environment. This corrosion can lead to roughening of surface and to grain boundary separation which allows radiochemicals to concentrate, making decontamination difficult and eventually leading to accelerated and unexpected intergranular corrosion failure and leakage. Similarly, improper control of environment can lead to failure by stress corrosion cracking. The following discussions present the metallurgical conditions and causes leading to sensitization of austenitic stainless steel and steps that can be taken to avoid sensitization. Controls to avoid stress corrosion cracking will also be discussed briefly.

Through these discussions, the engineer who must design fuel reprocessing plants, but who is not necessarily an expert in the metallurgy of stainless steels, can gain a better understanding and appreciation of intergranular corrosion and stress corrosion. These discussions should also aid the engineer in controlling the application and use of austenitic stainless steels to avoid or minimize unexpected and unnecessary corrosion failures of fuel reprocessing plant process equipment, structures, and components.

## I. Sensitization and Intergranular Corrosion of Austenitic Stainless Steel

Steels become "stainless," i.e., resistant to corrosion, by virtue of their chromium content. A minimum amount in the vicinity of 12 percent chromium by weight is required for a steel to exhibit stainless properties. Above this chromium level, a protective oxide film forms on the exposed stainless steel surface.

At ambient and mildly elevated temperatures, properly processed commercial austenitic stainless steels exist in metastable equilibrium. The equilibrium structures of plain iron-carbon-chromium-nickel stainless steels contain two phases (1) austenite, the face-centered cubic form of iron with chromium, nickel, and less than 0.01 weight percent (wt%) carbon in solid solution and (2) chromium carbide, $(Cr, Fe)_{23}C_6$. Properly processed commercial austenitic stainless steels, however, consist only of the austenite phase. They are metastable because they contain carbon in solid solution in excess of their solubility limits for these temperatures, i.e., they are supersaturated with carbon. These stainless steels are single phase because they have been rapidly cooled from elevated temperatures where the solubility of carbon is high and therefore is in solid solution. The rapid cooling prevents precipitation of excess carbon as the solubility of carbon decreases with decreasing temperature. At

ambient temperatures the alloy will remain in metastable equilibrium, i.e., the structure will remain austenitic with the carbon in solid solution because the diffusion of carbon is virtually nonexistent at these temperatures. However, when the austenitic stainless steels are subjected to elevated temperatures, e.g., in the range of 800 to 1600°F, carbon diffusion rates are high and the alloy will tend to reach stable equilibrium. The carbon diffuses to the grain boundaries where surface is available for the nucleation of a new phase. The carbon then precipitates in the form of very small and thin chromium carbides which grow at grain boundaries and into adjacent grains.

The chromium atoms that combine to form carbides are directly adjacent or close to the carbon atoms near the grain boundaries. With increased time at temperature and carbon levels above 0.02 wt% (the solubility limit of carbon at these higher temperatures), more carbides form at the grain boundaries and thus more chromium is depleted from these areas. This results in a band of steel surrounding the grain boundaries whose chromium level is substantially lower than that required to form a passive film. The corrosion properties of the band therefore approach those of plain carbon steel. The diffusion of chromium at these temperatures is slow, unlike that of carbon, and chromium atoms from the bulk of the grain do not reach the chromium-depleted zone in appreciable numbers. The metallurgical microstructure of austenitic stainless steel thus exposed to elevated temperatures consists of austenitic grains whose bulk chromium composition is nearly equal to the average chromium composition of the alloy. This structure is surrounded by an envelope (sometimes discontinuous) of chromium-depleted steel in contact with chromium carbides at and near the grain boundaries.

The chromium-depleted zone and the bulk of the grain form a dissimilar metal couple. The chromium-depleted zone is the anode of this couple and has a much smaller area than the remainder of the cathodic grain. When stainless steel of this structure is exposed to chemically aggressive solutions such as oxidizing acids, the chromium-depleted layer is actively corroded while the major portion of the grain remains unattacked. The attack completely removes the depleted layer surrounding the grains until the grains fall out of the structure. This gives rise to a high rate of corrosion penetration and to eventual failure.

Thermal treatments or exposures that cause chromium carbide precipitation at the grain boundaries with the accompanying chromium-depleted zones are called sensitization treatments or exposures. They leave the stainless steel in a sensitized condition or with a sensitized structure. This means that the stainless steel is sensitive to selective corrosion at the grain boundaries. The corrosion of the chromium-depleted layer surrounding the grain boundaries is called intergranular corrosion.

Temperature exposures for the commercial 3XX series austenitic stainless steels leading to sensitized structures susceptible to intergranular corrosion in most cases are in the range of 800 to 1600°F. In practical applications, sensitization of austenitic stainless steels may result from hot forming operations, stress relieving heat treatments, inservice exposure to elevated temperatures, and welding.

Several metallurgical schemes are used commercially to control or counteract sensitization and the resulting susceptibility to intergranular corrosion cracking of austenitic stainless steels. Many of the normal carbon grades 3XX series stainless steels contain a maximum of 0.08 wt% carbon, and a few types (e.g., 310) contain as much as 0.25 wt% carbon. One method of controlling sensitization is to lower the carbon content of the stainless steel to a level near its solubility limit at the sensitizing temperature range. Commercial grades of the 3XX series stainless steels are produced called the "L" grades, meaning low carbon content, (e.g., 304L) which contain less than 0.03 wt% carbon. At these carbon levels, the stainless steel will not sensitize in many practical and properly executed forming and welding processes when it is subjected to sensitizing temperatures for a reasonably short time. However, even the "L" (low carbon) grades of austenitic stainless steels will precipitate chromium carbides and become sensitized when subjected to sensitizing temperatures for longer times.

Another method for controlling sensitization in austenitic stainless steel is the addition to its composition of elements that, under certain conditions, are stronger carbide formers than chromium. Elements used for this purpose are titanium, niobium (columbium), and tantalum. Stainless steels containing these elements that have been properly processed to precipitate their carbides are called stabilized grades. Type 321 is an austenitic stainless steel that has been stabilized with the addition of titanium. Type 347 is a grade stabilized with niobium or niobium plus tantalum. These stabilizing elements are also strong oxide, sulfide, and nitride formers. Because the steel is normally deoxidized (by the addition of aluminum, for example) prior to the addition of the stabilizing element, very little of the stabilizing element is used up by the formation of its oxide. However, some of the stabilizing element added to the stainless steel combines with the sulfur and nitrogen present in the melt to form sulfides and nitrides. Therefore, to tie up all of the excess carbon present in the stainless steel with the stabilizing element, more than the stoichiometric amount necessary to form its carbide is required. In the commercial grades of stabilized stainless steels (e.g., 321 and 347), a minimum level of stabilizing element based on the carbon content is specified.

An understanding of how stainless steel is stabilized can be gained by consideration of the following tempera-

ture-metallurgical reaction relationships for the carbides in 3XX stainless steels:

a. Between ambient temperature and the lower bound temperature of the sensitization range, no carbide precipitation takes place.

b. In the sensitization temperature range, only the chromium carbide precipitates.

c. Between the upper temperature of the sensitization range and approximately 2250°F, chromium carbide dissolves and the stabilizing element carbide (of titanium, niobium, or tantalum) forms.

d. Above about 2250°F both the stabilizing element carbide and chromium carbide dissolve.

If the stainless steel with a stabilizing element is held at a temperature in the range between the upper sensitization temperature and approximately 2250°F (e.g., 1950°F), only the stabilizing element carbide forms and the excess carbon is tied up by its formation. The rate of cooling following this exposure does not significantly affect the precipitation of other carbides. Since the stabilizing carbide is also stable at lower temperatures, no carbon is available for formation of chromium carbide in the sensitization temperature range. Therefore, if a stabilized stainless steel is reheated in the sensitization temperature range where chromium carbides would normally form, there is no carbon available for their formation, and sensitization due to chromium depletion does not occur. The commercial stabilized stainless steels (e.g., 321 and 347) are given a stabilization heat treatment at the steel mill and their as-received structure consists of a stabilizing carbide in an austenitic matrix.

A third method of controlling intergranular corrosion susceptibility in sensitized austenitic stainless steel is through a solution anneal and quench heat treatment.[a] This consists of heating the stainless steel to a temperature of 1950 to 2050°F, maintaining that temperature long enough for all the carbides to go into solid solution, and then quenching or otherwise cooling the steel quickly enough through the sensitization temperature range to avoid reprecipitation of carbides. This treatment will provide a stainless steel with a single solid solution phase not susceptible to intergranular corrosion attack (unless it is again heated in the sensitization temperature range).

Two important phenomena associated with intergranular corrosion of fabricated stainless steel components

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[a] A solution anneal and quench heat treatment means heating to a suitable temperature, holding at the temperature long enough to cause all carbides to enter into solution, and then cooling rapidly enough to keep the carbon in solution.

are (1) weld decay and (2) knife-line attack. Weld decay is the intergranular corrosion in the heat-affected zone of the base metal at some distance from and parallel to the weld bead. Weld decay usually occurs in unstabilized austenitic stainless steel of normal carbon composition as a result of temperature exposure from the heat of welding and subsequent service in a corrosive environment. When a weld is made, some of the heat is dissipated through the base metal. The temperature is highest in the molten weld pool, and a complex thermal gradient exists through the weld and adjoining material. The temperature distribution in the metal surrounding the weld is a function of the base metal thickness and conductivity, preheat and interpass temperature, welding heat input and speed, and other factors. However, at some distance from the weld bead in the heat-affected zone, the base metal is exposed to temperatures in the sensitizing range. In the normal carbon grades and unstabilized stainless steels, a band of chromium-depleted steel parallel to the weld bead develops due to the precipitation of chromium carbides; the band is thus sensitized. If the weldment is subsequently exposed to aggressive solutions, intergranular corrosion occurs in this band of material parallel to the weld. This phenomenon is called weld decay.

Knife-line attack is another phenomenon that may occur in the stabilized grades of austenitic stainless steels as a result of welding. It is due to the sensitization of a very thin layer, a few grains wide, directly adjacent to and on either side of the weld bead. During welding this layer of stainless steel is exposed to temperatures just below its melting point. At these temperatures the solubility of carbon is very high and the stabilizing carbides go into solid solution. Subsequently this zone cools quickly enough through the temperature range (approximately 2250°F down to 1600°F) where the stabilizing carbides form and the carbon and stabilizing element remain in solution. This layer is then susceptible to sensitization. The layer will sensitize if the stainless steel is exposed to the sensitization temperature range where chromium carbide forms but the stabilizing carbide does not form. This exposure can result (1) from deposition of multiple weld beads, (2) when the thickness of the welded section is great enough to slow the cooling rate through the sensitization temperature range, or (3) if welded parts are given a postweld heat treatment, such as a stress relief, in the sensitization temperature range. If stabilized stainless steels that have been thus fabricated are exposed to corrosive media, intergranular corrosion in a very thin band on either side of the weld, called knife-line attack, may result.

As indicated by the previous discussion, intergranular corrosion may occur for several diverse reasons and many opportunities exist for stainless steels to be sensitized by the fabrication process or the service environment. Stainless steels of normal carbon content will usually be sensitized by welding. Therefore, these steels should be solution heat treated and quenched following welding for service in corrosive media. If a solution annealing and quenching treatment of the component is not feasible, low carbon grades or stabilized stainless steels should be used. However, as discussed, improper welding of these steels can also cause sensitization. Significant sensitization does not normally result when typical welding procedures and material chemistry are used and when no further heating of material occurs. The welding procedures and material chemistry should be controlled to prevent undue sensitization during welding. Control should be exercised to include the following: (1) maintaining low heat input to weld joint by controlling current, voltage, and arc travel speed, (2) limiting interpass temperature, (3) using stringer bead technique and the limiting of weaving, and (4) limiting the carbon content of the material where section thickness results in increased time at sensitization temperatures.

In nitric acid solutions and possibly in other highly oxidizing solutions, severe intergranular corrosion has been associated with the precipitation of sigma phase in molybdenum-containing types 316 and 317 and in the carbide stabilized types 321 and 347 stainless steels. The sigma phase is a metallurgical reaction product of ferrite and forms in the temperature range 1150 to 1550°F. Often the sigma phase is submicroscopic. Also, in nitric acid the austenitic stainless steels can undergo severe end-grain corrosion. This is accelerated corrosion of the stainless steel when the grains are exposed to the solution in transverse cross section, for example, the through thickness transverse cross section of rolled plate.

It should also be recognized that intergranular corrosion of austenitic stainless steels can take place in the nonsensitized condition when these steels are exposed to strongly oxidizing solutions. This corrosion occurs in exposures of these steels to strong boiling nitric acid solutions containing the $Cr^{6+}$ ion. This ion can be present and can accumulate in the solution as a result of the corrosion process of the stainless steel itself. The presence of any of the ions, $Cr^{6+}, Fe^{3+}, Ce^{4+}, Mn^{7+}$, or $V^{5+}$, in solutions of boiling nitric acid can cause intergranular corrosion of nonsensitized austenitic stainless steels. The phenomenon can be attributed to the segregation of elements to the grain boundaries, thereby altering the electrochemical properties of the boundary with respect to the grain and causing accelerated corrosion of grain boundary areas in the solutions mentioned above. Silicon and phosphorus can have a significant effect on the resistance of nonsensitized austenitic stainless steels to intergranular corrosion.

Proper choice of austenitic stainless steels is important; both the fabrication procedures and inservice environmental exposure conditions should be considered in the selection. It should be shown by corrosion testing

of as-received and fabricated materials and by qualification of procedures that stainless steels are not placed in service in fuel reprocessing plants in a sensitized condition.

## 2. Intergranular Corrosion Testing

Quality control testing for intergranular corrosion of austenitic stainless steels is needed to ensure that steels that have been sensitized and are susceptible to intergranular corrosion are not used for fuel reprocessing plant components exposed to aggressive solutions. These quality control corrosion tests are not designed to reproduce inservice conditions, but rather to detect metallurgical microstructural conditions known to cause inservice intergranular corrosion in aggressive solutions. The value of these tests, therefore, is to enable control of the use of sensitized stainless steel for service applications, not to predict the service life of stainless steel components.

Several corrosion tests are available for detecting susceptibility of stainless steel to intergranular corrosion due to sensitization by chromium carbide and/or sigma precipitation. Some of the more widely accepted tests have been standardized and are described in American Society for Testing and Materials (ASTM) Standard A 262-70, "Recommended Practices for Detecting Susceptibility to Intergranular Attack in Stainless Steels."[a] These tests have been proven useful by comparisons of laboratory and inservice test results. ASTM Standard A 262-70 describes recommended practices for five tests:

a. *Practice A* — Oxalic acid etch test for classification of etch structures of stainless steels,

b. *Practice B* — Ferric sulfate-sulfuric acid test for detecting susceptibility to intergranular attack in stainless steels,

c. *Practice C* — Nitric acid test for detecting susceptibility to intergranular attack in stainless steels,

d. *Practice D* — Nitric-hydrofluoric acid test for detecting susceptibility to intergranular attack in molybdenum-bearing austenitic stainless steels,

e. *Practice E* — Copper-copper sulfate-sulfuric acid test for detecting susceptibility to intergranular attack in stainless steels.

If these tests are used as recommended in ASTM A 262-70 and the limitations of the various practices for specific alloys are observed, the results of these tests can allow control of the use of austenitic stainless steels in fuel reprocessing plants.

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[a] Copies of this Standard may be obtained from ASTM, 1916 Race Street, Philadelphia, PA 19103.

Control can be accomplished by testing as-received material to ensure that it has been properly processed and heat treated and that it is of the proper composition. For example, results of the corrosion screening test can indicate whether low carbon grades are low enough in carbon content and whether stabilized grades are properly processed and contain enough stabilizing elements. Also, these tests should be used to qualify the welding process and procedure including, when required, any postweld solution or stabilization heat treatment. This is to ensure that stainless steel structures, systems, and components are not placed in service in a sensitized condition. Test weldments from which corrosion testing coupons are obtained should be made from each heat of stainless steel and for each welding and heat treatment process or procedure. Base metal of the same thickness and the same filler metal as the production weld should be used in making the test weldment. The same welding process and variables, such as heat input, travel speed, number of weld passes, and preheat and interpass temperature, should be used for both the test weldment and the production weld. The test weldment (prior to obtaining corrosion coupons) should be heat treated or otherwise exposed to time-temperature cycles to simulate any thermal exposure or treatment imposed on the production weldment and component after fabrication. The test weldment must be large enough for the corrosion testing coupons taken from it to simulate the microstructure and condition of (1) the bulk production weld and its associated heat affected zone and (2) the finished base material.

The boiling 65 wt% nitric acid test (Practice C, ASTM A 262-70) is sometimes considered too severe for stainless steels that are used in less corrosive media. The test detects intergranular corrosion due to chromium depletion and sigma phase. It can also show increased corrosion rates due to end-grain corrosion and attack of chromium carbides and of titanium carbides in stabilized stainless steels. Also a product of stainless steel corrosion itself, the highly oxidizing $Cr^{6+}$ ion increases the corrosiveness of the nitric acid solution. However, all of the above considerations are important for stainless steel service in nitric acid. Therefore, the boiling nitric acid test (Practice C, ASTM A 262-70) should be used for the intergranular corrosion testing of austenitic stainless steel exposed to nitric acid solutions in fuel reprocessing plants.

For details on how to perform the boiling nitric acid test, refer to the ASTM Standard A 262-70 practice. A brief description of the test is given here to facilitate following discussions. A cleaned and weighed stainless steel specimen is exposed to the boiling 65 wt% nitric acid solution for five consecutive 48-hour testing periods. Between each 48-hour test period the specimen is cleaned, reweighed, and then tested in fresh solution for each period. The test results consist of (1) weight loss data for each 48-hour period and (2) the average weight loss for the full 240-hour test.

The ASTM standard practice does not give criteria to enable determination of whether the test results indicate intergranular corrosion susceptibility of the stainless steel tested. When the data show increasing weight losses for successive 48-hour test periods, this should indicate susceptibility of the stainless steel tested to intergranular corrosion. Corrosion rates calculated from the weight loss data, exceeding 0.018 inches per year, should also indicate intergranular corrosion susceptibility. Metallographic examination of the corrosion tested specimen may also be performed to determine if intergranular corrosion took place during the test.

The other practices of ASTM A 262-70 may also be used, as applicable, for intergranular corrosion testing of stainless steels for service in solutions less corrosive than nitric acid. Of these other practices, Practices B and E are preferred, in that order. Practice A, the oxalic acid screening test can be used, as applicable, except for stainless steel service in nitric acid solutions when the boiling 65 wt% nitric acid test, Practice C of ASTM A 262-70, is the recommended test.

## 3. Stress Corrosion

The austenitic stainless steels in the annealed condition are susceptible to transgranular[a] stress corrosion cracking. The environments producing stress corrosion cracking normally have no detrimental effect on the general corrosion[b] resistance of the stainless steel. These environments include caustic solutions and chloride solutions, even at chloride concentrations of a few parts per million in the presence of an oxidizer or oxygen of a few parts per million concentration. The physical state of the exposure is important. For example, under alternate wetting and drying exposure when traces of chlorides have a chance to concentrate on the stainless steel surface, accelerated stress corrosion occurs. Stress corrosion cracking requires simultaneous action of both a tensile stress and some particular corrosive agent (although this agent would not normally result in general corrosion of the stainless steel). The stress may be applied or it may be a residual stress left in the structure from a fabrication operation.

To avoid stress corrosion cracking in those systems where it occurs, the stress can be eliminated or reduced to a level below a certain critical stress that is dependent upon the exposure temperature, the solution concentration, and the composition and microstructure of the stainless steel. Alternatively, the responsible chemical can be inhibited, eliminated, or reduced to a level below

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[a]Transgranular means through the grains; intergranular means along or at the grain boundaries.

[b]As used in this guide, general corrosion is the deterioration of metal by chemical or electrochemical reaction with its environment which proceeds uniformly over the exposed surface (e.g., the rusting of steel in the atmosphere).

which it has no effect. If either control of the stress or control of the chemical, or both, can be accomplished, then stress corrosion cracking can be avoided. In those cases where neither control of the stress nor control of the chemical can be accomplished, a different material must be sought that is not susceptible to stress corrosion (or other types of corrosion) in the particular environment.

If the stainless steel is sensitized, intergranular stress corrosion cracking sometimes occurs under the conditions that normally lead to transgranular stress corrosion cracking in the annealed stainless steel.

Intergranular stress corrosion cracking has occurred both in solution-annealed and in sensitized stainless steels and in environments that may not necessarily induce transgranular stress corrosion cracking. In these instances the role of the stress may be only to open the crack and allow solution to reach fresh metal while the failure is induced by intergranular corrosion. Examples of interest are intergranular stress corrosion cracking of austenitic stainless steel in high temperature-high purity water, cracking caused by fluoride-containing weld fumes, and cracking from fluoride residual contamination remaining on surfaces that have been pickled with nitric acid-hydrofluoric acid solutions. In situations similar to these, where stress-assisted intergranular corrosion occurs, those treatments that improve intergranular corrosion resistance can also improve the intergranular stress corrosion resistance. However those treatments do not necessarily eliminate intergranular stress corrosion cracking.

Process controls should be exercised during all stages of component manufacturing and construction to minimize exposure of stainless steel to contaminants that could lead to stress corrosion cracking. Since some degree of material contamination is inevitable during these operations, halogens and halogen-bearing compounds (e.g., die lubricants, marking compounds, and masking tape) should be avoided to the degree practical.

All cleaning solutions, processing compounds, degreasing agents, liquid penetrant examination materials, and other foreign materials should be completely removed at any stage of processing prior to any elevated temperature treatment and prior to any pressure testing. Reasonable care should be taken to keep (1) fabrication and construction areas clean, (2) components protected and dry during storage and shipment, and (3) all crevices and small openings protected against contamination. Pickling of stainless steel should be avoided. Special precautions should be taken to avoid surface contamination with fluorides from welding rod coatings and fluxes. The quality of water used for final cleaning or flushing of finished surfaces should meet, as a minimum, the requirements of ANSI Standard N45.2.1-1973,

"Cleaning of Fluid Systems and Associated Components During Construction Phase of Nuclear Power Plants."[a] Liquid penetrant examination materials should meet the requirement of T-630 of Article 6 of Section V of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code.[b]

## C. REGULATORY POSITION

Austenitic stainless steels of the AISI Type 3XX series used for safety-related process equipment with its associated vessels and piping, radioactive waste handling and storage systems, metal liners of process cells and waste storage tank vaults, and other safety-related structures, systems, and components of fuel reprocessing plants should meet the following conditions:

1. Stainless steels should not be placed in service in a sensitized condition that is susceptible to intergranular corrosion.

2. Nonsusceptibility to intergranular corrosion should be verified using ASTM A 262-70, "Recommended Practices for Detecting Susceptibility to Intergranular Attack in Stainless Steel," Practice C, the boiling 65 wt% nitric acid test, for stainless steel service in solutions of nitric acid. For other service, Practice C or the other practices of ASTM A 262-70 may be used as applicable and as discussed in Section B of this guide.

3. Nonsusceptibility to intergranular corrosion should be shown for stainless steel process equipment, structures, and components in their final fabricated condition prior to service in corrosive environments. This should be shown by corrosion testing of base material and by qualification corrosion testing of weldments and their associated heat-affected zones.

4. Quality control testing for intergranular corrosion should be performed' on the base materials of the austenitic stainless steel product forms produced from each different heat and final heat treatment practice. Qualification intergranular corrosion testing for fabricated components should be performed (a) for each change in stainless steel type as represented by a different AISI 3XX designation, using either base material having the maximum carbon content anticipated, or base material from each heat; (b) for each change in nominal thickness of the sections welded; (c) for each change in welding method or procedure including changes in joint design, filler metal type and size,

number of weld passes and postweld heat treatment practices; and (d) for any other important change in the fabrication of components. Test sections from which corrosion coupons are tested should be welded and treated to represent the production weldments and finished products. All important variables should be reproduced for fabrication and treatment of qualification test sections as discussed in Section B of this guide.

5. Stainless steel base materials used for component and system manufacture should be in a solution heat treated condition or in a stabilized condition for the stabilized grades. Nonsusceptibility to intergranular corrosion should be shown by corrosion testing of starting material, unless the entire component or system is to be solution heat treated or given a stabilization heat treatment after fabrication. In this case, both the weld with its heat affected zone and the base material should be qualification corrosion tested in their final fabricated and heat treated condition.

6. If fabricated components cannot be solution heat treated, the normal carbon grades stainless steels should not be used. Low carbon or stabilized stainless steels should be used if the fabrication process can be qualified by corrosion testing to show nonsusceptibility to intergranular corrosion.

7. Heat treatments in the sensitization temperature range (800 to 1600°F) after component fabrication and prior to corrosive environment exposure or inservice exposures to these temperatures should not be allowed unless it can be shown by appropriate tests or extensive inservice experience that the stainless steel will not be made susceptible to intergranular corrosion by these actions. Components on which inservice experience is based should be destructively tested (e.g., metallography and mechanical testing) to show positively that intergranular corrosion did not result in the component base materials, weldments, and heat-affected zones during service.

8. Stainless steels should be suitably cleaned and suitably protected against contaminants capable of causing stress corrosion cracking during fabrication, shipment, storage, construction, testing, and operation of process equipment, structures, and components. The quality of water used for final cleaning or flushing of finished surfaces should meet, as a minimum, the requirements of ANSI Standard N45.2.1-1973, "Cleaning of Fluid Systems and Associated Components During Construction Phase of Nuclear Power Plants."[a] Liquid penetrant examination materials should meet the requirements of T-630 of Article 6 of Section V of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code.[b]

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[a]Copies may be obtained from the American National Standards Institute, Inc., 1430 Broadway, New York, N.Y. 10018.

[b]Copies of the 1974 Edition may be obtained from American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, N.Y. 10017.

## D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the staff's plans for using this regulatory guide.

Except in those cases in which the applicant proposes an alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used in the evaluation of submittals for operating license or construction permit applications docketed after May 31, 1976.

If an applicant wishes to use this regulatory guide in developing submittals for applications docketed on or before May 31, 1976, the pertinent portions of the application will be evaluated on the basis of this guide.