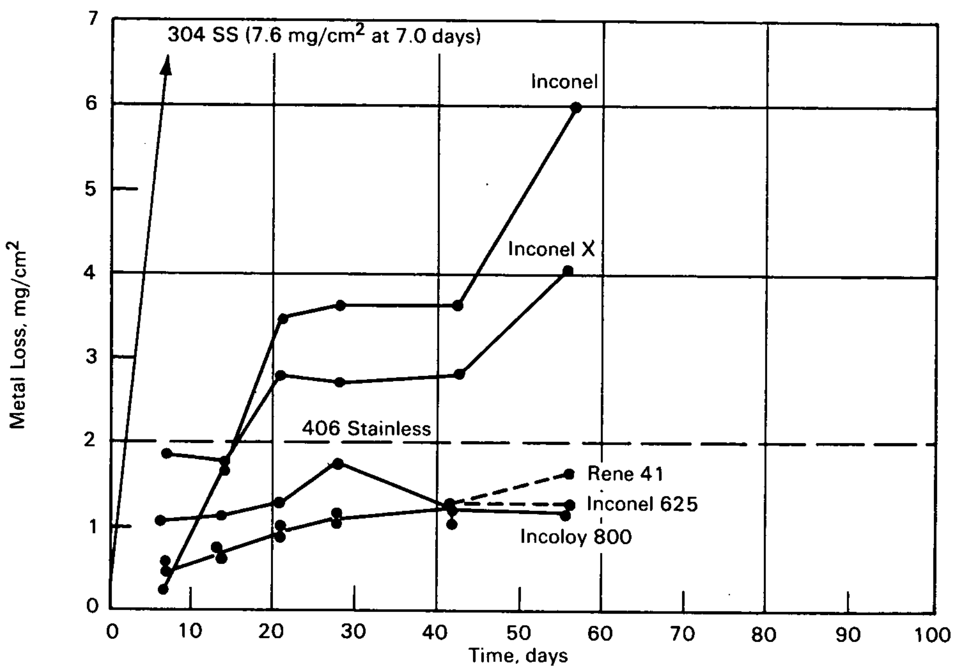
AEC-NASA TECH BRIEF

Study Made of Corrosion Resistance of Stainless Steel and Nickel Alloys in Nuclear Reactor Superheaters



Corrosion of Nickel alloys in flowing steam; 650°C, 42 kg/cm^2, 61 meters/sec velocity, 30 ppm oxygen.

The problem:

To determine the corrosion rate of stainless steel and nickel alloys used in nuclear reactor superheaters.

Incorporating a nuclear steam superheater before the turbogenerator in a boiling water nuclear electric power plant usually improves the cycle efficiency of the plant. Therefore, the thin, protective fuel element cladding that is necessary in nuclear reactors to reduce neutron losses must be resistant to superheated steam conditions. Typical conditions are: oxygen concentration of 20 to 30 ppm, stoichiometric amounts of hydrogen, temperature of 650°C, and pressure of about 42 kg/cm^2.

Much of the data reported in the literature on corrosion resistance of cladding, however, has been taken under normal operating conditions of nonnuclear boilers. Also, much of the data are typically obtained from weight gains and/or scale thickness; these measurements do not permit precise calculation of corrosion rates.

The solution:

Experiments performed under conditions found in nuclear reactor superheaters. These conditions include: superheated steam temperature as high as 650°C, pressure as high as 42 kg/cm^2, velocity as high as 91 m/sec, oxygen content as high as 30 ppm, and

(continued overleaf)

hydrogen content as high as 3.8 ppm. Samples are subjected to surface treatments (electropolishing, acid etching, grinding, grit blasting, or machining) before corrosion tests.

The metal alloys investigated are shown in the table.

The amount of corrosion is determined by weight loss of specimens after the metals are defilmed. The following are the results:

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Alloy			Major Constituent,[a] wt.%			
Nickel		Stainless Steel	Cr	Fe	Ni	Co
Incoloy	800		20.0	45.2	33.0	
Inconel	600		16.3		75.9	
	625		22.0		62.3	
	X750		15.13		72.5	
René	41		19.05		55.02	10.95
		304	18.2	70.41	8.76	
		316	17.5	64.15	13.45	
		321	18.0	69.23	9.64	
		347	18.6	66.96	10.8	
		403	12.3	86.83		
		405	12.5	87.22		
		406	13.1	81.04		
		410	12.5	86.67		
		410(E2)	11.6	87.37		
		430	16.3	82.69		
		446	24.7	74.21		

[a] Present in quantities greater than 8 wt.%

1. Alloys with machined surfaces:
   a. These show marked improvement in corrosion resistance to deoxygenated steam over samples whose surfaces are wet ground, electropolished, or acid pickled.
   b. This improvement is attributed to the fact that a machined surface is cold worked rather than annealed.
2. Electropolished type 304 stainless steel:
   a. Corrosion rate in oxygenated steam rises rapidly as temperature increases from 540°C to 650°C.
   b. Corrosion rate decreases with time in static oxygenated steam at 600°C or at 650°C.
   c. Corrosion rate is about 1.5 times higher in flowing oxygenated steam at 650°C than in static steam. Varying the velocity of the steam and the oxygen and hydrogen content of the steam has no effect on the corrosion rate in flowing steam at 650°C. Flaking and loss of outer corrosion coating is especially severe in flowing steam.
   d. Type 304 stainless steel is unsuitable at 650°C and higher, for use as a thin wall nuclear fuel element cladding.
3. Electropolished type 406 stainless steel:
   a. Corrosion rate is too small to be precisely measured in all the tests, static and dynamic.
   b. The outer corrosion coating does not flake.
   c. No embrittlement due to high temperature occurs.
   d. An aluminum content of 4.48 wt.% in this alloy is probably responsible for the good results, since the other stainless steel alloys with the same chromium content but without aluminum undergo considerably more corrosion.
   e. Type 406 stainless steel is superior to most of the high nickel alloys tested, in terms of general corrosion resistance, lower cost and neutron capture cross section. It is inferior in high temperature strength and in some fabrication aspects. It appears to be a promising material for high temperature steam applications.
4. Other electropolished alloys:
   a. Corrosion of the 400-series stainless steel alloys decreases with increasing chromium content.
   b. The nickel-based alloys, especially Inconel 625, are more corrosion resistant than 304 stainless steel in short static and dynamic tests at 650°C. Inconel 600 and Inconel X750 are the least corrosion resistant of the high nickel alloys in flowing steam.
   c. René 41 has very satisfactory corrosion resistance.

Comparative results obtained with types 304 and 406 stainless steels and several nickel alloys in flowing oxygenated steam at 650°C are shown.

Notes:

1. Electropolishing was chosen as the primary surface treatment because (as deduced from metallographic examinations of corroded alloys) it most nearly represents the intrinsic corrosion resistance of alloys tested. However, for many practical applications, it would be advisable to reduce corrosion losses by using a final treatment that results in a cold worked surface.
2. Additional details are contained in:
   (a) *Corrosion*, vol. 22, no. 5, p. 147–155 (1966) May.
   (b) *Jour. of the Electrochemical Society*, Vol. III, no. 10, October 1964, p. 1116–1121.
3. Inquiries concerning this innovation may be directed to:

   Office of Industrial Cooperation
   Argonne National Laboratory
   9700 South Cass Avenue
   Argonne, Illinois 60439
   Reference: B67-10051

Source: W. E. Ruther, S. Greenberg, R. R. Schlueter, R. H. Lee and R. K. Hart, Metallurgy Division (ARG-230)

Patent status:

Inquiries about obtaining rights for commercial use of this innovation may be made to:

Mr. George H. Lee, Chief
Chicago Patent Group
U.S. Atomic Energy Commission
Chicago Operations Office
9800 South Cass Avenue
Argonne, Illinois 60439