7-4 Elucidation of Corrosion Mechanism of Stainless Steel for Spent Fuel Reprocessing Plants

—Study of Corrosion Mechanism of Nitric Acid Solution Containing Neptunium—

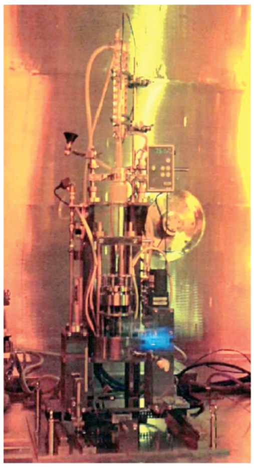

Fig.7-9 Appearance of corrosion testing apparatus
A corrosion testing apparatus was set in a hot cell - a room with thick concrete walls. A manipulator was also installed, which carries out corrosion tests under strong radiation.

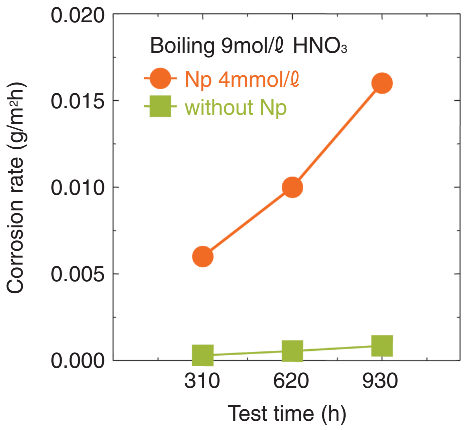

Fig.7-10 Corrosion rate of stainless steel in boiling HNO_3 solution at 70℃
Stainless steel was immersed in boiling HNO_3 solution at 70℃. It corroded greatly when there was a small amount of Np. The corrosion rate of stainless steel increased with time.

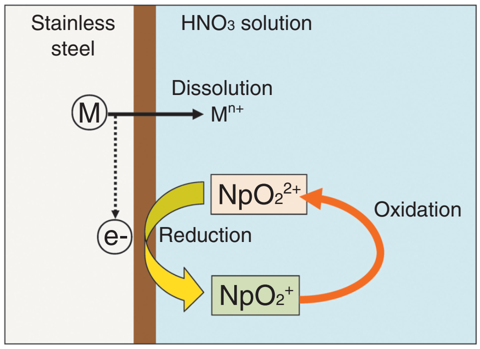

Fig.7-11 Schematic illustration of corrosion mechanism in HNO_3 solution with neptunium
On stainless steel, metal (M) is dissolved into M^{n+} by Np^{6+} (NpO_2^{2+}) which is reduced to Np^{5+} (NpO_2^{+}). In boiling HNO_3 solution, Np^{5+} is re-oxidized to Np^{6+}. This cycle is repeated during corrosion. This cycle promotes the corrosion of stainless steel.

Usable nuclear fuels (uranium and plutonium) are left in spent nuclear fuels from a nuclear power plant. A plant which chemically collects usable nuclear fuel from spent fuel, separates fission products, and safely treats radioactive wastes is called a spent fuel reprocessing plant. In Japan, there are two such plants, in Tokai-mura and Rokkasho-mura. Uranium is a limited fuel like oil. The recycling of nuclear fuel is very important for sustainable production and utilization of nuclear energy.

A very corrosive boiling nitric acid solution is used to dissolve nuclear fuel in a reprocessing plant. The solution contains plutonium and ruthenium which are dissolved from spent nuclear fuel. It has been known that these elements strongly corrode commercial grade stainless steel, and special corrosion-resistant stainless steels are used in reprocessing plants. Recently, it has been reported that a small amount of neptunium (Np) also promotes the corrosion of the stainless steel. The mechanism of corrosion acceleration by Np was investigated. The tests were conducted in the Waste Safety Testing Facility (WASTEF) that could handle radioactive materials such as spent nuclear fuel. Fig.7-9 shows the appearance of the corrosion testing apparatus set in a hot cell in WASTEF.

Fig.7-10 shows the corrosion rate of stainless steel which was immersed in boiling nitric acid (HNO_3) solution at 70℃ under reduced pressure. The solution contained a small amount of Np (ca.4mmol/ℓ), and the concentration of HNO_3 was 9mol/ℓ. The corrosion rate of stainless steel in the HNO_3 solution with Np was about 10 times higher than that without Np. This corrosion acceleration by Np was investigated using electrochemical and spectrochemical analyses that could examine the influence of ionic species in solutions. As shown in Fig.7-11, Np^{6+} (NpO_2^{2+}) caused the dissolution of a metal in the stainless steel and itself was thereby reduced to Np^{5+} (NpO_2^{+}). The Np^{5+} was re-oxidized to Np^{6+} in the HNO_3 solution. It was found that this cycle led to the increase in the corrosion rate of stainless steel in HNO_3 solutions with Np. We have been developing the new stainless steels, which are very corrosion-resistant to boiling HNO_3 solutions with corrosive ionic species such as Np.

The above knowledge is being utilized as basic data for the safe operation of Rokkasho reprocessing plant.

Reference
Motooka, T. et al., Corrosion Behavior of Stainless Steel in Nitric Acid Solutions Including Neptunium, Zairyo-to-Kankyo, vol.57, no.12, 2008, p.536-541 (in Japanese).