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Measurement of the Residual Sodium and Reaction Compounds on a Cleaned Cold Trap

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1. Introduction

The purpose of a cleaning process is to remove the residual sodium adhering to the component walls once it has been properly drained. It is necessary to clean and decontaminate a component, especially the large components of the primary coolant system; such as the intermediate heat exchangers and the primary pump. Improper and inadequate cleaning has in a number of cases resulted in problems in the storage, handling, and reuse of components [1,2]. Inadequate and incomplete removal of sodium results in residues which may contain metallic sodium and alkaline compounds such as sodium hydroxide, sodium oxide, sodium carbonate, and various types of alcoholates. Reinsertion of components containing these compounds into a high-temperature sodium system can result in either a intergranular penetration characteristic of a high-oxygen sodium or an accelerated corrosion due to oxygen. Cleaning methods are needed that will avoid a deleterious local overheating, material surface degradation or deposits, a chemical, physical, or mechanical damage, and external effects.

It is important to determine the levels of residual sodium that can be accepted so that those deleterious effects will not negate the reuse of the component.

The purpose of this paper is to measure the amount of the sodium and the reaction compounds remaining on a component after a cleaning and prepare acceptable criteria for the reuse of components which have been subjected to a sodium cleaning..

2. Cleaning Techniques

With the exception of liquid ammonia and oil, all reagents used for sodium react chemically with the sodium. The reagents principally employed are water, steam, liquid ammonia, methyl alcohol, ethyl alcohol, and oil. Limited experience has been obtained by using the higher alcohols and concentrated sodium hydroxide solutions. In principle, the reactions for water, steam, and alcohol can be represented by

$$ROH + Na \rightarrow NaOR + 1/2\ H_2$$

where ROH is a reagent.

$$Na + NH_3 \rightarrow NaNH_2 + 1/2\ H_2$$

First, the reaction is exothermic. If the rate of the reaction exceeds the system heat losses, large temperature rises can be a result. Second, the reaction liberates hydrogen gas. Because hydrogen is flammable, it is presumed that the system has been designed to safely prevent a hydrogen–oxygen explosion. The third consideration stems from the possible insolubility of the sodium reactants in the solvent. If the reaction product tends to be insoluble in the reagent, a buffer layer is set up, thus preventing a complete reaction.

3. Experimental

3.1 Cleaning Apparatus

3.1.1 Cleaning System

Superheated steam injection in a nitrogen gas atmosphere was adopted for the cold trap cleanup. Explosions were minimized by replacing any air in the cold trap with nitrogen gas. Figure 1 shows the P & I drawing of the sodium cleaning system. The sodium cleaning system consists of a steam supply system, nitrogen gas supply system, reactor (cold trap), gas release system, and a data acquisition system etc. Hydrogen which is evolved in the cold trap was released to the air with a monitoring and controlling of the hydrogen concentrating in nitrogen gas. Most of the connecting pipe and tube is ½ inch in diameter. Gas flow rate of the steam and nitrogen, the pressure and temperature, the hydrogen concentration in the nitrogen gas, moisture content in the nitrogen gas and the conductivity of the reactant were measured and controlled.

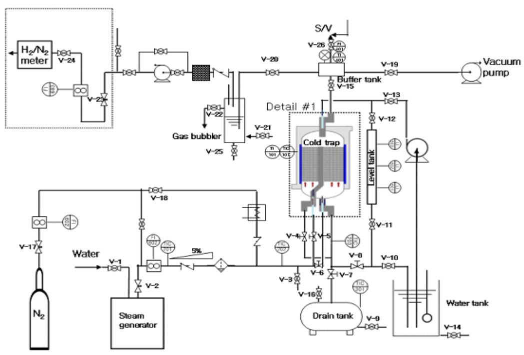

Figure 1. P & I drawing of sodium cleaning system.

3.2 Cleaning procedure

The first step of the sodium cleaning was to vacuum the cold trap and to fill the cold trap with nitrogen gas. The sodium in the cold trap was drained under the protection of nitrogen by a heating. The mixture of the steam-nitrogen under the protection of nitrogen was filled and the reaction rate was controlled by regulating the flow rate and the content of the vapor in the mixture. After the reaction was finished, water was filled from the effluent outlet. Nitrogen gas then started flowing to the cold trap with a 10 ~ 50 g/min, and it was kept almost constant. Initial steam flow rate was about 1.7 ~ 13g/min not so as to exceed the hydrogen concentration of 1% in the nitrogen gas.

4. Results

Figure 2 shows the accumulated sodium removal weight that was calculated from the hydrogen concentration in nitrogen gas. The calculated total sodium removal weight was just about 8.4 kg. And steam of about 11.6kg was used for the removal of the sodium.

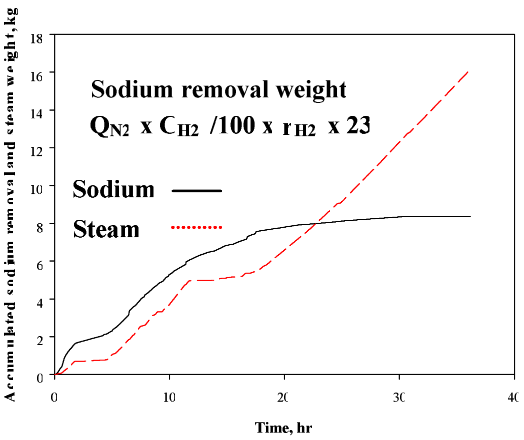

Figure 2. Sodium reaction rate.

Figure 3 shows the SEM photograph of the surface of the cold trap after a cleaning. EDX (Energy Dispersive X-ray Spectroscopy). As shown in the figure, an amount of oxygen was detected at the points of S2, S3, S4 and S5 on the SEM photograph. These results revealed that the a corrosion by an oxidation was progressed on the surface of the cleaned cold trap. It appeared that the reaction heat by sodium-water reaction and the reactant products had an effect on the corrosion by oxidation. It was estimated that the Na of less than 1 % detected at the points of S2, S3, and S4 was sodium oxide. Figure 4 shows the results of the elementary analysis by EDX. As shown in this figure, the presence of residual sodium and oxygen on the cleaning surface of cold trap was conformed

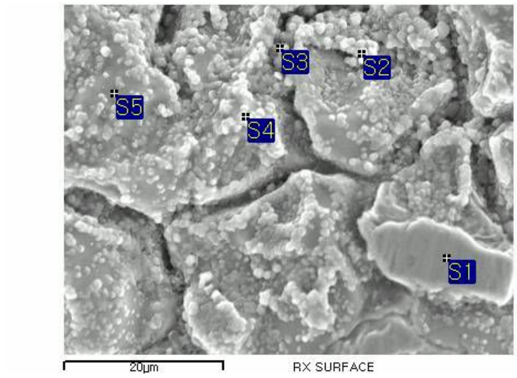

Figure 3. SEM photograph on the surface of the cold trap

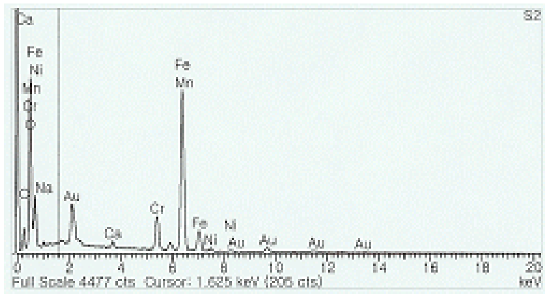

Figure 4. Result of elementary analysis by EDX

5. Conclusions

The study for removing the sodium from the components of a sodium purification loop enabled KAERI to acquire valuable experiences in cleaning components contaminated by sodium. The experiences acquired with this study will be applied to the project to clean contaminated components.

ACNOWLEDGEMENT

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