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Sodium removal by CO_2 bubbling and N_2-Steam Cleaning Method

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1. Introduction

The use of sodium as a working fluid necessitates the development of special post operation procedures for a cleaning of equipment removed for a disposal, repair, or other purposes. Consequently various methods and procedures have been developed for cleaning contaminated equipment and for a disposal of waste sodium and sodium contaminated waste. Improper and inadequate cleaning has in a number of cases resulted in problems in the storage, handling, and reuse of components [1,2].

Cleaning and disposal techniques generally involve a reaction of sodium with air, water, or some other chemical compound. Cleaning methods must be compatible with the equipment to be reused to avoid heat or corrosion damage etc. The methods used for cleaning sodium-contaminated equipment depend on the condition and types of equipment to be cleaned and whether the equipment is to be reused.

This paper describes basic experimental results for two cleaning methods. One is a N_2-steam cleaning method and the other is a CO_2 bubbling method. Both methods are investigated for a crevice cleaning.

2. Cleaning Techniques

2.1 N_2 -steam method

N_2-steam cleaning method has an advantage of increasing the sodium and water reaction rate on a sodium surface, as well as a diffusion of any hydrogen produced with it. This method is considered as a water rinse, so it can be easily adopted for the last process, after the water vapor method in an actual component cleaning process.
The following chemical reaction was taken into consideration.

$$Na + H_2O(g) \rightarrow NaOH(s) + 1/2\ H_2$$

where ROH is a reagent.

The rate of water vapor in the processing gas is limited, so that, even if all the water vapors reacted, the hydrogen rate in the exhaust gas is under the flammable limit of hydrogen in air.

3.2 CO_2 bubbling method

The principle consists of making a cold steam by heating a demineralised water reserve at the bottom of the cleaning reactor to 60℃. The cleaning reactor's carbon dioxide content is maintained, allowing for a constant transformation of the aqueous soda(NaOH) into sodium bicarbonate($NaHCO_3$), a white product, solid at room temperature, soluble in water and having no corrosive action. The following chemical reaction was taken into consideration.

$$Na + H_2O(g) \rightarrow NaOH + ½H_2$$

$$2NaOH(s) + CO_2(g) \rightarrow Na_2CO_3(s)$$

$$Na_2CO_3(s) + CO_2 + H_2O \rightarrow 2NaHCO_3$$

3. Experimental

3.1 Cleaning Apparatus

3.1.1 N_2 -steam method

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. This 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 is released to the air with a monitoring and control of the hydrogen concentration in nitrogen gas.

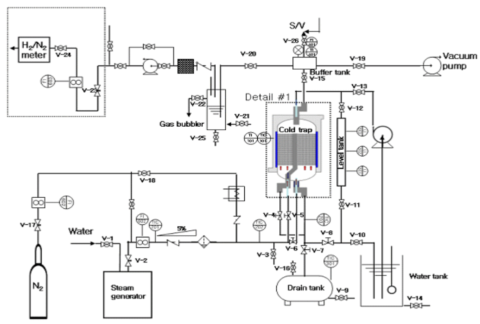

Figure 1. P & I drawing of N_2- steam cleaning system.

3.1.2 CO_2 bubbling method

Figure 2 shows the P & I drawing of the CO_2 bubbling system. This system consists of a CO_2 bubbler, gas supply system, reactor, gas release system, and a data acquisition system etc.

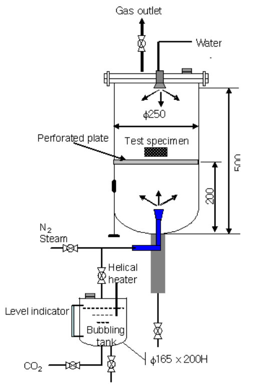

Figure 2. P & I drawing of CO_2 bubbling system.

3.2 Cleaning procedure

3.2.1 N_2 -steam method

A mixture of 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. Nitrogen gas then started flowing to the test reactor with a 10 ~ 50 g/min, and it was kept almost constant. Initial steam flow rate was about 1.7 ~ 13g/min so as not to exceed a hydrogen concentration of 1% in the nitrogen gas.

3.2.2 CO_2 bubbling method

The carbon dioxide is injected at the bubbler's low point in the water reserve, which causes a bubbling of the gas. By a bubbling the gas becomes humid and this transported humidity well reacts well with the sodium adhering to the component walls. The control of the reaction by a CO_2 bubbling is carried out by regulating the water temperature and the CO_2 flow rate.

4. Results

Figure 3 shows the crevice specimens with 0.3, 0.5, 0.7mm gaps after a cleaning by the CO_2 bubbling method. From these results, in the CO_2 bubbling method, the sodium was removed more easily from a narrow gap crevice.

Table 1 shows the results of the elementary analysis EDX (Energy Dispersive X-ray Spectroscopy). As shown in the results from the N_2-steam cleaning test on the table, an amount of oxygen was detected in the cleaning surface.

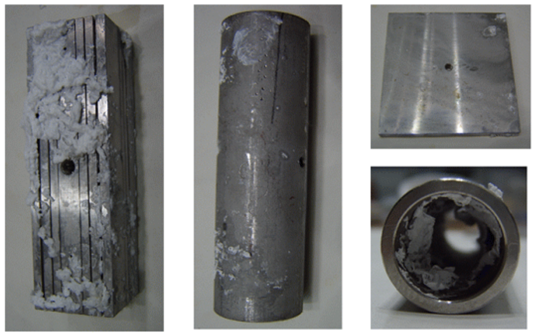

Figure 3. Specimen after the cleaning by CO_2 bubbling method

These results revealed that an corrosion by an oxidation was progressed on the surface of the cleaned specimen. It appeared that the reaction heat by the sodium-water reaction and the reactant products had an effect on corrosion by an oxidation. As shown in the results from the CO_2 bubbling test on the table, the presence of residual sodium and oxygen on the cleaning surface of the cold trap was not conformed

Point / Spectrum	N_2 - steam method						CO_2 bubbling method					
	O	Cr	Mn	Fe	Ni	Total	O	Cr	Mn	Fe	Ni	Total
P1	31.3	12.2	1	49.6	5.4	100		20.2	1.5	71.1	7.2	100
P2	42.5	10.6	1.4	41.3	4.2	100						
P3		21.4	1.4	71.5	5.7	100						
P4	57.5	8.4	0.2	31.4	2.5	100						
P5		19.8	1.4	70.9	7.9	100		20.3	1.6	70.4	7.7	100
P6	66.5	5.6	0.1	26	1.8	100						
P7	6.1	16.1	1.2	68.3	8.3	100		20.2	1.1	71.2	7.5	100

Table 1. Results 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 for 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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