STATE-OF-THE-ART SURVEYS ON SODIUM-WATER
REACTION PRODUCTS CLEANUP METHODS AND EQUIPMENT

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SODIUM WATER REACTION PRODUCTS
CLEANUP METHODS AND EQUIPMENT

Abstract

This report describes the basic cleaning methods and equipment which have been used to clean and requalify specimens and components that have been exposed to sodium. Data obtained from laboratory cleaning of test specimens which were earlier exposed to sodium, have been included for various sodium removal methods. Development programs on cleanup methods for removing sodium-water reaction products along with sodium from surfaces and the purification of Intermediate Heat Transport System (IHTS) sodium after emergency dump have been identified.

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1.0 SUMMARY AND CONCLUSIONS

The efforts described in this report are concerned with a survey of existing cleanup methods and equipment used for removing sodium and sodium-water reaction products from sodium exposed surfaces. The state-of-the-art reveals that cleaning methods and equipment used for removing sodium from sodium exposed surfaces are well known, but the relevant work on sodium-water reaction product removal has been very limited. No detailed description of cleaning methods and equipment has yet been published on sodium-water reaction product cleaning from LMFBF steam generator components, relief piping, and reaction product tanks, etc. Hence it is the intent of the writer to revise this draft of the State-of-the-Art at a later stage as more information on reaction product cleaning is made available from foreign contacts and future publications. However, the adequacy of the present cleaning methods and equipment have been examined for LMFBF steam generation components which are bulky in size and must be cleaned in place. The following conclusions are drawn:

- a) There is a need to determine the drainability of sodium with sodium-water reaction products versus time and temperature.
- b) There is a need to determine the solubility and reaction rate measurements of sodium-water reaction products with various types of alcohols and/or water vapor nitrogen mixture with controlled process conditions as established in sodium removal experiments.
- c) There is a need to demonstrate the cleanup process for removing sodium-water reaction products from steam generator components and from the IHTS loop. The cleaning process must enable requalification of steam generator components.

Since meager detailed information is available on the cleanup methods and equipment, development programs are recommended.

2.0 INTRODUCTION

The leakage of water or steam from the high pressure side of the sodium heated steam generators to the sodium side of the Intermediate Heat Transport System (IHTS) of the Liquid Metal Fast Breeder Reactor (LMFBR) results in the introduction of Sodium Water Reaction Products (SWRP) into the IHTS. The IHTS consists of Intermediate Heat Exchanger (IHX), Intermediate Sodium Pump, expansion tank and steam generators coupled with sodium water reaction pressure relief system (SWRPRS). The reaction products, if spread up to the IHX from the affected steam generator module, could affect the integrity of the steam generator, the IHX tubes and the intermediate sodium pump by means of corrosion attack, product deposition, and tube plugging. The cleaning of the IHX with cleaning fluids is an impossible task since IHX is in a reactor containment building.

The sodium dump subsystem is designed to remove sodium containing reaction products from the IHTS and this is intended to mitigate consequences to IHTS equipment. The sodium dumping operation is performed manually after a sodium-water reaction has been brought under control. A large sodium-water reaction is brought under control by activation of the Sodium-Water Reaction Pressure Relief Subsystem (SWRPRS), automatic reactor scram, IHTS sodium pump trip, water side isolation and inert gas purging, pressure relief and reaction products confinement in the reaction product separator tank (RPST), and centrifugal separator drain tank. For a water-to-sodium leak rate which is insufficient to produce a pressure in the IHTS, which would burst the rupture disc in the SWRPRS, the operating personnel would become aware of the leak by a high IHTS pressure alarm or a high hydrogen or oxygen level alarm from the Leak Detector Subsystem (LDS). Operations personnel will manually reduce reactor power and manually dump and isolate the water side of the affected module.

Nevertheless, both in small leaks and large leak situations, special cleanup problems arise for LMFBR steam generation components which are so bulky in size that they must be cleaned in place. These components have complex shapes with crevices and cracks in which sodium and reaction products may tend to hide out and which are difficult to reach with cleaning agents. Inadequate and incomplete removal of sodium and sodium-water reaction products result in residues which may contain metallic sodium and alkaline compounds such as sodium hydroxide, sodium oxide, sodium carbonate, and various types of alcoholates. Such residual material is particularly likely to be retained in configurations of complicated geometry into which cleaning agents cannot readily penetrate and in narrow crevices and small apertures. References 1, 2, 3, 4, and 5 have indicated that when the cleaning medium is aqueous, the sample is exposed to a highly alkaline environment, which can result in "caustic stress corrosion of austenitic stainless steel". The reaction of sodium and

reaction products with water and other cleansing media releases a considerable amount of heat and thus, in the absence of good heat transfer mechanisms, may result in a significant temperature rise in the part being cleansed. For some components of a delicate nature, this overheating may cause significant and irreversible damage.

This study is directed towards surveying applicable cleanup methods and equipment which are needed for cleaning the sodium and reaction products from the affected steam generator module (which is made of 2½Cr-1Mo), the RPST, the centrifugal separator, its drain tank, and the interconnecting piping following a large leak incident. Such cleaning methods would avoid deleterious local overheating, material surface degradation or deposits, chemical, physical or mechanical damage. In addition, this study also explores the feasible cleanup methods for cleaning the dirty sodium following a large leak incident and applicable requalification procedures for reuse of these components.

3.0 RELEVANT CLEANING METHODS AND EQUIPMENT

These methods and equipment are concerned with the removal of sodium from the sodium water reaction products and sodium exposed surfaces of affected steam generator module, interconnecting piping, reaction product separator tank (RPST) and centrifugal separator drain tank. This requires a demonstration of a cleaning process, establishment of a cleaning process chemistry (which includes bulk removal/removal from crevices/establishment of a thermal model/end point control), and establishment of a corrosion control criteria. Besides, the most feasible cleaning method and equipment should be simple and cause no hazard to the rest of the LMFBR power plant and the operating personnel involved.

3.1 Reaction Product Removal

The relevant work on sodium-water reaction product cleaning has been very limited. Interatom and Dounrey (U.K.) have performed large sodium-water reaction experiments in test rigs which were reused. In these experiments, the cleaning of the test rig was performed after every sodium-water reaction test. On this subject, neither Interatom nor Dounrey have published, in detail, their recommended sodium-water reaction product cleaning procedure. To obtain information on this subject, AEC-RDT issued a directive (Reference 6) to AI and GE to prepare a list of questions for discussion with Interatom and Dounrey representatives. References 7 and 8 list the records of these conference calls. For convenience, these references are also attached in the appendix. Reference 7 has indicated that the test rig was allowed to cool to about 120° - 150°C after immediately draining all the sodium and reaction products following a large Na-H₂O test. The above temperature range was maintained with electrical heaters for purposes of preventing condensation of steam. The system was then steamed with a nitrogen purge which was added to avoid the risk of oxygen break-through and possible H₂-O₂ explosion. During the steaming operation all temperatures were monitored and the steaming was suspended when they reach the 160°-170°C level. Above this level, it is mentioned that the potential for caustic corrosion damage existed. Steaming operations began slowly and never exceeded a rate of 150 kg per hour. Their earlier experience indicated that higher steam rates resulted in overheating (maximum observed temperature was 700°C) due to chemical reaction. The cleaning steam supply was 8 atm/150°C. Relief system materials were ferritic steel (0.7 - 0.8% Cr low alloy steel), except for stainless steel flanges on the cyclone tank. These flanges experienced corrosion damage and were replaced several times. The cleanup operations required approximately 24 hours not counting the cooldown time. Reference 8 has also confirmed the same above nitrogen with steam process being successfully employed in cleaning reaction products from the test vessel and relief piping (made of carbon steel) after every super NOAH test. Reference 9 has indicated that after each protector tube test rig (PTTR) test, the test bundle was removed from the containment shell in an inert atmosphere (sealed plastic bag) and visually examined. Subsequent to this examination the test bundle was thoroughly cleaned with a pressurized water spray through a hose to remove the adhering droplets of sodium and reaction products. However, the method used in Reference 9 is not applicable for LMFBR power plants. From experiences of References 7 and 8, water vapor (steam) nitrogen process for cleaning reaction products from steam generator components look promising.

3.2 Sodium Removal

Reference 9A has discussed in detail the need for developing methods to remove sodium from components which have been exposed to sodium. Given below is a summary of the methods discussed in the above reference.

One of the simplest and most attractive methods of removing sodium from surfaces is to heat the specimen in vacuum and evaporate the sodium. The disadvantage of this technique arises from the fact that, in addition to the metal, compounds of sodium which are not readily volatile will frequently be present on the sample - Na_2O , NaOH , or Na_2CO_3 , for example. To eliminate these, it is considered essential even when evaporative cleansing is employed to use an appropriate liquid solvent for these compounds subsequently.

Cleansing agents for use with sodium fall into two broad classes.

- (1) Fluids that dissolve metallic sodium, e.g., mercury, molten lead (Reference 10), or similar metals, and liquid ammonia.
- (2) Materials which react with sodium, e.g., water, alcohols, alkylhalides, or other compounds.

The solvent liquids have the advantage of not evolving hydrogen. They have the disadvantage of not readily dissolving Na_2O , Na_2CO_3 , and other contaminants commonly found with sodium. Both mercury and ammonia are used at comparatively low temperatures which is advantageous. Mercury and the molten metals like lead are opaque, which somewhat restricts observation of their action. Besides, mercury, particularly at higher temperatures tends to change stainless steel (largely by selective leaching of nickel). Low melting metals other than lead and mercury which dissolve sodium could be considered, but so far as it is known they have not been extensively tried. Liquid ammonia has the advantage of built-in indicator; a solution of sodium in this material is a deep blue (thought to be the color of the solvated electron), and if washing with ammonia is continued until the solvent no longer shows this color, this is a good preliminary indication that cleaning has been effective. With liquid ammonia, experimental conditions which discourage the amide formation reaction

must be carefully selected. This reaction is catalyzed by the presence of active metals such as iron, cobalt, and nickel. A discussion of the effect of various metals and alloys in catalytically promoting amide formation in liquid ammonia has been published by Watt, et. al., Reference 11. Some organic amines and hydrocarbons and other compounds are also known to dissolve sodium without significant reaction (the sodium-naphthalene-ether complex, for example), but these have not been extensively or successfully applied to the sodium cleaning problem. The removal of the last traces of the organic solvent without leaving carbonaceous residues has been difficult to achieve and to check.

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The principal cleaning agents which have been used belong to the category of materials which react with sodium. The alkyl halides mentioned have the marked disadvantage of introducing residual sodium halides and the possibility of stress corrosion cracking and similar effects. A number of the known reactions of sodium with other organic compounds (Reference 12) do not result in hydrogen evolution, but few have attracted much interest for sodium cleaning for a variety of reasons. Water (Reference 13) and various types of alcohol (Reference 14) have been much more extensively explored.

Water reacts rapidly with sodium to produce either hydroxide or the oxide; the compound formed depending on the temperature and other conditions. The reaction takes place with the evolution of hydrogen and a considerable quantity of heat. The process is quite rapid and the evolved heat tends to speed it up so that the reaction is autocatalytic and self accelerating, and without careful regulation and good preventative precautions, it often can get out of control. To avoid this, the alcohols which are subsequently discussed are of considerable interest. The rate of reaction of water with sodium can be reduced by diluting it with an inert solvent (dioxane, for example), but this technique has not been extensively explored. For reasons listed previously, water is often used in the form of its vapor, steam. This requires that the initial temperature of the reaction be high above the boiling point of water; and, in addition, the large heat of reaction previously mentioned tends to increase the temperature and thus, the reaction rate. For better control, steam cleaning is most often carried out in the presence of diluent gas; most frequently nitrogen. Air steam mixtures have also been used, but the presence of oxygen and the possibility of oxidation reactions with the component being cleaned as well as with sodium have tended to discourage this procedure. Rare gases are also used although their cost compared with nitrogen is a factor tending to restrict this practice. Carbon dioxide could also be used for this purpose although it is not inert to sodium and would tend to convert sodium oxide and sodium hydroxide to sodium carbonate; however, this gas does not appear to have been extensively explored as a diluent for steam. Other gases are, of course, conceivable. Steam can react at entrances to crack and unless NaOH is dissolved and washed away, the cracks will be sealed closed. For this reason, liquid water almost always is the wash medium for the final steps in the sodium cleaning process. Because of the previously mentioned surface tension difficulties with liquids, a prolonged contact time, frequent changes of wash water, and careful and judicious monitoring of the wash water for traces of sodium ions is mandatory.

The Russian literature, Reference 15, has reported that the evolution of gaseous hydrogen on reaction of alkali metals with water can be inhibited or prevented by using a dissolved oxidant, e.g., dichromate, permanganate, or hydrogen peroxide. The use of ionic species containing the heavy metals chromium and manganese for this purpose must be viewed with some suspicion, since they may leave metallic compound residues on the surfaces to be cleaned which may be as difficult to remove and as harmful in their effects as are sodium compound residues and which sometimes may be even worse because of their insolubility in water, compared with sodium compounds. Thirty percent hydrogen peroxide which the Soviet paper recommended does not yield heavy metal ions on reaction. Only preliminary tests of this material have been carried out in the United States (Reference 16), however, and these have not yet confirmed the Russian results.

The speed and vigor of the sodium-water reaction discussed previously has led to the extensive use of alcohols in the place of water. The alcohols react by a process parallel to the water reaction

Alcohols, generally speaking, react more slowly than water and evolve less heat. They are not usually as good solvents for the reaction product alcoholates, or for the oxide, hydroxide, carbonate, and other compounds which are frequently present. With alcohols as with other cleaning reagents, the process tends to be slowed down by the accumulation of reaction products, particularly if the reaction product solubility is low and if they tend to stick to the surfaces on which they are formed and constitute a barrier between the residual sodium and fresh reagent. For this reason the solvent characteristics of alcohols and similar materials for the corresponding alcoholates, as well as sodium oxide, sodium hydroxide, sodium carbonate, etc., are of some importance. Alcohols are often flammable and many which have been used have low boiling points as well. These factors, plus the hydrogen evolution problem, require that their use be carried out with great care and adequate safety precautions.

Following are some broad general relations on the use of alcohols for sodium cleaning:

- (1) All other factors being equal, low molecular weight alcohols react faster than those with larger molecules. Methanol (CH_3OH) is one of the fastest of the hydroxylic compounds.

- (2) For the same molecular weight, the speed of reaction follows the decreasing order:

where R, R', and R'' may be the same or different carbon containing groups. Thus, tertiary butyl alcohol, a common and relatively inexpensive material, reacts very slowly with sodium. Since it is miscible with water in all proportions, a technique which has been extensively used is to start a cleaning job with comparatively pure alcohol. As the reaction rate slows down (as indicated by a reduced rate of hydrogen evolution), the process is reinitiated by slow and careful addition of water to the alcohol. This is continued until the reagent is virtually all water.

- (3) Polyhydric (polyhydroxylic) compounds, such as ethylene glycol and glycerol and related commercial products like "Dowanol", have been used for sodium cleaning.

Ethylene
Glycol

Glycerol

Dioxane

These compounds tend to react more slowly and to be less volatile and readily flammable than monohydric alcohols of about the same molecular weight. Their solvent characteristics for reaction products and common sodium-contaminant products are frequently inferior to those of the compounds containing only a single hydroxyl group.

3.3 Final Rinse

In any sodium cleaning procedure, after all the metallic sodium and sodium compounds have been removed, it is equally important to thoroughly remove the last traces of the cleansing agent. Residual water or alcohol would be as bad in their effects on materials in sodium as residual Na_2O or

Na_2CO_3 . The removal of solvents and reagent materials from a surface after sodium cleaning is expedited by using rather volatile compounds for the final steps of the process. After water treatment, for example, a final rinse with alcohol (ethanol or methanol), perhaps followed by an ether flush and subsequent volatilization of the solvent by heat or vacuum (or both), is considered good practice. Instead of this two-step procedure, acetone is frequently used. This solvent has the advantage not only of being miscible with water in all proportions and thus dissolving residual water (like the alcohols), but also of being quite volatile (like ether, which has only limited solubility in water). Solvents used for these last steps should be of particularly high purity and leave no non-volatile residues behind on evaporation.

3.4 Reaction Product Cleanup by Sodium Circulation and Purification Method

Section 2.0 of this report stated that if reaction products do happen to reach the IHX during plant shutdown then the cleaning of IHX with solvent fluids as described in Section 3.2 of this report is an impossible task. It has been reported in Reference 25 that use of hot sodium circulation and purification method for cleanup in case of small leaks and the "final" cleanup of the IHTS including the IHX before the systems is ready for reuse is indeed feasible and has been well demonstrated. This is because reaction products are soluble in high temperature sodium and can be removed by cold trap operation. Because the cold trap capacity for removing sodium impurities is generally limited. This method is useful only for removing a limited amount of reaction products. Reference 25 has made no mention of rates of temperature increase during cleanup by sodium circulation.

3.5 Special Tools and Equipment to Facilitate Cleanup/Recovery

References 7, 8, 13, 14 and 25 have indicated that to facilitate cleanup and recovery after a large sodium water reaction, a stock of the following special tools and equipment at the LMFBR plant site is highly desirable. The storage of special tools and equipment will minimize plant downtime.

- (1) Twenty (20)- 55 gallon drums of ethylalcohol
- (2) One cleaning container for the steam generator (similar to shipping container).
- (3) Assorted pumps with motor
- (4) Fill and drain tank
- (5) Surge Tank
- (6) Pressure gauges
- (7) Flow meters
- (8) Needle valves

- (9) Gas cutting equipment, gas and area welding equipment
- (10) Pneumatic chisels and drills
- (11) Compressed air supply
- (12) Hydrotest equipment
- (13) Inert gas supply and the sparging system
- (14) Water and steam lances
- (15) Decanting tools and equipment
- (16) Inert plastic polyethylene bags
- (17) Thermocouples and associated temperature reading and recording instruments
- (18) PH meters
- (19) Meters for measuring electric resistivity of liquids
- (20) Trace heaters
- (21) Vacuum equipment
- (22) Helium leak tests
- (23) Gas chromatograph
- (24) Dyes for the dye penetration test
- (25) PVC gloves and aprons
- (26) Safe storage and handling of reaction products which may contain sodium.
- (27) Safety equipment such as area barriers, smoking signs, fire blankets, ansul extinguishers, fire hoses with fog nozzles, fire shields and face masks and a portable safety shower.

4.0 RELEVANT SODIUM REMOVAL EXPERIMENTS

Section 3.2 of this report has identified reaction products of various sodium removal processes. When operated in an ambient air atmosphere, water and alcohol base sodium removal processes combine with carbon dioxide in air to produce a low solubility white carbonate deposit. To avoid this deposit, which would not qualify to RDT Standard F5-1, exclusion of air from the processing is required.

Table 1, taken from Reference 17, shows the merits of various sodium removal processes such as atomized water in nitrogen gas, water vapor in nitrogen gas, alcohol process and evaporation in vacuum process. Reference 17 has concluded the following on process selection for sodium removal.

- (1) No single process is free of disadvantages or risk to component and facility
- (2) The water vapor nitrogen process is the most advanced technology that demonstrates methods of process control. It is supported by experimental data and plant experience on large components.
- (3) Atomized water, although promising for possible future operation, is yet to be demonstrated under controlled conditions.

Given below is a description of some of the relevant sodium removal experiments.

4.1 Removal of Sodium by Atomized Water Process

References 17, 18 and 19 have reported some laboratory experiments on sodium removal with this process. This process uses high pressure nitrogen gas to atomize water as a spray continuously circulated to increase its efficiency and rinse off caustic. The process has been reported to have been applied to a full scale loop model containing 120 kilograms of sodium monitored by 200 thermocouples, flow rate of 4.5 liters per hour of water and 1750 liters per hour of inert gas at 25 psia circulating at 3000 m³/hr, maintaining a temperature of 30°C with 18°C ambient. Reference 18 has indicated that Hanford Engineering Development Laboratory (HEDL) in the United States has performed five direct impingement tests on vertical panels of 304 stainless steel enclosed in a plastic container. Up to 10 grams of bulk sodium was placed in a catch basin below the wetted panel, and atomized spray was then impinged on the panel. In all cases, the ¼" thick sodium wetted panel showed a temperature increase of 30°F. The cup containing the bulk sodium had temperature spikes exceeding 500°F. The results of this direct impingement tests are shown in Table 2.

Further tests were conducted at HEDL in a new glass apparatus which was constructed per Figure 1 to locate the atomizing nozzle remote from direct impingement on the work. This apparatus also permitted more complete evacuation of oxygen. The first run (shown in Figure 2) condensed about 90% of the water prior to entering the reaction chamber; produced a very slow reaction on the 5 ml of sodium in the beaker and crevice sleeve specimen without any thermal spikes. The second and third runs (shown in Figure 3) located the spray nozzle

TABLE 1

SODIUM REMOVAL - PROCESS SELECTION

<u>Safety</u>	<u>Atomized Water</u>	<u>Water Vapor</u>	<u>Alcohol</u>	<u>Evaporation</u>
Ignition	4 v/o H ₂	4 v/o H ₂	4 v/o H ₂ Solvent	Loss of Vacuum
Sodium Reaction	Ignition	Controlled	Slow	No Reaction
<u>Structural</u>				
Caustic cracking on stainless steel	>250°F Uncertain	<250°F	<250°F	>800°F Uncertain
Sodium Removal	Require Drain	Require Drain	Require Drain	Drain Not Required
Processing Time	TBD	50 HR.	250 HR.	500 HR.
Microstructure	--	--	Potential Carbon Residue	Sodium Penetrates Grain Boundaries
<u>Economics</u>	--	--	Reagents	Capital Investment Pumps

TABLE 2

SODIUM REMOVAL - ATOMIZED WATER RESULTS

RESULTS			OPERATING CONDITIONS*	
Δ OF		IGNITION	SODIUM SURFACE (GM)	POOL
<u>PLATE</u>	<u>POOL</u>			
30		YES	1	0.0
30	380	YES	1	3.0
20	>500	YES	1	6.5
30	>500	YES	1	9.0
30	>500	YES	1	10.0

*4.5 L/HR. H₂O LIQUID + 1,750 L/HR. N₂ @ 25 LB /IN² ABSOL.

DIRECT IMPINGEMENT

Figure 1. HEDL Atomized Water Test Apparatus (AWTA)

a) FLAT INSTRUMENTED PLATE
b) DISASSEMBLED SLEEVE

c) ASSEMBLED SLEEVE
d) 5 ml BULK SODIUM IN BEAKER

Figure 2. HEDL Atomized Water Test Specimens, Run 1, View 2

Figure 3. Spatter of Caustic and Sodium After Thermal Spike in Atomized Water Process

close to the reaction chamber inlet. They also reacted slowly but condensed entering the 5 ml Na beaker producing an off-scale $>500^{\circ}\text{F}$ thermal spike for 10 minutes.

Two additional runs, employing the water vapor process were conducted simultaneously with the last two atomized runs. Identical specimens were used in both types of processes. The vapor process used five times less water at a higher temperature but cleaned the crevice and bulk samples at a rate of three to five times as fast. Results of these tests are summarized in Table 3.

4.2 Control of Caustic Cracking Experiments

Water in contact with sodium produces caustic which attacks stressed austenetic stainless steel and causes cracking. Since the objective of the sodium removal program is to requalify components for reuse in sodium without loss of structural integrity, caustic cracking must be avoided. Reference 20 has indicated that on many specimen configurations and section thicknesses of types 304, 316, 321, and 347 stainless steel cracking occurs above 250 F, with NaOH concentrations ranging from 1 to 100% at levels of 4 to 100% of yield. Uncertain conditions include the time to initiate cracking, influence of cold work and sensitization. Experiments of Reference 21 have indicated that the 2-1/4Cr-1Mo steel was extremely resistant to caustic cracking and has been chosen as the material for the steam generator.

The first step in controlling the cracking mechanism was to qualify a specimen configuration that would reproducibly fail when exposed to crack-initiating environment. Reference 17 has reported that evaluated specimens (See Figure 4) stressed beyond yield included (1) threaded bolts, (2) tensile bars, (3) welded U bends, (4) deflected sheet coupons, (5) wedge opening loaded (WOL) sections, and (6) as-welded pipe. The above tests have indicated that after exposure to 60% NaOH in the same container for 240 hours at 340°F , all specimens exhibited gross cracking except the sheet, pipe welds, and the WOL sections. The threaded bolt and tensile specimens were selected as being qualified for evaluation. Tests at Atomic International (AI) and HEDL have resulted in bracketing of crack initiation at 300°F at about 200 hours exposure. Results are summarized in Figure 5. This data is very essential for any water based sodium removal process, or alcohol process using a water rinse. The constraint in these cleaning processes are the time and temperature to avoid cracking.

4.3 Removal of Bulk Sodium Experiments (Water-Vapor Nitrogen Process)

Pools of undrained sodium in components provide opportunities to uncontrolled reaction with water. The large heat of reaction increases reaction temperature and evolution of hydrogen. In the absence of oxygen the hydrogen increase is relatively harmless. However, the local increase in temperature,

TABLE 3

COMPARISON OF PROCESSES
ATOMIZED WATER WITH WATER-VAPOR

Run No.	Feed			Temp. (°F)	Recirculation			Results			3 in. long 13 Mil gap (est % Na removed)	5g Na est reacted
	N ₂ (g) (l/hr)	H ₂ O(l) (l/hr)	H ₂ O/N ₂ Mole (%)		Total Flow l/hr	H ₂ O l/hr	H ₂ O/N ₂ Mole (%)	Run Time (hr)	Na Wet Surface hr to remove			
ATOMIZED WATER PROCESS												
1	660	0.492	---	RT	2220	0.033	6	48	2	60% in 48 hr 0.02 in/hr	60 mils depth in 48 hr.	
2	660	0.732	---	RT	8880	0.087	16	25	2	22% in 25 hr 0.01 in/hr	spike > 500°F reaction incomplete	
3	660	0.732	---	RT	8880	0.087	16	56	3	82% in 56 hr 0.02 in/hr	spike > 500°F reaction incomplete	
WATER-VAPOR-NITROGEN PROCESS												
1 concurrent with Run 2 above	1080	54	5 ^(a)	150-170	0	0	0	25	3	75% in 25 hr 0.05 in/hr	reaction complete	
2 concurrent with Run 3 above	1080	54	5 ^(a)	150-170	0	0	0	56	4	100% in 56 hr 70.03 in/hr	reaction complete	

(a) Mole% = Vol%

Figure 4. Examples of Specimen Configurations Exposed 240 Hours at 340° F to 60 v/o NaOH

Figure 5. Sodium Removal-Caustic Cracking Results—HEDL and AI

combined with the caustic environment can cause rusting and/or cause stress corrosion cracking. Reference 18 has indicated that studies have been made at HEDL in defining a set of operating conditions which will not cause local overheating. A maximum local temperature less than 250°F is considered acceptable since this is the minimum temperature which has caused stress corrosion cracking in commercial applications. Earlier emphasis has been on developing moist nitrogen process, but as described in Section 4.1 of this report, this method has resulted in slow reaction rates and thermal spikes in excess of 500°F. These thermal spikes were caused by condensate dropping back into sodium pool. Extensive development is required to prevent risk of these uncontrolled conditions. Therefore, testing of moist nitrogen process was discontinued in favor of water vapor nitrogen process.

The water vapor nitrogen process requires operating conditions of moisture concentrations and temperature that will produce steady-state reactions and avoid thermal spikes exceeding the caustic cracking threshold of 250°F. Such an operating envelope has been reported in references 18, 22, and 23. This operating envelope is shown in Figure 6. Figure 7 illustrates the results of water vapor nitrogen process for 40% H₂O vapor at 230°F in contrast to typical results of 150°F for 5% H₂O vapor. Reference 23 has reported 16 bulk sodium removal runs produced within this controlled envelope (shown in Figure 6) with only one case in which the temperature exceeded 250°F (See Table 4). It can be seen in Table 4; the case in question exceeded 250°F for only 0.16 hr by only 35°F. The sodium depths of these results vary from 0.5 to 2 inches in depth for 14 square inch areas.

As an added safety measure to assure against thermal spikes during bulk sodium reactions, operating limits more conservative than the stable envelope shown in Figure 6 was established. These parameters are 150°F + 10°F and 7.5 to 15% water concentration in the nitrogen gas. To date, 9 runs have been reported under these conditions (Table 5). The one over temperature run is the same as included in Table 4. The reaction rate of bulk of sodium within these operating conditions was found to be 0.02 inch ± 15% of sodium depth per hour (Figure 8) for 14 in.² of sodium surface. To date results indicate that reaction rate is constant for sodium depths of upto 2 inches.

At HEDL, the water vapor nitrogen process has been successfully demonstrated on hardware components for removing sodium from crevices, removing residual sodium from wetted FFTF pump bearing pockets and removing residual sodium from a two-inch diameter freeze seal valve. The Sodium Removal Development Apparatus (SRDA) for this process demonstration is shown photographically in Figure 9 and schematically in Figure 10.

Reference 24 has provided data to assure structural properties of 304 s/s exposed to the water-vapor-nitrogen process. This reference indicates that exposure of 304 s/s tensile bars to the HEDL recommended conditions of the water vapor nitrogen process has shown no loss of ductility or load carrying properties. These tests were performed by wetting the tensile bars in sodium, putting them under stress (100%, 0.2% offset yield), then carrying them through the cleaning process along with other tests (usually cups for bulk reaction

FIGURE 6 SRDA Bulk Sodium Water Vapor Reaction - Steady State and Specified Operating Conditions

Figure 7. Sodium Removal – Bulk Reaction – Typical Results

TABLE 4 SRDA Run Results Within Stable Envelope of Figure 6

RUN NO.	OPERATING CONDITIONS			RESULTS		POOL CONFIGURATION	
	CONC. H ₂ O (g) % (%)	TEMPERATURE		TIME		SODIUM DEPTH (IN.)	SODIUM AREA (IN.) ²
		INITIAL N ₂ INLET (°F)	MAX. SODIUM (°F)	TO COMPLETE REACTION (HR.)	ABOVE 250°F (HR.)		
3	7.5	170	<250	20	0	0.5	14
5	12	150	<250	19	0	0.5	14
8	6.0	170	<250	48	0	1	14
13	15	150	<250	57	0	0.5	14
17	7.5	150	<250	60	0	0.5	14
29	5.0	120	<250	41	0	0.5	14
32	5.0	160	<250	75	0	0.5	14
35	15	140	<250	17	0	0.5	14
36	5.0	140	<250	63	0	0.5	14
37	10	130	<250	68	0	0.5	14
39	15	160	<250	26	0	0.5	14
41	10	140	285	32	0.16	0.5	14
54	10	150	<250	107	0	2	14
55	10	150	<250	60	0	1	14
56	10	150	<250	82	0	2	14
59	10	150	<250	82	0	2	14

TABLE 5 SRDA Run Results Within Specified Operating Limits
(7.5 - 15% H₂O, 140° - 160°F) Inlet

RUN NO.	OPERATING CONDITIONS			RESULTS		POOL CONFIGURATION	
	CONC. H ₂ O (g) (%)	TEMPERATURE		TIME		SODIUM DEPTH (IN.)	SODIUM AREA (IN.) ²
		INITIAL N ₂ INLET (°F)	MAX. SODIUM (°F)	TO COMPLETE REACTION (HR.)	ABOVE 250°F (HR.)		
5	12	150	<250	19	0	0.5	14
13	15	150	<250	57	0	1	14
35	15	140	<250	17	0	0.5	14
39	15	160	<250	26	0	0.5	14
41	10	140	285	32	0.16	0.5	14
54	10	150	<250	107	0	2	14
55	10	150	<250	60	0	1	14
56	10	150	<250	82	0	2	14
59	10	150	<250	82	0	2	14

FIGURE 8 Reaction Rate of Sodium - Water Vapor Within Specified Operating Limits of 7.5 - 15% H₂O and 140° - 160°F Inlet

Figure 10. Schematic of Apparatus for Demonstrating Water Vapor Nitrogen Process

rate measurements). The cleaned bars were then tensile tested to determine mechanical properties. The data obtained is summarized in Table 6.

4.4 Removal of Sodium by Alcohol Process

Alcohol has been utilized for cleaning some large components because of its slow and controllable reaction rate and lower risk of damage. Despite its potential fire hazard, alcohol has been successfully used in cleaning large components, such as pumps and a steam generator. Careful attention to inert gas blanketing was utilized in these cases to minimize the fire hazard. Components to be cleaned by alcohol should be protected from air contamination since sodium oxide, hydroxide, and carbonate may inhibit reaction.

Following the failure of the sodium steam generators at the Enrico Fermi Power Plant in 1962, the steam generator tube bundle was removed by withdrawal into a nitrogen filled shipping container (Reference 25). The container was transferred to an outdoor cleaning facility equipped with a 50 ton crane, nitrogen supply, railroad tank car with ethyl alcohol, and required piping. All vents were fitted with flame arrestors and all components were grounded. The tubes which had failed were plugged and alcohol pumped into the remaining tubes at 20 gpm. Absence of hydrogen in the nitrogen purge indicated that sodium had not penetrated any of the unplugged tubes.

The shell side was cleaned by pumping alcohol into the shipping container at 10 gpm and sparging with nitrogen at 5 to 10 SCFM. Filling was interrupted periodically to monitor temperatures and pressures. During filling, the pressure increased about 3 psi and the hydrogen concentration in the vent line varied from 20 to 65%. The maximum local temperature observed was 100°F. The tube bundle was then soaked in alcohol for a total of about 60 hours, with a partial drain and refill after 12 hours to attempt to augment internal mixing. Then the alcohol was drained and the tubes dried with nitrogen.

The cleaned tube bundle showed a small white deposit, identified as sodium carbonate above the sodium operating level. The sections of the tubes immersed in sodium were covered with a fine gray powder, reported to be coroloy metal particles resulting from sodium reduction of the oxide film initially present on the tubes.

An EBR-II primary sodium pump was removed and cleaned after more than 32,000 hours of service because of shaft binding arising from oxidized sodium deposits (Reference 26). The pump was withdrawn into an argon filled caisson, allowed to cool, and the surface of the adherent sodium oxidized by slow introduction of air. Then the pump was partially disassembled and the parts transported to an outside metal covered concrete cleaning pad. Pump subassemblies were placed in argon filled tanks specifically designed for each unit. Ethyl alcohol was remotely pumped into each tank until the tanks were filled. Water was slowly added to the alcohol until a 50% mixture was obtained. When the sodium reaction was complete, the alcohol was drained and the subassembly washed with hot water. Subsequently, the pump assemblies were decontaminated

TABLE 6
SUMMARY OF NEW PROPERTIES DATA OF SRDA EXPOSED TENSILE SPECIMENS (304 S/S)

Fracture Appearance	Reduction of Area (%)	Elongation (%)	Magnetic Susceptibility Rank 1 Lo, 4 Hi	Strength		Process Media	Process Exposure (°F/hr)	Strain Prior To Exposure in./Specimen	Wetting Sodium Immersion Prior To Cleaning (°F Na) (Time-Hr)		Specimen Diameter	Surface Cracking
				Yield (Kpsi)	Ultimate (Kpsi)							
Ductile (Control)	75.1 74.3	72.5 72.0	1, 1	37. 39.4	93.1 91.0						0.5	None
Ductile	74.7	70.0	1	39.3	93.8	Steam	Steam Lance	0.005	~300	0.25	0.5	Slight**
Ductile	74.1	70.0	1	40.3	93.5	Steam	Steam Lance	0.005	~300	0.25	0.5	Slight
Ductile	73.6	68.5	2	39.8	93.2	Steam	Steam Lance	0.005	~300	0.25	0.5	No
Ductile	74.2	70.2	1	41.5	90.0	Steam	Steam Lance	0.005	~300	0.25	0.5	No
Ductile	80.8	73.2	4	70.4	103.9	10% H ₂ O-N ₂	150/113	0.004-0.001	~400	0.25	0.25	No
Ductile	70.3	67.5	4	68.6	104.7	10% H ₂ O-N ₂	150/26.5	0.005-0.004	~400	0.25	0.25	Yes
Ductile	71.3	71.0	4	68.1	103.7	10% H ₂ O-N ₂	150/26	0.005-0.003	~400	0.25	0.25	Slight
Ductile	80.2	83.0	4	66.9	104.1	5% H ₂ O-N ₂	120/69.5	0.003-0.002	850	~18	0.25	No
Ductile	80.3	74.8	3	69.7	103.6	10% H ₂ O-N ₂	Na/142	0.004-0.002	850	~18	0.25	Slight
Tested at	68.2	61.2	1	68.3	91.8	10% H ₂ O-N ₂	150/28	0.005-0.002	850	~18	0.25	No
elevated temp	71.3	54.4	1	64.6	90.0	10% H ₂ O-N ₂	150/~15	0.004-0.003	850	~18	0.25	No
Ductile	80.7	78.5	4	68.0	102.0	10% H ₂ O-N ₂	150/~15	0.006-0.002	850	~18	0.25	No
Ductile (Control)	78.7	81.0	4	66.7	102.5	10% H ₂ O-N ₂	(Spiked)*				0.25	No

* Maximum temperature 750°F over 250°F for ~1-1/3 hours.

** Surface cracking develops during tensile testing due to phase transformation, hydrogen embrittlement, or other causes.

with Turco No. 4521 (a proprietary organic acid solution made by Turco Products Division, Purex Corporation) and rinsed. Modifications to the pump to alleviate the sodium deposition on the shaft were accomplished and the pump returned to service. The pump, up till now, had been operated satisfactorily and had no noticeable effect upon their performance.

Reference 14 has presented the results of cleaning activities (through alcohol process) performed to remove residual sodium from the AI Modular Steam Generator. A temporary cleaning loop was installed and the residual sodium was removed while the MSG remained located in place at the Sodium Component Test Installation (SCTI). Cleaning was performed using three solvent flushes; one Dowanol PM, and two Ethanol. A summary of sodium removed along with the predicted residual is given in Figure 11. A total of 20.3 lbs of sodium was estimated to have been removed during the cleaning process. This value compares to a predicted initial value of 20.8 lbs remaining after sodium draining. Visual inspection of internal surfaces showed no evidence of any unreacted sodium even in crevice and bolt thread regions. A black residue was observed on internal surfaces and also collected in a filter during the initial cleaning stages. The residue was identified to be primarily the base metal ($2\frac{1}{2}\text{Cr}-1\text{Mo}$ ferritic steel) formed by chemical reduction of a surface oxide coating during sodium service. The alcohol process used for cleaning the MSG proved to be very safe and highly effective in removing the residual sodium from sodium coated surfaces.

4.5 Removal of Sodium by Vacuum Distillation

This process has been successfully employed on both a laboratory scale and on small components or systems to remove residual sodium superficially; its application to larger systems appears attractive, i.e., temperatures are no higher than those required for the system operation and may be lower, pressures do not require elaborate pumping systems, and times may not be excessive. However, even experience on a small scale and analysis of the extrapolation to larger systems reveals that the engineering to permit reliable use on large complex components is inadequate because of the following reasons:

1. Since oxides or other compounds of sodium are almost certain to be found to some degree, especially in components exposed to a cover gas, incomplete removal of sodium may result.
2. Residual compounds left after vacuum distillation may require chemical removal, probably with water or alcohol rinses.
3. Since the advantages of vacuum distillation are enhanced by performing it in situ (minimize oxidation, utilize trace heating, isolate with existing valves, etc.), water rinsing, if required, presents special problems in isolation from the remainder of the system. Vacuum distillation does however simplify subsequent removal of the component from the system for further cleaning.

PREDICTED RESIDUAL SODIUM

• VERTICAL SURFACES	6.4 lb
• CREVICES	
TUBE/TUBE SPACER GAP	1.1 lb
TIE ROD/SPACER GAP	0.4 lb
• HEEL	<u>12.9 lb</u>
TOTAL	20.8 lb

OBSERVED SODIUM REACTED

• VERTICAL SURFACES AND HEEL (AFTER 12 HOURS OF CLEANING)	17.0 lb
• CREVICES (REMAINDER OF CLEANING TIME)	<u>3.3 lb</u>
TOTAL	20.3 lb

CLEANING HISTORY		
SOLVENT	CLEANING TIME (days)	SODIUM REACTED (lb)
DOWANOL PM		
INITIAL	0.5	17.0
REMAINDER	10.5	1.3
FIRST ETHANOL	18	1.7
SECOND ETHANOL	<u>7</u>	<u>0.3</u>
TOTAL	36	20.3

Figure 11. MSG Cleaning Summary

4. Complex components which have long, intricate passages create long diffusion times, unless gas sweeping is used to accelerate vapor removal. Little experience exists with such techniques, which also increase the probability of oxidizing the remaining sodium.
5. All parts within an enclosed area to be vacuum distilled must be capable of being heated to at least 800°F.
6. Heating of large, complex structures with trace heating in the absence of sodium can result in thermal stresses, unless the heating is specifically designed for this purpose.
7. If the containment vessel for vacuum distillation is a part of the reactor system (pump tank, etc.) it must be designed for vacuum loads to temperatures of at least 800°F.
8. Sodium valves may not provide adequate isolation for vacuum distillation.

5.0 DEVELOPMENT PROGRAMS ON CLEANUP METHODS

The objectives of these programs are to develop cleanup methods and equipment for recovery following a large water leak incident. During this incident, Intermediate Heat Transport System (IHTS) loop drainage is usually initiated to prevent solidification of sodium-water reaction products in the system piping or components. During drainage sodium-water reaction products and droplets of sodium stick on the inside surface of the IHTS loop. The sodium-water reaction products are corrosive in nature and on some components they could cause a serious stress corrosion cracking problem. To put the IHTS loop back into operation after a large water leak requires that the inside surface of the IHTS loop be cleaned and sodium, if re-used, must have the acceptable levels of impurities. The development programs which are described below are aimed to obtain qualitative and quantitative data for recovery methods following a large water leak incident.

5.1 IHTS Loop Drainability

The first task in the development of cleanup methods is to establish process conditions under which the IHTS loop is easily drainable. This requires an experimental program in establishing the drainability of sodium with SWR products versus time and temperature. These tests should also provide information on the composition, melting point, viscosity and particle size distribution of the products of sodium-water reaction produced by various quantities and temperatures of water-steam.

5.2 Solubility and Reaction Rates Measurements of SWR Products

The literature survey has revealed that the water vapor nitrogen process under controlled process conditions and the alcohol process have been proved to be quite successful in removing sodium from the components. A logical approach should be to use the same above two cleaning processes for removing SWR products. This requires one must first determine the solubility and reaction rate measurement of SWR products using various types of alcohols or water vapor nitrogen mixture with controlled process conditions as established in Figure 6.

5.3 Cleanup Process Demonstration

Based on the test data as obtained in the above bench scale test, one must demonstrate the most feasible method of cleaning the SWR products and droplets of sodium. Such a cleaning process can be easily demonstrated in cleaning the Large Leak Test Rig (LLTR) after a large leak sodium-water reaction. Since temperature control is vital to most cleaning methods, strategic location of thermocouples to monitor the progress of the cleaning process at critical areas must be done. The end point of the cleaning process can be determined by checking for proper pH and resistivity of water during the final rinse. Visual observation of a cleaned surface or a dye penetrant method wherever in doubt about the structural integrity, should be a sufficient criteria for a requalification of a component for reuse.

5.4 Purification of IHTS Sodium After Emergency Dump

The literature survey has revealed that following IHTS system drainage the Sodium-Water Reaction Product Tanks will be cooled to 350-400°F in order to precipitate as much of the reaction products as possible. After cooldown, the liquid sodium is decanted off and purified in the cold traps if possible. Purification of decanted sodium may require a different design of standby cold traps than the normal operational ones. Such a sodium purification process has indeed been demonstrated for removing small amounts of impurities during Fermi operation in Reference 25. If the use of cold traps for removing large amounts of sodium impurities is feasible, then the sodium could be pumped from the dump tank through the purification system into temporary sodium storage such as railroad tank cars. The purification system should remove the hydrogen and oxygen from essentially the entire sodium loop. Since the sodium has been cooled to 350-400°F in the reaction products separator tank, the bulk of the reaction products for a large leak will stay in the reaction products tank along with the sodium heel. These insolubles are removed after decanting by mechanical or chemical means prior to refilling the system. The time required to place a loop back into operation after a large leak will be determined by the component repair time (estimated to be several weeks) rather than by the time required to cold trap the drained sodium. The requirement for cold trap capacity will depend upon the amount of impurities introduced into a loop due to steam generator leaks.

6.0 REFERENCES

1. Kittel, J. H., "Summary of Discussions - Meeting on Effects of Sodium Cleaning on Stainless Steel", Argonne National Laboratory, January 21, 1970.
2. Ruther, W. E., et al, "The Attack on the Cladding of EBR-II Driver Element - C-249-16", ANL-7537, March 1969.
3. Strain, R. V., "Effects of Sodium and Sodium Removal on the Microstructure of Type 304L Stainless Steel Tubing", ANL/EBR-006, 1969.
4. Smith, F. A., et al, "650°C Sodium, Free Surface, Stress and Wear Effects on Reactor-component Metals in Alkali Metal Components", Symposium Proceedings, Vienna, November 28 - December 2, 1966, p. 231, International Atomic Energy Agency, Vienna, 1967 (STI/PVB/143).
5. Cheng, C. F., and Ruther, W. E., "Potential Problems in the Removal of Sodium from Stainless Steel - Meeting on Effects of Sodium Cleaning on Stainless Steel", Argonne National Laboratory, January 21, 1970.
6. TWX-GE-SAN-PA61-A5.1-0218, J. M. Case to C. Backlund, March 16, 1973, "Questions Regarding Na/H₂O Reaction Product Cleaning Experience for Discussion with Foreign Contacts by Conference Call".
7. Letter, J. S. McDonald to J. M. Case, April 30, 1973, "Record of Conference Call Between AI-GE-RDT and Interatom Representatives Regarding Cleaning Procedures for Large Na/H₂O Reaction Test Rigs."
8. Letter, J. M. Case to C. V. Backlund, April 5, 1973, "Transcript of Conference Call with United Kingdom Representatives on Cleaning Procedures for Large Sodium Water Reaction Test Facilities".
9. Anand, R. K., Aiello, M., Degutis, G., "Protected Bayonet Tube Steam Generator, Proof of Principle Tests," FWC Document No. ND-74-23, June 28, 1974.
- 9a. "Surface Cleaning Methods for Materials Exposed to Sodium," LMFBR Program Plan, WASH-1105, 2nd Ed.; Volume V, Task 5A5.
10. Shirin, V. M., Karpov, A. V., Aristarkhov, N. N., Efimov, I. A., Mamaev, L. I. and Milovidov, I. V., "Use of Lead in Unloading Systems of Sodium Cooled Facilities." Conf-700307-7 Reactor Technology (TID-4500), February 1971.
11. Watt, G. W., et al, Ind. Eng. Chem. 46, 1022, 1954.
12. Sitting, Marshall, "Sodium - Its Manufacture Properties and Uses." American Chemical Society Monograph, Reinhold, New York, 1956.

13. Scott, J. M., et al, "Sodium Heated Steam Generator Model Tests at SGTR, Volume 1, Test Rig Operating Experience and Cleaning, Disassembly and Inspection of the Steam Generator Test Models", GEAP-10580-1, June 1972.
14. Harty, R. B., "MSG Test Report - Removal of Residual Sodium", TR-097-330-007, March 8, 1974.
15. Chaevskii, M. I., and Popovick, V. V., Soviet Materials Science 2, 373, 1966. Translated from Fisiko-Khimicheskaya Mekhanika Materialov 2, 522, 1966.
16. Dutina, D., Vallecitos Nuclear Center, General Electric Company, Personal Communication.
17. Balif, J. L., Borisch, R. R., Funk, C. W., Maffei, H. P., Spraul, J. and Stewart, A., "Annual Report FY 1973 Sodium Removal Program HEDL and AI", HEDL TC-6, Controlled Distribution Document, August 1973.
18. "Sodium Removal Presentation to ARD-LMEC in Support of FFTF Pump, AMCF and CHCF - September 17-18, 1973", HEDL ST-477, October 1, 1973.
19. "U.S. Atomic Energy Commission Summary Report and Papers of the Specialists Meeting on Decontamination of Plant Components from Sodium and Radioactivity at Dounreay Experimental Reactor Establishment, Caithness, Scotland - April 9-12, 1973", TID-26513.
20. "Preliminary Report" - HEDL Sodium Technology, Sodium Removal and Requalification Handbook - ST#468, June 1973.
21. Indig, M. E., "Caustic Cracking in Hot Aqueous and Superheated Steam Environments", General Electric Company, California, GEAP-12536, VC-79e, August 1974.
22. "HEDL Quarterly Technical Report, October, November, December, 1973", Volume 1, Materials Technology, HEDL-TME 73-6, Vol. 1.
23. "Technical Progress Report - Sodium Removal Program 189 Number 12615 - January - March 1974", HEDL TC-67 Controlled Distribution.
24. "Technical Progress Report - Sodium Removal Program 189 Number 12615 - April 1974", HEDL TC-87 Controlled Distribution.
25. Anderson, R. H., Ford, J. A., Lindsey, P. S., "Design, Fabrication, and Preliminary Operation of the Steam Generators for the Enrico Fermi Atomic Power Plant", APPA-307 (Atomic Power Development Associates, Inc.), August 1968.
26. Cerutti, B. C., Deegan, G. E., Nulton, J. D., Perry, W. H., and Seever, R. E., "Removal and Repair of EBR-II Primary Sodium Pump No. 1", ANL-7835 (Argonne National Laboratory), May 1972.

APPENDIX

This appendix contains copies of referenced items not generally available to the recipients of the attached document.

6. TWX-GE-SAN-PA61-A5.1-0218, J. M. Case to C. Backlund, March 16, 1973, "Questions Regarding Na/H₂O Reaction Product Cleaning Experience for Discussion with Foreign Contacts by Conference Call".
7. Ltr., J. S. McDonald to J. M. Case, April 30, 1973, "Record of Conference Call Between AI-GE-RDT and Interatom Representatives Regarding Cleaning Procedures for Large Na/H₂O Reaction Test Rigs".
8. Ltr., J. M. Case to C. V. Backlund, April 5, 1973, "Transcript of Conference Call with United Kingdom Representatives on Cleaning Procedures for Large Sodium Water Reaction Test Facilities".

MARCH 16, 1973
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ORIGINAL TO:

MR. C. V. BACKLUND, DIRECTOR OF PROGRAM COORDINATION
U.S. ATOMIC ENERGY COMMISSION SAN FRANCISCO OPERATIONS
BERKELEY, CA.

TELEX COPIES TO:

DIRECTOR, RDT

ASST. DIRECTOR FOR PROJECT MANAGEMENT

ASST. DIRECTOR FOR PLANT ENGINEERING

CHIEF, LIQUID METAL PROJECTS BRANCH

CHIEF, HEAT EXCHANGER BRANCH

ALL ABOVE CC'S TO US ATOMIC ENERGY COMMISSION, DIV. REACTOR DEVELOP.
& TECHNOLOGY, WASHINGTON D.C.

F. POUCHER

R.T. LANCET

J. S. MC DONALD

RDT SENIOR SITE REP

ALL ABOVE CC'S TELEX TO:

ATOMICS INTERNATIONAL

P.O. BOX 309

CANOGA PARK, CALIFORNIA

SUBJECT: QUESTIONS REGARDING NA/H₂O REACTION PRODUCT CLEANING
EXPERIENCE FOR DISCUSSION WITH FOREIGN CONTACT BY
CONFERENCE CALL

REFERENCE: TELECON J. FORD/J. PETERSON 3/14/73
TELECON J. AMOS/R. LANCET 3/12/73
SAME SUBJECT

QUESTIONS LISTED BELOW ARE IN RESPONSE TO A REQUEST BY JOHN FORD
AEC-RDT IN PREPARATION FOR A CONFERENCE CALL TO FOREIGN CONTACTS
TO OBTAIN INFORMATION ON CLEANING EXPERIENCE FOR SODIUM/H₂O LARGE
LEAK TEST FACILITIES.

A1 QUESTIONS:

1. WHAT IS YOUR BASIC METHOD OF REMOVING THE RESIDUAL SODIUM OR THE
REACTION PRODUCTS FOLLOWING A TEST, FROM THE TEST FACILITY,
THE REMAINDER OF THE TEST SYSTEM, AND THE REACTION PRODUCTS TANK?
2. WHAT PROBLEMS WERE ENCOUNTERED IN THE INITIAL USE OF THE CLEANUP
PROCESS, AND HOW WERE THEY RESOLVED?
3. IF SOLID REACTION PRODUCTS WERE ALLOWED TO REMAIN IN THE SYSTEM,
HOW WERE THEY REMOVED FROM THE SYSTEM?
4. HAVE YOU CONSIDERED THE USE OF ANY OF THE FOLLOWING METHODS? WHAT
WERE YOUR CONCLUSIONS AND EXPERIENCES IF YOU HAVE USED THEM? WHAT
LIMITATIONS DO YOU PLACE ON THEIR USE (E.G., FLUID TEMPERATURE,
SYSTEM TEMPERATURE, CLEANING TIME).
DO YOU HAVE A PREFERENCE?

A) MOIST NITROGEN

B) STEAM

C) WATER

D) ORGANIC SOLVENT

E) SODIUM RINSE

F) REACTIVE FLUIDS SUCH AS CO₂ AND LIQUID NH₃ A-2

DO YOU CLEAN THE RUPTURE RELIEF SYSTEM?

6. TO WHAT DEGREE DOES STRESS CORROSION SUSCEPTIBILITY INFLUENCE THE MATERIALS OR FABRICATION PRACTICE? WHAT DO YOU DO TO AVOID STRESS CORROSION?
7. WHAT ARE THE MAJOR PROBLEMS OR PROCEDURES WHICH DETERMINE THE CLEANING TIME?
8. WHAT WOULD YOU DO TO REDUCE CLEANING REQUIREMENTS?
9. DO YOU THINK THAT THE STEAM GENERATOR CLEANING PROBLEM WOULD BE GREATLY SIMPLIFIED BY A BOTTOM DRAIN THAT WOULD EMPTY THE STEAM GENERATOR IN A FEW MINUTES WHILE THE SODIUM IS STILL HOT?
10. WHAT EXPERIENCE DO THEY HAVE ON CLEANING VERY DIRTY SODIUM SUCH AS DECANTED SODIUM FROM REACTION PRODUCT TANK? HAVE THEY BEEN SUCCESSFUL USING NORMAL COLD TRAPPING. IS ACCELERATED CORROSION A POTENTIAL PROBLEM?
11. DO YOU HAVE EXPERIENCES WHICH WOULD DIFFERENTIATE SUSCEPTIBILITY TO STRESS-CORROSION AND GENERAL CAUSTIC CORROSION BETWEEN CARBON STEEL, 18-8 AUSTENITIC STEELS, INCOLOY 800, AND INCONEL 600?
12. DO YOU USE LINERS IN YOUR REACTION PRODUCT TANKS AND HAVE THEY CAUSED ANY CLEANING PROBLEMS?
13. HAVE YOU EXPERIENCED ANY TEMPERATURE AND PRESSURE CONDITIONS THAT WOULD PROHIBIT THE USE OF CARBON STEEL IN THE RELIEF SYSTEM?

GE QUESTIONS:

1. REPORTS OF THE FIRST 2 SUPER NOAH TESTS STATE THAT REACTION PRODUCTS COULD NOT BE DRAINED FROM THE TEST VESSEL AND IT WAS NECESSARY TO REMOVE THE BOTTOM HEAD AND MECHANICALLY REMOVE THE REACTION PRODUCT CAKE.
 - A. HAS A SUCCESSFUL PROCEDURE BEEN DEVELOPED DURING SUBSEQUENT TESTS TO DRAIN THE TEST VESSEL? IF SO DESCRIBE THE PROCEDURE.
 - B. HOW SOON AFTER A TEST SHOT IS DRAINING ATTEMPTED?
 - C. HOW LONG IS IT NECESSARY TO WAIT BEFORE OPENING THE TEST VESSEL AND WHAT ARE THE TEMPERATURE CONDITIONS INSIDE THE VESSEL WHEN IT IS OPENED?
 - D. HOW LONG A TIME PERIOD IS REQUIRED TO N2-STEAM CLEAN THE VESSEL?
 - E. DO REACTION PRODUCTS BURN WHEN EXPOSED TO STEAM?
2. IS IT SUPER NOAH PRACTICE TO CLEAN THEIR REACTION PRODUCT TANK BETWEEN EACH TEST? WHAT IS THE PROCEDURE?
3. HAS RUPTURE TUBE WATER SUPPLY LINE PLUGGING BEEN ENCOUNTERED?
4. HAS STEAM BEEN ALLOWED TO CONTINUE TO FLOW THROUGH THE SYSTEM AFTER A TEST SHOT AND IF SO, WHAT ARE THE EFFECTS?
5. DO REACTION PRODUCTS INTERFERE WITH SEPARATION OF VESSEL FLANGES?
6. DO REACTION PRODUCTS TEND TO STICK TO OR SHRINK AWAY FROM CONTAINER WALLS WHEN THEY SOLIDIFY?

WHEW BEING AS A BASIS FOR SEPARATOR DESIGN?

8. HOW EFFICIENT ARE CYCLONE SEPARATORS FOR OFF DESIGN EFFLUENT RELEASES?
9. WHAT SETTLING TIMES ARE ALLOWED FOR REACTION PRODUCT SEPARATION IN A REACTION PRODUCT TANK?
10. CAN RUPTURE DISC INSERTS BE REPLACED OR IS IT NECESSARY TO REPLACE THE COMPLETE ASSEMBLY? WHAT TYPE OF RUPTURE DISCS ARE USED? WHAT IS THE RESPONSE TIME OF THE DISC?

PROPOSED CALL PARTICIPANTS:

AI: J. S. MC DONALD - (213) 341-1000 EXT. 2349
R.T. LANCET OR F. POUCHER - (213) 341-1000 EXT. 1792

GE: J.R. PETERSON - (408) 297-3000 EXT. 259
J. C. AMOS - (408) 297-3000 EXT. 533

DISTRIBUTION:

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FROM J.M.CASE BRD GENERAL ELECTRIC CO. SUNNYVALE, CA.

Atoms International
North American Rockwell

P.O. Box 309
Canoga Park, California 91304

In reply refer to 73AT2592

April 30, 1973

Mr. J. M. Case, Program Manager
General Electric Company
310 DeGuigne Drive
Sunnyvale, California 94086

Reference: TWX GE-SAN-PA61-A5.1, J. M. Case to C. Backlund,
March 16, 1973, "Questions Regarding Na/H₂O Reaction
Product Cleaning Experience for Discussion with Foreign
Contacts by Conference Call."

Dear Mr. Case:

Subject: LMFBR Steam Generator Development Program PA-61-
Task A5.1; Conference Call with Interatom Representatives
to Discuss Na/H₂O Questions

Enclosed is a report covering the subject RDT/GE/AI/Interatom telephone conversation which was held on April 5, 1973. The discussions consisted of Interatom responses to AI questions listed in the referenced TWX. If there are any questions concerning the enclosed telephone conversation record, please contact the undersigned.

Very truly yours,

J. S. McDonald
J. S. McDonald, Manager
Special Projects

Enclosure as noted

Distribution - see page two

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RECORD OF CONFERENCE CALL BETWEEN
AI-GE-RDT and INTERATOM REPRESENTATIVES
REGARDING CLEANING PROCEDURES FOR
LARGE Na/H₂O REACTION TEST RIGS

Date

April 5, 1973

Participants

K. Dumm, Interatom
J. Yevick, USAEC-RDT (at beginning)
W. Wolfe, US representative at Interatom
J. Amos, GE
J. McDonald, AI

Discussion

Questions (as listed in GE TWX to SAN dated 3/16/73) were asked by McDonald and answered by Dumm unless otherwise indicated. At the outset, McDonald indicated that the conversation was being recorded and asked if there were any objections. There were none.

1. What is your basic method of removing the residual sodium or the reaction products following a test, from the test facility, the remainder of the test system, and the reaction products tank?

Answer

Prior to the test, the test section is isolated from the adjoining secondary sodium system by valves. After the shot, the test section is drained as quickly as possible in order to avoid precipitation of reaction products. Drainage within 15 minutes of the test is necessary in order to avoid major plugging and drainage problems. In one of the first tests on the program, several hours passed before an attempt was made to drain the system. As a result, a hard-mass had formed in the test section and a three week excavation effort was required to clean up the system. Dirty sodium from the test section and relief system is drained directly into barrels and returned to the supplier for recycling. Several hours after the shot, the isolated secondary system is drained to the sodium storage tank of the loop. The drain lines are 50 mm (2") in diameter and are heated to 350-400° C before each test to facilitate drainage.

After each test, the system is allowed to cool to about 120-150° C. For purposes of preventing condensation of steam during cleaning operations, temperatures are maintained at this general level by means of electrical heaters. After removal of instrumentation, the system is steamed with a nitrogen purge being added to avoid the risk of oxygen break-through and possible H₂-O₂ explosion. During the steaming operation, all temperatures are monitored and the steaming is suspended when they reach the 160-170° C level. Above this level, the potential for caustic corrosion damage exists. Steaming operations begin slowly and never exceed a rate of 150 kg per hour. Earlier experience indicated that higher steam rates resulted in overheating (maximum observed temperature was 700° C) due to chemical reaction. The cleaning steam supply is 8 atm. /150° C.

Relief system materials are ferritic steel (term used in this conversation to refer to 0.7 - 0.8% Cr low alloy steel), except for stainless steel flanges on the cyclone tank. These flanges have experienced corrosion damage and have been replaced several times. Ferritic material will be used throughout the SNR relief system. Ferritic material offers the advantage of having a low coefficient of thermal expansion and has the strength to withstand conditions in the relief system. During the early stages of the rupture relief transient, relief system temperatures are around 200° C while pressures are high. In the late stages of the transient, pressures are low, but temperatures reach 1000° C for short duration. These high temperatures are attributed to reaction between residual sodium film and moisture.

In response to questions by J. Amos, Dr. Dumm indicated that cleanup operations as described above require approximately 24 hours not counting the cool-down time. The turnaround time between tests is normally dictated by activities necessary in connection with the test section.

2. What problems were encountered in the initial use of the cleanup process, and how were they resolved?

Answer:

The same basic cleanup procedure has been employed since the beginning of the program. The only changes of any significance which have been made are (1) reducing steaming rate during cleaning, and (2) draining quickly after test shots as discussed after question 1.

Note:

Questions 3, 4, 5, and 7 of the previously noted TWX concern cleaning methods and relief system cleaning. They are answered in the response to Question 1. The following additional information regarding the relief system was provided. No information on reaction products particle distribution was available, but Interatom estimates that the average particle size discharging from the stack was in the range of 0.1 to 0.01 mm diameter. The reaction product cleanup system consists of two stages. The first is a simple cyclone, and the second is a spray tower. The cyclone efficiency is estimated to be 99.5%. The spray was incorporated primarily for experimental purposes. The second stage temperatures are in the range of 60 to 70°C and no corrosion problems have been observed. Ferritic material is used.

6. To what degree does stress corrosion susceptibility influence the materials or fabrication practice? What do you do to avoid stress corrosion?

Answer:

The general answer is covered in the response to Question 1. Additional information relative to ferritic steel susceptibility to reaction product corrosion was obtained early during a small leak test series in support of KNK. Early in the program, a series of 10 tests were conducted without any cleanup between tests. After the series was completed, the system was cleaned. No corrosion of the ferritic material was observed.

8. What would you do to reduce cleaning requirements?

Answer:

Dr. Dumm's only suggestion for simplifying cleanup was to install large access ports adjacent to the more complicated regions of the structure. This would facilitate control of the cleaning operations and subsequent inspection.

Note:

Question 9 of the previously referenced TWX concerns bottom drainage and is answered in the response to Questions 1 and 8.

10. What experience do they have on cleaning very dirty sodium such as decanted sodium from reaction product tank? Have they been successful using normal cold trapping? Is accelerated corrosion a potential problem?

Answer:

The answer to Question 10 is included in the response to Question 1. Dr. Dumm observed that cold trapping would not be a very efficient way of cleaning up the system after the shot. The sodium in the system would be saturated and the rate of reaction product removal would be very slow. Draining into the disposal barrels is much less time consuming.

11. Do you have experiences which would differentiate susceptibility to stress-corrosion and general caustic corrosion between carbon steel, 18-8 austenitic steels, Incoloy 800, and Inconel 600?

Answer:

Interatom has observed no particular problems with ferritic material to date. Their tests indicate Incoloy 800 to be more waste resistance than low alloy steels by a factor of 5 to 8. This compares with a factor of 80 that was indicated by the APDA test data.

12. Do you use liners in your reaction product tanks and have they caused any cleaning problems?

Answer:

In the initial test, a perforated liner was incorporated within the cyclone. The purpose of the liner was to shield the wall from thermal shock. The

perforations were to prevent the development of a differential pressure across the liner. During cleaning operations after the first test, steam reacted with residual sodium between the liner and wall near the bottom of the vessel. This reaction resulted in destruction of the liner. Since that time, the liner has only been employed in the upper part of the vessel. They have had no problems cleaning between wall and liner in the upper region.

Note:

Question 13 of the referenced TWX pertains to relief system temperatures and pressures. The answer is included in the response to Question 1.

NUCLEAR ENERGY
DIVISION

BREEDER REACTOR DEPARTMENT

GENERAL ELECTRIC COMPANY 310 DEGUIGNE DRIVE
SUNNYVALE, CALIFORNIA 94086, Phone (408) 297-3000

April 5, 1973

Mr. C. V. Backlund, Director
U. S. Atomic Energy Commission
San Francisco Operations Office
2111 Bancroft Way
Berkeley, California 94704

Subject: LMFBR Steam Generator Development Program
P.A. 61 - Task A5.1; Conference call with UK
Representatives to Discuss NA/H₂O Reaction
Product Cleaning Procedures for LLTR.

Reference: 1) TWX GE-SAN-PA61-A5.1, J.M. Case to
C.V. Backlund March 16, 1973 "Questions Regarding
NA/H₂O Reaction Product Cleaning Experience for
Discussion with Foreign Contacts by Conference Call".

Dear Mr. Backlund:

Forwarded herewith is a telephone transcript of a conference call from GE/RDT/AI to representatives of the UK Dunreay Experimental Establishment on March 29, 1973. This call was placed for the purpose of obtaining answers to the questions contained in Reference (1) regarding cleaning procedures for Large NA/H₂O reaction test facilities.

Should recipients have any questions in connection with this transcript, please contact our Mr. J. C. Amos, MC-S32, Ext. 533.

Yours very truly,

J.M. Case
Program Manager

mk
Attachment

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Letter: GE-SAN-PA61-A5.1-0239

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TRANSCRIPT OF CONFERENCE CALL WITH UNITED KINGDOM REPRESENTATIVES ON
CLEANING PROCEDURES FOR LARGE SODIUM/H₂O REACTION TEST FACILITIES

Held March 29, 1973 (0845-0930 PST)

Participants

J.Allen Bray, Dunreay Experimental Establishment UK
George Kinchin, Dunreay Experimental Establishment UK
John A. Ford, US-AEC-RDT
J.C.Amos, General Electric
J.R.Peterson, General Electric
Fred Poucher, Atomics International

Note:

The following transcript has been edited to eliminate duplication where information was repeated or rephrased for clarification. Questions were asked by J.C.Amos, GE and answered by J.A.Bray unless indicated otherwise.

Amos - Acknowledged that this call is being recorded. If any participants have any objection they should so indicate.

Ford - No objections, The British are recording it also.

Question 1 A

Reports of the first 2 Super Noah tests state that reaction products could not be drained from the test vessel and it was necessary to remove the bottom head and mechanically remove the reaction product cake. Has a successful procedure been developed during subsequent tests to drain the test vessel? If so describe the procedure.

Answer: No. We haven't been able to drain the reaction products because the reaction products are very viscous even at high temperatures. Temperatures up to 550°C. Our drain line is 2" diameter and has a bellows valve in it and so it is not likely that we will be able to drain this line. A larger line say a 6" line or greater would probably permit draining.

Question 1B

How soon after a test shot is draining attempted?

Answer; We have attempted to drain almost immediately after a test shot. Within 10 minutes but it hasn't been successful.

Question 1C

How long is it necessary to wait before opening the test vessel and what are the temperature conditions inside the vessel when it is opened?

Answer: We generally allow the test vessel to cool to ambient temperature. So the length of time is associated with the time required to cool from the final post reaction temperature which can be in the order of 550°C. This time can be as much as a matter of several days.

Question 1D

How long a time period is required to N₂-steam clean the vessel?

Answer: Steam cleaning process actual cleaning time is quite short about 24 hours but this has to be preceded by the pre-cleaning operation requiring removal of the reaction products and the draining of the sodium held up by the reaction products and finally the pipe work cleaning which is required to allow through flow of the N2-steam mixture.

Question 1E

Do reaction products burn when exposed to steam?

Answer: Not as far as we know. No they do not burn in our steam-nitrogen decontamination procedure but steam in the presence of air can ignite the heavily contaminated sodium.

Question

This is not on the list, however for the purpose of clarification how many tests have been run as of the present time?

Answer: Three shots with the Super Noah and 15 shots with its predecessor the Noah.

Question 2

Is it Super Noah practice to clean their reaction product tank between each test? What is the procedure?

Answer: Yes we do clean the reaction product tank between tests. If there is a lot of reaction products carryover the sodium is held up above the reaction products, that is the reaction products sink to the bottom of the tank. First of all it is necessary to drain the sodium. This we do by cutting through the reaction products from the bottom of the tank with a drill or propane gas burner. Then we can drain the sodium from the tank and proceed with our nitrogen steam cleaning right through the test vessel, the reaction product tank and the cyclone separator.

Question 3

Has rupture tube supply line plugging been encountered?

Answer: No.

Question 4

Has steam been allowed to continue to flow through the system after a test shot and if so, what are the effects?

Answer: No we haven't done that because it would tend to confuse any erosion or wastage damage resulting from the test and it would also add to the reaction products in the test vessel unless we had a very large vessel. On a vessel of our size, this is not practical. On the ESADA rig this might be a practical consideration.

Question 5

Do reaction products interfere with separation of vessel flanges?

Answer: Yes they do. The reaction products produce a very hard layer with strong adhesive properties. In early tests we fitted a steel liner in the test vessel to bridge the gap between the flanges, which is to say we welded a steel liner to the top port of the test vessel which was a snug fit

inside the flanges of the vessel. We abandoned this steel liner because it made flange sealing more difficult. It is possible by use of hydraulic jacks to part the flanges.

Question 6

Do reaction products tend to stick to or shrink away from container walls when they solidify?

Answer: No, it does stick to the vessel walls. In fact it has strong adhesive properties.

Question 7

What is the particle size distribution in Na_2O smoke used as a basis for separator design?

Answer: There is some information on particle size in sodium oxide smoke. Probably this is not the best for establishing the basis for separator design. More desirable perhaps is to look at sodium particle size of the sodium particulate being ejected. But of course sodium oxide and sodium hydroxide particles range effectively around 1 micron size over a range of .1 microns to 3 microns size have been identified.

Question 8

How efficient are cyclone separators for off design effluent releases?

Answer: We haven't any quantitative data on separator efficiencies but we have had very effective results on comparative tests where we have the cyclone separator in addition to the primary charge tank.

Peterson Question

In the super noah shots where you had good separation were all these shots at about the same initial leak rate or have they been different?

Answer: The first one had the same quantity of water but at a much lower leak rate than the other two. The first test was the one carried out without the cyclone separator.

Ford

You have qualitative results with and without the separator?

Answer: Yes

Question 9

What settling times are allowed for reaction product separation in a reaction product tank?

Answer: Well I guess we allow the cooling time for reaction product tank as the separation time which takes several days. Once the temperatures are below 300°C the reaction products have separated out. The melting point of the reaction products are around 300°C .

Question 10

Can rupture disc inserts be replaced or is it necessary to replace the complete assembly? What type of rupture discs are used? What is the response time of the disc?

Answer: We use two types of discs: 1) the conventional dished disc, and 2) a thin membrane supported by a falling door which in turn is supported by a

shear pin. The response time to rupture after the design rupture pressure is exceeded is a few milliseconds.

Peterson Question

What is the time after the initiation of the leak to the rupture?

Answer: About 30 to 40 milliseconds for the conventional type disc and about 10 to 25 milliseconds later for the shear pin supported disc.

Question

Could you tell us the range as a percentage of the rupture pressure between non-rupture pressure and the rupture pressure.

Answer: The disc ruptures at 69 psig and the initial condition is approximately 10 psi.

Other Questions Not On List Transmitted to UK

Question

Have you considered the use of any of the following methods? What were your conclusions and experiences if you have used them? What limitations do you place on their use (e.g., fluid temperature, system temperature, cleaning time). Do you have a preference?

- A. Moist nitrogen
- B. Steam
- C. Water
- D. Organic solvent
- E. Sodium rinse
- F. Reactive fluids such as CO_2 and liquid NH_3

Answer:

- A. Negative
- B. Not alone but with nitrogen. We have used steam in air.
- C. We only use water for the final water wash.
- D. We haven't used them for this purpose.
- E. No we haven't used sodium.
- F. No we haven't used either of those.

Question

To what degree does stress corrosion susceptibility influence the materials or fabrication practice? What do you do to avoid stress corrosion?

Answer: If we keep the decontamination temperature down. We try to keep all our decontamination procedures below 160°C we don't believe there is a stress corrosion problem.

Question

What experience do you have on cleaning very dirty sodium such as decanted sodium from reaction product tank? Have you been successful using normal cold trapping? Is accelerated corrosion a potential problem?

Answer: No we do not attempt to recover sodium. We dispose of it by burning.

Question

Do you use liners in your reaction product tanks?

Answer: No we have considered the use of liners and have carried out a detailed design on how to line the tank. But in any event we have not used liners. We consider the liner to be more trouble than it is worth.

Question

Have you experienced any temperature and pressure conditions that would prohibit the use of carbon steel in the relief system.

Answer: No

Question

Do you use carbon steel?

Answer: Yes. Carbon steel is used beyond inlet to the surge vessel. The short relief line between the test vessel and the surge vessel is 1 1/4Cr. All other relief system components are carbon steel.

Ford

I would like to clarify something on the first question. Allen you gave the time for steam cleaning as 24 hours following the pre-cleaning operations for removing the reaction products and draining the sodium. What is the time for that?

Answer: On the work schedule that we operate on I would say several weeks for the decontamination. About three weeks this is day work only, with a limited crew because of the limited access to the rig.

Peterson

What does a limited crew consist of?

Answer: Two or three maximum.

Ford Question

You have heard the questions we have asked and they are rather specific. Knowing our concerns and that we are working on a large leak test rig do you have any recommendations in this area of clean up which you feel that would be valuable to us?

Answer: I think that we are reasonably satisfied that the methods we use at present are adequate.

Note:

The telephone connection with UK was lost at this time and the call was terminated.