BAW-1030

LIQUID METAL FUEL REACTOR EXPERIMENT

PRELIMINARY HAZARDS EVALUATION FOR THE USE OF SODIUM IN THE BNL FOUR-INCH LOOP

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BY
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I. INTRODUCTION

The contemplated use of sodium in place of bismuth in the secondary system of the Four-Inch Loop at Brookhaven National Laboratory requires a re-valuation of the loops design.

This report covers those design changes deemed necessary for safe operation of the system. It also includes an evaluation of the possible hazards involved and methods of coping with them. The hazards evaluated are commonly encountered in a system using one hundred percent sodium. No attempt is made here to cover the hazards of a sodium-bismuth reaction. Although instrumentation reliability is a big factor in hazards evaluation, this subject was not considered on the basis that satisfactory instruments and techniques have been and can be developed to meet most situations.

II. SUMMARY AND CONCLUSIONS

Excluding the effects of a sodium-bismuth reaction, the use of sodium in the secondary system of the Four-Inch Loop is safe and practical. There are no indications that the design as presented in the Catalytic Drawings A13001 through A13004 is not applicable for sodium.

With the proper indoctrination of the personnel involved, there should be no anxiety whatsoever concerning the use of sodium.

The suggested changes and additions required for safe operation of the system are listed below:

A. ADDITIONS

1. Sodium dump tank
2. Pre-charging filters
3. Clam shell heaters for the sodium drums
4. NaK scrubbing system for inert gas
5. Cold trap
6. Sodium sampling apparatus
7. Steel shield to surround entire loop
8. Steel drip pans
9. Met-L-X fire extinguishers
10. Special personnel safety equipment
11. Plugging indicator
12. Oil to water heat exchanger for cooling the main pump motor

B. CHANGES

1. Elimination of water as a coolant to the main pump
2. Heating of gas lines

III. CHARGING THE SYSTEM

The system as it now exists will require an additional dump tank of at least fifty percent more capacity than the inventory for the sodium loop. This extra volume is required for the following reasons:

1. Expansion of the charge due to heating or draining the system while hot.
2. Extra capacity needed to make up losses during operation.
3. Gas space that is needed in the tanks at all times.
4. Reduction of thermal shock due to draining a hot system by carrying a cold reserve in the charge tank to mix with the hot fluid.

To minimize the introduction of impurities into the system, it would be desirable to receive the sodium shipment in drums. The sodium should be soaked for several days at a temperature of 500 F or higher, cooled to 250 F and then passed through porous metal filters with a hole size of 15 microns or less to remove the sodium oxide. The filters can be installed between the drums and the dump tank.

Impurities also can be introduced into the system in the cover gas. Since Lamp Grade gases are cheaper, they are recommended after proper treatment for removal of oxygen, water vapor, and hydrocarbons.

A satisfactory method of treatment involves passing the gas through a heated NaK scrubbing system. The system consists of two NaK scrubbers and three traps. The gas is passed alternately through a trap and then through a scrubber. The first scrubber is kept at about 500 F to increase the rate of reaction between the contaminents and the NaK. The second scrubber is held at ambient temperature to condense any NaK vapor that may be entrained in the gas.

IV. SYSTEM CLEANING

During fabrication of the system, all components should be installed free of grease, dirt,oil, and other foreign materials which later may react chemically with liquid sodium in the system. Some form of degreasing should be applied since all metals normally are coated with a layer of oil or grease during fabrication.

Ordinary degreasing solutions are satisfactory, but care must be taken to remove all traces of the solution to guard against halogenated hydrocarbons which could react chemically with the sodium.

Because the system is constructed of Croloy which rusts upon contact with air, it will be necessary to flush the entire system with hot NaK or sodium. The choice of the material rests with the economics involved.

A system that has been operated with sodium for a number of hours may be completely freed of sodium using alcohol, steam, and water flushes respectively. Sodium in the solid state goes into solution in alcohol. The longer chain alcohols dissolve the sodium more slowly than the shorter chain alcohols; consequently, the rate of heat evolution is slower.

Butyl alcohol can be used first and the number of carbons in the alcohol decreased with the amount of sodium analyzed in the effluent. Finally dry saturated steam followed by a water rinse is used if necessary.

V. DESIGN CONSIDERATIONS

A. COLD TRAPPING

A cold trap to meet the requirements of the Four-Inch Loop is essential. Consideration of the effect of excess oxygen on the Croloy bears this out. Concentrations of oxygen greater than 0.005 percent accelerate the corrosion of Croloy. Careful examination of the loop must be made to eliminate all points where inadvertent cold trapping could take place. Cold trapping will occur wherever the temperature of the container is below the solubility temperature of Na_2O for that particular concentration. Points of suspect are instrument taps, valves, heat exchangers, and gas vents. Heaters at these points will remedy the situation.

A plugging indicator should be installed in conjunction with the cold trap. This is necessary to measure the effectiveness of the cold trap when only the total impurities are considered.

Chemical analysis requires provisions for taking sodium samples from the system.

B. INSULATION

The type of insulation selected for a sodium system should take into account the violent reaction between free and absorbed water and the sodium of the system. Sodium also reacts to a lesser degree with any material containing chemically bound water such as calcium silicate insulation or 85 percent magnesia.

High-density mineral fiber felts, molded aerogel, molded diatomaceous earth (1900 F type), and high-temperature molded amosite have been used on large-scale experimental liquid sodium lines. These materials have displayed adequate, although not complete, resistance to flow of liquid sodium.

Since the Four-Inch Loop is an experimental facility, it would be well to choose an insulation that can be removed and reinstalled rapidly.

C. PUMPS

The presently proposed secondary system includes a Byron Jackson canned motor pump. The electric motor is cooled by a circulating water system. If sodium is used in this system, water would not be advised as a heat transfer agent for the motor.

With a small amount of modification, oil could be circulated in the motor jacket. The oil then could be cooled by an oil-to-water heat exchanger, eliminating the hazard of running water lines into the cell.

D. VENT LINES

Due to the higher vapor pressure of sodium compared to bismuth, it will be essential to electrically heat the vent lines. Heating should extend about two or three feet from the liquid-gas interface to prevent the condensation of sodium vapor. Plugging the line that equalizes the pressure between the surge tank and the dump tank by condensed sodium vapor, would keep the system from draining completely.

Gas lines also should be heated to keep any molten sodium that is inadvertently forced into the line from freezing. This possibility exists when the system is being charged, or when gas pressure in different parts of the system is not equal.

VI. MECHANICAL EQUIPMENT FAILURES

To predict all possible mechanical equipment failures that could occur in the Four-Inch Loop would be impossible. However, the two major equipment failures that should be considered are discussed in the following paragraphs:

A. FAILURE OF THE SODIUM PUMP

If both loops of the system are operating as a unit and the sodium fails, the air supply to the sodium-to-air heat exchanger must be shut down immediately. This will prevent the sodium in the sodium-to-air heat exchanger from freezing. The furnace should be shut down simultaneously. All of the electrical heating units for the piping and components should be turned on as the temperature of the loops approach the freezing points of the coolant.

The pump should then be examined to determine the extent of the failure; the results from this investigation will determine the subsequent procedure.

If the failure is minor and can be repaired in a few minutes, dumping of the system is unnecessary. However, extensive repairs would require draining the sodium system.

B. FAILURE OF THE AIR SUPPLY TO THE HEAT SINK

This situation will require immediate shut-down of the furnace until the source of the trouble is located. Dumping the system should proceed only if evaluation of the failure indicates a prolonged delay. As before, the system temperatures must be carefully watched to prevent freezing of the liquid metal in the lines and components.

VII. PERSONNEL AND EQUIPMENT PROTECTION

The necessity of protecting operating and maintenance personnel cannot be over emphasized; however, a too conservative attitude concerning the hazards of a sodium system may prove outside the limits of practicality. Experience in operating sodium loops has indicated that an adequate design, proper fabrication, and a good operating procedure materially reduce the chances for a major accident. On the other hand, minor equipment failures will result in a certain amount of damage to material, but need not injure personnel. Fatigue failures of bellows operating valves, stress failures of welds, or mechanical failures of seals will result in sodium fires. The magnitude of the fires will be a function of the rupture size, sodium temperature, system pressure, and alertness of the operators in bringing the fire under control.

The most common hazard encounterd in using sodium is the reaction of liquid sodium in air. It will ignite spontaneously in air at temperatures above 240 F. In virtually all high-temperature sodium systems, a leak will result in a sodium fire

Sodium reacts violently with water, generating hydrogen and enough heat to ignite the hydrogen in the presence of air. It is therefore necessary to minimize the number of water lines entering a sodium experimental area to reduce the chances of such a reaction occurring.

Since the sodium pressure in the Four-Inch Loop will be in excess of 50 feet of head, it would be advisable to enclose the loop with a temporary shield. The shield should be constructed of at least 16 gauge sheet metal on adequate steel framing and extend from floor to ceiling. A clearance of five feet should be left around the loop for access. Plexiglass ports should be placed strategically around the cell.

The purpose of the shield is two-fold. It will protect operating personnel from being sprayed by a jet of liquid metal, and will serve to confine the Na_2O vapors for immediate removal by the exhaust fans. The vapors are very dense and highly toxic, obscuring the source of the fire and hampering efforts to extinguish it.

Steel drip pans should cover any exposed concrete where there is a possibility of liquid sodium contact. These pans keep the sodium from reacting with the combined water in the concrete and confine the sodium puddle there by making it easier to extinguish.

Because sodium readily reacts with halogenated hydrocarbons and CO_2, any fire extinguishers using this type of material should be removed completely from the vicinity of the loop.

Sodium fires can be extinguished by oxygen starvation. For this purpose soda ash and alkali metal chlorides can be used. Commercially available extinguishing agents are most satisfactory. An impregnated free-flowing sodium chloride is available in pressurized extinguishers under the trade name of Met-L-X. These extinguishers should be placed at convenient locations throughout the loop area. Open buckets of Met-L-X for application to the fire by scooping would be even more convenient.

All personnel engaged in fighting fires or maintaining or operating equipment in an exposed area should have the following equipment available:

Eye protection - Cup-type safety goggles and non-inflamable full-length face shields.

Head protection - Aluminum "hard" hat.

Foot protection - Moulders shoes

Body protection - Full-length chrome leather coats.

Hand protection - Chrome leather gloves and in some instances asbestos gloves.

Respiratory protection - Self contained rebreather type respiratory equipment.

REFERENCES

Liquid-Metals Handbook, Sodium-NaK Supplement, TID-5277 July 1, 1955.