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Sandia Sodium Purification Loop (SNAPL) Description and Operations Manual

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Prepared by
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Albuquerque, New Mexico 87185 and Livermore, California 94550
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SANDIA SODIUM PURIFICATION LOOP (SNAPL)
DESCRIPTION AND OPERATIONS MANUAL

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ABSTRACT

Sandia's Sodium Purification Loop was constructed to purify sodium for fast reactor safety experiments. An oxide impurity of less than 10 parts per million is required by these in-pile experiments. Commercial, reactor grade sodium is purchased in 180 kg drums. The sodium is melted and transferred into the unit. The unit is of a loop design and purification is accomplished by "cold trapping". Sodium purified in this loop has been chemically analysed at one part per million oxygen by weight.

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BACKGROUND

Sandia National Laboratories is conducting research into various safety aspects of liquid metal fast breeder reactors (LMFBR). Molten sodium is used as the core coolant heat transfer fluid in this type of reactor. Experiments are to be performed on the coolability of uranium fuel debris beds in sodium as well as other experiments involving interaction of fuel with sodium. These experiments will be run in Sandia's Annular Core Research Reactor (ACRR), where neutronic heating will simulate decay heating or other histories associated with applicable accident scenarios. The results of these experiments will aid in the development and validation of models for predicting the consequences of reactor accidents.

Sodium is available from numerous suppliers in several grades-commercial, high purity, reactor, etc. However, no universally accepted standard exists for specifying the purity of sodium and, as a consequence, the impurities analysis must be specified for the particular application.

The impurities in sodium come from two areas, 1) those impurities that are contaminants from the manufacturing process or source materials and, 2) those impurities that result from contact with other materials during the transport, storage and use of the sodium. Calcium, carbon and potassium are impurities left in, or as a result of, the manufacturing process. Calcium chloride is added to the electrolytic cell to reduce the melting point of the sodium chloride. Carbon comes from the graphite electrodes used in the fused salt process. Potassium chloride is a contaminant in sodium chloride. Potassium is the largest single impurity typically found in sodium, but potassium and sodium are similar in their properties and this impurity is of little consequence in usual applications. Oxygen and hydrogen are impurities picked up in the transportation and use of sodium. The oxygen comes from contamination by the air through leaks and connections and as a contaminant in the cover gas system. Hydrogen comes from contact with moisture or hydrocarbons. Hydrogen is also generated in a reactor steam generator where the water oxidizes the steel tubes. Hydrogen readily diffuses through the tubes into the secondary sodium system. If it is not continuously cold trapped there, it diffuses into the primary sodium system.

The reasons for limiting the impurities in sodium are several. First, impurities may cause metallurgical changes in structural materials and fuel cladding. Second, some impurities affect the neutron moderating process. A tentative purchase specification⁽¹⁾ for sodium is shown in Table I. Oxygen and hydrogen are left blank and are typically controlled by an on-line saturation temperature⁺ of 200°C.

⁺explained in Theory of Operation Section.

Since the Sandia experiments are static as opposed to the flowing cooling systems of a reactor, a sodium loop has been built to bring the oxygen and hydrogen levels of reactor grade sodium to those typically found in an LMFBR, i.e., <10 ppmw.

THEORY OF OPERATION

The solubilities of oxygen and hydrogen in sodium are temperature dependent. The solubility increases with increasing temperature for both elements. The sodium purification loop is a closed recirculating system in which sodium is circulated at some elevated temperature. The loop has several parallel legs for such purposes as pumps, flow meters, instrumentation, heaters and etc. In one of these parallel legs is a cold trap. In the cold trap, the temperature of the flowing sodium is dropped to a temperature several hundred degrees Celsius below the temperature of the rest of the loop. The oxygen and hydrogen that were in solution at the higher temperature are now supersaturated at the lower temperature and precipitate out of the sodium as sodium oxide (Na_2O) and sodium hydride (NaH). The cold trap contains a fine stainless steel wire gauze which traps the precipitates. The Sandia loop is typically operated at $400^\circ\text{--}120^\circ\text{C}$. At 400°C , the solubility of oxygen in sodium is 412 ppmw and at 120°C it is 1 ppmw. These values are those proposed by Noden⁽²⁾. In 1973, Noden correlated the data from 217 separate analyses of the solubility of oxygen in sodium by a least squares technique. The solubility thus derived is given by the equation:

$$\log_{10}[\text{O}_x]_{\text{ppmw}} = 6.1579 - 2384.2/T \quad (1)$$

where

O_x is oxygen solubility in parts per million by weight
 T is temperature in Kelvin.

A plot of equation 1 is shown in Figure 1. The solubility is tabulated in Table II. Sreedharan and Gnanamoorthy⁽³⁾ resurveyed the literature in 1979 and concluded, "Noden's solubility equation is shown to be the most rational choice for the Na-O system."

The solubility of hydrogen in liquid sodium is reported by Whittingham⁽⁴⁾ to be given by the equation

$$\log_{10}[\text{H}]_{\text{ppmw}} = 6.467 - 3023/T \quad (2)$$

where

H is hydrogen solubility in parts per million by weight and
 T is temperature in Kelvin.

This least squares fit of experimental data is plotted in Figure 2 and tabulated in Table III.

TABLE I Procurement Specification Guide

<u>Impurity</u>	<u>Maximum Concentration wppm</u>	<u>Impurity</u>	<u>Maximum Concentration wppm</u>
Aluminum	10	Lithium	10
Barium	10	Mercury	35
Boron	x	Magnesium	x
Cadmium	x	Manganese	x
Calcium	10	Nickel	10
Carbon	30	Nitrogen	5
Cesium	5	Oxygen	*
Chromium	10	Phosphorus	20
Cobalt	x	Potassium	200
Copper	5	Rubidium	50
Hydrogen	*	Silicon	10
Indium	x	Silver	x
Iron	25	Strontium	10
Lead	10	Sulfur	30
		Tin	10
		Halogens	20

x Composition limits not set

* To be controlled in application

Figure 1. Solubility of Oxygen in Sodium

Table II
Solubility of Oxygen in Sodium

<u>Temp</u> <u>°C</u>	<u>Oxygen</u> <u>ppmw</u>	<u>Temp</u> <u>°C</u>	<u>Oxygen</u> <u>ppmw</u>
120	1.2	275	64.1
125	1.5	280	70.2
130	1.7	285	76.8
135	2.1	290	83.8
140	2.4	295	91.3
145	2.8	300	99.3
150	3.3	305	107.9
155	3.9	310	117.0
160	4.5	315	126.8
165	5.2	320	137.2
170	6.0	325	148.2
175	6.9	330	160.0
180	7.8	335	172.3
185	9.0	340	185.6
190	10.2	345	199.5
195	11.6	350	214.3
200	13.1	355	229.8
205	14.8	360	246.3
210	16.7	365	263.6
215	18.7	370	281.8
220	21.0	375	301.0
225	23.5	380	321.2
230	25.2	385	342.4
235	29.1	390	364.6
240	32.4	395	387.9
245	35.9	400	412.3
250	39.7		
255	43.9		
260	48.4		
265	53.2		
270	58.5

Figure 2. Solubility of Hydrogen in Sodium

Table III
Solubility of Hydrogen in Sodium

<u>Temp °C</u>	<u>Hydrogen ppmw</u>
120	0.06
130	0.09
140	0.14
150	0.21
160	0.31
170	0.44
180	0.62
190	0.87
200	1.19
250	4.86
300	15.53
350	41.18
400	94.44

From these solubility data, it can be seen that hydrogen is less soluble in sodium than is oxygen and that the cold trap reduces the hydrogen impurity in the sodium to a lower level than the oxygen impurity.

If the original charge of sodium contains calcium as well as oxygen ($\text{Ca} > 4$ ppmw), calcium oxide will be formed in preference to sodium oxide and will be precipitated in the cold trap⁽¹⁾.

Other impurities in the sodium are unaffected by the loop operation (except in a negative sense whereby the loop adds impurities). Other techniques of purifying sodium include hot traps (solid getters), soluble getters, filtration, settling and centrifuging - see Reference 1 for a discussion of these methods.

SODIUM LOOP DESCRIPTION

The sodium loop is shown schematically in Figure 3. Basically, the loop consists of the necessary pipes, tanks, valves, pumps, heaters and controls to safely circulate and maintain molten sodium at a temperature of 400°C . Since molten sodium is a hazardous material, a great deal of attention was devoted to the design of the loop. The loop is located in a remote area (Tech Area III) of Sandia National Laboratories where the consequences of a loop failure are minimized. The loop is under the complete control of a dedicated computer system.

Mechanical

Referring to Figure 3, the loop has two tanks; a supply tank (T1) used to fill the loop but not a part of the circulating system and tank T2 which holds the major portion of the circulating sodium. The capacity of the tanks are 68 (257ℓ) and 12 (45.5ℓ) gallons, respectively. The cold trap holds approximately 7 gallons (26ℓ) of sodium. All of the valves and expansion volumes in the loop have trace heaters. The tanks, cold trap, pump, piping and economizer have "calrod" type heaters. These heaters are necessary to get sodium flowing initially. Once flow has been established, the bulk heater supplies most of the energy necessary to raise and maintain the temperature of the circulating sodium at 400°C . The cold trap is of the forced-air convection type. The cold trap is shown in Figure 4. The economizer, which is in series with the cold trap, is used to assist in heating the cool sodium leaving the cold trap back to 400°C . It is a single pass counterflow heat exchanger.

Electromagnetic Pump

An A.C. conduction electromagnetic pump circulates the molten sodium in the loop. The pump operates on the principle of the "left-hand rule." This describes the direction of the force produced on a conductor by a current and a magnetic flux. The principle is illustrated in Figure 5.

Figure 3. Schematic of Sodium Purification Loop

Figure 4. Cold Trap

Figure 5. Left-Hand Rule

In a conduction-type electromagnetic pump, the liquid sodium is a conductor of electricity. When current passes through the pumping section perpendicular to the magnetic field, a force is produced in the liquid sodium within the pumping section that is at right angles to the current and magnetic field. Figure 7 shows how the current and flux are produced in the electromagnetic pump. Two current transformers, connected in series, supply the current in the secondary conductor (bus bars). The current flows through the pumping section wall to the liquid sodium and out the other wall. This forms a continuous current path across one flattened portion. The bus bars are attached to the pumping section using a high temperature braze. The magnetic flux in the pumping section is produced by coils on each leg of two U-shaped laminated magnetic iron cores. The cores are positioned so that the two flattened portions of the pumping section are in the air gaps. At a given voltage input to the pump, there will be a corresponding output of flow and developed head. The performance curve for the pump showing this flow-pressure relationship is shown in Figure 6.

The electromagnetic pump circulates sodium not only around the loop but also through the experimental apparatus when it is attached to the loop on one of the "exit" legs shown in Figure 3. In this way, contamination in the experimental apparatus may also be removed.

Cover Gas System

The loop is provided with a vacuum and cover gas system. This system provides for the initial purge from the loop of air and moisture, provides a vacuum to assist in filling the loop with sodium and provides a positive pressure inert gas cover (argon) so that any small leak will not allow air back into the system. Figure 8 is a schematic of the cover gas system.

Valves and Piping

All parts of the loop exposed to sodium are fabricated of stainless steel. The piping is 304L stainless steel and was chosen for its corrosion resistance and for its good welding characteristics. Each segment, before it was welded into the loop, was cleaned according to the procedure outlined in Table IV. This cleaning process insured that the loop itself introduced as few contaminants as possible into the original charge of sodium.

There are 114 welds on the loop. The welds were made with a tungsten/inert gas, automatic pipe welding machine. Each weld was x-rayed for flaws. The loop was tested with a helium leak detector after final assembly.

Bellows type valves are used on the loop. The stems of these valves do not rotate and the stainless steel bellows provides a positive barrier against sodium leakage. See Figure 9. Any attempt to operate a bellows valve when the sodium is still frozen will probably rupture the bellows.

Figure 6. Electromagnetic Pump
Flow Characteristics

Figure 7. Two-Stage Electromagnetic Pump

COVER GAS SYSTEM

Figure 8. Cover Gas System

TABLE IV
Cleaning Procedure

For piping system and components
intended for sodium service

1. Vapor degrease with Trichloroethylene
2. Caustic electro cleaner (sodium hydroxide)
3. Tap water rinse
4. Rinse in 50% by volume hydrochloric acid (to remove heavy oxides)
5. Tap water rinse, DI (Deionized water) rinse followed by tap water rinse
6. Rinse in 15% hydrogen peroxide at 125-130°F
7. Tap water rinse
8. DI water rinse (2 stages)
9. Dry with isopropyl alcohol

Figure 9. Bellows Valve

All valves on the loop are manually operated except one. Valve number 1 in Figure 3 is an electrically operated pneumatic valve. This valve is located on one corner of the loop that, by design, is the lowest point of the recirculating portion of the loop. When valve number 1 opens, all of the sodium drains back into the storage tank, T1, except for that sodium in the cold trap. Besides draining the loop on normal shutdown, valve number 1 acts as a safety valve when the loop is running unattended by opening on electrical power failure. However, it has been found necessary to circumvent this safety feature on occasion. Thunderstorms are frequent in this area during July and August. Lightning strikes cause power failures that last from a few seconds to as much as half an hour. The power failures cause valve number 1 to open and drain the loop, with the possible loss of several days of cold trapping time. To prevent this from happening, a bypass tube has been placed on valve number 1 that supplies gas pressure to both sides of the actuating diaphragm at the same time. The pressure bypass may be used only when the loop operator is present. On unattended operation, the valve is always placed in the mode that will drain the loop on power failure.

Instrumentation

Magnetic Flowmeters

The flow of sodium through the various legs of the loop is measured by magnetic flowmeters. These devices act in the reverse sense of the electromagnetic pump. A conductor moving in a magnetic field generates a current in a direction perpendicular to the moving conductor and to the field. Permanent magnets are used for the flowmeters since it is only necessary to produce millivolts for measurement purposes. See Figure 10. The emf generated by the sodium flowing in the meter may be calculated by the equation (5).

$$\text{emf(mv)} = \frac{QB(K1)(K2)(K3)}{3162d(K4)} \quad (3)$$

where

- Q = flow rate (gpm)
- d = pipe inside diameter (in.)
- B = flux density (gauss)
- K1 = pipe wall shunting factor
- K2 = end effect factor
- K3 = magnet temperature factor
- K4 = pipe expansion factor

$$K1 = \frac{2dD}{D^2 + d^2 + ((p1/p2)(D^2 - d^2))} \quad (3a)$$

where

- D = pipe outside diameter (in.)
- p1/p2 = ratio of electrical resistivities
(1=sodium, 2=pipewall)

Figure 10. Schematic of Electromagnetic Flowmeter

$$K4 = 1+a(T-T_0)$$

(3b)

where

a = coefficient of thermal expansion (pipe)

T = temperature (°F)

K2 and K3, the end effect and magnetic temperature factors, may be obtained from Figure 11 and 12. The sodium loop has flowmeters for one-half and three-quarter inch diameter pipes. The calculated outputs for these flowmeters are 0.48 and 0.32 mv/gpm, respectively. It is stated in Reference 5 that the difference between calculated and calibrated flow factors for these meters is within a few percent - entirely satisfactory for our purposes of dividing the flow of sodium between the various parallel legs of the loop.

Thermocouples

One hundred twenty-three thermocouples monitor temperatures around the loop. Fifty-eight connect to the computer. Forty-two connect to the manual control system and 23 are backup. The couples are type J, iron-constantan. Another 14 thermocouples are available on the two exit legs of the loop where experiments to be filled would be located. On thick sections such as valve bodies, the thermocouples were spot welded directly to the valve body. Rather than weld thermocouples directly to the piping, a special thermocouple well was designed. Drawings T72443 to T72445 (Fig. 13) give details of the well. The location of each thermocouple is shown on drawing T73298 (Fig. 14). A complete list of drawings for the loop is given in Appendix D. Any drawing referenced in the body of this report is also included in Appendix D.

Oxygen Meters

Three oxygen meters are installed on the sodium loop. Meters are manufactured by either General Electric Co. or by Westinghouse. The meters are similar in design. A solid electrolyte material separates two electrodes. The solid electrolyte is yttria doped thoria. One electrode is the molten sodium. For the reference electrode, GE uses a solid mixture of a metal and its oxide (gallium, indium or tin) whereas WE uses a gas. In the WE meter, the thoria is platinum coated on the gas electrode side. The gas electrode is normally air, but may have any oxygen concentration between 100% to below 10 ppm as long as the concentration is known and kept constant. Figure 15 shows a schematic of the WE cell. The solid electrolyte, thoria, has the ability to conduct oxygen ions by means of lattice vacancies. Since the oxygen activity in the sodium is so low, there is a spontaneous tendency in the cell for oxygen ions to migrate from the reference electrode to the sodium electrode. This migration results in the creation of an electrochemical concentration cell with a corresponding electromotive force (voltage). Measurement of this voltage gives an indication of the oxygen concentration in the molten sodium. The voltage is best measured by a differential electrostatic meter so that

Figure 11. Flowmeter End Effect

Figure 12. Flowmeter Temperature Correction Factor

oxygen ions are not driven to the sodium. The expected voltage output for the meters are as follows:

General Electric Meter

$$\text{emf} = 0.269 + \frac{160}{T} \text{ volts (sensor at 773K)} \quad (4)$$

where T is the cold trap temperature in degrees K

The temperature coefficient of the meter is given as 0.51 mv/K.

The Sandia loop operating at 400°C (673K) with a cold trap temperature of 120°C (393K) would give an output of about 675 mv.

Westinghouse Meter

$$\text{emf} = 1.843 - 0.064 \text{ Log } C \text{ volts (sensor at 744K)} \quad (5)$$

where C is the oxygen concentration in ppm.

The temperature coefficient of the meter is given by the manufacturer as $-0.068 - 0.055 \text{ Log } C \text{ mv/}^\circ\text{F}$.

The Sandia loop operating at 400°C (673K) with a cold trap temperature of 120°C (393K) would give an output of about 1.78v.

Figure 16 shows the averaged output of several meters from both manufacturers.

Calibration of these oxygen meters is difficult. One technique is to add a measured quantity of sodium hydroxide pellets to the sodium in the loop through a gate valve (Valve 21, Figure 3). This is a hazardous undertaking and was only performed at loop start-up. Typically, the oxygen concentration in the sodium is assumed to follow the equation of Noden (eq. 1). Experience has shown this to be a good assumption. The oxygen meters have been used as indicators only. During an experiment purification and filling session, the oxygen meters are monitored until they come to an equilibrium value, at which point the oxygen concentration is taken as the value associated with cold trap temperature.

The major problem with both meters is thermal shock sensitivity. The thoria solid electrolyte is extremely sensitive to cracking if the temperature change rate exceeds 2°C/min. This rate has been exceeded on numerous occasions. Power failure when the loop is unattended has been the main reason. The loop automatically drains on an unattended power failure, exposing the oxygen meters to fast cooling rates. Consequently, after several years of operation, only one of the meters is functional.

Figure 15. Schematic of Westinghouse Oxygen Meter

Figure 16. Oxygen Meter Output

Level Detection

Normal operation of the sodium loop requires that the amount of sodium in the storage tank, T1, and in the circulation tank, T2, be known. This is accomplished with two types of level detectors and a knowledge of the volumes of the tanks.

A multipoint level detector was designed and built for tank T2 on the loop. This detector is shown schematically in Figure 17. Seven stainless steel rods extend down into the tank through a flange. Each rod is electrically insulated from all other rods and also from the tank. Each rod extends to a different level in the tank. A light emitting diode is placed in series in the electrical circuit of each rod. A 5 volt source is imposed on each rod with the return circuit being the tank. As sodium raises in the tank, it contacts the lowest positioned rod and that diode lights. As sodium fills the tank, each diode in turn lights. Knowing the position of the rod tips above the tank bottom gives an indication of the level of the sodium in the tank and, consequently, the volume of the sodium. Tank elevation versus volume is given in Table V. A major problem with the multipoint level probe is that sodium vapor forms a frost. This frost collects on the rods making the location of the tip uncertain and sometimes shorts one rod to another. Gently tapping the probe flange will occasionally dislodge the frost. A second technique for measuring sodium in Tanks T1 and T2 is a "bubbling" manometer.

A schematic of a bubble manometer is shown in Figure 18. The manometer measures the difference in pressure between the bottom of the tank and the liquid sodium surface. A tube is inserted through the top of the tank with its opening at the bottom of the tank. An inert gas supply is connected to the tube. With sodium in the tank, the gas pressure is increased until approximately one bubble per second is generated. Bubbles in the tank cannot be seen so a bubble chamber is placed in the gas line. The pressure side of the manometer (the manometer well) is connected to the gas line while the top of the manometer is connected to the vapor space above the sodium. Various valves, checkvalves and vents are required to insure that the sodium never comes into contact with the liquid in the manometer or in the bubble chamber. The manometer scales are calibrated in gallons of sodium in the tank.

Power and Control

Computer

The entire sodium loop is under the control of a dedicated computer system. The loop operates for hundreds of hours at equilibrium without human intervention. The computer interrogates the various parts of the system, makes comparisons, decisions and issues commands or alarms. Figure 19 is a schematic of the system instrumentation, controls and alarms.

Figure 17. Probe Level Detector Schematic

TABLE V
TANK T1 VOLUME

h	V _{Total}	h	V _{Total}
[in]	[gal]	[in]	[gal]
.250	.357	12.000	42.523
.500	.828	12.250	43.510
.750	1.370	12.500	44.498
1.000	1.968	12.750	45.488
1.250	2.613	13.000	46.478
1.500	3.299	13.250	47.467
1.750	4.020	13.500	48.454
2.000	4.774	13.750	49.438
2.250	5.556	14.000	50.418
2.500	6.364	14.250	51.394
2.750	7.196	14.500	52.362
3.000	8.048	14.750	53.324
3.250	8.920	15.000	54.277
3.500	9.810	15.250	55.220
3.750	10.714	15.500	56.151
4.000	11.634	15.750	57.070
4.250	12.565	16.000	57.975
4.500	13.508	16.250	58.865
4.750	14.461	16.500	59.737
5.000	15.422	16.750	60.589
5.250	16.391	17.000	61.421
5.500	17.366	17.250	62.229
5.750	18.347	17.500	63.011
6.000	19.331	17.750	63.765
6.250	20.318	18.000	64.486
6.500	21.307	18.250	65.172
6.750	22.297	18.500	65.817
7.000	23.287	18.750	66.415
7.250	24.275	19.000	66.957
7.500	25.262	19.250	67.428
7.750	26.245	19.500	67.785
8.000	27.225		
8.250	28.199		
8.500	29.168		
8.750	30.130		
9.000	31.084		
9.250	32.030		
9.500	32.966		
9.750	33.892		
9.750	33.892		
10.000	34.818		
10.250	35.755		
10.500	36.701		
10.750	37.655		
11.000	38.617		
11.250	39.586		
11.500	40.560		
11.750	41.540

TABLE V
TANK T2 VOLUME

h	V _{Total}	h	V _{Total}
[in]	[gal]	[in]	[gal]
.105	.061	5.249	7.876
.210	.142	5.354	8.052
.315	.236	5.459	8.228
.420	.341	5.564	8.403
.525	.453	5.669	8.578
.630	.573	5.774	8.752
.735	.699	5.879	8.925
.840	.831	5.984	9.098
.945	.968	6.089	9.269
1.050	1.110	6.193	9.439
1.155	1.256	6.298	9.607
1.260	1.406	6.403	9.773
1.365	1.560	6.508	9.938
1.470	1.716	6.613	10.100
1.575	1.876	6.718	10.259
1.680	2.038	6.823	10.415
1.785	2.202	6.928	10.569
1.890	2.368	7.033	10.719
1.995	2.536	7.138	10.865
2.099	2.706	7.243	11.007
2.204	2.877	7.348	11.144
2.309	3.050	7.453	11.276
2.414	3.223	7.558	11.402
2.519	3.397	7.663	11.522
2.624	3.572	7.768	11.635
2.729	3.748	7.873	11.739
2.834	3.923	7.978	11.833
2.939	4.099	8.033	11.914
3.044	4.274	8.188	11.975
3.149	4.449		
3.254	4.624		
3.359	4.798		
3.464	4.972		
3.569	5.144		
3.674	5.316		
3.779	5.486		
3.884	5.655		
3.989	5.822		
4.094	5.988		
4.094	5.988		
4.199	6.153		
4.304	6.320		
4.409	6.489		
4.514	6.659		
4.619	6.831		
4.724	7.003		
4.829	7.177		
4.934	7.351

Figure 18. Bubble Manometer Level
Detector Schematic

Figure 19. Sodium Loop Instrumentation, Alarms and Control Schematic

Because sodium is a hazardous material, numerous failure modes must be anticipated and provisions made to minimize the consequences of these failures. In the event of a sodium leak and fire, heat and smoke detectors over the loop will alarm. Panic buttons at each outside door to the building scram the loop--draining the sodium back into the storage tank, kill all power to the loop and to the building heating and ventilating system--and send an alarm to the security center. Opening the door to the emergency shower sounds an alarm, turns on the shower and automatically calls an ambulance. In case the computer itself fails, a reset timer and relay turns off power to the loop. The timer is set to countdown from 5 minutes and to open the control power relay at that time. The computer must reset this timer within the 5 minutes if the loop is to continue to operate. Actually, the computer goes through a complete cycle about once every 30 seconds and resets the timer every third cycle. The loop also shuts down if the computer senses temperatures that are over a predetermined set point. This set point is different from the control set point. The actual control functions are:

1. Heater on-off (time on is variable)
2. Cold trap fan on-off
3. E.M. Pump on-off
4. Vacuum pump on-off
5. Drain valve open-close
6. Entire system on-off

The system is divided into control zones - called legs in Figure 3. The heaters in any leg operate independently. The length of time that a heater is on depends on how far the heater temperature is from the control temperature set point. The temperature of the entire system, a leg or an individual heater may be set with a single command. The exception to this is that the oxygen meter legs and the cold trap leg will not respond to a command to LOWER the temperature of the entire system. This is a safety feature to protect the oxygen meters and to keep from inadvertently freezing the cold trap. All other control functions are simple on-off. The flow of the electromagnetic pump is manually adjustable. A typical control circuit is shown in Figure 20. As shown in this figure, it is possible to control various functions manually. Any given heater may be turned on or off by setting a switch on the control panel. The same is true for the other functions. Wrapable heaters were used on the valves and expansion volumes and "cal-rod" type heaters on the piping and tanks. The valve heaters are one-half inch wide and of various lengths. They are rated at 48 watts per foot. The cal-rod heaters are tubular with inconel sheaths and magnesium oxide insulation. Heaters were rated at either 30 watts per inch or 22 watts per inch and 240 volts. All heaters except the pump heaters are operated at 120 volts to increase heater life. The heater switches are three position type. In the up position, the heater is under computer control, down it is manually on, and in the middle position it is off. The middle position is also a test position--if the heater is electrically good, the pilot light is off, if not, the pilot light glows softly (less brightly than when the heater is on).

Figure 20. Typical Control Circuit

Control Description

The computer control and data acquisition system consists of the following:

1.	Minicomputer	HP 9845B*
2.	Multiprogrammer	HP 6940B
3.	Interface Item 1 to Item 2	HP 59500
4.	Scanners (2)	HP 3495A
5.	Digital voltmeter	HP 3455A
6.	Power conditioner	Elgar 6000B
7.	Electrometers (2)	Keithly 642
8.	Disc drive for Item 1	HP 9895A

*HP = Hewlett Packard

Electrical connections for the computer control and data acquisition system are shown in Table VI. The first channel on each scanner card is a reference junction for the thermocouples on that card (i.e., 0, 20, 40, 60). Data can be acquired on paper, magnetic tape and disc. The computer program contains a plotting routine so that the data may be plotted as a function of time or some other variable. During normal operations, the results of each computer scan are shown on the screen. The screen display for one such scan is shown in Figure 21. After the date and time line, the channel number is shown in column one. There are three channels per line so the next channel number listed is Channel 4. Next, is a description of where that thermocouple is located. V10 stands for Valve Number 10. The next column gives the temperature for that channel and the fourth column the temperature deviation from the set point. A negative value means that the temperature shown is that many degrees below the set point. The above information is repeated for each channel. At the bottom of the screen display is a line of other than temperature information. The first five are the output of flowmeters in the described legs and the last three are the output of the oxygen meters. Several other lines of information may appear after the ones shown to include warnings of over temperatures, the fact that the fail-safe relay has been reset, or that data record number such-and-such was recorded on the disc or tape. Another form of data display is available. Looking at Figure 21 it is obvious that the operator would have to be close to the screen in order to read any values. The operator may select a display that he can see from anywhere in the control room. In this mode, the operator selects five channels that are of particular interest to him and by use of the "big on" command these five channels and the five flowmeter channels are displayed in large print on the computer screen. A display of this type is shown in Figure 22. Channels 16, 18, 44, 45 and 70 are shown with their corresponding temperatures while the five flowmeters show essentially zero flow. A listing of the computer control code is enclosed on microfiche on the inside back cover of this report.

TABLE VI
Sodium Purification Loop
Thermocouple/Heater Connections

CHN:		SYSTEM DESCRIPTION	T/C	CARD	HP3495A		HP6940B		
					CON	HEATER	CARD	PINS	
	0	-----	Ref.	1	0	--	--	--	
L	1	Oxygen loop 1 V10 inlet	100	1	1	28	1	1,A	
E	2	V11 return	92	1	2	29	1	2,B	R
G	3	V12 exp.vol.	96	1	3	30	1	3,C	E
	4	Oxygen meter 1	32	1	4	38	1	4,D	L
O	5	Expansion vol.	40	1	5	41	1	5,E	A
	6	Inlet pipe	52	1	6	10	1	6,F	Y
	7	Exit pipe	56	1	7	11	1	7,H	
<hr/>									
	8	Oxygen Loop 2 V8 inlet	102	1	8	26	1	8,J	S
L	9	V9 return	94	1	9	27	1	9,K	E
E	10	V13 exp. vol.	98	1	10	31	1	10,L	T
G	11	Oxygen meter 2	26	1	11	39	1	11,M	A
	12	Oxygen meter 3	30	1	12	40	1	12,N	
1	13	Expansion vol.	42	1	13	42	2	1,A	
	14	Inlet pipe	50	1	14	43	2	2,B	
	15	Exit pipe	54	1	15	12	2	3,C	
<hr/>									
L	16	Electromagnetic pump exit pipe	10	1	16	50		4,D	R
E									E
G									L
2	17	inlet pipe	--		--	--	-	----	A
									Y
<hr/>									
	18	Bulk heater inlet	16	1	18	Top	2	5,E	S
L	--		--	-	--	Top	2	6,F	E
E	--		--	-	--	Top	2	7,H	T
G	--		--	-	--	Top	2	8,J	
	19		14	1	19	Bottom	2	9,K	
3	--		--	-	--	Bottom	2	10,L	B
	--		--	-	--	Bottom	2	11,M	
	--		--	-	--	Bottom	2	12,N	
<hr/>									
	20	---	Ref.	2	0	--	-	----	
L	21	T2, Storage tank V4 inlet	104	2	1	22	3	1,A	R
E	22	V5 return	106	2	2	23	3	2,B	E
G	23	V21 port	108	2	3	37	3	3,C	L
	24	Bottom T/C	20	2	4	T2 Heater	3	4,D	A
4	25	Inlet pipe	84	2	5	44	3	5,E	Y
	26	Exit pipe	86	2	6	45	3	6,F	

TABLE VI Cont.

CHN:	SYSTEM DESCRIPTION	T/C	CARD	HP3495A		HP6940B		PINS	
				CON	HEATER	CARD			
L E G	27 Exit pipes	V14	122	2	7	32	3	7,H	S
	28	V15	118	2	8	33	3	8,J	E
	29	V16	116	2	9	34	3	9,K	T
	30	V17	120	2	10	35	3	10,L	
	31	Exit pipe V14-V17	78	2	11	17	3	11,M	C
5	32	Exit pipe V15-V16	74	2	12	18	3	12,N	
L E G 6	33 Tl, Storage tank	V1 inlet	124	2	13	19	4	1,A	
	34	V2 return	90	2	14	20	4	2,B	R
	35	V20 port	88	2	15	36	4	3,C	E
	36	Rt. end cap	2	2	16	Tl-side	4	4,D	L
	37	Lt. end cap	8	2	17	--	4	----	A
	38	Top T/LC	6	2	18	Tl-top	4	5,E	Y
	--		--	--	--	Tl-top	4	6,F	
	39	Bottom T/C	4	2	19	Tl-Bot-Rt	4	7,H	S
	--		--	--	--	Tl-Bot-Rt	4	8,J	E
	--		--	--	--	Tl-Bot-Lt	4	9,K	T
	--		--	--	--	Tl-Bot-Lt	4	10,L	
	--		--	--	--	Tl-Bot-Ctr	4	11,M	D
	--		--	--	--	Tl-Bot-Ctr	4	12,N	
L E G 7	40	---	Ref.	3	0	--	--	----	
	41 Tl, Storage tank	pipe	82	3	1	46	5	1,A	R
	42 Cold trap	V6 inlet	110	3	2	24	5	2,B	E
	43	V7 return	114	3	3	25	5	3,C	L
	44	Trap T/C 1	126	3	4	Heater 1	5	4,D	A
	45	Trap T/C 2	129	3	5	Heater 2	5	5,E	Y
	46	Inlet pipe	72	3	6	13	5	6,F	
	47	Transition pipe	70	3	7	14	5	7,H	S
	48	Recovery pipe	76	3	8	15	5	8,J	E
	49	Return pipe	80	3	9	16	5	9,K	T
L E G 8	50 Pipe loop	V3 control	112	3	10	21	5	10,L	
	51	Pipe	44	3	11	9	5	11,M	E
	52	Pipe	62	3	12	6	5	12,N	
	53	Pipe	48	3	13	8	6	1,A	
	--	Pipe	--	--	--	7	6	2,B	R
	54	Pipe	68	3	14	5	6	3,C	E
	55	Pipe	66	3	15	4	6	4,D	L
	56	Pipe	64	3	16	3	6	5,E	A
	57	Pipe	60	3	17	2	6	6,F	Y
	58	Pipe	58	3	18	1	6	7,H	
	59	(Not in Use)					6	8,J	

TABLE VI Cont.

CHN:	SYSTEM DESCRIPTION		T/C	CARD	HP3495A		HP6940B		
					CON	HEATER	CARD	PINS	
	60	---	Ref.	4	0	--	-	----	S
	61	Glove box GB1	200	4	1	71	6	9,K	E
	62	GB2	201	4	2	72	6	10,L	T
	63	Experimenters Ex1	202	4	3	73	6	11,M	
	64	Ex2	203	4	4	74	6	12,N	F
L									
E	65	Ex3	204	4	5	75	7	1,A	
G	66	Ex4	205	4	6	76	7	2,B	
	67	Ex5	206	4	7	77	7	3,C	
	68	Ex6	207	4	8	78	7	4,D	
	69	Ex7	208	4	9	--	-	----	R
9	70	Ex8	209	4	10	--	-	----	E
	71	Ex9	210	4	11	--	-	----	L
	72	Ex10	211	4	12	--	-	----	A
	73	Ex11	212	4	13	--	-	----	Y
	74	Ex12	213	4	14	--	-	----	
<hr/>									
Equipment Control Connections									S
	Cold trap blower	---	-	--	--	7	5,E		E
	Drain valve	---	-	--	--	7	6,F		T
	Vacuum pump	---	-	--	--	7	7,H		
	Sodium electromagnetic pump	---	-	--	--	7	8,J		G
	Fail safe timer	---	-	--	--	7	10,L &11,M		

Date: 03/17 Time 12:54:53

1	V10	22	0	V11	22	0	V12	22	0
4	OS1	22	0	EV1	22	0	H10	22	0
7	H11	22	0	V8	22	0	V9	22	0
10	V13	22	0	OS2	22	0	OS3	22	0
13	EV2	22	0	2-3	22	0	H12	22	0
16	H50EMPo	22	0	Noneemp	22	0	Bulk in	22	-0
19	Bulk out	22	-0						
21	V4	22	0	V5	21	0	V21	22	0
24	T2	22	-0	V4-T2	22	0	V5-T2	22	0
27	V14	21	0	V15	21	0	V16	21	0
30	V17	21	0	H17	21	0	H18	21	0
33	V1	22	0	V2	22	0	V20	22	0
36	TlEndCap	24	-0	TlEndCap	24	-0	TlTop	24	-0
39	TlBot	24	-0						
41	V20-T1	22	0	V6	22	0	V7	21	0
44	C.T.	21	1	C.T.	21	1	H13	22	0
47	H14	22	0	H15	22	0	H16	22	0
50	V3	21	0	H9	22	0	H6	22	0
53	H7&H8	22	0	H5	21	0	H4	22	0
56	H3	21	0	H2	22	0	H1	22	0
61	GB1	25	1	GB2	25	1	EX1	20	-0
64	EX2	20	1	EX3	20	0	EX4	20	1
67	EX5	20	-1	EX6	20	1	EX7	20	
70	EX8	20		EX9	20		EX10	20	
73	EX11	20		EX12	19				

Pump	OS1	OS2	C.T.	Exit	WHOUSE	G.E.2	G.E.3
.0001	.0001	-.0057	0.0000	.0001	.0107	.0001	0.0000

Fig. 21 Screen display for one scan of control program

16	21	PUMP	.000
18	22	OS1	.000
44	16	OS2	.011
45	16	C.T.	.000
70	18	EXIT	0.000

Figure 22. Screen Display in Large Type Mode (Control Program Keystroke "Big On")

Manual Control

In addition to the computer control system, a very simple manual control system is available. Its function was to assist in the original check out of the loop and the computer control program. It also would be used to control the oxygen meter legs in the event of other control failures. Finally, the system is used as a monitor to check suspect thermocouples. Many locations around the loop have two thermocouples at the same place. If the computer is reporting an illogical temperature, the temperature of the companion thermocouple may be checked with the manual system in order to isolate whatever problem exists. The following items are included:

1. Temperature controller (4)
2. Switch, thermocouple 20 position (2)

The manual control system details are shown on drawings T74697, CK-T74697, T74704 and CK-T74704.

OPERATING PROCEDURES

The Safe Operating Procedure for the sodium loop, SOP#05500 8103, should be read before any attempt is made to operate the loop.

In all of the following procedures, it is assumed that the loop is leak tight and is free of oxygen, moisture and other foreign substances. Since the loop has been in operation for several years, it is also assumed that the loop contains sodium in Tank T1, in the cold trap and in numerous other places where small amounts of sodium do not freely drain when the loop is shutdown.

Filling and Circulating Sodium in the Loop

All sections of the loop that are to be filled must be above the melting point of sodium, 97.83°C. In practice, the temperature is set to 200°C. To accomplish this, refer to Appendix A on procedures to load and execute the computer control program. Follow the checklist in Table VII.

Sodium now fills the circulating portion of the loop. Flow may be established by manually setting the pump control variac to some low value such as 15 to 20%. If pumping starts, it will be indicated on the pump flowmeter output meter which is just above the variac hand wheel and also on the computer screen. Quite often, pumping does not start immediately. In that case, leave the variac setting at 15 to 20% until pumping does start. It is common for a solid plug of sodium to exist in the pump even though temperatures indicate that all of the sodium should be melted. The pump thermal insulation, by design, is not as complete as other parts of the loop. Once flow is established, then the flow rate may be adjusted and the flow through the various legs of the loop partitioned. The experimental package should be brought to the same temperature as the loop and then Valves 14 & 15 or 16 & 17 should be opened to allow sodium to circulate through the

TABLE VII
Checklist
Filling the Loop with Sodium

1. ___ Start computer control program.
2. ___ Establish equilibrium at 200°C.
3. ___ Check gas bottles:
 ___ 4 argon
 ___ 1 nitrogen
 ___ 1 air (if using oxygen meter OS1).
4. ___ Close off Tank T1
 ___ Valves V1 electric and V2 manual
5. ___ Activate equilizing solenoid (isolate T1 cover gas)
6. ___ Close valves VG3, VG8, VG9, V8, V9, V10 and V11
7. ___ Open valve VG7
8. ___ Turn on vacuum pump
9. ___ Open valve VG6
10. ___ At approximately 15 inches of vacuum, close valve VG6
11. ___ Open valve V2 on Tank T1 until sodium reaches desired level
 ___ in Tank T2 as shown by L.E.D.'s on probe level detector.
12. ___ Close valve V2.
13. ___ Deactivate equilizing solenoid (connect T1 & T2 cover gas)
14. ___ Open valves VG3, VG8, and VG9.

package. Now the temperature of the loop can be brought to operating conditions; 120°C on the cold trap and 400°C elsewhere. At these settings, the oxygen level in the sodium should drop to about 1 ppm after about 4 days of circulating through the cold trap. An analysis report of the sodium furnished to two experiments is included as Appendix B.

Shutdown

Emergency shutdown may be accomplished by hitting any of the "panic" buttons. Normal shutdown can be achieved in several ways. The experimental package should be closed off from the rest of the loop by closing Valves 14 and 15 or Valves 16 and 17, whichever is appropriate. Next, the oxygen meter leg valves should be closed (Valves 8, 9, 10 and 11). The sodium can be drained into Tank 1 by opening Valve 1. The operator may drain the sodium at 400°C or may lower the temperature to 200°C before draining. It is best to have the temperature in Tank 1 the same as the sodium that will be draining into it to avoid thermal shock. The oxygen meter legs are not drained unless maintenance work is required on those legs. Their temperature is brought down slowly under either manual or computer control. Typically, about 12 psig of argon cover gas pressure is maintained on the loop at all times.

ACKNOWLEDGEMENT

The authors wish to acknowledge the most welcome assistance of Malcolm Woodward in debugging the computer control program.

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APPENDIX A

Load and Execute Computer Control Program

I. Preliminary Preparation

- A. Verify that the following power panel breakers are on:
 - 1. Power panel "A" - breaker 17
 - 2. Power panel "4L" - breakers 10, 29, 35 and 41
- B. Verify that the 5 volt power supply is on.
- C. Verify that the ELGAR LINE CONDITIONER is on.
- D. Verify that the two HP 3495A scanners are on.
- E. Verify that the HP 6940B MULTIPROGRAMMER is on.
- F. Verify that the HP 59500A MULTIPROGRAMMER INTERFACE is on.
- G. Verify that the HP 3455A DIGITAL VOLTMETER is on.
- H. Verify that the two Keithley 642 ELECTROMETERS are on.
- I. Verify that the "fail safe timer" is on.

II. Operating Procedures

- A. Load tape cassette titled "AUTOST" into the right cassette drive of the 9845B.
 - 1. If the HP 9845B is turned off:
 - a. Verify that AUTOST button is depressed.
 - b. Turn on the HP 9845B (the power switch is on the right side of the computer). The program will be loaded into the computer and will start to execute automatically.
 - c. Proceed to Paragraph III.
 - 2. If the HP 9845B is turned on:
 - a. Depress the key switch marked "K9" or "LOAD". The word LOAD will appear on the screen.
 - b. Type in: "AUTOST". The following is now displayed on the screen. Load "AUTOST".
 - c. Depress the "EXECUTE" key. The program "AUTOST" is then read into the computer. A square will appear on the lower righthand edge of the screen. This square indicates that the computer is busy. When the square disappears, the computer is ready for the next instruction.

- d. Depress the "RUN" key. This starts program execution.

III. Program Execution

- A. Program Identification (TITLE) - The program first outputs the program identification on the CRT as follows:

Bldg. 6505 - SODIUM PURIFICATION LOOP CONTROL PROGRAM
- B. Date and Time (DATE) - The subprogram outputs the current date and time as follows:

Date: MM/DD Time: Hr:Mn:Ss
- C. Temperature Read (RDTEMP) - The subprogram then reads in and displays all of the system temperatures. Temperatures are in degrees centigrade.
- D. Initial System Conditions (INITAL) - The subprogram examines the system temperatures and determines the initial conditions of the system. The following conditions are determined:
 1. If all temperatures are within 2°C of the ambient temperature, the program outputs:

 System at Ambient
 NO FLOW, NO HEATERS
 2. If some of the temperatures are at ambient and others are elevated, the program outputs:

 Part of System Elevated
 NO FLOW, MAINTAINING TEMPERATURES
 3. If all temperatures are elevated but some are below 120°C, the program outputs:

 System Temperatures Too Low for Flow
 NO FLOW, MAINTAINING TEMPERATURES
 4. If all temperatures are above 120°C, then the program outputs:

 System Ready for Flow
 FLOW POSSIBLE, MAINTAINING TEMPERATURES
- E. System Control Loop - The program reads the temperatures one more time before going into a control loop that consists of:
 1. Reading temperatures (RDTEMP).
 2. Determining which heaters are to be turned on (TPMON).

3. Applying heaters if required (HEATER).
4. Checking for any system changes (STROKE).
5. Return to 1.

F. System Changes (STROKE) - System changes are entered from the keyboard. The operator types in a command followed by a "STORE," "CONT," or "EXECUTE" key. Other changes can be executed by depressing one of the control keys, on the upper righthand side of the keyboard of the 9845B computer, K0 through K15 (these will be discussed in detail later). Some commands just require a single keystroke, while others are followed by additional instructions. The "BACK SPACE" and "BACK ARROW" keys delete a character from the input string. The "CLEAR LINE" key clears the input string. The commands are as follows:

1. Command String: TITLE - This command outputs the same information as presented in Paragraph III.A.:

Bldg. 6505 - SODIUM PURIFICATION LOOP CONTROL PROGRAM

2. Command String: CLOCK - The command interrogates the HP 98035A Real Time Clock for the current date and time.

- a. The program outputs:

Month: MM Day: DD
IS DATE CORRECT Y(ES) or N(O)?

If the date is correct, the operator depresses the "Y" key and then the "CONT" key. The program advances to Step c.

- b. If the date is incorrect, the operator depresses the "N" key and then the "CONT" key. The program continues:

ENTER NUMERIC Month 01(JAN)-12(DEC)?

The operator then types in the month followed and presses the "CONT" key. The program then outputs:

ENTER Day?

After the operator enters the day, the program returns to Step a.

- c. The program then outputs:

Time: Hr:Mn:Ss
IS TIME CORRECT Y(ES) or N(O)?

- d. If the time is correct, the operator depresses the "Y" key and then the "CONT" key. The program goes to Step f.
- e. If the time is correct, the operator depresses the "N" key and then the "CONT" key. The program continues:

ENTER Time FORMAT: Hr:Mn:Ss?

After typing in the time and pressing the "CONT" key, the program proceeds to Step c.

- f. If the date or time was corrected, then the program resets the HP 98035A Real Time Clock. In either case, the program outputs:

Date: MM/DD Time: Hr:Mn:Ss

- 3. Command String: DATE - This command outputs the current data and time as follows:

Date: MM/DD Time: Hr:Mn:Ss

- 4. Command String: TIME - This command outputs the current time as follows:

Time: Hr:Mn:Ss

- 5. Command String: INITAL - This command examines the system temperatures and determines the initial conditions of the system. Refer to Paragraph III.D. for the initial conditions.

- 6. Command String: EQUIP - This command lists the equipment on the HPIB bus.

- 7. Command String: CHGTMP - This command allows for the changing of the system control temperatures. The temperatures for the entire system, a given leg, or a specified channel can be changed.

- a. After entering the command string, the program follows up with the query:

ENTER SYS or LEG or CHN:

- b. If the operator enters SYS, the program follows up with the query:

ENTER Desired New Temperature:

After entering the temperature and when the subroutine CHGTMP is called, valves will be set 1%

higher than the pipe temperatures and exit pipes will be .5% higher.

NOTE: When changing system temperatures upward, the cold trap temperatures are restricted to 122°C (TPCOLD) if fan = 1.

When changing system temperatures downward, the oxygen meter temperatures will be held at their highest temperature. If it is desired to lower the oxygen meter temperature, the LEG command must be used for each leg.

- c. If the operator enters LEG, the program follows up with the second query:

ENTER Leg Number: Values 0 thru 9:

Each leg represents part of the system as defined below:

<u>Leg Number</u>	<u>Leg Definition</u>
0	Oxygen Meter Loop 1
1	Oxygen Meter Loop 2
2	Electromagnetic Pump
3	Bulk Heater
4	T2, Expansion Volume
5	Exit Pipes
6	T1, Storage Tank
7	Cold Trap
8	Pipe Loop
9	Glove Box and Experimenters

After entering the leg number, the program follows with the query:

ENTER Desired New Temperature:

After entering the temperature and when the sub-routine CHGTMP is called, valves will be set 1% higher than the pipe temperatures and exit pipes will be .5% higher.

- d. If the operator enters CHN, the program follows up with the second query:

ENTER Channel Number:

After entering the channel number, the program follows with the query:

ENTER Desired New Temperature:

After entering the temperature and when the sub-routine CHGTMP is called, the new temperature value is set.

8. Command String: PRINTER - This command allows the operator to change all printing from the screen (16) to paper hard copy (0), and back again. After entering the command string, the program follows up with the query:

ENTER 0 or 16:

The operator can then decide where he wants his printing: Screen (16) or Paper (0).

9. Command String: TMEMIN - This command string allows for the setting of the minimum heater time. After entry, the program follows up with the query:

ENTER New Value:

The time value is in seconds.

10. Command String: TMEMED - This command string allows for the setting of the median heater time. This command string operates in a similar manner as TMEMIN, as in 9 above.

11. Command String: TMEMAX - This command string allows for the setting of the maximum heater time. This command string operates in a similar manner as TMEMIN, as in 9 above.

12. Command String: TPCOLD - This command string allows for the setting of the Cold Trap temperature. After entry, the program follows up with the query:

ENTER New Value:

The temperature value is in degrees centigrade.

13. Command String: TMPLIM - This command string allows for the printing of the Temperature Limits table.

14. Command String: DEG.C - This command string allows for program control and printing of temperatures in degrees centigrade.

15. Command String: DEG.F - This command string allows for program control and printing of temperature in degrees Fahrenheit.

16. Command String: FAN - This command string allows for the operation of the Cold Trap fan. After entry, the

ENTER New Value:

<u>Value</u>	<u>Fan Operation</u>
0	Off
1	On

NOTE: When fan = 1, the temperature setpoint of Channels 44, 45 and 46 are set at 122°C and are not affected by the CHGTMP commands until fan is turned off. When the fan control is turned off, the setpoint of Channels 44, 45 and 46 will be controlled by the setpoint of Channel 41.

17. Command String: DRAIN - This command string allows for the operation of the Sodium Drain valve. After entry, the program follows up with the query.

ENTER New Value:

<u>Value</u>	<u>Valve Position</u>
0	Open
1	Close

18. Command String: VACUUM - This command string allows for the operation of the System Vacuum Pump. After entry, the program follows up with the query:

ENTER New Value:

<u>Value</u>	<u>Vacuum Pump Operation</u>
0	Off
1	On

19. Command String: PUMP - This command string allows for the operation of the Electromagnetic Pump. After entry, the program follows up with the query:

ENTER New Value:

<u>Value</u>	<u>Pump Operation</u>
0	Off
1	Enable

NOTE: The Pump is enabled and not on. The Pump is turned on and its speed is controlled through a Variac which is located below the 5-volt power supply.

G. The following commands are executed by depressing the command key and then answering any questions asked by the computer. The user must then press the "CONT" key to execute command.

1. Command Key: PAUSE - This key allows the computer operation to be temporarily suspended. After entry, the program follows up with the query:

System Paused: Press CONT to Continue:

When the operator is done, he can press the "CONT" key to continue the program.

2. Command Key: K0 (CRT) - This key produces the Command: PRINTER = 16.
3. Command Key: Shift K0 (PRINTER) - This key produces the command: PRINTER = 0.
4. Command Key: K1 (CHG. TEMP SYST)
5. Command Key: K2 (CHG. TEMP LEG 0) - This key produces the command: Enter Desired New Temperature
6. Command Key: K3 (CHG. TEMP LEG 1) - This key produces the command: Enter Desired New Temperature.
7. Command Key: K4 (FAN ON) - This key produces the command: FAN = 0 (Sets temp. of CHN's 44, 45, and 46 to the setpoint of CHN 24).
8. Command Key: Shift K4 (FAN ON) - This key produces the command: FAN = 1 (Sets temp. of CHN's 44, 45, and 46 to 122°C).
9. Command Key: K5 (DRAIN CLOSE) - This key produces the command: DRAIN = 0.
10. Command Key: Shift K5 - This key produces the command: DRAIN = 1.
11. Command Key: K6 - This key produces the command: VACUUM = 0.
12. Command Key: Shift K6 - This key produces the command: VACUUM = 1.
13. Command Key: K7 - This key produces the command: PUMP = 0.
14. Command Key: Shift K7 - This key produces the command: PUMP = 1.

15. Command Key: K8 - This key produces the command:
DEG.C.
16. Command Key: Shift K8 - This key produces the command:
DEG.F.
17. Command Key: K9 and Shift K9 (NOT IN USE).
18. Command Key: K10 - This key produces the command:
RELAY OPTION. This option gives a computer readout of
the relays status and also a read-back from the relays
for comparison.
19. Command Key: Shift K10 (NOT IN USE).
20. Command Key: K11 - This key produces the command:
PUMP MONITOR. This command monitors the flow meter for
the sodium pump. If the output of the flow meter drops
below .5V, the program will shut the pump off (PUMP =
0).
21. Command Key: Shift K11 - This key produces the com-
mand: NO PUMP MONITOR.
22. Command Key: K12 - This key produces the command:
RECORD DATA. The program will then interrogate the
user to find out which recording device to use--
cassette tape or floppy disc.
23. Command Key: Shift K12 - This key produces the
command: STOP RECORDING DATA.
24. Command Key: Shift K13 (BIG ON) - The computer will
now ask you for five CHN's to read. These five CHN's
and the five flow readings will now be printed on the
screen in large type. No other readings will be
printed on the screen.

NOTE: For a readout of the other CHN's, depress com-
mand key "SHIFT K0" (Printer).

25. Command Key: Shift K13 (BIG OFF) - This key produces
the command: BIG OFF. The key returns to the screen
to its normal printout.
26. Command Key: Shift K14 (ALARM SET) - This key produces
the command: SETMAX. The computer will now ask you
to "ENTER ALARM TEMPERATURE (DEGREES FAHRENHEIT)."
This temperature is different from the setpoint used to
control the temperature of the sodium loop.

NOTE: If five temperature channels reach the alarm
temperature setpoint, the computer will stop the

execution of the program. The heaters, pump, and Cold Trap fan will be turned off, and the loop will drain if the key switch is not in the manual mode.

27. Command Key: Shift K14 - This key produces the command: SET DISC TIME or SET TAPE TIME (the printout depends on which recording device you have selected. If you haven't chosen one yet, the computer will ask you which you want to use).

The computer will then output to the screen:

ENTER TIME BETWEEN DISC (OR TAPE)
RECORDS (MINUTES)

(If you do not use Key K14 to select a record interval, the computer will record each scan.)

28. Command Key: K15 (SCAN FAST) - This key produces the command: RAPID. In this mode of operation, the computer reads and prints only Channels 1-15 (oxygen meter loops 1 and 2). Note: In this mode, the system heaters are not being turned on. This mode is used when first opening oxygen Legs 1 and 2 to allow sodium flow to be established. In this mode you can monitor any rapid changes in temperature which might be harmful to the oxygen meters.
29. Command Key: Shift K15 (SCAN REG.) - This key produces the command: NORMAL. This key returns the computer to its normal printout and resumes controlling the system heaters.

APPENDIX B

Sodium Chemical Analysis

APPENDIX B

Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

October 15, 1982

Dr. D. J. Sasmor
Organization 9453
Sandia National Laboratories
P. O. Box 5800
Albuquerque, NM 87185

Dear Dr. Sasmor:

The two metallic sodium samples submitted per Purchase Document Number 26-8585 (July 19, 1982) have been analyzed for oxygen and uranium. Duplicate weighed ~ 5-g samples were distilled, the residues were dissolved in acid, and the resulting solutions were analyzed for sodium by atomic absorption and for uranium by isotope-dilution mass spectrometry. A blank was processed concurrently and the results were corrected for it. The sodium result was converted to an oxygen value by a factor of 0.348. The analytical results for the sodium contents in the residues and the conversions to oxygen concentration in the sample are:

<u>Sample</u>	<u>Sample wt, g</u>	<u>Total Na in Residue, μg</u>	<u>Total Na in Residue Corr for Blank, μg</u>	<u>Equivalent O_2 in Residue, corr for Blank, μg</u>	<u>O_2 in Sample, μg/g</u>
<u>D-7</u>					
Blank	-	3.3	-	-	-
Portion 1	4.844	17.7	14.4	5.0	1.0
Portion 2	4.463	16.8	13.5	4.7	1.0 ₅
<u>D-9</u>					
Blank	-	6.2			
Portion 1	5.523	7.7	1.5	0.52	0.1
Portion 2	5.093	10.2	4.0	1.4	0.3

Dr. S. J. Sasnor

- 2 -

October 15, 1982

The uranium contents of both samples were negligible, being less than 1 microgram of uranium per gram of sodium.

Sincerely,

P. T. Cunningham
CHM-1 Group Leader
Analytical Chemistry
MS-G740

PTC:vmw

Cy: G. Rosenblatt, CHM-DO, MS-J563
CRMO (2), MS-A150
CHM-1 Analytical File 23879
CHM-1 Analytical File 24179
File (3)

APPENDIX C
Data Graphs

START DATE AND TIME 03/08/82 10:09

START DATE AND TIME 03/08/82 10:09

COLD TRAP FLOW METER

START DATE AND TIME 03-08-82 10:09

START DATE AND TIME 03/09/82 10:09

APPENDIX D

Sodium Loop Drawing List and
Referenced Drawings

APPENDIX D
SODIUM LOOP DRAWING LIST

<u>DRAWING NO.</u>	<u>DESCRIPTION</u>	
T61519	FLOW METER ASSEMBLY	
T61520	MAGNET YOKE	
T61521	POLE SUPPORT, 3/4 INCH	
T61522	POLE SUPPORT, 1/2 INCH	
T61523	PIPE, 3/4 INCH	
T61524	PIPE, 1/2 INCH	
T61525	STUD, BRASS	
T61677	ECONOMIZER, COLD TRAP	
T61678	TANK, STORAGE T1	
T61679	TANK, EXPANSION T2	
T61680	TANK, HEATER	
T61681	EXPANSION TANK, OXYGEN METER	
T61682	STRUCTURE, SUPPORT	
T61683	HOUSING, COLD TRAP	
T61684	COLD TRAP	
T61685	SIDE INLET, METER HOUSING	
T61709 (3)	WELDMENT, SODIUM LOOP	
T62639	VAPOR TRAP	
T62645	MODIFIED HOUSING, OXYGEN METER	
T63746	LEVEL INDICATOR ASSEMBLY	
T63747	FEEDTHRU, 8 PIN, T1	
T63748	FEEDTHRU, 7 PIN, T2	
T63814	LEVEL INDICATOR, EXPANSION TANK, T2	
T65484	FLANGE, BLANK OFF	
T66642 (2)	NA PURIFICATION ROOM, BLDG. 6505	
T66957	ALUMINA	
T66958	KOVAR TUBE	
T66975	KOVAR TUBE, LARGE	
T66976	ALUMINA, 7 PIN	
T66977	ALUMINA, 8 PIN	
T69625	INSULATOR, LOOP FURNACE	
T69679	SCHEMATIC, SODIUM LOOP	
T70609	WRENCH, SPANNER	
T72443	ADAPTER, THERMOCOUPLE	} FIGURE 13
T72444	BLOCK, THERMOCOUPLE	
T72445	THERMOCOUPLE MOUNT ASSEMBLY	
T73298	THERMOCOUPLE LOCATIONS, SODIUM LOOP	} FIGURE 14
T73464	COLD TRAP, HEATERS AND THERMOCOUPLES	
T73934	HEATSINK, MOD. RELAY	
T74697 (2)	TEMPERATURE MONITOR CHASSIS #2	
T74704 (3)	TEMPERATURE MONITOR CHASSIS #1	
T74723	HANGER LAYOUT	
T74724	STRAP	
T74725	SPACER	
T74876	COVER GAS SYSTEM	
T74877	TANK T1 HEATERS	
T74878	TANK T2 HEATERS	
T74938	PLUMBING, VACUUM PUMP	

T74943	CONNECTOR FLANGE
T75475	FLANGE, BLANK OFF
T75476	SODIUM FILL LINE
T75507	CROSSOVER SODIUM FLOW
T75604	PANEL, ARGON GAS IN
T76176	HEATER ASSEMBLY (HEATER LIST)
T76733	PANEL, HEAT SINK
T76749	SOLID STATE RELAY ENCLOSURE PANEL
T77515	RING, INSULATION SUPPORT, COLD TRAP
T77526	ELECTRICAL JUNCTION BOX LOCATION
T85727	HEATER LOCATIONS, SODIUM LOOP
69747	WIRING DIAGRAM ALARM PANEL (PLANT ENGR.)
96071	SECURITY COMMAND CENTER ALARM PANEL

- 6 ITEMS 15 - 19 MAY BE OBTAINED FROM WM POWELL CO CINCINNATI OHIO 45214
7. ITEMS 25 THRU 30 ARE LONG TANGENT FITTINGS AND ARE AVAILABLE FROM HORACE T. POTTS CO ERIE AVE AND D STREET, PHILADELPHIA PA 19134
8. DO NOT WELD ITEM 12 ON UNTIL ASSY IS IN FINAL LOCATION.
9. ITEM 41 THRU 45 MAY BE OBTAINED FROM M. MASTER CARR SUPPLY CO., P.O. BOX 54960, LOS ANGELES, CALIF. 90054.
10. ITEM 48 MAY BE OBTAINED FROM UNISTRUT CORP. WAYNE MICH. 48184
11. PRESSURE TEST COMPLETE ASSEMBLY USING DRY NITROGEN TO A PRESSURE OF 250 PSI AT A TEMPERATURE OF 70° ± 20°F

NOTES

- 1 FOR GENERAL REQUIREMENTS SEE 9900000
- 2 WELD AND INSPECT PER 9912119 CLASS 1 ON ALL PIPING. USE NERT GAS INSIDE OF PIPE WHEN MAKING WELDS
- 3 IDENTIFIES WELD NUMBER FOR TRACEABILITY OF QUALITY CONTROL RECORD. ALL VISUAL, DYE PENETRANT AND RADIOGRAPHIC INSPECTION RECORDS SHALL BE REFERENCED TO DRAWING AND WELD NUMBER
- 4 CERTIFICATE OF MATERIAL CONFORMANCE TO BE SUPPLIED FOR ITEMS AS FOLLOWS:
ITEMS 23 & 24 SHALL CONFORM TO ASTM A 312
- 5 PIPING SYSTEM TO BE SUSPENDED IN SUPPORT STRUCTURE ITEM 11 WITH A SLOPE OF .062 INCHES PER FOOT IN DIRECTION INDICATED BY ARROWS ON SHEET 2

PART IDENTIFICATION		REVISIONS		DATE		BY	
PART NO.	DESCRIPTION	REV.	DESCRIPTION	DATE	BY	DATE	BY
T61709 000		A	C. TUCKER 2491/F. HST	3/4/77			
		B	ADDED ITEM 3 & DETAIL C REVISED PIPE CUTTING SCHEDULE CUTTING SCHEDULE 6.1.77	4/5/77			
		C	CHANGED PART NO. FOR ITEMS 43 & 44 AND 1. JANTY FOR ITEM 42 JIRGILL 2455/MASTIN 11.30	4/27/77			

PRESSURE DATA

OPERATING PRESSURE 20 P.S.I.

MAXIMUM ALLOWABLE 250 P.S.I.

WORKING PRESSURE (MAWP)

HAS A SAFE OPERATING PROCEDURE (SOP) BEEN PREPARED YES

OPERATING TEMPERATURE 752 MAX 250 MIN

SPECIFIC GAS OR LIQUID USED LIQUID SODIUM

RELIEF DEVICES NONE

HAS A PRESSURE SAFETY ANALYSIS REPORT (PSAR) BEEN PREPARED YES

ITEM NO.	DESCRIPTION	QTY	UNIT	REMARKS
AR 1000	UNISTRUT CHANNEL 3/8 x 1/8	10		
2 3013T16	EYE NUT 3/8 16 TAP	2		
1 4071K16	YOKE END 3/8 24 x 3/16	2		
4 4071K16	YOKE END 3/8 24 x 3/16	2		
2 3013T16	PIPE HANGER 3/8 PIPE x 3/8 TAP	2		
3 3013T16	PIPE HANGER 1/2 PIPE x 3/8 TAP	3		
AR	ROD STEEL 3/8 DA			
AR	WASHER FLAT 3/8			
AR	NUT HEX 3/8 - 3 UNC			
8	SCREW SOC HD. 0.25 UNC x 3/8 LG			
8	WASHER FLAT 1/2			
8	NUT HEX. SELF LOCKING 1/2 13 UNC			
8	STUD 1/2 - 13 UNC x 1/2 LG CRES 304			
4 33 204 2TSM	SWAGelok SOCKET WELD FITTING			
2	REDUCER ECCENTRIC 3/4 x 1/2 SCH 10 304L	7		
6	TEE 3/4 x 1/2 SCH 10 CRES 304L LONG TANGENT	7		
4	TEE 3/4 SCH 10 CRES 304L LONG TANGENT	7		
2	TEE 3/4 SCH 10 CRES 304L LONG TANGENT	7		
3	ELL 1/2 SCH 10 CRES 304L LONG TANGENT	7		
16	ELL 3/4 SCH 10 CRES 304L LONG TANGENT	7		
AR	PIPE 1/2 SCH 10 CRES 304L	4		
AR	PIPE 3/4 SCH 10 CRES 304L	4		
		22		
		21		
1 900961	PUMP ELECTROMAGNETIC SERIES II (M)	20		
10 2474 B5F	VALVE BELLOWS 1/2 x 1/3 SCH 0 STUBS	6		
3 2474 B5F	VALVE BELLOWS 3/4 x 1/3 SCH 0 STUBS	6		
1 2474 B5F	VALVE 3/4 x 1/3 - BE STUB ONE SIDE	6		
1 2474 B5F	VALVE 3/4 x 1/3 AIR OPERATOR	6		
1 2490 B5F	VALVE GATE 3/4 W/3 SCH 0 STUBS	6		
1 T61689-000	HOUSING OXYGEN METER (NEST HOUSS)	4		
2 T61689-000	HOUSING OXYGEN METER (G.E.)	13		
1 T61689-000	APOR TRAP	12		
1 T61619-200	FLOW METER 3/4"	11		
4 T61619-100	FLOW METER 1/2"	10		
2 T61681-000	EXPANSION TANK OXYGEN METER	3		
1 T61680-000	HEAT EX TANK	3		
		7		
1 T61683-000	HOUSING COLD TRAP	6		
1 T61677-000	ECONOMIZER COLD TRAP	5		
1 T61678-000	STORAGE TANK T1	4		
1 T61679-000	EXPANSION TANK T2	3		
1 T61684-000	COLD TRAP	2		
1 T61682-000	SUPPORT STRUCTURE	1		
NA 9912117	WELDING SPEC			
NA 9900000	GENERAL REQUIREMENTS			

NO.	DESCRIPTION	QTY	UNIT	REMARKS
1	900961	20		
10	2474 B5F	6		
3	2474 B5F	6		
1	2474 B5F	6		
1	2474 B5F	6		
1	2490 B5F	6		
1	T61689-000	4		
2	T61689-000	13		
1	T61689-000	12		
1	T61619-200	11		
4	T61619-100	10		
2	T61681-000	3		
1	T61680-000	3		
		7		
1	T61683-000	6		
1	T61677-000	5		
1	T61678-000	4		
1	T61679-000	3		
1	T61684-000	2		
1	T61682-000	1		

NO.	DESCRIPTION	QTY	UNIT	REMARKS
1	900961	20		
10	2474 B5F	6		
3	2474 B5F	6		
1	2474 B5F	6		
1	2474 B5F	6		
1	2490 B5F	6		
1	T61689-000	4		
2	T61689-000	13		
1	T61689-000	12		
1	T61619-200	11		
4	T61619-100	10		
2	T61681-000	3		
1	T61680-000	3		
		7		
1	T61683-000	6		
1	T61677-000	5		
1	T61678-000	4		
1	T61679-000	3		
1	T61684-000	2		
1	T61682-000	1		

NO.	DESCRIPTION	QTY	UNIT	REMARKS
1	900961	20		
10	2474 B5F	6		
3	2474 B5F	6		
1	2474 B5F	6		
1	2474 B5F	6		
1	2490 B5F	6		
1	T61689-000	4		
2	T61689-000	13		
1	T61689-000	12		
1	T61619-200	11		
4	T61619-100	10		
2	T61681-000	3		
1	T61680-000	3		
		7		
1	T61683-000	6		
1	T61677-000	5		
1	T61678-000	4		
1	T61679-000	3		
1	T61684-000	2		
1	T61682-000	1		

NO.	DESCRIPTION	QTY	UNIT	REMARKS
1	900961	20		
10	2474 B5F	6		
3	2474 B5F	6		
1	2474 B5F	6		
1	2474 B5F	6		
1	2490 B5F	6		
1	T61689-000	4		
2	T61689-000	13		
1	T61689-000	12		
1	T61619-200	11		
4	T61619-100	10		
2	T61681-000	3		
1	T61680-000	3		
		7		
1	T61683-000	6		
1	T61677-000	5		
1	T61678-000	4		
1	T61679-000	3		
1	T61684-000	2		
1	T61682-000	1		

NO.	DESCRIPTION	QTY	UNIT	REMARKS
1	900961	20		
10	2474 B5F	6		
3	2474 B5F	6		
1	2474 B5F	6		
1	2474 B5F	6		
1	2490 B5F	6		
1	T61689-000	4		
2	T61689-000	13		
1	T61689-000	12		
1	T61619-200	11		
4	T61619-100	10		
2	T61681-000	3		
1	T61680-000	3		
		7		
1	T61683-000	6		
1	T61677-000	5		
1	T61678-000	4		
1	T61679-000	3		
1	T61684-000	2		
1	T61682-000	1		

NO.	DESCRIPTION	QTY	UNIT	REMARKS
1	900961	20		
10	2474 B5F	6		
3	2474 B5F	6		
1	2474 B5F	6		
1	2474 B5F	6		
1	2490 B5F	6		
1	T61689-000	4		
2	T61689-000	13		
1	T61689-000	12		
1	T61619-200	11		
4	T61619-100	10		
2	T61681-000	3		
1	T61680-000	3		
		7		
1	T61683-000	6		
1	T61677-000	5		
1	T61678-000	4		
1	T61679-000	3		
1	T61684-000	2		
1	T61682-000	1		

NO.	DESCRIPTION	QTY	UNIT	REMARKS
1	900961	20		
10	2474 B5F	6		
3	2474 B5F	6		
1	2474 B5F	6		
1	2474 B5F	6		
1	2490 B5F	6		
1	T61689-000	4		
2	T61689-000	13		
1	T61689-000	12		
1	T61619-200	11		
4	T61619-100	10		
2	T61681-000	3		
1	T61680-000	3		
		7		
1	T61683-000	6		
1	T61677-000	5		
1	T61678-000	4		
1	T61679-000	3		
1	T61684-000	2		
1	T61682-000	1		

NO.	DESCRIPTION	QTY	UNIT	REMARKS
1	900961	20		
10	2474 B5F	6		
3	2474 B5F	6		
1	2474 B5F	6		
1	2474 B5F	6		
1	2490 B5F	6		
1	T61689-000	4		
2	T61689-000	13		
1	T61689-000	12		
1	T61619-200	11		
4	T61619-100	10		
2	T61681-000	3		
1	T61680-000	3		
		7		
1	T61683-000	6		
1	T61677-000	5		
1	T61678-000	4		
1	T61679-000	3		
1	T61684-000	2		
1	T61682-000	1		

NO.	DESCRIPTION	QTY	UNIT	REMARKS
1	900961	20		
10	2474 B5F	6		
3	2474 B5F	6		
1	2474 B5F	6		
1	2474 B5F	6		
1	2490 B5F	6		
1	T61689-000	4		
2	T61689-000	13		
1	T61689-000	12		
1	T61

TRIM STUBS ON VALVES TO OBTAIN OVERALL LENGTH INDICATED REQS. STUB ENDS TO BE MACHINED SQUARE REMOVE BURRS ON O.D. & I.D.

VALVE	LENGTH
V9	7.25
V10	5.25
V11	7.25
V12	6.12
V13	6.12

PIPE CUTTING SCHEDULE			
3/4" PIPE	1/2" PIPE	1/2" PIPE	1/2" PIPE
ITEM	ITEM	ITEM	ITEM
DESIGN	LENGTH	DESIGN	LENGTH
A	13.25	AA	6.75
B	2.75	BB	13.75
C	12.25	CC	24.75
D	31.25	DD	7.25
E	21.75	EE	28.00
F	9.75	FF	7.25
G	6.25	GG	7.25
H	21.75	HH	3.00
I	9.75		
J	13.75		
K	7.25		
L	7.25		
M	3.00		
N	3.62		
O	14.75		
P	24.75		
Q	33.75		
R	6.75		
S	33.50		
T	6.25		
U	22.50		
V	8.62		
W	3.45		
X	3.00		
Y	3.00		
Z	3.00		

NOTE: PIPE ENDS TO BE MACHINED SQUARE REMOVE BURRS ON O.D. & I.D.

UNCLASSIFIED

NOTES:

1. GENERAL REQUIREMENTS PER 9900000.
2. MATERIAL: ALUMINUM ROUND, 6061-T651, 3/4 DIA. PER QQ-A-225/8.

DESIGN AGENCY		REVISIONS			
PART NO.	NO.	ISSUE	DESCRIPTION	PREPARED BY	DATE
T72443-000	A	HAIR	2052/MARSHALL, 1725		11/20/80

AGENCY APPROVALS			SHEET		TITLE	
ORG	DATE	INITIALS	ISSUE	NO.	ADAPTER, T.C.	
2422			1			
1725					SHEET INDEX	
					PART CLASSIFICATION	
					UNCLASSIFIED	
					DWG CLASSIFICATION LEVEL	
					UNCLASSIFIED	
					SIZE	
					C	14213
					DWG NUMBER	
					T72443	
					SCALE	
					2/1	
					SHEET	
					1	OF 1

Figure 13 Adapter, Thermocouple

NOTES

1. GENERAL REQUIREMENTS ARE DEFINED IN 99000000.
2. MATERIAL: ALUMINUM BAR, 6061-T651, PER QQ-A-225/8.

DESIGN AGENCY		REVISIONS			
PART NO.	NO.	ISSUE	DESCRIPTION	PREPARED BY	DATE
SEE TABLE	A	HAID 2452/MASTIN	1767	3/7/80	

DWG NO.	A±.02	B±.010	C±.010	D±.010	E±.010
T72444-100	1.00	.750	1.100	.830 R	.500
T72444-200	.75	.500	.790	.525 R	.375
T72444-300	.75	.500	.680	.420 R	.375

AGENCY APPROVALS			SHEET		TITLE	
ORG	DATE	INITIALS	ISSUE	INDEX	BLOCK, THERMOCOUPLE	
			A			
PART CLASSIFICATION					SIZE	CODE IDENT. NO.
UNCLASSIFIED					C	14213
DWG. CLASSIFICATION LEVEL					DWG. NUMBER	T72444
UNCLASSIFIED					SCALE	2/1
					SHEET	1 OF 1

Figure 13 Block, Thermocouple

1. WELD AND INSPECT PER 9912117, CLASS II, USING ER4043 ELECTRODES PER AWS A5.10-69.
2. CLEARANCE HOLE THRU ASSY. TO BE .187 DIA MIN.

DESIGN AGENCY PART NO. NO.	REVISIONS					
	ISSUE	DESCRIPTION	PREPARED BY	DATE	CHNR	ENGR
SEE L.M.	A	HAID 2452/MASTIN 1767		3/1/80

[illegible]

Figure 13 Thermocouple Mount Assembly

Figure 14 Thermocouple Locations, Sodium Loop

DESIGN AGENCY		REVISIONS		DATE		CHG		BY	
773464 000		1	2	3	4	5	6	7	8
A		B (REVISED) 2/1/67		5/1/67					

1/2		HEATER		H 63	
1000000		GENERAL REQUIREMENTS			
		LIST OF MATERIAL			
AGENCY APPROVALS		SHEET 1		TITLE	
DATE		ISSUE A		OLD TRAF. HEATERS	
REV 1		SHEET INDEX		AND THE M. LIES	
		PART CLASSIFICATION		UNCLASSIFIED	
DWS CLASSIFICATION LEVEL		DWS NUMBER		E 1	
UNCLASSIFIED		DWS NUMBER		773464	
SCALE 1		SHEET		OF	

DWG NO. 773464

APPENDIX E

SODIUM LOOP COMPUTER CONTROL
PROGRAM

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