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Abstract

A brief description and the planned operating parameters of the ORNL-MTR-44 MSPR In-Pile Loop are given together with the operating characteristics of the major components of the loop.

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Purpose

This report summarizes the basic parameters of the MSPR In-Pile Loop, ORNL-MTR-44. No attempt is made to give a detailed description of the loop or the calculations involved in establishing these operating conditions.

Description

An In-Pile Loop is required to simulate the operating conditions of the MSPR to determine the compatibility of the proposed container materials and the salt. This loop is to be similar in design to the previous molten salt in-pile loop experiments (See Fig. 1 and Dwg. List in Appendix I). The loop is to be constructed of materials proposed for use in the MSPR and is to use as fuel a molten salt made up of uranium, beryllium, and lithium fluoride salts. The proposed loop consists of a section of 1/8 in. Schedule 40 pipe of a special alloy "Inor 8". The loop is "Hairpin" in form, having a pump located at the open end with the closed end of the "Hairpin" formed into a Helix coil. The Helix coil (nose) will be inserted into the high flux end of the MTR HB-3 beam hole. The heat generated by the fissioning of the fuel in the nose end of the loop will be removed by an air-cooled heat exchanger located on one leg only of the "Hairpin" between the discharge end of the nose coil and the pump inlet.

The proposed operating conditions of the loop are as follows:

Maximum loop temperature	1300°F
Fission power	7.5 Kw *
Fission power density	237 w/cc nose coil 55.6 w/cc total fuel
Total gamma heat generated	2 Kw
Salt flow	1.24 gpm **
Salt Reynolds No. Nose Coil Outlet	4600 **

* CF 58-8-11, MSPR In-Pile Loop ORNL-MTR-44 Power Generation

**Proposed For First Loop

The following operating conditions apply to the miscellaneous auxiliary equipment required for the operation of the loop:

Pump speed	3200 ^{***}
Heat exchanger heat load	8 Kw
Heat exchanger air flow	240 scfh
Water jacket heat removal	1.5 Kw
Water jacket flow	12 - 15 gpm
Hydraulic oil flow	1.32 gpm
Lub oil flow	0.5 - 1 cc/hr
Pump sump purge gas flow	0 Normally
Nose region purge gas flow	2 scfh
Pump purge gas "fission gas" trap temp	-40°F ^{**}
Nose purge gas trap temperature	-40°F
Trap Charcoal volume	550 in. ³
Trap charcoal weight	3.98 kg
Trap coolant	Freon 11 at -60°F

Loop Specifications

Pipe	Inor 8, 1/8 in., Schedule 40	
	ID = 0.269 in.	
	OD = 0.407 in.	
	Volume salt/in. length = 0.933	$\frac{\text{cc}}{\text{in.}}$
Inventory	Nose Coil	34 in. effective length 31.7 cc
	Loop legs	84 in. length 78.4 cc
	Pump	25 cc
	Total	135.1 cc
	Dilution Factor =	$\frac{\text{Total Inventory}}{\text{Nose Coil Inventory}} = 4.25$

*. Proposed for first loop

** CF 58-7-71, Evaluation of Fission Gas Adsorption Traps for ORNL-MTR-44 Loop Experiment, R. E. Adams, W. E. Browning

Weights of primary loop components:

<u>Component</u>	<u>Weight</u>	<u>Material</u>	<u>Specific Heat</u> <u>Btu/lb °F</u>
Pump impeller	311 gr	Inor 8	.095
Pump flinger	35 gr	Inor 8	.095
Pump housing	1472 gr	Inor 8	.095
Pump head	683 gr	Inor 8	.095
Pipe inlet-outlet	1200 gr	Inor 8	.095
Nickel block	3766 gr	Ni	0.12 at 1258°F
Heat exchanger sleeve	322 gr	Inconel	0.109

Loop Transient Characteristics Based on Fission Heat of 7.5 Kw

Salt temperature rise rate in nose reactor "On" circulation
stopped = +122°F/sec

Over-all loop temperature rise rate coolant air fails, reactor
"On", circulation continuing = +3.22°F/sec

Over-all loop temperature decay rate - reactor "Scram" coolant
air flow and loop circulation continue = -3.83°F/sec

Loop nose flow at a outlet temperature of 1300°F gpm at which heat
exchanger freezing may occur = ~0.3 gpm

Maximum water jacket nose temperature at 5 gpm 130°F water = 188°F

Temperature rise rate of inner water jacket nose cone assuming
loss of all water from water jacket = +35°F/sec

Convenient Relationships

Salt heat rate in Kw = $(0.162)(\text{gpm salt})(\Delta T \text{ °F salt})$

Air heat rate in Kw = $(0.000319)(\text{scfm air})(\Delta T \text{ °F air})$

Fuel Properties

Designation No. 130

Composition

<u>Compound</u>	<u>Mole %</u>	<u>Weight %</u>
BeF	37	47.5
LiF	62	44
UF ₄	1	8.5

Melting point = 860°F

Conductivity = 3 - 3.5 $\frac{\text{Btu}}{\text{hr } \frac{^\circ\text{F}}{\text{ft}} \text{ ft}^2}$

Specific heat ~ 0.56 $\frac{\text{Btu}}{\text{lb } ^\circ\text{F}}$

Viscosity = 14.6 $\frac{\text{lb}}{\text{ft/hr}}$ at 1300°F

Density = 120.8 $\frac{\text{lb}}{\text{ft}^3}$

Estimated Design Data of Inor-8 Material (Prepared for Preliminary Design Studies of MSRP)

I. Physical Properties

Density, lbs/in. ³	.32*
Melting temperature, °F	2370 - 2430
Electrical resistivity, microhm-cm	139
Thermal conductivity, Btu/in/ft ² - hr-°F	
at 212°F	85*
at 1200°F	120*
Modulus of elasticity, psi	
at room temp	32 x 10 ⁶ *
at 1200°F	25.5 x 10 ⁶ *
Specific heat, Btu/lb/°F	
at 212°F	.095
Mean Coef. of thermal expansion, in./in./°F	
212°F to 1032°F	8.6 x 10 ⁻⁶ *
32°F to 1800°F	8.5 x 10 ⁻⁶ *

II. Mechanical Properties (Material in annealed condition)

Short Time Tensile Properties	Room Temp	1300°F
Ultimate tensile strength, psi	115000*	60000*
Yield strength, psi	45000*	24000*
Elongation in 2 in., %	50*	20
Hardness, Rockwell B	90-100	

* Measured Values

Creep Rate	<u>Stresses - Psi</u>	
	<u>1200°F</u>	<u>1300°F</u>
<u>1% Extension</u>		
1000 hrs	12000	7000
100,000 hrs	7600	4000
<u>Rupture</u>		
10,000 hrs	18000	12000
100,000 hrs	14000	9000

Pump Performance

Fig. 2 and Fig. 3 give the pump performance and loop flow versus pump speed for the particular pump installed in the first loop. The non-linear relationship of rpm versus flow is due to the fact that the loop is operating in the transition region between laminar and turbulent flow.

Heat Exchanger Performance

Fig. 4 gives the heat exchanger performance based on numerous test data points, some of which are plotted on the figure. The curves were established by extrapolation of the test points for varying salt and coolant air flows, according to the Dittus Boelter relationship for heat transfer in fluids. The parameters used in Fig. 4 were chosen for convenience in predicting heat exchanger performance at the operating conditions of this loop. The salt Reynolds numbers and salt-to-air temperature difference of 1145°F on which these curves are based was chosen because under proposed loop temperatures the mean air-to-salt temperature difference will be within a few degrees of this point. Corrections must be made to these curves for any difference in mean air-to-salt temperature difference.

Fig. 5 gives the loop Reynolds number versus flow for various salt temperatures and is convenient for use in conjunction with Fig. 3.

Fig. 6 shows experimentally determined points which give the inlet salt temperature to the heat exchanger versus salt flow at which freezing of the salt will occur in the heat exchanger. These points

Fig. 2

Fig. Q3

Fig. 43

Fig. 5

Fig. 6

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were all determined at a coolant air flow of 450 scfm at 65°F to 80°F air inlet temperature. The upper line represents the point at which the first indications of freezing occur. The lower line represents the point at which actual flow stoppage occurred due to a frozen plug in the heat exchanger. At the lower line the heat exchanger becomes unstable, the salt flow decreases rapidly to zero as a plug is formed.

Fig. 7 gives the calculated pipe wall to salt interface temperature difference between the outlet end of the nose coil, which is the highest temperature in the loop, and the outlet end of the heat exchanger, which is the coldest part of the loop versus pump speed. The second curve on Fig. 7 gives the salt to pipe wall interface temperature at the heat exchanger outlet versus loop salt flow.

These curves are based on the Dittus Boelter relationship for the heat transfer of fluids, and were calculated for a heat exchanger load of 8 Kw with a salt inlet temperature to the heat exchanger of 1300°F. The salt film temperature drop used was that based on the mean conditions in the heat exchanger. Although this is not strictly correct, it is considered adequate in view of the uncertainties in the heat transfer relationships for large temperature differences and the precision with which the salt properties are known.

Loop Transient

Fig. 8 gives the temperature rise of the salt and pipe in the forward most nose coil in the event of flow stoppage with continued reactor operation. These figures are based on the results of previous calculations made for the ORNL-20 In-Pile Loop.

Fig. 7

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Fig. 8

Appendix 1

ORNL-MTR-44

In-Pile Loop Design Modifications to Correct
Previously Encountered Difficulties

Table I is a summary of the serious difficulties encountered in the operation of the six ORNL-20 in-pile loops. The following is a brief description of each difficulty and the method of correction.

Table I
Difficulties Encountered in the ORNL-20 In-Pile Loops

	<u>Loops</u>					
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
1. Electrical Failure	T*	T	M**	ok	ok	ok
2. Thermocouple Failure	-	-	T	M	ok	ok
3. Nose Purge Plug	-	-	ok	T	-	M
4. Pump Purge Plug	-	-	T	T	-	ok
5. Loop Filling	-	-	ok	ok	T	ok
6. Pump Speed Variation			M	M	-	T
7. Pump Speed Monitor Trouble	-	-	ok	ok	-	T
8. Trap Cooling	M	M	M	ok	ok	ok
9. Shielding	-	-	T	ok	-	ok
10. Coolant Air Control	-	-	ok	ok	-	T
11. Low Water Flow Alarm	-	-	M	M	-	M
12. Broken Nose Sniffer Line	-	-	ok	ok	ok	T

* T = trouble

** M = marginal

1. Electrical Failures

The first two loops failed to operate because of shorts in the electrical system. These were traced to a combination of marginal electrical insulation and the low dielectric strength at elevated temperature of the helium gas used in the nose region. This difficulty was corrected in Loop 3 by improving the insulation at the terminals of the heaters and by improved assembly technique. The insulation of Loop 3 was marginal; further improvement was achieved in subsequent loops by the use of conduits for all leads in the intermediate and rear section and the use of nitrogen gas, which has higher dielectric strength, in the nose region.

2. Thermocouple Failure

There was a high incidence of thermocouple loss in Loop 3. Improved methods of thermocouple bead spot welding reduced this loss in Loop 4 and further modification to reduce strains induced by loop thermal expansion reduced the thermocouple loss to insignificant values in succeeding loops.

3. Nose Purge Trap Plugging

In Loops 4 and 6 difficulty was encountered in plugging of the nose trap during start up. This has been traced to volatile products evolved from the nose insulation during initial heating. These substances collect in the refrigerated trap line, causing plugging. This is to be corrected in future loops by baking out the insulation prior to shipping the loop to the MTR. The effectiveness of the baking out procedure will be tested by purging through the hot loop to traps prior to shipment.

4. Pump Purge Plugging

In Loops 3 and 4 the pump purge traps plugged. This situation was alleviated in Loop 6 by reducing pump sump purge flow and turning off the bearing housing purge. This eliminates the carry over from the bearing housing to the traps of hot oil vapors which are believed to have precipitated the plugging. It has been established in Loop 3, 4, and 6, which operated at higher power levels than planned for

ORNL-MTR-44, that the purge may be cut off without build up of activity in the hydraulic oil. In addition, the traps of the new loop will be at -40°C which is above the freezing point of the oil whereas previous traps were operated at -150°C to -180°C .

5. Loop Filling

ORNL-20 loops 1, 2, and 5 failed to fill, loops 1 and 2 because of electrical failure in the fill line heaters described under "Electrical Failures". Loop 5 failed to fill because of a fill line plugged by a precipitation of zirconium oxide. This was controlled in future loops by more careful preparation of the fuel. In addition, the salt in this loop melts at 860°F as compared with 1040°F for the salt of the previous loops.

6. Pump Speed Variation

Loops 3 and 4 were troubled by minor pump speed variation and Loop 6 by severe speed variation. The difficulties of Loops 3 and 4 are attributable to close clearances in the hot region of the pump and the blowing of oil from the bearing housing into the pump sump region where it subsequently coked. The oil was blown past the unbalanced shaft seal into the pump sump when the bearing housing purge trap plugged thereby pressurizing the bearing housing. The modifications described under "Purge Plugging" should correct this. In addition the pump clearances have been opened up and the oil trap to collect oil leakage past the shaft seal has been increased in size from about 5 to 50 cc.

Speed variations in Loop 6 were the result of flooding of the pump sump. During the operation foreign material plugged the hydraulic oil orifice necessitating the shut down of the pump while the plug was removed. Shutting the pump down will cause the salt to drain from the impeller to the sump which was marginal in size. In this case sufficient salt drained into the sump to flood it permitting salt to flow along the shaft to colder regions of the pump where it froze. This was borne out by post run hot cell examination. It was possible to restart the pump only by the application of excessive amounts of heat to the pump. However, some salt was still frozen around the shaft causing rubbing and speed fluctuation. The present pump has a sump of double the capacity permitting stopping and restarting of the pump at will. The pump will be filled and purged while operating to prevent such problems.

7. Pump Speed Monitor Trouble

A number of erroneous scrams and alarms in the past have been caused by the pump speed monitor. These in general were caused by transients in the electrical system such as may be induced by the turning on or off of equipment. These transients cause high speed indications. The high speed scram action has been eliminated from the circuit since there can be no serious loop malfunction from an increase in pump speed. In addition, the speed monitor has been modified to reduce its sensitivity to transients.

8. Trap Cooling

In the past the charcoal purge traps have been refrigerated by the use of large quantities of liquid nitrogen. Although no serious difficulty was caused by this, the logistics of obtaining sufficient liquid nitrogen and the idiosyncrasies of the liquid nitrogen system were a constant source of difficulty to both reactor and loop operators. The traps have been redesigned (increased in size) to permit operation at -40°C instead of -150°C to -180°C . The reduction in refrigerant requirements thus obtained permits the use of commercial refrigeration equipment which should eliminate the difficulties previously encountered with this system.

9. Shielding

Loop 3 cubical shielding was inadequate. The situation was corrected by the provision of a new cubical door which reduced the radiation emitted from the cubical to tolerance levels. Some radiation difficulties were encountered from the back diffusion of gas from the fuel up the purge lines subsequent to the plugging of the traps. The plugging of the purge traps was discussed above (4). In addition, valves have been installed adjacent to the cubical in the purge inlet lines. These valves can be shut off in the event of purge difficulties thereby preventing back diffusion beyond the shielded cubical.

10. Coolant Air Control

The loop coolant air control although satisfactory in Loop 3 and 4, was marginal. During the operation of Loop 6 it caused considerable difficulty and is considered to be partially responsible for other ensuing difficulties. The controller and control valve are being changed to one which should give better performance on this loop.

11. Low Water Flow Alarm

In the past numerous low water flow alarms have been a source of annoyance. Previously the water flow to the loop water jacket had been set at 20 gpm with an alarm at 15 gpm and Jr. Scram at 10 gpm. Transients in the water system pressure were sufficient to cause persistent alarms at the 15 gpm range, although never a scram. The latest calculations indicate that 5 gpm water flow is adequate for the water jacket. It is proposed to set the water flow at 12-15 gpm with an alarm at 10 gpm and Jr. Scram at 5 gpm. This should eliminate this source of annoyance.

12. Broken Nose Sniffer Line

During the operation of Loop 6 the "Nose Sniffer Line" broke off the heat exchanger at the weld joint of the "Sniffer" tube to the heat exchanger. This prevented adequate monitoring for leaks of the section of fuel pipe passing through the heat exchanger. This line, a 1/8" stainless steel tube welded to the heat exchanger outer sleeve, was subjected to severe flexing due to the thermal cycling induced in the loop by the malfunction of the coolant air control (Section 10). It is hoped that the new coolant air control will preclude thermal cycling. However, the weld joints in this "Sniffer" tube have been reduced from 3 to 1 and the remaining weld is braced by a bracket which makes the application of flexure stresses at the weld impossible.

General

In addition to the above modifications this loop should be inherently more reliable. The power density and operating temperatures are lower and the loop has a higher thermal inertia due to the removal of one leg of the heat exchanger and the installation of a solid nickel block in its place. In addition, the freezing temperature of the salt is 860°F, 180°F lower than that of previous loops. The result is that temperature transients are not as severe and set points can be set further from the operating point such as a 100°F temperature rise before scram instead of 50°F. Further, in the event of loss of flow it has been shown that the loop will not melt so long as the reactor is scrammed, whereas in the previous loop this was marginal.

The lower power density and temperature permits the operation of the pump at lower pump speeds and temperatures and reduces the coolant air requirements, thereby increasing the life of the in-pile pump and reducing the load on the air compressors.

The pump has been modified in a number of respects. The sump is sufficiently large to permit stopping the pump at any time the reactor is not at power so that repairs can be made on external equipment. Clearances have been increased in the pump and the pump housing rigidity greatly increased to eliminate the possibility of interference from thermal stresses.

In addition, numerous modifications, especially in the installation of power and instrumentation leads in conduits with double hermetic seals between all regions and the atmosphere, minimize the possibility of leaks.

Fig. 1.

Appendix II

ORNL-MTR-44

Set Point and Operating Controls Tabulation

The following is a tabulation of the proposed loop operating and control point settings with a brief justification where applicable. The tabulation for consistency follows the order given in ORNL Dwg. Q-1960-25-E, "Control Information Block Diagram".

Instrument Air Pressure = Normal 21 psig
Alarm 17.5 psig

No specific control action is associated with failing instrument air since with loss of instrument air reactor shutdown will be initiated by ensuing erroneously indicated malfunction of other systems.

Coolant Air Flow = Alarm < 125 SCFM

Normal operation will require air flows of 270 - 300 SCFM. The alarm is to alert the operator that all is not normal. If control action is required, it will be provided for by other parameters. At low reactor power air flow will be below the alarm point.

Air Compressor Off = Alarm

Alarm when circuit to ORNL compressor drops. No control action; it is simply a warning to the operator. Control actions are initiated on failing air pressure.

Air Pressure Less Than 50 psig = Alarm Emergency N₂ "On"

Normal pressure is 120 psig. If air pressure drops below 50 psig and the loop temperature is above 1200°F an alarm is initiated, emergency nitrogen is turned on, and the reactor is put in slow set back. The emergency nitrogen (1600 SCF) should be ample to provide cooling until the reactor power is reduced below the point requiring loop cooling.

MTR Air Supply - Manual Switch

A manual switch on the panel permits the operator to turn on MTR air into the loop as an emergency back up for the emergency nitrogen supply.

Nitrogen Cylinder Pressure Below 800 psig - Alarm

The 8 bottle supply for the emergency nitrogen supply is so connected that all leakage will be drawn from a single bottle, leaving the others at full pressure. When this bottle drops to 800 psig the operator is warned that the bottle needs replacement. There is no need for control action.

Nose Nitrogen Cylinder Pressure Below 200 psig - Alarm

When the nitrogen bottle manifold supplying nitrogen for the nose purge drops to 200 psig an alarm warns the operator that new bottles must be installed. There is no need for control action.

Helium Cylinder Pressure Below 200 psig - Alarm

When the helium bottle manifold supplying helium for the various purges drops to 200 psig an alarm warns the operator that new bottles must be installed. No need for control action.

Pump Purge Less Than 100 cc/hr - Alarm

In the event that a malfunction causes the pump sump purge normally 200 cc/hr to drop to less than 100 cc/hr an alarm warns the operator of the abnormal condition. No immediate control action is required.

Bearing Housing Purge Less Than 100 cc/hr - Alarm

In the event that the bearing housing purge is in use (normally to be off) an alarm warns the operator of a decrease in flow below 100 cc/hr. No immediate control action is required.

Liner Pressure Greater Than 12 psig - Alarm

Liner Pressure Greater Than 15 psig - Jr. Scram

Liner pressure (gas pressure in the nose region of the loop) should normally be 8 - 10 psig. A rise in this pressure indicates either a shift in the purge pressure regulator, a plug in the purge line in which event the monitoring system for a leak in the fuel pipe would not function, or a leak of heat exchanger air or water jacket water in the nose region. The alarm is to prevent unnecessary scrams due to a malfunctioning regulator. The occurrence of any of the other malfunctions is cause for reactor shutdown.

Hydraulic Sump Pressure Less Than 15 Inches Water - Alarm

The hydraulic oil sump of the hydraulic power unit supplying pressure to the in-pile pump motor must be slightly pressurized (normal 20 inches water) to prevent cavitation in the hydraulic pump. The alarm is to warn the operator of an abnormal condition. No automatic control action is required. Cavitation of the hydraulic pump may cause in-pile pump speed variation but will not result in pump stopping.

Water Flow Less Than 10 gpm - Alarm

Water Flow Less Than 5 gpm - Jr. Scram

Normal water flow is to be 12 to 15 gpm. Calculations indicate 5 gpm to be adequate to prevent over heating of the nose cone of the water jacket. The alarm warns the operator that corrective action is indicated. The scram is to take care of uncontrollable low water flow.

Demineralized Water "On"

Refers to a solenoid valve in the MTR demineralized water supply system and is not a part of the ORNL-MTR-44 control system.

Water Pressure Less Than 50 psig

An alarm warns the operator in the event that the water jacket supply pressure drops to 50 psig to indicate an abnormal condition. There is no control action; control being actuated on low water flow.

Hydraulic Oil Flow Less Than 0.7 gpm - Alarm

Hydraulic Oil Flow Less Than 0.58 gpm - Jr. Scram

Normal hydraulic oil flow to the pump motor is 1.3 gpm. A reduction in flow is an indication of a reduction in pump rpm. Low pump speed with the resultant reduction in salt flow could precipitate a frozen heat exchanger. 0.58 gpm is equivalent to 1400 rpm. This control is a back up for the pump speed monitor set to cause a Jr. Scram at 1500 rpm.

Pump Speed Less Than 1800 or Greater Than 3500 rpm - Alarm

Normal pump speed will be in the order of 3200 rpm. This alarm is to warn the operator of an abnormal drift in pump speed to permit corrective action before control action is initiated.

Pump Speed Less Than 1500 rpm - Jr. Scram

Normal pump speed is about 3200 rpm. A reduction in pump speed will result in reduced fuel flow and may precipitate freezing in the heat exchanger and ensuing over heating of the nose section. This control action is backed up by "Low Hydraulic Oil Flow".

High Temperature - Above 1350°F - Monitored on Two Separate Continuous Recorders - Alarm

High Temperature - Above 1400°F - Monitored on Two Separate Continuous and One Multipoint Recorder - Scram

A number of malfunctions can cause high loop temperatures, primarily loss of circulation of the fuel or loss of coolant. Normal maximum loop temperatures will be 1300°F. The 1350°F alarm point is to give the operator a chance to initiate corrective action. The 1400°F scram point is based on temperature rise rates in the event of a loss of fuel circulation. Under these conditions with a scram at 1400°F the maximum expected pipe temperature would be less than 1850°F.

Low Temperature - Below 1050°F - Monitored on Two Separate Continuous Recorders - Alarm

Low Temperature - Below 1000°F - Monitored on Two Separate Continuous Recorders - Fast Set Back

Normal minimum loop indicated temperature will be about 1200°F. To prevent the possibility of a high temperature excursion in the event of loss of circulation from freezing a plug in the cold end of the loop with the reactor at power two continuous recorders monitor the cold end of the loop providing an alarm at 1050°F followed by a Fast Set Back at 1000°F. The salt freezes at 860°F. This control is designed in particular to cover the case where a reactor scram has occurred followed by a severe loss of loop temperature (the loss of reactor power will normally cause a downward temperature excursion in the loop). If the loop temperature is too low there is the possibility of a frozen plug having been formed which if the reactor came "On" would cause a high temperature excursion in the nose due to the lack of circulation.

Loss of Instrument Air Pressure

Coolant air control valve closes on loss of instrument air pressure. The valve is operated by instrument air pressure. The loss of instrument air will result in a reactor Jr. Scram. If the air is not turned off loop freezing would follow; therefore, a fail closed valve is used. In

the event that only instrument air to the valve fails closing of the air valve will result in a high loop temperature scram. Loop temperature rise rate in the event of loss of coolant air is $3.22^{\circ}\text{F}/\text{sec}$. Therefore, the loss of air flow would be caught by "Low Air Flow Alarm" and if possible a control action averted.

Reactor Power Below 10% of Normal - Alarm and Automatic Setting of Loop Controls to Isothermal Operation

In the event of a reactor power reduction to less than 4 M.W.* it is necessary that the loop be put on isothermal operation to prevent freezing since there will be insufficient fission heat to maintain loop temperatures. An ORNL-MTR-44 reactor power monitor chamber, the output of which is monitored on a recorder, is installed in a vertical graphite hole "V.G." near HB-3. In the event of a power reduction to 10% the loop heaters will come on the coolant air will be cut off if loop temperatures are below 1400°F .

Nose Purge Activity Above 15 mr/hr - Scram

The outlet nose purge gas is monitored for activity by two sets of paired G.M. tubes. This gas normally has no activity. Activity in this gas indicates a break in the loop fuel pipe or pump and is cause for shutdown.

Manual Switches FCX 18 and FCX 19

These switches control solenoid valves on the inlet and outlet of the nose purge gas line in the vicinity of the cubical. These valves are operated manually by the operator in the event of an indicated break in the fuel piping to contrin the fission products in the loop rather than permitting their continued flow into the traps, until such time as a controlled release of the activity can be affected.

Coolant Air Activity Above 20 mr/hr - Scram

The outlet coolant air is monitored for activity by two sets of paired G.M. tubes to provide double tracking. Coolant air exhaust will normally have a low background. Any rise above background is an indication of a leak of fuel into the coolant air and is cause for immediate shutdown. The loop is so constructed, having a double wall heat exchanger with the surface between the two walls monitored by nose purge gas, that normally the nose purge gas activity or nose purge (high liner) pressure would cause a shutdown when the first of the two walls failed but before the failure of both walls could cause activity to reach the coolant air.

* This setting may require change based on experience

Hydraulic Oil Activity - Alarm

Two unshielded GM Tubes are located on the hydraulic system to monitor the oil for activity. The only path for activity to enter the hydraulic oil system is by leaking through the two pump shaft seals into the hydraulic motor housing. Buildup of activity would be slow. No immediate control action is required. The hydraulic system is itself canned and vented to the stack.

Stack Activity - Alarm

The effluent from the pump purge gas traps is monitored for activity before entering the MTR off gas system. This alarm is for the purpose of alerting the operator that the charcoal fission gas traps are not functioning properly. No control action.

Radiation Activity Recorders - 90% Scale - Alarm

All the activity monitors previously described are monitored on a multipoint recorder for a continuous record. Should any activity rise above background so as to drive these recorders to 90% scale an alarm will be tripped to warn the operator of increasing activity. This is in addition to the specific alarms described above and in general will occur ahead of the specific alarm.

Air Radiation Activity Monitor Recorders - 90% Scale - Alarm

There are six air activity monitors which sample air from various areas around the experiment as follows: two in the HB-3 cubical, two in the area outside the cubical, and two in the equipment area on the north balcony. The output of these monitors is recorded on a multipoint recorder. If the output of any monitor is such as to drive the recorder to 90% scale, an alarm is sounded to warn the operator of the condition.

Trap Temperature TRX-14-1 Above -20°F - Alarm

A multipoint recorder monitors the temperature of both the nose and pump purge refrigerated charcoal traps. Normal temperature for these traps is -40°F. This alarm is for the purpose of warning the operator of the abnormal condition; no automatic control action is required.

Control Power Off (Circuit Breaker 14) - Jr. Scram

Failure of control power will drop the Jr. Scram relay causing a reactor shutdown. This precludes operation without power to the ORNL-44 instrument panel.

Hydraulic Pilot Motor Controls

These controls are for the purpose of regulation of the hydraulic power unit which drives the pump.

Bill of Materials

BM-6245 - Loop

<u>Dwg. No.</u>	<u>Description</u>
F-6245	Assembly Front Half
F-6246	Assembly Rear Half
E-6972	Thermocouple Application
F-6971	Calrod Applications
B-679	Outer Cap
B-678	Inner Cap
C-44	Moly Boot Sub-Assembly
D-913	Sheet .020 Thk. x 12"
B-914	Sheet .020 Thk. x 6"
D-6737-58	Outer Jacket, 5-1/2 OD x .065 Wall
D-6737-59	Inner Jacket Front 5-1/8 OD x .065 Wall
D-6694-1	Sniffer Clamp Front
D-6694-2	Sniffer Clamp Rear
F-6245-8	Socket Hd. Screw #10-24 x 5/8 Long
D-6707-9	Fill Tank Sub-Assembly
B-692	Tubing 1-1/2 OD x 1/16 Wall
A-693	Cap
A-902	Tubing 1/4 OD x .025 Wall
D-6707-4	Tubing 5/16 OD x .049 Wall
D-6707-5	Pad
D-6707-6	Tubing 1/4 OS x .035 Wall
BM-6813	Heat Exchanger & F-Loop Assembly
B-915	Tubing 1/4 OD x .030 Wall

<u>Dwg. No.</u>	<u>Description</u>
D-6722-12	Tubing 1/4 OD x .030 Wall
D-6722-13	Jacket Spacer
D-6722-14	Plate
BM-6278	Motor Pump Assembly
B-1974-1	Oil Trap Sub-Assembly
B-1974-2	Tubing 1/4 OD x .032 Wall
B-1974-3	Tubing 3/16 OD x .032 Wall
D-1974-4	Bar-1-1/4 Diameter
B-1974-5	Tubing 1-1/4 OD x .062 Wall
F-6245-17	Crush Washer 3/8 ID x 3/4 OD x 1/8 TK
F-6245-18	Binding Wire 20 Ga.
F-6245-19	Swagelok Connector #600-1-6-316
F-6245-20	Crush Washer 1/4 ID x 5/8 OD x 1/8 TK
D-6813-13	Patch - (Make from part D-6812-9)
F-6245-22	Swagelok Connector #300-1-4-316
F-6715-23	Tubing 5/8 OD x .035 Wall
F-6715-24	Tubing 7/8 OD x .035 Wall
D-6812-14	Tube (Make from part D-6812-9)
D-6694-6	Shield
D-6694-4	Shield
D-6694-5	Shield
D-6694-3	Shield
F-6719-30	Tubing 1/16 OD x .012 ID
F-6719-31	Tubing 1/8 OD x .032 Wall
F-6719-32	Tubing 1/8 OD x .028 Wall
F-6719-33	Tubing 3/8 OD x .035 Wall
F-6719-34	Tubing 3/8 OD x .035 Wall

<u>Dwg. No.</u>	<u>Description</u>
F-6719-35	Tubing 3/16 OD x .028 Wall
F-6719-36	Tubing 1/8 OD x .032 Wall
F-6719-37	Tubing 1/4 OD x .032 Wall
F-6719-38	Tubing 1/8 OD x .032 Wall
F-6719-39	Tubing 1/4 OD x .032 Wall
F-6719-40	Tubing 1/8 OD x .032 Wall
F-6719-41	Tubing 3/16 OD x .028 Wall
F-6712-42	Tubing 1-1/4 OD x .065 Wall
F-6712-43	Tubing 1-1/4 OD x .062 Wall
F-6712-44	Tubing 1-1/4 OD x .062 W 11
F-6712-45	Tubing 1-1/4 OD x .062 Wall
D-6812-15	Patch (Make from part D-6812-14)
D-6812-16	Tube (Make from part D-6812-14)
D-6814-6	Patch (Make from part D-6814-4)
D-6814-7	Tube (Make from part D-6814-4)
D-6903-12	T.C. Seal Box - Sub-Assembly
D-6903-1	Winchester Electronics Hermetic Plug
D-6903-2	Right Side Plate
D-6903-3	Left Side Plate
D-6903-4	Bottom Plate
D-6903-5	Rear Plate
D-6903-6	Seal Plate
D-6903-7	Front Plate
D-6903-8	Center Top Plate
D-6903-9	Winchester Electronics Hermetic Plug
D-6903-10	Top Cover Plate
D-6903-11	Top Cover Plate

<u>Dwg. No.</u>	<u>Description</u>
D-6904-8	Power Seal Box Sub-Assembly
D-6904-1	Stupakoff Multi-Terminal Header
D-6904-2	Bottom Plate
D-6904-3	Front Plate
D-6904-4	Top Center Plate
D-6904-5	Back Plate
D-6904-6	Seal Plate
F-6719-54	Tubing 3/16 OD x .032 Wall
F-6719-55	Tubing 3/16 OD x .032 Wall
D-6904-7	Top Cover Plate
D-6722-82	Jacket Spacer Rear
F-6245-58	Shimstock .002 TK x 3" Wide
F-6245-59	Shimstock .002 TK x 3" Wide
F-6245-60	Insulation "Thermofrax"
D-6737-61	Tubing 5-1/8 OD x .065 Wall
F-6715-62	Tubing 1" OD x .032 Wall
F-6714-63	Tubing 1" OD x .032 Wall
F-6245-64	Hollow Set Screw - Flat Pt. 3/8
D-6704-65	Filler Plate
C-710	Collar
D-6708-67	Bulkhead Intermed.
F-6715-68	Tubing 7/8 OD x .035 Wall
F-6719-97	Tubing 1-1/4 OD x .065 Wall
F-6245-70	Refrasil Quartz Sleeving
F-6714-71	Tubing 1 OD x .035 Wall
F-6719-98	Tubing 1-1/4 OD x .065 Wall
D-6708-72	Bar 1" Diameter
D-6708-74	Bulkhead Rear
D-6704-75	Pinch and Shear Box Assembly
D-6704-1	Clamp
D-6704-2	Clamp Block

<u>Dwg. No.</u>	<u>Description</u>
D-6704-3	Square Hd. Set Sc. 1/2
D-6704-4	Ket
D-6704-5	Crusher
D-6704-6	Clamp (Make from end off D-6704-1)
D-6704-7	Cutter Lance
D-6704-8	Tie
D-6704-9	Keeper
D-6725-76	Rear Shell Assembly
D-6725-1	Tubing 6-3/4 OD x 1/8 Wall
D-6725-2	Plate
D-6725-4	Plate
D-6725-3	Roller Sub-Assembly
D-6722-1	Plate
D-6722-2	Rod
D-6722-5	Rod
D-6722-77	Plate
F-6746-78	Titeflex Connection
B-4837	He Tube
B-4837	Plate
B-4837	Hollow Set Sc. 1/2 Dog Pt.
B-4837	Rod
B-4837	Plain Washer
B-4837	Dowell
D-6708-80	Channel 1-1/2 x 1-1/2 x 3/16
D-6808-81	Plate
E-6970-9	T.C. Seal Plate
D-6707-83	Rod
F-6246-84	Cotter Pin

<u>Dwg. No.</u>	<u>Description</u>
F-6246-85	Flat Washer
F-6246-86	Pipe Union
E-6970-8	Rear T.C. & Power Seal Box Sub-Assembly
E-6970-1	Plate
E-6970-2	Winchester Seal Hrme.
E-6970-3	Plate
E-6970-4	Plate
E-6970-5	Plate
E-6970-6	Stupakoff Multit-Terminal Header
E-6970-7	Plate
E-6970-10	Plate
F-6719-89	Tubing 1/8 OD x .032 Wall

BM-6278 - Pump:

D-6278	Assembly
D-6278	Socket Hd. Screw
D-6278	Socket Set Screw Cone Point
B-2288	Oil Tube
D-6278	Socket Head Screw
D-6278	Hex. Jam Nut No. 8-32
D-6278	Vlier Spring Plunger No. S-51
D-6277	Nichrome
B-1990	Helium Inlet Tube
D-6278	Vickers Hydraulic Motor MF-24-3906-30-BC4
B-2114	Spline Bushing
B-1573	Motor Seal Retainer
D-6278	Rubber "O" Ring

<u>Dwg. No.</u>	<u>Description</u>
B-1290	Sub-Assembly Rear Bellows Seal
B-2263	Rear Seal Runner
D06278	Taper Pin No. "O"
B-2317	Retaining Nut
D-6278	Roller Bearing, Norma-Hoffman R-112 or Equal
D-6277	Pin
D-2284	Bearing Housing
C-384	Sleeve Spacer
D-2113	Shaft-Rough Mach.
D-6278	Ball Bearing MRC 102 KS-F1-SX-A7-XF-RP-6-9 (ABEC-3) with Bronze Retainer
B-2262	Forward Seal Runner
B-1292	Assembly - Forward Bellows Seal
B-381	Housing Spacer
C-1004	Heat Dissipator-Pump Bulkhead
D-6276	Sub-Assembly Rear Housing & Pump Bulkhead
D-6277	Pin
B-2255	Plug
B-2111	Flinger
C-2109	Impeller
D-2112	Pump Housing Assembly
D-2319	Pump Head
B-2161	Temporay Screw
D-6277	Tube
D-6277	Tube
D-6277	Tube
B-560	End Cap
D-6277	Dissipator

<u>Dwg. No.</u>	<u>Description</u>
D-6277	Spacer Washer
D-6277	Gasket Washer
D-6278	Hollow Jam Nut
D-1972	Preliminary Machining
B-1241	Filler Tube
B-560	Sump Tube
B-561	Filler Tube
D-6280	Baffle
B-4156	Tube
D-2110	Sub-Assembly - Shaft
B-2321	Stub L.H.
B-2322	Stub R.H.
B-1284	Insert
B-1289	Sub-Assembly Rear Bellows Seal
B-1285	Fulton-Sylphon A-1505-A-15 (10 Convolutions) (Alternative) SS-115001-12 (11 Convolutions)
B-1286	Back Plate - Rear Seal
B-1287	Front Nose Piece
B-1291	Sub-Assembly Forward Bellows
B-1288	Back Plate - Front Seal

BM-7183 Traps:

F-7183	Main Assembly
D-7178-1	Outer Can
D-7178-3	Can
D-7178-4	Plate
D-7178-2	Pump Purge Inlet

<u>Dwg. No.</u>	<u>Description</u>
F-7183	Main Assembly
D-7178-1	Outer Can
D-7178-3	Can
D-7178-4	Plate
D-7178-2	Pump Purge Inlet
D-7179-1	Bearing Purge Inlet
D-7179-2	Trap Outlet
D-7180-6	Shield
D-7181-1	Plug
D-7181-3	Crossover
D-7181-4	Elbow
D-7181-6	Elbow
D-7181-7	Elbow
F-7182-11	Bundle Sub-Assembly
D-7180-3	End Plate
D-7180-4	Plate
D-7180-1	Can
D-7180-2	End Plate
D-7181-2	End Plate
D-7181-5	Can
F-7182-6	Refrigeration Line
F-7182-7	T.C. Sub-Assembly
F-7182-8	Weld Adapter
F-7182-9	Thermocouple
F-7182-10	End Plate
F-7182-8	Spacer
F-7183-13	Adsorber

<u>Dwg. No.</u>	<u>Description</u>
F-7183-14	Insulation
F-7183-15	Insulation
F-7183-16	Elbow, 90°, Short Radius
F-7183-17	Refrigeration Line
F-7183-18	1/4 OD Tube Tee No. 2611 Anaconda or Equal
F-7183-19	3/4 Thk. - Fiberfrax Layer

BM-7234 - Traps:

F-7234	Main Assembly
D-7178-1	Outer Can
D-7178-3	Can
D-7178-4	Plate
D-7232-1	Gas Inlet
D-7179-1	Gas Outlet
D-7232-2	Short Crossover
D-7180-6	Shield
D-7181-1	Plug
D-7181-3	Crossover
F-7233	Bundle Sub-Assembly
D-7180-3	End Plate
D-7180-4	Nipple
D-7180-5	Plate
D-7180-1	Can
D-7180-2	End Plate
D-7181-2	End Plate
D-7181-5	Can
F-7182-6	Refrigeration Line
F-7182-7	T.C. Sub-Assembly

<u>Dwg. No.</u>	<u>Description</u>
F-7182-8	Weld Adapter
F-7182-9	Thermocouple
F-7182-10	End Plate
D-7232-3	End Plate
F-7182-12	Filter
F-7182-13	Stainless Steel 40 Mesh Screen
F-7182-14	Fiberfrax
D-7232-4	End Spacer
F-7182-8	Spacer
F-7234-1	Adsorber
F-7234-2	Insulation
F-7234-3	Insulation
F-7234-4	Elbow, 90°, Short Radius
F-7234-5	Refrigeration Line
F-7234-6	3/4 Thk. Fiberfrax Layer

Reference Drawings

ORNL Drawings:

<u>Dwg. No.</u>	<u>Description</u>
E-19397	Absorber Shield In-Pile Loop
E-19389	Track Assembly - Loop Loading Tray
D-2-02-054-1263	In-Pile Loop Retracting Mechanism
F-2-02-054-5051	Remote Retractor Layout
B-2-02-054-4837	Individual Clamp For 1/8" Tubing
B-2-02-054-5059	Individual Clamp For 1/4" Tubing
E-2-02-054-4201	In-Pile Loop Shipping Crate
E-2-02-054-5782	In-Pile Cubical Arrangement

MTR Drawings:

MTR-E-3272-ORNL-20	Reactor Building Basement Piping
MTR-651-IDO-1	ORNL-P & W Compressor Building
MTR-651-IDO-2	ORNL-P & W Compressor Building
MTR-651-IDO-3	ORNL-P & W Compressor Building
MTR-651-IDO-4	ORNL-P & W Compressor Building
MTR-651-IDO-5	ORNL-P & W Compressor Building
MTR-651-IDO-6	ORNL-P & W Compressor Building
MTR-651-IDO-7	ORNL-P & W Compressor Building
MTR-651-IDO-8	ORNL-P & W Compressor Building
MTR-E-3471	MTR-HB-3-ORNL-20 Cubical Paraffin Shield
MTR-E-3470	MTR-HB-3-ORNL-20 Cubical Barytes Shield

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