

DESIGN, CONSTRUCTION, AND TESTING OF A LARGE MOLTEN SALT FILTER

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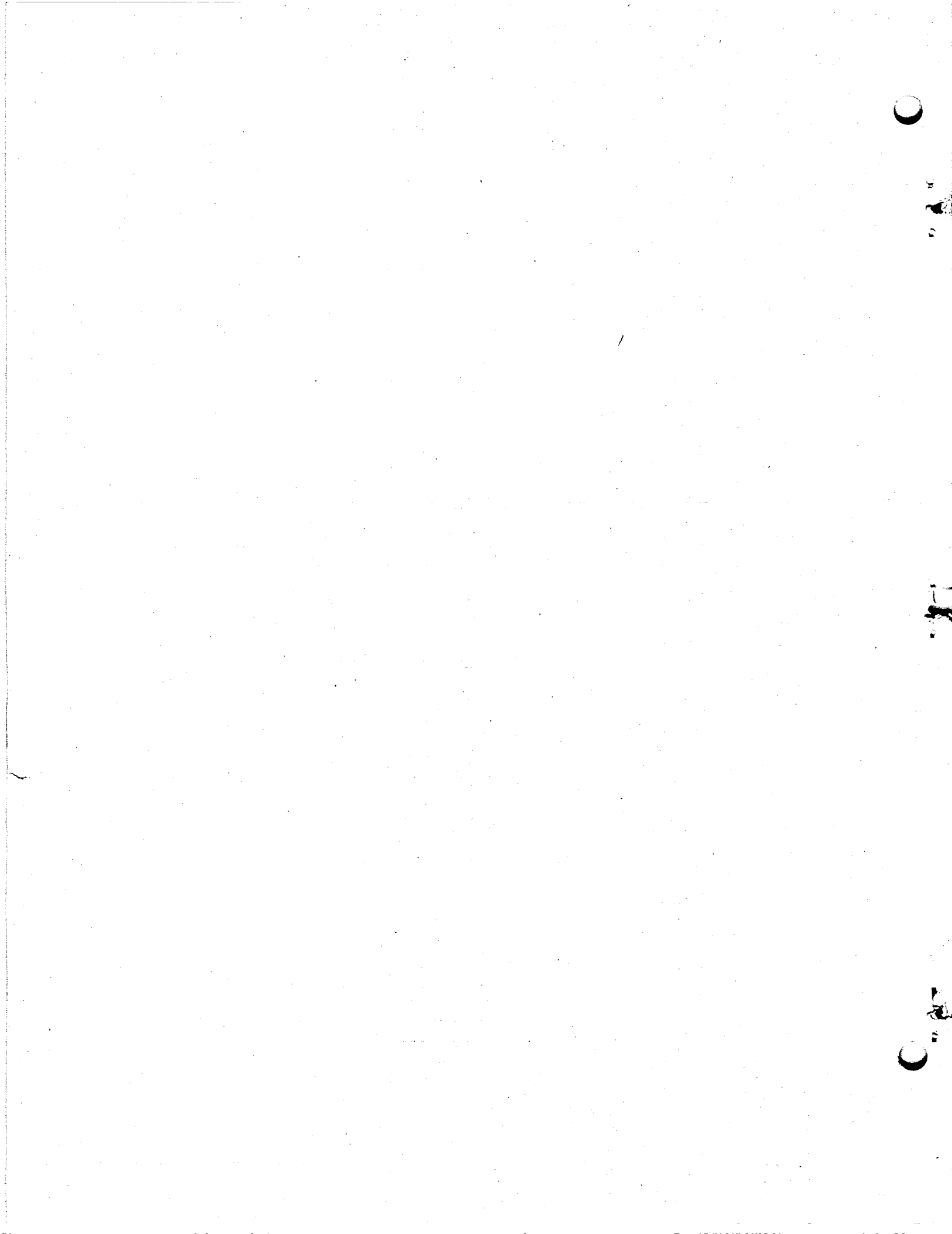
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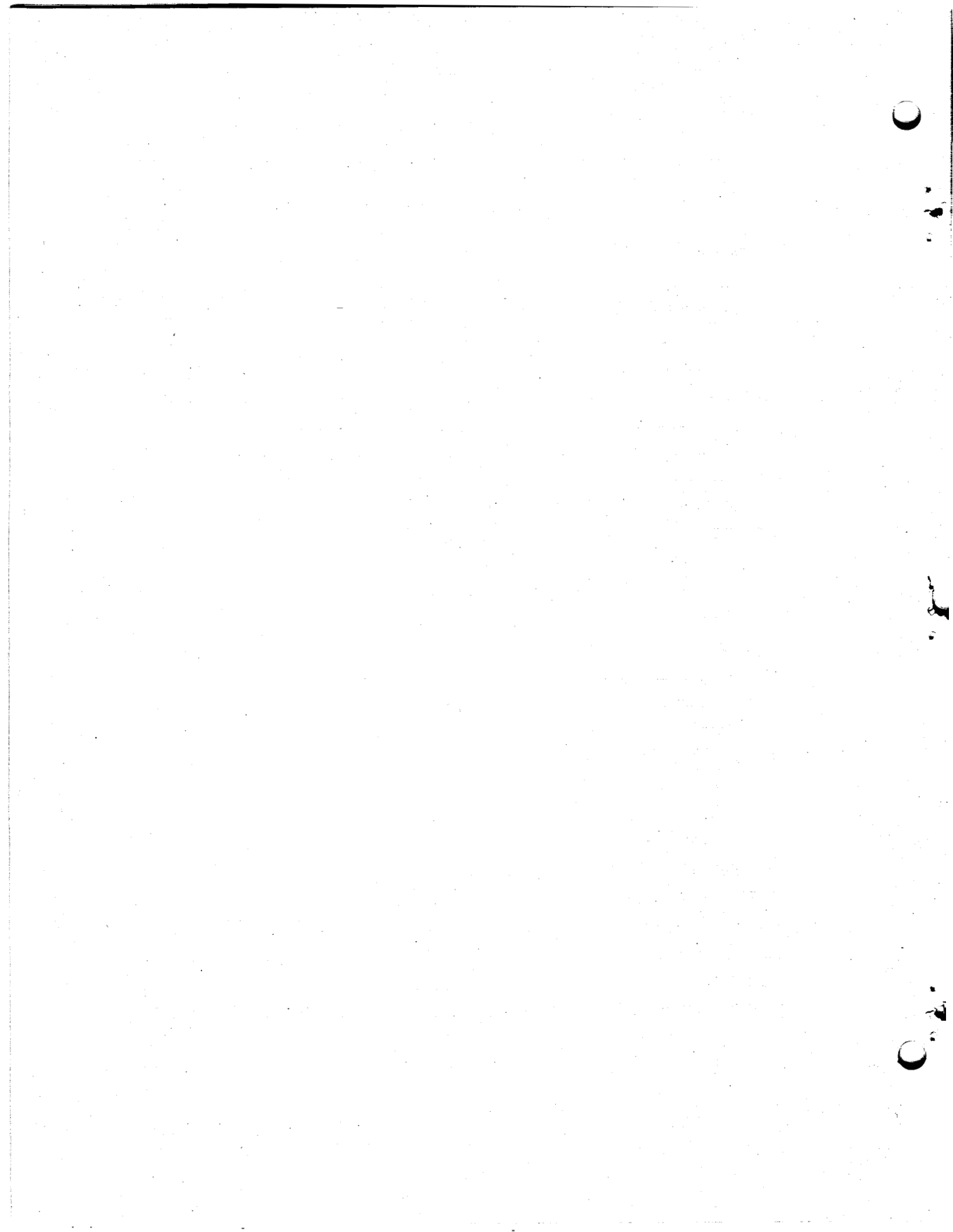
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## ABSTRACT

The Molten Salt Reactor Experiment uses mixtures of fluoride salts as fuel. Routine on-site processing of these molten salts results in formation of corrosion products. This report describes development, design, construction, installation, and testing of a large salt filter to remove these corrosion products. The filter is designed to remove approximately 15 kilograms of corrosion products from 9000 kilograms of flush and fuel salt at a temperature of 1200°F.

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## INTRODUCTION

The fuel in the Molten-Salt Reactor Experiment (MSRE) is a molten mixture of fluoride salts (LiF, BeF<sub>2</sub>, ZrF<sub>4</sub>, and UF<sub>4</sub>). The UF<sub>4</sub> required for criticality is less than one mole percent of the mixture. The MSRE, a forerunner of breeders operating in the thorium-<sup>233</sup>U cycle, started up with <sup>235</sup>U. Sufficient <sup>233</sup>U later became available and the experimental program of the reactor was expanded to include operation with this fissile material.<sup>1,2</sup> The changeover involved stripping the original UF<sub>4</sub> from the other fluorides (carrier salt) by the fluoride volatility process, in an on-site processing plant,<sup>3</sup> then adding <sup>233</sup>UF<sub>4</sub>-LiF as required.

The fluorination of the salt is accompanied by formation of corrosion-product fluorides which, if left in the carrier salt, would interfere with the routine monitoring of corrosion during reactor operation. In principle, the corrosion products could be removed simply by reducing them to insoluble metallic form, then filtering the molten salt. A problem was the filter. Small sintered-metal filters had been used extensively to filter

molten salts at temperatures to 1200°F, but the design of a filter for this high temperature and large enough to handle around 15 kg of corrosion products in 9000 kg of salt was a different order of magnitude. This report tells how such a filter was successfully developed and used. It describes the concept, development tests, final design, construction, installation, and operation.

## DESIGN CRITERIA

### Physical Layout of the System

Figure 1 shows the piping layout of the filter, storage and processing tanks. The salt inlet line of the filter is about 6 ft higher in elevation than the maximum salt level in the processing tank. From the bottom of the filter the molten salt drains by gravity to the storage tanks, about 20 ft below in another cell.

### Sequence of Operations

Two 70-ft<sup>3</sup> batches of salt were to be processed — the flush salt and the fuel salt. Salt properties are given in Table 1. The operation was to begin with transfer of an entire salt batch, by helium gas pressure from one of the storage tanks, through the filter to the processing tank. At this time the salt should contain essentially no solids and should back-flow through the clean filter element with very little pressure drop.

The salt was to be sparged with gaseous fluorine to convert the UF<sub>4</sub> to volatile UF<sub>6</sub> which leaves the salt to be collected on NaF. During this fluorination corrosion of the Hastelloy-N<sup>(a)</sup> vessel would produce NiF<sub>2</sub>, FeF<sub>2</sub>, and CrF<sub>2</sub>, all of which are soluble in the salt. Since these

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<sup>(a)</sup>Ni, Mo, Cr, Fe (70 - 18 - 7 - 5%) specially developed alloy with high temperature strength and corrosion resistant to molten salt. Commercially available from Haynes Stellite as "Hastelloy-N" and International Nickel Co. as INCO-806.

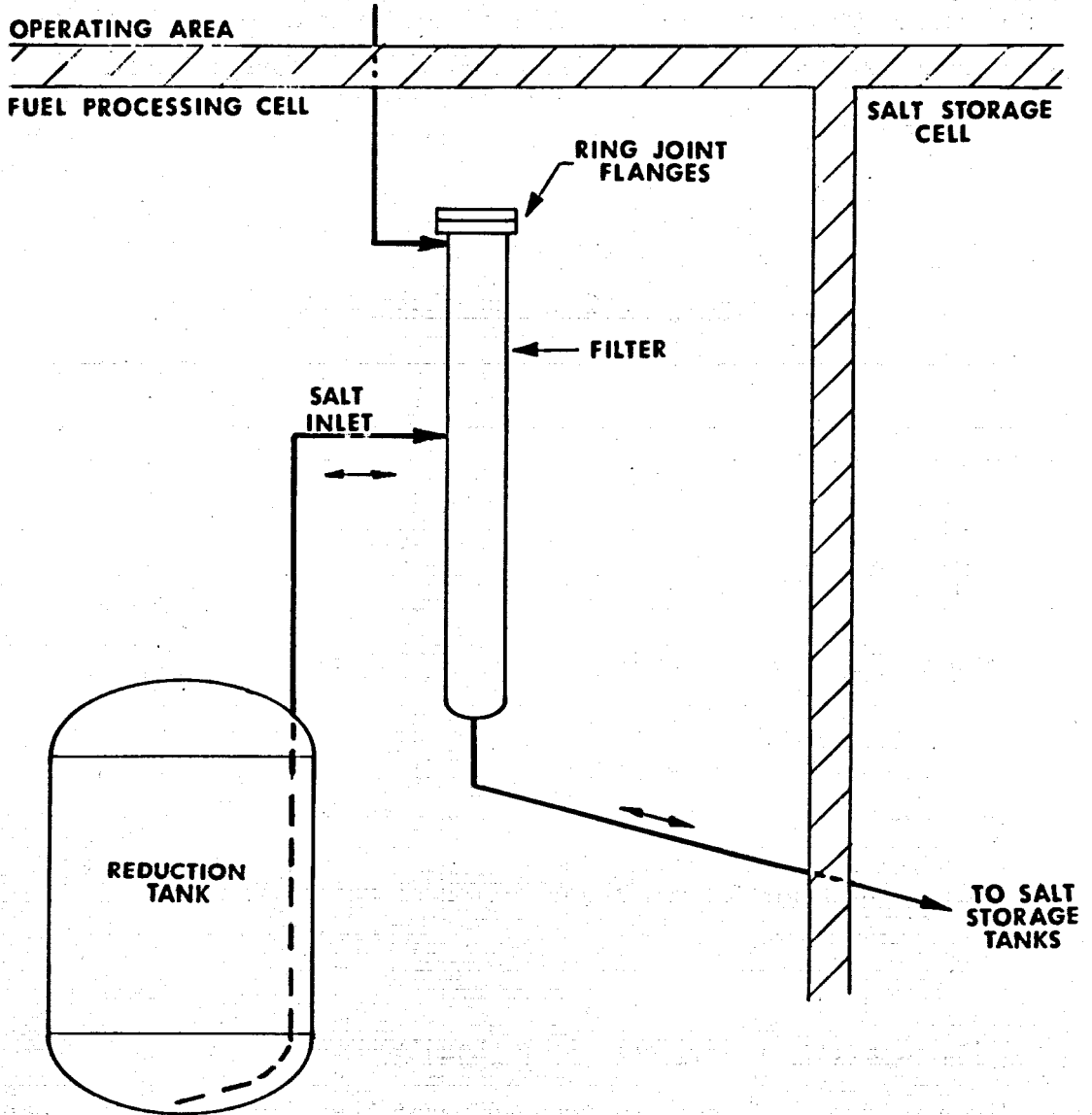


Fig. 1. Physical Layout of the System.

soluble fluorides would interfere with corrosion monitoring during reactor operation, they would have to be removed from the salt. The  $\text{NiF}_2$  would be reduced by hydrogen sparging to metallic nickel and the  $\text{FeF}_2$  and  $\text{CrF}_2$  would be reduced with pressed zirconium metal shavings to Fe and Cr metal. The salt batch would then be filtered to remove these precipitated metals before being sent to the salt storage tanks.

Table 1  
Properties of Fuel and Flush Salts

	Fuel Salt <sup>a</sup>	Flush Salt <sup>a</sup>
Composition, mole %:		
LiF	65	66
BeF <sub>2</sub>	29.2	34
ZrF <sub>4</sub>	5	
UF <sub>4</sub>	~ 0.82	~ 0.03
Average Physical Properties:		
	@ 1200°F	@ 1065°F
Viscosity, lb/ft-hr	18	20
Density, lb/ft <sup>3</sup>	147	126
Liquidus Temperature, °F	813	856

<sup>a</sup>After 15,000 hours of fuel salt circulation in the reactor piping system and before fluorination of the salt.

#### Quantities of Corrosion Products to be Handled

Since salt of this composition had never been fluorinated in plant-scale equipment the exact corrosion rate was not known. However, because of the smaller surface/volume ratio it was expected that corrosion would be less than the 0.5 mil/hr experienced in small scale work.

Assuming a corrosion rate of 0.1 mil/hr and a total fluorine sparge time (flush + fuel salt) of 70 hours, it was estimated that 15 kg of



corrosion products as metal would be produced. One filter element should have sufficient volume on the upstream side of the filter media for this weight of metal if the bulk density is not lower than 50% of the solid metal density. A large safety factor in the filter capacity was the large amount of metals remaining as sediment in the feed tank during small scale filter tests.

#### Pressure Drop

The filter element must withstand a pressure differential of 18 psig tending to collapse the filter during filtration. This is 150% of the minimum pressure at the end of the filtration when the transfer gas pressure releases through the loaded filter.

The filter element must also withstand a pressure differential of 30 psig tending to burst the filter media during transfer to the processing tank. This is 150% of the salt head from the bottom of the storage tank to the filter element.

#### Temperature

The filter element must have the required strength at 1200°F, which is the maximum expected temperature during salt transfer.

#### Pressure

The maximum pressure on the filter housing will be 30 psig.

#### Maintenance

The filter element must be replaceable by remote maintenance in case of plugging.

### EXPERIMENTAL PROGRAM

The selection of a high-temperature filter media for molten salt is limited to materials that have high-temperature strength, corrosion resistance in molten salt, and adequate filtration efficiency. The temperature and corrosion requirements limit the material selection to high-nickel alloys such as Inconel and Hastelloy-N. Inconel was chosen because of

availability. To select the type and size of filter media that would satisfactorily remove the corrosion products expected in fluorination of the MSRE fuel and flush salts required an experimental program.<sup>4</sup> The experimental program was composed of two parts. In the first part, molten salt was prepared to simulate the conditions expected after fluorination of the MSRE fuel salt. The second part consisted of salt-filtration tests of two types of filter media under conditions which approximated those anticipated in the reactor application.

#### Reduction of Corrosion Products Fluorides

The experimental program was carried out with a 104-kg batch of the fluoride mixture,  $\text{LiF-BeF}_2\text{-ZrF}_4$  (65 - 30 - 5 mole %) which was prepared from the component fluoride salts by routine production procedures. After treatment to remove oxygen and sulphur impurities,  $\text{CrF}_2$ ,  $\text{FeF}_2$ , and  $\text{NiF}_2$  were added to the salt mixture to simulate the conditions expected after fluorination of the MSRE fuel salt. The salt mixture was hydrofluorinated to insure complete dissolution of the corrosion product fluorides. Analysis of a filtered sample of the salt taken after dissolution is compared with expected concentrations in Table 2.

The  $\text{NiF}_2$  in the salt mixture was reduced with a hydrogen sparge and the gas effluent periodically analyzed for HF. Since equilibrium data produced very low hydrogen utilization during reduction of  $\text{FeF}_2$  and  $\text{CrF}_2$ , data were obtained on reduction of these fluorides with pressed zirconium metal turnings added to the salt mixture. Analysis of filtered samples taken near the conclusion of the zirconium addition period are also shown in Table 2.

#### Salt Filtration Studies

Filtration tests were conducted using 40- $\mu$  pore size sintered porous nickel (Micro Metallics Corp.) and two grades (20 and 41- $\mu$  pore size) of sintered fiber metal (Huyck Metals Co.). Each filter was fabricated as a 2-5/8-in. diameter plate so that geometric surface areas of all filters would be identical.

The experimental assembly used for the filtration tests was essentially that used for the routine production of fluoride mixtures. Tests were

Table 2

Corrosion Product Fluorides in Batch of Salt for Filter Media Test

Material	Quantity Added (g)	Estimated Concentration* (ppm)	Results of Analysis of Filtered Samples* (ppm)		
			After Hydro-fluorination	After Addition of 253 g Zr	After Addition of 327 g Zr
CrF <sub>2</sub>	80	445	470	9	26
FeF <sub>2</sub>	50	286	620	60	44
NiF <sub>2</sub>	800	4680	3700	<30	36

\*Concentrations reported on a metal basis.

made under static conditions by allowing the melt to remain quiescent for a minimum time of 4 hours prior to transfer, and also made by rapidly sparging the melt with helium just prior to salt transfer at 650°C. The pressure drop across the filter varied from 22.5 to 20.8 psi as the level of salt in the treatment vessel decreased. A summary of the filtration tests is shown in Table 3.

The fiber metal media (designed FM-250 by the manufacturer) which had a porosity of 78% and a stated removal efficiency of 98% for particles larger than 10 microns in diameter was recommended for the MSRE. Filtration times for this material were about 1.19 and 1.36 hours per cubic foot of salt mixture (Runs 7 and 4). The occasional plugging of the filter in Tests 4 and 5 suggests that the loading capacity of the 40-micron filters may be about 50 to 75 grams of metal particles or about 9 to 14 grams per square inch of filter surface.

Samples of the salt mixture were taken before the first filtration experiment and downstream from the filter plate after Tests 4, 6, and 7. Analysis of these samples are given in Table 4. Only 1.8 to 3.4% of metals reduced from solution passed through the FV-250 fiber metal media.

It was concluded that the FM-250 fiber metal media would filter as well as the porous metal media that had been used successfully to filter small batches of the original salt loadings for the MSRE and was less susceptible to plugging.

## FINAL DESIGN

### Analysis of MSRE Fuel Cell Salt Filter Pressure Vessel

Calculations were made to determine that stresses in the pressure vessel for the filter would be within the allowable stresses for Class-C vessels of Section III of the ASME Boiler and Pressure Vessel Code.<sup>5</sup> Design data are given in Table 5 and construction details are shown on Drawings E-NN-D-49036 and E-NN-D-49037.

Table 3

Summary of Filtration Tests

Salt Composition: LiF-BeF<sub>2</sub>-ZrF<sub>4</sub> (65-30-5 mole %)  
 Wt of Salt Mixture: 104.1 kg  
 Volume of Salt at 650°C: 1.7 ft<sup>3</sup>  
 Indicated Pressure Differential: 11 psig forepressure vs vacuum

Test No.	Filter Material	Pore Diameter Microns	Salt Conditions	Transfer Time Hours	Weight Gain Grams	Remarks
1	Monel fiber metal	20	Static		22	Test terminated after 2 hrs. Essentially no salt transfer.
2	Porous Nickel	40	Static	0.5	7	No visible material on filter or evidence of failure.
3	Porous Nickel	40	Agitated	1.75	44	
4	347 SS fiber metal	41	Static	2.0	77	Test stopped after 90 kg transfer.
5	Porous Nickel	40	Static	2.17	63	Filter plugged after 40 kg transfer. Material on filter predominantly salt.
6	Porous Nickel	40	static	1.84	19	Balance of salt transferred filter ruptured.
7	347 SS fiber metal	41	Agitated	2.0	67	
8	Porous Nickel	40	Static	1.75	22	80 kg back transfer of salt from receiver to treatment vessel. Filter plugged.

Table 4

Summary of Analytical Results  
During Filtration Tests

<u>Sample Interval</u> <u>Filtered Sample</u>	<u>Impurity Concentration (ppm)</u>			
	<u>Cr</u>	<u>Ni</u>	<u>Fe</u>	<u>Total</u>
Before Test 1	26	36	44	106
After Test 4	15	84	66	165
After Test 6	16	256	132	404
After Test 7	17	19	49	85

Table 5

Design Data for Large Salt FilterGENERAL

Construction Material	Inconel 600
Pneumatic Pressure Test	
Pressure Vessel without Filter Element, psig	625
Filter Element Inner Core Can, psig	100
Helium Vacuum Leak Rate to Inside	
Pressure Vessel (without filter element), cc/sec of helium	$<1 \times 10^{-8}$
Filter Element Inner Core Can, cc/sec of helium	$<1 \times 10^{-8}$
Design Temperature	
Pressure Vessel, °F	1200
Filter Element, °F	1200
Design Pressure, psig	35
Operating Temperature, °F Maximum	1200
Operating Pressure, psig Maximum	35

FILTER PRESSURE VESSEL

Size	6 inch, Sch. 40, pipe
Length	7 feet -10 inches
Salt Inlet and Outlet Size	1/2 inch, Sch. 40, pipe
Access for Filter Element	6 inch, 300 lb, ring joint flange (special)
Flange Seal	R-45, O-ring, Copper, Leak-detected (special)

FILTER ELEMENT

Filter Media	FM-250 Feltmetal
Porosity, %	84
Mean Pore Size (Microns)	59
Filteration Rating when Filtering Liquids	
Nominal (98%), microns	10

Table 5 (continued)

FILTER ELEMENT (continued)

Tensile Strength @ 100°F, psi	800
@ 1200°F, psi	571
Modulus of Elasticity @ 1200°F, psi	$3.5 \times 10^{-5}$
Thickness, inch	0.096
Pressure Drop for Clean Water	
@ 10 gpm/ft <sup>2</sup> in psi	0.1
@ 100 gpm/ft <sup>2</sup> in psi	0.85
Total Filtering Area, ft <sup>2</sup>	8.65
Filter Media-Perforated Metal Support	
Thickness, inch	0.078
Open Area, %	32
Quantity of Salt to be Filter, kg	9,000



Stresses in the vessel are due to the 35-psig internal pressure and the axial temperature gradient along the vessel from the heated section at 1200°F through a 25-in. insulated section and a 7-1/2-in. bare metal section at 200°F on the end. The axial temperature gradient causes discontinuity stresses because of the resulting differential radial expansion of the vessel.

The temperature gradient was determined through the use of the "Astra Heating"\* computer program at approximately 1-in. increments for the 32.5-in. on length outside the heated zone. The maximum temperature differential of 56°F per linear inch is near the heated zone at the highest temperature and lowest allowable stress. There is no temperature gradient across the wall of the pipe so there are no radial thermal stresses.

The sum of the stresses due to pressure and the temperature gradient are less than three times the Code allowable stress for primary stresses, so the design is therefore satisfactory.

#### Filter Element Design

In small scale batch operations, sintered porous nickel filters have been used successfully as reported earlier. However, it was decided to investigate the use of fiber metal filter media for possible improvement in capacity. Although experimental tests did not show any significant improvement in performance, it was decided to use the fiber metal because of its adaptability and availability to fabrication requirements. (A cylindrical porous filter would have to be fabricated by the manufacturer.) Inconel was chosen as the material of construction not only because of its strength at elevated temperature, but also because of its corrosion resistance to molten salt.

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\* Generalized Heat Conduction Code written for the IBM-6090 Computer by ASTRA, INC. under contract to the Atomic Power Development Associates of Detroit, Michigan, (Fermi Reactor); reported as The Heating Program, Heat Engineering and Transfer in Nine Geometries, R. R. Liguori and J. W. Stephenson, ASTRA, INC., Raleigh, North Carolina, January 1, 1961.

Both the burst (from internal pressure) and the collapse strength of the inner and outer filter elements were considered in the design of the filter element. Design data are given in Table 5. The burst strength is important only during back flow when transferring salt to the processing tank. The formula<sup>6</sup>

$$p = \frac{2 s t}{dia}$$

was used in the calculation where  $s$  is the tensile strength of the fiber metal at 1200°F.

$$s = \frac{s (\text{Inconel @ } 1200^\circ)}{s (\text{Inconel @ } 100^\circ)} \times s (\text{fiber metal @ } 100^\circ) = \frac{52,500}{73,000} \times 800 = 571 \text{ psi.}$$

The outer filter element was calculated to have a burst strength of 25 psi and the inner filter 34 psi with no safety factor. The worst conceivable case would be if the filter element were almost completely restricted from the flush salt filtration and the fuel salt was then transferred to the processing tank. Since the burst strength of the outer element is less than the 30 psig specified in the design criteria, the buoyancy of the filter in the salt on transfer to the processing tank is necessary for the filter to meet the burst strength requirement. The filter element has a weight of 57 lbs and a horizontal area of 25 in.<sup>2</sup>. Construction details are shown on Drawing E-NN-D-49038 and Figures 2 and 3. A pressure of only 2.3 psi will therefore cause flotation of the element and by-passing of salt through the seat. This pressure is further reduced by the buoyancy of the element so there is no danger of rupture of the element if the filter is above the melting point of the salt.

To prevent collapse of the filter element it was necessary to provide a perforated back-up plate against the inner filter surface. The maximum external pressure is applied to the filter at the end of filtration when the transfer gas pressure blows into the gas space above the filter element. At this time there will also be the maximum restriction of the filter from collected solids. In calculating the collapse strength, the formula<sup>7</sup>  $ps = \frac{2 E t^3}{(1-m^2)D^3}$  was used where  $E$  is the modulus of elasticity,  $t$  and  $D$  are the thickness and diameter of the element and  $m$  is Poisson's

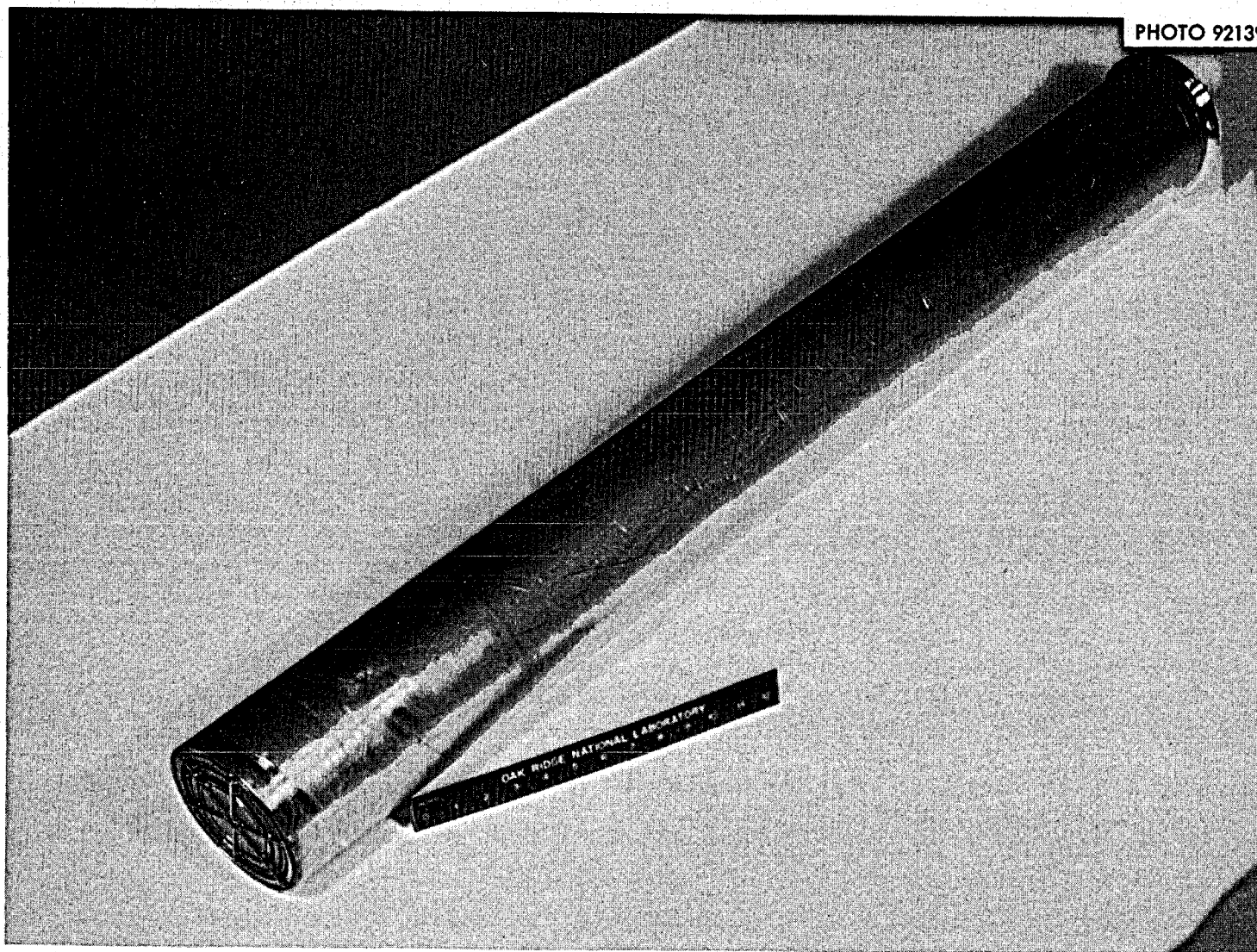


Fig. 2. Filter Element, Top and Side View.

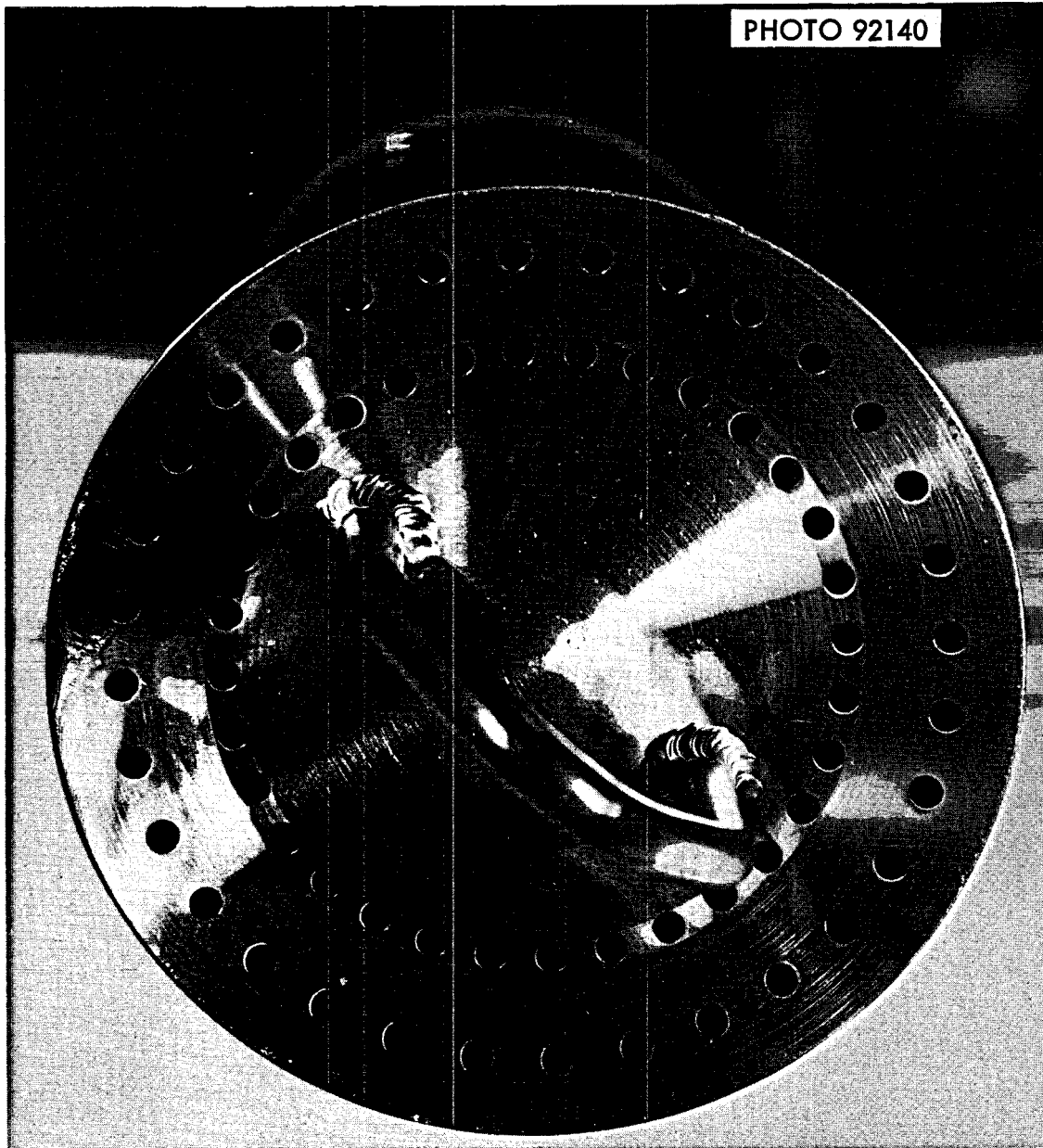


Fig. 3. Filter Element, Bottom View.

ratio (0.3). E for the fiber metal is 1.75% of solid Inconel and is  $3.5 \times 10^5$  psi @ 1200°F. Considering the fiber metal without the backup, the outer element has a collapse strength of only 6.5 psi and the inner element 16.3 psi without a safety factor. Since the minimum final transfer pressure is 12 psi for the fuel salt (without any flow  $\Delta P$ ), it is evident that a backup is required. An 0.078-in. thick Inconel perforated sheet with 32% open area was used as a backup because of availability. This plate alone has a collapse strength (for the larger element) of 131 psi. To provide a safety factor of 4 the operating procedure specifies a maximum transfer plus gas space pressure of 35 psi.

The filter element can move upward during salt back-flowing and by-pass salt through the seat, but it has to reseal after flotation to minimize leakage in the main direction of salt flow. Mating spherical seating surfaces are provided between the filter element and pressure vessel for ease in self-sealing.

#### Electric Heater Design

Electric heaters are provided to permit preheating of the filter and to maintain the temperature of the salt during a transfer. Maintenance requirements are minimized by designing the heaters with excess capacity so they can be operated at reduced voltage to promote longer life. Also duplicate spare heaters are installed and connected ready for use with only minor, out-of-cell wiring changes. The tubular heaters are 0.315-in. OD Inconel sheath with nichrome elements rated 500 watts per foot of heater. A layer of stainless steel shim stock is installed between the heaters and the thermal insulation to prevent the heaters from being in direct contact with the insulation.

The controls that are used limit the available installed capacity to 3500 watts; 2400 watts in the lower control (FSF-1) and 1000 watts in the upper control (FSF-2). (See Drawing E-NN-D-49036.) Control of the electrical input to the heaters is from manual powerstats. The voltage setting required was determined during startup testing, and manual stops were set to limit the controls to hold the temperature to 1300°F or below. During startup testing, 1600 watts for the lower section and 500 watts for

the upper section were required to preheat the filter. Only the heaters on the lower section are required for normal transfer of salt. If salt freezes in the upper section of the filter because of unforeseen difficulties, heaters on the upper control will be used to preheat this section.

#### Instrumentation Design

A helium supply is provided and instrumented to assure the presence of a gas cushion in the filter at all times and to purge the connecting lines with helium before filtration. Temperature instruments are provided both to indicate that the equipment is above the salt melting point and as an indication of salt level.

Figure 4 shows the helium supply to the filter. The solenoid valve is interlocked with the salt freeze valves to prevent the accidental pressuring of molten salt from a salt storage tank to the reactor by helium through the filter. Accidental filling of the reactor is further prevented by the pressure control valve limiting the pressure to 15 psig — sufficient to fill the reactor only 1/2 full — and the flow restrictor which would limit the salt transfer rate to 5 liters per minute — only 30% of the normal reactor fill rate. The check valves prevent back-flow of radioactive gases to the operating area. PI-B indicates the pressure in the gas space above the filter element. This pressure is transmitted to the operating area by a transmitter contained in a cubicle vented to the processing cell.

Temperatures are monitored by eleven thermocouples attached to the outer wall of the filter housing. Nine of these are read out on a 0 - 2000°F recorder. The other two (at the same elevation as Points 7 and 9) are connected to temperature switches which actuate annunciators and provide interlock contacts in the pressurization and vent valve control circuits. Since the upper heater will be normally off, temperature points 5, 6, 7, 8, and 9 will be heated only by conduction unless the salt level rises higher than normal. If this occurs there will be an alarm and the pressurization valve will close when point 7 reaches 1000°F. When point 9 reaches 350°F there will be an alarm, the pressurization valve

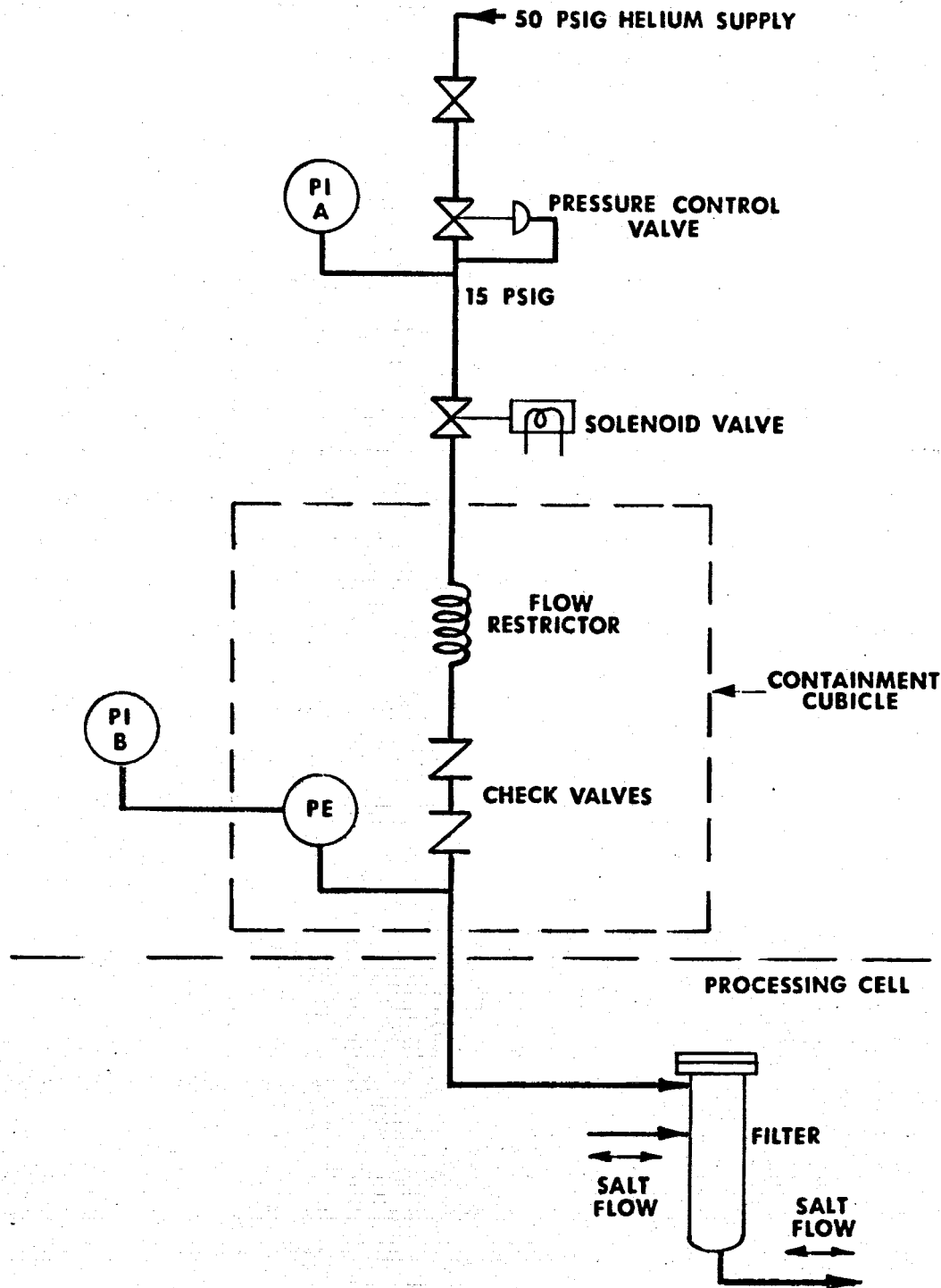


Fig. 4. Helium Supply Instrumentation.

will close and the salt-tank vent valve will open. Rise in salt level could be caused by a restricted filter element, leaking ring-joint flange and/or leaking check valves.

## FABRICATION

### Procurement of Materials

All salt-containing parts are fabricated from Inconel-600 material. Pipe, fitting, and plate were purchased from vendors according to applicable American Society for Testing and Materials Specifications<sup>8</sup> with certified chemical and physical properties. After receipt in ORNL, the material received additional liquid penetrant<sup>9</sup> and ultrasonic inspection.<sup>10</sup> This inspection is routinely given material used to fabricate MSRE equipment that will contain high-temperature radioactive gases and fluids. This additional inspection is considered partial insurance against equipment failure and the need for expensive and time-consuming remote maintenance.

The filter media (sintered Inconel fibers) was purchased in 18 x 20-inch sheets from Huyck Metals Company. This special material was selected and purchased after numerous consultations with the vendor about its unique design properties.

### Shop Fabrication

The filter housing and element were fabricated in Oak Ridge National Laboratory shops from Drawings E-NN-D-49036, E-NN-D-49037, and E-NN-D-49038. High quality nuclear fabrication specifications and techniques that met or exceeded the requirements for Class "C" vessels of Section III of the ASME "Pressure Vessel Code"<sup>5</sup> were used to fabricate the filter. Forming and welding of the fibrous Inconel filter-media metal<sup>11</sup> required the development of special fabrication techniques. Special procedures were also utilized to prevent the filter-media from becoming contaminated with foreign material during fabrication.

Welds<sup>11</sup> of all Inconel pressure-containing parts were liquid-penetrant inspected<sup>9</sup> and radiographed.<sup>12</sup> Other Inconel welds received liquid-penetrant



inspection. Welds of the fibrous metal filter-media were visually inspected. All welding was performed by welders qualified in the weld procedures specified on the drawings.

A pneumatic test was performed on the pressure vessel, without the filter element, as specified in ASME Code. The inner core can of the filter element was pneumatically tested at 100 psig to insure against failure at operating pressure and temperature.

After pneumatic tests, the pressure vessel and inner core can of the filter element were separately leak-tested by evacuating the inside and flooding the outside with helium. Helium leakage to the inside was less than  $1 \times 10^5$  cc/sec of both subassemblies.

A polydispersed aerosol, dioctylphthalate (DOP) was forced through the fibrous metal filter element at various stages of fabrication and monitored to determine if any large cracks had developed during fabrication.

#### Quality Assurance

The salt filter is designed to operate at 1200°F temperature and 35-psig pressure and contain highly radioactive fluids and gases. Since remote maintenance of radioactive equipment is difficult and time-consuming, every effort, within practical limits, was made to obtain the necessary quality level to minimize maintenance on the filter during the life of the experiment.

Once the adequate quality level was established, necessary material requirements, fabrication specifications, and test procedures were selected and placed on fabrication drawings. These drawings, special instructions, and inspected material were delivered to the shop for fabrication. Discussions between shop management, inspectors, and MSRE representatives were arranged to discuss the quality of fabrication desired, possible problem areas, and completion schedule. This was done to reduce the possibility of misunderstanding and the possible reduction in quality and/or additional cost and additional time to rebuild the filter. One of the most important factors for good quality assurance is the establishment of a strong, working relationship between project management,

shop management, and inspection personnel to make sure the requirements on the drawings are followed and the results reported.

#### Schedule and Cost

Conceptual design and development tests began in late November 1967. They progressed concurrently until completion in late January 1968. Procurement began in mid-January 1968 and materials were received and inspected in time to begin fabrication in late February. Fabrication of one filter assembly and one spare filter element was completed and tested by late March 1968.

Fabrication costs of one filter housing and two filter elements consists of \$4800 for material, \$1300 for material inspection, and \$5200 for shop labor.

#### INSTALLATION

The filter assembly was installed in the fuel-processing system after all other piping was completed (see Fig. 5). Since the fuel-processing cell is comparatively small and crowded, some difficulty was encountered in locating the assembly. One of the prime requirements in locating the filter was to provide direct access from above so that filter elements could be replaced by remote maintenance techniques. Close coordination between the installers and the remote maintenance group in locating the filter assembly resulted in the filter assembly being installed in a location which is accessible for element replacement with minimum difficulty.

Welding caused some problems since part of the piping system was contaminated with small quantities of non-radioactive salt from a previous test run. This salt had to be completely removed from the immediate weld area to prevent contamination of the connecting welds. Valuable assistance was given by the welding inspection group on the best methods to follow in cleaning and welding in this contaminated piping system. As a result of close cooperation, all welding passed the necessary inspection and test specifications.

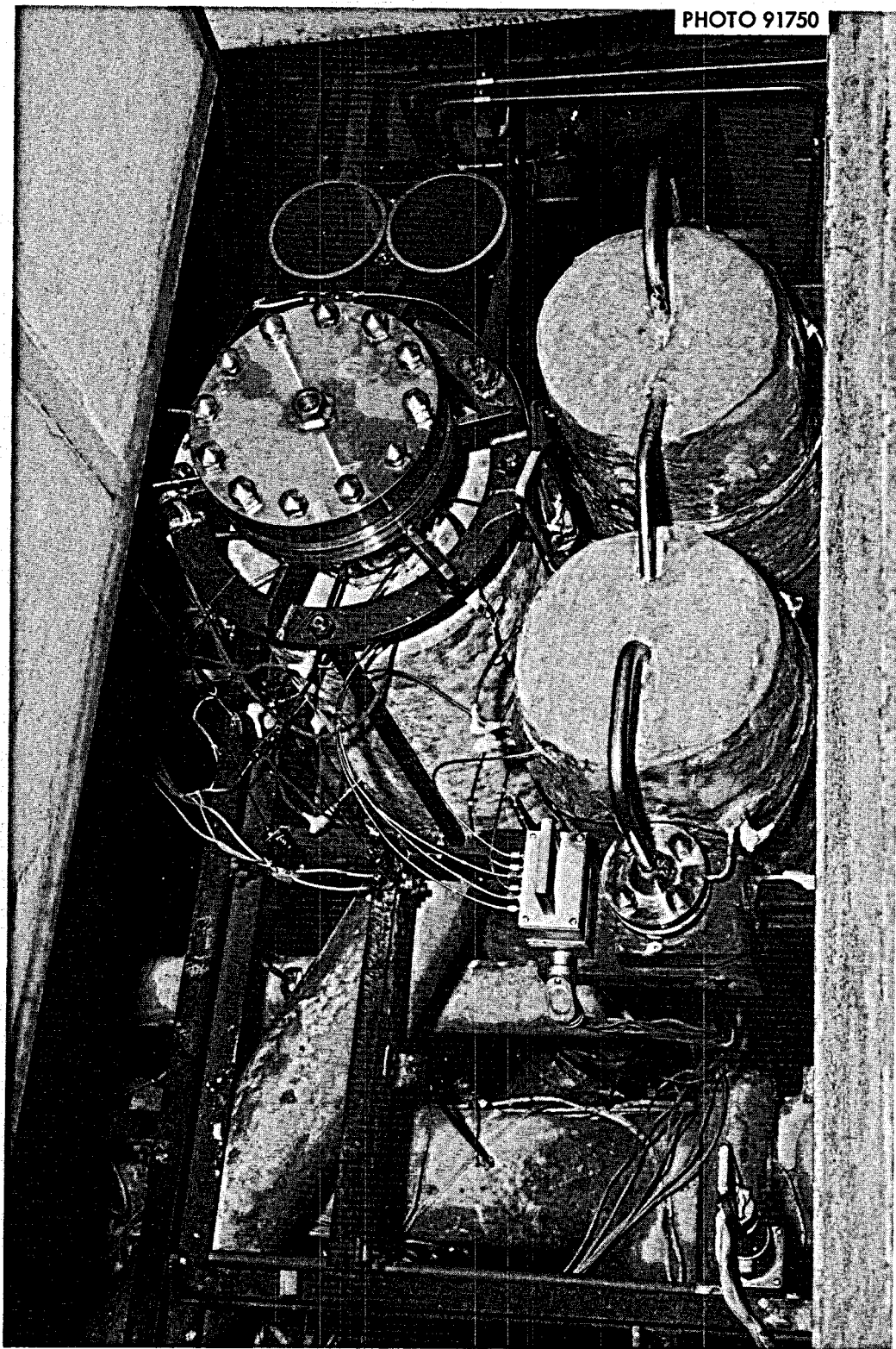


Fig. 5. Filter Assembly Installed in Fuel Processing Cell.

## PLANT PERFORMANCE

On May 6, 1968 an opportunity was provided for determining the temperature distribution prior to radioactive operation. To compensate for past and anticipated removals of salt from the reactor fuel system, 3-1/2 ft<sup>3</sup> of clean carrier salt (67 mol % LiF, 33% BeF<sub>2</sub>) was passed through the filter. Figure 6 shows the temperature distribution over the upper half (gas space) of the filter. Also shown are the temperatures obtained later with the flush and fuel salt filtrations which correspond closely. From these temperatures, the temperature switches at points 7 and 9 were set to alarm and stop salt transfer at 1000°F and 350°F respectively. The temperature 2 inches below the ring joint (Pt. 9) was only 250°F indicating that the uninsulated flange joint was probably below 200°F. The remote leak detection on the flange indicated no leakage during the heat-up, transfer, or subsequent cool-down.

During August 1968, both flush and fuel salt batches were transferred to the processing tank through the filter, fluorinated, the structural metal fluorides reduced and the salt filtered as it was returned to the reactor drain tanks. In each of these operations there was no detectable pressure drop across the filter and the filtration was accomplished in about two hours. The amount of metals removed from the salt is shown in Table 6. The total of both batches is 10 kg. Since visual inspection of the processing tank after filtration was not possible it is not known how much of the reduced metals remained in the tank and how much is on the filter element.

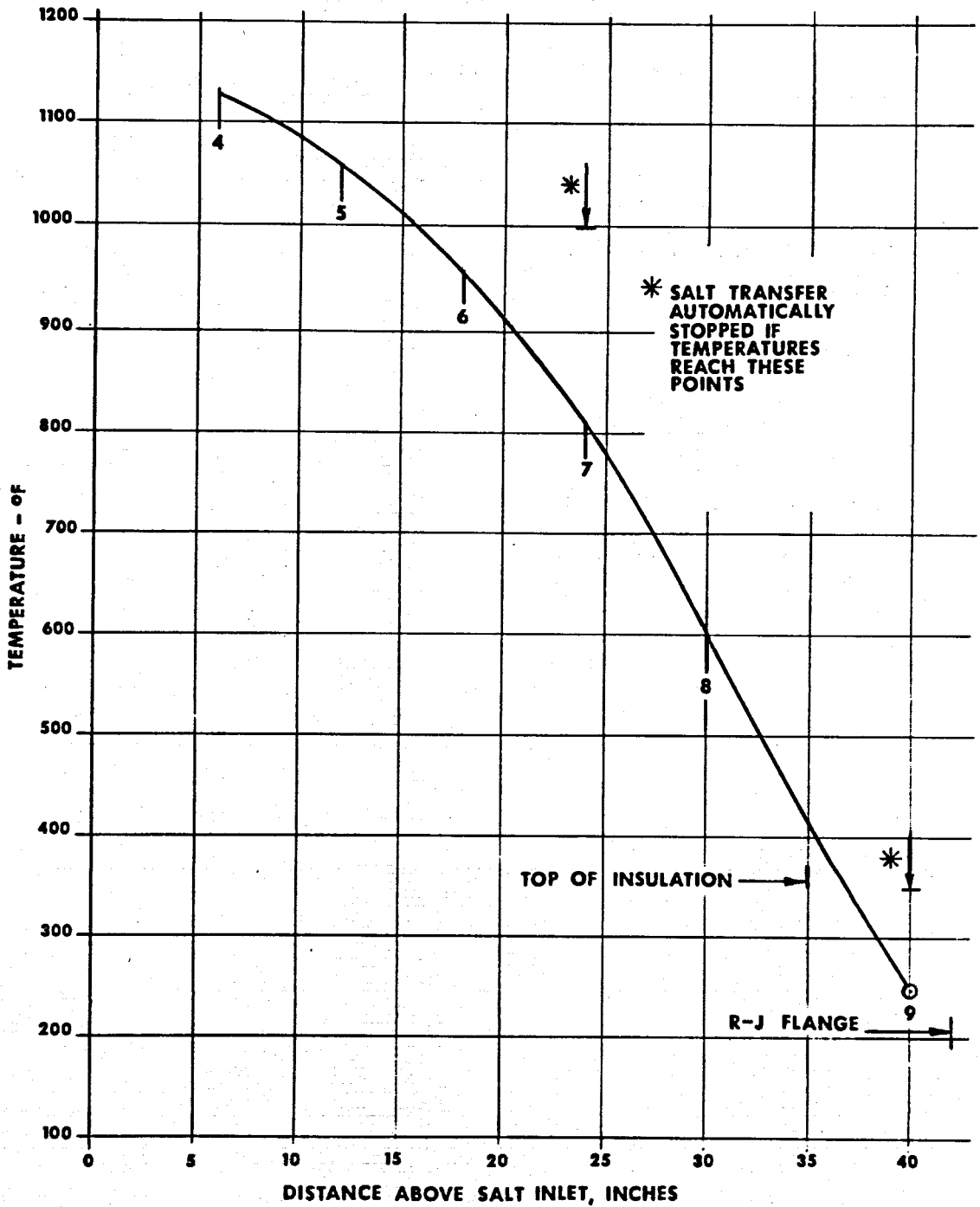


Fig. 6. Salt Filter Temperatures.

Table 6

Radioactive Salt Filtration

## Changes in Concentration

	ppm			Total
	Ni	Fe	Cr	
<u>Flush Salt</u>				
Before Reduction	516	210	133	859
After Reduction and Filtration	<u>26</u>	<u>141</u>	<u>76</u>	<u>243</u>
Removed by Filter	490	69	57	616
<u>Fuel Salt</u>				
Before Reduction	840	400	420	1660
After Reduction and Filtration	<u>60</u>	<u>110</u>	<u>34</u>	<u>204</u>
Removed by Filter	780	290	386	1456
<u>Weights Removed, Grams</u>				
	Ni	Fe	Cr	Total
From Flush Salt	2110	297	245	2652
From Fuel Salt	3900	1450	1930	7280

## ACKNOWLEDGMENT

We gratefully acknowledge the contributions of the following Reactor Division personnel:

C. W. Collins for assistance in preparing the section on Pressure Vessel Design.

P. N. Haubenreich for assistance in preparing the Introduction and report content.

T. L. Hudson for assistance in preparing the section on Electric Heating Design.

B. H. Webster for assistance in preparing the section on Installation.

J. H. Shaffer and L. E. McNeese of Reactor Chemistry Division for performing and reporting the developmental work. Information contained in their CF Report has been condensed and included in this report.

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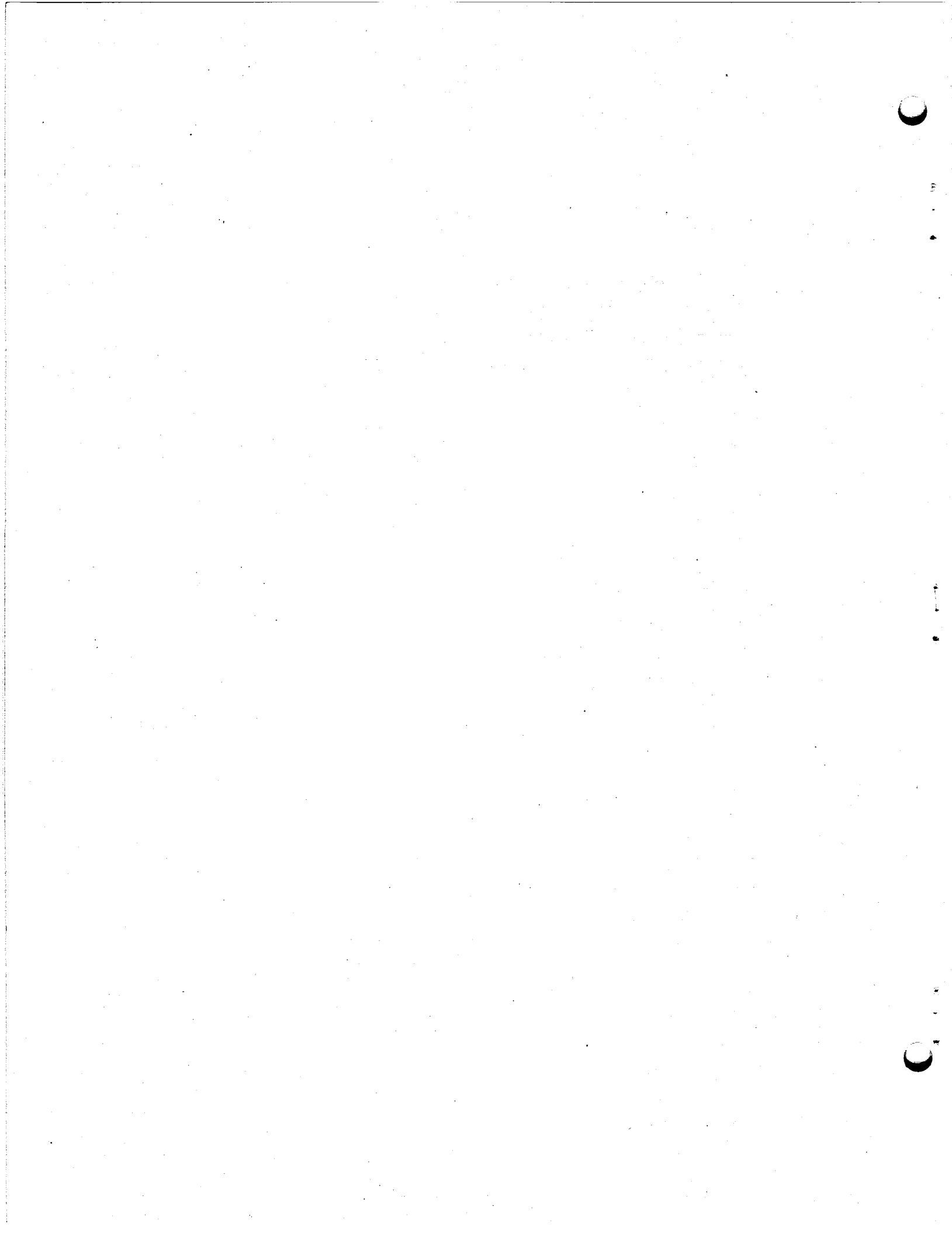
## APPENDIX

Fabrication Drawings — Salt Filter

E-NN-D-49036 — Assembly

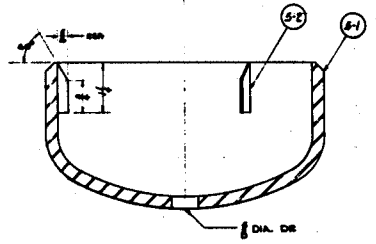
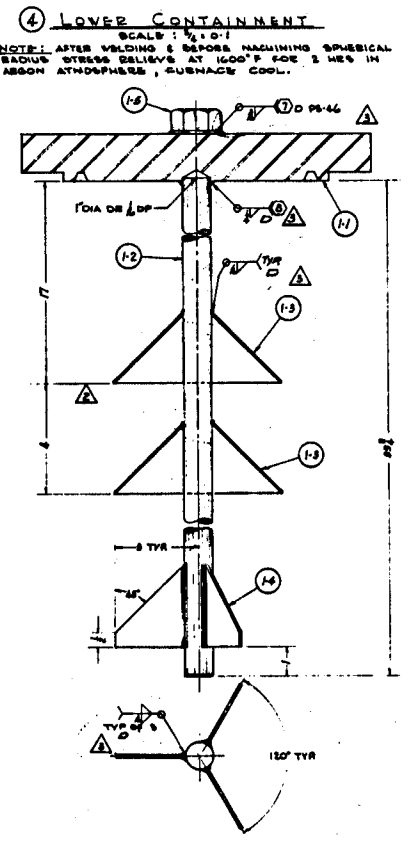
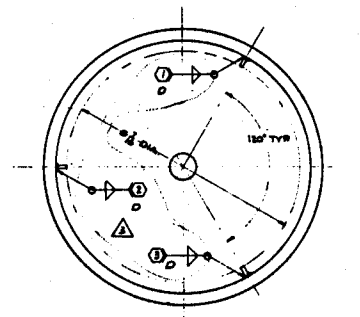
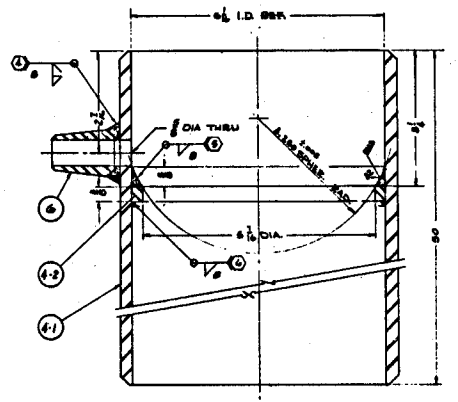
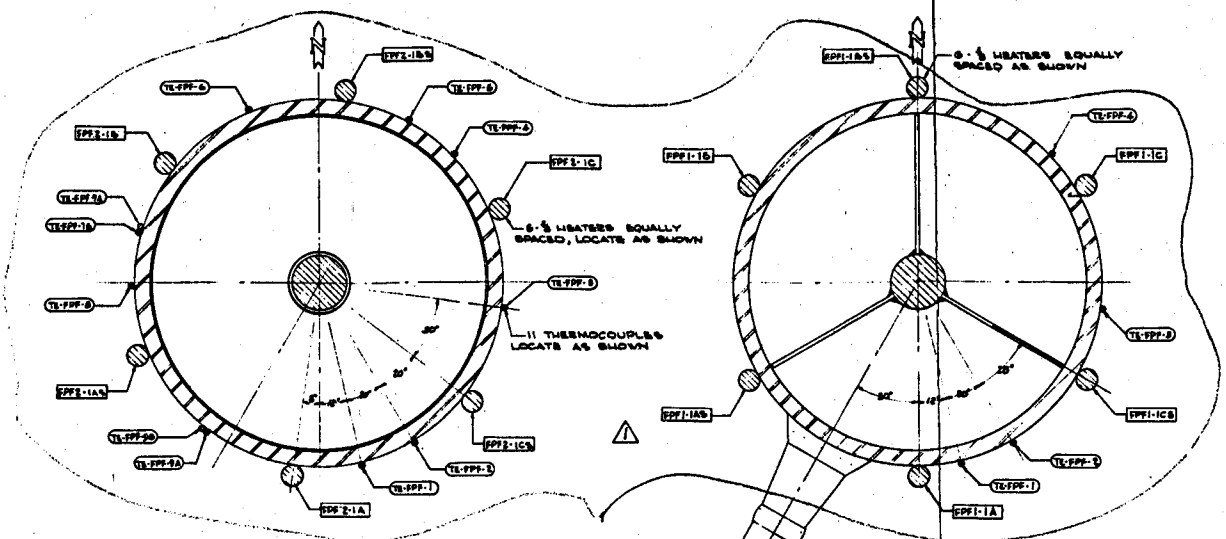
E-NN-D-49037 — Details

E-NN-D-49038 — Filter Element Subassembly — Details

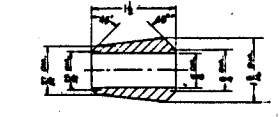
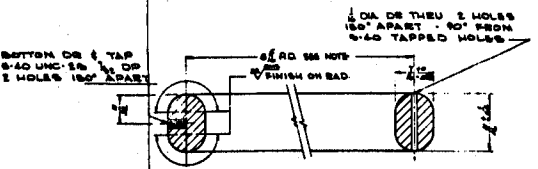
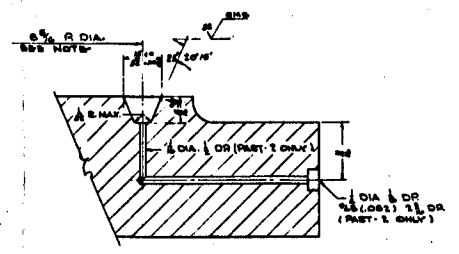
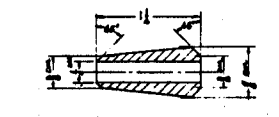
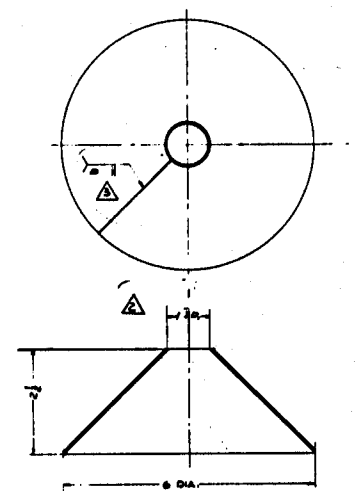




PARTS LIST					
PART	DWG NO.	REQD	DESCRIPTION	STOCK SIZE	MATERIAL



5 6 SCH 40 PIPE CAP - MODIFICATION  
SCALE: 1/4" = 1'-0"



NOTE: THE AVERAGE PITCH DIA. AS INDICATED BY MEASURING (5) DIA'S 60° APART SHALL BE WITHIN ±.002 OF THE NOM. DIA. & SHALL BE CONCENTRIC ABOUT THE & WITHIN .003 T.I.B.

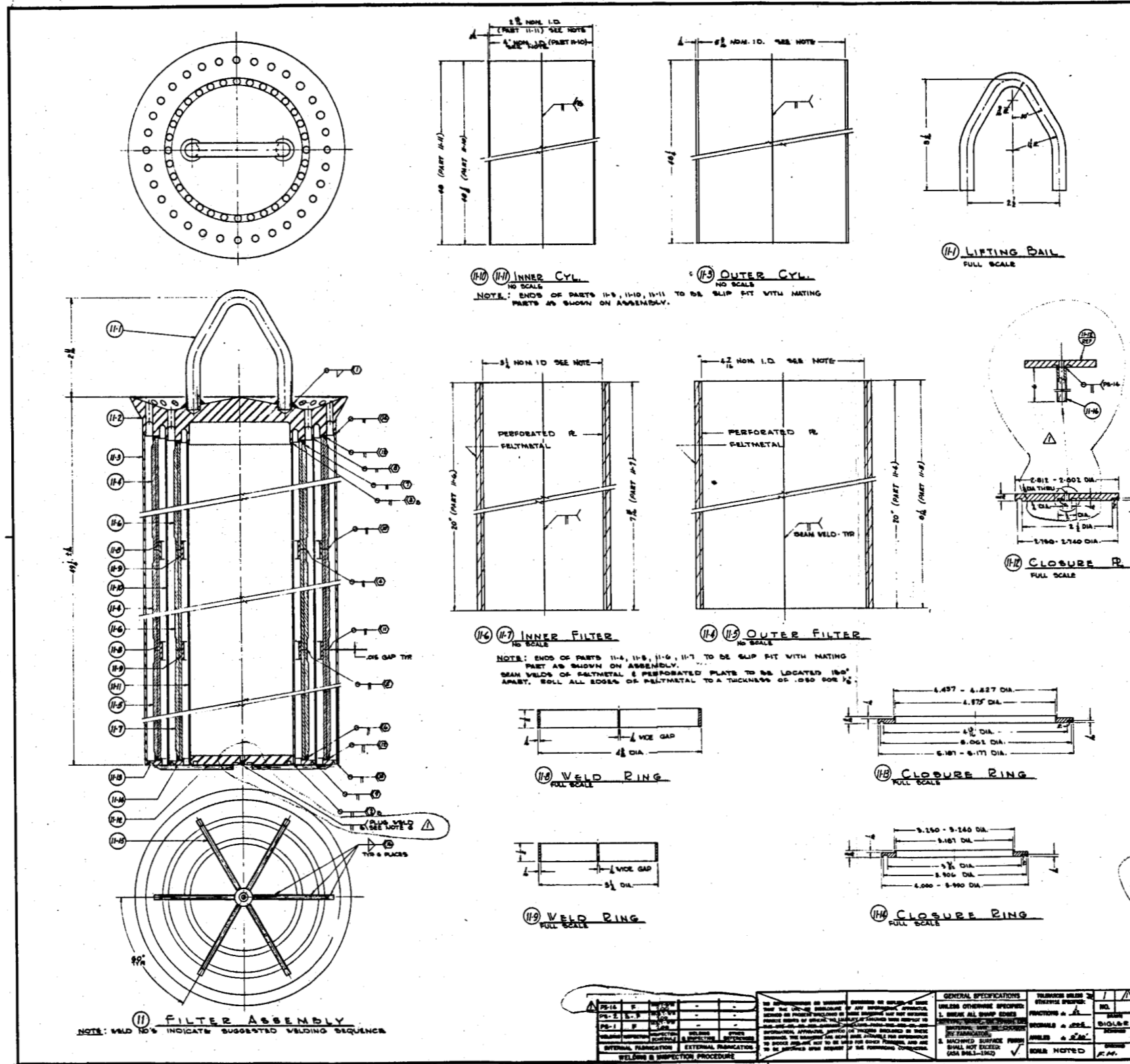
NOTE: THE AVERAGE PITCH DIA. AS INDICATED BY MEASURING (5) DIA'S 60° APART, SHALL BE WITHIN ±.002 OF THE NOMINAL DIA.

UNLESS OTHERWISE SPECIFIED:  
1. BREAK ALL SHARP EDGES  
2. FINISH ALL SURFACES  
3. MACHINED SURFACE FINISH SHALL NOT EXCEED:  
4. ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED

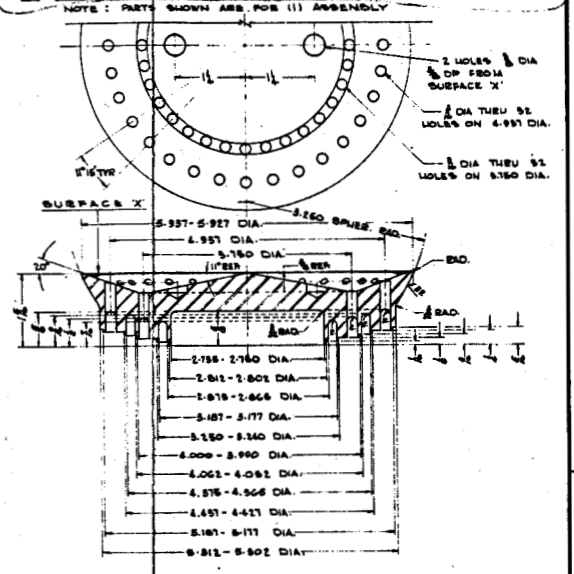
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2	...	...	...	...

REFERENCE DRAWING	NUMBER
GENERAL SPECIFICATIONS	...
WELDING & INSPECTION PROCEDURE	...
...	...

MRO794 RNO57E 1



PARTS LIST					
PART	QTY	REQD	DESCRIPTION	STOCK SIZE	MATERIAL
11-1	1	1	FILTER ASSEMBLY		INCONEL
11-2	1	1	LIFTING BALL	1/2 DIA X 1 LB	INCONEL
11-3	1	1	TOP CLOSURE PLATE	6 DIA X 1 1/2	INCONEL
11-4	1	1	OUTER CYLINDER	6 DIA X 48	INCONEL
11-5	1	1	INNER CYLINDER	4 1/2 DIA X 48	INCONEL
11-6	1	1	INNER FILTER	5 1/2 DIA X 30	INCONEL
11-7	1	1	OUTER FILTER	5 1/2 DIA X 30	INCONEL
11-8	1	1	VELD RING	4 1/2 DIA X 1/2	INCONEL
11-9	1	1	VELD RING	6 DIA X 1/2	INCONEL
11-10	1	1	CLOSURE RING	6 DIA X 1/2	INCONEL
11-11	1	1	CLOSURE RING	6 DIA X 1/2	INCONEL
11-12	1	1	VELD RING	6 DIA X 1/2	INCONEL
11-13	1	1	VELD RING	6 DIA X 1/2	INCONEL
11-14	1	1	VELD RING	6 DIA X 1/2	INCONEL
11-15	1	1	VELD RING	6 DIA X 1/2	INCONEL
11-16	1	1	VELD RING	6 DIA X 1/2	INCONEL



**NOTES:**

- PERFORM DOP (DIOCTYL PHTHALATE) EFFICIENCY TEST ON ASSEMBLY USING POLYDISPERSE AEROSOL. EFFICIENCY SHALL BE 99.9% OR BETTER FOR AVERAGE PARTICLE SIZE OF 0.8 MICRONS. SET: OVAL REPORT 8445. TEST OF HIGH EFFICIENCY FILTERS & FILTER INSTALLATIONS AT OBNL.
- FILTER ELEMENT MAY BE HANDLED ONLY IF ELEMENT IS PROTECTED AGAINST MOISTURE, OIL, LUBRICANTS, ETC.
- AFTER WELDING PARTS 11-4, 11-5, 11-6, 11-7 & PARTS 11-8, 11-9, 11-10, 11-11 UNITS TO BE GIVEN DOP TEST BEFORE PROCEEDING AS PER NOTE 1.
- PNEUMATIC TEST INNER CYL. (PARTS 11-5, 11-6 & 11-7) WITH NITROGEN @ 100 PSIG & HOLD FOR 2 HOURS WITHOUT ANY PRESSURE DROP.
- HELIUM-VACUUM LEAK CHECK INNER CYL. LEAK TO THE INSIDE SHALL BE LESS THAN 1.0 X 10<sup>-6</sup> CC/SEC. OF HELIUM.
- AFTER LEAK CHECK CUT OFF TUBE (PART 11-6) & PLUG WELD.
- DYE-CHECK WELDS OF INNER CYL. AFTER PRESSURE & LEAK CHECK.

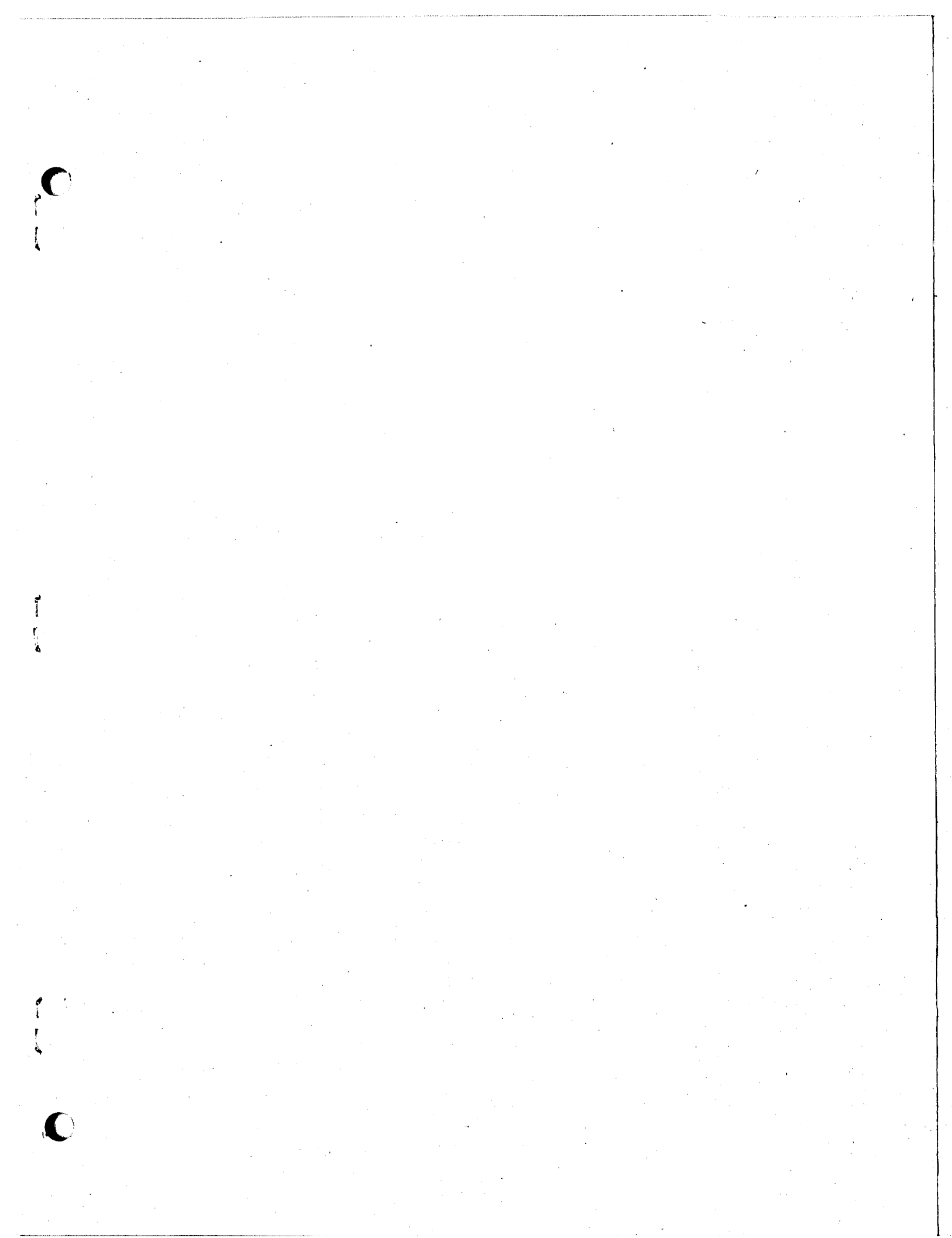
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3	1	11/1/61	ISSUED FOR FABRICATION	W.L.	

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