Evaluation of Emergency Cooling Water Suystem

by

Reactor Technology

E. I. du Pont de Nemours and Company

Savannah River Site

Aiken, South Carolina 29808

MASTER

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EVALUATION OF EMERGENCY COOLING WATER SYSTEM

I. Percent of Emergency Cooling Water That Goes to Fuel

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EVALUATION OF EMERGENCY COOLING WATER SYSTEM

I. Percent of Emergency Cooling Water That Goes to Fuel

1.00 INTRODUCTION

Evaluation of the adequacy of the emergency cooling water addition system (ECWA system) requires analysis of the postulated accidents for which the system is required to function. Analysis of these accidents requires a knowledge of the amount of the ECW added that goes to the fuel; both the total amount to the fuel and the amount to the ^{central} ~~central~~ fuel assemblies. This section of the memorandum presents the methods used to calculate the flows to the fuel and the results of the calculations.

2.00 SUMMARY

Table 2.1 shows the percent of the ECW that will go to the fuel for the loss of pumping power accident with the reactor full and for the double-ended plenum inlet line break accident (the "70 Criteria" design basis accident - DBA) with an ECW addition rate of 11,000 gpm. It also shows the expected flow rate to the central fuel tubes. These accidents are the most severe of the no leak and leak accidents so flows would be higher for all other accidents. These results were used in evaluating the adequacy of the ECWA system.

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Table 2.1

FLOW TO FUEL

Charge	<u>ED</u>		<u>High Flux</u>	
	<u>Loss</u> <u>of</u> <u>Pumps</u>	<u>75,500</u> <u>gpm</u> <u>Leak</u>	<u>Loss</u> <u>of</u> <u>Pumps</u>	<u>92,500</u> <u>gpm</u> <u>Leak</u>
Accident				
Percent ECW to Fuel				
. All Rotovalves Open	79	-	44	-
. Rotovalves 2 and 5 closed	87	-	57	-
. All Rotovalves Closed	100	-	100	-
. Pumps On - Rotovalves Open	-	76.4	-	60.9
Flow to Center Tube For Large Leak With 11,000 GPM Supply to Plenum	-	2.14	-	28.1
With A Leak In Systems 1, 3, 4 or 6				

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3.00 DISCUSSION

The calculation methods are separated into two sections because the flow paths and hydraulic conditions are different for the two accidents. For loss of pumping power: the reactor stays full, water flows out of the vacuum breakers and guide tubes, and backflow occurs from the plenum or addition point backward through the heat exchangers and pumps to the bulk moderator space in each system where rotovalves are open after the pumps stop rotating. For a plenum line break: the reactor is drained and remains drained as long as the pumps operate, flow is down through the fuel and out of the outlet nozzles, flow is lost from the plenum through the broken nozzle, there is backflow through the septifoil system, and there is no backflow through the heat exchangers and pumps because the pumps are operating.

3.10 Loss of Pumping Power Accident

The percent of flow to the fuel can be calculated if the internal and external hydraulic characteristics of the system are known. The external hydraulics are those for backflow (from addition point or plenum to reactor) via the heat exchangers, piping, pumps, and septifoil system. The internal hydraulics are those for flow across the plenum and through the fuel. This accident differs from the line break accident in that the reactor is full of water and the water losses from the plenum are smaller.

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3.00 DISCUSSION (continued)

This section gives the methods used to calculate the flow to the fuel for the power loss accident. The results in percent are given in Table 2.1.

3.11 External Hydraulics

3.111 Main Piping and Heat Exchangers

For near normal flow rates, the equations in reference 1 were used to calculate the resistance of the heat exchangers and process piping. These equations are given in Table 3.11. The equation for the C Area suction lines was used for all areas because they have the lowest resistance and more backflow would be calculated using the lower resistance.

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Table 3.11RESISTANCE OF PIPE AND HEAT EXCHANGERS AT NORMAL FLOWS

1. Resistance of line to plenum = ΔH_{16}^1 in ft.

$$\Delta H_{16}^1 = 132.02 \left(\frac{u}{p}\right)^{0.2} \frac{Q_{16}^{1.8}}{(20,000)^{1.8}}$$

Where:

(u/p) = kinematic viscosity, ft²/secQ₁₆ = flow in the 16-inch line, gpm

2. Resistance of suction line in C Area = ΔH_{24}^1 in ft

$$\Delta H_{24}^1 = 14.5 \left(\frac{u}{p}\right)^{0.2} \frac{Q_{24}^{1.8}}{(20,000)^{1.8}} + 5.78 \frac{Q_{24}^2}{(20,000)^2}$$

Where:

Q₂₄ = flow in the 24-inch line, gpm

3. Resistance from pump through heat exchanger = ΔH_{HX}^1 in ft.

$$\Delta H_{HX} = 482.55 \left(\frac{u}{p}\right)^{0.2} \frac{Q_{HX}^{1.8}}{(20,000)^{1.8}} + 58.16 \frac{Q_{HX}^2}{(20,000)^2}$$

Where:

Q_{HX} = flow through the heat exchanger, gpm

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3.00 DISCUSSION (continued)

3.11 External Hydraulics (continued)

3.111 Main Piping and Heat Exchangers (continued)

For the lower flow rates that occur when flow is supplied by the ECWA system, these equations were converted to equations in terms of friction factor because the equations in Table 3.11 assume the friction factor is a constant divided by Reynold's number to the 0.2 power and they are only valid at near normal flows. The modified equations are given in Table 3.12 and typical resistances are shown in Table 3.13.

The resistance of the pipes and heat exchangers to flow from the plenum through the pumps to the reactor (backflow) was considered to be the same as for flow in the normal direction.

f_{16} = Moody friction factor in 16-inch pipe between pump and heat exchanger

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Table 3.13TYPICAL HEAD LOSSES

	Heat Loss, ft			
	500	1000	5000	10,000
• Flow rate, gpm				
• Loss through fuel, ΔH_f	0.013	0.029	0.212	0.842
• Loss across plenum, ΔH_{PL}	0.004	0.012	0.036	0.300
• Loss in 16 inch line to plenum, ΔH_{16}	0.010	0.040	0.920	3.470
• Loss in heat exchanger	0.249	0.547	-	-
• Loss in 24-inch line reactor to pump, ΔH_{16}	0.006	0.021	-	-
• Loss across pump, ΔH_p	1.600	3.320	-	-
• Loss in S-foil system, ΔH_{SF}	1.55 ft at 100 gpm/stm			

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3.00 DISCUSSION (continued)3.11 External Hydraulics (continued)

3.112 Septifoil System

The septifoil flow equation below was developed from curves in reference 1.

$$\Delta H_{SF} = 14,400f \left(\frac{Q_{SF}}{1333} \right)^2$$

Where:

ΔH_{SF} = The head loss from the heat exchanger to the bulk space, feet

f = Moody friction factor, reference 2.

Q_{SF} = Flow per system through septifoils, gpm

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3.00 DISCUSSION (continued)

3.11 External Hydraulics (continued)

3.113 Pumps

When the pumps are operating, they add energy to the system. The pump head curve shown on Figure 3.11 is valid for these cases.

When the pumps are not operating and there is reverse flow through them, they have the resistance shown on Figure 3.12. This curve was constructed using the generalized graph in reference 3, and correcting it for a measured point from reference 4. The generalized curve gave a resistance 21.8 ft. (or about 20%) less than the measured value of 110 ft. at 14,000 gpm.

FIGURE 311
BINEHRA PUMP HEAD
CURVE

TOTAL
DYNAMIC
HEAD, FT

0 10000 20000 30000
FLOW THROUGH PUMP, GPM

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3.00 DISCUSSION (continued)3.12 Plenum Resistance

3.121 Plenum Gradient for Mark 14-ED Charge

The equation from reference 1 for full reactor charges was used for normal flow rates. At low flows, the equation below, that is in terms of friction factor, was used. It is assumed the flow distribution at low flows is the same as at normal flow with the plenum full.

$$\Delta H_{PL} = 1014f \left(\frac{Q_f}{120,000} \right)$$

Where:

ΔH_{PL} = the plenum gradient, ft.

f = Moody friction factor, reference 2

Q_f = flow to fuel and sparjets, gpm

Figure 3.13 shows plenum gradient at low flows.

FIGURE 3.13
MARK INED PLENUM
GRADIENT

- RX TANK OVERFLOWING

PLENUM
GRADIENT, FT.

1000
1500

2000

4000

6000

8000

10000

12000

FLOW TO FUEL, GPM

Figure 3.14
High Flux Plenum
Gradient
Rx overflow

PLENUM
GRADIENT
' FT

0 2000 4000 6000 8000 10000 12000

Flow to Fuel, GPM

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3.00 DISCUSSION (continued)3.12 Plenum Resistance (continued)

3.122 Plenum Gradient for High Flux Charge

The equation for pressure drop across a bank of staggered tubes (reference 5) was used to determine the pressure drop across each row of sleeves in the reactor plenum.* The total plenum ~~product~~^{GRADIENT} is the sum of the individual pressure drops for each row of tubes.

Equation:

$$\Delta H_{PL} = \frac{15}{1} 0.005807 (V_n) \quad \text{1.8}$$

Where:

ΔH_{PL} = the plenum gradient, feet.

V_n = the velocity between sleeves for row n
in feet per second.

Figure 3.14 shows the plenum gradient for the high flux charge at low flows.

* This equation coupled with the slot flow equation in section 3.23 gave a fair agreement with test data for I Area with a low level (Figure 3.26).

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3.00 DISCUSSION (continued)3.13 Fuel Charge

3.131 Resistance of Mark 14-ED Charge

For normal full flow, the test station equations are used along with plenum gradient to get the total charge resistance. To simplify the calculations at low flow rates, it was assumed that the flow distribution, row by row, is the same as long as the reactor is full. With this assumption, the resistance of the charge varies as the resistance of the fuel assemblies and targets in the center of the reactor. For the Mark 14-ED charge, the charge resistance was assumed to vary as the resistance of a cell consisting of one fuel tube and one target. The fuel and target equation used are:

$$\Delta H_{M14} = (113f + 8.4) \left(\frac{Q_{M14}}{100} \right)^2 \quad \text{and}$$
$$\Delta H_{M30} = (692f + 8.35) \left(\frac{Q_{M30}}{100} \right)^2$$

Where:

 ΔH_{M14} and ΔH_{M30} = assembly head losses, feet Q_{M14} and Q_{M30} = assembly flows, gpm f = Moody friction factor, reference 2

It should be noted that the ratio of fuel to target flow in the cell changes at low flows because of friction factor changes. In some cases, one is in laminar flow when the other is not.

Figure 3.15 shows charge flow versus head at the center of the plenum for low flows.

FIGURE 3.15
MARK 14-ED FUEL RESISTANCE

FUEL RESISTANCE,
FT. AT PLENUM CENTER

0 2000 4000 6000 8000 10000 12000
FUEL FLOW, GPM

Figure 3.16
Hi Flux Fuel Resistance

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3.00 DISCUSSION (continued)

3.13 Fuel Charge

3.132 Resistance of High Flux Charge

Fuel resistance for the high flux was determined using the hydraulic data predicted in reference 6. The equation used was:

$$\Delta H_{HS\phi} = 5.49 f (V)^2$$

Where:

$\Delta H_{HS\phi}$ = assembly head losses, feet

V = Average assembly velocity, feet per second

f = Moody friction factor

Figure 3.16 shows charge flow versus head at the center of the plenum for low flows.

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3.00 DISCUSSION (continued)3.14 Calculation of Percent Flow to Fuel

Finding the percent flow to the fuel consists of finding the amounts of backflow and fuel flow that require the same plenum head and add up to the 11,000 gpm available ECW flow. The results of the calculations are shown on Table 2.1.

3.141 Backflow in Addition Systems (2 and 5)

The equations related to backflow in systems 2 and 5 are below. There were used with those in section 3.142 for trial and error determination of backflow.

$$\Delta H_f + \Delta H_{PL} + \Delta H_{16A} = \Delta H_{HX} + \Delta H_P + \Delta H_{24} \text{ and,}$$

$$\Delta H_f + \Delta H_{PL} + \Delta H_{16A} = \Delta H_{SF}$$

$$Q_B = 5500 - Q_{16A} \text{ and,}$$

$$Q_F = 11,000 - 2 Q_B - 2 Q_{SFA} - 4 Q_{BO} - 4 Q_{SFO}$$

Where:

ΔH_{16A} = resistance of 16-inch line in systems 2 and 5 to normal flow (5500 gpm - Q_B) $\frac{1}{2}$ feet

Q_{16A} = flow to plenum in systems 2 or 5 (5500 - Q_B) $\frac{1}{2}$ gpm

Q_B = backflow through heat exchangers and pumps in systems 2 and 5 $\frac{1}{2}$ gpm

Q_{BO} = backflow in systems other than 2 and 5 $\frac{1}{2}$ gpm

Q_{SFA} = septifoil flow in 2 and 5 $\frac{1}{2}$ gpm

Q_{SFO} = septifoil flow in other four systems $\frac{1}{2}$ gpm

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3.00 DISCUSSION (continued)3.14 Calculation of Percent Flow to Fuel (continued)

3.142 Backflow In Systems 1, 3, 4 and 6

These equations relate to backflow in systems 1, 3, 4, and 6 and are used with equations in section 3.142 for trail and error solution to get backflow.

$$\Delta H_f + \Delta H_{PL} = \Delta H_{16} + \Delta H_{HX} + \overset{\Delta H_P}{\Delta H_{SF}} + \Delta H_{24}$$

$$\Delta H_f + \Delta H_{PL} + \Delta H_{16} = \Delta H_{SF}$$

$$Q_f = 11,000 - 2 Q_B - 2 Q_{SFA} - 4 Q_{BO} - 4 Q_{SFO}$$

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3.00 DISCUSSION (continued)

3.20 Plenum Line Break Accident

This accident differs from the pump power loss accident because the reactor drains rapidly and the losses from the plenum are larger. The drained reactor changes the hydraulics in the fuel and plenum at low flow rates and makes the flow to the fuel limited by the plenum slot resistance. Because the pumps would be running following a leak, the only backflow would be the flow to the septifoils. The only other loss from the plenum would be that which leaks out of the broken line.

This section gives the methods used to determine the leak rate, the backflow rate, and the flow rate to the fuel for the plenum line break accident.

3.21 External Hydraulics

3.211 Main Piping and Heat Exchangers

The methods and equations in section 3.111 apply to all calculations of external system resistance for the main piping and heat exchangers.

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3.00 DISCUSSION (continued)3.20 Plenum Line Break Accident (continued)3.212 Septifoils

The flow to the septifoils no longer follows the equation in 3.112 because the reactor is empty and at low flows most of the water to the septifoils is discharged from the lowest row of holes. The equation used for septifoil flow is given below.

$$\Delta H_{SF} = 1.51 \times 10^{-4} (Q_{sys})^2 + 0.736 \times 10^{-4} (Q_1)^2$$

Where:

ΔH_{SF} = height of liquid in heat exchanger discharge and septifoils piping minus the liquid level in the septifoils feet

Q_{sys} = total flow to the septifoils from one pump system, gpm,

Q_1 = flow through bottom row of holes in septifoils, gpm.

When the valve for the second term of the equation above is less than 1.0 feet, Q_1 equals Q_{sys} ; when the value becomes greater than 1.0 feet, then:

$$Q_{sys} = Q_1 + Q_2 + Q_3 + \dots + Q_n$$

Where:

Q_2 = flow through second row of holes in septifoil, gpm.

Q_n = flow through nth row of holes in septifoil

Figure 3.20 shows the septifoil system flow versus water level in the external D₂O system piping.

RESISTANCE
 Septifail Flow per tank system
 Reactor R-604 Drained

$\Delta H, \text{ ft} = (\text{water level in piping} - \text{water level in S-POLL})$

DRIVING FORCE, ft

(LIQUID LEVEL IN
 PIPING - LEVEL IN
 S-POLL)

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3.00 DISCUSSION (continued)3.20 Plenum Line Break Accident (continued)

3.22 Leak Rate and Resistance

3.221 Pumps Running - Water in Reactor

For a sudden-double end break: plenum pressure would decrease, the pumps for the unbroken systems would increase their flow rate and a new equilibrium operating pressure that would provide reduced flow through the fuel and leakage from the plenum would rapidly be established. At the same time, the flow through the pump on the broken system would increase until the resistance of the lines, heat exchangers, and nozzle (the broken end of the line) match a point on the pump head curve. The total leakage rate would be the flow through the pump on the broken system plus the leak from the plenum. It is assumed that equilibrium leakage rate would be attained almost immediately to simplify calculations. This section gives the method used to calculate the leak rate. Table 2.1 gives the calculated leak rates for Mark 14-ED and high flux.

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3.00 DISCUSSION (continued)

3.20 Plenum Line Break Accident (continued)

3.22 Leak Rate and Resistance (continued)

3.2211 Plenum Leak

The equilibrium point is where the external system resistance plus the head at the edge of the plenum minus the decrease in reactor level equals a point on the pump head curve (Figure 3.11).

Because the plenum pressure is high, fuel resistance plus plenum gradient must be used to get the pressure at the edge of the plenum. The equations used for fuel resistance and plenum gradient are given below.

Mark 14-ED

$$\Delta H_{f14} = 137 \left(\frac{Q_{F14}}{150,000} \right)^2$$

and

$$\Delta H_{PL14} = 35.3 \left(\frac{Q_{F14}}{150,000} \right)^{1.8}$$

High Flux

$$\Delta H_{fHI} = 244 \left(\frac{Q_{FHI}}{103,000} \right)^2$$

and

$$\Delta H_{PLHI} = 58.7 \left(\frac{Q_{FHI}}{103,000} \right)^{1.8}$$

3.00 DISCUSSION (continued)

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3.20 Plenum Line Break Accident (continued)

3.22 Leak Rate and Resistance (continued)

3.2211 Plenum Leak (continued)

Where:

 ΔH_f = fuel head loss, feet~~x~~ ΔH_{PL} = plenum gradient, feet Q_f = flow to fuel, gpm.14 refers to Mark 14-ED charge~~x~~HI refers to high flux charge~~x~~

The leak from the plenum via a nozzle should have a pressure drop of about one velocity head and this should be the pressure at the edge of the plenum.

$$\Delta H_L = 0.01554 \frac{(Q_L)^2}{644}$$

and

$$\Delta H_L = \Delta H_f + \Delta H_{PL}$$

Where:

 ΔH_L = head loss for leak, feet Q_L = leak rate, gpm.

3.00 DISCUSSION (continued)

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3.20 Plenum Line Break Accident (continued)3.22 Leak Rate and Resistance (continued)3.2211 Plenum Leak (continued)

The flow to the plenum at any ΔH_L is:

$$Q_{PL} = Q_L + Q_f$$

Where:

$$Q_{PL} = \text{flow to plenum, gpm}$$

The external system resistances were determined using the equations in 3.111 and assuming a septifoil flow loss of 1200 gpm per system as a constant for simplification.

To get the leakage rate from the plenum, a head required curve for flow to the plenum (in terms of flow per pump) was constructed using the external system resistances and ΔH_L (equal to $\Delta H_f + \Delta H_{PL}$). This curve (Figure 3.21) was plotted on a pump head curve and the intersection was used as the operating point assuming there would be no cavitation. Leakage rates for lower levels were determined by subtracting the level decrease from the pump head curve and getting a new intersection. With this operating point, the ΔH_L was used to calculate the leakage rate from the plenum.

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3.00 DISCUSSION (continued)3.20 Plenum Line Break Accident (continued)

3.22 Leak Rate and Resistance (continued)

3.2212 Pump Side Leak

To get the leakage rate from the pump side of the broken line, the section 3.111 equations for heat exchanger and suction lines were used and the loss at the end of the pipe was assumed to be one velocity head. These total resistances were plotted as a head required curve (Figure 3.21) on the pump head curve and treated in the same way as the head required curves for plenum flow to get operating points at various levels. All operating points were above 32,000 gpm. Because the pumps will cavitate somewhere slightly above 30,000 gpm with 30°C water flowing a rate of 31,000 gpm was assumed for this loss.

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3.00 DISCUSSION (continued)3.20 Plenum Line Break Accident (continued)3.22 Leak Rate and Resistance (continued)3.222 Pumps Running - No Water in Reactor

After the reactor is pumped dry and the pump suction legs are empty, the pumps hold the leg of water to the plenum (and prevent backflow), but there is no flow to the plenum or the leak. When emergency cooling water is added, a part of it is lost through the leak.

The closest hydraulic model of the leak when the plenum is not full is an overflow line. The equation for such a line was used to calculate leak rates and is given below.

$$Q_e = 1495.5 (L)^{3/2} H$$

Where:

$$H = h + 0.25$$

h is the height of liquid in plenum in feet

Q_e is leak rate in gpm

L is pipe cord length of liquid level, H, feet

When the plenum is full at the edge, it is assumed that there is one velocity head loss through the leak and rates are calculated for velocity head in the inlet line.

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3.00 DISCUSSION (continued)3.20 Plenum Line Break Accident (continued)

3.23 Plenum and Fuel Resistance

After the reactor is drained and emergency cooling water is added, the flow to the fuel will be limited by the resistance of the plenum slots and the flow distribution is much different than for a full reactor. To determine if flow is adequate, the flow to the assemblies in the center of the reactor must be determined as must the flow that goes to the plenum. This section gives the methods used to calculate the plenum resistance assuming flow is distributed like it would be adding water equally to two systems on opposite sides of the plenum. The leak case is somewhat different from this because operation of the bottom addition system will result in more water being added to one side and leakage through a broken line will change the plenum distribution some.

The equation developed for pressure drop across the plenum (section 3.122) was used to calculate the plenum gradient for a Mark 14-ED charge and a high flux charge. A step by step calculation starting in the reactor center was used to determine the flow to the fuel in each row of fuel assemblies versus plenum slot height. The velocity for each row was determined from the sum of the flows passing through the row and the height of water at the row. The equation for flow to a fuel position is:

3.00 DISCUSSION (continued)

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3.20 Plenum Line Break Accident (continued)

3.23 Plenum and Fuel Resistance

$$\Delta H_{\text{slots}} = 0.5 (Q_{\text{slots}})^{0.62}$$

Where:

 ΔH_{slots} = height of liquid in reactor at the row, inches
~~clusters~~ Q_{slots} = flow of liquid into sleeve, gpm

Figure 3.22 shows the plenum gradient for a Mark 14-ED charge at low flows with the reactor empty and Figure 3.24 shows the plenum gradient for the high flux charge.

This method gives a central tube flow of 3.3 gpm for an ED charge at 13,400 gpm total flow compared to a minimum of 3.6 gpm measured for a full charge in L Area (Figure 3.26 and reference 7).

Figure 3.23 shows the flow to the center fuel tube versus the total flow to the fuel for a Mark 14-ED charge with the reactor empty and Figure 3.25 shows the flow to the center fuel tube versus the total flow to the fuel for a high flux charge.

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3.00 DISCUSSION (continued)3.20 Plenum Line Break Accident (continued)

3.23 Plenum and Fuel Resistance

Table 3.21 shows the plenum head and flow distribution with a large leak. It gives the results of the row by row calculated pressure drop across the reactor plenum with the reactor empty, and with a Mark 14-ED charge. The total fuel flow is about 8,000 gpm.

Table 3.21WATER LEVEL IN PLENUM AND FUEL FLOW BY ROWS

<u>Row</u>	<u>Plenum Water Level, inches</u>	<u>Fuel Flow, gpm</u>
1	0.75	2.0
2	0.7719	2.05
3	0.8112	2.23
4	0.8619	2.45
5	0.9441	2.83
6	1.0536	3.36
7	1.1923	4.10
8	1.3682	5.15
9	1.5759	6.45
10	1.8378	8.30
11	2.1561	10.7
12	2.5510	14.0
13	3.0547	19.2
14	3.7122	25.8
15	4.6146	36.3

FIGURE 3.22
MARKED PLENUM
GRADIENT VS
FLOW REACTOR TANK DRAINED

Figure 3.24
HIGH FLUX PLENUM
GRADIENT
— REACTOR TANK DRAINED

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3.00 DISCUSSION (continued)3.20 Plenum Line Break Accident (continued)

3.24 Calculation of Flow to Fuel

The percent flow to the fuel can be found by finding the leak rate, septifoil backflow, and fuel flow that add up to 11,000 gpm for the same plenum head. This is a trail and error solution of equations presented in sections 3.212, 3.222, and 3.223.

Knowing the actual flow to the fuel, the flow to the central tubes can be determined from Figure 3.23 or Figure 3.25.

Figure 3.23
MARKED FLOW DISTRIBUTION
- ECW ADDITION
- Reactor Level Low

GENERAL HEX
FLOW PER POSITION, gpm

Total Cooling Water Flow to Fuel, gpm

FIGURE B.26
COMPARISON OF TEST DATA
TO CALCULATED FUEL
FLOWS FOR A FULL
CHARGE WITH THE
REACTOR DRAINED

FLOW
THROUGH
SLOTS
TO PUL AND
INJECTS, gpm

NOTE: THE ACTUAL EXPONENT AT
THE OUTER RIMS IS MORE
COMPLICATED BECAUSE AT
SOME FLOWS THE RESISTANCE
OF THE CRIPPLED ASSEMBLY
LIMIT FLOW INSTEAD OF THE
SLOTS.

FLY:

▲ L AREA DATA FOR 13400 GPM
WITH A 3 FOOT REACTOR
LEVEL (REFERENCE 1) -
MEASURED AT POSITIONS
ON A LINE PERPENDICULAR
TO THE LINE THROUGH THE
TWO OPPOSITE SYSTEMS
SUPPLYING WATER.

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