Texas Utilities Generating Company

Comanche Peak Steam Electric Station

Unit 1

Report

Evaluation of Paint and Insulation Debris Effects on Containment Emergency Sump Performance

March 1984

Gibbs & Hill, Inc.
Engineers, Designers, Constructors
New York, New York

AMENDMENT 1

for Gibbs & Hill Report dated March 1984 on

"Evaluation of Paint and Insulation Debris

Effects on Containment Emergency Sump Performance"

blocked by the paint particles forming a heap next to the screens with an angle of repose of 45 degrees.

The results of the calculation for pressure losses across the sump screens due to insulation debris indicate that the required NPSH would not exceed the available NPSH for the recirculation pumps.

The quantity of paint that has any potential for transport to the sump screens will be the indeterminate-paint in the sump area itself.

To determine the maximum amount of paint debris that can be tolerated, the following three cases were evaluated and presented in Table 7-2:

Case-1: No screen blockage. All paint debris is below the outer screen level i.e., 6" coaming plate.

Case-2: Same as Case-1 with additional paint debris accumulation between the outer and inner screens.

Case-3: 50 percent screen blockage by paint debris.

The results of these calculations presented in Table 7-2 indicate that the maximum acceptable paint accumulation is about 117,000 sq. ft. for a screen blockage of 50 percent. The total quantity of paint which has a potential to transport debris to the sumps is less than the maximum acceptable paint accumulation.

Based on the above evaluations for fibrous insulation and paint debris effects on the emergency sump performance, the following conclusions are arrived at:

a. Fibrous insulation on piping has no potential for forming debris which can block the sump screens.

b. Paint failure in areas other than the steam generator compartments 1 and 4 and the immediate sump area (Azimuth 0-110 and 300-360 degrees) will not be transported to cause screen blockage.

c. Even if all the paint in the containment failed, it will be acceptable because the sump blockage will still be less than 50 percent.

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EVALUATION OF PAINT AND INSULATION DEBRIS EFFECTS ON CONTAINMENT EMERGENCY SUMP PERFORMANCE

MARCH 1984

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1.0 PURPOSE AND BACKGROUND

1.1 Purpose

The purpose of this report, is to determine if the debris resulting from failure of paint and insulation inside the CPSES Unit 1 containment due to a LOCA will adversely affect performance of the containment emergency sumps.

1.2 Background

The paint inside the CPSES containment is used to protect the carbon steel surfaces from corrosion. It also provides a decontaminable surface for concrete and carbon steel. The paint materials and the application procedures are required to comply with specification 2323-AS-31 "Protective Coatings" for CPSES. This specification ensures compliance with USNRC requirements and the American National Standards Institute ANSI N101.2 and N512 (Protective Coatings for Nuclear Plants).

The paint systems used in the containment were tested and approved to withstand the following conditions during normal and LOCA conditions:

- Radiation
- Temperature
- Humidity
- Immersion and Spray from LOCA
- Decontamination Operations
- Flame Spread and Retardant Properties

Most of the paint used in the CPSES containments meets these requirements. However, some portions of the coated components or surfaces have not been fully concurred with by the independent QA/QC activities during component manufacturing or plant construction.

Following appropriate management review by the Owner, a decision was made to classify the paint on such components or surfaces as indeterminate and to maintain a log (referenced to as "Protective Coatings Exempt Log") of these situations to facilitate evaluation of the potential effect these indeterminate conditions may have on the performance of the containment emergency sumps.

This report also includes the post-LOCA evaluation of insulation failure as a part of Unresolved Safety Issue A-43 generic to all nuclear plants.

2.0 CONCLUSIONS

2.1 Conclusions

This report evaluates the effects of debris from insulation and paint failure on the safety function of the containment emergency recirculation sumps for CPSES Unit 1 following a LOCA. The conclusions of this evaluation are as follows:

a. This report shows that all the paint inside the containment could fail without adversely affecting sump performance.

b. The locations in containment from which paint could find its way to the sumps are determined in this study to be a small area in the vicinity of the sumps at 808 ft elevation.

c. Fibrous insulation on piping will not form debris which can be transported to the sump screens and cause blockage of sump screen during the recirculation phase of the LOCA.

d. Failure of metallic insulation will not affect the safety function of the emergency sumps.

3.0 INSULATION DEBRIS GENERATION

3.1 Types of Insulation

Most of the thermal insulation inside the containment on both piping and equipment is of the reflective metallic type, composed of stainless steel. The high efficiency metallic thermal insulation is composed of fibrous media and very fine heat resistant particulate matter, totally encased in stainless steel. All antisweat insulation is fiberglass encapsulated in metal casing and used on cold water piping.

All metallic insulation, with the exception of the reactor coolant pipe insulation inside the primary shield concrete, is designed to remain in place during an SSE. Sample panels of insulation are seismically tested to confirm the design. A series of pressurization tests are also performed to ensure that the insulation maintains its structural integrity under post-accident pressures as well as containment structural acceptance test and leakage rate test pressures. A thermal transient test is performed on sample insulation panels to ensure that the insulation maintains its structural integrity during post-accident temperature transients. This test consists of heating the sample panel to 650°F and quenching with cold water.

The reflective metallic insulation assemblies are specified to withstand seismic forces resulting from acceleration of 3g in both horizontal directions and 3g in the vertical direction caused by the SSE. The insulation structural mounting frames and panel attachments to the mounting frames are designed to maintain their structural integrity during the SSE.

In order to verify that the insulation meets the required seismic criteria, the insulation supplier has tested a typical assembly on a generic basis. The tests consisted on an initial sinusoidal input frequency between 3 and 100 Hz to determine the resonant frequency condition followed by an endurance test at the lowest resonant frequency. The insulation assembly was subjected to 10g's in both the horizontal and vertical directions. No damage or distortion to the structure was observed.

3.2 Identification of Accident

The initiating events for the insulation debris are the postulated loss of coolant accidents described in the FSAR. The design basis pipe break locations, their orientations, and their sizes have been determined. With this identification, an enveloping process was undertaken to locate breaks which have maximum potential for unacceptable debris generation. The following criteria were used to isolate the non-critical breaks for this evaluation:

- Breaks with barriers interposed between the break and the containment sumps were not considered if no flow path exists which would allow the transport of debris to the sumps.

- Breaks for which the expanding fluid jet does not impinge on insulated targets were not considered.

- Small diameter breaks in the same location and with effects similar to large diameter breaks were not considered.

- Analysis of longitudinal failures was required only in those cases whose postulated circumferential pipe failures do not target large areas of containment accommodating insulated targets.

A field walkdown was performed in the containment of Unit 1 to determine which breaks had the greatest potential for generation of insulation debris. Eighteen high energy pipe breaks were selected for further investigation. The evaluation concentrates on the breaks which generate the maximum amount of debris, where debris transport to the sump is relatively direct, and those which generate fibrous insulation. None of these breaks would be of the magnitude which would cause the activation of the safety injection or containment sprays. Therefore, the availability of the safeguards sumps are not required and sump blockage is not a concern. The quantities of debris generated are provided for comparative purposes only. As discussed under insulation transport (Section 4.0), reflective insulation cannot reach the sump and therefore an evaluation of quantities of this type debris was not required.

High efficiency insulation was also evaluated. This insulation, which is a mineral wool type, 1/4-inch thick, is fully encapsulated in 1/8-inch thick sheeting of type 304 SS. The insulation is located at pipe whip restraints and in the gap between the restraints and the pipe. In accordance with NUREG/CR-2791, this type of insulation is treated as similar to the reflective metallic insulation.

The potential for reflective metallic insulation transport to the ECCS sumps was evaluated based on the criteria provided in NUREG-0869 Table A-8. To apply these criteria, the flow velocities in various zones of the containment developed in Section 6 of this report were used. The maximum velocity in any zone around the ECCS sumps was determined to be less than 0.5 ft/sec, which is significantly smaller than the 2.0 ft/sec limit in NUREG-0869 for "zero potential for screen blockage" criteria. Based on this evaluation, it is concluded that reflective metallic insulation will not reach the sumps and cause any blockage.

Anti-sweat insulation around chilled water and component cooling water piping account for the fibrous insulation on piping inside the containment.

The mechanisms which were postulated for insulation debris generation are:

- Jet Impingement
- Pipe Whip
- Pipe Impact

Jet Impingement: Jet impingement is the most significant of the debris generation mechanisms for insulated pipe. All targets that intercept the jet resulting from the selected breaks are investigated. It was assumed, for conservatism, that all fibrous insulation within the vicinity of the break being investigated was dislodged and available for transport to the containment sumps. This is more conservative than NUREG/CR2791 which assumes that any insulation subject to a stagnation force in excess of 0.5 psi will result in dislodgement from the pipe. Further, NUREG/CR-2791 assumes the jet from the break covers a certain spray angle. For this report, it was conservatively assumed that all insulation in the break area is affected.

Pipe Whip: All insulation on the ruptured segment between the break location and the plastic hinge constitutes debris. However, for CPSES Unit 1 containment, the high energy lines are not insulated with fibrous insulation. Therefore, this concern does not have to be addressed for this type of insulation. For high efficiency insulation, where the insulation is wedged between the pipe whip restraint and the pipe, it is not possible for the insulation to be dislodged as a result of pipe whip. Therefore, no insulation debris will be created as a result of the pipe whip for fibrous and high efficiency insulation.

Pipe Impact: NUREG/CR-2791 assumes that five fabrication lengths of insulation on the impacted pipe are dislodged. This includes two lengths upstream and two lengths downstream of the impact point, and one length at the point of impact. For this analysis, as discussed above, all fibrous insulation in the vicinity of the break is dislodged. Again, this is more conservative than the NUREG/CR-2791 assumptions. No high-efficiency insulation debris can be generated by this mechanism.

If the impacted pipe is smaller in diameter than the whipping pipe, it may also be ruptured and generate additional debris. However, the metallic insulation debris generated in this manner would sink and not reach the sumps.

3.2 Result of Insulation Debris Determination

The quantities of fibrous insulation generated from various postulated breaks are shown on Tables 3-1 through 3-5.

In the case of high efficiency insulation, it was conservatively assumed that insulation from five pipe whip restraints of safety injection pipes would be dislodged as a result of jet impingement from a pipe break. This resulted in the generation of about 40 square feet of high efficiency insulation.

TABLE 3-1

FIBROUS INSULATION TAKE OFF

DRAWING NO. 2323-M1-0507

Case No.	Location	Line Size	Feet of Insulated Pipe	Square Feet of Insulation
1	El. Below 860'-0" Southwest Quadrant	3"	31	40.6
		6"	68	142.4
			Total	183.0
2	El. Below 860'-0" Northeast Quadrant	3/4"	43	31.0
		1"	29	22.8
		2"	74	77.5
		3"	163	213.2
		4"	141	221.4
		6"	109	228.2
			Total	794.1
3	El. Below 860'-0" Northeast Quadrant	3/4"	20'-0	14.4
		2"	3'-0	3.1
		3"	97'-0	126.9
		4"	160'-0	251.2
			Total	395.6
4	Part Plan El. 842'-0" Wall	3/4"	17'-0	12.3
		2"	44'-0	46.0
		3"	20'-0	26.2
		4"	185'-0	290.5
			Total	375.0

TABLE 3-2

FIBROUS INSULATION TAKE OFF

DRAWINGS NO. 2323-M1-0511

Case No.	Location	Line Size	Feet of Insulated Pipe	Square Feet of Insulation
1	El. Above 832'-6" 0° Near Cont. Wall	3/4"	20	14.4
		1"	21	16.5
		2"	65	68.1
		3"	16	20.9
		4"	172	270.0
		8"	50	130.9
			Total	521
2	El. Above 832'-6" 315° Azimuth	3/4"	32	23
		1"	11	8.6
		2"	38	40.0
		3"	52	68.1
		4"	126	197.8
		6"	115	240.7
		8"	26	68.0
			Total	646
3	El. Above 832'-6" 19° Azimuth	3/4"	38	27.3
		1"	10	7.8
		2"	37	38.7
		3"	46	60.2
		4"	111	174.3
		8"	12	31.4
			Total	340

TABLE 3-3

FIBROUS INSULATION TAKE OFF

DRAWI'IG NO. 2323-M1-0511-01

Case No.	Location	Line Size	Feet of Insulated Pipe	Square Feet of Insulation
1	El. Below 832'-6" Northwest Quadrant of Cont.	1"	40	31.4
			Total	31.4
2	El. Below 832'-6" West Side of Cont.	1"	22	17.3
		2"	51	53.4
			Total	70.7
3	El. Below 832'-6" Southwest Quadrant of Cont.	1"	5	4.0
		2"	66	69.2
		4"	91	142.9
			Total	216.1

TABLE 3-4

FIBROUS INSULATION TAKE OFF

DRAWING NO. 2323-M1-0513

Case No.	Location	Line Size	Feet of Insulated Pipe	Square Feet of Insulation
1	El. Below 836' Reactor Coolant	1-1/2"	2	2.0
	Pump No. 01	2"	37	38.8
			Total	40.8
2	El. Below 836' Reactor Coolant	1-1/2"	2	2.0
	Pump No. 02	2"	44	46.0
			Total	48.0
3	El. Below 836' Reactor Coolant	1-1/2"	2	2.0
	Pump No. 03	3"	30	39.3
			Total	41.3
4	El. Below 836' Reactor Coolant	1-1/2"	2	2.0
	Pump No. 04	2"	23	24.1
			Total	26.1

TABLE 3-5

FIBROUS INSULATION TAKE OFF

DRAWING NO. 2323-M1-0513-01

Case No.	Location	Line Size	Feet of Insulated Pipe	Square Feet of Insulation
1	El. 835'-0" Stm. Gen. No. 1 Compt.	3/4"	51	36.8
		2"	11	11.6
		3"	90	117.8
		4"	15	23.6
			Total	189.8
2	El. 836'-0" Stm. Gen. No. 4 Compt.	3/4"	38	27.4
		2"	44	46.1
		3"	144	188.3
		4"	7	11.0
			Total	272.8
3	El. 836'-0" Stm. Gen. No. 2 Compt.	3/4"	44	31.7
		2"	11	11.6
		3"	95	124.3
		4"	11	17.3
			Total	184.9
4	El. 836'-0" Stm. Gen. No. 3 Compt.	3/4"	56	40.4
		3"	138	180.6
		4"	12	18.9
			Total	239.9

4.0 INSULATION DEBRIS TRANSPORT

The methodology described in this report is based on NUREG/CR-2791 and NUREG/CR-2982 Rev. 1. The evaluation of long term transport of debris involves only the metallic insulation because all the fibrous insulation is assumed to be floating debris. All the floating debris is assumed to reach the sump screens.

The transport of the insulation debris occurs in two phases.

The first phase relates to the transport of debris caused by the initiating event, such as pipe whip and jet impingement. This mechanism of transport is normally a transient, terminated by dislodging of all the insulation in the effected zone.

The affects of short term transport are not significant for this evaluation for the following reasons:

- Even if the metallic insulation reaches near sump region, it will not be transported to the sump screens because the water velocities are very low (0.2 to 0.5 ft/sec) compared to the minimum transport velocity of 2.0 ft/sec (NUREG-0869).
- All the fibrous insulation is conservatively assumed to be transported to the sumps and to cover the sump screens.

The second phase of transport begins with the recirculation of the sump water and continues as long as the ECCS recirculation is active.

4.1 Recirculation Phase Transport

Following a loss of coolant accident and the initiation of the ECCS, the containment will be flooded with water. All the water used for the initial phase of the ECCS is provided from the refueling water storage tank. At the end of this phase of ECCS operation, the water collected in the containment sumps is recirculated.

The transport mechanism for the debris is complex because of the various flow paths and hydraulic resistances present in the containment. In order to simplify the methodology, various assumptions were made to produce conservatively limiting conditions which reflect the long term debris transport. The major assumptions were:

a. Water cascading from the point of coolant loss and the containment spray will eventually flow to the containment sumps.

b. No stagnant areas exist within containment.

c. The transport velocity is sufficient to move all the floating debris to the sump screens.

d. The force required to transport sinking debris was a resultant of the friction between the debris and the floor, the normal force exerted by the debris and the buoyancy force.

The long term transport evaluation for insulation material was done by a step by step methodology using NUREG-0869 criteria as follows:

Step-1 Determine the flow of water to various zones in the containment during the recirculation phase of the ECCS and containment spray operation.

Step-2 Determine the minimum water level inside the containment for the postulated accident.

Step-3 Calculate flow velocities for each path to the ECCS sump inside the containment. The calculation is based on using open channel flow equations. The flow is apportioned to each parallel path based on equal pressure drop for each flow path.

Step-4 Using the flow velocities established in Step-3, determine the maximum velocity near the sump.

Step-5 If the velocity calculated in Step-4 is less than 2.0 ft/sec, then reflective metallic insulation will not be transported to the sump screens. It was conservatively assumed that all the fibrous insulation will be transported to the sump screens.

Step-6 Based on the evaluation in Step-5, the quantity of insulation transported to the sump screens and the resulting sump affects were calculated as discussed in Section 7.0.

The containment water levels, and flow velocities for each zone are discussed in Section 6.2 and presented in Tables 6-19 through 6-24. From this information it was determined that the worst case water velocities in the zones near the emergency sumps will not exceed 0.5 ft/sec. Based on the criteria in Step-5, it is concluded that:

a. The metallic reflective insulation will not reach the sump screens.

b. All the fibrous insulation was conservatively assumed to be transported to the sump screens.

The high efficiency insulation will behave like the reflective metallic insulation, because the material is encapsulated in 1/8-inch stainless steel (Ref. NUREG/CR-2791 Page A-23).

5.0 PAINT DEBRIS GENERATION

The indeterminate-paint in the CPSES containment for each unit can be categorized into two groups, as follows:

Group 1. Paint materials used are qualified by test for use inside containment but the applied coatings did not get full concurrence of the independent QA/QC activities.

Group 2. Some of the equipment installed in the containment is coated with material not qualified in accordance with ANSI N101.2.

The extent of indeterminate-paint inside the CPSES containment is quantified in the "Protective Coating Exempt Log" maintained by the Owner.

5.1 Paint Failure Modes:

Failure modes must be postulated for the indeterminate-paint to arrive at the required input parameters for the evaluation of debris effects inside the containment.

A generalized listing of the various approaches that can be used to predict paint failure modes is as follows:

Approach 1: All the indeterminate-paint fails and dislodges from the surfaces.

Approach 2: Only a portion of the indeterminate-paint fails. In this case, factors can be applied to distinguish between Group 1 and Group 2.

Approach 3: Same as 2 above but with less conservative factors for general paint dislodging. To this add the quantity of paint debris from a calculated worst case initiating event (pipe rupture, jet impingement and vibration).

Using Approach 2 or 3 would require extensive testing and collection of reliable data to support the assumptions. There is no data currently available to support the assumptions related to the quantity of paint expected to fail for a given scenario. In view of this, although it is very conservative, Approach 1 was used for this evaluation.

5.2 Paint Debris Characterization

To evaluate the mechanism and the rate of transport of paint debris to the emergency sumps, all the significant characteristics of the paint debris should be established. The most important parameters are the specific gravity, coefficient of friction, and size of the paint debris.

Each of these parameters is important in determining the transportability of the debris from its point of origin to the emergency sumps. Specifically, these parameters affect the force required to move the paint particles in the water flowing to the sumps.

The data on paint characteristics is very limited and the variation in the available data is high. Where specific data is not available, an estimated range was used based on analogy with similar material properties. The range of values used and the basis for the major parameters used in this evaluation are as follows:

Specific Gravity: The specific gravity of cured paint films generally vary from 1.5 to 4.0. A density range of 90 to 200 pounds per cubic foot was used. The worst case is the lowest specific gravity for the calculation of transportability of the debris.

Size: Size of paint particles influences calculation of the area of material normal to flow. Increase in size of particles tends to increase the force available to move the debris whereas increase in mass of the particles tends to increase the force required to move the debris. The effect of paint particle size is not linear. In view of this, a range of paint particle sizes was chosen to encompass the possible sizes that could be produced to 1/16 inch diameter. The smallest particle that can block the sump screen is 1/8 inch which is the size of the sump inner screen opening. A cylindrical shape for the paint particle was chosen because this shape provided the most conservative results. The particle sizes evaluated ranged from 1/16 to 128 inches and the particle thicknesses used were 3, 5, and 10 mils.

The thicknesses chosen are representative of the paint films applied at CPSES. The drag coefficient for cylindrical shapes in the selected range is constant for Reynold's numbers above 1,100. The Reynold's number is dependent on the velocity, viscosity, and density of the flowing medium and the area of the particle normal to the flow.

Coefficient of Friction: The coefficient of friction between paint particles and the concrete floor, and between the particles

themselves is required to calculate the force required to move the particles. The friction coefficients given in NUREG CR-2971 for calcium silicate particles were used for the transport velocity determination. The particulate nature of the calcium silicate particle make them analogous to the paint particles. In addition, informal discussions with Carboline and CIBA-Giegy indicated that friction coefficient data observed were in the range proposed for calcium silicate. For conservatism the friction coefficient was varied and the effect on the transport velocity calculated.

6.0 PAINT DEBRIS TRANSPORT

The transport mechanism for paint debris is similar to that for the fibrous insulation discussed in Section 4.0. The NUREG/CR-2791 methodology addresses short term and long term transport of insulation debris inside containment. The short term transport is associated with the initiating event such as pipe whip, pipe impact and jet impingement. For the purposes of the evaluation of paint debris transport, the short term transport was not considered because it was conservatively assumed that all the indeterminate-paint fails.

The long term transport begins at the initiation of the recirculation phase of the post-LOCA operation. Dislodged paint is subjected to a circulating water flow due to the operation of the containment recirculation pumps. Fluid velocity, debris density, and debris size were analyzed to determine if long term transport occurs.

This evaluation established the transport velocity required to move the paint particles and the available velocity when the safety injection, residual heat removal, and spray systems utilize the containment sump. These velocities were then compared to determine the potential for paint migration to the sumps.

6.1 Paint Transport Velocity

Using the basic concepts of NUREG-CR-2791 for insulation debris, the transport velocity for paint particles was derived. First, tumbling motion was considered. A model of the forces on a cylindrical paint particle with its surface area perpendicular to the water flow was developed (see Figure 6-1). F_A is the force available to tumble or flip the paint particle so that its surface area will be parallel to the water flow. To tumble, the available force (F_A) must exceed the friction between the particle and the floor, ($\mu s\ F_N$). Where μs is static friction coefficient and F_N is the force exerted by the paint particle normal to the floor, its weight. To find the minimum velocity to tumble the paint particle F_A is set equal to $\mu s\ F_N$ as follows from Section 4.5 of NUREG-CR-2791:

$$F_A = \frac{C_D\ Ap\ Pw\ \bar{v}^2}{2gc}$$

$$F_N = (Pm-Pw)\ V_M\ (g/gc)$$

$F_L = 0$ for tumbling per NUREG

$$F_A = \mu s\ (F_N - F_L) = \mu s\ F_N$$

$$Ap = \pi d^2/4$$

$$V_M = (\pi d^2/4)t$$

$$\frac{C_D\ (\pi d^2/4) Pw\ \bar{v}^2}{2\ gc} = \left[(Pm-Pw)\quad (\pi d^2/4)\ t\right]\mu s$$

Equation 1

$$\text{Tumble Velocity} = \bar{v} = \left[\frac{\mu s\,(Pm-Pw)\ (t)\ \ 2gc}{C_D . Pw}\right]^{0.5}$$

F_L = lift force

Pw = density of water

Pm = density of material

V_M = volume of material

Ap = area normal to flow

$\bar{v}$ = average water velocity

C_D = drag coefficient

d = diameter of particle

t = thickness of particle

g = gravitational force

gc = Newtons constant

Similarly, the model for slide velocity was developed as shown on Figure 6-2. For a particle to slide, F_A should be greater than the force required to move the particle. The major differences in the derivation are that the friction coefficient used is now the dynamic coefficient, the lift force (F_L) will be equal to (F_A) and areas normal to the flow Ap now equals (d•t). Thus,

$$F_A = \frac{C_D\ (d \cdot t)\ Pw\ \bar{v}^2}{2gc}$$

$$F_N = (Pm - Pw) V_M (g/gc)$$

$$F_L = F_A$$

$$F_A = \mu d\ (F_N - F_A)$$

$$(1 + \mu d)\ F_A = \mu d\ F_N$$

$$\frac{(1 + \mu d)\ C_D\ (d \cdot t)\ Pw\ \bar{v}^2}{2\ gc} = \mu d\ \left[(Pm-Pw)\ \ (\pi d^2/4.t)\right]$$

$$\text{Slide Velocity} = \bar{v} = \left[\frac{\mu d\ \ (Pm-Pw)\ \ (\pi d/4)\ \ 2\ gc}{(1 + \mu d)\ C_D \cdot Pw}\right]^{0.5}$$

Tables 6-1 through 6-9 show the expected transport velocities for several different particles sizes, at several different paint densities, at three containment conditions, and three particle thicknesses. Both the tumble and slide transport velocities are calculated and presented in these tables. Tables 6-10 through

6-18 show the effect of varying the friction and drag coefficients. The following conclusions can be drawn from the data presented in these tables:

- The thickness of the paint particle, in the 3-10 mils range, has no affect on its transport velocity.
- The smaller the paint particle size, the higher is the potential for its transport.
- The greater the relative density difference between the paint and the water, the lower is the potential for transport.
- The higher the drag coefficient between the paint particle and the moving water, the higher is the potential for transport.
- Variation in the friction coefficient between paint particle and concrete floor of the containment does not significantly affect the transport velocity.

6.2 Available Water Velocity

Following the post-LOCA safety injection phase, when the contents of the RWST are exhausted, valving is aligned to provide for a recirculating flow of water from the containment emergency sumps.

The flow of fluids entering and exiting the containment during the recirculation phase of a LOCA were examined. Two basic conditions were analyzed to assure conservative results as follows:

1) Containment spray operating with a water level of 4.5 feet

2) Containment spray, safety injection, and residual heat removal systems operating with a water level of 9.5 feet.

Flow within the containment is assumed to be represented by a number of parallel open channel flows. Accordingly, pressure drop from the break region to the sump is constant for each flow path, and the summation of mass flows through the various paths equals the pump flow rate. The magnitude of the flow rate through each opening is dependent upon the hydraulic resistance presented by the path.

As described in NUREG CR-2791, a flow resistance map of the containment floor was developed as shown on Figure 6-3. A point source of flow was selected and the potential paths of flow to the sumps were determined. The source of RHR and SI water was postulated to be from a reactor coolant pipe break in steam generator compartment no. 4 which is closest to the sumps. The

source of spray water was point 14 in Figure 6-3. This source of spray water will create a uniform distribution of spray water at the 808 ft. elevation of the containment. Figures 6-4 and 6-5 show the flow paths for the SI and RHR flow, and the spray flow respectively. Figure 6-5 represents the case of low water level. In the case of high water level the spray and RHR/SI contribution will be combined to yield the maximum flow through a given opening on branch.

The resistances were determined as the length divided by the area of each branch or opening in the flow path. The area will vary depending on the water level chosen and the channel width. The fraction of flow in each branch was determined by combining the resistances as in an electrical circuit diagram and proportioning the flows by resolving the parallel and serial resistances.

The pathways and velocities are developed in the form of "circuit" diagrams for the RHR/SI flows and spray flows as shown on Figures 6-6 and 6-7 respectively. The resistance determinations are tabulated on Tables 6-19 and 6-20 for openings and branches respectively. The velocities and flows resulting at high and low water levels are tabulated in Tables 6-21 and 6-22.

The velocity of fluids from the upper levels of containment generated by spray system was estimated and presented in Table 6-23. All openings in the containment floors at upper levels are provided with nominal 4" curbs or toe plates. To assess the fluid velocities in each zone (Figure 6-8), the largest spray flow was assumed.

6.3 Long Term Paint Transport

During the recirculation phase of post-LOCA operation, the paint particles tend to move with the water towards the sump. The potential for this motion is higher if the available water velocity (motive force) is greater than the velocity required to move the particle (transport velocity).

The transport velocities for paint particles of various sizes were calculated and presented in Tables 6-1 through 6-9. Each table represents different combination of paint thickness, and containment temperature. From these tables, it was determined that the minimum threshold velocity to initiate motion will be greater than 0.25 feet per second for all particles above 1/8 inch size.

The available water velocities in various zones of the containment are presented in Tables 6-22, 6-23 and 6-24. The location numbers in these tables correspond to the numbers marked in Figure 6-3. The flow velocities in open areas range from 0.003 to 0.33 feet per second. The velocities in the narrow

passages and openings range from 0.18 to 1.5 feet per second. The velocities in the immediate vicinity of the sumps range from 0.1 to 0.44 feet per second. Figures 6-9 and 6-10 show areas where the water velocities are expected to be higher than the threshold velocity for paint transport, at high and low water levels respectively. From these figures it can be concluded that most of the indeterminate-paint, if it fails, will not be transported to the sumps. The zones in the containment that have any potential for paint transport to the sumps are steam generator compartments 1 and 4, and the annular space between the containment wall and the primary coolant shield wall at elevation 808 ft. in the azimuths 0-110° and 300-360°. These zones were determined based on the results of the paint transport analysis presented in Figures 6-9 and 6-10.

TABLE 6-1

TRANSPORT VELOCITY SUMMARY

PAINT THICKNESS = 10 MILS

Cont.pres PSI	60	Drag coef	1.1
Cont.temp F	307	Fric coef static	0.6
		Fric coef dynamic	0.42
Water density Lb/cf	57.0		
Viscosity water	0.000073		
Thickness Mils	10		

SLIDE VELOCITY fps

Paint den. lb/cf	90	100	120	150	200
Tumble vel. fps	0.131	0.149	0.180	0.219	0.272
Dia.in					
128	9.17	10.46	12.67	15.39	19.08
64	6.48	7.40	8.96	10.88	13.49
32	4.58	5.23	6.33	7.69	9.54
16	3.24	3.70	4.48	5.44	6.75
8	2.29	2.62	3.17	3.85	4.77
4	1.62	1.85	2.24	2.72	3.37
2	1.15	1.31	1.58	1.92	2.39
1	0.81	0.92	1.12	1.36	1.69
0.5	0.57	0.65	0.79	0.96	1.19
0.25	0.41	0.46	0.56	0.68	0.84
0.125	0.29	0.33	0.40	0.48	0.60
0.0625	0.20	0.23	0.28	0.34	0.42

TABLE 6-2

TRANSPORT VELOCITY SUMMARY

PAINT THICKNESS = 5 MILS

Cont.pres PSI	60	Drag coef	1.1
Cont.temp F	307	Fric coef static	0.6
		Fric coef dynamic	0.42

Water density Lb/cf	57.0
Viscosity water	0.000073
Thickness Mils	5

SLIDE VELOCITY fps

Paint den. lb/cf	90	100	120	150	200
Tumble vel. fps	0.092	0.105	0.128	0.155	0.192
Dia.in					
128	9.17	10.46	12.67	15.39	19.08
64	6.48	7.40	8.96	10.88	13.49
32	4.58	5.23	6.33	7.69	9.54
16	3.24	3.70	4.48	5.44	6.75
8	2.29	2.62	3.17	3.85	4.77
4	1.62	1.85	2.24	2.72	3.37
2	1.15	1.31	1.58	1.92	2.39
1	0.81	0.92	1.12	1.36	1.69
0.5	0.57	0.65	0.79	0.96	1.19
0.25	0.41	0.46	0.56	0.68	0.84
0.125	0.29	0.33	0.40	0.48	0.60
0.0625	0.20	0.23	0.28	0.34	0.42

TABLE 6-3

TRANSPORT VELOCITY SUMMARY

PAINT THICKNESS = 3 MILS

Cont.pres PSI	60	Drag coef	1.1
Cont.temp F	307	Fric coef static	0.6
		Fric coef dynamic	0.42
Water density Lb/cf	57.0		
Viscosity water	0.000073		
Thickness Mils	3		

SLIDE VELOCITY fps

Paint den. lb/cf	90	100	120	150	200
Tumble vel. fps	0.072	0.082	0.099	0.120	0.149
Dia.in					
128	9.17	10.46	12.67	15.39	19.08
64	6.48	7.40	8.96	10.88	13.49
32	4.58	5.23	6.33	7.69	9.54
16	3.24	3.70	4.48	5.44	6.75
8	2.29	2.62	3.17	3.85	4.77
4	1.62	1.85	2.24	2.72	3.37
2	1.15	1.31	1.58	1.92	2.39
1	0.81	0.92	1.12	1.36	1.69
0.5	0.57	0.65	0.79	0.96	1.19
0.25	0.41	0.46	0.56	0.68	0.84
0.125	0.29	0.33	0.40	0.48	0.60
0.0625	0.20	0.23	0.28	0.34	0.42

TABLE 6-4

TRANSPORT VELOCITY SUMMARY

PAINT THICKNESS = 10 MILS

Cont.pres PSI	20	Drag coef	1.1
Cont.temp F	250	Fric coef static	0.6
		Fric coef dynamic	0.42
Water density Lb/cf	58.8		

Viscosity water	0.000127
Thickness Mils	10

SLIDE VELOCITY fps

Paint den. lb/cf	90	100	120	150	200
Tumble vel. fps	0.125	0.144	0.175	0.214	0.266
Dia.in					
128	8.78	10.08	12.29	15.00	18.67
64	6.21	7.13	8.69	10.61	13.20
32	4.39	5.04	6.15	7.50	9.33
16	3.10	3.57	4.35	5.30	6.60
8	2.19	2.52	3.07	3.75	4.67
4	1.55	1.78	2.17	2.65	3.30
2	1.10	1.26	1.54	1.88	2.33
1	0.78	0.89	1.09	1.33	1.65
0.5	0.55	0.63	0.77	0.94	1.17
0.25	0.39	0.45	0.54	0.66	0.83
0.125	0.27	0.32	0.38	0.47	0.58
0.0625	0.19	0.22	0.27	0.33	0.41

TABLE 6-5

TRANSPORT VELOCITY SUMMARY

PAINT THICKNESS = 5 MILS

Cont.pres PSI	20	Drag coef	1.1
Cont.temp F	250	Fric coef static	0.6
		Fric coef dynamic	0.42
Water density Lb/cf	58.8		
Viscosity water	0.000127		
Thickness Mils	5		

SLIDE VELOCITY fps

Paint den. lb/cf	90	100	120	150	200
Tumble vel. fps	0.088	0.102	0.124	0.151	0.188
Dia.in					
128	8.78	10.08	12.29	15.00	18.67
64	6.21	7.13	8.69	10.61	13.20
32	4.39	5.04	6.15	7.50	9.33
16	3.10	3.57	4.35	5.30	6.60
8	2.19	2.52	3.07	3.75	4.67
4	1.55	1.78	2.17	2.65	3.30
2	1.10	1.26	1.54	1.88	2.33
1	0.78	0.89	1.09	1.33	1.65
0.5	0.55	0.63	0.77	0.94	1.17
0.25	0.39	0.45	0.54	0.66	0.83
0.125	0.27	0.32	0.38	0.47	0.58
0.0625	0.19	0.22	0.27	0.33	0.41

TABLE 6-6

TRANSPORT VELOCITY SUMMARY

PAINT THICKNESS = 3 MILS

Cont.pres PSI	20	Drag coef	1.1
Cont.temp F	250	Fric coef static	0.6
		Fric coef dynamic	0.42
Water density Lb/cf	58.8		
Viscosity water	0.000127		
Thickness Mils	3		

SLIDE VELOCITY fps

Paint den. lb/cf	90	100	120	150	200
Tumble vel. fps	0.068	0.079	0.096	0.117	0.146
Dia.in					
128	8.78	10.08	12.29	15.00	18.67
64	6.21	7.13	8.69	10.61	13.20
32	4.39	5.04	6.15	7.50	9.33
16	3.10	3.57	4.35	5.30	6.60
8	2.19	2.52	3.07	3.75	4.67
4	1.55	1.78	2.17	2.65	3.30
2	1.10	1.26	1.54	1.88	2.33
1	0.78	0.89	1.09	1.33	1.65
0.5	0.55	0.63	0.77	0.94	1.17
0.25	0.39	0.45	0.54	0.66	0.83
0.125	0.27	0.32	0.38	0.47	0.58
0.0625	0.19	0.22	0.27	0.33	0.41

TABLE 6-7

TRANSPORT VELOCITY SUMMARY

PAINT THICKNESS = 10 MILS

Cont.pres PSI	10	Drag coef	1.1
Cont.temp F	200	Fric coef static	0.6
		Fric coef dynamic	0.42
Water density Lb/cf	60.1		

Viscosity water	0.000194
Thickness Mils	10

SLIDE VELOCITY fps

Paint den. lb/cf	90	100	120	150	200
Tumble vel. fps	0.121	0.140	0.171	0.210	0.262
Dia.in					
128	8.50	9.82	12.03	14.73	18.38
64	6.01	6.94	8.50	10.42	13.00
32	4.25	4.91	6.01	7.37	9.19
16	3.00	3.47	4.25	5.21	6.50
8	2.12	2.45	3.01	3.68	4.59
4	1.50	1.74	2.13	2.60	3.25
2	1.06	1.23	1.50	1.84	2.30
1	0.75	0.87	1.06	1.30	1.62
0.5	0.53	0.61	0.75	0.92	1.15
0.25	0.38	0.43	0.53	0.65	0.81
0.125	0.27	0.31	0.38	0.46	0.57
0.0625	0.19	0.22	0.27	0.33	0.41

TABLE 6-8

TRANSPORT VELOCITY SUMMARY

PAINT THICKNESS = 5 MILS

Cont.pres PSI	10	Drag coef	1.1
Cont.temp F	200	Fric coef static	0.6
		Fric coef dynamic	0.42
Water density Lb/cf	60.1		
Viscosity water	0.000194		
Thickness Mils	5		

SLIDE VELOCITY fps

Paint den. lb/cf	90	100	120	150	200
Tumble vel. fps	0.086	0.099	0.121	0.148	0.185
Dia.in					
128	8.50	9.82	12.03	14.73	18.38
64	6.01	6.94	8.50	10.42	13.00
32	4.25	4.91	6.01	7.37	9.19
16	3.00	3.47	4.25	5.21	6.50
8	2.12	2.45	3.01	3.68	4.59
4	1.50	1.74	2.13	2.60	3.25
2	1.06	1.23	1.50	1.84	2.30
1	0.75	0.87	1.06	1.30	1.62
0.5	0.53	0.61	0.75	0.92	1.15
0.25	0.38	0.43	0.53	0.65	0.81
0.125	0.27	0.31	0.38	0.46	0.57
0.0625	0.19	0.22	0.27	0.33	0.41

TABLE 6-9

TRANSPORT VELOCITY SUMMARY

PAINT THICKNESS = 3 MILS

Cont.pres PSI	10	Drag coef	1.1
Cont.temp F	200	Fric coef static	0.6
		Fric coef dynamic	0.42
Water density Lb/cf	60.1		

Viscosity water	0.000194
Thickness Mils	3

SLIDE VELOCITY fps

Paint den. lb/cf	90	100	120	150	200
Tumble vel. fps	0.066	0.077	0.094	0.115	0.143
Dia.in					
128	8.50	9.82	12.03	14.73	18.38
64	6.01	6.94	8.50	10.42	13.00
32	4.25	4.91	6.01	7.37	9.19
16	3.00	3.47	4.25	5.21	6.50
8	2.12	2.45	3.01	3.68	4.59
4	1.50	1.74	2.13	2.60	3.25
2	1.06	1.23	1.50	1.84	2.30
1	0.75	0.87	1.06	1.30	1.62
0.5	0.53	0.61	0.75	0.92	1.15
0.25	0.38	0.43	0.53	0.65	0.81
0.125	0.27	0.31	0.38	0.46	0.57
0.0625	0.19	0.22	0.27	0.33	0.41

TABLE 6-10

TRANSPORT VELOCITY SUMMARY

DRAG COEFFICIENT = 1.5

Cont.pres PSI	10	Drag coef	1.5
Cont.temp F	200	Fric coef static	0.6
		Fric coef dynamic	0.42
Water density Lb/cf	60.1		
Viscosity water	0.000194		
Thickness Mils	3		

SLIDE VELOCITY fps

Paint den. lb/cf	90	100	120	150	200
Tumble vel. fps	0.057	0.066	0.080	0.098	0.123
Dia.in					
128	7.28	8.41	10.30	12.62	15.74
64	5.15	5.94	7.28	8.92	11.13
32	3.64	4.20	5.15	6.31	7.87
16	2.57	2.97	3.64	4.46	5.56
8	1.82	2.10	2.57	3.15	3.93
4	1.29	1.49	1.82	2.23	2.78
2	0.91	1.05	1.29	1.58	1.97
1	0.64	0.74	0.91	1.12	1.39
0.5	0.45	0.53	0.64	0.79	0.98
0.25	0.32	0.37	0.46	0.56	0.70
0.125	0.23	0.26	0.32	0.39	0.49
0.0625	0.16	0.19	0.23	0.28	0.35

TABLE 6-11

TRANSPORT VELOCITY SUMMARY

DRAG COEFFICIENT = 1.2

Cont.pres PSI	10	Drag coef	1.2
Cont.temp F	200	Fric coef static	0.6
		Fric coef dynamic	0.42
Water density Lb/cf	60.1		
Viscosity water	0.000194		
Thickness Mils	3		

SLIDE VELOCITY fps

Paint den. lb/cf	90	100	120	150	200
Tumble vel. fps	0.063	0.073	0.090	0.110	0.137
Dia.in					
128	8.14	9.40	11.51	14.11	17.60
64	5.75	6.65	8.14	9.97	12.44
32	4.07	4.70	5.76	7.05	8.80
16	2.88	3.32	4.07	4.99	6.22
8	2.03	2.35	2.88	3.53	4.40
4	1.44	1.66	2.04	2.49	3.11
2	1.02	1.17	1.44	1.76	2.20
1	0.72	0.83	1.02	1.25	1.56
0.5	0.51	0.59	0.72	0.88	1.10
0.25	0.36	0.42	0.51	0.62	0.78
0.125	0.25	0.29	0.36	0.44	0.55
0.0625	0.18	0.21	0.25	0.31	0.39

TABLE 6-12

TRANSPORT VELOCITY SUMMARY

DRAG COEFFICIENT = 0.9

Cont.pres PSI	10	Drag coef	0.9
Cont.temp F	200	Fric coef static	0.6
		Fric coef dynamic	0.42
Water density Lb/cf	60.1		
Viscosity water	0.000194		
Thickness Mils	3		

SLIDE VELOCITY fps

Paint den. lb/cf	90	100	120	150	200
Tumble vel. fps	0.073	0.085	0.104	0.127	0.159
Dia.in					
128	9.39	10.85	13.30	16.29	20.32
64	6.64	7.67	9.40	11.52	14.37
32	4.70	5.43	6.65	8.14	10.16
16	3.32	3.84	4.70	5.76	7.18
8	2.35	2.71	3.32	4.07	5.08
4	1.66	1.92	2.35	2.88	3.59
2	1.17	1.36	1.66	2.04	2.54
1	0.83	0.96	1.18	1.44	1.80
0.5	0.59	0.68	0.83	1.02	1.27
0.25	0.42	0.48	0.59	0.72	0.90
0.125	0.29	0.34	0.42	0.51	0.63
0.0625	0.21	0.24	0.29	0.36	0.45

TABLE 6-13

TRANSPORT VELOCITY SUMMARY

DRAG COEFFICIENT = 0.7

Cont.pres PSI	10	Drag coef	0.7
Cont.temp F	200	Fric coef static	0.6
		Fric coef dynamic	0.42
Water density Lb/cf	60.1		
Viscosity water	0.000194		
Thickness Mils	3		

SLIDE VELOCITY fps

Paint den. lb/cf	90	100	120	150	200
Tumble vel. fps	0.083	0.096	0.118	0.144	0.180
Dia.in					
128	10.65	12.30	15.08	18.47	23.04
64	7.53	8.70	10.66	13.06	16.29
32	5.33	6.15	7.54	9.23	11.52
16	3.77	4.35	5.33	6.53	8.15
8	2.66	3.08	3.77	4.62	5.76
4	1.88	2.18	2.67	3.27	4.07
2	1.33	1.54	1.88	2.31	2.88
1	0.94	1.09	1.33	1.63	2.04
0.5	0.67	0.77	0.94	1.15	1.44
0.25	0.47	0.54	0.67	0.82	1.02
0.125	0.33	0.38	0.47	0.58	0.72
0.0625	0.24	0.27	0.33	0.41	0.51

TABLE 6-14

TRANSPORT VELOCITY SUMMARY

FRIC.COEFF.DYNAM. = 0.1

Cont.pres PSI	10	Drag coef	1.1
Cont.temp F	200	Fric coef static	0.6
		Fric coef dynamic	0.1
Water density Lb/cf	60.1		
Viscosity water	0.000194		
Thickness Mils	3		

SLIDE VELOCITY fps

Paint den. lb/cf	90	100	120	150	200
Tumble vel. fps	0.066	0.077	0.094	0.115	0.143
Dia.in					
128	4.71	5.44	6.67	8.17	10.19
64	3.33	3.85	4.71	5.78	7.21
32	2.36	2.72	3.33	4.08	5.09
16	1.67	1.92	2.36	2.89	3.60
8	1.18	1.36	1.67	2.04	2.55
4	0.83	0.96	1.18	1.44	1.80
2	0.59	0.68	0.83	1.02	1.27
1	0.42	0.48	0.59	0.72	0.90
0.5	0.29	0.34	0.42	0.51	0.64
0.25	0.21	0.24	0.29	0.36	0.45
0.125	0.15	0.17	0.21	0.26	0.32
0.0625	0.10	0.12	0.15	0.18	0.23

TABLE 6-15

TRANSPORT VELOCITY SUMMARY

FRIC.COEFF.DYNAM. = 0.2

Cont.pres PSI	10	Drag coef	1.1
Cont.temp F	200	Fric coef static	0.6
		Fric coef dynamic	0.2
Water density Lb/cf	60.1		
Viscosity water	0.000194		
Thickness Mils	3		

SLIDE VELOCITY fps

Paint den. lb/cf	90	100	120	150	200
Tumble vel. fps	0.066	0.077	0.094	0.115	0.143
Dia.in					
128	6.38	7.37	9.03	11.06	13.80
64	4.51	5.21	6.38	7.82	9.76
32	3.19	3.68	4.51	5.53	6.90
16	2.26	2.61	3.19	3.91	4.88
8	1.59	1.84	2.26	2.77	3.45
4	1.13	1.30	1.60	1.96	2.44
2	0.80	0.92	1.13	1.38	1.72
1	0.56	0.65	0.80	0.98	1.22
0.5	0.40	0.46	0.56	0.69	0.86
0.25	0.28	0.33	0.40	0.49	0.61
0.125	0.20	0.23	0.28	0.35	0.43
0.0625	0.14	0.16	0.20	0.24	0.30

TABLE 6-16

TRANSPORT VELOCITY SUMMARY

FRIC.COEFF.DYNAM. = 0.3

Cont.pres PSI	10	Drag coef	1.1
Cont.temp F	200	Fric coef static	0.6
		Fric coef dynamic	0.3
Water density Lb/cf	60.1		
Viscosity water	0.000194		
Thickness Mils	3		

SLIDE VELOCITY fps

Paint den. lb/cf	90	100	120	150	200
Tumble vel. fps	0.066	0.077	0.094	0.115	0.143
Dia.in					
128	7.51	8.67	10.62	13.01	16.24
64	5.31	6.13	7.51	9.20	11.48
32	3.75	4.34	5.31	6.51	8.12
16	2.65	3.07	3.76	4.60	5.74
8	1.88	2.17	2.66	3.25	4.06
4	1.33	1.53	1.88	2.30	2.87
2	0.94	1.08	1.33	1.63	2.03
1	0.66	0.77	0.94	1.15	1.43
0.5	0.47	0.54	0.66	0.81	1.01
0.25	0.33	0.38	0.47	0.58	0.72
0.125	0.23	0.27	0.33	0.41	0.51
0.0625	0.17	0.19	0.23	0.29	0.36

TABLE 6-17

TRANSPORT VELOCITY SUMMARY

FRIC.COEFF.DYNAM. = 0.5

Cont.pres PSI	10	Drag coef	1.1
Cont.temp F	200	Fric coef static	0.6
		Fric coef dynamic	0.5
Water density Lb/cf	60.1		
Viscosity water	0.000194		
Thickness Mils	3		

SLIDE VELOCITY fps

Paint den. lb/cf	90	100	120	150	200
Tumble vel. fps	0.066	0.077	0.094	0.115	0.143
Dia.in					
128	9.02	10.42	12.77	15.64	19.51
64	6.38	7.37	9.03	11.06	13.80
32	4.51	5.21	6.38	7.82	9.76
16	3.19	3.68	4.51	5.53	6.90
8	2.26	2.61	3.19	3.91	4.88
4	1.59	1.84	2.26	2.77	3.45
2	1.13	1.30	1.60	1.96	2.44
1	0.80	0.92	1.13	1.38	1.72
0.5	0.56	0.65	0.80	0.98	1.22
0.25	0.40	0.46	0.56	0.69	0.86
0.125	0.28	0.33	0.40	0.49	0.61
0.0625	0.20	0.23	0.28	0.35	0.43

TABLE 6-18

TRANSPORT VELOCITY SUMMARY

FRIC.COEFF.DYNAM. = 0.6

Cont.pres PSI	10		Drag coef	1.1
Cont.temp F	200		Fric coef static	0.6
			Fric coef dynamic	0.6
Water density Lb/cf	60.1			
Viscosity water	0.000194			
Thickness Mils	3			

SLIDE VELOCITY fps

Paint den. lb/cf	90	100	120	150	200
Tumble vel. fps	0.066	0.077	0.094	0.115	0.143
Dia.in					
128	9.57	11.05	13.54	16.59	20.70
64	6.77	7.82	9.58	11.73	14.63
32	4.78	5.53	6.77	8.30	10.35
16	3.38	3.91	4.79	5.87	7.32
8	2.39	2.76	3.39	4.15	5.17
4	1.69	1.95	2.39	2.93	3.66
2	1.20	1.38	1.69	2.07	2.59
1	0.85	0.98	1.20	1.47	1.83
0.5	0.60	0.69	0.85	1.04	1.29
0.25	0.42	0.49	0.60	0.73	0.91
0.125	0.30	0.35	0.42	0.52	0.65
0.0625	0.21	0.24	0.30	0.37	0.46

TABLE 6-19

AVAILABLE WATER INVENTORY

SOURCE	QUANTITY, CF
REACTOR COOLANT	8020
REFUELING WATER STORAGE TANK	60160
ACCUMULATORS	3400
CHEMICAL ADDITIVE TANK (1)	600

NOTE 1. 30 PERCENT SODIUM HYDROXIDE

TABLE 6-20

OPENING RESISTANCES

FROM FIGURE 6-3

OPENING NO.	LENGTH FT.	AREA SQ.FT.	RESISTANCE L/A, 1/FT.
1	17.00	17.90	0.95
2	4.00	88.00	0.05
3	26.00	57.00	0.46
4	14.00	17.90	0.78
5	30.00	49.90	0.60
6	11.00	111.60	0.10
7	14.00	17.90	0.78
9	4.00	88.00	0.05
10	14.00	17.90	0.78
11	16.00	104.50	0.15
14	29.00	38.00	0.76

NOTES:1.REFERENCE DRAWING 2323-M1-0523R.1
2.SOURCE IN COMPARTMENT 4

TABLE 6-21

BRANCH RESISTANCES

FROM FIGURE 6-3

BRANCH FROM	TO	LENGTH FT.	AREA SQ.FT.	RESISTANCE L/A, 1/FT.
SOURCE	1	12.00	60.50	0.20
SOURCE	2	23.00	72.00	0.32
1	3	13.00	142.50	0.09
3	13	6.00	180.50	0.03
2	4	34.00	60.50	0.56
4	6	20.00	209.00	0.10
1	5	16.00	76.00	0.21
5	14	61.00	114.00	0.54
14	11	63.00	161.00	0.39
11	6	38.00	142.50	0.27

NOTES: 1. REFERENCE DRAWING 2323-M1-0523R.1
2. SOURCE IN COMPARTMENT 4

TABLE 6-22

AVAILABLE VELOCITIES
HIGH WATER LEVEL

Branches

Location # From	To	Velocity, fps RHR	Spray	Total
Source	1	0.102	NEG	0.102
Source	2	0.073	NEG	0.073
1	3	0.036	NEG	0.036
3	13	0.028	0.054	0.082
2	4	0.087	NEG	0.087
4	6	0.025	NEG	0.025
1	5	0.014	0.129	0.143
5	14	0.009	0.086	0.095
14	11	0.006	0.099	0.105
11	6	0.007	0.113	0.120

Openings

Opening Location #	Velocity, fps RHR	Spray	Total
1	0.345	NEG	0.345
2	0.060	NEG	0.060
3	0.090	0.172	0.262
4	0.294	NEG	0.294
5	0.021	0.197	0.218
6	0.056	0.144	0.200
11	0.010	0.153	0.163
14	0.027	0.680	0.707

Note: Refer to Figure 6-9 for zones inside containment corresponding to the location numbers.

TABLE 6-23

AVAILABLE FLOW AND VELOCITIES
LOW WATER LEVEL

Branches Flows and Velocities

Location # From	To	Branch Flow, cfs	Area, ft^2	Velocity, fps
14	5	9.83	54.0	0.182
5	3	9.83	36.0	0.273
14	11	16.04	76.4	0.210
11	6	16.04	67.5	0.238
3	13	9.83	85.6	0.115

Opening Velocities

Location # Opening	Flow, cfs	Area, ft^2	Velocity, fps
3	9.83	27.0	0.364
5	9.83	23.6	0.416
11	16.04	49.5	0.324
6	16.04	52.9	0.303
14	25.87	18.0	1.437

Note: Refer to Figure 6-10 for zones inside containment corresponding to the location numbers.

TABLE 6-24

CONTAINMENT SPRAY FLOW[2]

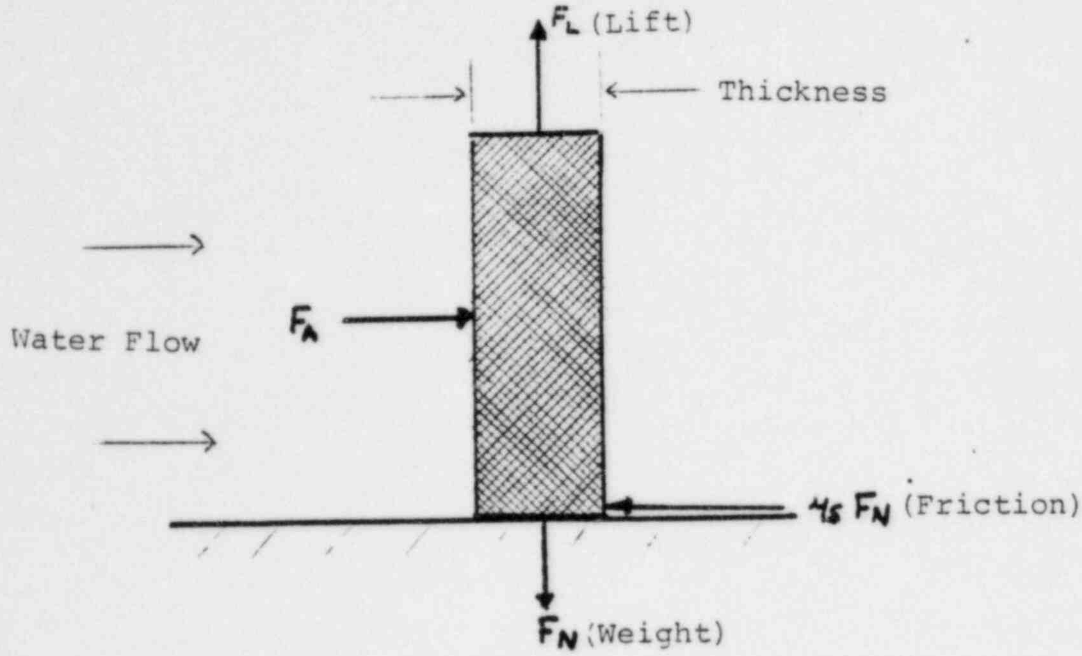
Zone[1]	One Train Operating Flow (GPM)	Velocity[3] (ft/sec)	Two Trains Operating Flow (GPM)	Velocity[3] (ft/sec)
A	4165	0.066	8330	0.131
B	1018	0.016	2036	0.032
C	213	0.003	426	0.007
D	410	0.006	820	0.013
E	Unsprayed			

Notes:

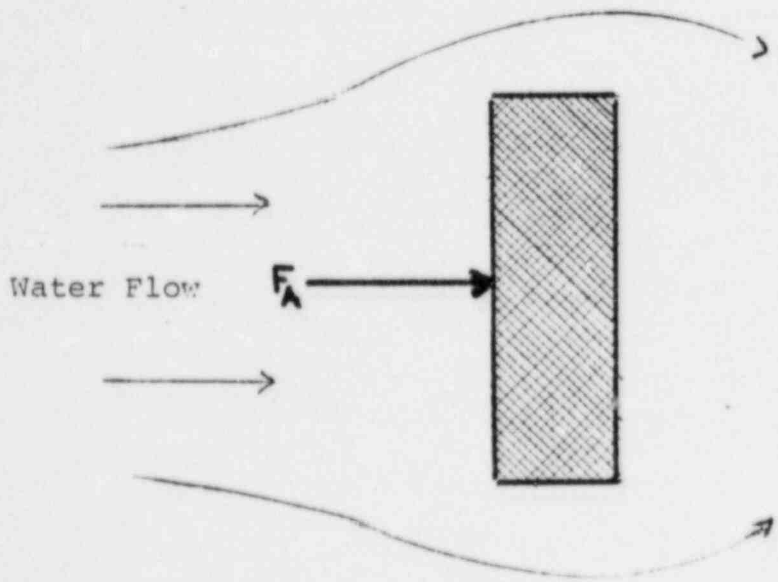
(1) Spray zones are shown on Figure 6-8.

(2) Flow values are from FSAR Table 6.5-5.

(3) Velocities based on 4" curb and 424 ft. perimeter.



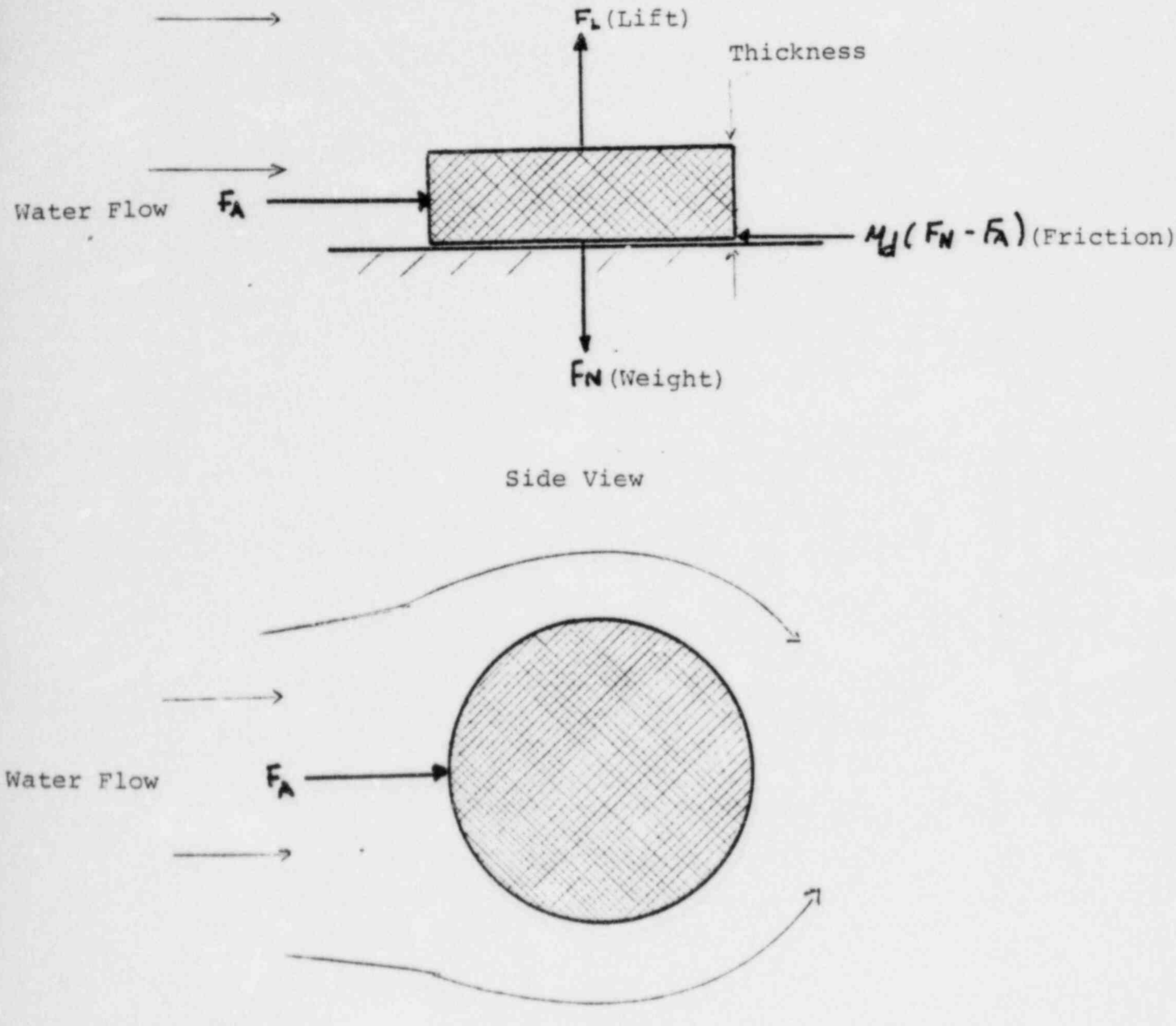
Side View



Plan View

TUMBLE TRANSPORT MODEL

FIGURE 6-1



Plan View

SLIDE TRANSPORT MODEL

FIGURE 6-2

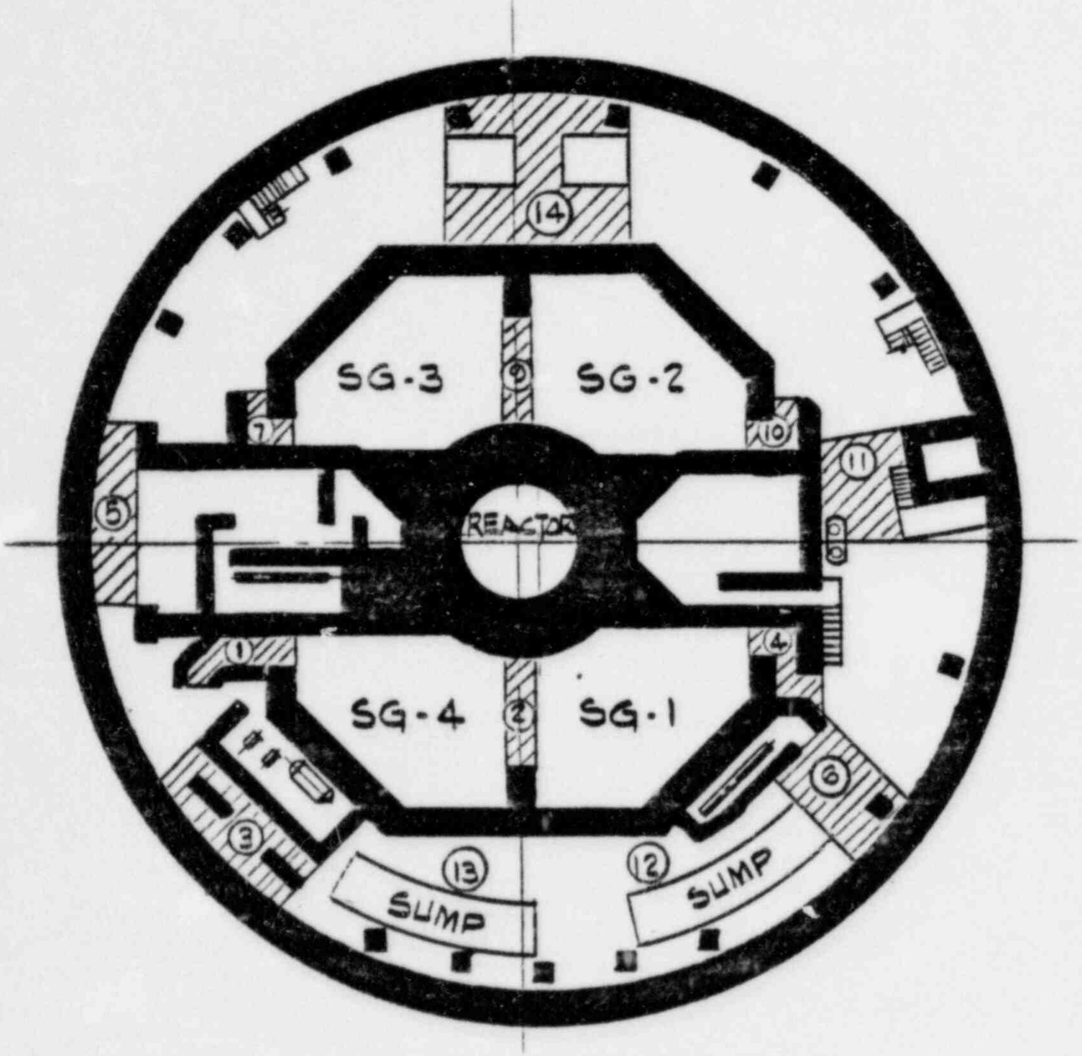


FIGURE 6-3

FLOW RESISTANCE MAP

Note: Location 8 not used.

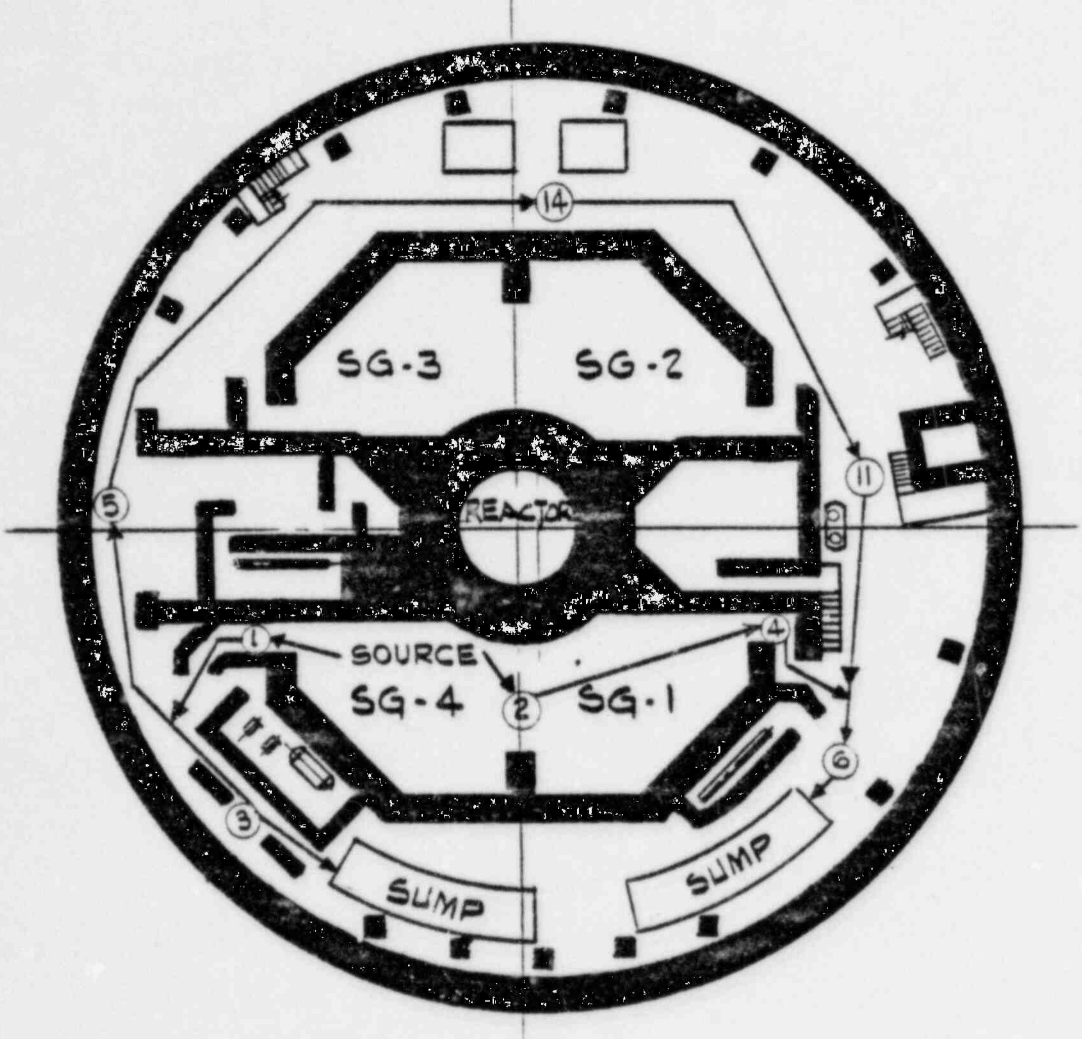


FIGURE 6-4
RHR/SI FLOW PATHS

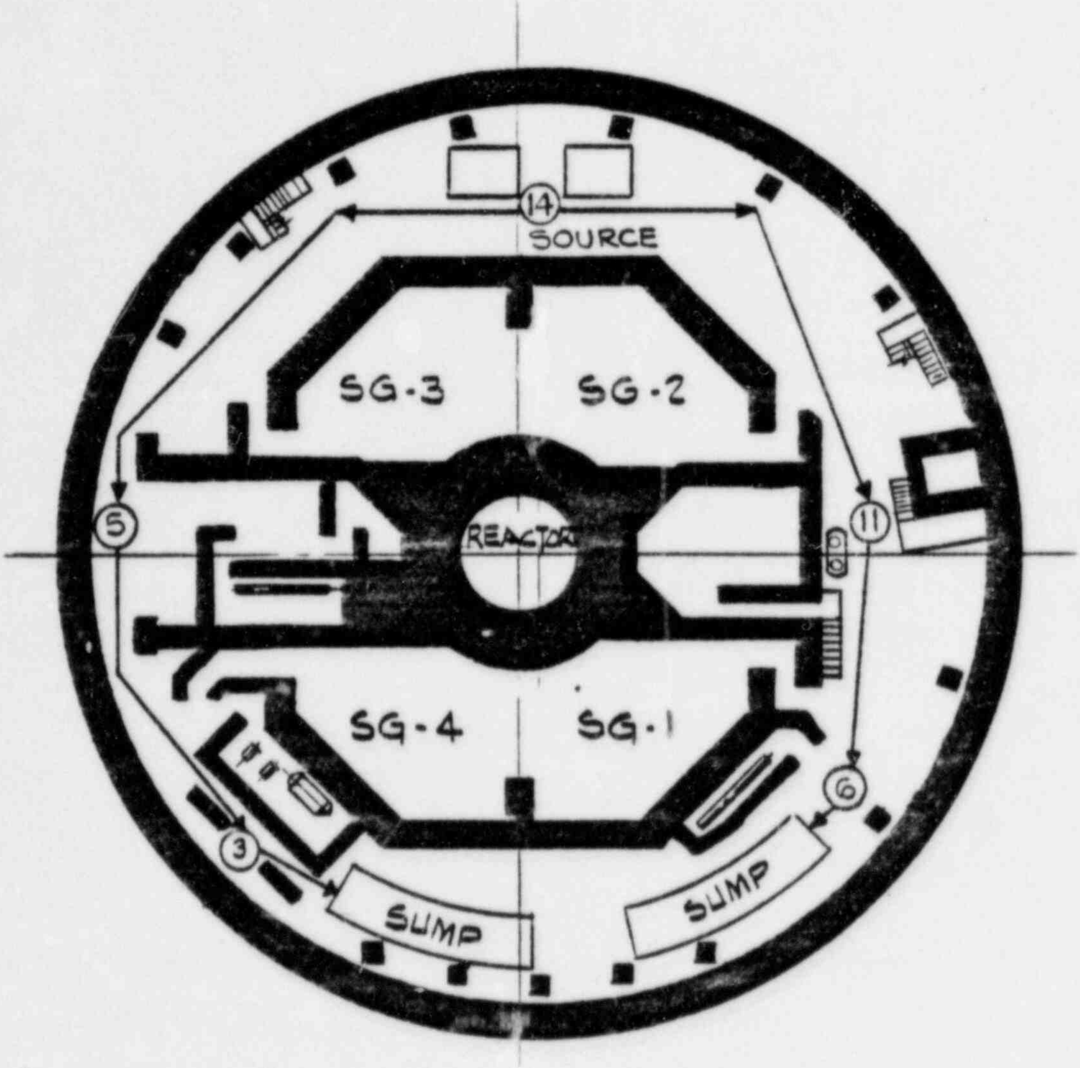
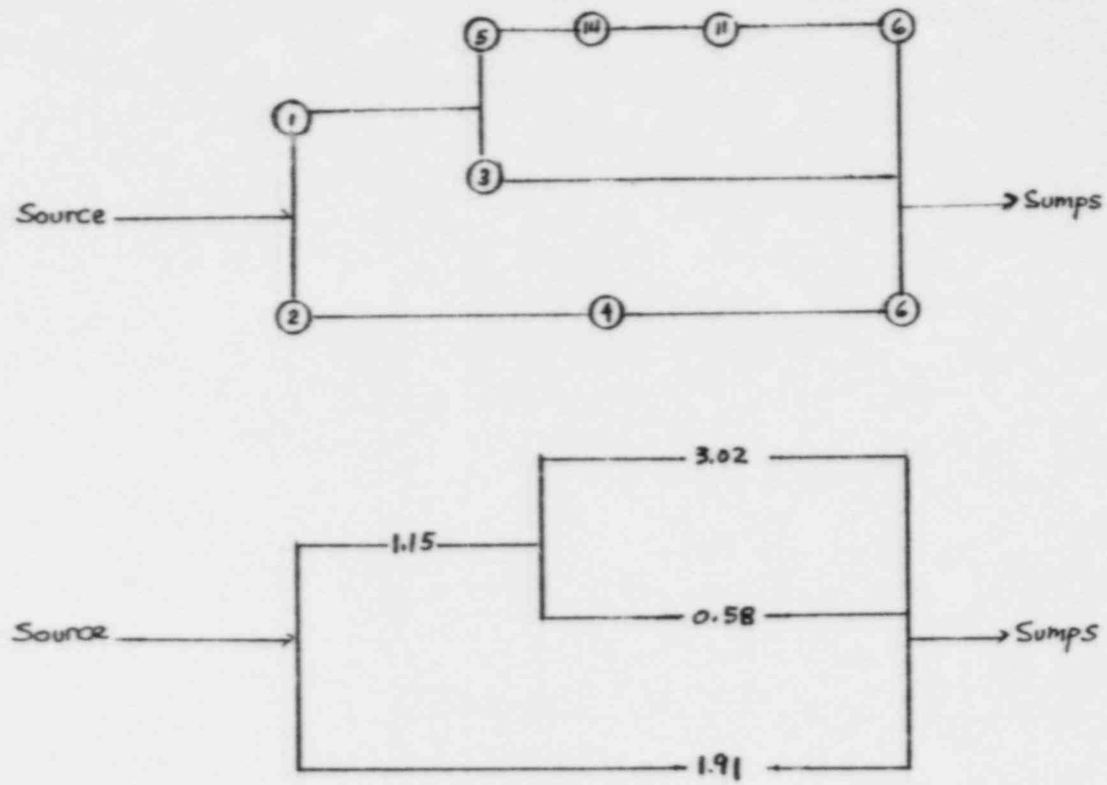


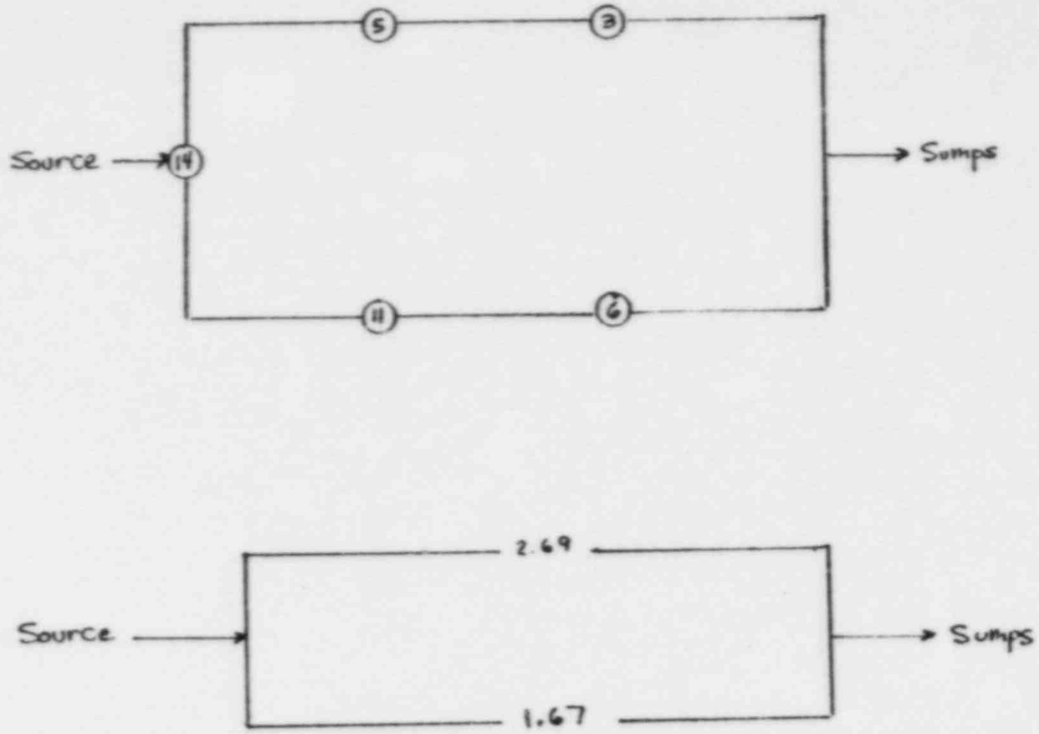
FIGURE 6-5

SPRAY FLOW PATHS



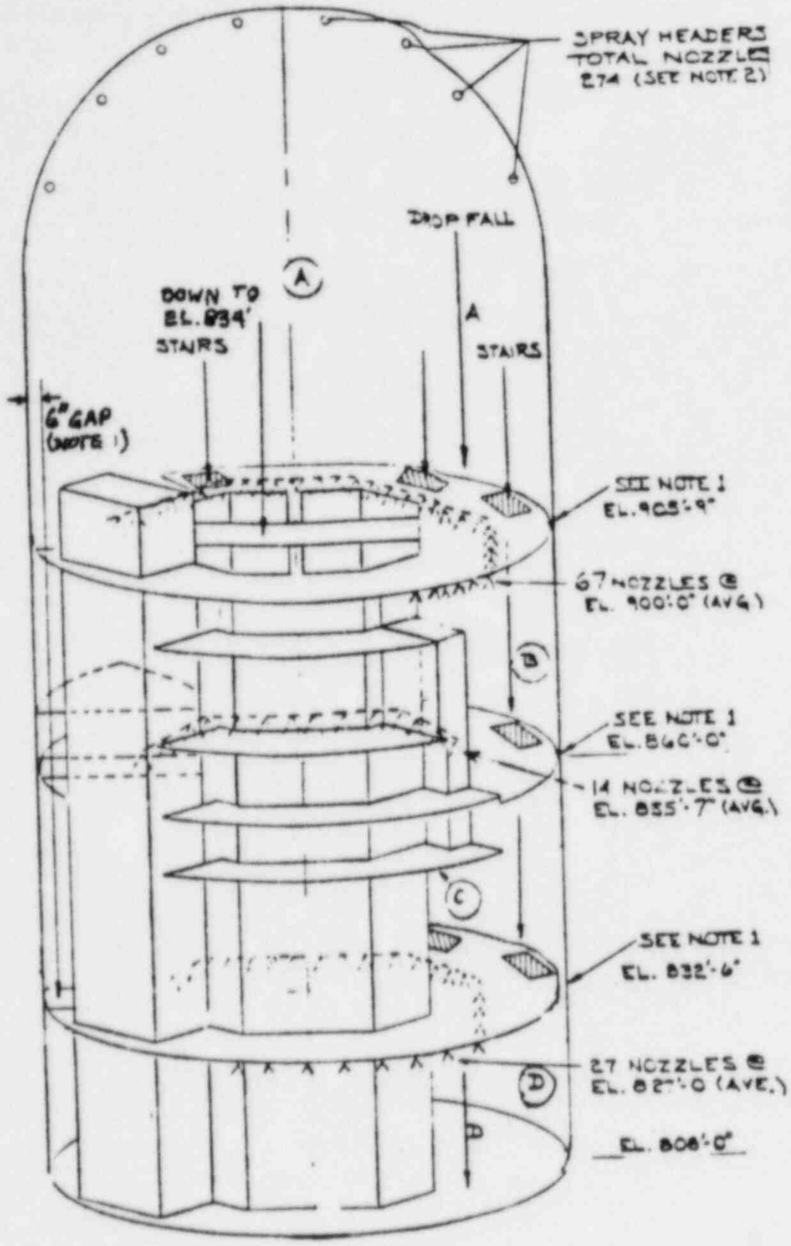
"CIRCUIT" DIAGRAM -- RHR/SI

FIGURE 6-6



"CIRCUIT" DIAGRAM -- SPRAY

FIGURE 6-7



Notes: 1. 6" Gap between Floor & Containment Wall Allows for Dropfall Between Floors.

2. Number of Nozzles shown for each Floor is for One Train only.

FIGURE 6-8

CONTAINMENT SPRAY ZONES

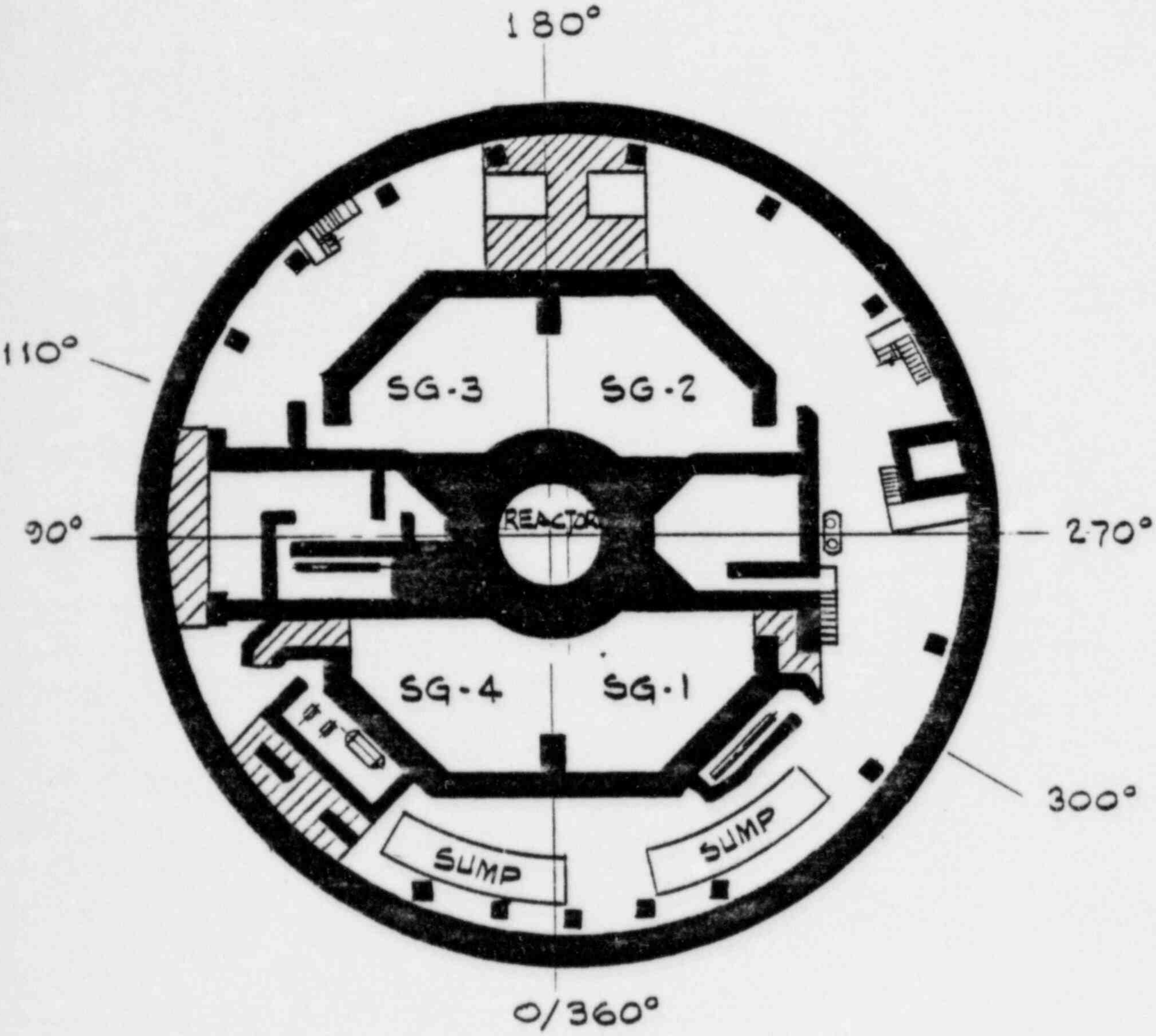


FIGURE 6-9

AREAS EXCEEDING THRESHOLD VELOCITY

HIGH WATER LEVEL

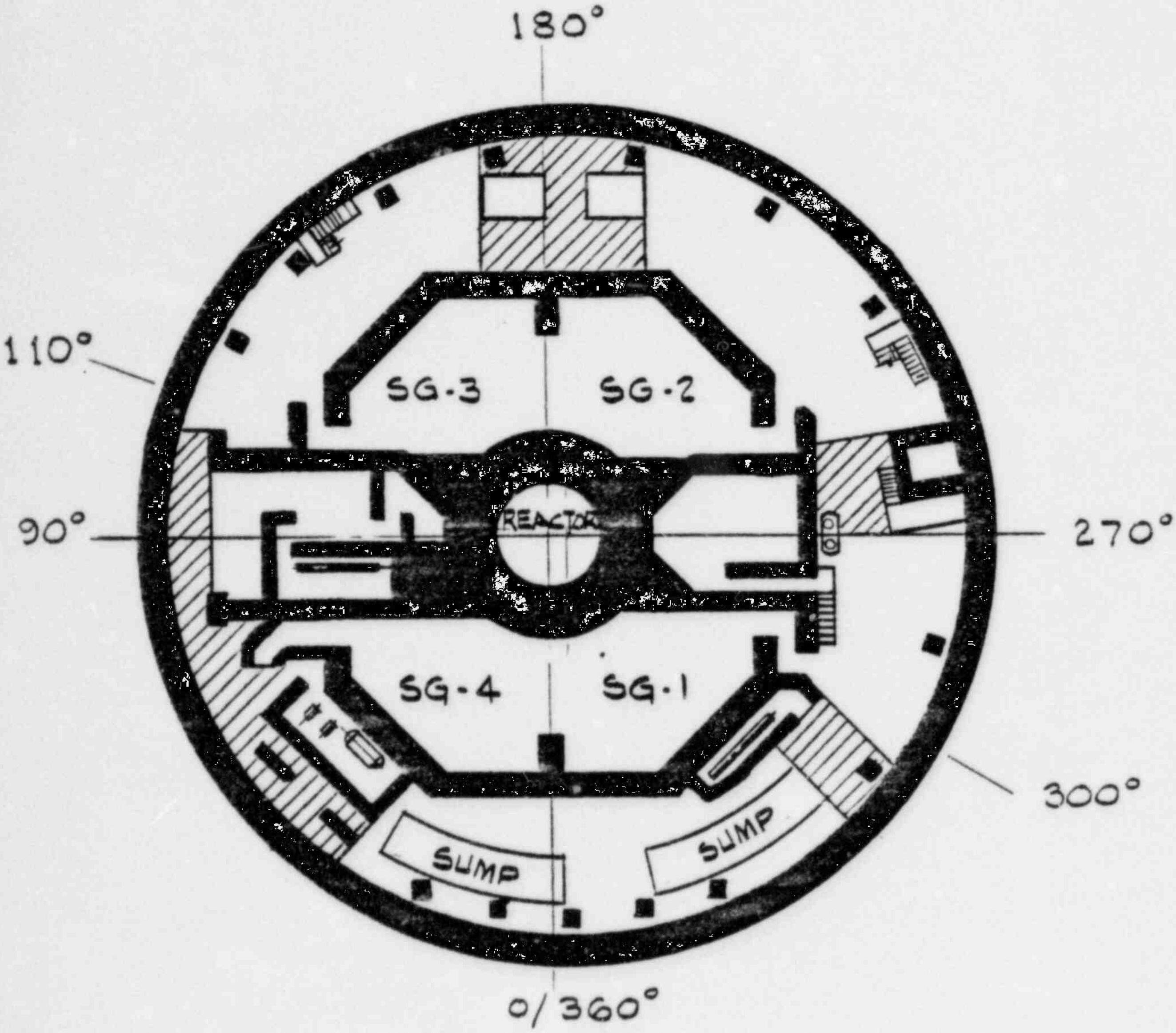


FIGURE 6-10

AREAS EXCEEDING THRESHOLD VELOCITY

LOW WATER LEVEL

7.0 DEBRIS EFFECTS ON EMERGENCY SUMPS

Each of the two containment recirculation sump screens has a total thru-flow area of 386 ft^2. The sump screen design is in accordance with the requirements of Regulatory Guide 1.82 with a thru-screen velocity of 0.2 fps assuming 50 percent of the screen area is covered by debris. Figure 7-1 shows the arrangement of an Emergency Sump.

During the recirculation phase, adequate NPSH for the Containment spray pumps is ensured in accordance with NRC Regulatory Guide 1.1 except the NPSH is calculated using the static head between the bottom of the Containment (elevation 808 ft) and the pump centerline elevation, minus the piping friction losses. It is assumed that the Containment ambient pressure is equal to the vapor pressure of the sump liquid.

Figure 7-2 shows the relationship between the available NPSH and the pump flow during the recirculation phase and shows the required NPSH including a 10 percent margin.

The NPSH for each containment spray pump during the recirculation phase is summarized in Table 7-1.

Blockage of the sumps by debris will tend to increase the pressure losses across the sump screens. The increase in pressure losses will depend on the extent of the blockage and the porosity of the debris. The increase in pressure losses will reduce the available pump NPSH. This can have an adverse effect on the operation of the recirculation pumps, if it exceeds the margin between available and required NPSH.

For totally impermeable debris, the pressure loss across the sump screens is calculated based on the area available for flow, excluding the projected blockage area.

For porous debris, such as the fibrous, the methods recommended in NUREG/CR-2791, Section 5, is used to evaluate the pressure losses across the screen. The evaluation of fibrous insulation debris generation (Section 3.0) shows that there are no zones inside the containment where such insulation can fail to cause debris coincident with a demand for the emergency sump operation. However, sump pressure drop calculations using the quantities in Tables 3-1 to 3-5 were performed.

Any paint debris that is transported to the sump by sliding along the concrete surface will accumulate on the floor. This is because the water velocity at the screens is much lower than the velocity required to put the debris into suspension. However, for a conservative first approximation, to determine if pressure losses are excessive, it was assumed that the screens will be

blocked by the paint particles forming a heap next to the screens with an angle of repose of 45 degrees.

The results of the calculation for pressure losses across the sump screens due to insulation debris indicate that the required NPSH would not exceed the available NPSH for the recirculation pumps.

The quantity of paint that has any potential for transport to the sump screens will be the indeterminate-paint in the sump area itself.

To determine the maximum amount of paint debris that can be tolerated, the following three cases were evaluated and presented in Table 7-2:

Case-1: No screen blockage. All paint debris is below the outer screen level i.e., 6" coaming plate.

Case-2: Same as Case-1 with additional paint debris accumulation between the outer and inner screens.

Case-3: 50 percent screen blockage by paint debris.

The results of these calculations presented in Table 7-2 indicate that indeterminate-paint in the sump area cannot result in any blockage of the sump screens.

Based on the above evaluations for fibrous insulation and paint debris effects on the emergency sump performance, the following conclusions are arrived at:

a. Fibrous insulation on piping has no potential for forming debris which can block the sump screens.

b. Paint failure in areas other than the steam generator compartments 1 and 4, and the immediate sump area (Azimuth 0-110° and 300-360°) will not be transported to cause screen blockage.

TABLE 7-1

CONTAINMENT SPRAY PUMP NPSH[1]

Pump No.	1	2	3	4
Static Head (psi)	13.28	13.28	13.28	13.28
Piping Friction Losses (psi)	5.1	4.94	5.3	4.91
Entrance Losses (psi)	0.51	0.51	0.51	0.51
NPSH (psi)	7.67	7.83	7.74	7.87
NPSH (ft. H_2O) (available)	18.71	19.11	18.89	19.18

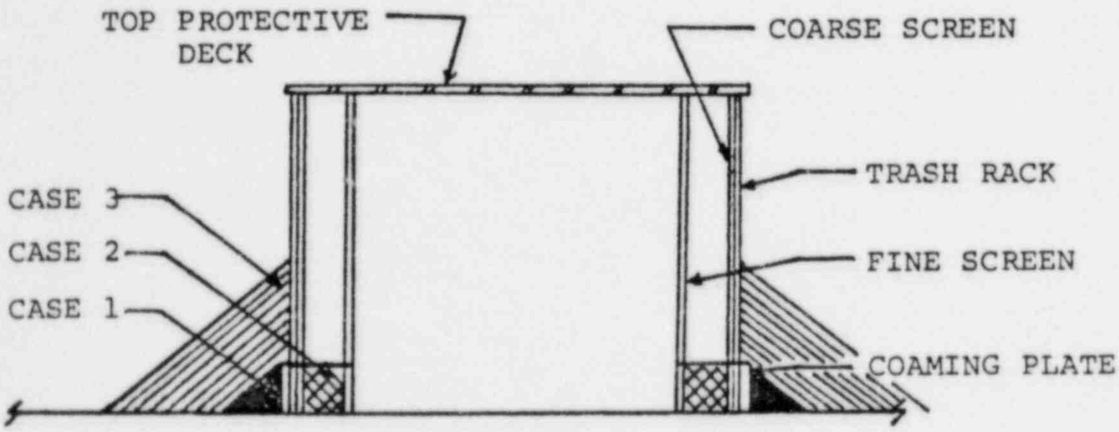
Note:

[1] Reference: FSAR Section 22 of "NRC Questions and Responses" pp 22-30.

TABLE 7-2

COATING ACCUMULATION AT SUMP SCREENS[1]

Case No.(2)	Coating Accumulation Height, Inches(3)	Percent Screen Blockage, %(4)	Evaluation Paint Area Sq. Ft.(5)
1	6	0	5,760
2	6	0	26,700
3	27	50	117,100



Notes:

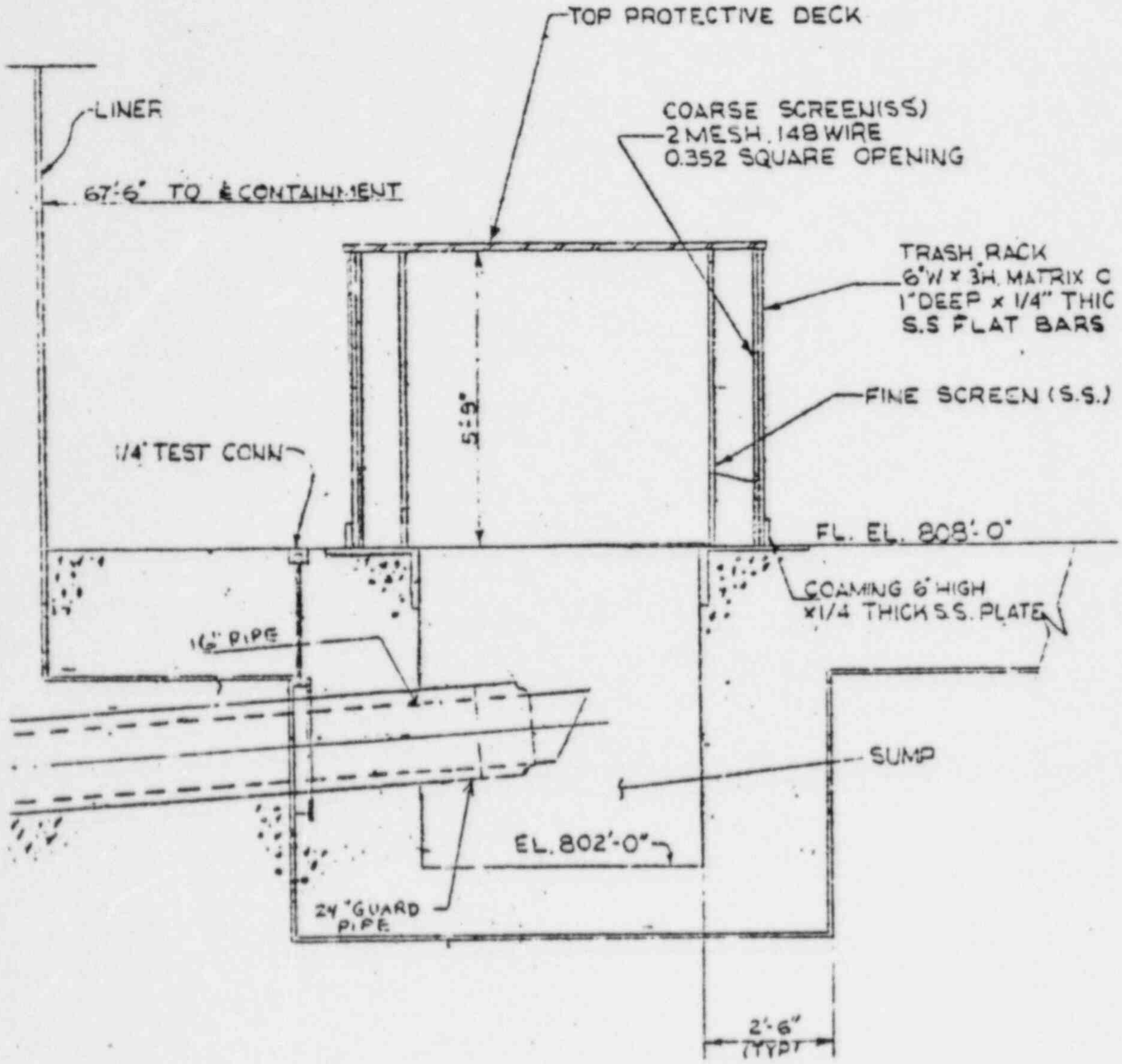
(1) Uniform buildup around the sump perimeter is assumed with an angle of repose of 45°.

(2) Case 1: Accumulation to 6" ht. at coarse screen only.
Case 2: Accumulation to 6" ht. at coarse screen and in area between the screens.
Caes 3: Accumulation to 27" (Equivalent to 50 percent screen blockage)

(3) See diagram above.

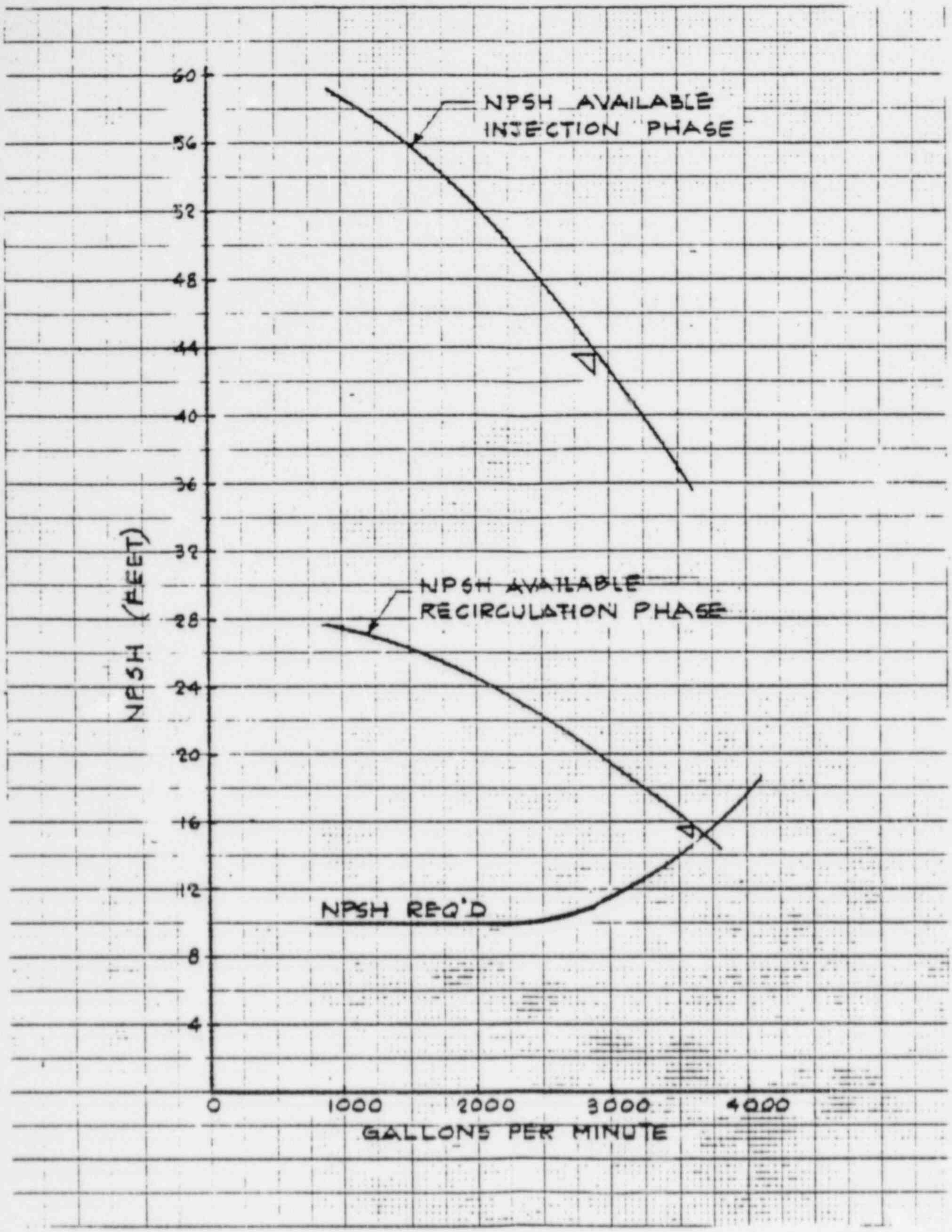
(4) Percent blockage refers to the coating "piled height" divided by the water depth, 4.5 feet, at low water level. Note lower 6" of screen is coaming plate, see diagram Note 3.

(5) Equivalent area assumes a coating thickness of 0.01" (10 mils) and a density correction of 50 percent to account for voids when piling at the screen.



CONTAINMENT EMERGENCY SUMP

FIGURE 7-1



CONTAINMENT SPRAY PUMP NPSH

FIGURE 7-2

Ref: FSAR Fig. 6.2.2-2