NORTHEAST UTILITIES

THE CONNECTICUT LIGHT AND POWER COMPANY
WESTERN MASSACHUSETTS ELECTRIC COMPANY
HOLYOKE WATER POWER COMPANY
NORTHEAST UTILITIES SERVICE COMPANY
NORTHEAST NUCLEAR ENERGY COMPANY

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October 15, 1985

Docket No. 50-423
B11771

Director of Nuclear Reactor Regulation
Mr. B. J. Youngblood, Chief
Licensing Branch No. 1
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Reference: (1) W. G. Counsil letter to B. J. Youngblood, dated April 16, 1985.

Dear Sir:

Millstone Nuclear Power Station, Unit No. 3
Revised Response to SER Confirmatory Item #27

In Reference (1), Northeast Nuclear Energy Company (NNECO) submitted a response to SER Confirmatory Item #27 concerning the calculated containment sump approach velocity. As a result of conversations with your Mr. R. Palla concerning our Reference (1) response, NNECO has revised the response to address questions raised by Mr. Palla regarding the effect of partial sump screen submergence on the velocity calculations.

Please note that the attached analysis supersedes that submitted in Reference (1).

We believe that this information should resolve Confirmatory Item #27.

Very truly yours,

NORTHEAST NUCLEAR ENERGY COMPANY
et. al.

BY NORTHEAST NUCLEAR ENERGY COMPANY
Their Agent

J. F. Opeka
Senior Vice President



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STATE OF CONNECTICUT )
) ss. Berlin
COUNTY OF HARTFORD )

Then personally appeared before me J. F. Opeka, who being duly sworn, did state that he is Senior Vice President of Northeast Nuclear Energy Company, an Applicant herein, that he is authorized to execute and file the foregoing information in the name and on behalf of the Applicants herein and that the statements contained in said information are true and correct to the best of his knowledge and belief.

Lorraine J. D'Amico
Notary Public

My Commission Expires March 31, 1988

## SER Confirmatory Item No. 27 - Sump Flow Apprcach Velocity

Response:

### Introduction

Regulatory Guide 1.82 recommends a maximum sump approach velocity of 0.2 ft./sec. concurrent with 50 percent screen blockage in the design of the containment recirculation sump. As shown in the insulation transport tests reported in NUREG-2982, 0.2 ft./sec. is the minimum velocity required to move small shredded pieces of fibrous insulation. Larger pieces were shown to require much higher velocities to be moved.

For Millstone 3, the maximum sump velocity at the screens is 0.15 ft./sec. assuming full screen submergence and no blockage. The containment recirculation system starts prior to full screen submergence and will operate for a short period of time before the water level in the containment sump has risen to above the top of the screens. This results in a coolant velocity at the screens slightly in excess of 0.2 ft./sec. for a short duration. Since the layout of the containment is such that insulation debris cannot be transported directly to the sump screens by the break jet, any screen blockage could only be caused by transport of insulation pieces along the containment floor from where they would drop from upper elevations.

A bounding assessment of the effects of insulation debris was performed to show the worst-case hypothetical effect on the recirculation pumps. The maximum amount of insulation damaged by a pipe rupture and available for transport to the sump screens was determined. All of this insulation was conservatively assumed to be transported to the containment floor without regard to the actual transport mechanisms. A simplified conservative model was developed to estimate transport of insulation along the containment floor to the screens. Detailed assumptions and justifications regarding debris loading on the sump screens with time are discussed below.

The resultant effect on the recirculation pumps was determined in the form of reduced available NPSH, as the insulation used in Millstone 3 would not totally block sump flow, but merely introduce an additional head loss. The following is a detailed description of the quantification of the head loss to the recirculation pumps from insulation debris.

An assessment of insulation damage and debris formation was made for several postulated primary system pipe ruptures. Figure 1, extracted from WCAP-8082, shows a schematic of the primary system piping along with the postulated break locations by number. Each of the numbered breaks were considered on the basis of potentially inflicting significant damage to the insulation for debris generation via jet impingement. Primary system breaks were selected for debris assessment because they are limiting for the NPSH available to the containment recirculation pumps. Judgements and assumptions regarding potential damage were based on the geometric location of the break and the direction of the jet flow.

Of all cases considered, the limiting case selected for detailed analysis was based on the potential of generating the highest debris volume. This case shows a potential reduction in available NPSH for the recirculation pumps due to

increased pressure drop at the containment sump screens. However, there remains adequate margin between the available and required NPSH. Accordingly, the containment recirculation system reliability would not be compromised.

Estimate of Insulation Debris

The jet impingement model used to estimate the extent of insulation damage is found in NUREG/CR-2791 and depicted schematically in Figures 2 and 3. All guillotine breaks considered in the analysis were found to be "shadowed" breaks, or partially shadowed breaks because of the restricted pipe movement. For the one "partially shadowed" break (break 4), the unshadowed jet is assumed to emerge 45 degrees from the break in two opposed directions along the approximate centerline of the pipe. The shadowed jet emerges perpendicular to the pipe centerline in the general shape of a disk. In the debris assessment of break 4, the shadowed jet does not create significant debris. Shadowed jets from the other guillotine breaks would only extend as shown by the "shadowed segment" sketch in Figure 3. These breaks will cause less insulation damage than the "partially shadowed" break 4.

A distance of 5 L/Ds from the break for the 45 degree jet is assumed for the purpose of assessing significant insulation damage. This is considered to be a conservative assumption as relatively fragile fiberglass cloth-encapsulated pillows can withstand the pressure at about 5 L/Ds (NUREG/CR-3170). The Millstone 3 fiberglass system is significantly more durable being stainless steel encapsulated. Insulation beyond 5 L/Ds would, at worst, become dislodged in "as-fabricated" pieces and therefore sustain minimal damage.

Within the damage region (see Figure 2) all insulation in the direct line of the jet is assumed to sustain damage. To account for smaller piping and equipment in the vicinity of the jet, the volume of damaged insulation estimated from the large primary coolant system components and piping is increased by 10 percent. The limited pipe movement prevents additional insulation damage from pipe whip. Partially "shadowed" guillotine break 4 was calculated to generate a total of 90 cubic feet of debris up to a maximum distance of 5 L/Ds from the break source. Split break 7 was found to generate the second highest quantity of debris at 70 cubic feet. In accordance with NUREG/CR-2791, 30 percent of the total debris is assumed to be fine suspended fibers and is readily transportable to the screens. Forty percent of the debris is medium-sized pieces. These fragments may be transported to the screens at a slower rate than the small suspended fibers if the flow velocity toward the screens is sufficiently high. The remaining 30 percent is comprised of large pieces which do not readily transport to the screens.

Debris Transport and Screen Loading

There is expected to be some retention of insulation debris in the steam generator cubicle and some delay in the transport of debris that eventually does reach the containment floor. However, transport of the insulation debris to the containment floor is conservatively bounded by assuming 100 percent of the

damaged insulation reaches the floor by 660 seconds, the time the containment recirculation pumps start. "As-fabricated" sections beyond the 5 L/D damage zone which may be dislodged will be retained in the steam generator cubicle. Other debris generated by jet impingement, such as paint chips and aggregate from concrete, is not significant compared to the quantity of fibrous insulation debris generated.

Given enough time, all insulation pieces could eventually reach the vicinity of the sump and may add to the debris load on the screens. However, screen blockage by large insulation pieces occurs only if the water velocity is of sufficient magnitude (greater than or equal to 0.7 ft./sec.) to move the debris. Table 1 indicates that the sump water velocity is significantly less than 0.7 ft./sec, therefore, large pieces of debris would not add to the screen load. This leaves 70 percent of the 90 cubic feet total volume (63 cubic feet) available for loading on the sump screens. The effect of this debris on pump performance is maximized by loading this 63 cubic feet on the screens at the time the containment recirculation system fills and begins normal operation at 724 seconds.

Table 1 gives the sump water level and submerged screen area used in determining water velocity and debris head loss at 724 seconds. The development of this data considered a number of conservative assumptions aimed at minimizing the sump water level while concurrently maximizing the head loss across the screens. The conservative assumptions are:

1. Maximum Containment Recirculation System flow for maximum water velocity at the screens.

2. Velocity at the screens based on the area of screens submerged.

3. Containment floor water inventory estimate considers:

    a. Large pump suction rupture consistent with type of break necessary to generate significant quantities of debris.

    b. Limiting single failure of one low head safety injection pump.

    c. Significant water hold-up on upper containment floors and surfaces.

4. Debris is transported to the containment floor prior to pump start and then rapidly to the sump screens once the pumps start.

5. Debris covers only the fine mesh screens.

6. Debris evenly covers the fine mesh screens up to the level of screen submergence. Since the head loss equation is approximately linear with debris thickness, there is no advantage or disadvantage to assume other than an even debris distribution.

Figure 4 shows a cross-section of the containment sump with key elevations noted. Elevation (-)23'-2", the water level at 724 seconds, is where debris transport is conservatively assumed to be complete. The water level continues to rise, with full screen submergence occurring at 2100 seconds. Total debris loading occurring at only 48 percent screen submergence and 12 minutes elapsed time is a very conservative result given that NUREG/CR-2791 indicates much longer transport times under similar conditions.

Determination of Available NPSH

Alden Research Laboratory Report ARL 489/83/1 (also NUREG-0897, Revision 1) contains an empirical relationship for head loss of water flowing through fibrous insulation. Specifically, the empirical formula was developed for the identical fibrous insulation used in the Millstone 3 stainless steel encapsulated system. The head loss is:

$$h = 68.3 \quad U^{1.79} \, t^{1.07}$$

where:

- h is the head loss in ft.
- U is the water velocity in ft./sec.
- t is the calculated thickness of the insulation on the screens in ft.

The above equation was used to determine the head loss at 724 seconds. This will be the maximum head loss since all insulation debris which could be transported to the screens is assumed to be loaded on the screens, and the water level is at the lowest level during normal system operation. The lowest water level results in the minimum submerged screen area, and thus the highest screen approach velocity during system operation.

Table 1 summarizes the results of the debris assessment for break 4 giving the screen submergence, volume of calculated debris, the resulting thickness on the screens, the screen approach velocity, the head loss, and the resultant NPSH margin at 724 seconds. Although the NPSH margin would be reduced, adequate margin remains in the worst case studied. This margin would provide assurance that the reliability of the containment recirculation system is not significantly affected by the potential of debris generation resulting from a postulated primary system pipe break and the subsequent head loss due to blockage of the containment recirculation sump screens. Therefore, the design of the containment recirculation sump meets the design objectives of Regulatory Guide 1.82, although the recommended maximum velocity is slightly exceeded.

References

1. Methodology for Evaluation of Insulation Debris Effects, NUREG/CR-2791, SAND 82-7067.

2. Containment Emergency Sump Performance, NUREG-0897, Revision 1 Draft, December 1983.

3. Susceptibility of Fibrous Insulation Pillows to Debris Formation Under Exposure to Energetic Jet Flow, NUREG/CR-3170 (also SAND 83-7008), March 1983.

4. Postulated Break Locations in the Steam Generator Cubicle, WCAP-8082.

5. Alden Research Laboratory Report No. ARL 489/83/1 (also referenced in NUREG-0897, Revision 1, Draft).

6. Buoyancy, Transport and Head Loss of Fibrous Insulation, NUREG/CR-2982, SAND 82-7205.

<u>TABLE 1</u>

CONTAINMENT RECIRCULATION SYSTEM NPSH EVALUATION

DEBRIS ASSESSMENT OF GUILLOTINE BREAK 4

| | |
|---|---|
| Time of sytem reaching operating conditions (sec) | 724 |
| Total system flow (4 pumps) (gpm) | 12,609 |
| Emergency sump screen submergence elevation | (-)23'2" |
| Screen area submerged ($ft^2$) | 118 |
| Percent of screens submerged | 48 |
| Screen approach velocity (ft/sec) | 0.24 |
| Volume of insulation debris on screens ($ft^3$) | 63 |
| Thickness of insulation debris (ft) | 0.53 |
| Head loss across debris thickness (ft) | 2.69 |
| NPSH available to pumps (ft) | 17.2 |
| NPSH required (ft) | 5 |
| NPSH margin (ft) | 12.2 |
| Time to fully submerge screens (sec) | 2100 |
| Screen approach velocity at full submergence (ft/sec) | 0.12 |

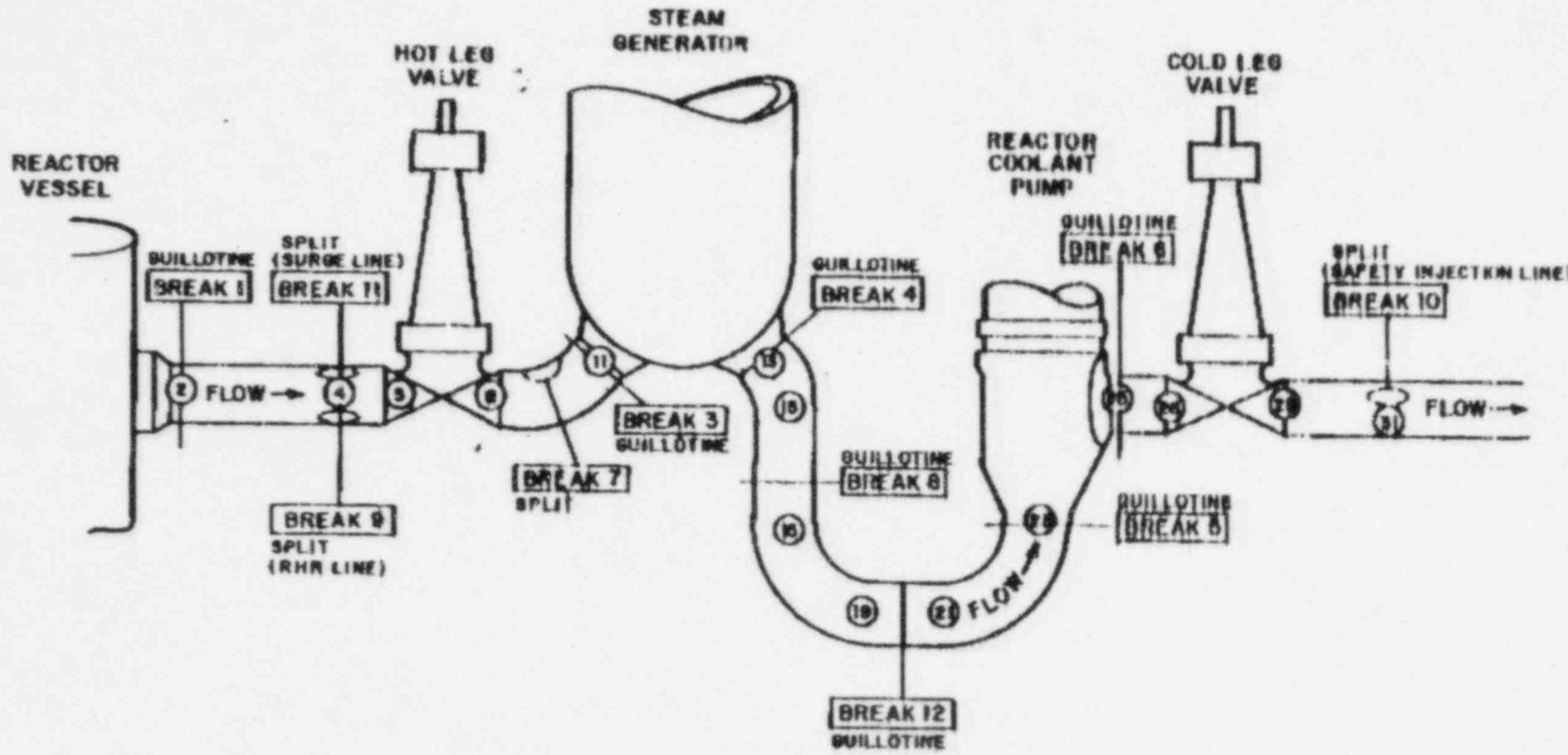
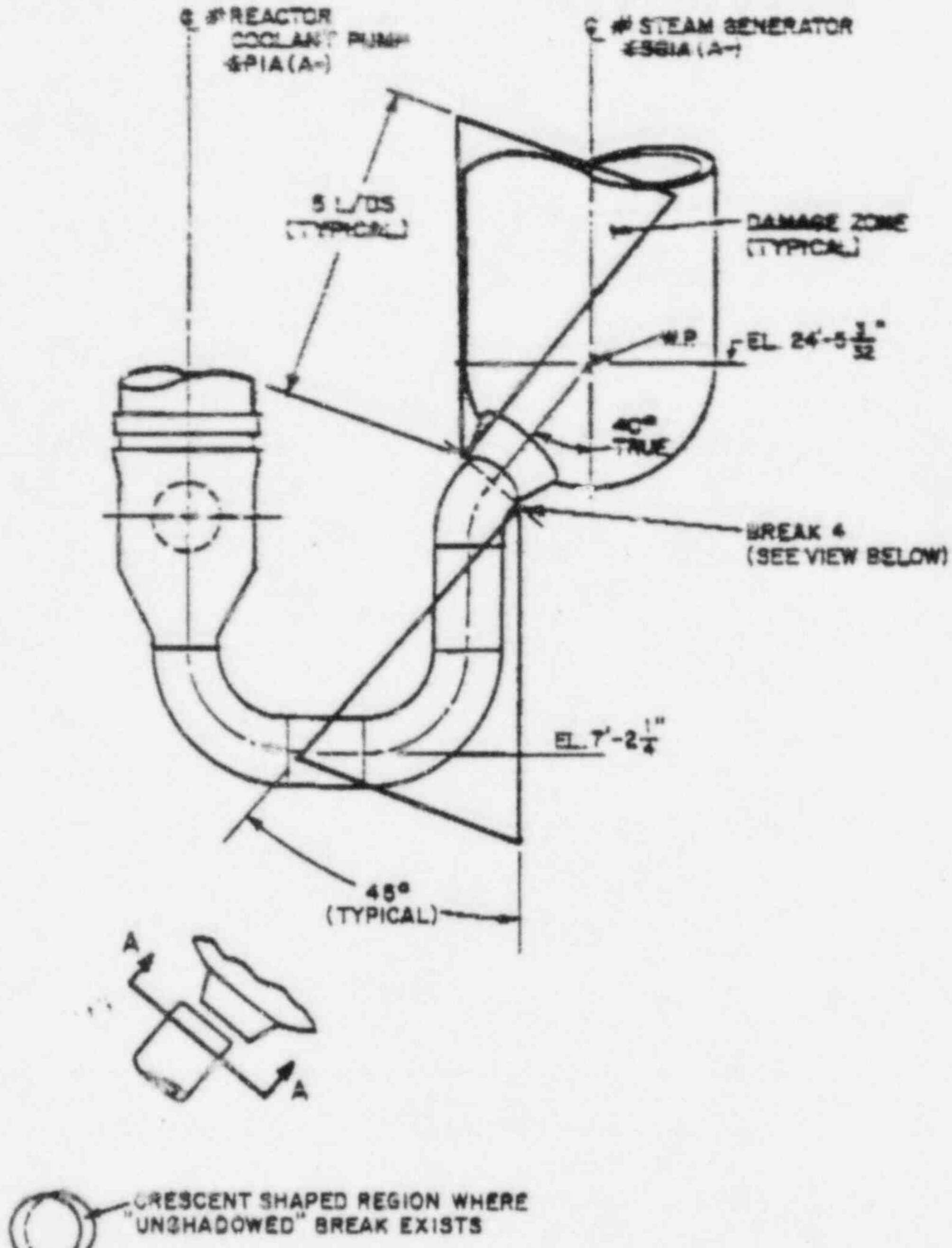



FIGURE 1
SCHEMATIC OF PRIMARY SYSTEM
NUMBERED BREAK LOCATIONS
MILLSTONE NUCLEAR POWER STATION
UNIT 3




NOTE:
SEE FIGURE 3 FOR TOTAL JET IMPINGEMENT MODEL

FIGURE 2
JET IMPINGEMENT MODEL
MILLSTONE NUCLEAR POWER STATION
UNIT 3

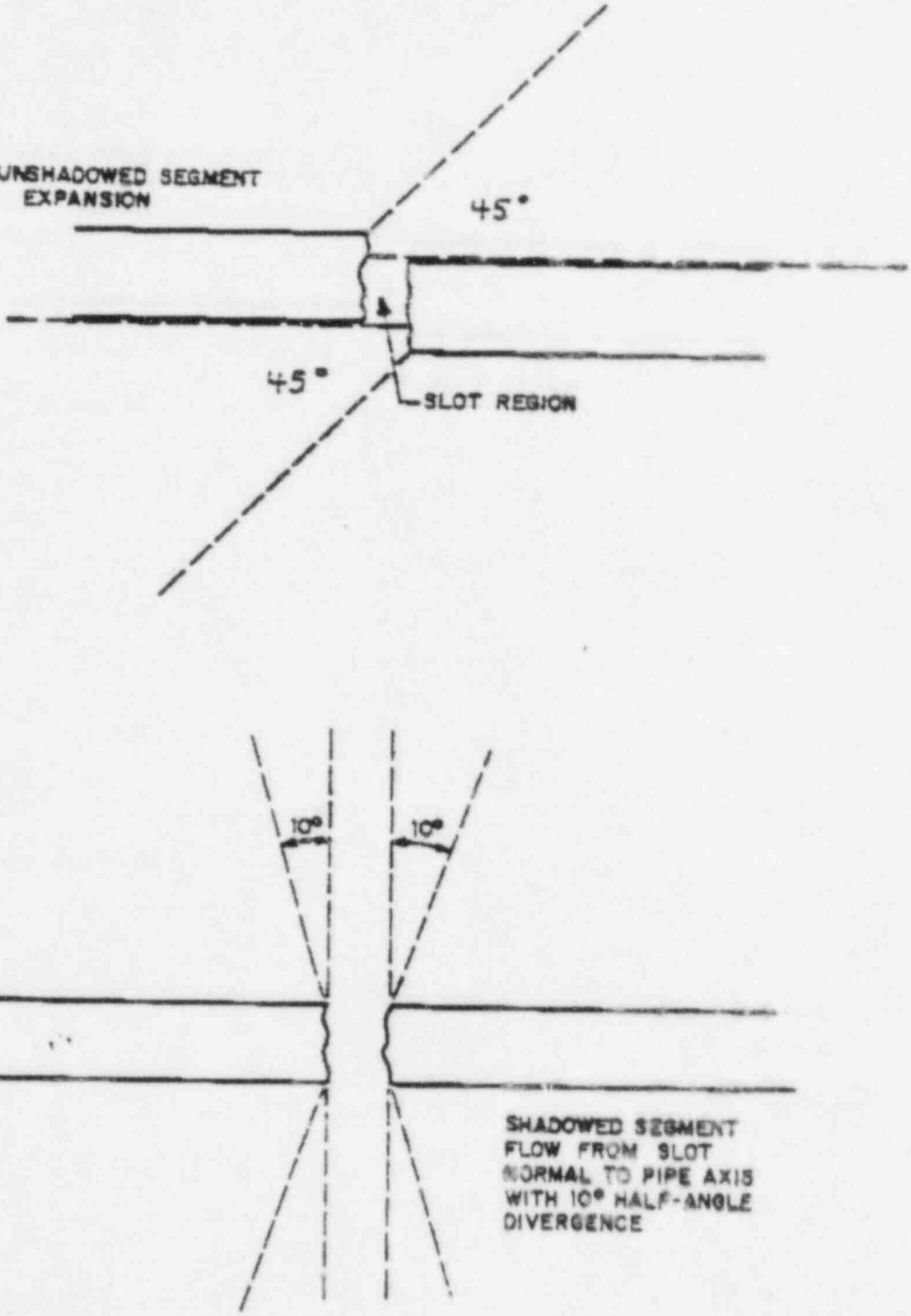
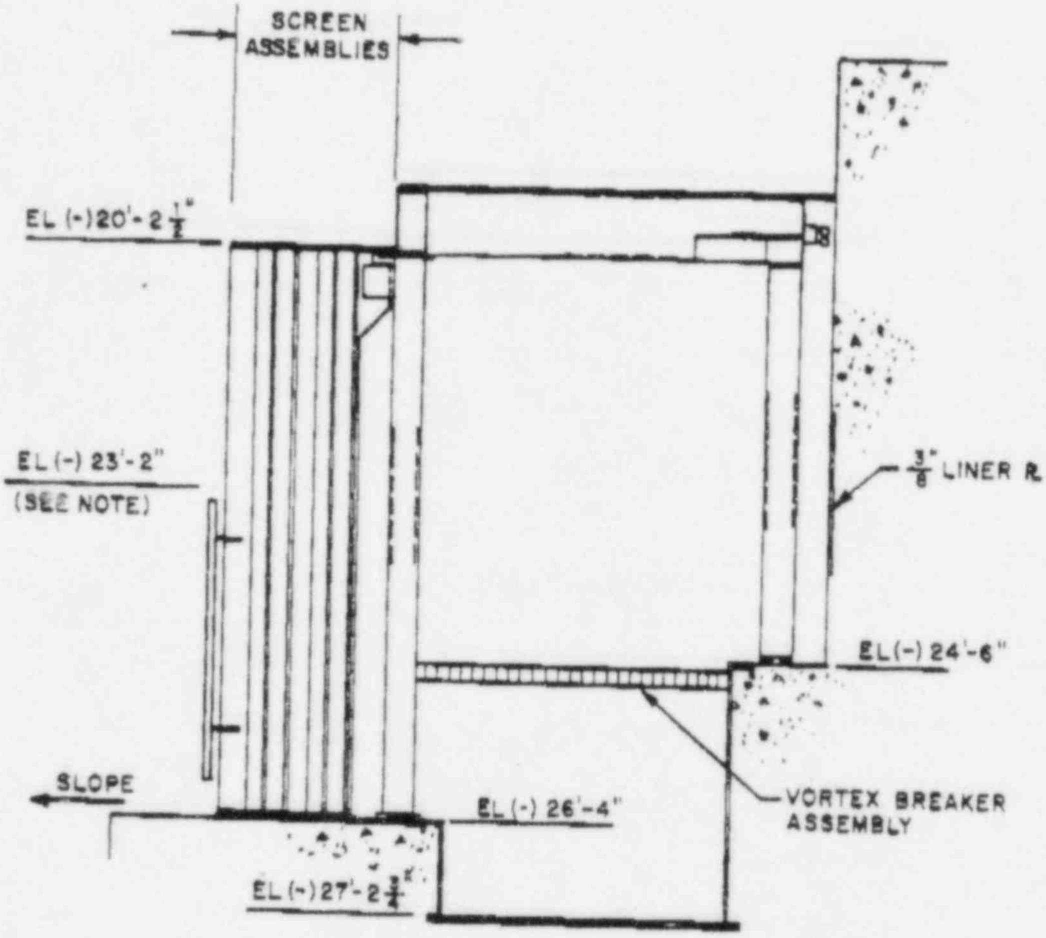



FIGURE 5
TOTAL JET IMPINGEMENT MODEL
MILLSTONE NUCLEAR POWER STATION
UNIT 3




NOTE:

ELEVATION (-) 23'-2" IS THE THEORETICAL HEIGHT AT WHICH ALL SIGNIFICANT DEBRIS TRANSPORT ENDS.

FIGURE 4
CROSS-SECTION OF CONTAINMENT RECIRCULATION SUMP
MILLSTONE NUCLEAR POWER STATION
UNIT 3