TORUS INSPECTION AND ANALYSIS OF THE

EFFECT ON THE RELIEF VALVE BLOWDOWN FORCES ON THE TORUS BAFFLES

NINE MILE POINT NUCLEAR STATION

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TORUS INSPECTION AND CHANGES

On April 24, 1972, all water was removed from the torus to facilitate a thorough inspection of the interior of the suppression chamber. It was found that 18 baffle components were moved from their original installation position. In every case, the 3/8" bolts which secured the baffles at the drywell wall were broken. In addition, two baffles were loose but remained in place. In every case, except for one baffle component, all disturbed baffles were next to an electromatic relief valve outlet. The sixth baffle component down from the top in the first baffle counterclockwise from sphere number 2 was moved at the outer end. This component may have been improperly secured at construction. A chart of the inspection results is given in Table I. The smaller baffle elements were conveyed horizontally clockwise away from the relief valve pipe outlet and were found on the bottom of the torus adjacent to the ring girder. The larger and heavier baffle elements were found just below the baffle askew of the torus axis.

All baffle components centered on the downcomer spheres through which the electromatic relief piping is installed were removed from the torus. Figure 1 shows the location of all 30 baffles and the electromatic relief pipes. In the original installation of the baffles in the torus, there is no assurance that the bolting was either over torqued or secured too loosely. This could have contributed to bolt failure. The design was based upon installing the baffles with 3/8" bolts without any pre-loading on the bolts. All the original 3/8" bolts will be removed from the torus baffles. These will be replaced by new A307 3/8" bolts secured by lock nuts and washers. Care will be taken that the lock nuts are drawn snug without applying tension to the bolts. This will assure that the bolts will not be loosened due to vibration and that the load on the bolts will be only that transmitted from the baffles.

The interior surfaces of the torus are unpainted. These were examined particularly at the water line elevation and were found to be in good condition.

The inside of the downcomers from the drywell to the torus were visually inspected. A bent brace was found on the exhaust pipe from #113 electromatic relief valve at the elbow in the distribution sphere number 5. The brace is a 2 1/2" X 2 1/2" X 3/8" angle which is intended to convey axial thrust from the electromatic relief valve discharge pipe to the wall of the distribution ball. The brace will be replaced and supplemented as indicated in the analysis section of this report.

BAFFLE FAILURE ANALYSIS

The displacement of the torus baffles was apparently caused by operation of the electromatic relief valves. When a relief valve is opened, steam quickly pressurizes the fluid in the discharge pipe. This creates a pressure disturbance which propagates through the water in the submerged end of the relief piping and then expands outward into the suppression pool. Following this pressure disturbance and resulting from it, there is a net movement of the water in the pool outward from the pipe exit. As the steam pressurizes the fluid in the discharge pipe, it forcefully expels the water initially in the pipe. When this water exits the pipe at a considerable

velocity, it generates turbulant expansion motion in the surrounding water. Immediately following this slug of water is a slug of compressed gas. This is nitrogen which was initially in the relief valve piping compressed by the steam flow. As this mass of compressed gas is suddenly injected into the suppression pool, it expands rapidly, displacing the water in the suppression pool to the sides and upwards. It is this last action which alone is capable of displacing the baffles located adjacent to the discharge of the electromatic vent piping. The preceding mechanisms are expected to generate much lower forces. After the short term actions attenuate, a steady steam flow will exist resulting in forces within the design limits of the baffles.

A conservative analytical model was used to scope the severity of the baffle loading resulting from the expansion of the compressed air bubble. The analytical model assumes that water velocity at any point measured radially from the relief valve pipe exit is the velocity of the expanding surface of a spherical bubble. The bubble is conservatively assumed to be expanding at a volumetric rate equal to the maximum rate at which the compressed air is discharged from the pipe exit. Some of the major assumptions used in this model are:

1. The compressed gas is discharged at the speed of sound in order to maximize the flow rate into the pool. The speed of sound is dependent on temperature only and the maximum possible value of nitrogen temperature (520°F) was used to maximize the discharge velocity (1,540 feet per second).

2. The compressed gas expands instantaneously to the torus pressure of about 15 psia as it exits the relief valve pipe. This maximizes the gas volume and rate at which the water is being displaced.

3. The water has no inertia and moves directly with the expansion of the slug of gas.

Based on this analytical model, a fluid velocity of 225 feet per second was calculated for the baffle location which is approximately 21 inches from the pipe exit. Water with this velocity flowing between the baffles would generate about a 950 psi pressure differential on the baffles. It has been calculated that a fluid velocity of about 11 feet per second would generate a pressure difference of approximately 2.2 psi which would be sufficient to dislodge baffles. Thus the model correctly predicts that the nearest set of baffles would be displaced by this phenomena. The next nearest baffle to the electromatic relief valve discharge is at a distance of 12.5 feet. At this distance, a fluid velocity of 4 feet per second was calculated. The pressure difference resulting from this velocity (approximately .5 psi) is within the design limits of the baffles and thus the model predicts that baffles at or beyond this distance would not be displaced by this phenomena.

The observed results of electromatic relief valve blowdown into the torus serve as good verification of the theoretical model. In five out of

the six baffles located adjacent to the relief valve pipe outlets from two to five baffle components were displaced. With the one exception noted in the inspection section, all the other baffles remained in place. Judging by the oxide deposits on the displaced baffles, broken bolts and torus surfaces, it appears that the baffles may have been displaced during an early relief valve blow. Any subsequent pressure mechanisms originating from blowdown proceeded largely unimpeded but with diminishing force toward the further baffles. (12'-6" from electromatic relief discharge pipe)

JUSTIFICATION FOR REMOVING BAFFLES

The following discussion will show that baffles can be removed without adversely affecting the pressure suppression performance. This will be shown for the extreme case of removing all baffles or the more practical case of removing only part of the baffles. Suppression chamber baffles were originally included in the design to prevent a short term overpressure (pressure exceeding the end point pressure) of some 6 psig as observed in a series of 1/4 scale tests performed at Moss Landing. The basis for their removal is threefold:

1. The suppression chamber design pressure is 35 psig. Even if the observed overpressure were to occur, the design pressure of the suppression chamber would not be exceeded.

2. Convincing evidence exists that the overpressure would not occur in a full scale geometry.

3. The installation of baffles is not required to prevent aximuthal sloshing, uniform distribution, or other fluid perturbations.

The design pressure for the drywell and suppression chamber was established on the basis of the Bodega Bay pressure suppression tests.[1] The direct applications of these tests in the design of pressure suppression containment resulted in a suppression chamber design pressure of 35 psig. Item 1, above, is the keypoint in justifying the deletion of the baffles, i.e., the design pressure of 35 psig is higher than the maximum pressure as interpreted from full scale test data.

The support of Item 2 above is based on a detailed study of the quarter scale test data available. In Figure 2, the measured pressure response of the suppression chamber is illustrated for the 1/4 scale tests with and without baffles and for the full scale tests which were, in essence, fully baffled. Note that with no baffles the quarter scale suppression chamber pressure at about 0.7 seconds is greater than the end of transient pressure. This early overpressure was the original basis for the baffles. Note, also,

[1] Bodega Bay Preliminary Hazards Summary Report, Appendix 1, Docket #50-205, December 28, 1962.

that at approximately the same time as the overpressure in the 1/4 scale tests, a pressure peak occurred in the full scale tests. However, in the full scale test the pressure peak did not exceed the end of transient pressure. This difference in mean pressure at the time of the peak was caused by a difference in the pressure rate in the suppression chamber. In the 1/4 scale tests, the drywell and suppression chamber volumes were reduced by 1/4. The downcommer diameter was also reduced by 1/4, which reduced the flow area per downcommer to approximately 1/16 of full scale. With fourteen downcomers, the total vent flow area was approximately the same for both tests, the total mass flow rate into the suppression chamber was the same. Therefore, the 1/4 smaller suppression chamber air volume was pressurized four times as fast. This results in accentuating the pressure peak for the 1/4 scale tests, since the average pressure at the time it occurred was much higher than for the full scale tests.

It is possible to calculate the suppression chamber mean pressure rise assuming complete condensation in the suppression chamber pool. The overpressure peak can be simulated by superimposing a mass flow into the suppression chamber air volume which is condensed after a short delay. It has been determined that a sinusoidal input can reasonably reproduce the quarter scale test pressure response with and without baffles (See Cooper Station Docket #50-298, Amendment 1, Appendix A). Applying the same input to the full scale tests confirms that the pressure peak would not exceed the end of transient pressure.

The basis for using baffles to control or limit azimuthal sloshing of water in the suppression chamber is based upon two postulated effects, i.e.:

a. Sloshing could result in large waves which might uncover the downcomer ; and

b. Sloshing could result in danger to the vent header due to an uplifting force caused by large waves.

Neither of these postulated effects is of concern. Tests from both the Humboldt and Bodega series of pressure suppression tests proved that condensation would be complete even if the downcomers were uncovered during the blowdown; therefore, postulated uncovering of the downcomers is not cause for concern. With respect to the second postulated effect, the loading imposed by wave action is less than 30% of the loading imposed by jet action on the downcomers during venting. Since the maximum jet action and the wave action will never be time superimposed one upon the other, the design of the vent header to withstand the larger force from the immediate jet action avoids any concern with respect to the later waves action. Further, it is highly improbable that large wave action would be established in the first place. The natural frequency of the suppression chamber pool is quite low (on the order of 0.1 cps for large waves) and there is no apparent exciting force of a sufficiently low frequency to establish a large wave. The venting action would be a uniform, (circumferentially) high frequency loading which, at most, would exit many small waves, but not a large one. The small waves would not have a large enough emplitude to be of any concern and would die out quite rapidly, therefore, large wave action is not likely to be established.

Finally, the vents will blowdown nearly uniformly since the resistance of the vents is much higher than the resistance encountered by the steam-mass flow traversing the drywell to any of the vents. This should preclude any inherent tendency to initiate sloshing in the first place.

The effect of removing the baffles on the previously calculated containment pressure response is marked on the attached Figure 3 which is taken from the Nine Mile Point FSAR. As was demonstrated by the experimental tests previously discussed, the short term pressure during vent clearing is higher for the "no baffle" case than for the "baffle" but only about 5 psi higher and still considerably below the maximum end point pressure of about 25 psig. Furthermore, it is observed the duration of the pressure "blip" is only about 0.5 seconds, which is exaggerated by the log scale. Therefore, it is concluded that the removal of baffles does not reduce existing safety margins because the half second pressure blip is much less than the previously calculated maximum of 25 psig and well below the design pressure of 35 psig. Since the half second pressure blip was considered insignificant due to its lesser magnitude than the 25 psig maximum end point pressure, it was not included in the original FSAR curve.

PARTIAL REMOVAL OF BAFFLES

The preceding discussion has shown that the pressure suppression concept functions properly either with or without baffles as substantiated by experimental data, and that the peak containment pressure is not affected by total baffle removal. Furthermore, experimental data (Bodega Bay Preliminary Hazard Summary Report, December 28, 1962) demonstrates that steam condenses in subcooled water over a wide range of temperatures and that baffles are not required in order for steam to condense in subcooled water.

Removal of one set of baffles nearest the vent discharge has the same effect as moving the baffles further apart. In effect, the local discharge region does not "see" the baffles which are further away and the local response will be essentially the same as the "no baffle" case. Therefore, the referenced experimental data is applicable.

Since pressure suppression tests demonstrate that steam condenses in subcooled water, and that baffles are not required in order for steam to condense, it is concluded that partial removal of baffles will not affect the pressure suppression concept.

RELIEF VALVE DISCHARGE PIPING

The relief valve discharge flow is piped to the suppression pool where the steam is condensed. The "as built" discharge piping enters the water

normal to the pool surface and terminates at a point approximately 4 feet beneath the torus water surface. This discharge point is approximately centered in the torus.

Recent inspection of the suppression chamber revealed that the torus surface directly below the point of discharge shows no indication of erosion due to vent discharge impingement. There are no other structural components within the vicinities of vent relief discharge points, so further analysis of forces on structural components in this area is not required. Except as noted in the vent section, there is no other evidence of deficienies in current design.

BLOWDOWN VENT PIPE ANCHORAGE

The electromatic relief valve vent piping from the electromatic relief valves at its connection to the sphere as it exits into the torus has been re-analyzed using an actual steam flow of 640,000 lbs. per hour. The force at the elbow (see sketch) is 11,500 lbs. The existing strut at this elbow has been re-analyzed and found to be insufficient to sustain this force. Another angle of the same size will be added in parallel with the existing angle to all relief valve downcomers to withstand this force. The area where this strut bears on the vent piping sphere has been re-analyzed and found to be within code allowable for the 11,500 lb. force. As already noted, the alignment of one of these struts with the centerline of the 14" pipe, as installed, has shown a misalignment. This misalignment will cause a horizontal force at the elbow, thus imposing an additional load at the penetration of the vent pipe into the torus. Since it is difficult to assure perfect alignment of this strut, a horizontal strut will be added to all vent pipes to prevent this additional stress. The attached sketches show the misalignment of the original strut and the additional horizontal strut at the fourteen inch vent pipe.

TABLE I

TORUS INSPECTION

TORUS AZIMUTH	BAFFLE NUMBER	RELIEF VALVE NUMBER	SPHERE NUMBER	COMPONENTS MOVED	COMPONENTS LOOSE	BENT BRACE LOCATION
0° (	18B					
(	18A					
18°	17		9			
36° (	16B					
(	16A					
54°	15	121	8	3		
72° (	14B					
(	14A					
90°	13	122	7	3	2	
108° (	12B					
(	12A					
126°	11		6			
144° (	10B					
(	10A					
162°	9	123	5			
180° (	8B					
(	8A					
198°	7	11[illegible]	4	2	2	X
216° (	6B					
(	6A					
234°	5	~~113~~	3			X
252° (	4B					
(	4A					
270°	3	111	2	5		
288° (	2B					
(	2A					
306°	1	112	1	4		
324° (	20B					
(	20A					
342°	19		10			

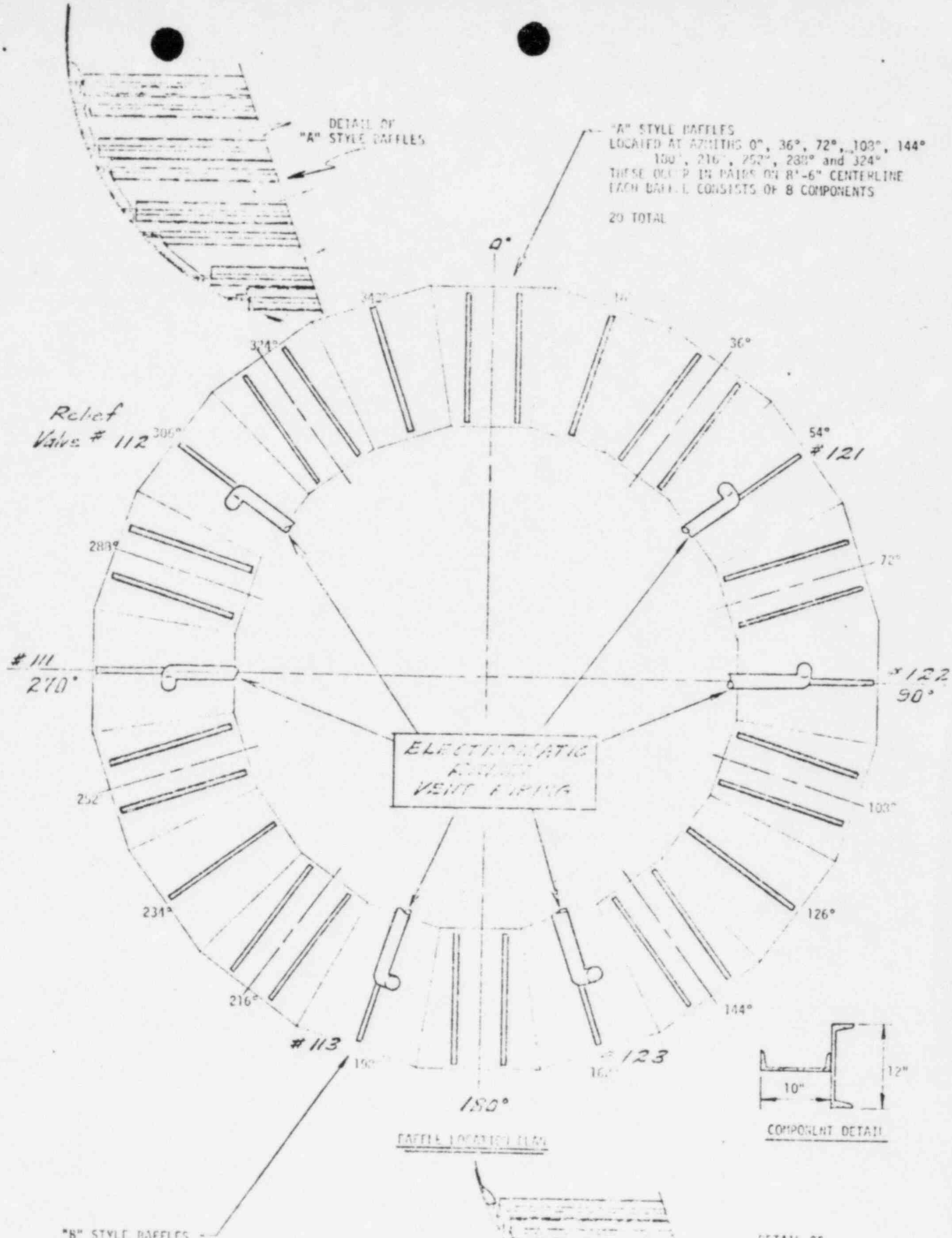
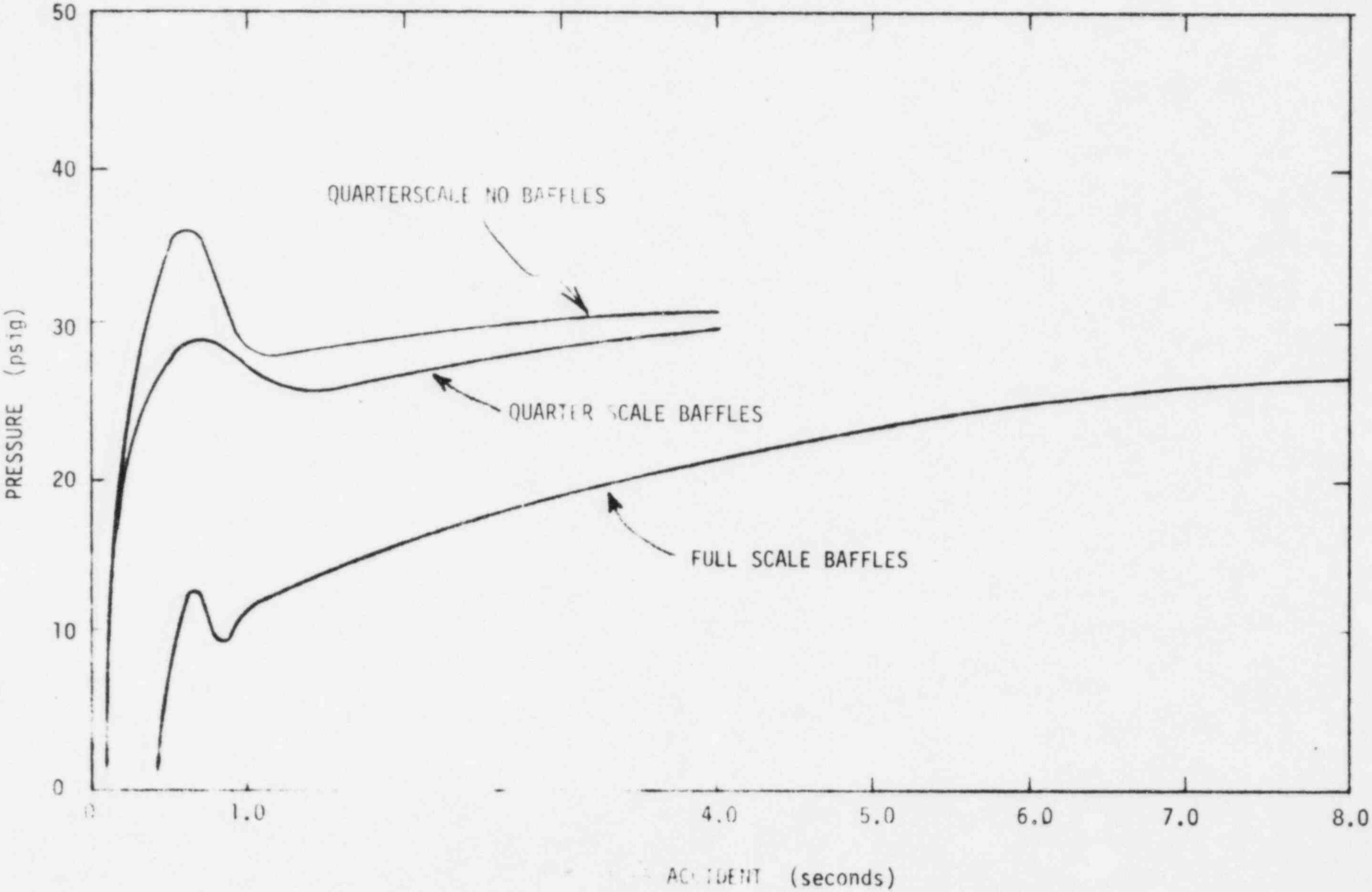

DETAIL OF
"A" STYLE BAFFLES
"A" STYLE BAFFLES
LOCATED AT AZIMITHS 0°, 36°, 72°, 108°, 144°
180°, 216°, 252°, 288° and 324°
THESE OCCUR IN PAIRS ON 8'-6" CENTERLINE
EACH BAFFLE CONSISTS OF 8 COMPONENTS
20 TOTAL
0°
342°
36°
324°
Relief
Valve # 112
306°
54°
121
288°
72°
111
270°
122
90°
ELECTROMATIC
RELIEF
VENT PIPING
252
108°
231°
126°
216°
144°
113
123
198°
162°
180°
12"
10"
BAFFLE LOCATION PLAN
COMPONENT DETAIL
DETAIL OF
"B" STYLE BAFFLES
"B" STYLE BAFFLES
LOCATED AT AZIMITHS 18°, 54°, 90°, 126°, 162°
198°, 234°, 270°, 306° and 342°
EACH BAFFLE CONSISTS OF 6 COMPONENTS
10 TOTAL
NOTE: THE SIX "B" STYLE BAFFLES AT THE ELECTROMATIC
RELIEF VENT PIPE LOCATIONS HAVE BEEN REMOVED.

FIGURE 1



... PRESSURE RESPONSE FROM
... AND QUARTER SCALE TESTS

LOSS OF COOLANT ACCIDENT
SUPPRESSION CHAMBER PRESSURE
STRETCH POWER

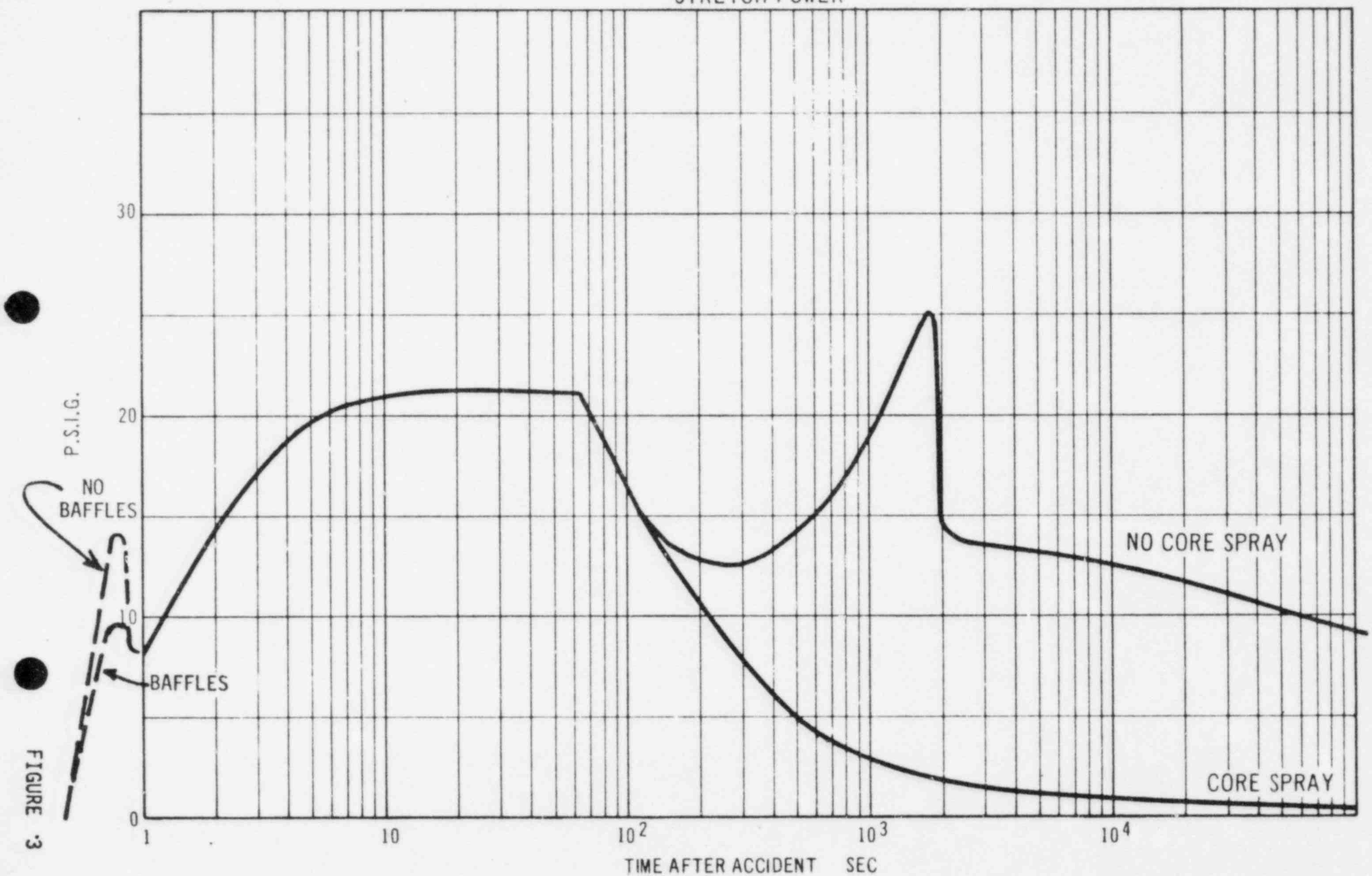


FIGURE 3

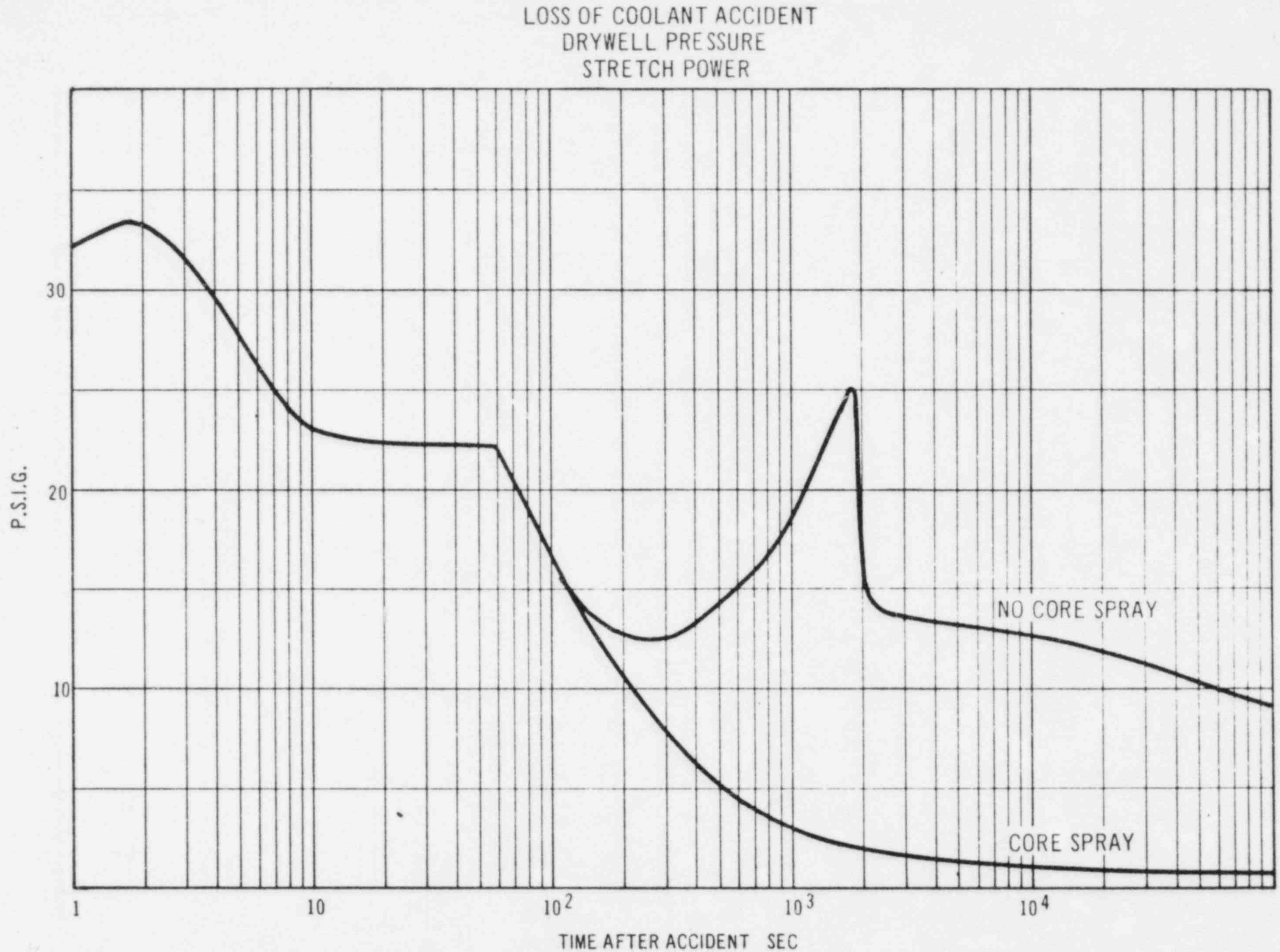
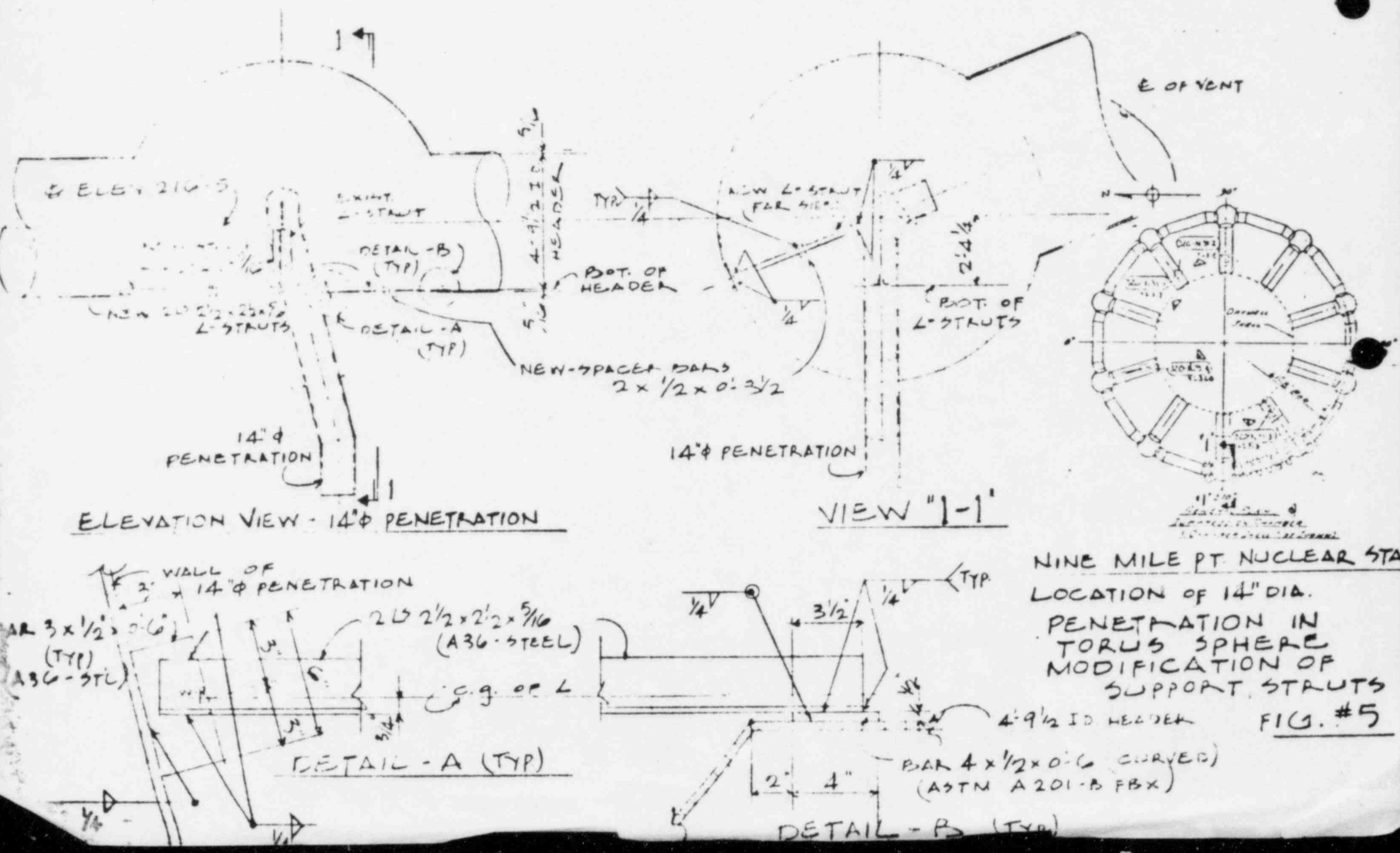

LOSS OF COOLANT ACCIDENT
DRYWELL PRESSURE
STRETCH POWER
P.S.I.G.
30
20
10
1
10
10^2
10^3
10^4
TIME AFTER ACCIDENT SEC
NO CORE SPRAY
CORE SPRAY

FIGURE 4



NINE MILE PT NUCLEAR STA

LOCATION OF 14" DIA. PENETRATION IN TORUS SPHERE MODIFICATION OF SUPPORT STRUTS

FIG. #5