GPU Nuclear

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5211-82-145

Office of Nuclear Reactor Regulation
Attn: John F. Stolz
Operating Reactors Branch No. 4
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D.C.   20555

Dear Sir:

Three Mile Island Nuclear Station, Unit 1 (TMI-1)
Operating License No. DPR-50
Docket No. 50-289
Containment Flood Level Calculations

Enclosed please find our analysis of the containment flood level which is
being submitted for NRC review in accordance with Partial Initial Decision
(PID) of December 14, 1981 p. 302 and which is supportive of our responses
to IE Bulletin 79-01B. The analysis also addresses why the calculated
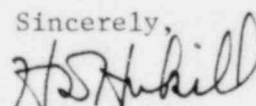flood level is lower than that experienced during the TMI-2 accident.

In the ASLB hearings there was some ambiguity as to the refinement of the
maximum flood level from 5.94 ft. to 5.66 ft. This adjustment was warranted
because the original calculation had assumed design tank volumes rather
than available volumes (down to the nozzles). Additionally, an adjustment
was made for the dome at the bottom of the steam generators which, for
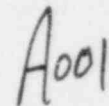convenience, was originally assumed to be a right cylinder (See Figure 4).

After the above calculations were performed, two additional leakage criteria
were evaluated:

For the normal leakage from other systems in the reactor building analysis,
300 valves of an average size of 3 inches were assumed to be leaking with
an average leakage of 10 cc/hr/in. of diameter. This results in 2.3 gph
or 1656 gal. in 30 days or .02 ft. increase in water level over a 30 day
time period. (Maximum Flood Level after 30 days – 5.68 ft.)

In conclusion, the maximum flood level following a LOCA is conservatively
calculated to be 5.66 ft. Finally, assuming normal leakage from other
systems, the maximum flood level after 30 days would be 5.68 ft. All
required instruments located in the Reactor Building are above these
calculated levels.

Sincerely,

H. D. Hukill   A001

H. D. Hukill
Director, TMI-1

cc: R. C. Haynes
     R. Jacobs   GPU Nuclear is a part of the General Public Utilities System

I.   INTRODUCTION

As an integral part of the Environmental Qualification of Electrical
Equipment Program it became necessary to review the topic of submergence
as a potential harsh condition to which instruments inside the
containment building were exposed. As a result of this concern the
maximum flood level was calculated for design basis accidents (Large
Break LOCA and Steamline/Feedline Break). This report documents the
method and the calculations employed and compares the conditions that
resulted at TMI-2 during and following the accident at TMI-2 with the
postulated conditions at TMI-1.

II.   METHODS

In order to determine the maximum Reactor Building (RB) flood level, the
amount of water which could be added to the building must be calculated.
The large break LOCA sequence involves rupture of the Reactor Coolant
System (RCS) followed by automatic actuation of the safety systems. The
High Pressure Injection (HPI) system will inject water from the Borated
Water Storage Tank (BWST) upon system actuation. As the RCS pressure
continues to fall, the passive Core Flood Tanks (CFTs) will inject their
contents and the Low Pressure Injection (LPI) system will begin to
inject. Coincident with this event, a high RB pressure will actuate the
RB spray, which will also inject water from the BWST as well as the
contents of the spray additive (NaOH) tank.

Feedwaterline (FL) or Steamline (SL) breaks inside the Reactor Building
differ from a LOCA in that no rupture of the RCS occurs. Thus, a water
volume is retained within the RCS, the CFTs are not actuated and the LPI
does not inject. Additional water sources, however, must be considered.
The break initiates RB spray due to high RB pressure. In addition, the
inventory of the steam generators and feed water addition before feed
isolation (before feed pump trip and pump coast-down), as well as FL
water inventory between the isolation valve and the break (which enters
the reactor building due to fluid flashing in the feed water piping),
must be considered. The RCS does not rupture and therefore, its volume
is not included.

For both the LOCA and Feedwaterline/Steamline break it is conservatively
assumed that the Borated Water Storage Tank (BWST) and sodium hydroxide
(NaOH) tank are emptied due to HPI and RB Spray actuation. The volumes
used were available maximums to provide conservatism. The Emergency
Feedwater System (EFW) will continue to add water through the break until
it is also isolated by manual operator action. The rate at which this
addition can occur is dependent upon the number of EFW pumps which are
operating and the hydraulics of the EFW. Cavitating venturis have been
installed and will limit the EFW flow to the affected steam generator to
approximately 600 GPM. Based on this flow rate about 90 minutes of
injection would be required before the RB water level from a FL/SL break
would be expected to exceed that calculated for a LOCA. Since operator
action will occur in much less than 90 minutes, it is clear that LOCA is
the limiting case for RB flooding. Therefore, the post-LOCA conditions
are the limiting case and these are used in this analysis.

The floodable volume/per foot of elevation of the Reactor Building was calculated by determining the unobstructed volume of the building and then subtracting from it the non-floodable volumes of major equipment and structures.

III.   ASSUMPTIONS

The assumptions and conservatism used in calculating volumes of the major equipment and structures were:

1. The reactor vessel cavity is not floodable. (See Figure 1.)

$$Dcav = 2 \times Rcav = 2 \times 16'6" = 33'$$

$$Vcav = \pi Dcav^2/4 = 855 \ ft^3/ft$$

Rcav = radius of reactor vessel cavity
Dcav = diameter of reactor vessel cavity
Vcav = volume of reactor vessel cavity

2. The enclosed elevator shaft in the lower elevation of the Reactor Building is not floodable. (See Figure 1.)

$$Les = 11ft \quad Wes = 9ft$$

$$Ves = LW = 99 \ ft^3/ft$$

Les = length of elevator shaft
Wes = width of elevator shaft

3. Major concrete volumes and major equipment volumes were conservatively estimated and deducted from the RB volume in calculating the free volume. (See Figure 1.)

a. "D" Ring
$R_D = 23'9", \ T_D = 4', \ L_D = (24'9" + 20'3") \times 2 = 90ft$
$Vdr = 2 \ RT + LT = 1007 ft^3/ft$

R_D = radius of D Ring
T_D = thickness of D Ring
L_D = length of D Ring

b. RCDT Compartment
$L = \ell_1 + \ell_2 + \ell_3 + \ell_4 + \ell_5 + \ell_6$
$L = 9'6" + 7' + 30' + 3' + 9'6" + 11' = 70', \ T = 1'6"$
$Vrcdt = LT = 105 \ ft^3/ft$

L = length of wall
T = wall thickness

c. RB Tapered Zone
$Vt = 296 \ ft^3/ft$ (see Figure 5)

d. Let down Cubicle Wall

$$Vld = W_1T_1 + W_2t_2 + W_3t_3 + W_4t_4 + W_5t_5$$
$$Vld = 12' \times 2' + 13' \times 3' + 10' \times 2' + 8' \times 4' + 6' \times 2'$$
$$Vld = 127 \ ft^3/ft.$$

       W = length of wall
       t = thickness of wall

e. The RB sump is initially full as is the trench.

$$Vs = 1170 \ ft$$
$$Vtr = L \times W \times D$$
$$Vtr = 30' \times 10' \times 1.5' = 450 ft^3$$

f. Steam Generator Lower Heads

$$Vsgh \ 13 \ ft^3/ft \quad (See \ Figure \ 4)$$

4. Make up tank volume was not assumed to be injected into the RB since the makeup tank is isolated during HPI.

$$Vmut = 507 \ ft^3$$

5. Entire RCS volume was assumed to be spilled into RB. (Note that in case of a LOCA water will still be contained in the reactor vessel at all times up to the nozzles. This volume was assumed to be spilled in this analysis. With the liquid level at the top of the core approximately 2020 ft remains in the vessel and 2980 ft remains in the loops.)

Vrv = reactor vessel volume
Vsg = steam generator volume
$Vpzr$ = volume of pressurizer
$Vpsp$ = volume of pressurizer spray piping
$Vpsg$ = volume of pressurizer surge piping
Vhl = volume of hot leg piping
Vcl - volume of cold leg piping
Vrp = volume of reactor coolant pumps

$$Vrcs = Vrv + 2Vsg + Vpzr + Vpsp + Vpsg + Vhl + Vcr + 4Vrcp$$
$$Vrcs = 4058 \ ft^3 + 2(2030 \ ft^3) + 800 \ ft^3 + 2ft^3 + 20ft^3 + 979 \ ft3 + 1102ft3 + 4(56ft^3)$$
$$Vrcs = 11,245 \ ft^3$$

6. No credit is taken for the water mass which may be held up as steam in the containment atmosphere or due to localized pocketing on elevated containment floors.

7. Air inleakage from outside the Reactor Building is negligible (2 gallons in 30 days). - See Table 3.

8. No leakage from containment to the outside is assumed.

9. No credit is taken for absorption by materials such as concrete or puddling in the building or the buildup of film from spray. (See Figures 2 and 3).

IV.   CALCULATIONS OF FLOOD LEVEL

A. Reactor Building Floodable Volume per foot of Height

$$Vrb = \frac{\pi \, Drb^2}{4} = 13,273 \text{ ft}^3/\text{ft}$$

   Drb = diameter of Reactor Building = 130 ft
   Vrb = volume of Reactor Building

Vfv = Vrb - (Vcav + Ves + Vdr + Vrcdr + Vld + Vt + Vsgh)

Vfv = 10,771 ft^3/ft

   Vfv = floodable volume

B. Water Volume (LOCA & SL/FL)

   Vloca = 60,962 ft^3 = 455,966 gal (Table 1)

   V sl/fl = 51,822 ft^3= 387,629 gal (Table 2)

C. Flood Level (LOCA & SL/FL)

   $Lloca = \dfrac{60,962 \text{ft}}{10,771 \text{ ft}^3/\text{ft}} = 5.66$ ft

   (286'8" elevation)

   $Lsl/fl = \dfrac{51,822 \text{ ft}^3}{10,771 \text{ ft}^3/\text{ft}} = 4.81$ ft   (285' 9-3/4" elevation)

V.   COMPARISON WITH TMI-2 ACCIDENT CONDITIONS

In order to further evaluate the accuracy of the calculated post-accident flood level, the TMI-2 experience was evaluated as follows:

The maximum TMI-2 Reactor Building water inventory occurred well into the accident and was approximately 625,000 gal. Several water sources contributed to this volume which are not appropriate for consideration in the TMI-1 analysis.

First, 180,000 gal. were contributed from the Reactor Building Emergency Cooling System through a stuck open relief valve. The 180,000 gal. volume was verified by two independent methods: First, the volume of water added to the RCS from the BWST and other make-up sources (boric acid mix tank, demineralized water, and RC bleed tanks) was subtracted from the total RB water volume. Second, the quantity of unborated water required to produce the observed sump chemistry conditions accounting for known boron additions was calculated. The relief valve was set at 125 psig although the combined discharge pressure of the river water pumps (which had new impellers) exceeded this value. This same situation does

not exist on TMI-1. TMI-1 has separate cooling coils for normal and emergency cooling and each coil relief valve is set at 200 psig. A similar influx of water in TMI-1 will not occur since the shut-off head of the emergency cooling water pumps is less than 200 psig. Thus, this source of water is not appropriate for inclusion within this analysis.

Second, a management decision was made at TMI-2 not to recirculate RB sump water. As a result, additional outside water sources (boric acid mix tank, demineralized water, and reactor coolant bleed tanks) were injected into the RCS to keep up with the leakage. This decision, and the water additions, were made because of the specifics of the TMI-2 event. They represent, however, a deviation from the planned post-event sequence and, therefore, are not appropriate for inclusion in the TMI-1 analysis. Furthermore, the lessons learned from TMI-2 (i.e., containment isolation, high point vents, post-accident shielding, and leakage reduction) have been incorporated in TMI-1 per NUREG 0737. Thus, a decision to not recirculate sump water is not expected.

VI.   VITAL INSTRUMENTATION LOCATION

Steam generator and pressurizer water level measurements are key parameters used to monitor plant operation and accomplish safe shutdown. Information provided by such measurements is important for maintenance of natural circulation cooling in the reactor coolant system. The level transmitters for the steam generator and pressurizer level instruments are located in the lowest elevation of the Reactor Building at a height above the floor that may make them vulnerable to flooding following certain postulated accidents. These transmitters were subsequently raised above their initial location to position them above the water level resulting from the worst case design basis accident. The lowest instrument elevation is 5.81 ft. above the RB floor as measured from the bottom of the transmitter housing. The electronics are actually located 0.19 ft. above this point.

VII.   CONCLUSIONS

Based on the above conservative evaluation and the assumptions stated in Section II, it is concluded that the maximum flood level for the Reactor Building is 5.66 ft above the floor in the immediate time frame following a LOCA.

The pressurizer and steam generator level instruments as installed are above the maximum water level that would occur.

The event at TMI-2 is not directly comparable with the analysis for TMI-1. It can be used for comparison only if appropriate corrections are applied. After subtracting those additions which are not applicable, and considering the specifics of the TMI-2 accident, it is concluded that the calculated flood level for TMI-1 is conservative.

TABLE 1

Sources of Water
For a Loss of Coolant
Accident (LOCA)

Water Sources	Available Volumes - (ft.)
BWST 360,000 gal.	46,292
CFT (2)	2,080
NaOH Tank 12,750 gal.	1,345
RCS Volume	11,245
TOTAL	60,962 ft. = 455,966 gal.

TABLE 2

Sources of Water
Feedwater Line/Steam Line Break (FL/SL)
Inside Containment

Water Sources	Available Volumes - ft.
BWST	46,292
NaOH Tank	1,345
Steam Generator	3,412
Feedwater flow (TOTAL)	205
Feedwater volume (TOTAL)	568
TOTAL	51,822 ft. = 387,629 gal.

TABLE 3

Calculation of Water Addition to RB Sump
Due to Air Increase

a) Calculate the total weight of air inside the R.B.:

$$W = 5.3983 \times 10^6\left(\frac{P}{T}\right)$$

where W = Weight of air in RB, lb

   P = Partial pressure of air within the containment (psia)
    = $P_{Total} - P_{Water\ Vapor} \approx P_{Total}$

   T = Air Temperature

at 80°F and - 2 psig (12.7 psia)

   $W = 1.2696 \times 10^5$ lb.

b) Calculate wieght of air leakage for 30 days. Assuming outleakage is equal to inleakage at equal pressure differential:

at 2 psig max. allow. leakage = 0.02% wt. for 24 hours.

   W air leakage for 30 days =

   = (W) (% allow. leakage/day) (30 days) = 761 lb air.

c) Calculate amount of moisture that will precipitate (assuming 80% RH in the Reactor Bldg.

$$RH = \frac{Pw}{Pw(sat)}$$
     RH = relative humidity
     Pw = vapor partial pressure
     Pwsat = Vapor partial pressure at saturation
     Pt = Total vapor pressure

Amt. of moisture = $\dfrac{.622 \times Pw}{Pt - Pw}$

At 100°F & 100% RH outside air (14.7 psia)

 Pw(sat) = .94924 psia (100% steam)

 Amt. of moisture = $\dfrac{.622 \times .94924}{14.7 - .94924} = .0429$ $\dfrac{lb\ H_2O}{lb\ dry\ air}$

At 80°F & 80% RH

 Pwsat = .50683 psia

 Pw = .8 × .50683 = .405464 psia

Amt. of moisture $= \dfrac{.622 \times .405464}{14.7 - .405464} = .0176 \ \dfrac{\text{lb } H_2O}{\text{lb dry air}}$

Amt. of mositure condensation =

$= (.0429 - .0176) \ \dfrac{\text{lb } H_2O}{\text{lb dry air}} \ X \ 761 \ \dfrac{\text{lb dry air}}{30 \text{ days}} =$

$= 19.25 \text{ lbs } H_2O \ / \ 30 \text{ days}$

$= \dfrac{19.25 \text{ lbs}/30 \text{ days}}{8.33 \text{ lbs}/\text{gal}} \qquad = \underline{2.31 \text{ gal}/30 \text{ days}}$
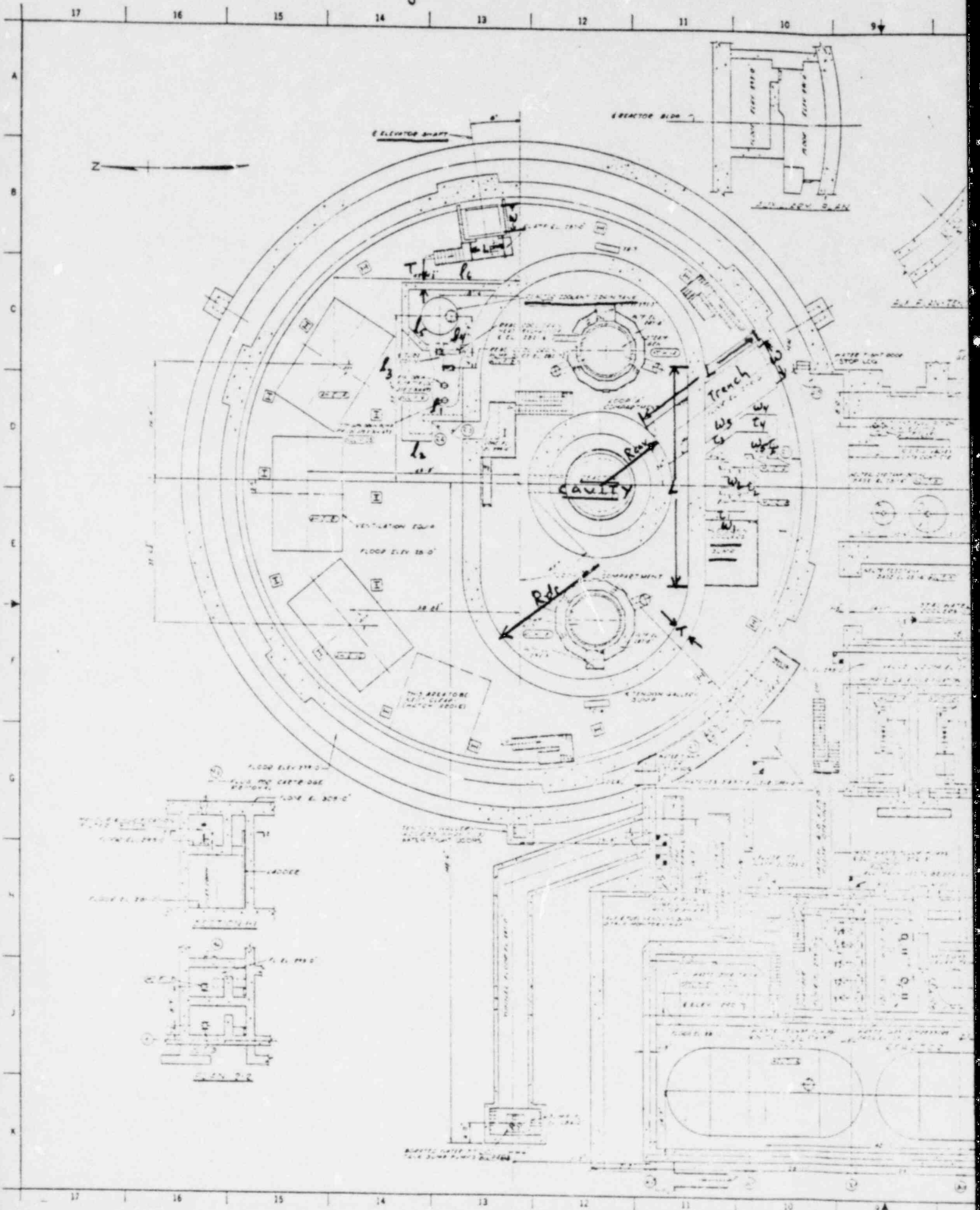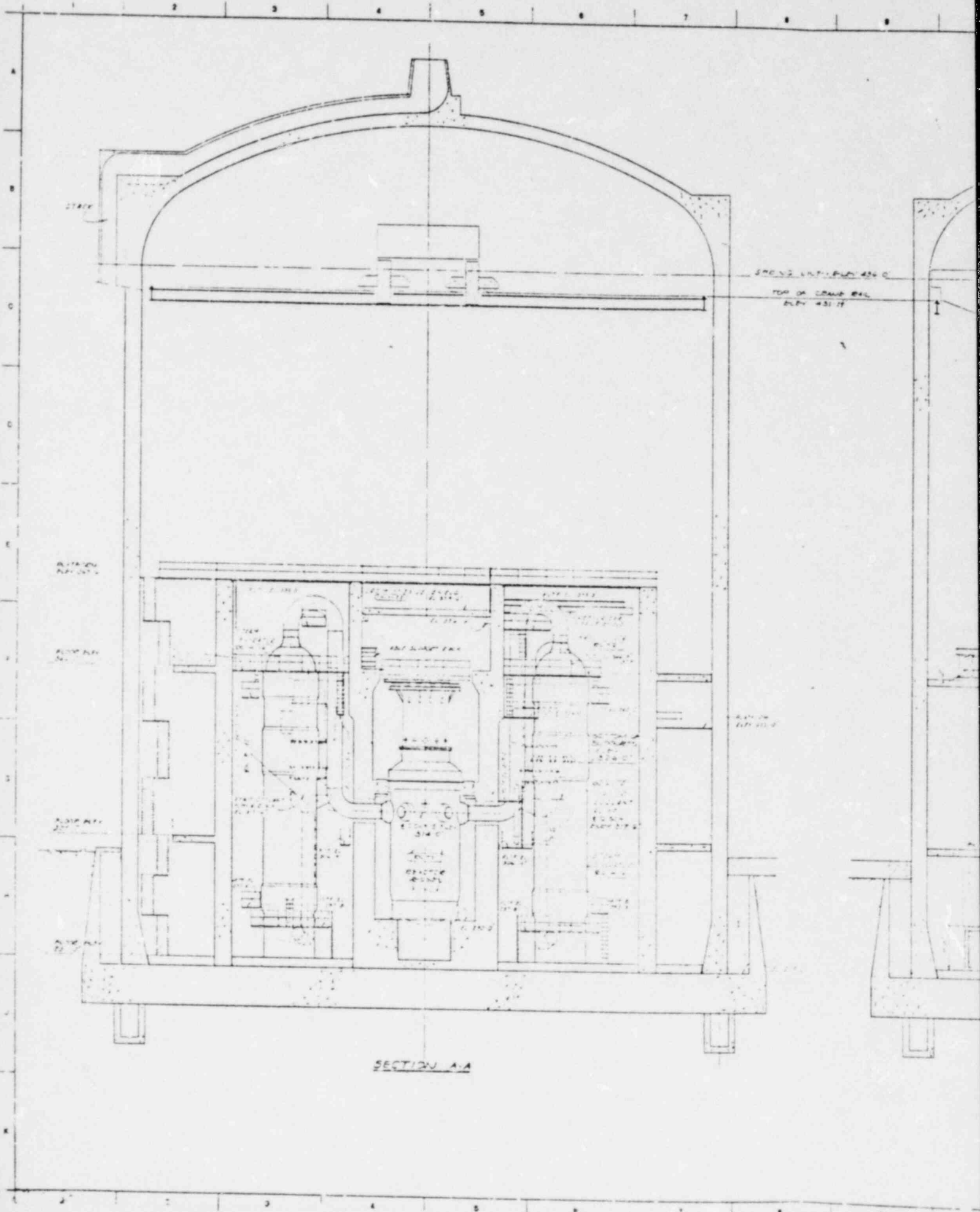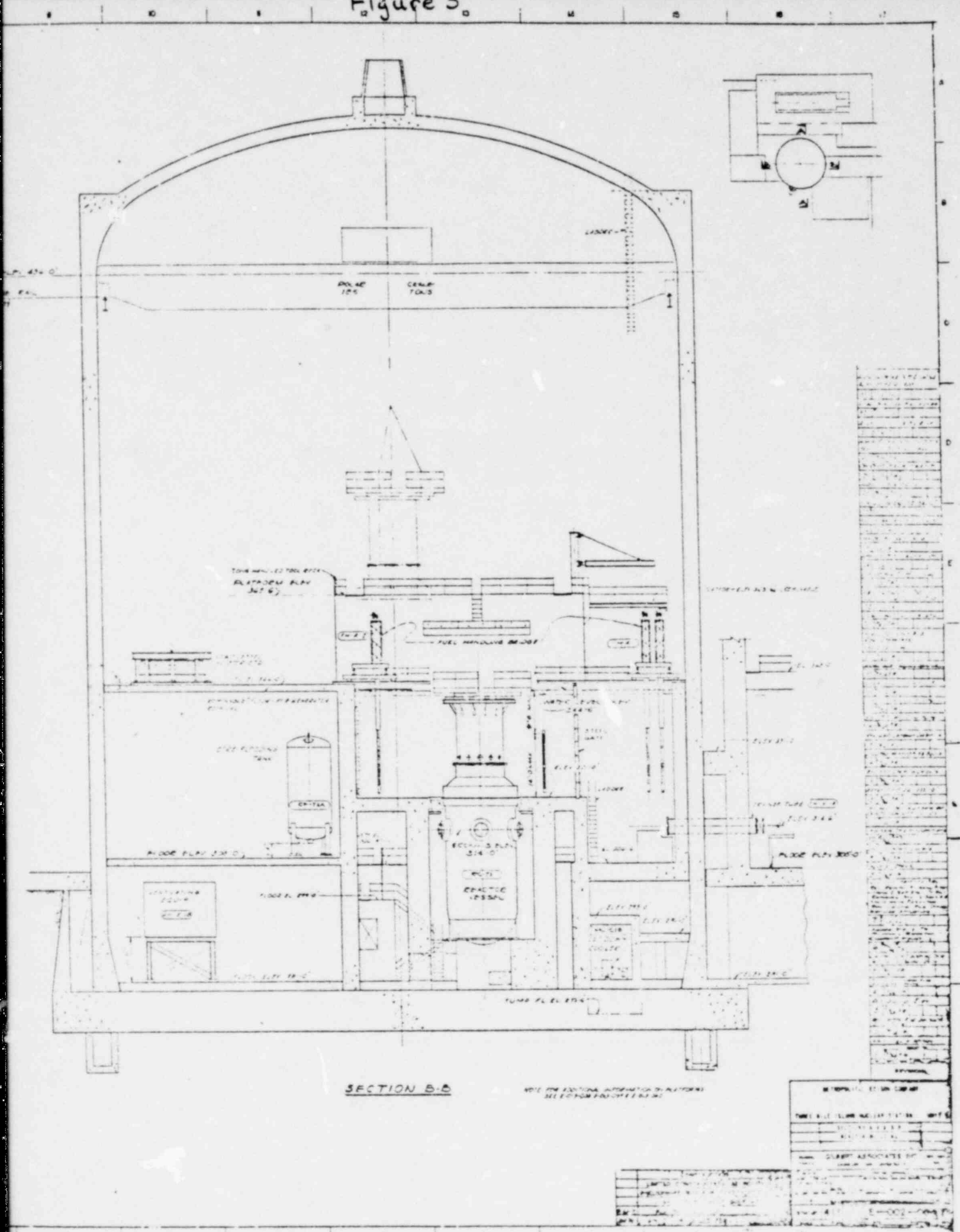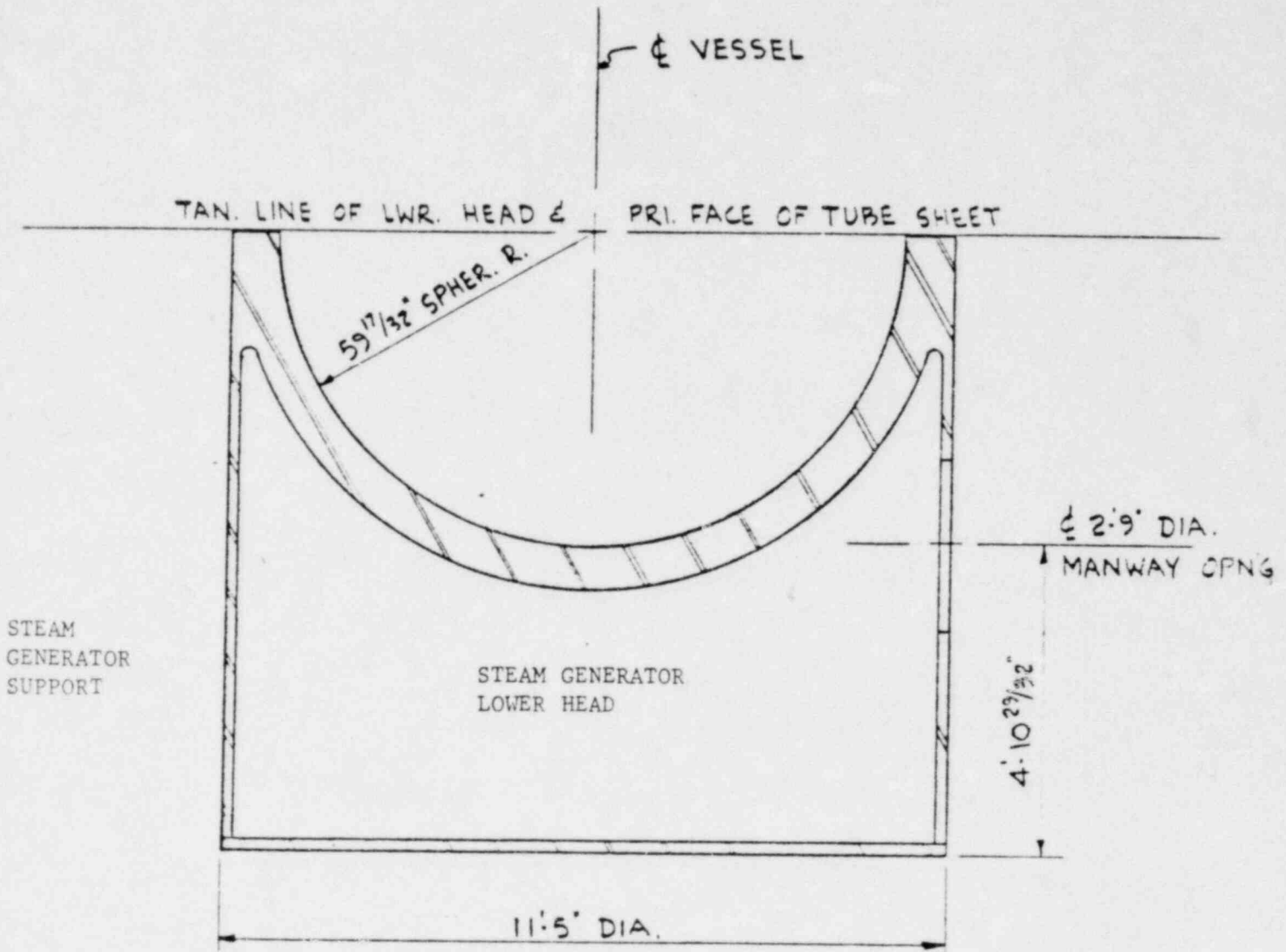
Figure 1

Figure 2

SECTION A-A

Figure 5.

SECTION B-B

FIGURE 4

NON-FLOODABLE VOLUME BENEATH A STEAM GENERATOR

The tangent line elevation is 9'-9" above the floor elevation per Babcock & Wilcox Drawing 131149E.

Thus the low point on the steam generator head will be 49.47 inches (4.12 ft.) above the floor based on a head metal thickness of 8 inches (per Babcock & Wilcox Drawing 131120E).

Thus, the submergence will be 5.66 - 4.12 = 1.54 Ft.

The volume of this sphere segment is:

$$V = \pi H^2 \left(R - \frac{H}{3} \right) \qquad\qquad H = 1.54 \text{ Ft}$$
$$R = 5.63 \text{ Ft } (67\,^{17}/_{32}")$$
$$V = 38.1 \text{ Ft}^3$$

Total volume displaced by two steam generator heads is:

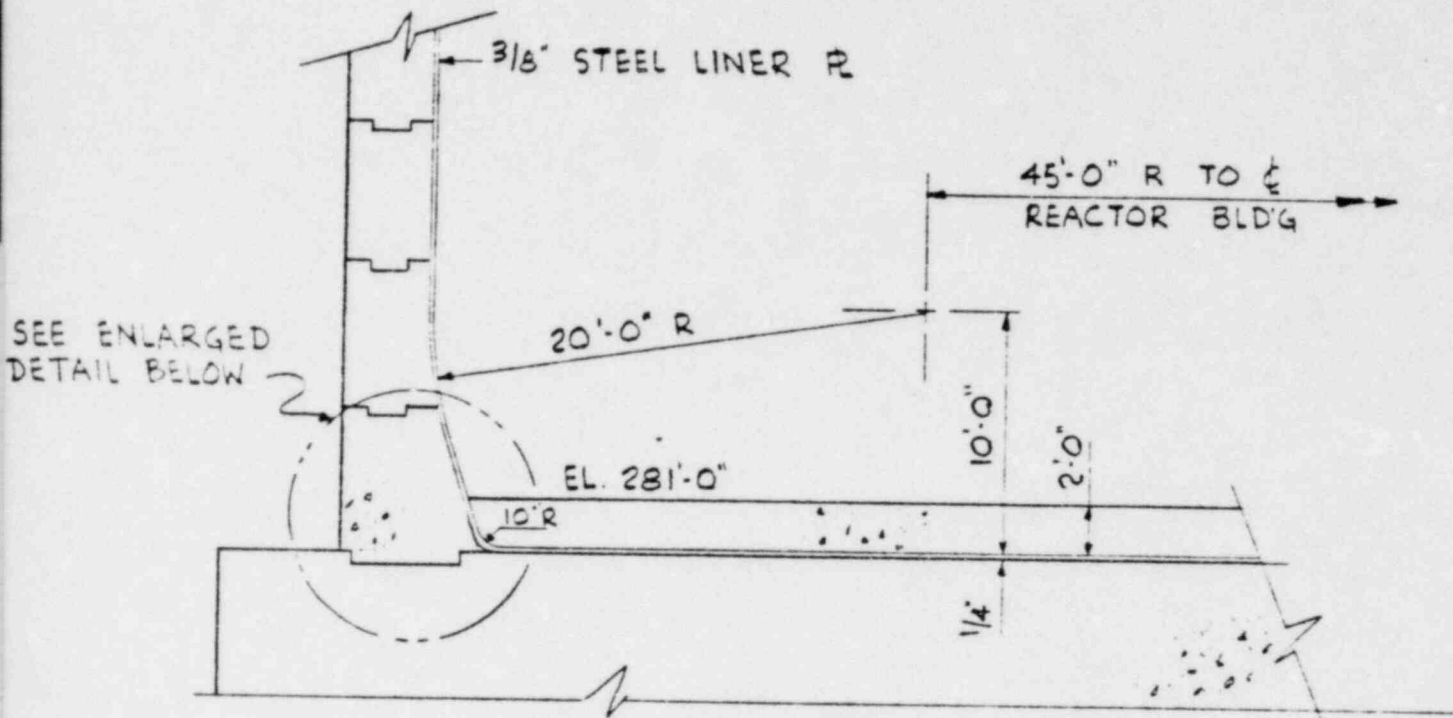$$V = 76.2 \text{ Ft}^3$$
$$V_{sg} = \frac{V}{H} = 13.5 \text{ Ft}^3/\text{ft}$$

FIGURE 5

VOLUME OF REACTOR BUILDING

TAPERED ZONE

(REF. GAI DWG. E-421-030)

Assuming a final water height of H = 5.66 Ft

Approximate the shaded area as a Triangle

$$B = 2 - \frac{2}{TAN\theta} \qquad \theta = 74^{\circ}-46'$$

$$B = 1.46 \text{ Ft}$$

$$A = \frac{BH}{2}$$

$$= 4.13 \text{ Ft}^2$$

Volume is πDA D = Diameter of Center of Gravity of Area

$$D = 130 \text{ Ft} - \frac{1.46}{3} \times 2$$

$$= 129 \text{ Ft}$$

$$V = \pi(129)(4.13) = 1674 \text{ Ft}^3$$

$$V_t = \frac{V}{H} = 296 \text{ Ft}^3/\text{Ft}$$