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SUBJECT: Forwards rev to facility position re siesmic design of category I structures.

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Gentlemen:

In the Matter of the Application of	)	Docket No. 50-438
Tennessee Valley Authority	)	50-439

BELLEFONTE NUCLEAR PLANT (BLN) - TRANSMITTAL OF REVISION TO TVA POSITION REGARDING SEISMIC DESIGN OF CATEGORY I STRUCTURES (TAC #79276)

Reference: TVA letter to NRC dated February 14, 1991, "Transmittal of TVA Position Regarding Seismic Design of Category I Structures (TAC #79276)"

As a result of TVA's continuing engineering effort at BLN and discussion with NRC reviewers, TVA is revising its position with regard to the peak broadening. Information contained in the enclosure to this letter supersedes the information provided by the referenced letter.

The enclosed position states that TVA will use ±15 percent peak broadening in the revision and validation of the seismic building models for Category I structures. To aid the staff in its review of this position, the paragraphs affected by this revision are identified by bars in the right margin of the enclosure.

The information and positions discussed in the enclosed paper are related to two additional position papers submitted to the staff on February 14, 1991 (seismic ground motion) and March 13, 1991 (piping and distributive systems).

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A written staff position on the enclosure is requested by August 23, 1991.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

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ENCLOSURE

BELLEFONTE POSITION PAPER REGARDING SEISMIC DESIGN OF CATEGORY I STRUCTURES

PURPOSE

This document describes TVA's approacb for verifying the seismic design of Seismic Category I structures at the Bellefonte Nuclear Plant (BLN), and for generating new floor response spectra for seismic analysis of piping and equipment located within the structures. TVA requests NRC staff concurrence that the methods and criteria described herein are sufficient to demonstrate that the seismic design of Category I structures and tbe new floor response spectra are adequate for completion and licensing of BLN.

SUMMARY

The existing seismic building models for Seismic Category I structures will be revised and validated. New seismic loads and floor response spectra will be generated based on the revised building models and the new ground motion time histories discussed in Bellefonte Position Paper Regarding Seismic Design Ground Motion (1). The Category I structures will be reevaluated for the new seismic loads. This approach will provide reasonable assurance that the seismic design of Category I structures at BLN and the new floor response spectra are adequate.

BACKGROUND

General seismic design criteria for Seismic Category I structures for BLN are provided in TVA design criteria documents and are described in Section 3.7 of the Bellefonte Final Safety Analysis Report (FSAR). The Category I structures were designed and analyzed using dynamic analysis methods. The design and analysis criteria were generally in accordance with current NRC guidelines as given in the applicable sections (3.7.1, 3.7.2, and 3.7.3) of the Standard Review Plan (2) and applicable Regulatory Guides (RG 1.61, RG 1.92, and RG 1.122) (3), (4), (5). The structural responses were computed by the response spectra modal analysis method using idealized 3-dimensional lumped mass models. Floor response spectra were computed by the time history modal analysis method for the two horizontal and vertical directions. The key seismic analysis criteria for Category I structures are summarized in Table 1. The NRC staff approved the seismic design criteria for Seismic Category I structures in its May 24, 1974, Safety Evaluation Report (6) on TVA's application for a construction permit for BLN.

The Category I structures consist of the following:

<u>Reactor Building</u> Each Reactor Building (one for each unit) is composed of three structures: a reinforced concrete secondary containment (Figure 1), a post-tensioned concrete primary containment (Figure 2), and the interior reinforced concrete structure (Figure 3). All three structures are supported on a common foundation which is supported on bedrock.

<u>Auxiliary-Control Building</u> The Auxiliary-Control Building is a reinforced concrete structure common to both units (Figure 4). The Auxiliary-Control Building is supported on bedrock at elevation 615 ft.

<u>Diesel Generator Building</u> Each Diesel Generator Building (one for each unit) is a reinforced concrete structure supported on bedrock (Figure 5).

<u>Main Steam Valve Room B</u> Each Main Steam Valve Room B (one for each unit) is a reinforced concrete structure supported on bedrock (Figure 6). The structure is supported by four-foot-thick walls which are surrounded by backfilled soil on three sides.

<u>Intake Pumping Station</u> The Intake Pumping Station is a cellular box-type reinforced concrete structure common to both units (Figure 7). The structure is embedded into rock on the north and south sides up to elevation 580 ft. The west side is backfilled with granular soil up to elevation 600 ft. The east side is the intake side.

<u>Borated Water Storage Tank (BWST)</u> Each BWST (one for each unit) is a cast-in-place reinforced concrete cylindrical structure supported on bedrock, as illustrated in Figure 8, and surrounded by about 30 feet of backfilled soil. The reinforced concrete retaining wall is also supported on bedrock.

The original design and analysis of the Category I structures for both units is 100 percent complete. Construction of the Category I structures is essentially complete for both units.

During reviews of the seismic design of BLN, several potential issues regarding the seismic building models and the methods and inputs used to generate the floor response spectra were identified. The issues pertain to the implementation of the seismic design criteria, not the criteria themselves, and are summarized in Table 2. While no single issue is sufficient to warrant generation of new seismic loads and floor response spectra, given the number of issues identified, and the fact that seismic reanalyses are considered necessary for some safety-related systems (e.g., piping), TVA elected to generate new seismic loads and floor response spectra for all Category I structures (except the BWSTs which were considered adequate).

TECHNICAL POSITION AND APPROACH

TVA's technical position and approach for verifying the seismic design of Seismic Category I structures and generating new floor response spectra are as follows:

1. New Seismic Analyses The existing seismic building models will be revised and validated, and new seismic loads and floor response spectra will be generated for all Category I structures except the Borated Water Storage Tanks (BWSTs). These include the Reactor Building, Auxiliary-Control Building, Diesel Generator Building, Main Steam Valve Room B, and Intake Pumping Structure.

   Each BWST is a reinforced concrete cylindrical tank supported on rock and is considered acceptable without further evaluation because the cumulative effects of the issues below are considered insignificant for this relatively simple structure. There are no other Category I tanks supported on the ground.

   The new seismic analyses will be based on the new synthetic time histories discussed in Reference (1), and revised seismic building models and inputs which address the issues with the original analyses listed in Table 2. These issues will be resolved as follows:

   1 - Integration Time Step New time history analyses will be performed using an integration time step of 0.005 seconds in accordance with the recommendation from the seismic design assessment report for the Watts Bar plant (7).

   2 - Offsets Between the Centers of Mass and Rigidity The seismic building models will be revised to include the calculated offsets between the centers of mass and the centers of rigidity of the building floor elevations.

   3 - Concrete Elastic Modulus The seismic analyses will be revised to use a lower value of elastic modulus for reinforced concrete structures (all Category I structures except the primary containment structure). The new elastic modulus will be based on studies performed by Stone and Webster for the Watts Bar plant (8) which show that the effective concrete elastic modulus under seismic loading may be 0.5 to 0.75 times the modulus indicated by static laboratory tests. The elastic modulus for the post-tensioned primary containment structure will also be reevaluated, and an appropriate value will be selected for the new seismic analyses. For each structure, a single mean value for the concrete elastic modulus will be used for all seismic analyses. Effects due to variations in the modulus are accounted for by peak broadening of the floor response spectra.

   4 - Nuclear Steam Supply System (NSSS) - Structure Interaction The Reactor Building seismic model (in particular the interior concrete structure) will be revised to include simplified models (mass and stiffness) of the major NSSS equipment.

   5 - Vertical Mass The seismic building models will be revised to include the appropriate mass for generation of the vertical floor response spectra.

6 - Number of Frequencies The spectral accelerations for the new floor response spectra will be determined at 75 frequencies plus the significant structural frequencies in accordance with Regulatory Guide 1.122.

7 - Peak Broadening The peaks of the floor response spectra will be broadened ± 15 percent in accordance with Regulatory Guide 1.122, Revision 1. Peak broadening accounts for uncertainties in the structural frequencies due to variations in the material properties of the structure and soil, and approximations in the seismic building models.

8 - Vertical Floor Flexibility A floor flexibility study will be performed to determine the additional amplification of the vertical floor response spectra for "vertically flexible" floors. Dynamic models with flexible floor slabs coupled to the existing seismic building models will be used to generate the vertical flexible-floor response spectra. A family of curves will be generated for each damping value. The family of curves will be the floor response spectra at various mass ratios (i.e., the ratio of the mass of the equipment to the mass of the floor).

2. Category I Structures The impact of the new seismic loads on Category I structures will be evaluated in accordance with the following methodology.

a. The forces (axial and shear) and moments (bending and torsional) in the Category I structures will be determined based on the new seismic analyses (Set B loads) and will be compared with the forces and moments based on the original analyses (Set A loads). From this comparison, elevations of the buildings where the Set B loads exceed the Set A loads by more than 10 percent will be identified.

b. For each elevation identified in Step a above, structural members most affected by the higher Set B loads will be selected for detailed evaluation. Considerations in selecting structural members for evaluation will include the following:

- Members with relatively little available margin, and major shear walls and columns supporting large floor slabs.
- Structural members in the principal directions (i.e., north-south and east-west directions) with the largest increase in loads.
- Exterior shear walls and interior walls, and columns farthest from the shear center of the building.

c. For each structural member selected in Step b above, the factored loads (or stresses) will be calculated for the higher Set B loads. The calculated factored loads (or stresses) will be compared with the design allowable capacities (or stresses) and evaluated as follows:

- If the Set B factored loads (or stresses) are less than the design allowables, then the member will be considered adequate.

- o If the Set B factored loads (or stresses) exceed the design allowables, then the factored loads (or stresses) of other similar load carrying members (e.g., members of the same type) at that elevation will also be calculated. All load carrying members for which the Set B loads cannot be shown to meet the design allowables will be dispositioned on a case-by-case basis.

d. The evaluation of Category I structures for the new seismic loads will be documented in calculations and cross-referenced to the original design calculations.

TECHNICAL JUSTIFICATION

The technical justification for TVA's approach to verifying the seismic design of Seismic Category I structures is as follows:

1. New Seismic Analyses The new seismic analyses (i.e., determining new seismic loads and generating new floor response spectra) will address the issues regarding the original analyses identified in Table 2. The planned resolutions of these issues are noted in Item 1 of the preceding section. The new seismic analyses will be in accordance with current NRC guidelines in Sections 3.7.1, 3.7.2, and 3.7.3 of the Standard Review Plan.

2. Category I Structures The methodology for evaluating Category I structures will verify that the new seismic loads will not significantly affect the adequacy of Category I structures. Any structures which are found not to meet design allowables will be dispositioned on a case-by-case basis.

The approach outlined in this paper will provide reasonable assurance that the seismic design of Category I structures at BLN and the new floor response spectra are adequate.

REFERENCES

1. Bellefonte Position Paper Regarding Seismic Design Ground Motion, Enclosure to TVA Letter from E. G. Wallace to NRC dated February 14, 1991.

2. NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, LWR Edition, U.S. Nuclear Regulatory Commission, Section 3.7.1, Revision 2, August 1989, Section 3.7.2, Revision 2, August 1989, Section 3.7.3, Revision 2, August 1989.

3. Regulatory Guide 1.61, Damping Values for Seismic Design of Nuclear Power Plants, U.S. Atomic Energy Commission, October 1973.

4. Regulatory Guide 1.92, Combining Modal Responses and Spatial Components in Seismic Response Analysis, Revision 1, U.S. Nuclear Regulatory Commission, February 1976.

5. Regulatory Guide 1.122, Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components, Revision 1, U.S. Nuclear Regulatory Commission, February 1978.

6. Safety Evaluation of the Bellefonte Nuclear Plant Units 1 and 2, U.S. Atomic Energy Commission, May 24, 1974, Sections 3.8 and 3.9.

7. Seismic Assessment Report - Watts Bar Nuclear Plant, Prepared by Bechtel North American Power Corporation for Tennessee Valley Authority, 1989, page 3-4.

8. Modulus of Elasticity Modification for Concrete Under Seismic Loading, Watts Bar Nuclear Plant, Stone and Webster Engineering Corporation, September 25, 1989.

9. NUREG-1232, Volume 3, Supplement 1, Safety Evaluation Report on Tennessee Valley Authority: Browns Ferry Nuclear Performance Plan, Browns Ferry Unit 2 Restart, U.S. Nuclear Regulatory Commission, page 2-8.

10. NUREG-0011, Safety Evaluation Report - Tennessee Valley Authority, Sequoyah Nuclear Plant Units 1 and 2, U.S. Nuclear Regulatory Commission, March 1979, page 3-12.

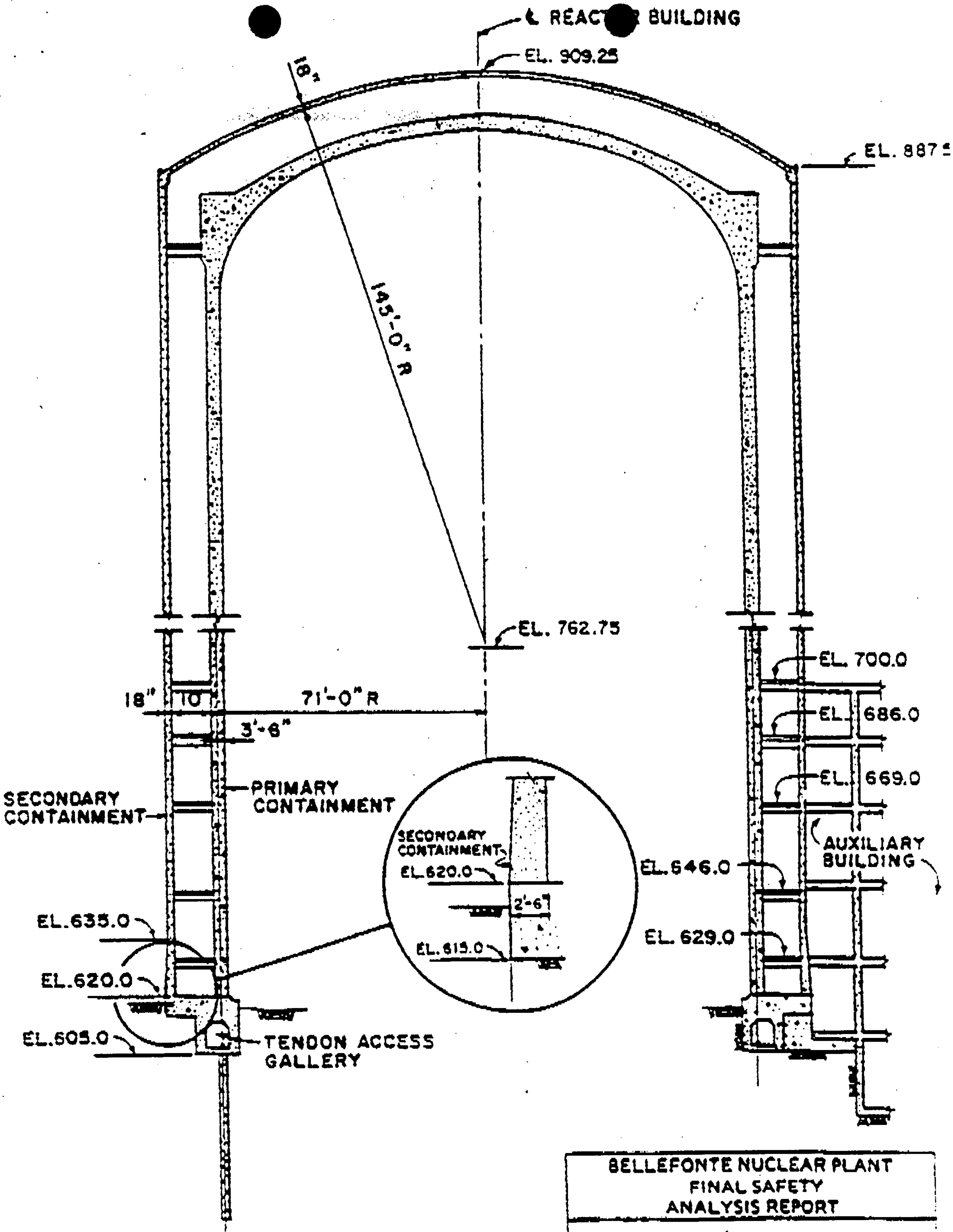
TABLE 1

BELLEFONTE NUCLEAR PLANT
KEY SEISMIC ANALYSIS CRITERIA FOR CATEGORY I STRUCTURES

ATTRIBUTE	VALUE
1. Design ground response spectrum	Reg. Guide 1.60 shape • SSE - 0.18g PGA • OBE - 0.09g PGA
2. Ratio of vertical to horizontal acceleration	<u>Frequency</u> / <u>Ratio</u> <0.25 — 0.67 0.25-3.5 — Varies from 0.67 to 1.0 >3.5 — 1.0
3. Foundation	All Category I structures are founded on rock (shear wave velocity equal to 10,000 fps)
4. Soil-structure interaction	Rock with spring constants from Whitman, 1966
5. Analysis method	Time history modal analysis method and response spectra modal analysis method
6. Structural models	Idealized 3-dimensional lumped mass models
7. Damping	<u>Building</u> — <u>OBE</u> <u>SSE</u> Reactor Building Primary Containment — 2 5 Secondary Containment — 4 7 Interior Concrete — 4 7 Other Category I Structures — 4 7
8. Combination of modal responses	Square root of the sum of the squares (SRSS) with absolute sum of closely spaced modes
9. Combination of spatial components	SRSS of three directions (N-S, E-W, and vertical)
10. Peak broadening	±15 percent*
11. Stability	Limiting values for sliding and overturning OBE 1.5 SSE 1.1
12. Structural Codes	Reinforced Concrete - ACI 318-71 (Ultimate Strength Design) Steel - AISC (1971) Post-Tensioned Concrete - ACI-359-73**

* 10 percent peak broadening was used in the original design criteria

** As identified in FSAR Chapter 3



BELLEFONTE NUCLEAR PLANT
FINAL SAFETY
ANALYSIS REPORT

SECOND VIEW OF
SECONDARY CONTAINMENT
FIGURE 3.7.2-2
REVISED BY AMENDMENT 23 11/5/82

Figure 1
SECONDARY CONTAINMENT

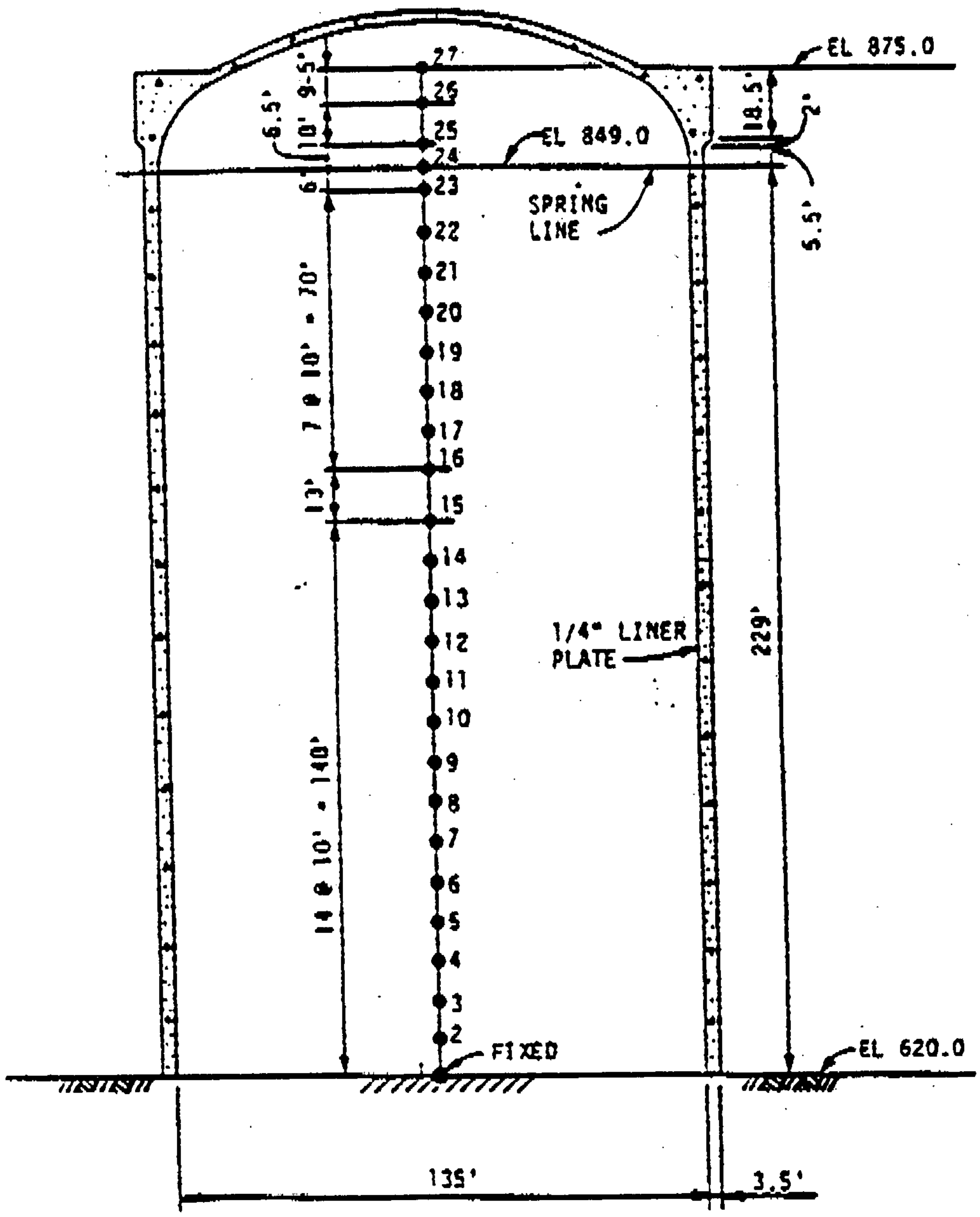
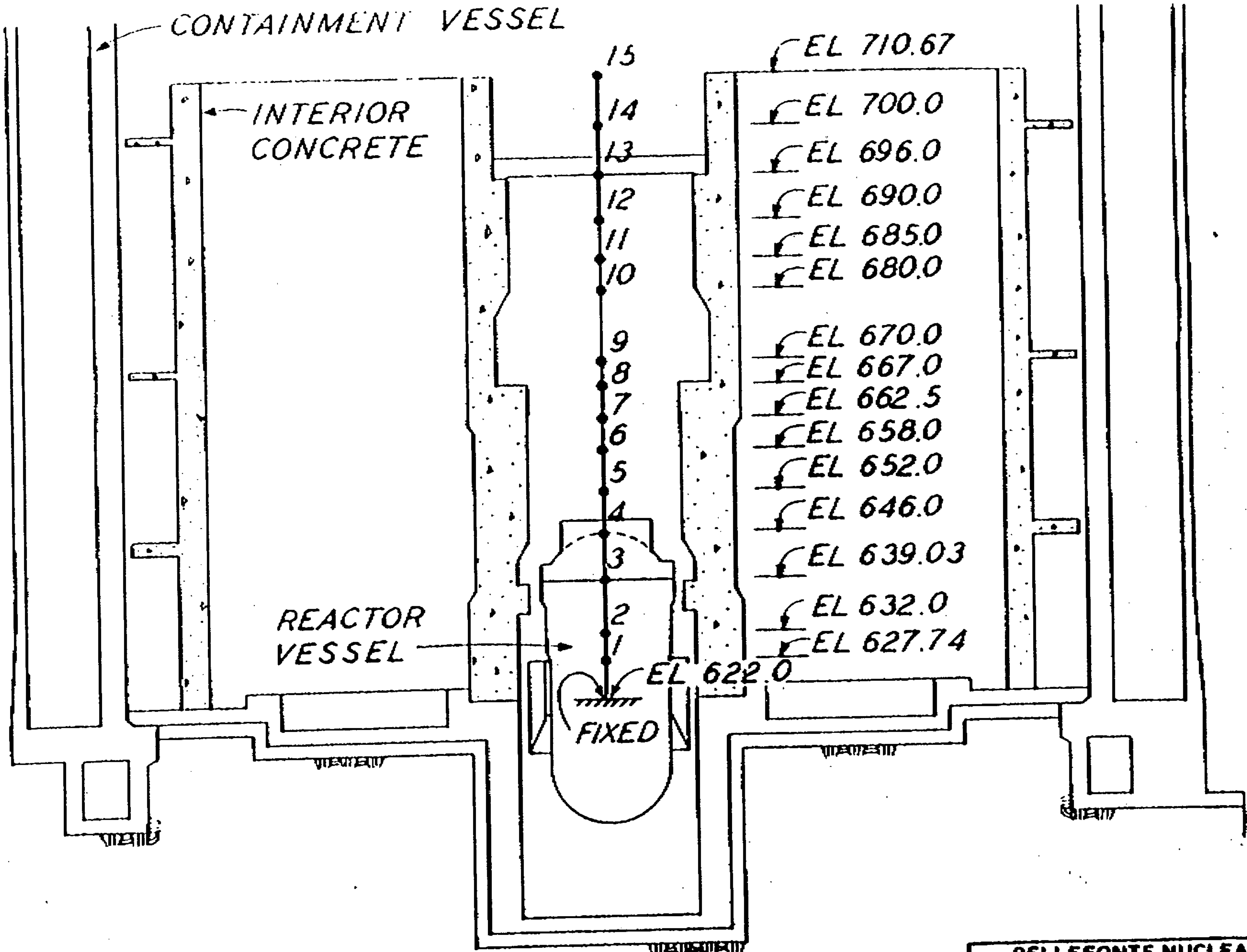


Figure 2
PRIMARY CONTAINMENT

BELLEFONTE NUCLEAR PLANT
FINAL SAFETY
ANALYSIS REPORT

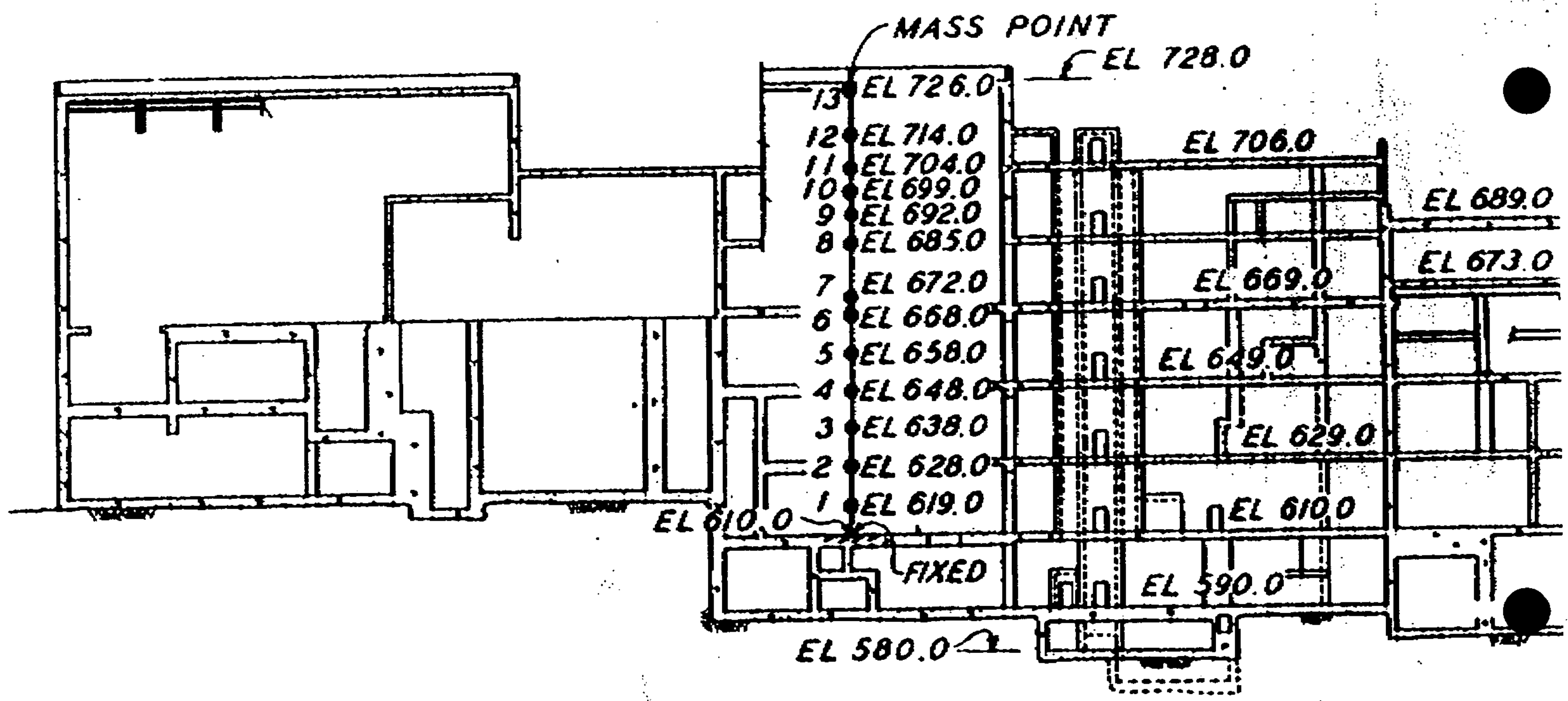
SECTIONAL ELEVATION OF PRIMARY
CONCRETE CONTAINMENT STRUCTURE
LUMPED MASS MODEL FOR
DYNAMIC ANALYSIS
FIGURE 3.7.2-6



BELLEFONTE NUCLEAR PLANT
FINAL SAFETY
ANALYSIS REPORT

SECTIONAL ELEVATION OF
INTERIOR CONCRETE STRUCTURE
LUMPED MASS MODEL FOR
DYNAMIC ANALYSIS
FIGURE 3.7.2-8

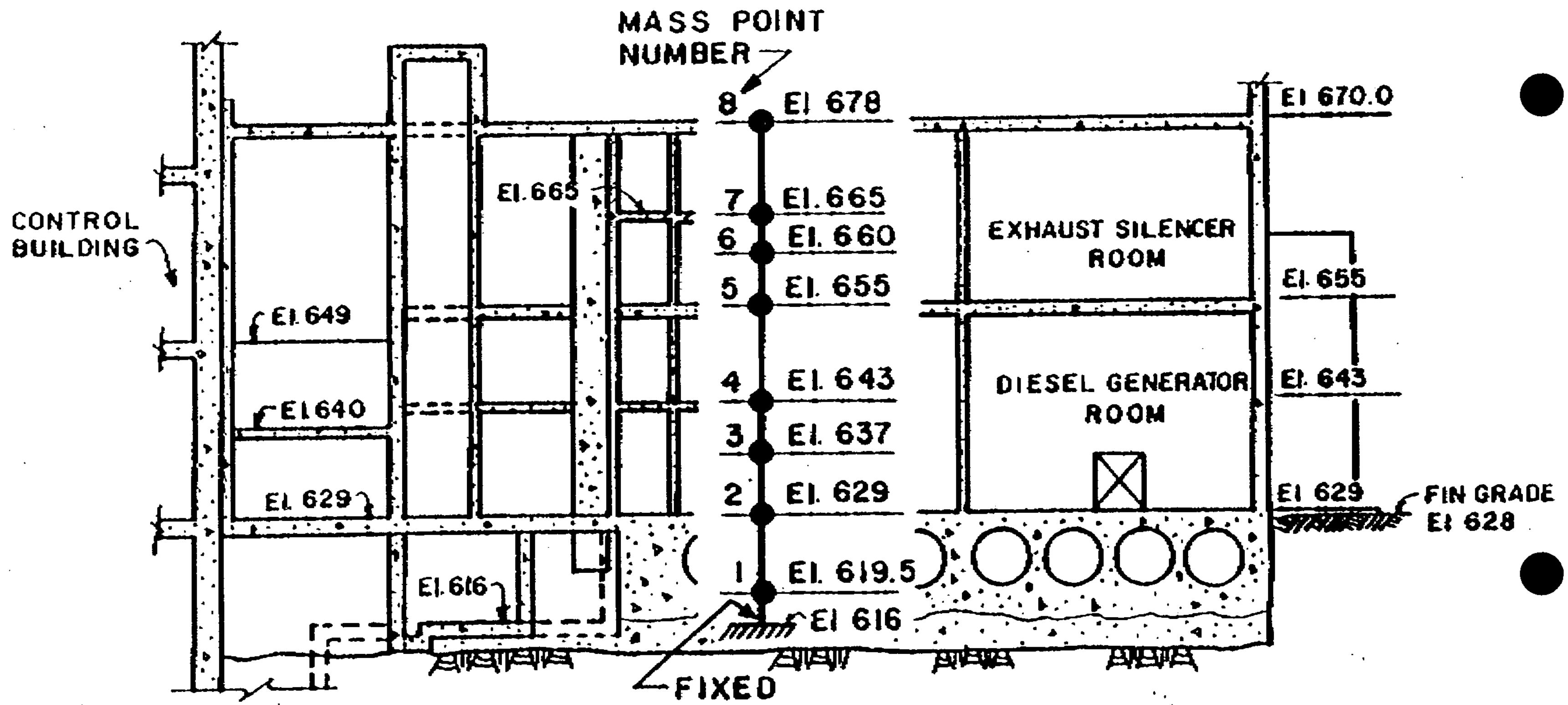
Figure 3.
INTERIOR CONCRETE



BELLEFONTE NUCLEAR PLANT
FINAL SAFETY
ANALYSIS REPORT

SECTIONAL ELEVATION OF AUXILIARY-CONTROL BUILDING LUMPED MASS MODEL FOR DYNAMIC ANALYSIS
FIGURE 3.7.2-9

Figure 4
AUXILIARY-CONTROL BUILDING



BELLEFONTE NUCLEAR PLANT
FINAL SAFETY
ANALYSIS REPORT

SECTION ELEVATION OF
DIESEL GENERATOR BUILDING
LUMPED MASS FOR
DYNAMIC ANALYSIS
FIGURE 3.7.2-10

Figure 5
DIESEL GENERATOR BUILDING

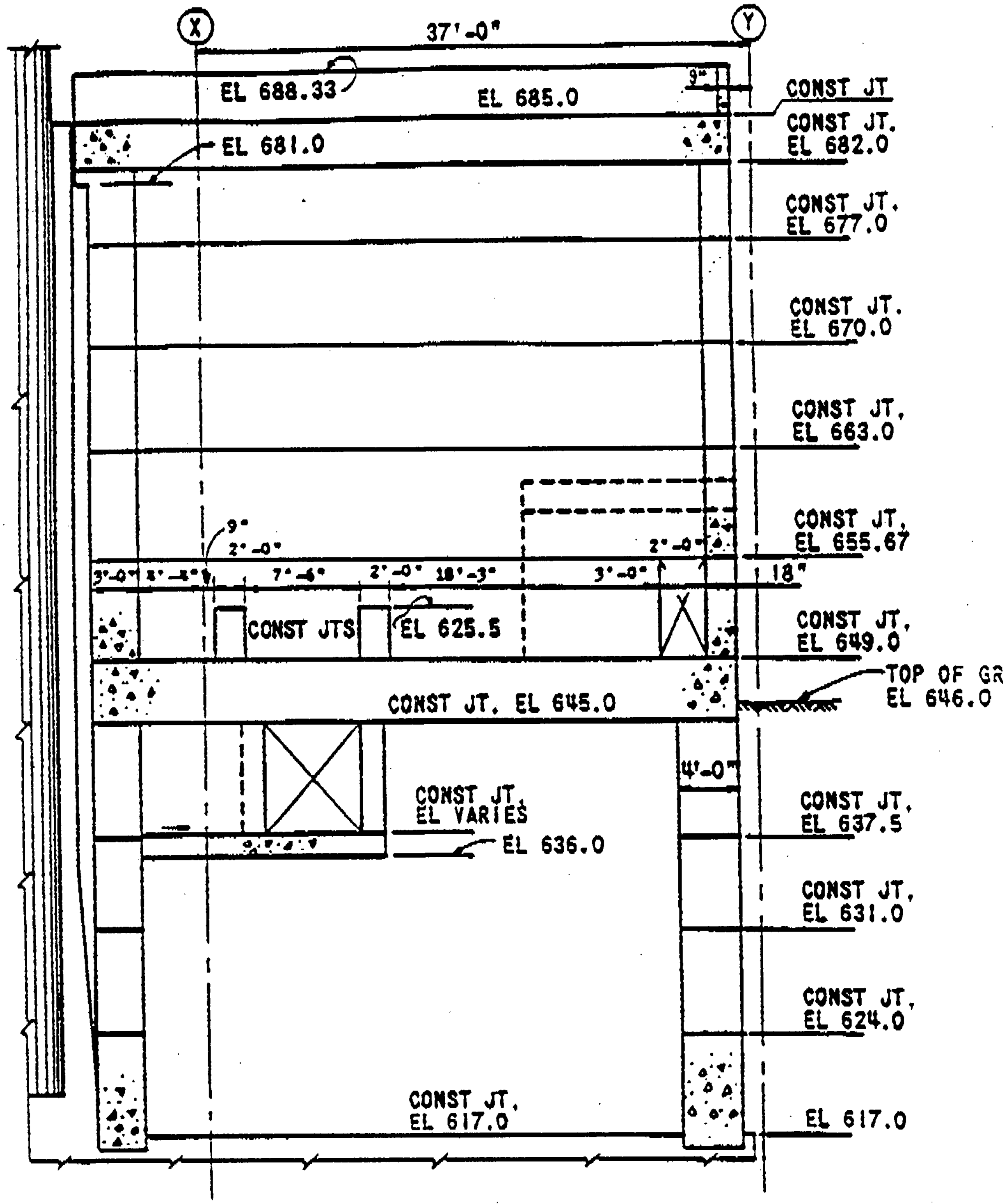
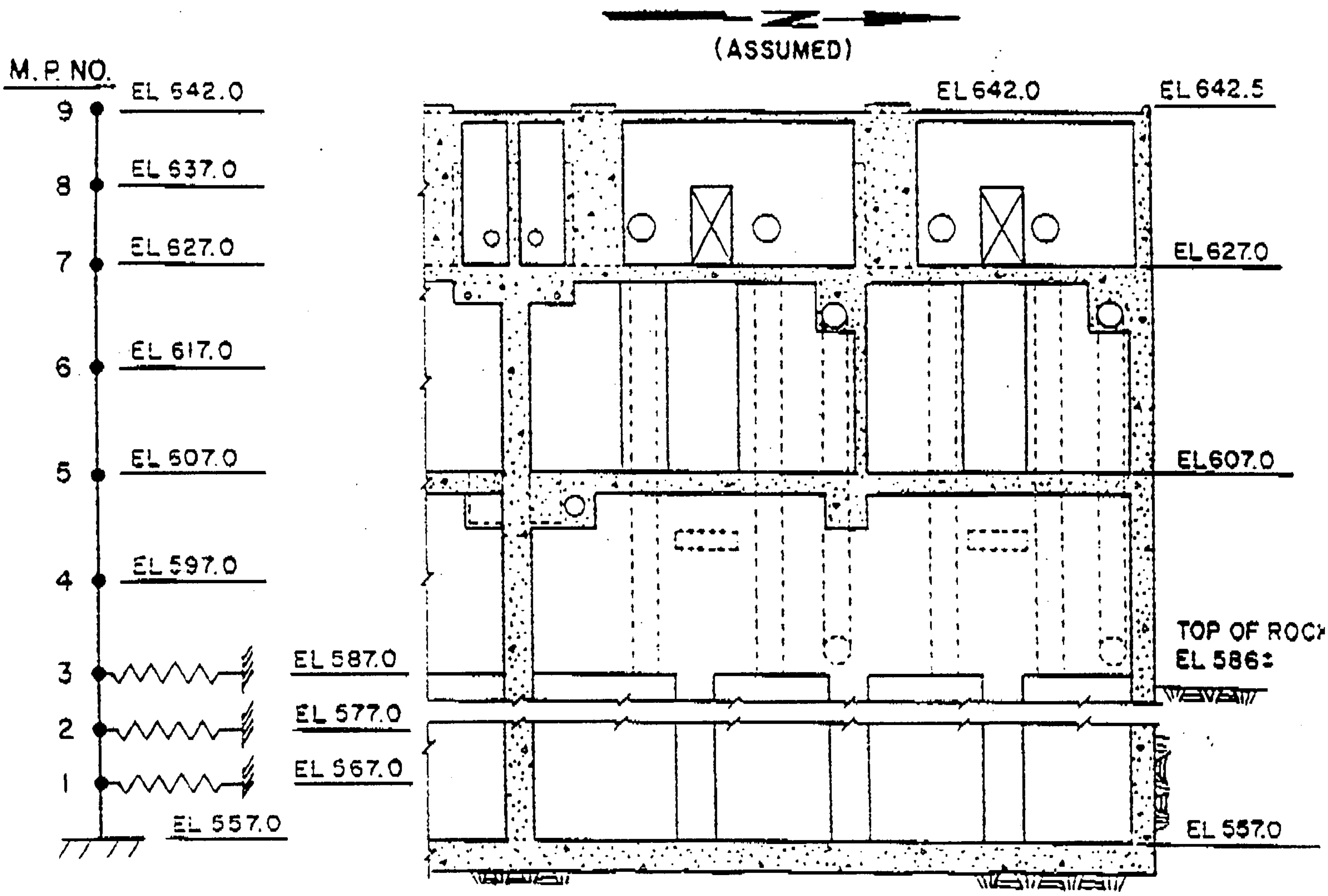


Figure 6
MAIN STEAM VALVE ROOM B

BELLEFONTE NUCLEAR PLAN
FINAL SAFETY
ANALYSIS REPORT

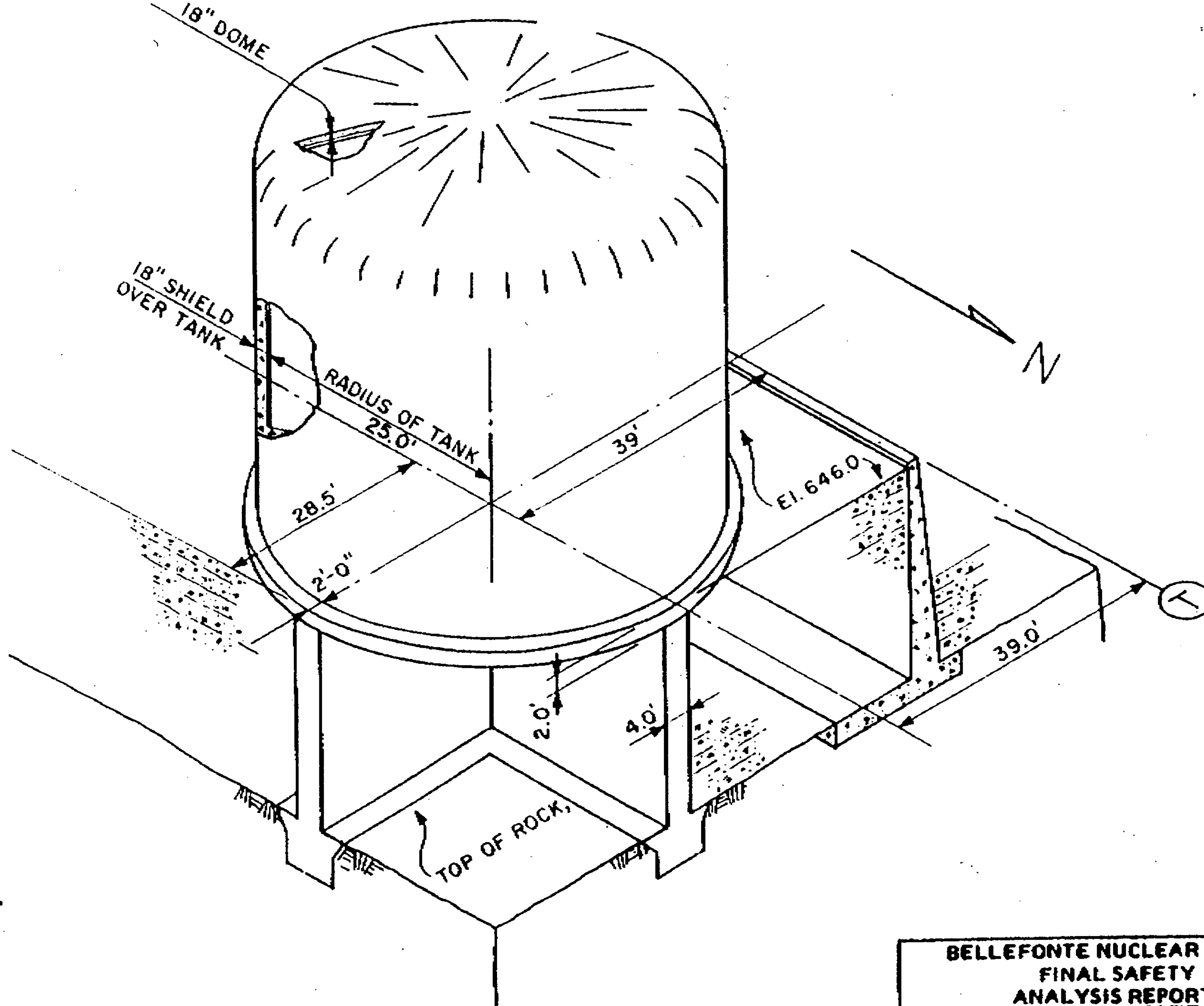
SECTION VIEW OF
MAIN STEAM VALVE ROOM B
FIGURE 3.7.2-20



BELLEFONTE NUCLEAR PLANT
FINAL SAFETY
ANALYSIS REPORT

SECTIONAL ELEVATION OF ERCW
PUMPING STATION AND
LUMPED MASS MODEL FOR
DYNAMIC ANALYSIS
FIGURE 3.7.2-11

Figure 7
INTAKE PUMPING STATION



BELLEFONTE NUCLEAR PLANT
FINAL SAFETY
ANALYSIS REPORT

BORATED WATER TANK
RETAINING WALL SKETCH
FIGURE 3.7.2-12

Figure 8
BORATED WATER STORAGE TANK

Table 2

SUMMARY OF ISSUES WITH SEISMIC ANALYSES

Issue	Description
1. Integration time step.	The integration time step used in time-history analyses (0.01 sec) was larger than the value (0.005 sec) recommended in a seismic design assessment of the Watts Bar Nuclear Plant by Bechtel (7). This could affect the accuracy of the high frequency results.
2. Modeling offsets.	In the dynamic building models, the offset between the center of mass and center of rigidity of the building was not modeled. This could affect the accuracy of the torsional response of the buildings. This effect would be greatest on unsymmetrical buildings (e.g., the Reactor Building).
3. Concrete elastic modulus.	The concrete elastic modulus used in the seismic analyses (5.0×10^6 psi) was based on static tests performed by TVA for the particular 'fly ash' concrete used in TVA nuclear projects starting with Sequoyah. Results of these tests indicated that the measured elastic modulus at two years was higher than the ACI 318 Code value. However, subsequent studies performed in connection with Watts Bar show that the effective elastic modulus under dynamic loading conditions may be lower than that indicated by static tests. A lower concrete elastic modulus would result in lower calculated fundamental frequencies of the structures and tend to shift the peaks of the floor response spectra curves to a lower frequency range.
4. NSSS-structure interaction.	The mass and stiffness of the NSSS equipment was not explicitly included in the seismic model of the interior concrete structure. This could possibly affect the calculated response of the NSSS.
5. Vertical mass.	The mass used in the analyses to generate the vertical floor response spectra was less than the total mass of the buildings. This could affect the vertical floor response spectra.
6. Number of frequencies.	The number of frequencies and frequency interval used to generate the floor response spectra (55 frequencies plus the significant structural frequencies) was not consistent with Regulatory Guide 1.122 (5) (75 frequencies plus the significant structural frequencies).

Table 2

SUMMARY OF ISSUES WITH SEISMIC ANALYSES

(Continued)

Issue	Description
7. Peak broadening.	The peaks of the floor response spectra curves were broadened %10 percent to account for uncertainties in the analyses. Regulatory Guide 1.122 (5) recommends that peaks be broadened %15 percent unless parametric studies are performed to justify a lower value.
8. Vertical floor flexibility.	In the generation of the floor response spectra, the floors were assumed to be rigid. Floor flexibility effects could result in additional amplification of the floor response spectra for "vertically flexible" floors. A floor is considered to be "vertically flexible" if the fundamental frequency of the slab is less than two times the dominant spectral peak.