ENCLOSURE

WATTS BAR NUCLEAR PLANT
UNITS 1 AND 2

EVALUATION OF STRUCTURES, PIPING, AND EQUIPMENT FOR THE 84th PERCENTILE EARTHQUAKE

CEB-81-50

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TENNESSEE VALLEY AUTHORITY

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1.0 Introduction

The Tennessee Valley Authority (TVA) was informed by the Nuclear Regulatory Commission (NRC) in a letter dated December 27, 1977, that there has arisen a question concerning the seismic design basis for the Sequoyah, Watts Bar, and Bellefonte Nuclear Plants. Initially, the question was addressed on a seismological and geotechnical basis resulting in TVA performing several investigations and studies. Later, prior to granting an operating license for Sequoyah, reanalyses and detail reviews of the seismic qualification of piping, structures, and mechanical equipment was performed for Sequoyah. The results of this reevaluation were reviewed by the NRC staff in TVA's offices. A list of the more significant correspondence relating to the question raised in the December 1977 letter is given in Table 1.

The Watts Bar Nuclear Plant is very similar to Sequoyah. A comparison of the two plants was provided to the NRC at the request of personnel from the structures branch during a site visit in July 1981. A copy of the comparison is given in the appendix.

This report, along with the other TVA reports, provides additional information to support the design of the Watts Bar Nuclear Plant for safe shutdown earthquake (sse) ground motions used in the design and the adequacy of the design for the 84th percentile earthquake. The report specifically addresses the seismic design of rock supported structures, soil supported structures, piping, and electrical and mechanical equipment.

2.0 Summary and Conclusion

All structures, piping, and electrical and mechanical equipment at Watts Bar Nuclear Plant are qualified for the 84th percentile earthquake.

3.0 Comparison of 84th Percentile Earthquake with the Safe Shutdown Earthquake

The evaluation of structures and the generation of floor response spectra for piping analysis and equipment qualification for the 84th percentile earthquake utilize the sse structural damping values of Regulatory Guide 1.61: 7 percent for reinforced concrete structures and 4 percent for welded steel structures. The 84th percentile spectra were transmitted to the NRC in the phase II reports shown in table 1.

The Watts Bar seismic design for the sse was based on 5-percent structural damping for reinforced concrete structures and 1-percent structural damping for the steel containment vessel. The steel containment vessel is the only rock supported category I steel structure at Watts Bar.

Consequently, comparisons are made of the Watts Bar sse spectra at 5-percent damping with the 84th percentile spectra at 7-percent damping for reinforced concrete structures and of the Watts Bar sse spectra at 1-percent damping with the 84th percentile spectra at 4-percent damping for the steel containment vessel.

3.1 Rock Supported Structures

3.1.1 Reinforced Concrete Structures

The sse spectrum used in the design of rock supported concrete structures is shown in figure 1 along with the spectrum of the 84th percentile earthquake. This figure shows that the 84th percentile spectrum exceeds the sse spectrum over portions of the frequency range. The maximum amount that the 84th percentile acceleration spectra exceeds the sse acceleration spectra is 25 percent at frequencies above 33 hertz.

As discussed in the introduction and in the appendix, the rock supported structures at Watts Bar are very similar to the equivalent rock supported structures at Sequoyah. However, the Watts Bar concrete structures generally have considerably greater amounts of reinforcement due to the higher seismic design loads. The rock supported concrete structures at Sequoyah have been qualified for the 84th percentile earthquake. Therefore, the rock supported concrete structures at Watts Bar are qualified for the 84th percentile earthquake.

3.1.2 Steel Containment Vessel

The sse spectrum used in the design of the steel containment vessel is shown in figure 2 along with the spectrum of the 84th percentile earthquake. This figure shows that the sse spectrum envelopes the 84th percentile spectrum for all periods greater than 0.047 seconds (frequencies less than 21 hertz). The floor response spectrum for the intersection of the cylindrical shell and hemispherical dome is shown in figure 6. It can be seen from this spectrum that the containment vessel is responding primarily in a single mode at a period of 0.123 seconds (8.1 hertz). Since the Watts Bar sse spectrum exceeds the 84th percentile spectrum by approximately 20 percent at this frequency, the structural response of the vessel would be smaller for the 84th percentile earthquake than for the design sse. Therefore, the Watts Bar containment vessel is qualified for the 84th percentile earthquake.

3.1.3 Comparison of Stresses in Watts Bar and Sequoyah Structures

Detailed stress analyses were performed for three Sequoyah reinforced concrete structures for the 84th percentile earthquake. At the points of maximum stress at Sequoyah, the equivalent stresses were calculated for the Watts Bar structures. The results are shown in table 2. The Watts Bar equivalent stresses are less than or equal to the maximum Sequoyah stresses.

For the steel containment vessels at Watts Bar and Sequoyah, the loss of coolant accident (LOCA) loads are by far the most severe loads. For Watts Bar the stress due to sse seismic loads is only 20 percent of the total stress in the shell for the load combination including LOCA loads.

The Watts Bar containment vessel is very similar to the Sequoyah containment vessel and has thicker walls of higher strength steel (ASME SA-516 grade 70 versus grade 60) than the Sequoyah containment vessel. Therefore, the stresses in the Watts Bar containment vessel will be less than the equivalent stresses in the Sequoyah containment vessel for the 84th percentile earthquake.

3.2 Soil Supported Structures

The method of analysis used in the seismic design of soil supported structures is shown in figure 7. The seismic input for soil supported structures was generated by taking artificial earthquake time histories and inputing them into a shear beam analysis of the soil deposit above rock using 10-percent soil damping. The shear wave velocity of the soil was varied a minimum of ± 30 percent to account for uncertainties in the properties of the soil. The spectra calculated at the base of the structures from the time histories varies with the depth of the soil above rock and the properties of the soil. Maximum and minimum soil sse spectra are shown in figure 3 with the 84th percentile spectra. Since the Watts Bar soil sse spectra are much larger than the 84th percentile spectra over all periods, all soil supported structures are qualified for the 84th percentile earthquake.

3.3 Piping and Electrical and Mechanical Equipment

Floor response spectra for the seismic qualification of piping and equipment were generated from acceleration time histories of artificial earthquakes. The top-of-rock spectra of these acceleration time histories along with the 84th percentile spectra are shown in figure 4 for the reinforced concrete structures and in figure 5 for the steel containment vessel. These figures show that the Watts Bar top-of-rock spectra completely envelope the 84th percentile spectra. As discussed in section 3.2 above and as shown in figure 3, the top-of-soil spectra from acceleration time histories completely envelope the 84th percentile spectra. Consequently, all piping, electrical and mechanical equipment, and other attachments designed from floor response spectra have been qualified for the 84th percentile earthquake.

TABLE 1

84TH PERCENTILE EARTHQUAKE

Submittals	Summary Submittal/Contents	Date
NRC letter to TVA	Informed TVA of question concerning seismic design base for Sequoyah, Watts Bar, and Bellefonte	December 1977
Phase I report	Justification of the seismic design criteria for the Sequoyah, Watts Bar, and Bellefonte Nuclear Plants	May 1978
Phase II report	Justification of the seismic design criteria for the Sequoyah, Watts Bar, and Bellefonte Nuclear Plants	August 1978
Phase II report (revised)	Included responses to six NRC questions, additional clarification, and results of four additional investigations	August 1979
NRC review of seismic design calculations for Sequoyah	Review of category I structures by structures branch (Knoxville)	March 1979
NRC review of seismic design calculations for Sequoyah	Review of piping and mechanical equipment qualification by mechanical branch (Knoxville)	March 1979
TVA-NRC meeting on Sequoyah	Scope of reevaluation of electrical and mechanical equipment	April 1981

TABLE 2

COMPARISON OF MAXIMUM STRESSES IN WATTS BAR AND SEQUOYAH CONCRETE STRUCTURES FOR THE LOAD COMBINATIONS INCLUDING SEISMIC LOADS FOR THE 84TH PERCENTILE EARTHQUAKE

Structure	Point of Maximum Stress at Sequoyah	Maximum Stress Sequoyah	Equivalent Stress Watts Bar
Shield building	Outside face rebar at base	54,200	29,900
Interior concrete structure	Inside face rebar at base	29,500	4,400
Auxiliary control building	Outside face rebar at base	16,400	16,400

COMPARISON OF 84TH PERCENTILE SPECTRUM AND THE WATTS BAR SSE SPECTRUM

FOR CONCRETE STRUCTURES

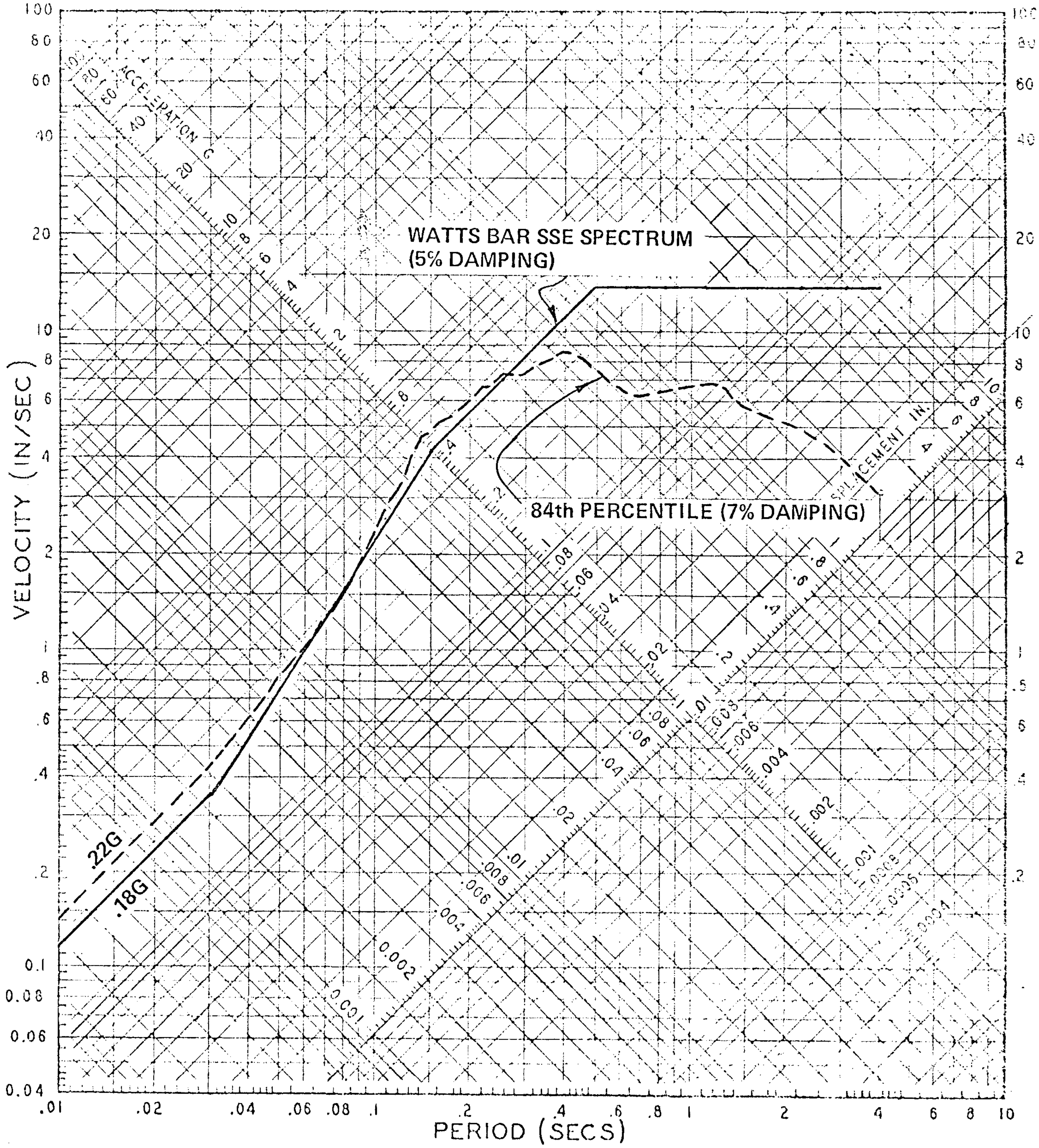


FIGURE NO. 1

COMPARISON OF 84TH PERCENTILE SPECTRUM, AND THE WATTS BAR SSE SPECTRUM FOR STEEL STRUCTURES

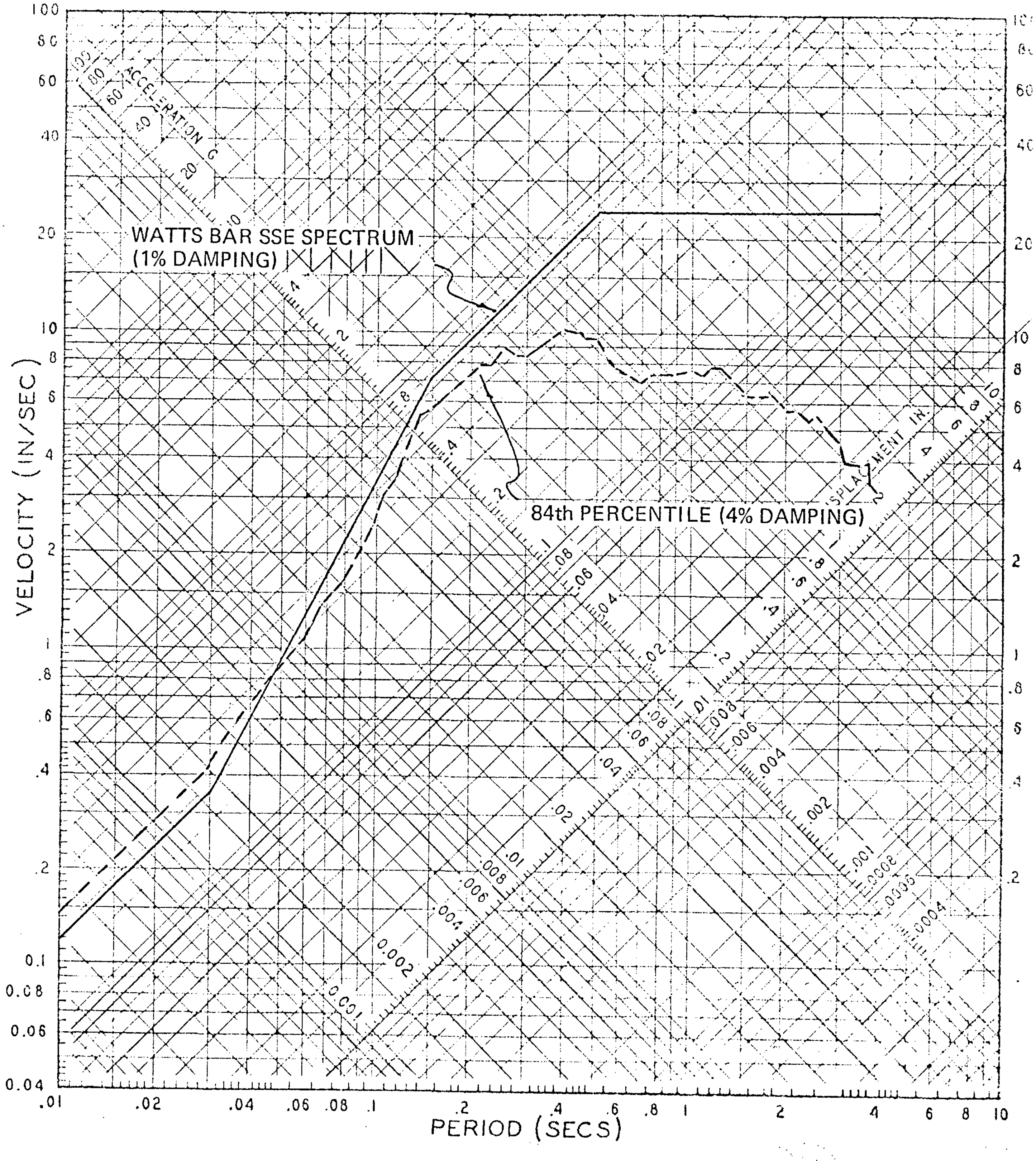


FIGURE NO. 2

COMPARISON OF 84TH PERCENTILE SPECTRUM AND THE WATTS BAR TOP-OF-SOIL SSE SPECTRA

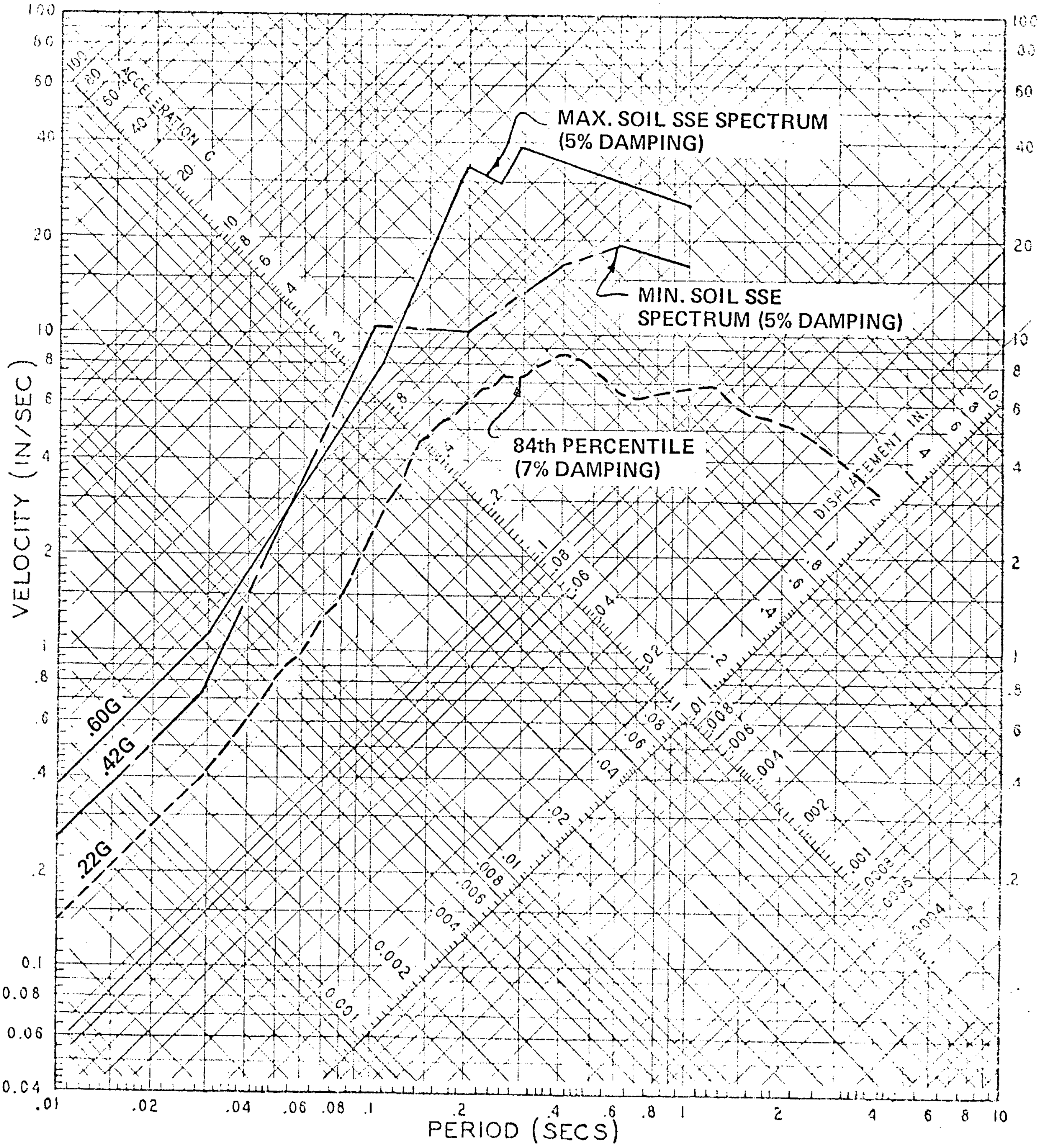


FIGURE NO. 3

SPECTRUM, AND THE WATTS BAR
SPECTRUM OF ARTIFICIAL EARTHQUAKE
TIME HISTORIES FOR THE SSE
FOR CONCRETE STRUCTURES

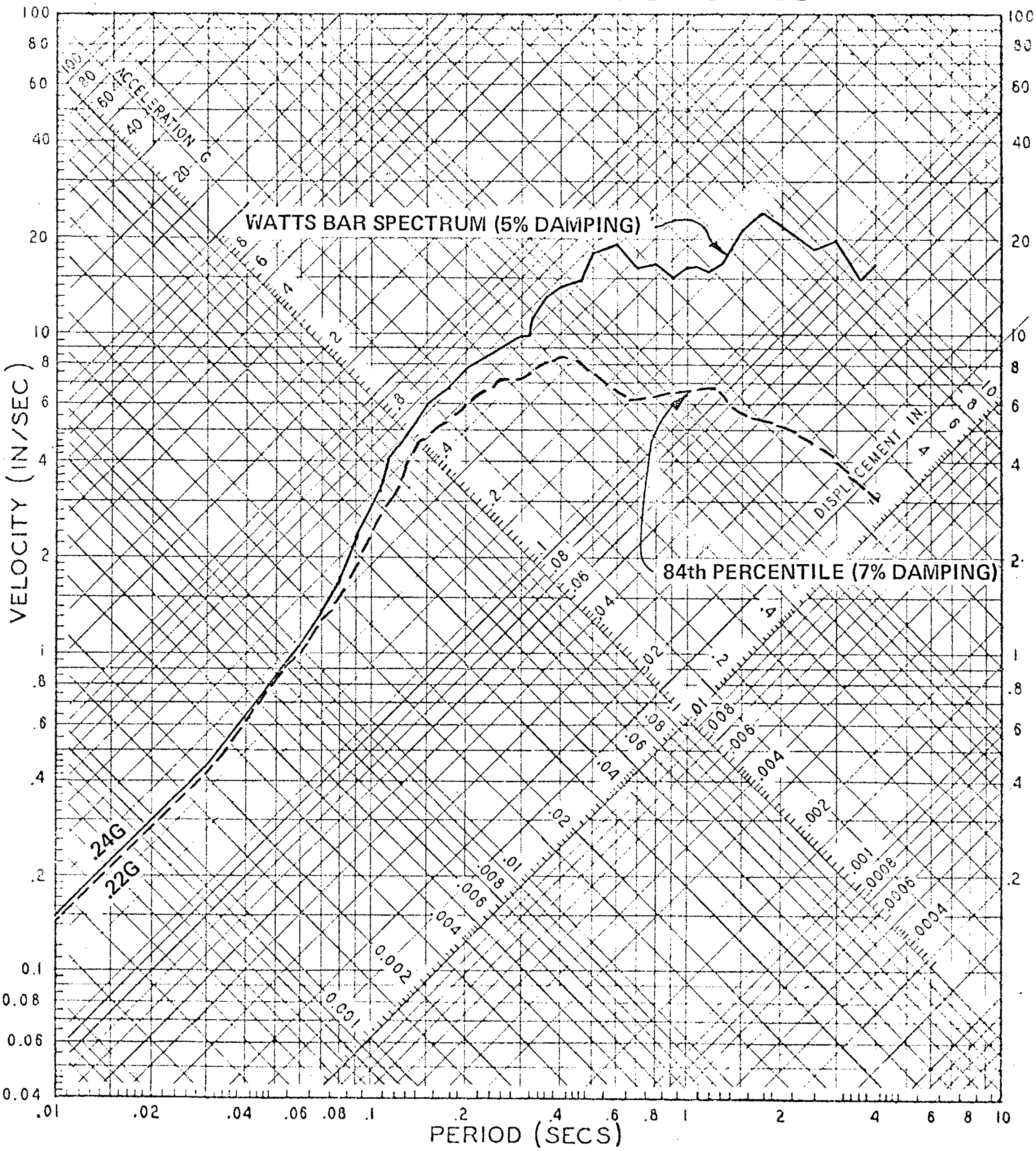


FIGURE NO. 4

COMPARISON OF 84TH PERCENTILE SPECTRUM, AND THE WATTS BAR SPECTRUM OF ARTIFICIAL EARTHQUAKE TIME HISTORIES FOR THE SSE FOR STEEL STRUCTURES

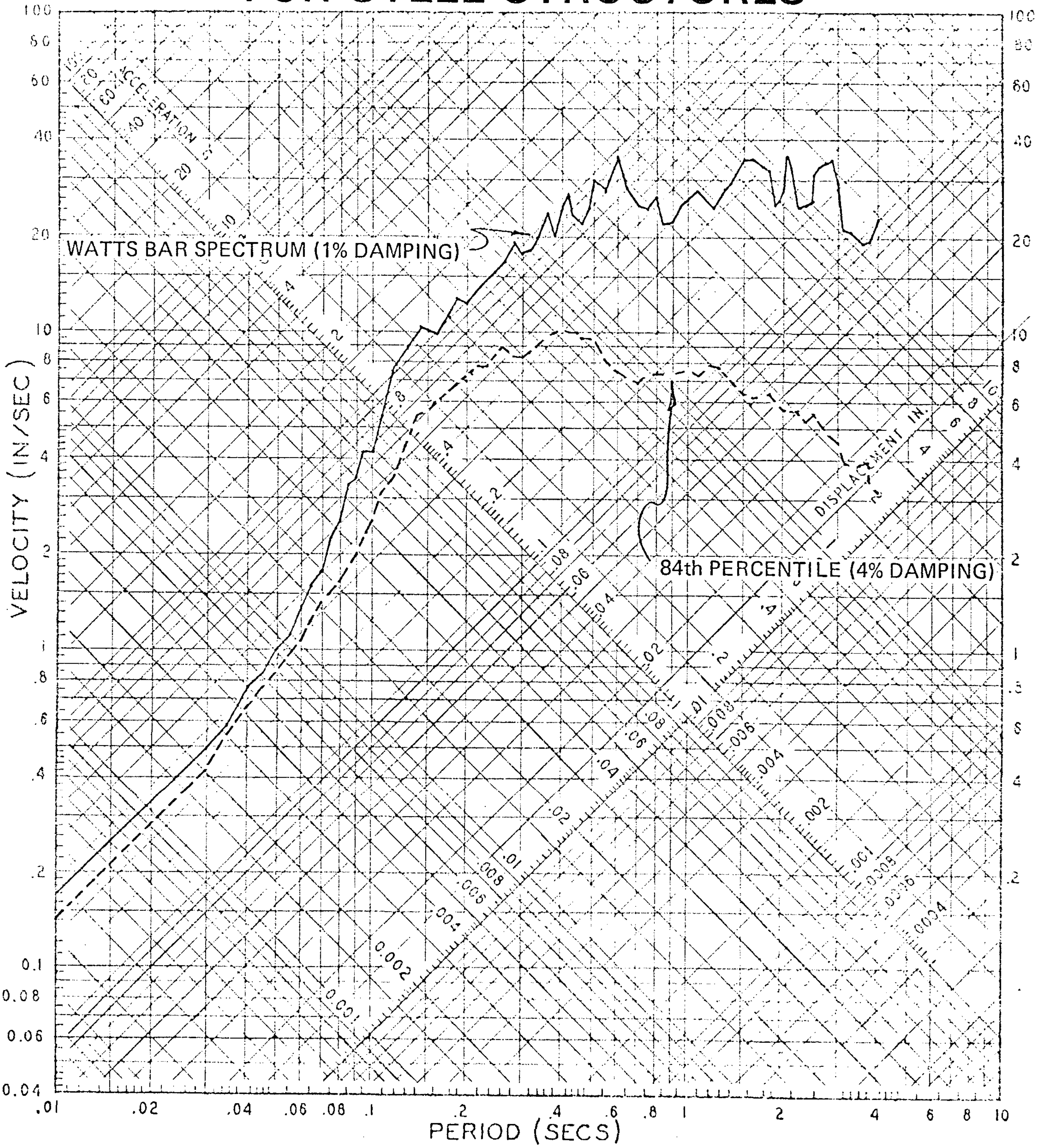
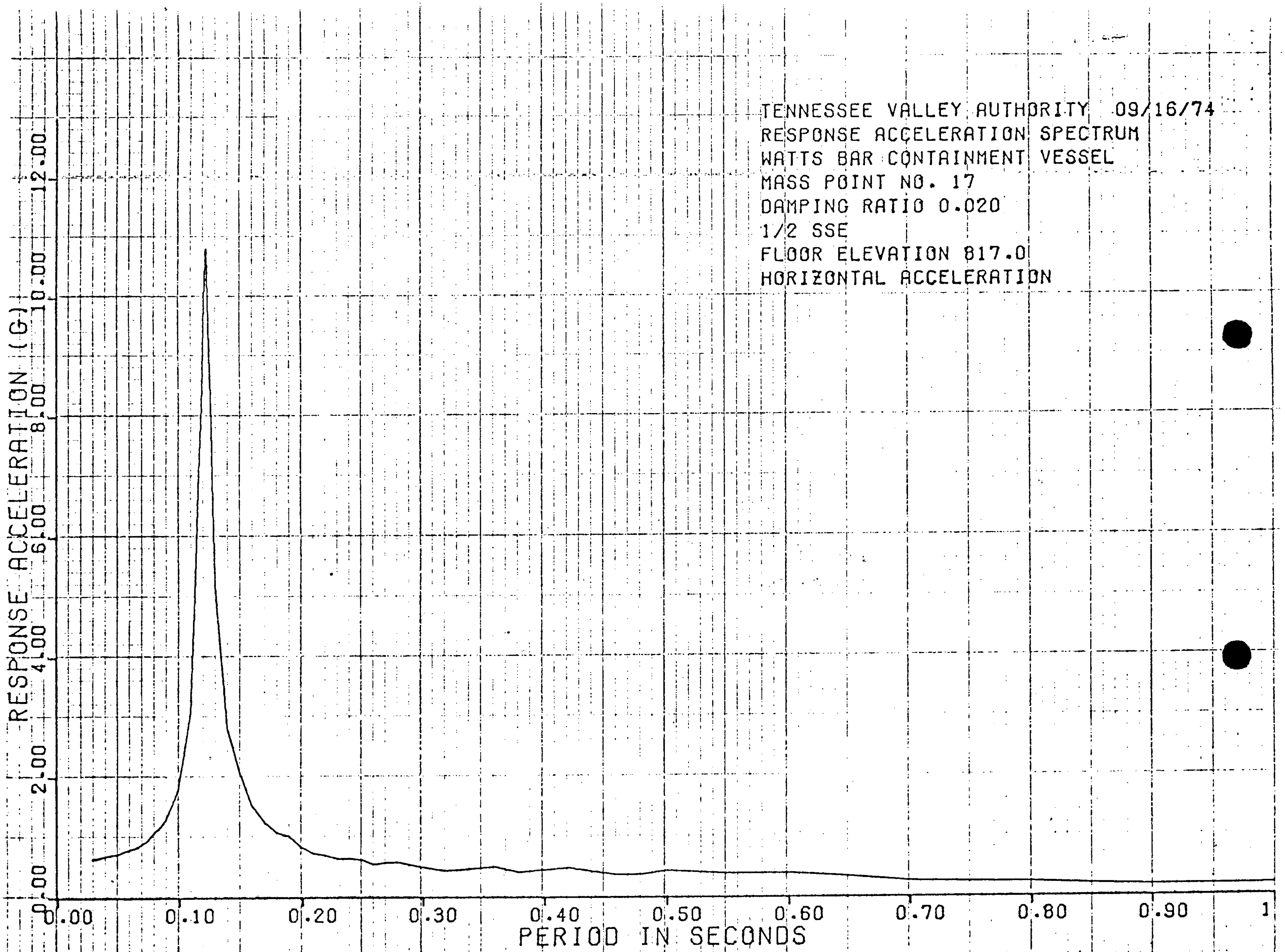


FIGURE NO. 5


TENNESSEE VALLEY AUTHORITY 09/16/74
RESPONSE ACCELERATION SPECTRUM
WATTS BAR CONTAINMENT VESSEL
MASS POINT NO. 17
DAMPING RATIO 0.020
1/2 SSE
FLOOR ELEVATION 817.0
HORIZONTAL ACCELERATION
RESPONSE ACCELERATION (G)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1
PERIOD IN SECONDS
FIGURE 6

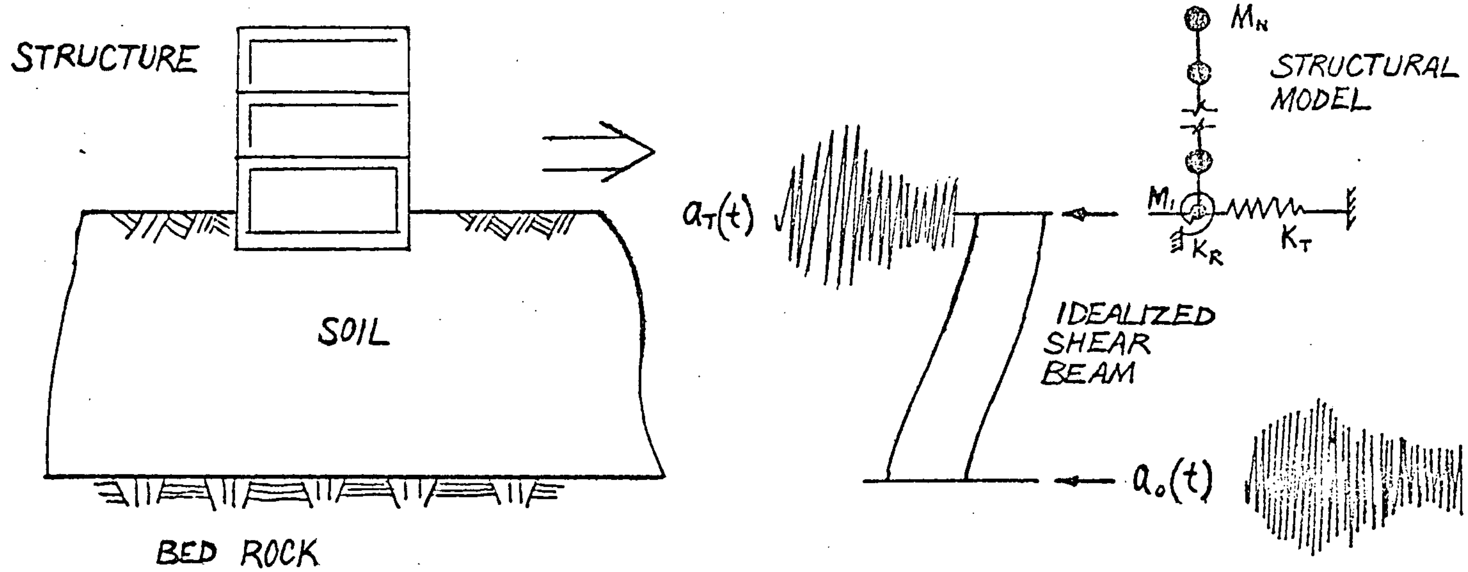

STRUCTURE
SOIL
BED ROCK
$a_T(t)$
M_N
STRUCTURAL MODEL
M_1
K_R
K_T
IDEALIZED SHEAR BEAM
$a_o(t)$

FIGURE 7

APPENDIX

COMPARISON OF STRUCTURES AT WATTS BAR NUCLEAR PLANT WITH EQUIVALENT STRUCTURES AT SEQUOYAH NUCLEAR PLANT

Watts Bar Nuclear Plant (WBN) main plant structures were intended to be physically identical to Sequoyah Nuclear Plant (SQN) main plant structures. However, the seismic loads at WBN are somewhat larger than those at SQN because of differences in the shapes of the design spectra and the input ground motions. (Both SQN and WBN are designed for 0.09 g, operating base earthquake, and 0.18 g, safe shutdown earthquake, defined at top of rock.) Because of the larger seismic load and the attempt to duplicate at WBN the SQN structural dimensions, member sizes, etc., the amount of reinforcement in the concrete structures is generally greater at WBN that at SQN. In addition, certain structures (Intake Pumping Station, Discharge Overflow Structure, Standpipe Structure, and ERCW Support Slab) are not physically identical at SQN/WBN.

I. Reactor Building

A. Major Physical Differences

The major physical difference between the WBN and SQN reactor buildings is that the SQN base slab is anchored to bedrock with reinforcing bars and WBN requires no anchorage.

B. Loads and Loading Combinations

1. The load combinations are essentially the same when comparing WBN and SQN reactor building structures. Both structures were required to satisfy the load combinations recommended by the American Concrete Institute (ACI)-American Society of Mechanical Engineers Joint Committee contained in the code (ACI 359) for Concrete Reactor Vessels and Containments.

2. The loads were essentially the same except that the loss of coolant accident design pressures for WBN are a little higher than those for SQN.

C. Design and Analysis Procedures

In most cases the analyses and design methods for WBN were similar to SQN.

II. Auxiliary Control Building

A. Major Physical Differences

1. The auxiliary control building at WBN is comprised of three separate category I structures: auxiliary and control building, the waste packaging area, and the condensate demineralizer waste evaporator building. For SQN, in addition to the structures listed above, the additional equipment building is also a separate category I structure. The additional equipment building is in the same general location as the structure for WBN but is separated from the rest of the auxiliary building by a 2-inch expansion joint filled with fiberglass insulation. The additional equipment building at WBN is an integral part of the auxiliary building.

2. The entrance of the railroad into the auxiliary building is on the unit 1 side for SQN and on the unit 2 side for WBN. This situation creates some physical differences for those category I structures located within that vicinity. The waste packaging area for both plants are opposite hand from one another. Also, the additional equipment buildings are reversed for both plants. That is, the SQN unit 1 structure is the same as the WBN unit 2 structure. Conversely, the SQN unit 2 structure is the same as the WBN unit 1 structure.

3. The waste packaging area structures for SQN and WBN are supported on H-bearing piles and crushed stone backfill, respectively. The structures for both plants have generally the same configuration except the interior walls are opposite hand as compared to each other (item 2).

4. The auxiliary and control buildings for both plants are founded on rock. At SQN the 2-foot-thick base slab is anchored into rock to resist hydrostatic uplift pressures under flood conditions. At WBN the auxiliary building portion of the base slab is 7-feet thick while the control bay portion is 5-feet thick. Due to these thicknesses anchorage into rock is not required to resist hydrostatic uplift pressures.

B. Loads and Loading Combinations

The loads and loading combinations are essentially the same when comparing WBN and SQN category I structures.

C. Design and Analysis Procedures

1. In most instances the designs for WBN were duplicated from SQN. WBN was designed in accordance with ACI 318-71; whereas at SQN the waste packaging area and the condensate demineralizer waste evaporator building were designed in

accordance with ACI 318-71 and the auxiliary and control building was designed in accordance with ACI 318-63.

2. The base slab for the waste packaging area at SQN was designed to be supported by a bearing pile foundation. The corresponding base slab for WBN was designed as a slab on an elastic foundation.

III. Main Steam Valve Rooms

A. Major Physical Differences

The structures are basically the same except for two major differences.

1. The east steam valve rooms at SQN are vented by the use of blowout panels in the roof and east walls. The north steam valve rooms at WBN are vented by separate compartments added to the ends of the structures and blowout panels in the roof.

2. The east steam valve rooms at SQN are supported by eight concrete caissons four feet in diameter anchored into rock. The north steam valve rooms at WBN rest on a grillage of reinforced concrete foundation walls supported to rock.

B. Loads and Loading Combinations

The loads and loading combinations are essentially the same for both plants.

C. Design and Analysis Procedures

1. The east steam valve rooms at SQN were originally designed to be supported on spread footings. Due to excessive settlement of the structures, the decision was made to underpin the base slabs of each structure. Large concrete caissons were designed to be socketed into rock and anchored into the existing base slabs.

2. The north steam valve rooms at WBN rest on reinforced concrete walls placed on rock.

IV. Diesel Generator Building

A. Major Physical Difference

The only major physical difference between the diesel generator buildings for both plants is in the configuration of the base slabs. The base slab for the structure of SQN is supported on soil. A concrete apron extending 13 feet from the edge of the structure on each side was used to decrease the bearing pressures on the soil subgrade. The base slab for the structure at WBN is supported on a crushed stone backfill. Due to higher allowable bearing pressures, the concrete apron mentioned above for SQN was not needed for WBN.

B. Loads and Loading Combinations

The loads and loading combinations are identical for the structures at both plants.

C. Design and Analysis Procedures

There were essentially no differences in the design and analysis procedures.

V. Pipe Tunnels

A. Major Physical Differences

The major physical differences are in the concrete thickness. WBN has 24-inch walls and roof with a 36-inch base slab. SQN has 18-inch walls and roof with a 24-inch base slab.

B. Load and Loading Combinations

The major difference in loads is the addition of vertical automobile missile impact at WBN. Loading combinations are essentially the same.

C. Design and Analysis Procedures

WBN was designed in accordance with ACI 318-71, whereas SQN was designed in accordance with ACI 318-63.

VI. Refueling Water Storage Tank

A. Major Physical Differences

The only major physical difference between the SQN and WBN refueling water storage tank foundations is the arrangement of the shear keys. SQN utilizes two perpendicular shear keys 3' deep along the centerline of the circular foundation (53'-6" diameter); WBN utilizes a 6' deep shear key located at the outer edge of the circular foundation (57'-0" diameter) and continious along the circumference of the foundation.

B. Loads and Loading Combinations

The load combinations are essentially the same when comparing SQN and WBN Refueling Water Storage Tanks.

C. Design and Anlalysis Procedures

Design and analysis procedures are essentially the same.

VII. 125-Ton Auxiliary Building Crane

A. Major Physical Differences

The main structural members of the trolley are bolted to the end trucks for WBN and welded for SQN.

B. Loads and Loading Combinations

Loads and loading combinations are the same.

C. Design and Analysis Procedures

The crane bridges were designed by TVA using the same procedure for both plants. The remainder of each crane was designed by different vendors using their own procedures, but all results were reviewed by TVA.

VIII. 175-Ton Polar Crane

A. Major Physical Differences

The SQN trolley has four wheels and the main structural members are bolted to the end trucks. The WBN trolley has six wheels, is made of two sections pinned together, and the main structural members are welded to the end trucks.

B. Loads and Loading Combinations

Loads and loading combinations are the same.

C. Design and Analysis Procedures

The crane bridges were designed by TVA using the same procedure for both plants. The remainder of each crane was designed by different vendors using their own procedures, but all results were reviewed by TVA.

IX. ERCW Support Slab, Intake Station, Discharge Overflow Structure, and Standpipe Structures

As discussed above, these structures were not physically duplicated at WBN from SQN. These structures were designed independently and the FSAR's and Design Criteria should be reviewed for detailed information concerning physical differences, loads and loading combinations, and design analysis procedures.