TENNESSEE VALLEY AUTHORITY
CHATTANOOGA, TENNESSEE 37401
400 Chestnut Street Tower II

November 30, 1982

Director of Nuclear Reactor Regulation
Attention: Ms. E. Adensam, Chief
Licensing Branch No. 4
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Ms. Adensam:

In the Matter of the Application of)	Docket Nos. 50-390
Tennessee Valley Authority)	50-391

Enclosed are responses to TVA action items resulting from the NRC's geotechnical audit of Watts Bar Nuclear Plant conducted September 22 through 24, 1982. This completes TVA action with the exception of the analysis of axial stresses on buried pipe which will be provided by March 5, 1983.

If you have any questions concerning this matter, please get in touch with D. P. Ormsby at FTS 858-2682.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

L. M. Mills

L. M. Mills, Manager
Nuclear Licensing

Sworn to and subscribed before me
this 30th day of Nov, 1982.

Bryant M. Lowery
Notary Public

My Commission Expires 4/8/86

B001

Enclosure
cc: U.S. Nuclear Regulatory Commission
Region II
Attn: Mr. James P. O'Reilly, Regional Administrator
101 Marietta Street, Suite 3100
Atlanta, Georgia 30303

ENCLOSURE
WATTS BAR NUCLEAR PLANT UNITS 1 AND 2

NUCLEAR REGULATORY COMMISSION
AUDIT ON GEOTECHNICAL DESIGN FEATURES

Action Item 1

Provide the following information related to the cyclic load tests on silty sands.

A. Procedures used to obtain test samples.

B. Lab procedures used during testing.

C. Correlation between drill holes and specific equipment used for each hole.

D. Composition of the drill string used for each hole.

Response:

Part A

The initial field investigation was completed between July 24 and August 19, 1975, with two Mobile model B-50 drills. The standard penetration test (SPT) borings were advanced by dry methods using 3-3/8-inch internal diameter (I.D.) hollow stem augers. Standard 2-inch split barrel samplers complying with specification ASTM D 1586 and equipped with light duty spring retainers were used for sampling. The string of tools was exclusively AW drill rods. Safety-type 140-lb drive hammers were used. One wrap of rope was used on the cathead. Blow counts were recorded for each 0.5-ft interval driven and sample recovery recorded. Drilling and sampling were in accordance with ASTM D 1586 procedures. Sample descriptions were recorded on both the drilling log and sample tags. Samples were immediately sealed in glass pint jars and temporarily stored in an onsite building to avoid extreme temperatures.

The undisturbed sampling borings were also advanced by dry methods, but using 6-inch I.D. hollow stem augers. Samples were taken with 5-inch-diameter thin-walled tubes conforming to specifications in ASTM D 1587 and attached to a piston-type sampler. Samples were sealed on both ends with at least 1 inch of beeswax-paraffin sealing wax. Depths of sample recovery were recorded on drill logs and sample tags. Samples were transported on rubber padded racks for temporary storage to an onsite building to avoid extreme temperatures. A covered vehicle with rubber padded racks was used to transport the samples from temporary storage to TVA's Singleton Materials Engineering Laboratory. Certified soils technicians performed all handling, moving, and transportation of specimens. A report was issued on March 17, 1976.

A subsequent field exploration was completed between May 30 and July 3, 1979. Equipment used was a CME-55 drill and a Mobile B-50 drill. The methods and sampling equipment used on the SPT borings exactly match those described above for the report of March 17, 1976.

Rotary drilling methods were used between sampling elevations in the undisturbed sample borings. Bentonite drilling fluid was used. The 5-1/2-inch wide drag bit was equipped with baffles which deflected the drilling fluid upward. Samples were obtained with 5-inch diameter thin-walled tubes attached to a piston sampler. Samples were sealed on both ends with a beeswax-paraffin mixture and temporarily stored onsite to protect them from extreme temperatures. They were transported to the laboratory on rubber-padded racks in a vehicle driven by a soils technician.

No engineering testing was required on these samples. However, following standard practice, the tube samples were extracted and unit weights and general classification tests conducted and recorded, although not formally reported. A report was issued on November 1, 1979.

Additional SPT borings were completed between November 4 and 24, 1981. All borings were drilled with a Mobile B-61 drill. Procedures followed the recommendations in attachment 1A.

On all Watts Bar Nuclear Plant ERCW assignments, one drill operator was assigned to and stayed with, a specific drill. Exceptions would normally occur only in case of illness or other personal emergencies. Such situations are not documented.

Ropes used in drilling are normally replaced when noticeably worn on the initiative of either the driller or inspector. There are no specific guidelines or documentation. During the 1975 and 1979 investigations, it is judged that the ropes were used and somewhat limp. During the 1981 investigations, the ropes were new and stiff in accordance with specific instructions.

During all investigations, a 140-pound Mobile safety-type drive hammer, model No. 006981, was used.

Test pits were excavated by a Gradall excavator equipped with a 3 yd^3 smooth bucket. Side walls were excavated to about a 1 to 1 slope. Dewatering was facilitated by installing a section of perforated 18-inch-diameter pipe surrounded by a 3/4 inch ($\pm$) crushed stone filter. Samples were obtained by benching into the side wall and hand trimming 1 ft^3 blocks with handtools. The trimmed top and sides were covered with three alternating layers of cheesecloth and paraffin. The sample was then cut at the bottom which was covered in a similar manner. Samples were placed in a wooden box surrounded with damp sawdust padding. A soil technician immediately transported the blocks on styrofoam pads to the laboratory. A report was issued on December 21, 1981.

Part B

Details of the Cyclic Triaxial Test Procedure Applied on Specimens from the Watts Bar Nuclear Plant ERCW Conduit Investigation

1. Test specimens were hand-trimmed from the undisturbed samples by a senior technicial using a split trimming tube 2.8 inches in diameter and 6.3 inches in height.

2. After removal from the trimming tube, the specimen was encased in a rubber membrane, the average thickness of which had been previously determined, and was then placed on the bottom platen of the triaxial testing machine.

3. The membrane was sealed at the top and bottom platens with O-rings. A small vacuum of about five inches of mercury was applied to the specimen.

4. Measurements of specimen diameter were made with pi tape at the center and at the quarter points. The specimen height was determined with a steel rule at 90-degree intervals around the specimen.

5. After zeroing the readout of axial load, deformation, pore water pressure, and cell pressure, the cyclic triaxial cell was assembled. Then the vacuum in the specimen was gradually reduced to zero while simultaneously increasing cell pressure to 3 psi.

6. The specimen was flushed continuously and slowly with distilled deaerated water from bottom to top at a pressure of 10-in. water head until no air bubbles were observed exiting from the specimen.

7. A back pressure was then applied to the specimen in an increment of 10 lb/in^2. The pressure differential between the cell and back pressure was maintained at 3 lb/in^2 throughout the saturation phase.

8. Step 6 was repeated at every level of the back pressure increment. At the final stage of back pressure saturation, Skempton's pore pressure parameter B was checked with drainage lines closed and at 6 lb/in^2 confining pressure. The parameter B was defined as:

$$B = \frac{\Delta u}{\Delta \sigma_3}$$

where Δu = pore pressure increase

$\Delta \sigma_3$ = an increase in confining pressure

9. After completion of saturation, the specimen was consolidated overnight at 2000 psf confining pressure.

10. Prior to the cyclic loading test, the B value was checked again. Step 6 was repeated if needed.

11. During consolidation, the change in height and the volume change of the specimen were measured. Thus, the area, volume, and dry density of the specimen after consolidation could be calculated.

12. In addition, specimen and pore water pressure system leaks were checked by closing the drainage lines and measuring pore water pressure response. The change of pore water pressure was less than 2 percent of the confining pressure over a 5-minute interval.

13. The specimen was cyclically loaded without drainage using a pneumatic system which applied a square wave with a degraded rise time at a frequency of 1 Hz. (See NRC publication NUREG-0031, p. 96.)

14. During cyclic loading, changes in axial load and deformation, pore water pressure, and confining pressure were recorded on 8-inch photosensitive paper using a Honeywell Visicorder.

15. Cyclic loading was continued until a double-amplitude strain of 20 percent was attained.

16. After completion of cyclic loading, the test specimen was dried in a conventional oven for determination of moisture content.

Part C

See attachment 1C for correlation between drill holes and specific equipment used for each hole.

Part D

See Attachment 1D for composition of the drill string used for each hole.

ATTACHMENT 1A
RECOMMENDED PROCEDURES AND GUIDELINES FOR STANDARD PENETRATION TESTING WATTS BAR NUCLEAR POWER PLANT (ACTION ITEM 1)

General

The procedures shall conform to ASTM D 1586 with the following modifications and additions.

Drilling

1. Rotary drilling methods and drilling mud shall be used. Casing shall not be used except as needed in the upper few feet of the boring to provide good circulation of the driling mud.

2. Drilling mud shall be sufficiently viscuous to lift the cuttings out of the boring and provide a clean hole at the time of sampling, to minimize caving and sloughing of the borehole walls, and to minimize water losses. As a guideline, the marsh funnel viscosity of the drilling mud should be equal to or greater than 40.

3. The hole diameter shall be 4 to 5 inches.

4. The drilling bits shall be fishtail bits equipped with deflectors to provide radial or upward discharge of the drilling fluid. The use of bits that discharge drilling fluid directly down onto the soil at the bottom of the borehole is not permitted.

5. The hole shall be thoroughly cleaned of cuttings prior to sampling.

6. The depth of the borehole shall be measured after drilling and prior to insertion of the sampler into the borehole. (This can be accomplished from knowledge of the lengths of drill rods in the hole during drilling.)

Sampling

1. The required sampler dimensions are given in ASTM D 1586. Typically, however, these samplers are manufactured with a slightly larger inside diameter to provide a space for thin liners. It is preferred to use the typical sampler but without using the liners.

2. The level of drilling mud in the boring is required by ASTM D 1586 to be at or above the ground water level. However, in rotary drilling, it is desirable and practical to have the water level essentially at the ground surface during both drilling and sampling.

3. The depth of the drill hole shall be measured after inserting the sampler. This depth shall be compared with the depth measured after drilling to indicate any accumulation of cuttings in the borehole.

4. A rope-and-cathead system shall be used to lift and release the falling weight. Two turns of rope shall be provided around the cathead.

5. The sampler should be driven for the full 18 inches. A record of the blows for each 6 inches of drive should be maintained.

6. After recovering the sample, the length of recovery shall be measured, and the entire sample shall be examined and classified.

7. Samples shall be stored in glass jars sealed to preserve the natural water content of the soil. The pieces of samples shall be maintained as intact as possible (i.e., intact sample pieces should not be broken up and mixed together). Jars shall be labeled to identify the location and position of the sample pieces in the sampler.

Record Keeping

In addition to the usual boring log, a log shall be maintained for each sample. It is suggested that this log be on an 8-1/2 by 11-inch sheet of paper showing the entire sample length. Information to be shown thereon includes:

1. Total length of drive of the sampler (usually 18 inches).

2. Position of the recovered sample in the sampler.

3. Total recovery (in inches) and percent recovery.

4. The record of the blows for each 6 inches of drive.

5. The description and classification of the sample along its length (different segments may have different description and classifications if changes in soil type occur in the sample.)

6. Identification of the jars containing the pieces of the sample.

(PART C)

ATTACHMENT 1C

WATTS BAR NUCLEAR PLANT

ERCW CONDUIT

1976 REPORT

Boring No.	Drill No.	Drill Model	Boring Depth
SS-65	91930	Mobile B-50	50.5
SS-67	91930		44.5
SS-69	91930		66.1
SS-71	91930		59.4
SS-73	92251		37.8
SS-74	92251		34.2
SS-75	92251		41.5
US-75	92251		10.0
SS-76	92251		31.5
SS-77	92251		40.9
US-77	92251		22.0
SS-78	92251		25.5
SS-80	92251		61.7
SS-82	91930		37.5
SS-84	91930		35.6
SS-86	92251		38.5
SS-87	92251		43.4
SS-88	91930		42.1
SS-90	91930		58.8
SS-92	91930		45.3
US-92	92251		22.0
SS-93	91930	Mobile B-50	19.3

WATTS BAR NUCLEAR PLANT

ERCW CONDUIT

1976 REPORT

(Continued)

Boring No.	Drill No.	Drill Model	Boring Depth
SS-94	92251	Mobile B-50	12.2
US-94	92251		8.2
SS-95	92251		21.3
SS-96	91930		31.8
SS-97	91930		45.2
SS-97A	91930		14.5
US-97A	92251		8.3
SS-99	91930		29.8
SS-101	91930		24.8
SS-103	91930		44.0
US-103	92251		19.1
SS-104	91930		33.3
SS-105	92251		10.0
SS-106	92251		31.9
US-106	92251		10.5
SS-107	91930		26.0
US-107	92251		23.3
SS-108	91930		16.8
US-108	92251	Mobile B-50	8.3

WATTS BAR NUCLEAR PLANT

ERCW CONDUIT

1979 REPORT

Boring No.	Drill No.	Drill Model	Boring Depth
SS-131	92357	CME-55	36.0
SS-132	419991	CME-75	38.0
SS-133	419991	CME-75	39.5
SS-134	419991	CME-75	45.5
SS-135	419991	CME-75	45.0
SS-136	91930	Mobile B-50	44.0
SS-137	419991	CME-75	32.0
SS-138	419991	CME-75	42.5
SS-139	92357	CME-55	54.0
SS-140	419991	CME-75	38.5
SS-141	419991	CME-75	39.5
SS-142	419991	CME-75	46.5
SS-143	419991	CME-75	46.0
SS-144	419991	CME-75	45.5
SS-145	419991	CME-75	40.5
SS-146	91930	Mobile B-50	71.5
SS-147	91930	Mobile B-50	57.5
SS-148	419991	CME-75	38.0
SS-149	419991	CME-75	36.0
SS-150	419991	CME-75	21.0
SS-151	419991	CME-75	34.0
SS-152	91930	Mobile B-50	26.0
SS-153	91930	Mobile B-50	26.0
SS-154	419991	CME-75	31.5
SS-155	91930	Mobile B-50	21.0
SS-156	419991	CME-75	21.0
SS-157	91930	Mobile B-50	25.5
SS-158	419991	CME-75	28.0
SS-159	419991	CME-75	33.5
SS-160	91930	Mobile B-50	33.5
SS-161	419991	CME-75	37.0
SS-162	91930	Mobile B-50	31.5
SS-163	419991	CME-75	33.5

WATTS BAR NUCLEAR PLANT

ERCW CONDUIT

1979 REPORT
(cont'd)

Boring No.	Drill No.	Drill Model	Boring Depth
SS-164	91930	Mobile B-50	40.0
SS-165	419991	CME-75	41.0
SS-166	91930	Mobile B-50	37.0
SS-167	91930	Mobile B-50	34.5
SS-168	419991	CME-75	37.0
SS-169	419991	CME-75	39.0
SS-170	419991	CME-75	71.0

WATTS BAR NUCLEAR PLANT

ERCW CONDUIT

1981 REPORT

Boring No.	Drill No.	Drill Model	Boring Depth
SS-49A	93634	Mobile B-61	25.0
SS-50A	93634		26.8
SS-65B	93634		26.5
SS-134A	93634		26.0
SS-135A	93634		26.5
SS-138A	93634		26.0
SS-138B	93634		24.5
SS-138C	93634		24.5
SS-143A	93634		30.5
SS-143B	93634		29.5
SS-143C	93634		30.0
SS-158A	93634		21.5
SS-161A	93634		26.5
SS-163A	93634	Mobile B-61	30.5

ATTACHMENT 1D

DRILL ROD LENGTHS AND WEIGHTS VERSUS SPT SAMPLE DEPTHS

APPLYING TO 1976 AND 1979 REPORTS

Boring Depth (ft)	Drill Rod* (AW) Length (ft)	Drill Rod* (AW) Weight (lbs)
0 - 5	5	21
5 - 10	10	42
10 - 15	15	63
15 - 20	20	84
20 - 25	25	105
25 - 30	30	126
30 - 35	35	147
35 - 40	40	168
40 - 45	45	189
45 - 50	50	210
50 - 55	55	231
55 - 60	60	252
60 - 65	65	273
65 - 70	70	294
70 - 75	75	315

Weight of safety hammer and drive stem	178.8 lbs
Weight of safety hammer	140.0 lbs
Weight of drive stem	38.8 lbs
Weight of split barrel sampler	15.7 lbs
Length of split barrel sampler	2.8 ft

*rods in 5 ft increments

DRILL ROD LENGTHS AND WEIGHTS VERSUS SPT SAMPLE DEPTHS

1981 REPORT

Boring Depth (ft)	Drill Rod* (AW) Length (ft)	Drill Rod* (AW) Weight (lbs)
0 - 6.5	5	21
6.5 - 9.0	10	42
9.0 - 14.0	15	63
14.0 - 19.0	20	84
19.0 - 24.0	25	105
24.0 - 29.0	30	126
29.0 - 34.0	35	147
34.0 - 39.0	40	168

Weight of safety hammer and drive stem	178.8 lbs
Weight of safety hammer	140.0 lbs
Weight of drive stem	38.8 lbs
Weight of split barrel sampler	15.7 lbs
Length of split barrel sampler	2.8 ft

*rods in 5 ft increments

Action Item 2

Provide the rationale used for concluding that the samples used in the cyclic testing are representative of actual field conditions.

Response:

Based on a comparison of the soil classification, grain size distribution, and densities of the test pit samples with samples from the soil borings, it can be concluded that the test pit samples are representative of the actual field conditions.

Tables 1 and 2 are comparisons of the classification data for the samples from test pits 1 and 2, respectively with the classification data for SM soils from the split-spoon borings closest to each test pit respectively. Figure 1 is a plot of the gradation of the samples from test pit 1 compared with the range of gradations for the split-spoon samples given in table 1. Figure 2 is a plot of the gradation of the samples from test pit 2 compared with the range of gradations for the split-spoon samples given in table 2. The information contained in these tables and figures shows that the data on the undistributed block samples correlates very well with the data from the split-spoon borings nearest the test pits.

Tables 3 and 4 are tabulations of the classification data for the split-spoon samples from the borings along the ERCW pipeline in the area south of the cooling towers and in the main plant area respectively, and have a factor of safety less than 1.05 as calculated and presented by our consultant in the report, "Liquefaction Evaluation of the ERCW Pipeline Route-Watts Bar Nuclear Plant." (Reference a letter from L. M. Mills to E. Adensam dated November 16, 1982.) These factors of safety are calculated on the basis of standard penetration test blow counts and are summarized in table 1 of the referenced report. Figure 3 is a plot showing the mean gradation for the test pit samples in comparison with the maximum, minimum, and mean gradations of the split-spoon samples in table 3. Figure 4 shows the same information, but for the split-spoon samples in table 4. These two figures show reasonably good correlation between the gradation of the test pit samples and the gradations of the split-spoon samples that have the lowest factors of safety in our liquefaction analysis.

Table 5 is a comparison of the classification and density data on the test pit samples and the undistributed SM samples taken along the ERCW pipeline. The average density for the undistributed samples from the soil borings was 90.4 lb/ft^3 and for the undistributed samples from the test pits was 86.4 lb/ft^3. This is reasonably good agreement. Since the test pit samples had a lower density than the samples from the undistributed borings, this indicates that the results from the test pit samples are not only valid but are representative of the worst field conditions at the site.

TABLE 1

SUMMARY OF CLASSIFICATION DATA

Pit No.	Sample No.	Gravel (%)	Sand (%)	Fines (%) Silt (%)	Fines (%) Clay (%)	Class	LL	PI	W (%)
1	1A-1	0	57	27	16	SM	NP	NP	24.7
(el. 706.6)	1A-2	0	67	21	12	SM	NP	NP	28.6
	1A-3	0	63	23	14	SM	NP	NP	28.5
	1A-4	0	64	24	12	SM	NP	NP	26.9

Split-Spoon Boring Sample	Elevation	Gravel (%)	Sand (%)	Fines (%)	Class	LL	PI	W (%)
SS-134	710.2	0	74	26	SM	NP	NP	29.3
	708.2	0	69	31	SM	NP	NP	27.5
SS-134A	710.2	0	65	35	SM	23.0	1.0	30.0
	709.6	0	69	31	SM	NP	NP	29.1
	707.7	0	63	37	SM	24.0	2.0	27.9
	707.2	0	57	43	SM	24.0	1.0	28.9
	706.4	0	68	32	SM	NP	NP	31.9
SS-135A	714.5	0	51	49	SM	31.0	3.0	24.3
	712.5	0	67	33	SM	NP	NP	22.8
	710.5	0	71	29	SM	NP	NP	24.3
	708.5	0	71	29	SM	NP	NP	34.2
	706.8	0	67	33	SM	22.0	1.0	27.0
	704.2	2	63	35	SM	NP	NP	30.9

TABLE 2

SUMMARY OF CLASSIFICATION DATA

Pit No.	Sample No.	Gravel (%)	Sand (%)	Fines (%) Silt (%)	Fines (%) Clay (%)	Class	LL	PI	W (%)
2	2A-1	0	69	22	9	SM	NP	NP	26.7
Red to	2A-2	0	69	20	11	SM	NP	NP	28.9
Brown Sand	2A-3	0	66	25	9	SM	NP	NP	26.1
(el. 707.5)	2A-4	0	67	23	10	SM	NP	NP	26.2
2	1A-1	0	66	25	9	SM	NP	NP	33.3
Dark Brown	1A-2	0	64	25	11	SM	NP	NP	32.4
Sand	1A-3	0	64	26	10	SM	NP	NP	31.2
(el. 706.5)									

Split-Spoon Boring Sample	Elevation	Gravel (%)	Sand (%)	Fines (%)	Class	LL	PI	W (%)
SS-138	712.0	0	51	49	SM	28.1	2.5	24.0
SS-138A	713.2	0	50	50	SM	29.0	3.0	25.1
	711.2	0	64	36	SM	NP	NP	22.1
	707.4	0	60	40	SM	28.0	2.0	35.6
	705.4	0	69	31	SM	22.0	1.0	27.8
	705.0	0	79	21	SM	NP	NP	29.1
	703.0	0	79	21	SM	NP	NP	38.4
SS-138B	710.6	0	58	42	SM	27.0	3.0	24.7
	708.6	0	54	46	SM	34.0	5.0	36.2
	706.6	0	63	37	SM-SC	27.0	5.0	30.0
SS-138C	710.6	0	62	38	SM-SC	27.0	4.0	27.5
	708.6	0	54	46	SC	31.0	11.0	34.1

TABLE 3

SUMMARY OF CLASSIFICATION DATA

Split-Spoon Boring Sample	Elevation	Gravel (%)	Sand (%)	Fines (%)	Class	LL	PI	W (%)
SS-49A	690.7	2	67	31	SM	NP	NP	30.0
SS-50	697.8	0	57	43	SM	NP	NP	28.2
SS-50	693.8	0	53	47	SM	NP	NP	31.5
SS-134	710.5	0	74	26	SM	NP	NP	29.3
SS-134A	709.5	0	65	35	SM	23.0	1.0	30.0
SS-135A	708.5	0	71	29	SM	NP	NP	34.2
SS-65	706.0	0	66	34	SM	28.9	3.5	28.2
SS-65B	709.2	0	62	34	SM	25.0	1.0	33.1
SS-65B	707.2	0	66	34	SM	25.0	1.0	32.5
SS-138A	707.2	10	46	44	SM	25.0	2.0	28.1
SS-140	706.7	0	64	36	SM	NP	NP	38.7

TABLE 4

SUMMARY OF CLASSIFICATION DATA

Split-Spoon Boring Sample	Elevation	Gravel (%)	Sand (%)	Fines (%)	Class	LL	PI	W (%)
SS-158	711.5	0	56	44	SM	22.7	2.5	32.2
SS-162	713.8	0	64	36	SM	NP	NP	34.3
SS-163	717.0	0	55	45	SM	27.2	3.3	31.1
SS-163	715.0	0	57	43	SM	29.7	4.7	33.5
SS-163A	717.5	0	55	45	SM	30.0	3.0	36.3
SS-84	713.4	0	58	42	SM	24.8	2.2	30.1
SS-128	712.1	1	83	16	SM	NP	NP	23.7
SS-125	714.4	0	92	8	SM	NP	NP	20.0
SS-25	715.6	0	52	48	SM	NP	NP	29.2
SS-130	715.7	0	77	23	SM	NP	NP	17.8
SS-130	713.7	0	85	15	SM	NP	NP	15.5

TABLE 5 (Sheet 1)

COMPARISON OF CLASSIFICATION AND DENSITY
DATA OF TEST PIT AND UNDISTRIBUTED BORING SAMPLES

Pit No.	Sample No.	Class	Grain Size Analysis Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PI (%)	W (%)	γ_d pcf	R_D[1] (%)
1	1A-1	SM	0	57	27	16	NP	NP	24.7	91.6	88.5
(el. 706.6)	1A-2	SM	0	67	21	12	NP	NP	28.6	88.7	78.5
	1A-3	SM	0	63	23	14	NP	NP	28.5	89.5	81.5
	1A-4	SM	0	64	24	12	NP	NP	26.9	88.8	78.9
2	2A-1	SM	0	69	22	9	NP	NP	26.7	84.6	68.8
Red to	2A-2	SM	0	69	20	11	NP	NP	28.9	82.9	61.9
Brown Sand	2A-3	SM	0	66	25	9	NP	NP	26.1	83.6	64.7
(el. 707.5)	2A-4	SM	0	67	23	10	NP	NP	26.2	82.8	61.5
2	1A-1	SM	0	66	25	9	NP	NP	33.3	85.7	61.7
Dark Brown	1A-2	SM	0	64	25	11	NP	NP	32.4	86.1	63.3
Sand	1A-3	SM	0	64	26	10	NP	NP	31.2	86.4	64.5
(el. 706.5)											

TABLE 5 (Sheet 2)

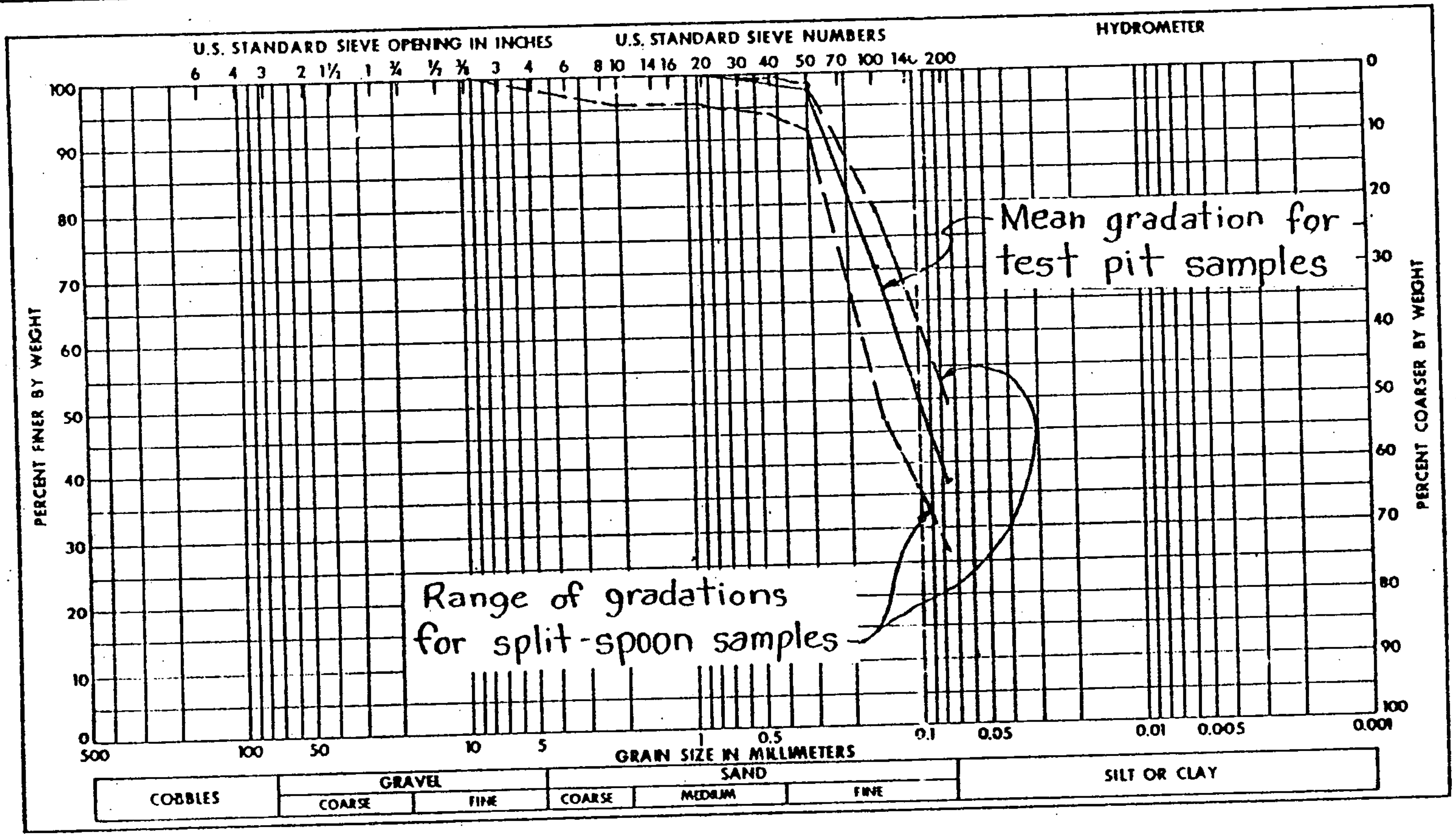
Undistributed Boring No.	el.[2]	Class	Grain Size Analysis Gravel (%)	Sand (%)	Silt (%)	Clay (%)	LL (%)	PI (%)	W (%)	γ_d pcf	R_D[1] (%)
US-50-1	701.4	SM	0	59	25	16	31.6	6.1	26.6	92.4	ND[3]
	698.9	SM	0	82	14	5	NP	NP	33.0	84.0	ND
	696.4	SM	0	88	9	4	NP	NP	28.9	93.1	ND
	695.3	SM	0	53	34	14	23.1	NP	31.1	90.4	ND
	694.2	SM	0	80	15	5	NP	NP	30.5	93.5	ND
US-50-1A	703.9	SM	0	64	24	12	NP	1.0	25.9	95.0	ND
	701.6	SM	0	67	22	11	NP	NP	37.8	79.2	ND
US-65-1	711.9	SM	0	70	22	8	NP	NP	22.2	88.6	ND
	709.4	SM	2	60	25	13	NP	NP	22.7	90.3	ND
	707.2	SM	0	65	24	11	NP	NP	33.4	87.0	ND
	705.2	SM	3	49	30	16	26.1	2.8	31.6	92.3	ND
US-77	715.1	SM	0	67	22	13	NP	NP	28.9	92.2	ND
US-92	715.9	SM	5	74	15	6	NP	NP	16.0	96.6	ND

Notes:

[1] R_D was determined in accordance with ASTM D2049.

[2] Elevation at top of sample.

[3] Not determined.



Soil Symbol		Liquid Limit, %	
Moisture Content, %		Plastic Limit, %	
Specific Gravity		Plasticity Index, %	
		Shrinkage Limit, %	

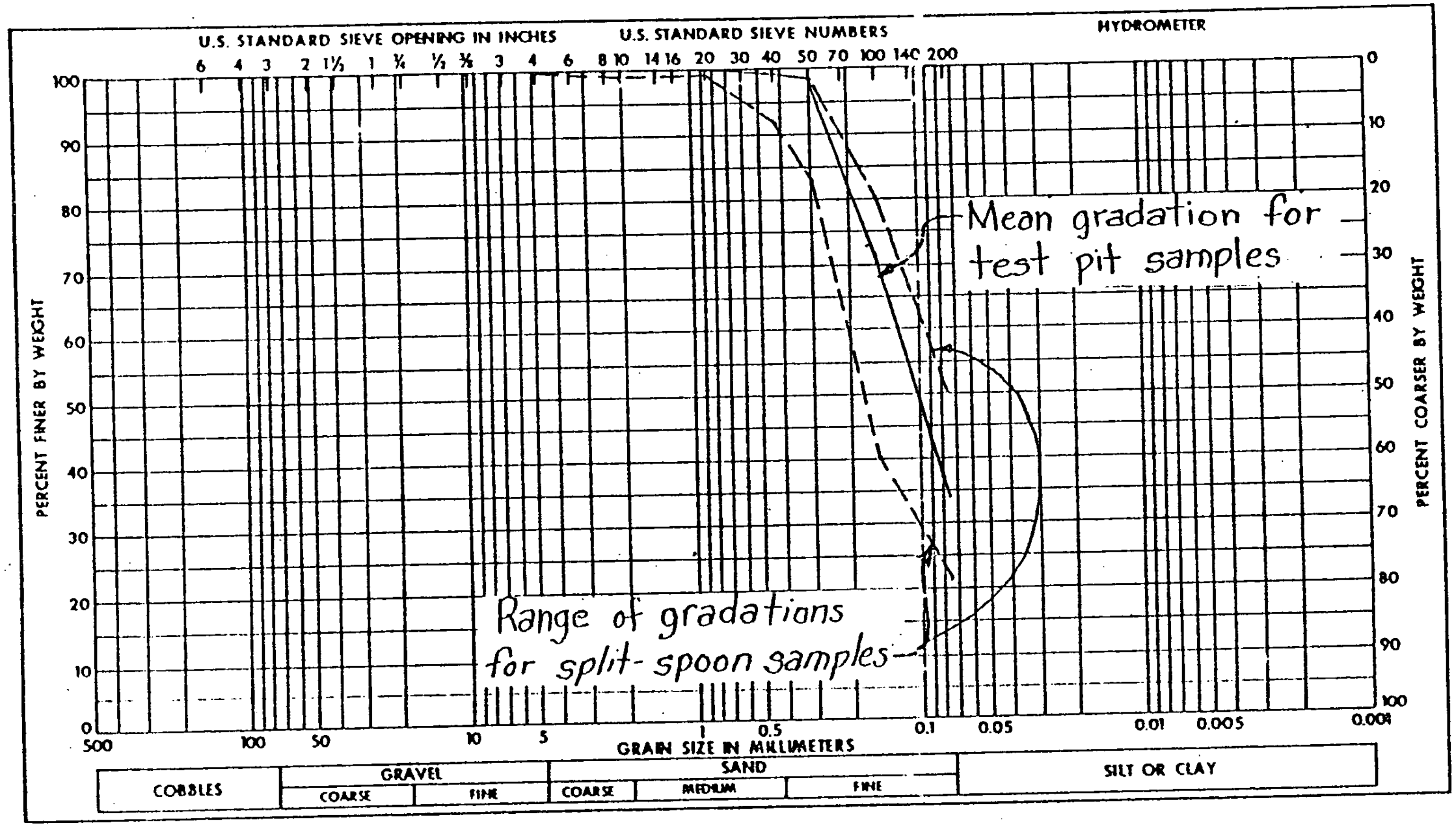
Remarks: *Comparison of Test Pit #1 samples with SM samples from split-spoon borings 134, 134A, & 135A*

Project Watts Bar Nuclear Plant Liquefaction Study
Feature ERCW Pipeline

Figure 1

GRAIN SIZE ANALYSIS

Tested by: ______ Reviewed by: ______



Soil Symbol		Liquid Limit, %	
Moisture Content, %		Plastic Limit, %	
Specific Gravity		Plasticity Index, %	
		Shrinkage Limit, %	

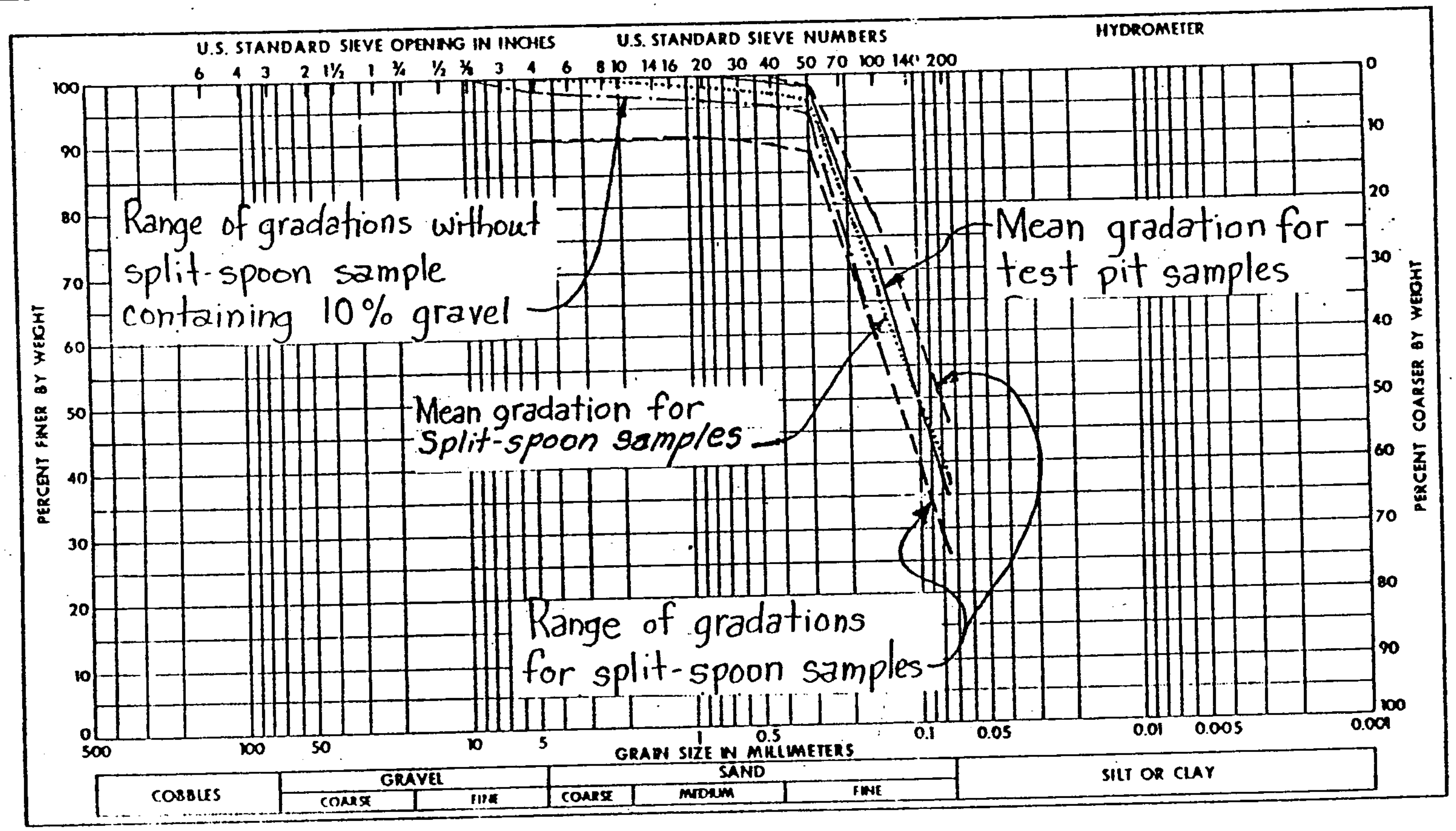
Remarks: Comparison of Test Pit #2 samples with SM (without gravel) samples from split-spoon borings 138, 138A, 138B, 138C, & 139

Project Watts Bar Nuclear Plant Liquefaction Study
Feature ERCW Pipeline

Figure 2

GRAIN SIZE ANALYSIS

Tested by: ______ Reviewed by: ______



Soil Symbol		**Liquid Limit, %**	
Moisture Content, %		**Plastic Limit, %**	
Specific Gravity		**Plasticity Index, %**	
		Shrinkage Limit, %	

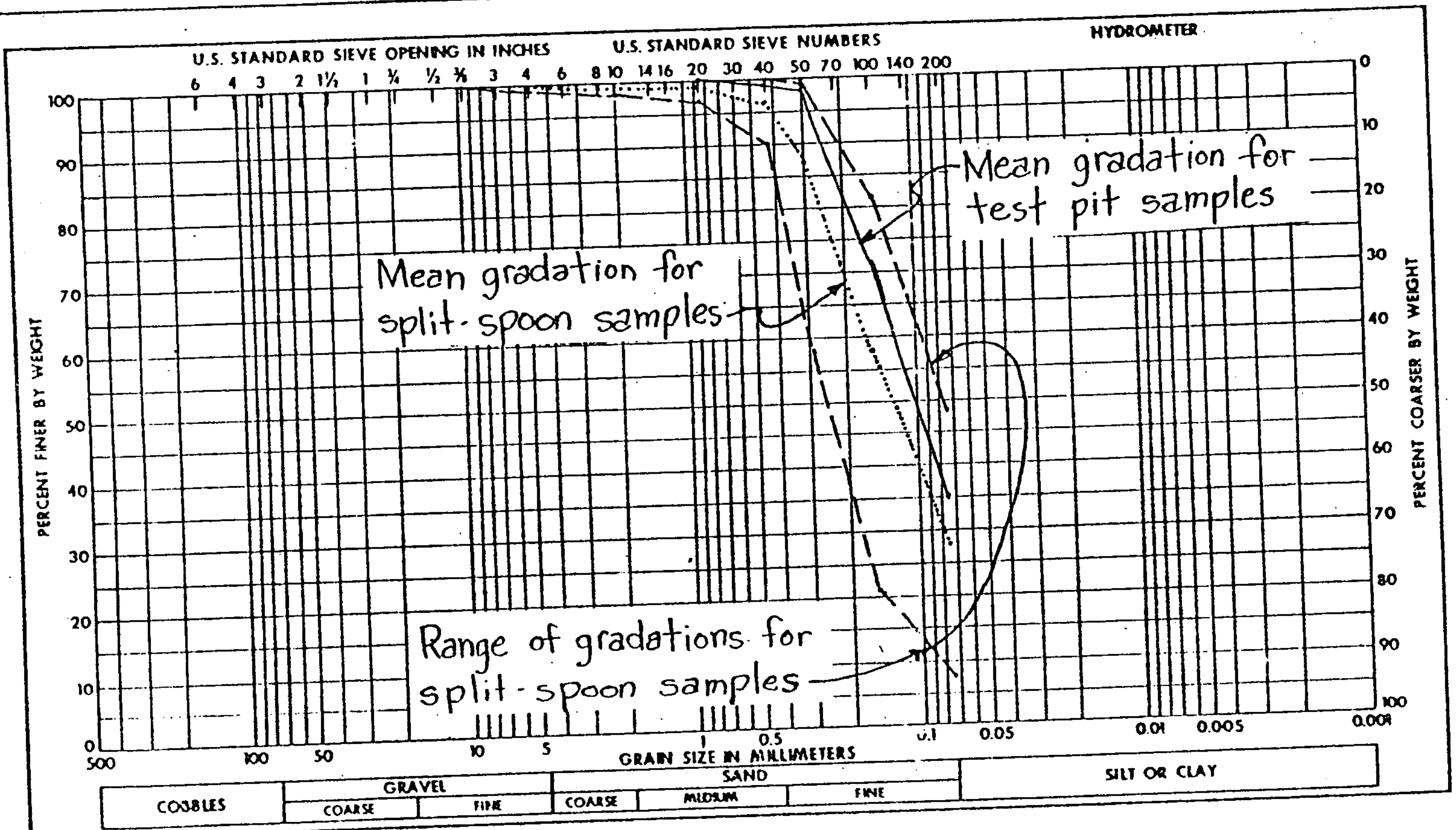
Remarks: Comparison of test pit samples with split-spoon samples from south of the cooling towers

Project Watts Bar Nuclear Plant Liquefaction Study
Feature ERCW Pipeline

Figure 3

GRAIN SIZE ANALYSIS

Tested by: ______________ Reviewed by: ______________



Soil Symbol		Liquid Limit, %	
Moisture Content, %		Plastic Limit, %	
Specific Gravity		Plasticity Index, %	
		Shrinkage Limit, %	

Remarks: Comparison of test pit samples with split-spoon samples from the main plant area

Project Watts Bar Nuclear Plant Liquefaction Study
Feature ERCW Pipeline

Figure 4

GRAIN SIZE ANALYSIS

Tested by: ______ Reviewed by: ______

Action Item 4

Verify that buried pipe is conservatively designed to withstand axial stresses under earthquake conditions.

Response:

This information will be supplied by March 5, 1983.

Action Item 5

Provide the Watts Bar Design Criteria for Buried Pipe.

Response:

Attached is TVA's Watts Bar Nuclear Plant Design Criteria WB-DC-40-31.5 "Design Criteria for Seismically Qualifying Buried Piping Systems".

TENNESSEE VALLEY AUTHORITY
DIVISION OF ENGINEERING DESIGN
MECHANICAL DESIGN BRANCH

WATTS BAR NUCLEAR PLANT

DESIGN CRITERIA
FOR
SEISMICALLY QUALIFYING BURIED PIPING SYSTEMS

WB-DC-40-31.5

May 23, 1972

UNCONTROLLED COPY

Sponsor Engineer E. Douglas Mysinger

Submitted J. E. Key Jr.

Recommended [illegible]

Approved D. B. Weaver

Reviewed Not Required
(NSSS Vendor as Required)

Mechanical	Electrical	Civil	Architectural
[illegible] CAC WMO [illegible]	[illegible] CHS RMH	RJH RCG OHR [illegible]	

Revisions

No. _____ Pages _____ Spon Engr _____ Subm _____ Recm _____ Appd _____ Date _____.

Mechanical	Electrical	Civil	Architectural	NSSS Vendor

CONTENTS

1.0 SCOPE

This document establishes criteria for seismic design and analysis of nuclear safety related buried piping systems. These criteria shall ensure that the system will withstand, without disrupting service, the ground accelerations imposed on the system by a safe shutdown earthquake. Where there is a conflict between this guide and the detailed specifications, the detailed specifications shall govern.

2.0 PROCEDURE

The primary emphasis in the seismic design of a buried piping system is to show through analysis that the system incorporates adequate flexibility to permit differential movement without damage, or sufficient strength in the pipe to exceed the soil strength.

2.1 DESIGN

2.1.1 No section of pipe shall be severed to install a flexible coupling without an analysis to show that the stresses in the pipe exceed code allowables, and that the coupling is necessary to relieve strains resulting from differential movement.

2.1.2 Option 1: If the analysis of the piping system indicates a necessity for flexibility at the penetration, the preferable design is to protect the pipe with an oversize opening in the structure and a flexible guard pipe as shown in Figure 2.1.2-1. If additional protection, support, or flexibility is required, a guard box should be considered.

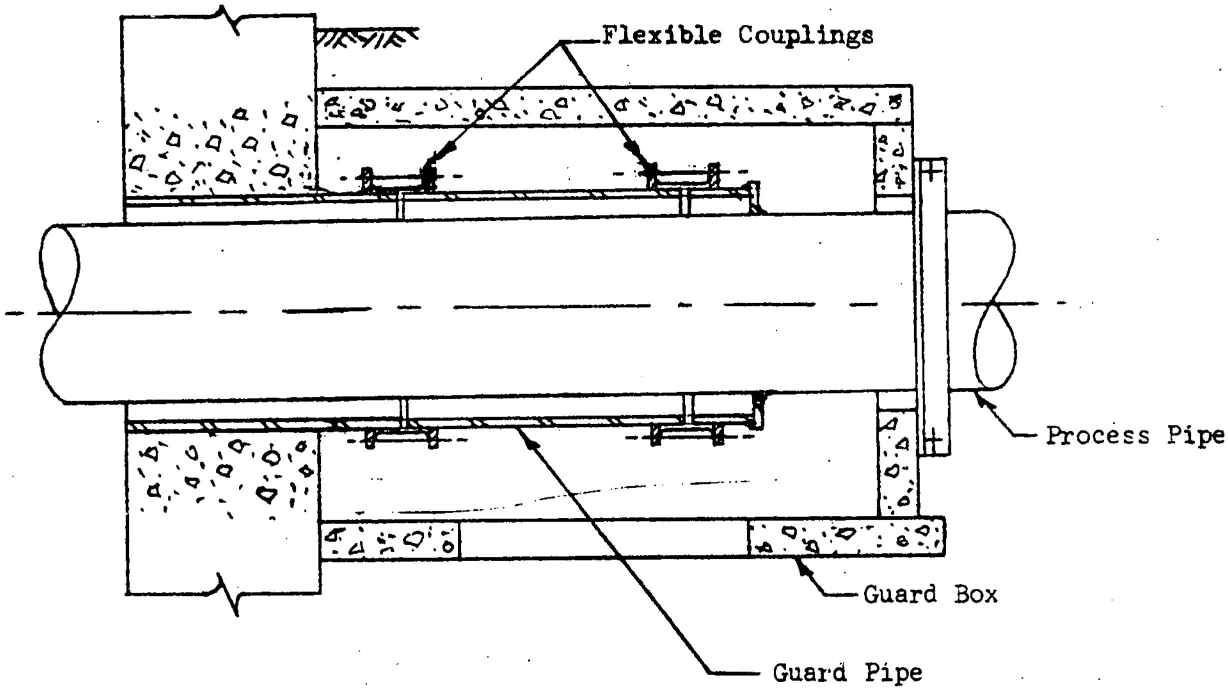


Figure 2.1.2-1

The flexible guard pipe consists of two flexible couplings and a section of oversize pipe. The guard pipe must be large enough to provide adequate clearance to permit one joint to move with the structure and one with the soil without contacting the process pipe. One end of the guard pipe is mounted in the structure to be penetrated and the other end is attached to the process pipe, with one coupling near the structure and the other near the attachment to the process pipe. Inside the structure, the process pipe must be supported with spring hangers for a minimum distance which varies with pipe diameter. At the penetration into the structure, additional flexibility, if required, may be provided the buried piping by a guard box. If used, one end of the guard box shall be supported on and butt against the structure, but shall not be attached to the structure. The box design shall provide adequate clearance to permit movement of the structure, pipe, and box without contacting the pipe.

2.1.3 <u>Option 2</u>: If Option 1 is not usable for a particular piping system design, Option 2 may be used. At the penetration into the structure, protect the buried piping from differential movement of the soil and structure by a guard box and flexible coupling as shown in Figure 2.1.3-1.

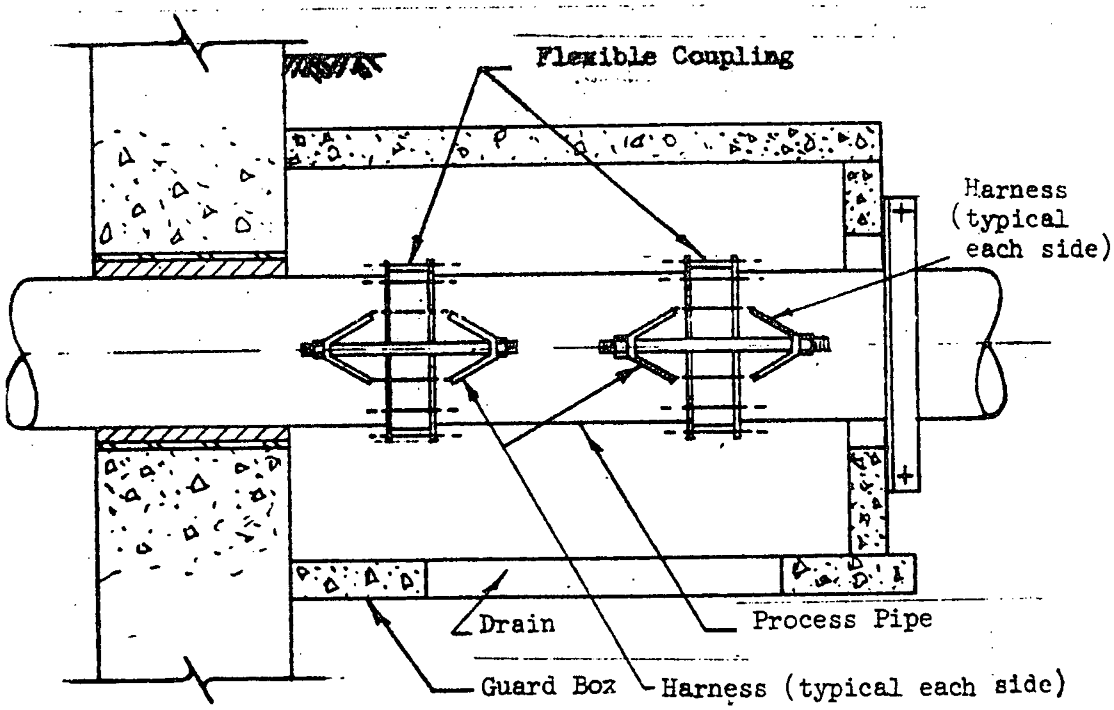
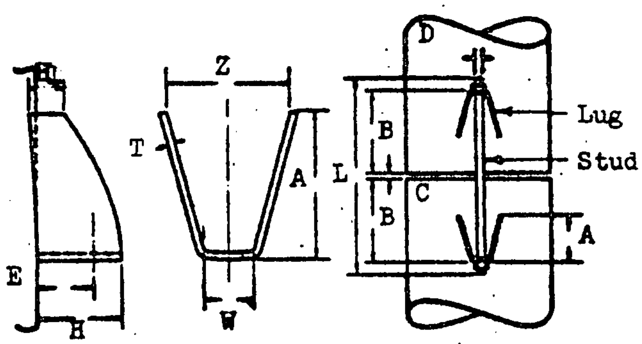


Figure 2.1.3-1

The guard box shall be supported on and butt against the structure, but not be attached to the structure. Locate one coupling near the structure and one near the soil end of the guard box. Design the box to provide adequate clearance to permit one joint to move with the structure and one with the soil without contacting the pipe. This method has the advantage of providing maximum flexibility and deflection in a limited area; however, the pipe is severed to install the coupling and is weakened longitudinally. This requires either a harness across the coupling to maintain longitudinal structural integrity, or that the severed pipe be securely anchored in the structure to resist the longitudinal force created by the pipe pressure. Pipelines having their intake from or discharge into an open reservoir or channel normally do not require longitudinal containment at the flexible couplings.

Table 2.1.3-1 provides the design criteria for an acceptable harness for pipe of 14- through 24-inch diameter and pressures to 150 psi. For larger pipe, or pressure, a complete design and stress analysis shall be required for each application.



Pipe Dia	Wall	Max Press.	A	W	Z	T	H	E	H1	D	Hole Dia
14	0.375	150	9-1/4	1-7/8	5-1/2	3/8	4	2-11/16	2	1	1-1/8
16	0.375	150	10-5/8	1-7/8	6-1/2	3/8	4	2-13/16	2	1	1-1/8
18	0.375	150	12	2-3/8	7-1/8	1/2	4-3/8	3	2-1/4	1-1/4	1-3/8
20	0.375	150	13-3/8	2-3/8	8-1/4	1/2	4-3/8	3-1/8	2-1/4	1-1/4	1-3/8
24	0.375	150	16	2-7/8	10	1/2	5	3-7/16	2-1/2	1-1/2	1-5/8

Table 2.1.3-1

The stud sizes are based on the use of two heat-treated studs with a minimum yield of 70,000 psi. The lug design is based on a material conforming to SA 285, Grade C, or equal.

2.1.4 The depth of the buried piping shall be maintained at a minimum throughout the design.

2.1.5 Where practical, underground piping in the field shall be routed to avoid unstable ground and shall not pass from natural ground into a fill area. In areas, such as adjacent to buildings, where underground piping systems must traverse the interface between native soil and engineering fill, an analysis must be made. This analysis shall include calculations to determine: (1) if the pipe has sufficient strength to bridge between the building and virgin soil, and support the soil above the pipe without exceeding the allowable strength of the material; or (2) if the pipe has sufficient strength to exceed the soil bearing strength and thereby redistribute the pipe loads without exceeding the code allowable. If the analysis shows that the pipe stresses are excessive, one of the preceding methods of installing flexible couplings may be used, or a beam may be designed to bridge across the fill area and support the pipe.

2.2 ANALYSIS

2.2.1 All nuclear safety related buried piping must be analyzed using either the methods shown below or other current dynamic seismic analytical methods, and must comply to ASME Boiler and Pressure Vessel Code, Section III.

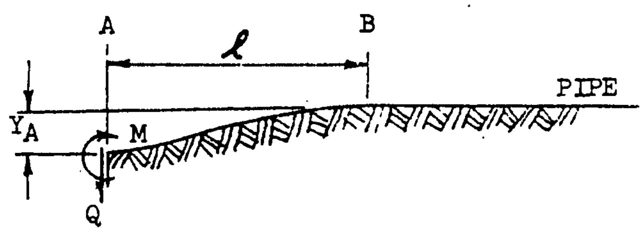
2.2.2 A dynamic seismic analysis of underground piping can be performed using the Engineering Data System computer program and appropriate seismic response spectrum of the soil. The analysis requires that the pipe be modeled with a series of fictitious members representing soil stiffness. Spacing of these fictitious members should be at each of the lumped mass points and there should be one spring member in the lateral and vertical direction at each such point. The fictitious member should consist of unit lengths, unit modulus of elasticity, and the area should be equal to the tributary soil stiffness, K. The tributary soil stiffness for each spring can be calculated as follows:

$$K = \frac{E \times D \times L}{0.37\,(1-\mu^2)\sqrt{D \times L}}$$

Where: E = Dynamic modulus of soil, psi
D = Outside diameter of pipe, inches
μ = Poisson's ratio for soil
L = Tributary length of pipe to the point under consideration. Approximately equal to the distance between fictitious points.

2.2.3 If a suitable anchor is not provided at the point where the pipe penetrates the structure, the dynamic seismic analysis must be continued inside the structure to a suitable location for terminating the analysis. This approach is mandatory in order to ensure that the stress levels in the pipe and pipe support structure do not exceed the allowables specified by the ASME Boiler and Pressure Vessel Code, Section III. However, when analyzing the pipe inside the structure, the soil may be considered an anchor and the pipe analysis terminated at that point.

2.2.4 Pipe stresses due to the relative movement of the soil and the building, whether they are caused by seismic deflections or by settlement of the soil, must be calculated, and combined with those stresses resulting from seismic ground deformation. These stresses may be calculated from the following values for shear and moment:



Y_A = Building deflection, in.
ℓ = Affected length of pipe, in.
A = Penetration into structure
Q = Shear force in pipe, lb
M_A = Bending moment in pipe, in.-lb
θ_A = Slope in pipe at penetration, radians
θ_B = Slope in pipe at end of affected length, radians

Assume: θ_A and $\theta_B = 0$

Then:
$$M_A = \frac{0.498\ Q}{\lambda}$$

$$Q = \frac{0.988\ Y_A\ K}{\lambda}$$

For: $K = D K_o$ and

$$\lambda = \sqrt[4]{\frac{K}{4 E I}}$$

Where: K_o = Modulus of foundation, lb/in.^{3}
D = Outside diameter of pipe, in.
E = Young's modulus of pipe material, psi
I = Moment of inertia of pipe, in.^{4}

2.2.5 An alternate, simplified method of hand calculating the pipe stress due to a seismic disturbance may be used. This analysis will be conservative and will provide the maximum earthquake response and maximum bending stress in the pipe. If the pipe stress exceeds the allowable stress using this method, the more exact analysis described in paragraph 2.2.2 must be used.

The soil is considered to be a horizontal 1-layer system which responds to the earthquake by moving in a continuous sinusoidal plane wave and supported by a second layer or base material. The top layer is assumed to pick up accelerations from the base material.

Utilizing the average values for the shear wave velocity and density for the top layers, the ground deformation pattern in terms of wave length and amplitude is determined. The buried pipes are assumed to deform along with the surrounding soil layers. Since no shearing between the pipe and soil is considered to occur, no relative displacement between the soil and the lines is considered.

$$V_{ST} = \frac{\sum V_S h'}{h}$$

Where: V_{ST} = Average shear velocity in the top layers of soil, ft/sec
V_S = Shear velocity in each layer of soil, ft/sec
h' = Depth of each layer of soil, ft
h = Total depth of top layers of soil, ft

The fundamental period of the single layer is calculated from the following equation:

$$T = \frac{4\ h}{V_{ST}} \text{ (seconds)}$$

If the depth of the soil layer varies over the distance traversed by the buried pipe, both cases, for maximum and minimum depths, must be considered and results summarized.

The dynamic magnification factor for a single-layered undamped system is calculated from the equation:

$$DAF = \frac{\rho_B\ V_{SB}}{\rho_T\ V_{ST}}$$

Where: DAF = Dynamic amplification factor for the soil layer
ρ_B = Density of the base rock, lb/ft^3
ρ_T = Average density of the soil layer, lb/ft^3
V_{SB} = Shear wave velocity in the base rock, ft/sec
V_{ST} = Shear wave velocity in the soil layer, ft/sec

$$\text{Displacement} = \left(\frac{T}{2\pi}\right)^2 \times \text{Accel}$$

Where: Accel = % G x g
g = Local acceleration of gravity, ft/sec^2
% G = Value for the appropriate period from the SSE seismic response curve for the base rock, ft/sec^2

The value of the "wave length" is calculated using:

$$\text{Wave length (per cycle)} = V_{ST}\quad T$$

Then using the above data, calculate the bending moment resulting from the seismic disturbance. The buried pipe must follow the soil and deform to a sine wave distortion. The maximum bending moment is given by:

$$M = \frac{\pi^2 E I A}{L^2}$$

Where: M = Maximum bending moment, ft-lb
E = Modulus of the pipe, psi
I = Moment of inertia of the pipe, $in.^4$
A = Maximum amplitude (displacement x DAF), ft
L = One-half the wave length, in.

The corresponding bending stress is obtained by dividing the moment by the section modulus of the pipe.

Combining the above bending stress with the bending stress from paragraph 2.2.4 provides the maximum stress in the pipe. This stress level will occur in the pipe at the wall of the penetrated structure. The pressure stress must be combined with the above stresses to determine the primary stress.

3.0 ALLOWABLE STRESS LEVEL

The nuclear safety related ASME Boiler and Pressure Vessel Code, Section III, Classes 2 and 3 buried piping shall be designed for a safe shutdown earthquake. The maximum allowable primary stress will be calculated as shown:

$$P_m = 1.2 \, S_m$$

Where: P_m = Primary general membrane stress intensity
S_m = Allowable stress value from Reference 3

4.0 REFERENCES

1. Effects of Site Conditions on Earthquake Intensity, John H. Wiggins, Jr., Structural Division, ASCE Journal, April 1964.

2. Site Characteristics of Southern California Strong Motion Stations - Part 2, R. B. Mathiesen, C. Martin Duke, David J. Leeds, University of California, Los Angeles, Report No. 64-15, 1964.

3. ASME Boiler and Pressure Vessel Code, Section III, Nuclear Power Plant Components, 1971.

Action Item 6

Verify that the sheet pile wall design is adequate under flood conditions when passive pressure is reduced.

Response:

The sheet pile wall design is adequate for flood conditions. The design was checked for a flood condition at elevation 700. The flood level of elevation 700 was assumed to saturate the soil within the sheet pile wall and a sudden reservoir drawdown condition was assumed outside the sheet pile wall. The earth pressures were calculated based on an angle of internal friction (ϕ) of soil of 32^{o}, moist unit weight of soil (γ moist) of 120 lb/ft^3, and a submerged unit weight of soil (γ_{sub}) of 65 lb/ft^3. The passive pressure outside the retaining wall was based on the above angle ϕ and γ_{sub}. The wall was analyzed using these values and was found adequate for this case. In addition, passive pressures using submerged conditions were checked for other load cases, including earthquake, and found to be adequate.

Action Item 7

Verify that weep holes have been provided in the sheet pile walls.

Response:

The weep holes were included in the original construction, but they were located approximately a foot below grade instead of above grade as indicated on the drawings. This condition has been nonconformed The problem will be corrected by cutting new weep holes above grade, or by excavating a trench along the face of the sheet pile wall down to the existing weep holes and backfilling with a free draining granular material, or by some other technique to assure free draining of the drains behind the sheet pile walls.