Client: Duke Power Carolinas, LLC Calculation No. 07Q3691-CAL-003

Title: Analysis of Buried HDPE Piping System— Nuclear Service Water (NSW) Supply Line Diesel Generator "1A" Unit 1

Project: Catawba Unit #1 and Unit #2 – Buried HDPE Pipe Design and Analysis

Method: Computer and Manual Calculations

Acceptance Criteria: N/A

Remarks:

Verification Method ☒ Design Review Method ☐ Alternate Calculation ☐ Qualification Test ☐ Other ☐ No Verification Necessary

Results:

Computer Programs Used	Program Name	Version/Revision	Computer Type	QA Verified
	ADLPIPE	4F10.1	PC	YES
	Microsoft Word	2003	PC	N/A
	Mathcad	2000	PC	N/A

REVISIONS

Revision No.	0		
Description	Original Issue		
Total Pages (Cumulative)	96		
By/Date	S. Haile 11-10-08		
Checked/Date	Bruce P. Dubovecky 11-11-08		
Approved/Date	[signature] 11-11-08		

Stevenson & Associates

CALCULATION COVER SHEET

CONTRACT NO. 07Q3691

TABLE OF CONTENTS

Calculation Continuation Sheet

Client	Duke Power Carolinas, LLC	Calculation No.	07Q3691-CAL-003
Project	Catawba Unit # 1 and #2 – Buried HDPE Piping Design and Analysis		
Title	Analysis of Buried HDPE Piping System— Nuclear Service Water (NSW) Supply Line Diesel Generator "1A" Unit 1		
By:	[signature] Date 11/10/08	Chk'd by	[signature] Date 11/11/08

Document Index

DIN No.	Document Number/Title	Revision, Edition, Date	Reference	Input	Output
1	"Nondestructive Evaluation: Seismic Design Criteria for Polyethylene Pipe Replacement Code Case," EPRI, Palo Alto, CA, 2006, Report Number 1013549	September 2006	☐	☒	☐
2	"Guidelines for the Seismic Design of Oil and Gas Pipeline Systems," ASCE	1984	☐	☒	☐
3	"Catawba Updated Final Safety Analysis Report"	Rev. 12, April 2006	☐	☒	☐
4	"Polyethylene (PE) Pressure Pipe and Fittings, 4in. (100 mm) through 63 in. (1,575 mm) for Water Distribution and Transmission," ANSI/AWWA C906-99, American Water Works Association, 6666 West Quincy Ave., Denver, CO 80235	March 1, 2000	☐	☒	☐
5	Catawba Nuclear Station Units 1&2, Yard Layout, Buried Systems, Drawing No. CN-1038-09.		☐	☒	☐
6	Catawba Nuclear Station Units 1&2, Yard Layout, Buried Systems, Drawing No. CN-1038-03.		☐	☒	☐
7	Catawba Nuclear Station Units 1&2, Yard Layout, Buried Systems, Drawing No. CN-1038-04.		☐	☒	☐
8	HDPE Product Catalog, ISCO Industries	Version 2.1, 2005	☐	☒	☐
9	Ladish General Catalog No. 55	1971	☐	☒	☐
10	Navco Piping Catalog	Edition No. 10, June 1, 1974	☐	☒	☐
11	ASME Boiler and Pressure Vessel Code, Section III, Division I, Subsection ND-3600	1998 Edition with 2000 Addenda	☐	☒	☐
12	ASME BPVC Code Case N-755, High Density Polyethylene (HPDE) Buried Pipe, Section III, Division I, Class 3	March 22, 2007	☐	☒	☐
13	CNS ISFSI Haul Path Evaluation Calculation, CNM 1140.04-0005 001	Rev. 0, December 21, 2006	☐	☒	☐
14	Request for relief Number 06-CN-003 "Use of Polyethylene Material in Nuclear Safety-Related Piping Applications" (TAC Numbers MD 3729 and MD 3730)	March 13, 2008	☒	☐	☐
15	S&A Calculation 07Q3691-CAL-001 "Calculation of Soil Spring Stiffness for Buried HDPE Pipe"	Rev. 0, 2008	☐	☒	☐
16	Catawba Nuclear Station Units 1 and 2 Calculation CNC-1206.02-84-001, "Nuclear Service Water Pipe Seismic Analysis (Buried Portion)"	Rev. 16 9-7-06	☐	☒	☐

CALCULATION CONTINUATION SHEET

Client	Duke Power Carolinas, LLC	Calculation No.	07Q3691-CAL-003
Project	Catawba Unit # 1 and #2 – Buried HDPE Piping Design and Analysis		
Title	Analysis of Buried HDPE Piping System— Nuclear Service Water (NSW) Supply Line Diesel Generator "1A" Unit 1		
By:	[signature] Date 11/10/08	Chk'd by	[signature] Date 11/11/08

DIN No.	Document Number/Title	Revision, Edition, Date	Reference	Input	Output
17	Bonney Forge Stress Intensification Factors: Weldolet, Sockolet, Thredolet, Sweepolet, Latrolet, Insert Weldolet, Bulletin SI-1	1988	☒	☐	☐
18	S&A Calculation 07Q3691-CAL-002 "Calculation of Equivalent Thermal Strain for Seismic Analysis of Buried HDPE Pipe"	Rev. 0, 2008	☐	☒	☐
19	Catawba Nuclear Station Specification CNS-1206.02-01-008	Rev. 1, January 3,1998	☐	☒	☐
20	018B00Y020GPLOT_Digitized Spectra (4-14)	-	☐	☒	☐
21	Young, W. C., "Roark's Formulas for Stress and Strain".	McGraw-Hill, Sixth Edition, 1989	☒	☐	☐
22	Fatigue and Capacity Testing of High-Density Polyethylene Pipe and Pipe Components Fabricated from PE4710 (1015062)	Final Report, December 2007	☒	☐	☐
23	3691-LSC-002, "HDPE Pipe Interface Loads Applied to Steel Pipe"	March 17, 2008	☒	☐	☐
24	S&A Calculation 07Q3691-CAL-011, "Definition of Break Selection Criteria and Functional Capability Criteria for the Piping Design Specification"	August 30,2008	☒	☐	☐
25	S&A Calculation 07Q3691-CAL-013, "Technical Basis for Design Acceptance Criteria"	September, 30, 2008	☐	☒	☐
26	CNS-1574-00_RN-00-0002, " ASME Design Specification for the Nuclear Service Water System (RN) Diesel Generator Cooling Supply and Return Piping; Modification, Repair, and Replacement"	Preliminary Draft	☐	☒	☐
27	S&A Document 3691-DI-001, " Design Instructions for Analysis of Polyethylene Pipe"	Rev. 0, 7/2008	☒	☐	☐
28	Welding Research Council Bulletin 300, "Technical Position on Industry Practice"	December, 1984	☒	☐	☐
29	ASME Boiler and Pressure Vessel Code, Section III, Division I, Subsection ND-3600	1989 Edition	☐	☒	☐
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐

1.0 PURPOSE OR OBJECTIVE

Catawba Nuclear Station has decided to replace the buried nuclear service water piping lines connecting the 42-in Nuclear Service Water System (NSWS) supply and return headers to Unit 1 and Unit 2 Diesel Generator (DG) buildings. The existing 10-in carbon steel piping will be replaced by 12-in high-density polyethylene (HDPE) piping. The purpose of this calculation is to demonstrate the Design Basis ASME BPVC Code and Regulatory compliance for the buried HDPE piping system connecting the 42-in supply header 'A' to the DG building of Unit 1.

2.0 SCOPE AND LIMITATIONS

Results of this calculation are limited to the 12-in buried HDPE piping system supplying cooling water from the 42-in NSWS supply header 'A' to the to the Diesel Generator Building of Unit 1. The piping model goes from the anchor at the wall (column lines 38 & EE) to the 42"ø Supply A header pipe of the NSWS. There is a manhole (MH-2) at Diesel Generator Building Unit 1, and there is also a manhole (MH-6) at the connection to the 42" ø Supply A header pipe of the NSWS. The manholes provide access to the steel to HDPE flanged connections for the purpose of inspection and maintenance of the steel to HDPE connections. The HDPE pipe passes through the wall penetration of the manhole, but is not attached to the structure. The manhole does not transfer any load to the HDPE pipe. The gap between the manhole penetration and the HDPE pipe is sealed to prevent water from entering the manhole through this penetration. The piping qualification includes the following:

(a) The Steel Pipe from the Unit 1 Diesel Generator Building anchor steel to the High Density Polyethylene (HDPE) pipe Flange.
(b) HDPE Piping from Steel – HDPE Flange near the Unit 1 Diesel Generator Building Anchor to the Steel – HDPE Flange near the 42" NSWS Supply Header 'A'
(c) The Steel Pipe from the Steel – HDPE Flange anchor to the 42" NSWS Supply Header 'A', including qualification of the 12" NSWS Supply Header 'A' branch connection to the NSWS Supply Header pipe.

3.0 DEFINITIONS

Nomenclature per Ref. [14], Request for Relief Number 06-CN-003, "Use of Polyethylene Material in Nuclear Safety-Related Piping Applications" (TAC Numbers MD 3729 and MD 3730). This nomenclature may differ somewhat from the nomenclature used in the ASME BPVC Code Case N-755 Ref. [12]. Nomenclature is provided at point of use.

A = Cross sectional area of pipe [in^2]
α = Coefficient of thermal expansion [in/in/^{o}F]
B_1 and B_2 = Primary stress indices
B' = Burial factor
BS = Building settlement loads
c = Allowance for erosion or mechanical damage, [in]
D = Outside diameter of pipe [in]
DR = Dimensional ratio of pipe; for OD-controlled pipe, DR = D/t
DW = Deadweight of pipe and contents [lb]

E' = Modulus of soil reaction [psi]
E_{pipe} = Elastic modulus of pipe [psi]
f_0 = Ovality correction factor
F = Impact factor for surface loads.
FS = Factor of safety (FS = 2.0 Level A, 1.8 for Level B, and 1.5 for Levels C and D)
γ_{soil} = Specific weight of the soil [lb/ft^3]
γ_{water} = Specific weight of the water [lb/ft^3]
H **=** Height of fill (or cover) above top of pipe [ft]
k = Longitudinal stress factor
K = Bedding factor, usually 0.1.
K_o = Coefficient of soil pressure at rest, 0.5 to 1.0, may conservatively be taken as 1.0
K_{po} = Spring due to pipe ovaling [lb/in]
L = Deflection lag factor (recommended values: 1.0 for short term and 1.5 for long term loads)

OBE_w = Operating Basis Earthquake due to effects of seismic wave passage
OBE_S = Operating Basis Earthquake due to effects of soil movement
OBE_D = Operating Basis Earthquake due to effects of anchor movements
P_D = Long-term design pressure for the pipe [psi]
P_A , P_B , P_C *and* P_D = Maximum Pressures for Service Levels A through D [psi]
P_{bs} , P_{cs} , *and* P_{ds} = Surge Pressures for Service Levels B through D [psi]
P_E = Vertical soil pressure loads due to weight of soil cover [psi]
P_{gw} = Ground water pressure loads [psi]
P_L = Vertical surcharge (transportation) loads [psi]
PS = Loads due to pump startup and shutdown
R = Buoyancy reduction factor
S_h = Design allowable stress for HDPE piping at temperature [psi]
S_y = Yield stress [psi]
SSE_w = Safe Shutdown Earthquake due to effects of seismic wave passage
SSE_S = Safe Shutdown Earthquake due to effects of soil movement
SSE_D = Safe Shutdown Earthquake due to effects of anchor movements
$T_{A,max}$, $T_{B,max}$, $T_{C,max}$ *and* $T_{D,max}$ = Maximum temperature for Service Levels A through D [^{o}F]
$T_{A,min}$, $T_{B,min}$, $T_{C,min}$ *and* $T_{D,min}$ = Minimum temperature for Service Levels A through D [^{o}F]
t = actual (not nominal) pipe wall thickness [in]
t_{min} = Minimum allowable pipe wall thickness [in]
VOT = Valve Operating Transients
ν = Poisson's ratio for piping
v_r = Poisson ratio for the bedrock
W_P = Weight of empty pipe [lb/ft]
W_w = Ground water floatation loads [lb]
Z = Section modulus of pipe cross section [in^3]

4.0 ASSUMPTIONS

4.1 Assumptions Not Requiring Verification

[1] Due to the small Seismic Building Displacement of the Unit 1 Diesel Generator Building (0.003"), the seismic response of the buried steel pipe from the Diesel Generator building anchor to the HDPE piping is predominantly due the effect of seismic wave passage. The effect of the Diesel Generator Building Amplified Floor Response does not need to be considered in the analysis of the buried pipe. Ref. [25].

[2] Per discussion with Catawba Systems Engineering, it is concluded that the buried HDPE piping at Catawba is not subjected to any pressure surge loads. Ref. [25]

[3] Seismic Anchor Movements of 0.003" are much less than 1/16" and, therefore, will have negligible effect on the piping and are not considered in the analysis

4.2 Assumptions To Be Verified

[1] Stress Intensification Factors (SIF's) for mitered elbows less than 90º are enveloped by SIF's of 90º elbows.

5.0 ANALYSIS METHODOLOGY AND APPROACH

5.1 Background

The buried water supply system to and from the Diesel Generator (DG) buildings to the 42-in Nuclear Service Water System (NSWS) currently uses 10-in carbon steel pipes. Catawba Nuclear Station (CNS) has decided to replace the 10-in steel pipes with 12-in high-density polyethylene (HDPE) pipes. There are a total of eight cooling water piping lines—four supply lines and four return lines.

- Two cooling water supply lines to the DG building of Unit 1. One line originates from the 42-in supply header 'A' and the other originates from the 42-in supply header 'B'.
- Two cooling water supply lines to the DG building of Unit 2. One line originates from the 42-in supply header 'A' and the other originates from the 42-in supply header 'B'.
- Two cooling water return lines originating from the DG building of Unit 1. One line returns water to the 42-in return header 'A' and the other returns water to the 42-in return header 'B'.
- Two cooling water return lines originating from the DG building of Unit 2. One line returns water to the 42-in return header 'A' and the other returns water to the 42-in return header 'B'.

The HDPE pipes are connected to the steel pipes by means of a flanged joint. At the DG building wall entrance, a transition is made from 10-in to 12-in using a 10x12 steel reducer with flanges to provide the necessary flanged connection to the HDPE pipe and a means of providing future access for examination of all joints from the inside surface per Ref. [14]. At the 42-in header side, a short 12-in flanged steel pipe is welded to the header. An additional steel flanged joint attached to the 12-in pipe provides the necessary connection to the HDPE pipe and serves as future access. The HDPE piping system is considered anchored at both ends.

The buried HDPE piping system considered in this calculation is the cooling water supply line from the 42-in supply header 'A' to the Diesel Generator Building of Unit 1. The effects of pressure, deadweight, seismic and temperature loads on the buried HDPE piping are analyzed.

5.2 Methodology and Approach

The piping is qualified to the requirements of the Piping Design Specification Ref. [26]. The Design Specification is based on ASME BPVC Code Case N-755 Ref. [12] and the commitments in Relief Request Number 06-CN-003 Ref. [14]. In addition, further guidance on design and analysis methods is provided in EPRI Report 1013549 Ref. [1] and S & A Design Instruction 3691-DI-001 Ref. [27]. However, the controlling design document is the Piping Design Specification Ref. [26].

The Code of Record for the Design and Analysis of the HDPE Pipe is the 1998 Edition of the ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection ND up to and including the 2000 Addenda. However, ND-3600 of the ASME Boiler and Pressure Vessel Code 1989 Edition shall be used to comply with the limitations imposed by 10 CFR 50.55 a (b) (1) (iii) except as amended by the governing document Relief Request Number 06-CN-003 Ref. [14]. The piping is classified as ASME Class 3 Duke Class C.

The piping system is analyzed using a combination of hand calculations and the ADLPIPE computer program. ADLPIPE analyzes complex piping systems subjected to static and dynamic loads. The basic load cases (deadweight, thermal, seismic OBE, seismic SSE, etc.) and their combinations (such as thermal plus seismic) are included in the ADLPIPE analysis.

Stresses in steel pipes are automatically computed by ADLPIPE according to an ASME Code year of interest. However, ADLPIPE does not calculate the stresses for all piping load cases and combinations in the HDPE pipe because HDPE material, properties, and qualification criteria are not yet included in the ADLPIPE computer code. Therefore, manual calculations are performed for the HPDE piping according to the relief request Ref. [14] which is consistent with the ASME BPVC Code Case N-755 [Ref. 12]. The required manual calculations are presented in sections 5.2.1 and 5.2.2.

5.2.1 HDPE Calculations Dependent Only on HDPE Design Conditions and Pipe Size

These calculations do not require ADLPIPE analysis results as input. The pipe size and the design conditions are the only inputs needed to perform the manual calculations in this section.

Minimum Required Wall Thickness

Per Section 3131.1 of Ref. [12], the minimum required wall thickness (t_{min}) of straight pipe sections is determined from:

$$t_{\min} = \frac{P_D D}{2S + P_D} + c \qquad (5.1)$$

where:

P_D = internal design gage pressure at the specified design temperature, psi
D = outside diameter of pipe, in
S = allowable stress, psi
c = allowance for mechanical and erosion damage, in.

The actual wall thickness of the HDPE pipe shall not be less than t_{min} .

Ring Deflection

Per Section 3210 of Ref. [12], the deflection of the pipe diameter (Ω) due to soil and surcharge loads should be less than the maximum allowable value (Ω_{max}):

$$\Omega = \frac{1}{144} \cdot \frac{K \cdot L \cdot P_E + K \cdot P_L}{\frac{2E_{pipe}}{3}\left(\frac{1}{DR - 1}\right)^3 + 0.061 F_s E_s} \le \Omega_{\max} \qquad (5.2)$$

where:

$P_E = \rho_{saturated} H_w + \rho_{dry}(H - H_w)$
K_b = bedding factor
L = deflection lag factor, 1.25 to 1.50, or 1.0 if using the soil prism pressure
P_E = vertical soil pressure due to earth loads, [lb/ft^2]
P_L = vertical soil pressure due to surcharge loads, [lb/ft^2]
E_{pipe} = apparent modulus of elasticity of pipe at 50 years, [psi]
DR = dimensional ratio of pipe (D/t)
D = outside pipe diameter, [in]
F_s = soil support factor
E' = modulus of soil reaction, [psi]
$\rho_{saturated}$ = density of saturated soil, [lb/ft^3]
ρ_{dry} = density of dry soil, [lb/ft^3]
H = height of ground cover, [ft]
H_w = height of water table above pipe, [ft]
t = minimum pipe wall thickness, [in]

Compression of Sidewalls

The circumferential compressive stress (σ_{SW}) in the sidewalls of pipe and miters due to soil and surcharge loads per Section 3220 of Ref. [12] should be less than 1000 psi. This 1000 psi is based on PE-3408 material and assumes a temperature of 70º F. Per Ref. [25] the allowable value at a temperature of 140º F for PE-4710 material is 530 psi. The value used in this analysis is 500 psi which is conservative. This 140º F temperature was selected because it is the maximum discharge line temperature. This lower bound value was conservatively applied to all eight piping analyzes.

$$\sigma_{SW} = \frac{(P_E + P_L) \cdot DR}{2 \times 144} \leq 500 psi \qquad (5.3)$$

where:

P_E = vertical soil pressure due to earth loads, [lb/ft^2]
P_L = vertical soil pressure due to surcharge loads, [lb/ft^2]
DR = dimensional ratio of pipe (D/t)
D = outside pipe diameter, [in]
t = minimum pipe wall thickness, [in]

Buckling Due to External Pressure

External pressure from ground water, earth loads, and surcharge loads on the buried HDPE pipe shall not cause the pipe to buckle per Section 3221.1 of Ref. [12]; that is,

$$\frac{P_E + P_L + P_{gw}}{144} \leq 2.8 \cdot \left[R \cdot B \cdot E_s \frac{E_{pipe}}{12 \cdot (DR-1)^3} \right]^{1/2} \qquad (5.4)$$

where:

$$R = 1 - 0.33 \frac{H_{gw}}{H}$$

$$B = \frac{1}{1 + 4e^{-0.065H}}$$

P_E = vertical soil pressure due to earth loads, [lb/ft^2]
P_L = vertical soil pressure due to surcharge loads, [lb/ft^2]
P_{gw} = pressure due to ground water, [lb/ft^2]
R = buoyancy reduction factor
B' = burial factor
E_{pipe} = modulus of elasticity of pipe, [psi]
E' = modulus of soil reaction, [psi]
DR = dimensional ratio of pipe (D/t)
H = depth of cover, [ft]
H_{gw} = height of ground water above pipe, [ft]
D = outside pipe diameter, [in]
t = minimum pipe wall thickness, [in]

Effects of Negative Internal Pressure

Per Section 3221.2 of Ref. [12], when the pipe is subjected to a negative internal pressure, it should withstand the differential pressure (ΔP) without credit for the surrounding soil, that is:

$$\Delta P \le \frac{f_o}{2}\frac{2E_{pipe}}{(1-\upsilon^2)}\left(\frac{1}{DR-1}\right)^3 \quad (5.5)$$

where:

- f_o = ovality correction factor
- E_{pipe} = modulus of elasticity of pipe, [psi]
- ν = Poisson's ratio (0.35 for short duration loads to 0.45 for long duration loads)
- DR = dimensional ratio of pipe (D/t)
- D = outside pipe diameter, [in]
- t = minimum pipe wall thickness, [in]

Floatation

To prevent floatation by groundwater, the buried pipe must have sufficient cover or be anchored to the ground. Per Section 3222 of Ref. [12], the following criterion must be satisfied:

$$W_w < W_P + \frac{P_E \cdot D}{12} \quad (5.6)$$

where:

- W_w = weight of water displaced by pipe, [lb/ft]
- W_P = weight of empty pipe, [lb/ft]
- P_E = vertical soil pressure due to earth loads, [lb/ft^2]
- D = outside pipe diameter, [in.]

5.2.2 HDPE Calculations Requiring the Input of Geometry Specific Loads

The manual calculations in this section require the ADLPIPE analysis results as input. HDPE pipe stresses are computed using the forces and moments obtained from ADLPIPE analysis. The stress calculations are performed both for straight pipes and mitered elbows.

Longitudinal Stress

Per Section 3223.1 of Ref. [12], the longitudinal stresses due to axial forces and bending moments resulting from applied mechanical loads shall not exceed *k*S*:

$$B_1\frac{P_A D}{2t} + 2B_1\frac{F_a}{A} + B_2\frac{M}{Z} \le k \cdot S \quad (5.7)$$

where:

B_1 and B_2 = primary stress indices defined in Table 3223-1 of Ref. [12]
P_A = design or service level A, B, C or D pressure, [psi]
D = outside diameter of pipe at the section where the evaluation is conducted, [in.]
t = nominal pipe wall thickness at the section where the evaluation is conducted, [in.]
F_a = axial force due to the specified design, level A, B, C or D applied mechanical loads, [lb]
M = resultant bending moment due to the specified design, level A, B, C or D applied mechanical loads, [in.-lb]
A = cross section area of pipe at the section where the force is calculated, [in^2]
Z = section modulus of pipe cross section at the section where the moment is calculated, [in^3]
k = longitudinal stress factor per Table 3223-2 of Ref. [12]
S = allowable stress per Table 3021-1 of Ref. [14], [psi]

Thermal Expansion and Contraction

(a) Fully Constrained Thermal Contraction

The tensile stress, per Section 3311.1 of Ref. [12], resulting from the assumption of fully constrained thermal contraction of the buried pipe when $T_{water} < T_{ground}$, increased by the tensile stress due to axial contraction from Poisson effect, shall not exceed the allowable stress (S):

$$\sigma_\tau = \left| E_{pipe} \cdot \alpha \cdot \Delta T - \upsilon \frac{P \cdot D}{2t} \right| \le S \quad (5.8)$$

where: E_{pipe} = modulus of elasticity of pipe, [psi]
α = coefficient of thermal expansion, [in/in/^{o}F]
$\Delta T = T_{water} - T_{ground} < 0$
ν = Poisson's ratio (0.35 for short duration loads to 0.45 for long duration loads)
P = internal design gage pressure including pressure spikes due to transients from anticipated water hammer events, [psi]
D = outside pipe diameter, [in.]
t = nominal pipe wall thickness, [in.]
S = allowable stress, psi, from Table 3021-1 Ref. [14]

(b) Fully Constrained Thermal Expansion

The tensile stress resulting from the assumption of fully constrained thermal expansion of the buried pipe when $T_{water} > T_{ground}$, per Section 3311.2 of Ref. [12], shall not exceed the allowable stress (S):

$$E_{pipe} \cdot \alpha \cdot \Delta T \le S \quad (5.9)$$

where:

E_{pipe} = modulus of elasticity of pipe, [psi]
α = coefficient of thermal expansion, [in/in/^{o}F]
$\Delta T = T_{water} - T_{ground} > 0$
S = allowable stress, psi, from Table 3021-1 Ref. [14]

Client	Duke Power Carolinas, LLC	Calculation No.	07Q3691-CAL-003
Project	Catawba Unit # 1 and #2 – Buried HDPE Piping Design and Analysis		
Title	Analysis of Buried HDPE Piping System— Nuclear Service Water (NSW) Supply Line Diesel Generator "1A" Unit 1		

By:	[signature]	Date	11/10/08	Chk'd by	[signature]	Date	11/11/08

(c) Alternative Evaluation for Thermal Expansion or Contraction

When the soil stiffness is accounted for to calculate the pipe expansion and contraction stresses, per Section 3311.3 of Ref. [12], the stresses must satisfy the following condition:

$$\frac{i \cdot M_C}{Z} + \frac{F_{aC}}{A} \leq 1100\,psi \tag{5.10}$$

where:

i = stress intensification factor
F_{aC} = axial force range due to thermal expansion or contraction and/or the restraint of free end displacement, [lb]
M_C = resultant moment range due to thermal expansion or contraction and/or the restraint of free end displacement, [in.-lb]
A = cross section area of pipe at the section where the force is calculated, [in^2]
Z = section modulus of pipe cross section at the section where the moment is calculated, [in^3]

Non-repeated Anchor Movements

Per Section 3312 of Ref. [12], the effects of any single non-repeated anchor movement shall meet the requirements of the following equation:

$$\frac{i \cdot M_D}{Z} + \frac{F_{aD}}{A} \leq 2 \cdot S \tag{5.11}$$

where:

i = stress intensification factor
F_{aD} = axial force due to the non-repeated anchor motion, [lb]
M_D = resultant moment due to the non-repeated anchor motion, [in.-lb]
A = cross section area of pipe at the section where the force is calculated, [in^2]
Z = section modulus of pipe cross section at the section where the moment is calculated, [in^3]
S = allowable stress, psi, from Table 3021-1 Ref. [14]

Seismic Induced Stresses

Per Section 3410 of Ref. [12], the stresses in the buried pipe due to soil strains caused by seismic wave passage, seismic soil movement, and building seismic anchor motion effects, where applicable, must satisfy the following equation:

$$\frac{i \cdot M_E}{Z} + \frac{F_{aE}}{A} \leq 1100\,psi \tag{5.12}$$

where:

i = stress intensification factor

F_{aE} = axial force range due to the combined effects of seismic wave passage, seismic soil movement, and building seismic anchor motion effects, [lb]

M_E = resultant moment range due to the combined effects of seismic wave passage, seismic soil movement, and building seismic anchor motion effects, [in.-lb]

A = cross section area of pipe at the section where the force is calculated, [in^2]

Z = section modulus of pipe cross section at the section where the moment is calculated, [in^3]

Seismic wave passage, seismic soil movement, and building seismic anchor motions are combined by square root sum of the squares. This equation is applicable to both OBE and SSE. Ref. [25] Section 7.0 provides the basis of this applicability.

5.2.3 Steel Pipe Criteria

The steel pipe from the Diesel Generator building anchor to the HDPE pipe flange connection and from the HDPE pipe flange connection to the 42"ø supply header are qualified in the ADLPIPE analysis in accordance with the requirements of Ref. [29]. The stresses for the steel pipe are shown in Section 7.4.

6.0 ANALYSIS INPUTS

6.1 Design Loads

Design temperature and pressure values supplied by Duke Power Carolinas and used as input in this calculation are listed in Table 6.1.

Design Temperature	100 ºF
Ambient Temperature	55 ºF
Minimum Temperature	32 ºF
Maximum Temperature	100 ºF
Design Pressure	100 psig
Operating Pressure	75 psig

6.2 Pipe Properties

Geometric and other relevant properties for the pipes used in this calculation are shown in Table 6.2. Outside diameter (OD), thickness and weight values for steel pipes were taken from standard piping catalogs, Ref. [10]. For IPS HDPE pipe the values were obtained from ANSI/AWWA Standard C906-99, Ref. [4] and the thickness values were obtained from Ref. [12]. Weight values were taken from manufacturers' literature. For the same nominal pipe size, the ODs of the HDPE and the steel pipes are equal; therefore, the IPS sizing system is used.

[redacted]

	Cr-Mo Steel Pipe		Carbon Steel Pipe	HDPE Pipe/Elbow
Nominal size	10-in	12-in	12-in	12-in
Material	A6XLN(1)	A6XLN(1)	A-106, Gr. B	PE 4710(2)
Schedule	Standard	Standard	Standard	DR 11/DR 9
Outside Diameter [in]	10.75	12.75	12.75	12.75
Wall Thickness [in]	0.365	0.375	0.375	1.159/1.417
Contents	Water	Water	Water	Water
Wt. of Contents [lb/ft]	34.1	49.0	49.0	37.0/33.5
Wt. of Pipe [lbs/ft]	40.5	49.6	49.6	18.4/22

(1) This is a manufacturer’s designation for a Cr-Mo alloy used for piping as SB-675 and SB-690, for forgings as SB-462, and for castings as SB-366.

(2) The cell classification of PE 4710 material is 445574C

6.3 Material Properties

Properties of A-106 carbon steel and A6XLN (Cr-Mo) are given in Tables 6.3a and 6.3b. The values in Table 6.3a were obtained from the 1989 edition of the ASME B&PVC, Section III [Ref. 29]. The values in Table 6.3b were obtained from the 1998 edition of the ASME B&PVC, Section III, Part D [Ref. 11].

[redacted]

Temperature, T [^oF]	32	55	65	100
Coeff. of Thermal Exp., α[in/in/^oF]	$6.5x10^{-6}$	$6.5x10^{-6}$	$6.5x10^{-6}$	$6.5x10^{-6}$
Modulus of Elasticity, E [ksi]	27,900	27,900	27,900	27,900
Allowable Stress, S_c [psi]	15,000	15,000	15,000	15,000
S_h [psi]	15,000	15,000	15,000	15,000
Yield Stress, S_y [psi]	35,000	35,000	35,000	35,000

[redacted]

Temperature, T [°F]	32	55	65	100
Coeff. of Thermal Exp., α[in/in/°F]	8.2×10^{-6}	8.2×10^{-6}	8.2×10^{-6}	8.2×10^{-6}
Modulus of Elasticity, E [ksi]	28,000	28,000	28,000	28,000
Allowable Stress[(1)], S_c [psi]	24,300	24300	24,300	24,300
S_h [psi	24,300	24,300	24,300	24,300
Yield Stress[(2)], S_y [psi]	45,000	45,000	45,000	45,000

Notes:
(1) A6XLN is a manufacturer's designation for the following Cr-Mo alloys: SB-675, SB-690, and SB-462. The allowable values shown here correspond to the minimum values listed in the 1998 BPVC ASME Code.
(2) The yield strength shown here corresponds to that of SB-675, SB-690, and SB-462.

The mechanical properties of HDPE vary significantly with load duration. Therefore, different values must be used for different load cases. Tables 6.3c thru 6.3f provide the mechanical properties of HDPE for various load durations.

Mechanical properties obtained for 50-year load duration are given in Table 6.3c. These properties are used for deadweight and thermal analysis.

[redacted]

Temperature, T [°F]	32	55	65	100
Coeff. of Thermal Exp., α[in/in/°F]	90×10^{-6}	90×10^{-6}	90×10^{-6}	90×10^{-6}
Modulus of Elasticity[(1)], E [ksi]	28	28	28	23
Allowable Stress, S [psi]	800	800	800	620
Poisson's Ratio, ν [-]	0.45	0.45	0.45	0.45

(1) Per Table 3210-3 of Ref. [12]

Mechanical properties obtained for short-term load duration are shown in Table 6.3d. These are used for OBE, SSE, and equivalent thermal strain analysis.

[redacted]

Temperature, T [°F]	32	55	65	100
Coeff. of Thermal Exp., α[in/in/°F]	$90x10^{-6}$	$90x10^{-6}$	$90x10^{-6}$	$90x10^{-6}$
Modulus of Elasticity(1), E [ksi]	110	110	110	100
Allowable Stress(2), S [psi]	1200	1200	1200	940
Poisson's Ratio, ν [-]	0.35	0.35	0.35	0.35

(1) Per Table 3210-3 of Ref. [12] (Load Duration < 10 hr.)
(2) The allowable stress for short duration listed in Table 3223-3 of Ref. [12] are used

[redacted]

Temperature, T [°F]	32	55	65	100
Coeff. of Thermal Exp., α [in/in/°F]	$90x10^{-6}$	$90x10^{-6}$	$90x10^{-6}$	$90x10^{-6}$
Modulus of Elasticity(1), E [ksi]	44	44	44	36
Allowable Stress(2), S [psi]	840	840	840	620
Poisson's Ratio, ν [-]	0.35	0.35	0.35	0.35

(1) Per Table 3210-3 of Ref. [12]
(2) The allowables for 10-year duration listed in Table 3131-1 of Ref. [12] are used. This is conservative.

[redacted]

Temperature, T [°F]	32	55	65	100
Coeff. of Thermal Exp., α[in/in/°F]	$90x10^{-6}$	$90x10^{-6}$	$90x10^{-6}$	$90x10^{-6}$
Modulus of Elasticity(1), E [ksi]	32	110	110	26
Allowable Stress(2), S [psi]	840	840	840	620
Poisson's Ratio, ν [-]	0.35	0.35	0.35	0.35

(1) Per Table 3210-3 of Ref. [12]
(2) Per Table 3131-1 of Ref. [12]

6.4 HDPE to Steel Boundary

The HDPE pipe is connected to the steel pipe by means of a flanged connection. The following piping components are used for the joints at the entrance to the DG building wall and at the 42-in header:

- A 10-in by 12-in steel reducer
- 10-in, 150-lb ANSI B16.5 raised face welding neck steel flanges
- 12-in, 150-lb ANSI B16.5 raised face welding neck steel flanges
- A 12-in, short-radius, 90° steel elbow
- Two HDPE flange adapters
- Two special steel backup rings that possess the same bolt pattern as 12-in, 150-lb steel flanges and are used in conjunction with the HDPE adapters

Relevant properties for the above piping components were obtained from manufacturers' catalogs – Ref. [9] for the steel components and Ref. [8] for the HDPE components and steel backup rings. The properties are listed in Table 6.6.

[redacted]

Piping Component	Nominal Size [in]	Thickness [in]	Length [in]	O. D. [in]	Weight [lb]
150-lb, Welding Neck Steel Flange	10	0.365	4	12(1)	54
	12	0.375	4.5	14.375(1)	88
Steel Reducer	10x12	NA (2)	8	NA (2)	34
90° Steel Elbow	12	0.375	12(3)	12.75	80
HDPE Flange Adapter	12	1.55	12	12.75	24
Steel Backup Ring	12	1.25	1.25	19	24

(1) These values represent the diameter of the flange hub at base.
(2) OD and thickness for a reducer are variable and are not required as input.
(3) This is the center to face length; it is also equal to the radius of the elbow.

6.5 HDPE Elbows

The piping system includes 30°, 45°, 60° and 90° HDPE mitered elbows. The mitered elbows are size DR 9 (one DR ratio lower than the HDPE pipe that is DR 11) to comply with the requirements of the ASME BPVC Code Case N-755 Paragraph -3132(d) Ref. [12]. These elbows are modeled according to the manufacturer's catalog specifications [Ref. 8]. The 30° mitered elbow has 3 segments as shown in figure 6.5a. The 45° mitered elbow has 3 segments as shown in figure 6.5b. The 60° mitered elbow has 5 segments as shown in figure 6.5c. The 90° mitered elbow has 5 segments as shown in figure 6.5d. This piping analysis has 30°, 45°, 60°, and 90° mitered elbows in the model.

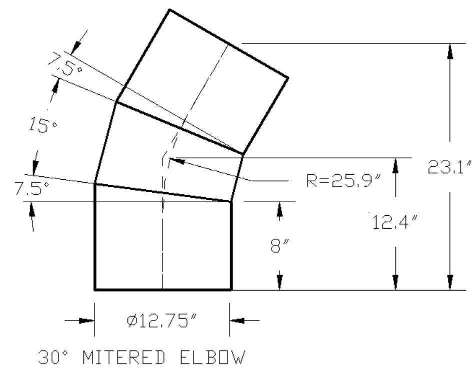


Fig. 6.5a: Geometry of 30° HDPE mitered elbow

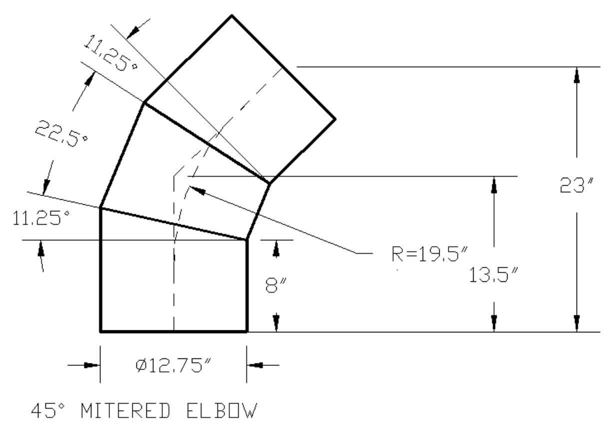


Fig. 6.5b: Geometry of 45° HDPE mitered elbow

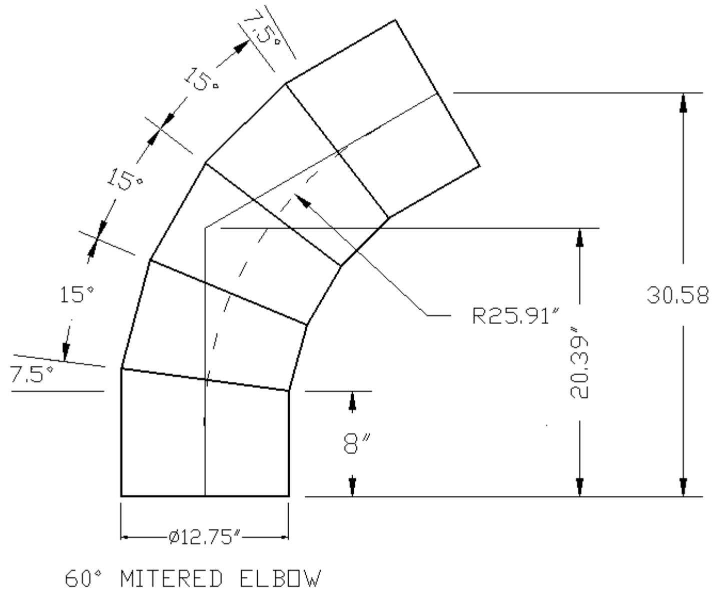


Fig. 6.5c: Geometry of 60^o HDPE mitered elbow

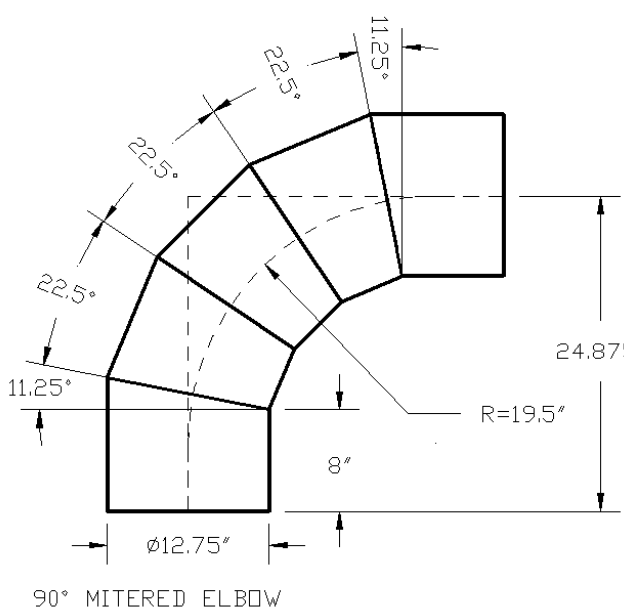


Fig. 6.5d: Geometry of 90^o HDPE mitered elbow

6.6 Stress Indices and SIFs

ADLPIPE automatically calculates stress indices and stress intensification factors (SIF) for the steel piping components based on the 1989 ASME BPVC Code Ref. [29]. The 10-in and 12-in steel piping has butt welded fittings. The analysis is based on the 1989 Class 3 ASME Code.

6.6.1 HPDE Pipe

The buried HDPE piping is a DR 11 butt welded, straight pipe. The following stress index and SIF values, as listed in Tables 3223-1 and 3311.2-1 of Ref. [12], are used:

Stress Indices:	$B_1 = 0.5$
	$B_2 = 1.0$
Stress Intensification Factor:	$i = 1.0$

6.6.2 HPDE Mitered Elbows

The mitered elbows are DR 9. SIF and stress index values for these components, as obtained from Tables 3223-1 and 3311.2-1 of Ref. [12], are as follows:

Stress Indices:	$B_1 = 0.69$
	$B_2 = 1.64$
Stress Intensification Factor:	$i = 2.0$

These SIF's are for 5 segment 90º mitered elbows. Per Ref. [25] Section 6.1, it is assumed these Stress Indices and SIF's envelope the 3 segment 30º and 45º mitered elbows, and the 5 segment 60º mitered elbows.

6.6.3 Flexibility Factors for Mitered Elbows

The flexibility factor calculated by ADLPIPE for the 12"ø mitered elbows is 1.79 ≈ 1.82 which is the calculated flexibility factor per Table NB-3673.2 (b)(1), Section 5.6.2.3 of Ref. [22]. The preliminary mean flexibility factor from testing Ref. [22] of the 12"ø elbows is 2.15 for in-plane and 2.44 for out-of-plane Ref. [22]. The lower flexibility factor calculated by ADLPIPE will result in higher moments on the piping system due to less flexibility. The calculated Stress Intensification Factor (SIF) calculated from Table NB-3673.2(b)(1) for 12" ø elbows is 1.04 in-plane and 0.87 out-of-plane. This piping analysis uses a 2.0 SIF for in-plane and out-of-plane for the mitered elbows which is from the ASME BPVC Code Case N-755 Ref. [12].

6.6.4 Weldolet

A Weldolet is used for attaching the 12-in pipe to the 42-in header. The stress intensification factor for the Weldolet is determined from the following equation given in Ref. [17]:

$$i = \frac{0.9}{(3.3t/r)^{2/3}}$$

where: i = stress intensification factor

t = nominal wall thickness of run pipe [in]

r = mean radius of run pipe [in]

For the 42-in diameter pipe, t = 0.500 in. [Ref. 10], and the mean radius, r = (42–0.500)/2 = 20.75 in. The stress intensification factor is therefore:

$$i = \frac{0.9}{(3.3 * 0.5/20.75)^{2/3}} = 4.87$$

6.7 Soil Springs

The buried piping is subject to loads from earthquake, temperature and surrounding soil. To determine the pipe stresses resulting from these loads, the soil spring stiffness is required as input. Soil spring stiffness values obtained from Ref. [15] and shown below will be used as input in the ADLPIPE analysis of the piping system. Soil springs are generally applied at 2 ft intervals around elbows (over 6ft sections on each side of elbows) and at 10 ft intervals elsewhere.

[redacted]				
H = 5 ft	Lateral	130	3120	15600
	Vertical	540	12960	64800
	Axial	425	10200	51000
H = 7.5 ft	Lateral	155	3720	18600
	Vertical	705	16920	84600
	Axial	615	14760	73800
H =13.25 ft	Lateral	195	4680	23400
	Vertical	1055	25320	126600
	Axial	1055	25320	126600

Note that soil spring stiffness values for pipe sections of length other than shown in Table 6.7 can be determined by proportion.

6.8 Seismic Analysis Input

6.8.1 Seismic Anchor Motion

Per Calculation CNC-1206.02-84-0001 [Ref. 16] provided by CNS, the seismic displacement of the DG building is less than 0.003 inches for OBE or SSE analysis. The 42”ø Supply Line is attached at the Auxiliary Building and has the following seismic displacements Lateral = 0.014328” < 1/16 in, Axial = 0.01374” < 1/16 in, and Vertical = 0.0” for OBE or SSE analysis. These displacements are considered insignificant for this analysis and a seismic anchor motion analysis is therefore not conducted

6.8.2 Seismic Wave Passage

Since the piping system is completely buried and isolated from aboveground piping, the methodology of Non-Mandatory Appendix D of the ASME BPVC Code Case N-755 will be used to qualify the piping for seismic wave passage. In Ref. [18], the strains due to seismic wave passage were computed and then converted to an equivalent thermal strain resulting in a temperature change (ΔT) of 10 ^{o}F. This change in temperature will be used as input in the ADLPIPE computer model of the piping system to determine the seismic loads.

6.8.3 Decoupling of 12” Steel Pipe

If the ratio of the moment of inertia of the run pipe to branch pipe (decoupled pipe) is equal to or greater than 25, the branch piping may be considered to have no significant effect on the response of the run pipe. Ref. [28]. $I_{12\text{” branch pipe}}$ = 300 in^4 ; $I_{42\text{” run pipe}}$ = 14037 in^4 ; Ratio of run to branch is 46. The analysis of the decoupled piping shall consider the thermal, seismic, and other movements of the run pipe at the intersection point. There are no thermal or seismic anchor movements (See section 6.8.1) on the run pipe. The steel buried pipe will not have seismic response from the seismic wave passage. Therefore, there are no anchor movements at the 12” pipe (branch) to the 42” pipe (run) connection.

6.9 Piping Layout

The layout of the piping system is shown in the following drawings provided by Duke Power Carolinas: CN-1038-09 [Ref. 5], CN-1038-03 [Ref. 6] and CN-1038-04 [Ref. 7]. Dimensions and orientations of piping shown on these drawings were used in generating the ADLPIPE computer model for the piping system. A sketch of the piping layout is shown in Fig. 6.9.

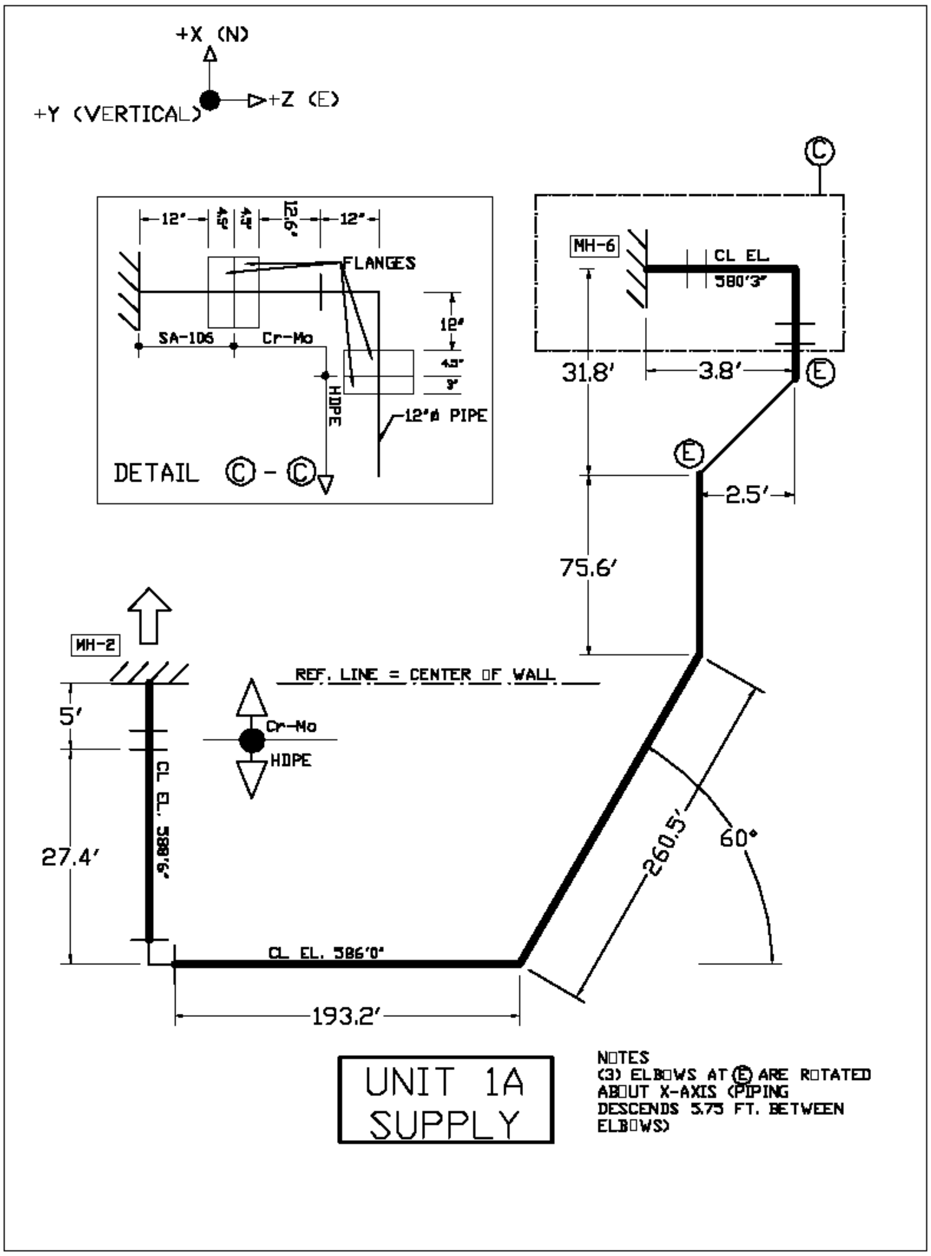


Figure 6.9

6.10 Pipe Criteria – Steel and HDPE

The pipe load combinations considered are shown in Tables 6.10(a) -- Steel

Table 6.10(a) - Buried Steel Piping Load Combinations

Service Level	Stress Condition	Load Combination
Design	Primary	P
	Primary	P + DW
A	Primary	P_a
	Primary - - Longitudinal Stress	P_a + DW
	Secondary	Range of ($T_{a\ min}$, $T_{a\ max}$)
	Non Repeated Anchor Motion	BS
B	Primary	P_b
	Primary	P_{bs}
	Primary - - Longitudinal Stress	P_b + DW + VOT P_b + DW+PS
	Secondary – Thermal and Seismic	(a) Range of ($T_{b\ min}$, $T_{b\ max}$) (b) $\lvert T_b\ max \rvert + \lvert [OBE_W^2 + (\lvert OBE_S \rvert + \lvert OBE_D \rvert)^2]^{1/2} \rvert$ (c) $\lvert T_b\ min \rvert + \lvert [OBE_W^2 + (\lvert OBE_S \rvert + \lvert OBE_D \rvert)^2]^{1/2} \rvert$
C	Primary	P_c
D	Primary	P_d
	Secondary - Seismic	$[SSE_W^2 + (\lvert SSE_S \rvert + \lvert SSE_D \rvert)^2]^{1/2}$

The pipe load combinations considered and shown in Table 6.10(b) -- HDPE

Table 6.10(b)- Buried HDPE Piping Load Combinations		
Service Level	**Stress Condition**	**Load Combination**
Design		P_D
		P_D + DW
A	Primary - Side Wall Compression	$P_E + P_L$
	Primary - Buckling due to External Pressure	$P_E+P_L+P_{gw}$
	Primary - Flotation	W_W
	Primary -- Pressure	P_a
	Primary - - Longitudinal Stress	P_a + DW
	Secondary	Range of ($T_{a\ min}$, $T_{a\ max}$)
	Non Repeated Anchor Motion	BS
B	Primary - Side Wall Compression	$P_E + P_L$
	Primary - Buckling due to External Pressure	$P_E+P_L+P_{gw}$
	Primary – Flotation	W_W
	Primary - Pressure	P_b
	Primary – Pressure + Surge Pressure	$P_b + P_{bs}$
	Primary – Longitudinal Stress	P_b + DW
	Primary – Pressure + Longitudinal Stress + Short Term	P_b + DW+ VOT P_b + DW +PS
	Secondary – Thermal	Range of ($T_{b\ min}$, $T_{b\ max}$)
	Secondary – Seismic	$[OBE_W^2 + (\lvert OBE_S \rvert + \lvert OBE_D \rvert)^2]^{1/2}$
C	Primary - Side Wall Compression	$P_E + P_L$
	Primary - Buckling due to External Pressure	$P_E+P_L+P_{gw}$
	Primary – Flotation	W_W
	Primary - Pressure	P_c
	Primary – Pressure + Surge Pressure	$P_c + P_{cs}$
	Secondary – Thermal	Range of ($T_{c\ min}$, $T_{c\ max}$)
D	Primary - Side Wall Compression	$P_E + P_L$
	Primary - Buckling due to External Pressure	$P_E+P_L+P_{gw}$
	Primary – Flotation	W_W
	Primary - Pressure	P_d
	Primary – Pressure + Surge Pressure	$P_d + P_{ds}$
	Secondary – Thermal	Range of ($T_{d\ min}$, $T_{d\ max}$)
	Secondary – Seismic	$[SSE_W^2 + (\lvert SSE_S \rvert + \lvert SSE_D \rvert)^2]^{1/2}$

Client	Duke Power Carolinas, LLC	Calculation No.	07Q3691-CAL-003
Project	Catawba Unit # 1 and #2 – Buried HDPE Piping Design and Analysis		
Title	Analysis of Buried HDPE Piping System— Nuclear Service Water (NSW) Supply Line Diesel Generator "1A" Unit 1		
By:	[signature] Date 11/10/08	Chk'd by	[signature] Date 11/11/08

6.11 Acceptance Criteria – Steel and HDPE

The criteria used to evaluate the adequacy of the buried steel piping system are summarized in Table 6.11(a).

Table 6.11(a) - Buried Steel Piping Capacity Criteria

Service Level	Stress Condition	Capacity Criteria
Design	Primary	Requirements of ND-3640
	Primary	ND-3652, Equation (8) with a Stress Limit of 1.5 S_h
A	Primary	Less than 1.0 P
	Primary - - Longitudinal Stress	ND-3653.1, Equation (9) with a stress limit of Lesser of 1.8 S_h or 1.5 S_y
	Secondary	ND-3653.2(a), Equation (10) with a stress limit of S_A
	Non Repeated Anchor Motion	ND-3653.2(b), Equation (10a) with a stress limit of 3.0 S_c
B	Primary	Less than 1.1 P
	Primary - - Longitudinal Stress	ND-3653.1, Equation (9) with a stress limit of Lesser of 1.8 S_h or 1.5 S_y
	Secondary – Thermal and Seismic	ND-3653.2(a), Equation (10) with a stress limit of S_A
C	Primary	Less than 1.8 P
D	Primary	Less than 2.0 P
	Secondary - Seismic	ND-3653.2(a), Equation (10) with a stress limit of S_A

The criteria used to evaluate the adequacy of the buried HDPE piping system are summarized in Table 6.11(b).

Table 6-11(b) - Buried HDPE Capacity Criteria

Service Level	Stress Condition	Capacity Criteria
Design		Requirements of N755-3131.1
		Requirements of N755-3223.1 with k=1.0
A	Primary – Side Wall Compression	500 psi (N755-3220) (1)
	Primary – Buckling due to External Pressure	Requirements of N755-3221.1
	Primary – Flotation	$W_P+[P_E*(D/12)]$
	Primary	Less than 1.0 * P_D
	Primary – Longitudinal Stress	Requirements of N755-3223.1 with k=1.0
	Secondary – Thermal	1100 psi (N755-3311.3)
	Non Repeated Anchor Motion	2*S (N755-3312)
B	Primary – Side Wall Compression	500 psi (N755-3220) (1)
	Primary – Buckling due to External Pressure	Requirements of N755-3221.1
	Primary – Flotation	$W_P+[P_E*(D/12)]$
	Primary – Pressure	Less than 1.1 * P_D
	Primary – Surge Pressure	1.5 * P_D
	Primary – Longitudinal Stress	Requirements of N755-3223.2 or 0.4*Material tensile strength at yield
	Secondary – Thermal	1100 psi (N755-3311.3)
	Secondary – Seismic	1100 psi (N755-3410)
C	Primary –Side Wall Compression	500 psi (N755-3220) (1)
	Primary – Buckling due to External Pressure	Requirements of N755-3221.1
	Primary – Flotation	$W_P+[P_E*(D/12)]$
	Primary – Pressure	Less than 1.33 * P_D
	Primary – Surge Pressure	2.0 * P_D
	Secondary - Thermal	1100 psi (N755-3311.3)
D	Primary – Side Wall Compression	500 psi (N755-3220) (1)
	Primary – Buckling due to External Pressure	Requirements of N755-3221.1
	Primary – Flotation	$W_P+[P_E*(D/12)]$
	Primary – Pressure	Less than 1.33 * P_D
	Primary – Surge Pressure	2.0 * P_D
	Secondary –Thermal	1100 psi (N755-3311.3)
	Secondary -- Seismic	1100 psi (N755-3410)

7.0 ANALYSIS

The analysis of the piping system is done per the Piping Design Specification Ref. [26] using analysis methods consistent with the relief request Ref. [14], and the ASME BPVC Code Case N-755 Ref. [12] as outlined in Section 5.2 of this calculation. The calculations presented in Section 5.2.1 are dependent only on design conditions and pipe size. For the calculations described in Section 5.2.2, the loads acting on the piping system (due to pressure, deadweight, thermal, seismic, etc.) for the various service levels are required. These loads are determined using the ADLPIPE computer program.

7.1 Computer Model

The run starts at the DG building wall of Unit 1 (Node Pt. = 100) and ends at the centerline of the 42-in Supply Header ‘A’ (Node Pt. = 5600). The piping system is considered anchored at each end.

A steel flange is welded to the 10-in pipe coming out of the DG building wall. A 10x12 steel reducer, with flanges on both ends, is attached to the 10-in pipe coming out of the DG building wall. A flanged joint is created (Node Pt. 130) between the steel reducer and the HDPE pipe by fusing an HDPE flange adapter, with a steel backup ring mounted on it, to the end of the HDPE pipe. The steel backup ring and the flange on the reducer have the same bolt pattern.

A 12-in pipe with a flange on one end is welded to the 42-in header. An additional 12-in steel pipe with flanges welded to its ends extends to Node Pt. 5490. A flanged joint between the steel pipe and the HDPE pipe is created (Node Pt. 5490) by fusing an HDPE flange adapter, with a steel backup ring mounted on it, to the end of the HDPE pipe. The steel backup ring and the flange on the 12-in pipe piece have the same bolt pattern.

Various mitered elbows are used as the HDPE pipe is routed from Node Pt. 130 at EL. 588’-6” to Node Pt. 5490 at EL. 580’-3”.

Details of the piping dimensions and routing are found in Refs. [5], [6], and [7]. The isometric sketch of the piping system is attached in Appendix A. The ADLPIPE computer model was created for this piping system using the inputs listed in Section 6 of this calculation. Soil springs were generally applied at 2 ft intervals around elbows and at 10 ft intervals in the remaining section of the piping. A complete listing of the ADLPIPE model (input file) and analysis results (output file) are attached in Appendix B.

7.2 Results of ADLPIPE Analysis

7.2.1 Load Cases Analyzed

Steel and HDPE pipe load cases as well as load combinations analyzed using the ADLPIPE piping analysis program are shown in Tables 7.2.1a and 7.2.1b. Thermal cases are required for Level A, B, C, and D because of the time dependence of the Elastic Modulus for HDPE pipe. The following durations were assumed for each service level:

Service Level A: 50 Years Ref. [14] E_c = 28,000 psi E_h = 23,000 psi
Service Level B: 10 Years Ref. [14] E_c = 32,000 psi E_h = 26,000 psi
Service Level C: 1000 Hrs Ref. [14] E_c = 44,000 psi E_h = 36,000 psi
Service Level D: 1000 Hrs Ref. [14] E_c = 44,000 psi E_h = 36,000 psi

Load Type	Load Case
Deadweight + Pressure	10
Level A Thermal at Minimum Temperature, T_{min} = 32^o F (ΔT = -23^o F)	21
Level A Thermal at Maximum Temperature, T_{max} = 100^o F (ΔT = 45^o F)	22
Level B Thermal at Minimum Temperature, T_{min} = 32^o F (ΔT = -23^o F)	23
Level B Thermal at Maximum Temperature, T_{max} = 100^o F (ΔT = 45^o F)	24
Level C/D Thermal at Minimum Temperature, T_{min} = 32^o F (ΔT = -23^o F)	25
Level C/D Thermal at Maximum Temperature, T_{max} = 100^o F (ΔT = 45^o F)	26
Thermal at T = 65^o F (ΔT = 10^o F)(1)	30

(1) This is a pseudo-seismic case. ΔT is the equivalent temperature rise for computing the seismic loads on the piping system.

[redacted]

Load Type	Load Case
Level A : Absolute Range of Load Cases 21 and 22	27
Level B : Absolute Range of Load Cases 23 and 24	28
Level C/D : Absolute Range of Load Cases 25 and 26	29
Level D : Absolute Range of Load Case 30 (SSE)	31
Level B : Load Case 31 / 1.875 (OBE) (1)	32
Level B: Absolute Thermal Max (L.C. 24) + OBE Seismic (L.C. 32)	40
Level B: Absolute Thermal Min (L.C. 23) + OBE Seismic (L.C. 32)	41
Level B: Max of Load Case 28, 40 and 41	45

(1) Per page 94 of Ref. [16], OBE = SSE/1.875.

7.2.2 Summary of HDPE Loads at Critical Locations

The loads acting at the critical locations on the HDPE pipe (i.e., where the maximum stresses occur) for Service Levels A, B, C and D are extracted from the results of the ADLPIPE analysis. These loads are summarized in Tables 7.2.2a to 7.2.2d and will be used for computing pipe stresses as described in Section 5 of this calculation.

Service Level A

[redacted]

Load Case	Straight Pipe				Mitered Elbow			
	F [lb]	Node No.	**M** [ft-lb]	Node No.	**F** [lb]	Node No.	**M** [ft-lb]	Node No.
10	0	540	490	540	7	270	62	270

[redacted]

Load Case	Straight Pipe				Mitered Elbow			
	F [lb]	Node No.	**M** [ft-lb]	Node No.	**F** [lb][1]	Node No.	**M** [ft-lb]	Node No.
27 (Level A)	4438	5250	799	5250	3740	870	1266	870
28 (Level B)	4925	5250	898	5250	4216	870	1459	870
29 (Level C/D)	6398	5250	1194	5250	5708	870	2095	870

[1] Values shown here were obtained from the SRSS of forces acting on the mitered elbow. Using these values for axial force is therefore conservative.

Service Level B

[redacted]

Load Case	Straight Pipe				Mitered Elbow			
	F [lb]	Node No.	**M** [ft-lb]	Node No.	**F** [lb][1]	Node No.	**M** [ft-lb]	Node No.
32 (OBE)	2295	840	678	840	2375	860	1085	860

[1] Values shown here were obtained from the SRSS of forces acting on the mitered elbow. Using these values for axial force is therefore conservative.

Service Level D

[redacted]

Load Case	Straight Pipe				Mitered Elbow			
	F [lb]	Node No.	**M** [ft-lb]	Node No.	**F** [lb][1]	Node No.	**M** [ft-lb]	Node No.
31 (SSE)	4302	840	1270	840	4453	860	2033	860

[1] Values shown here were obtained from the SRSS of forces acting on the mitered elbow. Using these values for axial force is therefore conservative.

7.3 Calculations per the ASME BPVC Code Case N-755

The HDPE piping system was analyzed per the Design Specification Ref. [26] which is consistent with Relief Request 06-CN-003 Ref. [14], and the ASME BPVC Code Case N-755 Ref. [12], as described in Sections 5.2.1 and 5.2.2, of this calculation. The manual calculations were performed using MathCad. The design conditions and the maximum loads obtained from ADLPIPE analysis (as listed in Tables 7.2.2a to 7.2.2d) were used to qualify the HDPE piping based on the applicable criteria for the applicable load cases. The manual calculations are provided below:

Manual Calculations Per ASME BPVC Code Case N-755:

Define Variables:

$S := 620 \cdot \frac{lb}{in^2}$	Allowable stress at 100º F
$E_{pipe50y} := 23000 \cdot \frac{lb}{in^2}$	Elastic modulus at 100º F for 50 yr load duration
$E_{pipe10h} := 100000 \cdot \frac{lb}{in^2}$	Elastic modulus at 100º F for short term load duration
$E' := 2000 \cdot \frac{lb}{in^2}$	Modulus for fine grain sand compacted to > 95%
$W_p := 18.4 \frac{lb}{ft}$	Weight of empty pipe per foot
$\gamma_w := 62.4 \frac{lb}{ft^3}$	Specific weight of water
$P := 100 \frac{lb}{in^2}$	Design pressure, psig
$\gamma_{soil} := 105 \cdot \frac{lb}{ft^3}$	Specific weight of dry soil
$L := 1.5$	Deflection lag factor
$K_{bed} := 0.1$	Bedding factor
$D := 12.75 \cdot in$	Outside diameter of pipe
$t = 1.159 \cdot in$	Minimum wall thickness for DR-11 pipe, Ref. [12]
$t = 1.417 \cdot in$	Minimum wall thickness for DR-9 pipe, Ref. [12]
$DR = \frac{D}{t}$	Dimensional ratio (DR = 11 for straight pipe and DR = 9 for mitered elbows)
$c := 0.0 in$	Allowance for mechanical and erosion damage

Section 3131.1 - Minimum Required Wall Thickness

Calculate the pressure design thickness, t_{min}:

$$t_{min} := \frac{P \cdot D}{(2 \cdot S + P)} \qquad t_{min} = 0.95in$$

Determine the minimum required wall thickness, t_{design}:

$$t_{design} := t_{min} + c \qquad t_{design} = 0.95in$$

Pipe wall thickness (DR 11), t = 1.159 in > 0.95 in...**O.K.**

Pipe wall thickness (DR 9), t = 1.417 in > 0.95 in...**O.K.**

Note that DR-11 governs. Therefore, for subsequent calculations, only DR-11 needs to be considered; that is::

$$DR := 11$$

Section 3210 - Ring Deflection

Determine the vertical soil pressure (P_L) due to surcharge loads.

Per Drawing No. CN-1038-03 [Ref. 5], the Transporter Haul Path crosses over the HDPE pipe lines of Unit 1. The Haul Path is at EL. 594'-0" and the pipe centerline is at EL. 586'-0". Hence, the soil depth from surface to top of pipe = 7.5 ft.

$$H := 7.5ft$$

As shown on page 21 of 79 of Ref. [13], the maximum vertical soil pressure (P_V) due to the combined weight of the transporter and cask at 7.5 feet below surface, not including impact, is:

$$P_V := 11.40\frac{lb}{in^2}$$

This soil pressure value was obtained based on a cask weight of 310 kip and transporter weight of 170 kip. Per Sheet 25 of EC./VN No. CD500920D (DOC. ID. 32-5053646-01 Rev. 1) dated 2-20-07, the cask weight is 314.6 kip, which is 1.5% greater than the original value used in computing soil pressure. Therefore, in this calculation, the vertical soil pressure value will be increased by 1.5%; that is:

$$P_V := 1.015 \cdot P_V \qquad P_V = 11.571\frac{lb}{in^2}$$

Per Ref. [13], the impact load factor (F) due to the cask dropping from a maximum height of 8.0 inches is:

$$F := 3.033$$

The maximum vertical soil pressure due to surcharge loads, including impact, is computed by applying the impact load factor to the combined weight of the transporter and cask. This is conservative since the impact load factor actually applies to the cask weight only. Therefore:

$$P_L := F \cdot P_v \qquad P_L = 35.09 \frac{lb}{in^2}$$

Calculate the vertical soil pressure due to earth loads. Note that there is no water above pipe; hence, dry soil is the only source of pressure.

$$P_E := \gamma_{soil} \cdot H \qquad P_E = 5.47 \frac{lb}{in^2}$$

Compute the ring deflection Ω by letting Soil Support Factor, $F_s = 0$. Note that as shown in Table 3210-2 of Ref. [12], the value of F_s depends on properties of the trench and native soil, and on pipe diameter and trench width. Using zero for Fs (see equation below) will yield a conservative value for Ω.

$$F_s := 0$$

Compute the ring deflection Ω .

$$\Omega_1 := \frac{K_{bed} \cdot L \cdot P_E}{\frac{2 \cdot E_{pipe50y}}{3} \cdot \left(\frac{1}{DR - 1}\right) + 0.061 \cdot F_s \cdot E'} \qquad \Omega_1 = 5.35 \times 10^{-4}$$

$$\Omega_2 := \frac{K_{bed} \cdot P_L}{\frac{2 \cdot E_{pipe10h}}{3} \cdot \left(\frac{1}{DR - 1}\right) + 0.061 \cdot F_s \cdot E'} \qquad \Omega_2 = 5.26 \times 10^{-4}$$

Note that the equation given in Ref. [12] for computing Ω includes a conversion factor of 144. Since MathCad automatically converts units, this conversion factor is not included in the above equation.

$\Omega := \Omega_1 + \Omega_2$ $\qquad\qquad$ $\Omega = 1.06\times 10^{-3}$

The maximum allowable ring deflection (Ωmax) is given in Ref. [12] as percent of the original diameter.
Per Table 3210-1 of Ref. [12], for DR = 11:

$\Omega max = 5\% = 0.05 > \Omega = 1.06\times 10^{-3}$ ....**O.K.**

Section 3220 - Compression of Sidewalls

Calculate the circumferential compressive stress (σ_{sw}) in the sidewalls of pipe and miters.

$$\sigma_{sw} := \frac{(P_E + P_L)\cdot DR}{2} \qquad \sigma_{sw} = 223.1\frac{lb}{in^2}$$

Note that the equation given in Ref. [12] for computing σ_{sw} includes a conversion factor of 144.
Since MathCad automatically converts units, the conversion factor is omitted here.

Compare σ_{sw} to the allowable stress value of 500 psi:

$\sigma_{sw} = 223.1\frac{lb}{in^2} < 500\ psi$ ....**O.K.**

Section 3221.1 - Buckling Due to External Pressure

Check that external pressure from ground water (Pgw), earth loads (P_E) and surcharge loads (P_L) does not cause the pipe to buckle.

$$Phydro = \left(Pgw + P_E + P_L\right) \le 2.8 \cdot \left[R_b \cdot B \cdot E' \cdot \frac{E_{pipe50y}}{12 \cdot (DR - 1)^3}\right]^{0.5}$$

Note that the equation provided in Ref. [12] for computing the external buckling pressure includes a conversion factor of 144. The conversion factor is not needed here since MathCad automatically converts units.

There is no water above the pipe. Hence:

$H_{gw} := 0ft$ $\qquad$ $P_{gw} := 0 \frac{lb}{in^2}$

$R_b := 1 - 0.33 \frac{H_{gw}}{H}$ $\qquad$ $R_b = 1$

Compute the burial factor, B. Note that for computing burial factor, height of soil above pipe (H) needs to be redefined as a quantity H_B with no units.

$H_B := 7.5$

$$B := \frac{1}{1 + 4 \cdot \exp\left(-0.065 \cdot H_B\right)} \qquad B = 0.289$$

$$P_{gw} + P_E + P_L = 40.6 \frac{lb}{in^2}$$

$$2.8 \cdot \left[R_b \cdot B \cdot E' \cdot \frac{E_{pipe50y}}{12 \cdot (DR - 1)^3}\right]^{0.5} = 93.2 \frac{lb}{in^2}$$

($P_{gw} + P_E + P_L$) is less than 93.2 lb/in^2...**O.K.**

Section 3221.2 - Effects of Negative Internal Pressure

$$\Delta P \le \frac{f_o}{2} \cdot \frac{2 \cdot Epipe10h}{\left(1 - \nu^2\right)} \cdot \left(\frac{1}{DR - 1}\right)^3$$

$f_o := 0.64$ Ovality correction factor per Table 3221.2-1 for 5% ovality

$\nu := 0.35$ Use short-term values for elastic modulus and Poisson ratio

$$\frac{f_o}{2} \cdot \frac{2 \cdot E_{pipe10h}}{\left(1 - \nu^2\right)} \cdot \left(\frac{1}{DR - 1}\right)^3 = 72.9 \frac{lb}{in^2}$$

Therefore, ΔP may not exceed 72.9 psi.

Section 3222 - Flotation

For floatation, the minimum height of soil above top of pipe (H = 5ft) should be used to calculate the vertical earth load P_E . Therefore, compute the vertical earth load based on H = 5ft.

$H := 5ft$

$P_E := \gamma_{soil} \cdot H$ $\qquad P_E = 3.65 \frac{lb}{in^2}$

$W_w < W_p + P_E \cdot D$ The equation given in Ref.[12] includes a conversion factor of 12. Mathcad automatically converts units; therefore, the conversion factor is not needed here.

$W_w := \frac{\pi \cdot D^2}{4} \cdot \gamma_w$ W_w is the unit weight of the water displaced by the pipe

$$W_w = 55.3 \frac{lb}{ft}$$

$$W_p + P_E \cdot D = 576.2 \frac{lb}{ft}$$

W_w is less than $W_p + P_E \cdot D$ ....**O.K.**

Calculation of Stresses Per Code Case N-755 [Ref. 12]

Define Variables:

$Pa := 100 \cdot \frac{lb}{in^2}$ — Design or Service Level A, B, C, or D pressure

$D := 12.75 \cdot in$ — Outside diameter of pipe and mitered elbow

Properties of Straight Pipe — Straight pipe is DR-11

$D_i := 10.432 \cdot in$ — Inside Diameter of straight pipe, per Ref. [12]

$t := 1.159 \cdot in$ — Wall thickness of straight pipe, per Ref. [12]

$A := \frac{\pi}{4} \cdot \left(D^2 - D_i^2\right)$ $\quad A = 42.2 in^2$ — Cross sectional area of straight pipe

$Z := \left(\frac{\pi}{32}\right) \cdot \frac{D^4 - D_i^4}{D}$ $\quad Z = 112.3 in^3$ — Section modulus of straight pipe

$i := 1.0$ — Stress Intensification Factor of straight pipe (per Table 3311.2-1)

$B_1 := 0.5$ $\quad B_2 := 1.0$ — Stress Indices of straight pipe (per Table 3223-1)

Properties of Mitered Elbow — Elbow is DR-9

$D_{ie} := 9.916 \cdot in$ — Inside Diameter of elbow, per Ref. [12]

$t_e := 1.417 \cdot in$ — Wall thickness of elbow, per Ref. [12]

$A_e := \frac{\pi}{4} \cdot \left(D^2 - D_{ie}^2\right)$ $\quad A_e = 50.5 in^2$ — Cross sectional area of elbow

$Z_e := \left(\frac{\pi}{32}\right) \cdot \frac{D^4 - D_{ie}^4}{D}$ $\quad Z_e = 129.0 in^3$ — Section modulus of elbow

$i_e := 2.0$ — Stress Intensification Factor of elbow (per Table 3311.2-1)

$B_{1e} := 0.69$ $\quad B_{2e} := 1.64$ — Stress Indices of elbow (per Table 3223-1)

The Design/Operating Temperature is 100 degrees F. The design pressure for the inlet line is 100 psig. The Level A, B, C, and D operating pressure for the inlet line is 75 psig. The maximum deadweight and presure loads (Load Case 10) are obtained from the ADLPIPE analysis and listed in Section 7.3 of this calculation. Qualification of the HDPE pipe is based on Design Level factors and Allowable stress using the Design temperature and pressure. Design pressue envelopes Service Levels A, B, C, and D pressures.

3223.1 - Longitudinal Stress Design

$S := 620 \cdot \frac{lb}{in^2}$ — Allowable stress at 100 degrees F (per Table 3131-1)

$k := 1.0$ — Longitudinal Stress Factor for Design (per Table 3223-2)

$k \cdot S = 620 \frac{lb}{in^2}$

<u>Straight Piping Section</u>: — Straight pipe is DR-11

$$B_1 \cdot \frac{P_a \cdot D}{2 \cdot t} + 2 \cdot B_1 \cdot \frac{F_a}{A} + B_2 \cdot \frac{M}{Z} \le k \cdot S$$

$F_a := 0 \cdot lb$ — Axial force due to deadweight on the straight pipe

$M := 490 \cdot lb \cdot ft$ — Resultant bending moment due to deadweight on the straight pipe

$$B_1 \cdot \frac{Pa \cdot D}{2 \cdot t} + 2 \cdot B_1 \cdot \frac{F_a}{A} + B_2 \cdot \frac{M}{Z} = 327.4 \frac{lb}{in^2}$$ which is less than $620 \frac{lb}{in^2}$ ....**OK**

<u>Mitered Elbow</u>: — Elbow is DR-9

$$B_{1e} \cdot \frac{P_a \cdot D}{2 \cdot t_e} + 2 \cdot B_{1e} \cdot \frac{F_{ae}}{A_e} + B_{2e} \cdot \frac{M_e}{Z_e} \le k \cdot S$$

$F_{ae} := 7 \cdot lb$ — Axial force due to deadweight on the mitered elbow

$M_e := 62 \cdot lb \cdot ft$ — Resultant bending moment due to deadweight on the mitered elbow

$$B_{1e} \cdot \frac{Pa \cdot D}{2 \cdot t_e} + 2 \cdot B_{1e} \cdot \frac{F_{ae}}{A_e} + B_{2e} \cdot \frac{M_e}{Z_e} = 320.1 \frac{lb}{in^2}$$ which is less than $620 \frac{lb}{in^2}$ ....**OK**

3311 - Design for Thermal Expansion and Contraction

Soil springs were applied to account for the soil stiffness. Therefore, the alternative method of 3311.3 is used: The maximum thermal range force and moment were used to check the stresses in the HDPE pipe. The thermal range of Service Level C/D envelopes Service Level A and B.

Straight Piping Section:

Straight pipe is DR-11

$$i \cdot \frac{M_c}{Z} + \frac{F_{ac}}{A} \le 1100 \cdot \frac{lb}{in^2}$$

$F_{ac} := 6398 \cdot lb$ — Axial force range due to thermal expansion and/or contraction on the straight pipe (Level C/D)

$M_c := 1194 \cdot ft \cdot lb$ — Resultant moment range due to thermal expansion and/or contraction on the straight pipe (Level C/D)

$$i \cdot \frac{M_c}{Z} + \frac{F_{ac}}{A} = 279.2 \frac{lb}{in^2}$$ which is less than $1100 \frac{lb}{in^2}$ ....**OK**

Mitered Elbow:

Elbow is DR-9

$$i_e \cdot \frac{M_{ce}}{Z_e} + \frac{F_{ace}}{A_e} \le 1100 \cdot \frac{lb}{in^2}$$

$F_{ace} := 5708 \cdot lb$ — Axial force range due to thermal expansion and/or contraction on the mitered elbow (Level C/D)

$M_{ce} := 2095 \cdot ft \cdot lb$ — Resultant moment range due to thermal expansion and/or contraction on the mitered elbow (Level C/D)

$$i_e \cdot \frac{M_{ce}}{Z_e} + \frac{F_{ace}}{A_e} = 502.8 \frac{lb}{in^2}$$ which is less than $1100 \frac{lb}{in^2}$ ....**OK**

3312 - Nonrepeated Anchor Movements

There are no nonrepeated (thermal) anchor movements .

3410 - Seismic Induced Stresses

This is applicable for both SSE and OBE loads. These stresses are based on evaluation of the SSE (Level D) conditions which also qualifies the piping for OBE (Level B) conditions as OBE loads are lower and OBE and SSE limits are the same

Straight Piping Section: Straight pipe is DR-11

$$i \cdot \frac{M_E}{Z} + \frac{F_{aE}}{A} \le 1100 \cdot \frac{lb}{in^2}$$

$F_{aE} := 4450 \cdot lb$ Axial force range due to seismic loads on the straight pipe

$M_E := 1268 \cdot ft \cdot lb$ Resultant moment range due to seismic loads on the straight pipe

$$i \cdot \frac{M_E}{Z} + \frac{F_{aE}}{A} = 240.9 \frac{lb}{in^2}$$ which is less than $1100 \frac{lb}{in^2}$ ....**OK**

Mitered Elbow: Mitered elbow is DR-9

$$i_e \cdot \frac{M_{Ee}}{Z_e} + \frac{F_{aEe}}{A_e} \le 1100 \cdot \frac{lb}{in^2}$$

$F_{aEe} := 4453 \cdot lb$ Axial force range due to seismic loads on the mitered elbow

$M_{Ee} := 2033 \cdot ft \cdot lb$ Resultant moment range due to seismic loads on the mitered elbow

$$i_e \cdot \frac{M_{Ee}}{Z_e} + \frac{F_{aEe}}{A_e} = 466.4 \frac{lb}{in^2}$$ which is less than $1100 \frac{lb}{in^2}$ ....**OK**

7.4 Stress Summary for Unit 1 Steel Pipe

Acceptance Criteria	Calculated Stress [psi]	Allowable Stress [psi]	Calculated / Allowable	Node Point
Equation 8 (Design)	2137	22500	0.09	5560
Equation 9 (Level A)	1612	27000	0.06	5560
Equation 9 (Level B)	1612	27000	0.06	5560
Equation 10 (Level A)	6025	22500	0.27	5560
Equation 10 (Level B)	7101	22500	0.32	5560
Equation 10 (Level C/D)	6296	22500	0.28	5560

7.5 Flange Summary for Unit 1 HDPE Pipe

The EPRI flange capacity tests, Ref. [22], demonstrated that if the pipe stresses at the fusion joint joining the HDPE flange adapter to the piping were less than the maximum code capacities, the flanges were adequate. For this system, all pipe stresses at the fusion joint, joining the HDPE flange adapter to the piping are less than the maximum permitted code capacities.

8.0 RESULTS

The HDPE piping system was found to be adequate. Table 8.a summarizes these results.

Table 8.a
Result Summary for 12" HDPE Pipe

Acceptance Criteria	Calculated Value	Allowable Value	Calculated / Allowable	Node Pt.
Minimum Required Wall Thickness	0.95"	1.159"	0.82	N/A
Ring Deflection	0.00106"	0.05"	0.02	N/A
Compression of Side Walls	223.1 psi	500 psi	0.45	N/A
Buckling Due to External Pressure	40.6 psi	93.2 psi	0.44	N/A
Effects of Negative Internal Pressure	> - 72.9 psi	0 psi	***0.0	N/A
Flotation	55.3 lb/ft	576 lb/ft	0.10	N/A
Deadweight + Pressure Stress – Straight Pipe	327.4 psi	620 psi	0.53	5150
Deadweight + Pressure Stress – Mitered Elbow	320.1 psi	620 psi	0.52	270
Thermal Stress – Straight Pipe	279.2 psi	1100 psi	0.25	5190
Thermal Stress – Mitered Elbow	502.8 psi	1100 psi	0.46	870
Seismic SSE Stress – Straight Pipe	240.9 psi	1100 psi	0.22	5120
Seismic SSE Stress – Mitered Elbow	466.4 psi	1100 psi	0.42	870

*** The HDPE pipe is not under a vacuum per the Design Specification Ref. [26]

The steel piping system was found to be adequate. Table 8.b summarizes these results

Table 8.b
Result Summary for 10" and 12" Steel Pipe

Acceptance Criteria	Calculated Stress [psi]	Allowable Stress [psi]	Calculated / Allowable	Node Point
Deadweight and Pressure (Design)	2137	22500	0.09	5560
Deadweight and Pressure (Level A)	1612	27000	0.06	5560
Thermal (Level A)	6025	22500	0.27	5560
Deadweight and Pressure (Level B)	1612	27000	0.06	5560
Thermal and Seismic (Level B)	7101	22500	0.32	5560
Seismic (Level C/D)	6296	22500	0.28	5560

8.1 Functionality Capability and Break Postulation

This piping analysis meets functional capability as defined in Ref. [24].   The maximum Level D Pressure and Temperature do not exceed design Pressure and Temperature. All piping stress limits given in ASME BPVC Code Case N-755 are met for all applied Level D loads and the capacities used in this review are based on the Design Temperature.

This piping is classified as moderate energy as defined in Ref. [24]. Moderate energy piping is piping that has a temperature of less than 200 º F and a pressure of 275 psig or less.   Per Ref [26], for this piping, the maximum temperature is 100º F and the operating pressure is 75 psig.   Leak cracks are to be postulated at points based on the following equation:

$$\frac{PD}{4t} + 0.75i\left[\frac{M_A}{Z} + \frac{F_{aA}}{A}\right] + i\left[\frac{M_C}{Z} + \frac{F_{aC}}{A}\right] + i\left[\frac{M_E}{Z} + \frac{F_{aE}}{A}\right] \le 0.4(1.1S + 1100 + 1100)psi = 0.4(1.1S + 2200)psi$$

where:

P = Operating pressure
D = Outside pipe diameter

t = Nominal pipe wall thickness
i = Stress intensification factor
A = Cross sectional area of pipe
Z = Section modulus of pipe
F_{aA} = Axial force due to deadweight loads
F_{aC} = Axial force range due to thermal loads
F_{aE} = Axial force range due to seismic loads
M_A = Moment due to deadweight loads
M_C = Moment range due to thermal loads
M_E = Moment range due to seismic loads

The deadweight, thermal, and seismic loads at the critical locations will be taken from Tables 7.2.2a to 7.2.2d for straight pipe and mitered elbows and checked to the postulated break equation. The maximum stresses for deadweight, seismic and thermal cases may occur at different locations. The equation uses the maximum stresses even when they are found in separate locations. This is conservative.

S = 620 psi → 0.4(1.1S + 2200) = 0.4 (1.1*620 + 2200) = 1153 psi

<u>For straight pipe</u>:

D = 12.75 in t = 1.159 in A = 42.2 in^2 Z = 112.3 in^3
P = 75 psi i = 1.0 0.75i = 1.0 (Note: 0.75i cannot be less than 1.0)
M_A = 490 ft-lb = 5880 in-lb M_C = 1194 ft-lb = 14328 in-lb M_E = 1270 ft-lb = 15240 in-lb
F_{aA} = 0 F_{aC} = 6398 lb F_{aE} = 4302 lb

Substituting these values into the equation yields:

$$\frac{75*12.75}{4*1.159} + 1.0\left[\frac{5880}{112.3} + \frac{0}{42.2}\right] + 1.0\left[\frac{14328}{112.3} + \frac{6398}{42.2}\right] + 1.0\left[\frac{15240}{112.3} + \frac{4302}{42.2}\right] = 776\,psi < 1153\,psi$$

Therefore, there are no postulated moderate energy leak cracks on the straight HDPE piping.

<u>For mitered elbows</u>:

D = 12.75 in t = 1.417 in A = 50.5 in^2 Z = 129.0 in^3
P = 75 psi i = 2.0 0.75i = 1.5
M_A = 62 ft-lb = 744 in-lb M_C = 2095 ft-lb = 25140 in-lb M_E = 2033 ft-lb = 24396 in-lb
F_{aA} = 7 lb F_{aC} = 5708 lb F_{aE} = 4453 lb

Substituting these values into the equation yields:

$$\frac{75*12.75}{4*1.417} + 1.5\left[\frac{744}{129} + \frac{7}{50.5}\right] + 2.0\left[\frac{25140}{129} + \frac{5708}{50.5}\right] + 2.0\left[\frac{24396}{129} + \frac{4453}{50.5}\right] = 1348\,psi > 1153\,psi$$

The thermal and seismic loads used in the above calculation occur at the 30^o mitered elbow (Node Points 860/870). Therefore, moderate energy leak cracks are postulated on the 30^o mitered elbow.

Client	Duke Power Carolinas, LLC	Calculation No.	07Q3691-CAL-003
Project	Catawba Unit # 1 and #2 – Buried HDPE Piping Design and Analysis		
Title	Analysis of Buried HDPE Piping System— Nuclear Service Water (NSW) Supply Line Diesel Generator "1A" Unit 1		
By:	[signature]	Date	11/10/08
Chk'd by	[signature]	Date	11/11/08

From the ADLPIPE analysis results, the second most stressed mitered elbow is the 45° mitered elbow at Node Point 5145. The maximum thermal loads (Load Case 29) and the maximum seismic loads (Load Case 31) for this elbow are as follows:

M_C = 1801 ft-lb = 21612 in-lb
F_{aC} = 3763 lb

M_E = 1663 ft-lb = 19956 in-lb
F_{aE} = 2729 lb

For deadweight loads, conservatively use the maximum values shown in Table 7.2.2a. Hence:

M_A = 62 ft-lb = 744 in-lb
F_{aA} = 7 lb

Substituting the above values into the equation for postulating medium energy leak crack yields:

$$\frac{75*12.75}{4*1.417}+1.5\left[\frac{744}{129}+\frac{7}{50.5}\right]+2.0\left[\frac{21612}{129}+\frac{3763}{50.5}\right]+2.0\left[\frac{19956}{129}+\frac{2729}{50.5}\right]=1079\,psi<1153\,psi$$

Therefore, there are no postulated moderate energy leak cracks on this 45° mitered elbow or the remaining mitered elbows.

Client	Duke Power Carolinas, LLC	Calculation No.	07Q3691-CAL-003
Project	Catawba Unit # 1 and #2 – Buried HDPE Piping Design and Analysis		
Title	Analysis of Buried HDPE Piping System— Nuclear Service Water (NSW) Supply Line Diesel Generator "1A" Unit 1		
By:	[signature] Date 11/10/08	Chk'd by [signature]	Date 11/11/08

8.2 Final Loads at the Anchor at the Diesel Generator Building due to Soil Effects

The maximum loads acting from the HDPE pipe for Service Levels A, B, C and D acting on the anchor at the face of the Diesel Generator Building are extracted from the results of the ADLPIPE analysis. These loads are summarized in Tables 8.2a and 8.2b and compared to the maximum loads that the HDPE pipe can contribute to anchor load at the face of the Diesel Generator Building.

Table 8.2a: HDPE Loads from ADLPIPE for Anchor at Diesel Generator Building

Load Case	Node Point	Fx (lbs)	Fy (lbs)	Fz (lbs)	Mx (ft-lb)	My (ft-lb)	Mz (ft-lb)
10 (DW)	100	0	517	0	1	0	1234
27 (Th)	100	6688	0	0	13	0	0
28 (Th)	100	7555	0	0	15	0	0
29 (Th)	100	10274	0	0	23	1	0
31 (SSE)	100	7738	0	0	26	2	2
32(OBE)	100	4127	0	0	14	1	1

Table 8.2b: HDPE Loads combined for maximum forces and moments to be compared to allowable interface loads applied to the steel pipe per Ref. [23]

Load Case	Node Point	Axial Force (lbs)		Shear Force (lbs)		Resultant Moment (in-lbs)	
		Combined from ADLPIPE	Maximum	Combined from ADLPIPE	Maximum	Combined from ADLPIPE	Maximum
10 (DW)	130	0	4200	99	4200	517	100000
27 (Th)	130	6688 (1)	4200	0	4200	156	100000
28 (Th)	130	7555 (1)	4600	0	4600	180	100000
29 (Th)	130	10274 (1)	5500	0	5500	276	100000
31 (SSE)	130	7738 (1)	4600	0	4600	313	100000
32 (OBE)	130	4127	4600	0	4600	169	100000

(1) The thermal axial forces exceed the maximum for the HDPE pipe. These forces are acceptable due to the very small shear force and moment at the same node point. Therefore, the loads shown above will be used as input for the anchor design at the Diesel Generator Building.

8.3 Final Loads at the Centerline of the 42" ø Supply Line due to Soil Effects

Table 8.3a: HDPE Loads from ADLPIPE at the Centerline of the 42" ø Supply Line

Load Case	Node Point	Fx (lbs)	Fy (lbs)	Fz (lbs)	Mx (ft-lb)	My (ft-lb)	Mz (ft-lb)
10 (DW)	5600	0	2202	0	336	0	4664
27 (Th)	5600	5904	0	163	9	32332	1
28 (Th)	5600	6621	0	188	11	36230	1
29 (Th)	5600	8835	1	273	18	48233	2
31 (SSE)	5600	6304	1	264	25	34021	4
32 (OBE)	5600	3362	1	141	13	18143	2

8.4 Branch Line Qualification

The branch line meets the 1989 ASME BPVC Code allowable stresses. Table 8.4a below shows the results of the ADLPIPE analysis for the branch line (Nodes 5490 to 5560).

Table 8.4a
Result Summary for 12" Steel Branch Line

Acceptance Criteria	Calculated Stress [psi]	Allowable Stress [psi]	Calculated / Allowable	Node Point
Deadweight and Pressure (Design)	2137	22500	0.09	5560
Deadweight and Pressure (Level A)	1612	27000	0.06	5560
Thermal (Level A)	6025	22500	0.27	5560
Deadweight and Pressure (Level B)	1612	27000	0.06	5560
Thermal and Seismic (Level B)	7101	22500	0.32	5560
Seismic (Level C/D)	6296	22500	0.28	5560

9.0 CONCLUSIONS

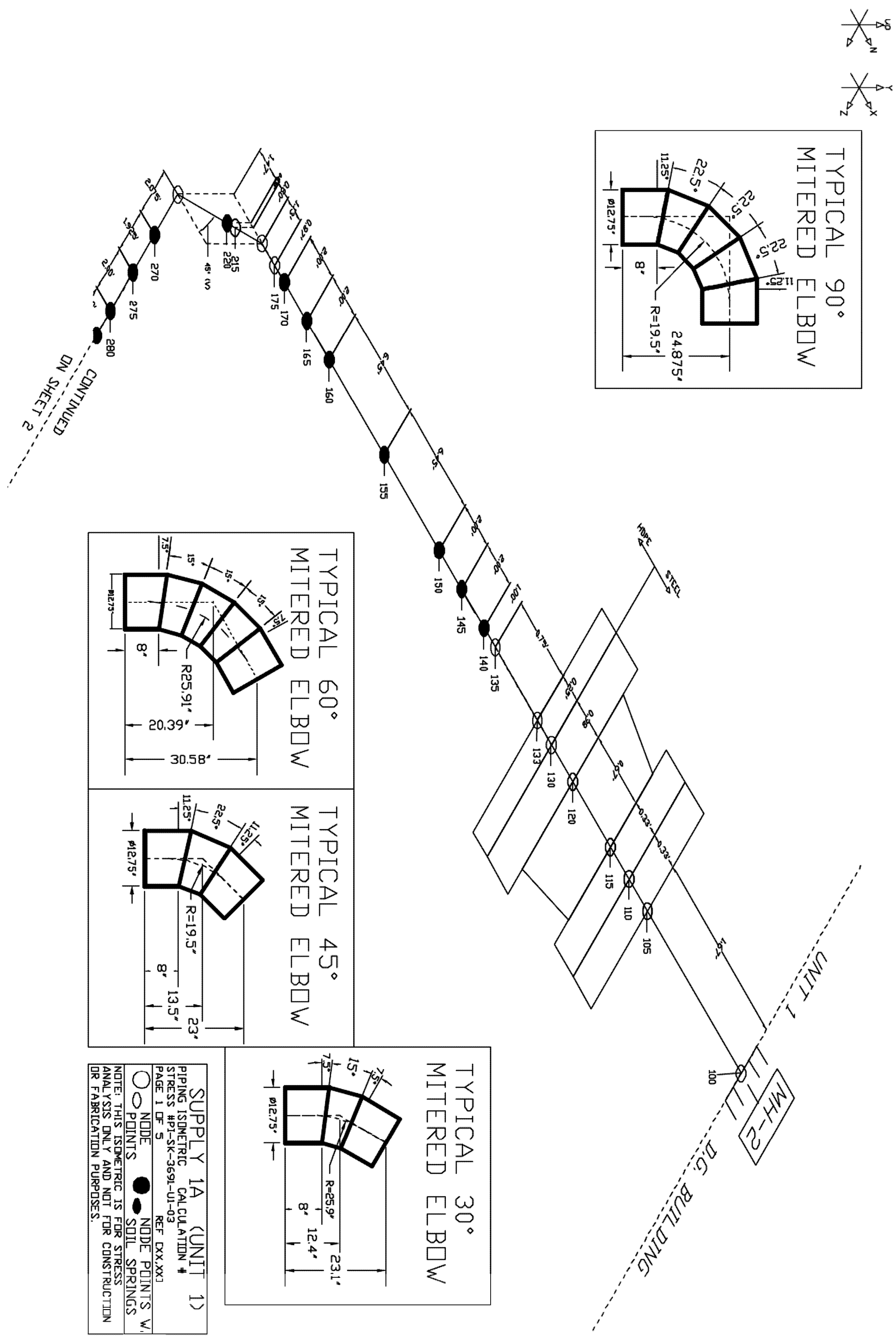
The existing 10-in carbon steel buried nuclear service water piping lines connecting the 42-in Nuclear Service Water System (NSWS) Supply Header 'A' to Unit 1 Diesel Generator (DG) building piping at the Catawba Nuclear Station will be replaced by 12-in high-density polyethylene (HDPE) piping system. This calculation determined that the buried HDPE piping system connecting the 42-in Supply Header 'A' to the DG building of Unit 1 meets all applicable acceptance criteria as defined in the piping design specification Ref. [26] which is consistent with the Relief Request, Ref. [14], and the ASME BPVC Code Case N-755 [Ref. 12] as summarized in Table 8-1.

Appendix A

ADLPIPE Model Isometrics

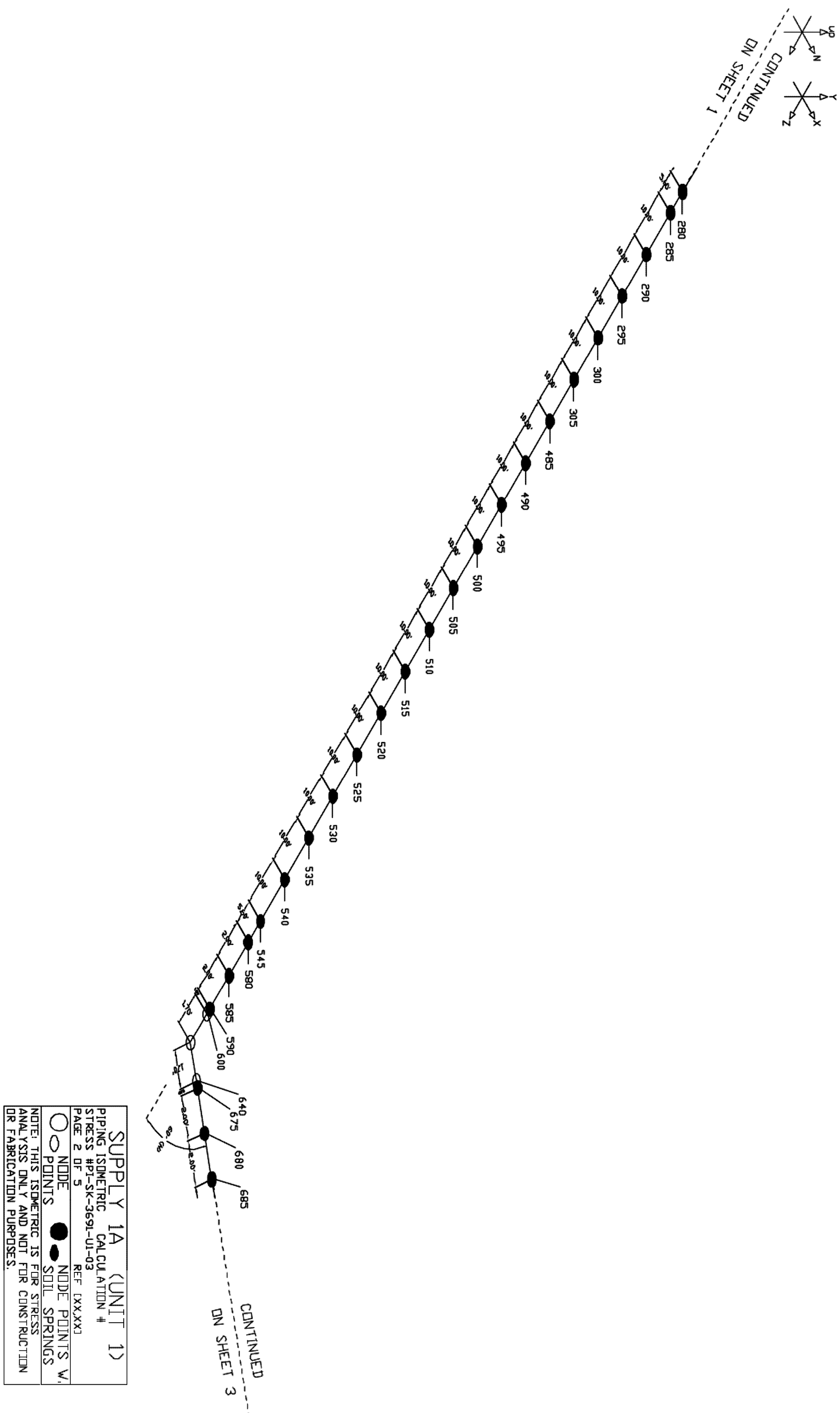
CALCULATION CONTINUATION SHEET

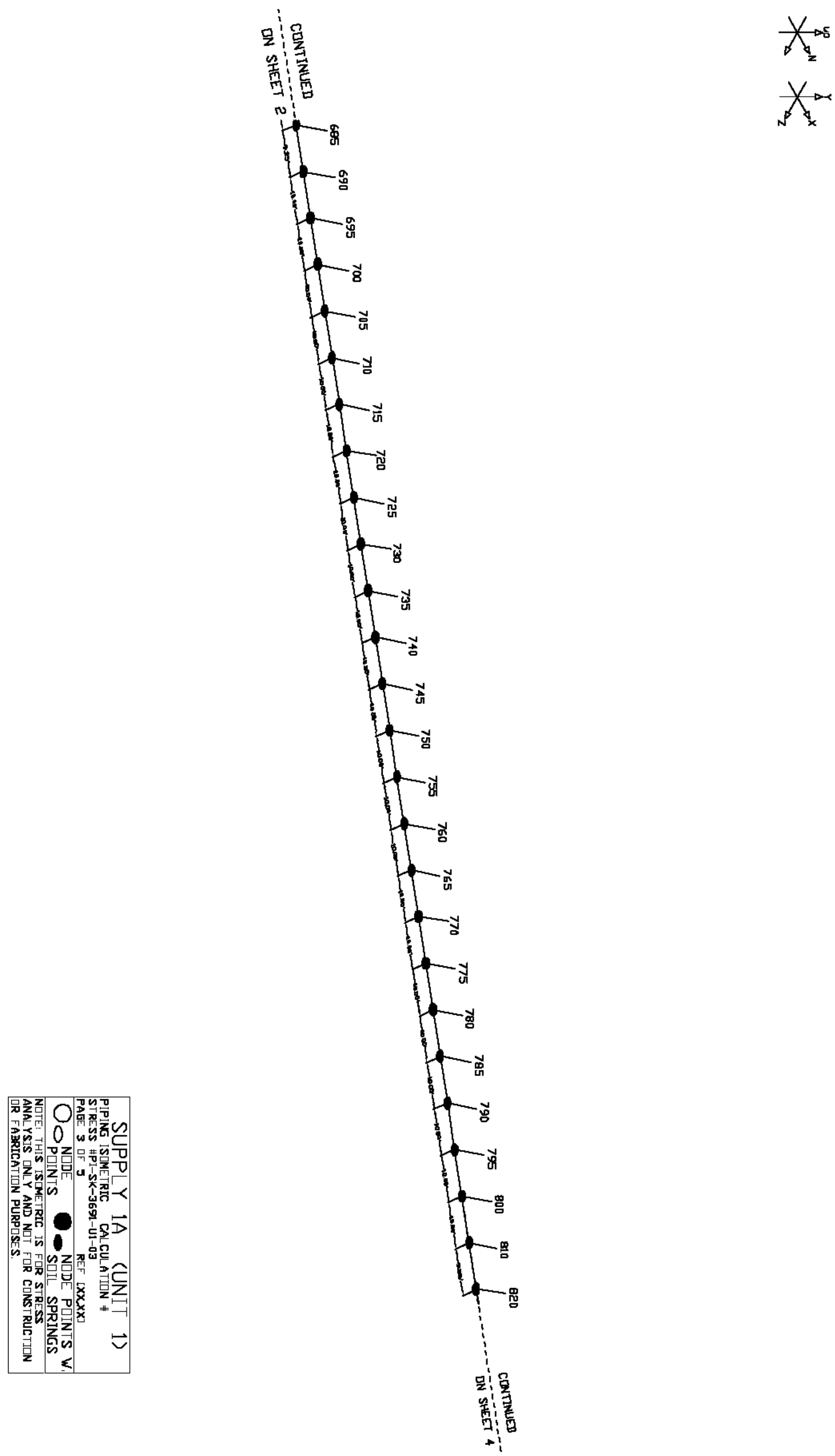
Client	Duke Power Carolinas, LLC	Calculation No.	07Q3691-CAL-003
Project	Catawba Unit # 1 and #2 – Buried HDPE Piping Design and Analysis		
Title	Analysis of Buried HDPE Piping System— Nuclear Service Water (NSW) Supply Line Diesel Generator "1A" Unit 1		
By:	[signature] Date 11/10/08	Chk'd by	[signature] Date 11/11/08



CALCULATION CONTINUATION SHEET

Client	Duke Power Carolinas, LLC	Calculation No.	07Q3691-CAL-003
Project	Catawba Unit # 1 and #2 – Buried HDPE Piping Design and Analysis		
Title	Analysis of Buried HDPE Piping System— Nuclear Service Water (NSW) Supply Line Diesel Generator "1A" Unit 1		
By:	[signature]	Date 11/10/08	Chk'd by [signature] Date 11/11/08

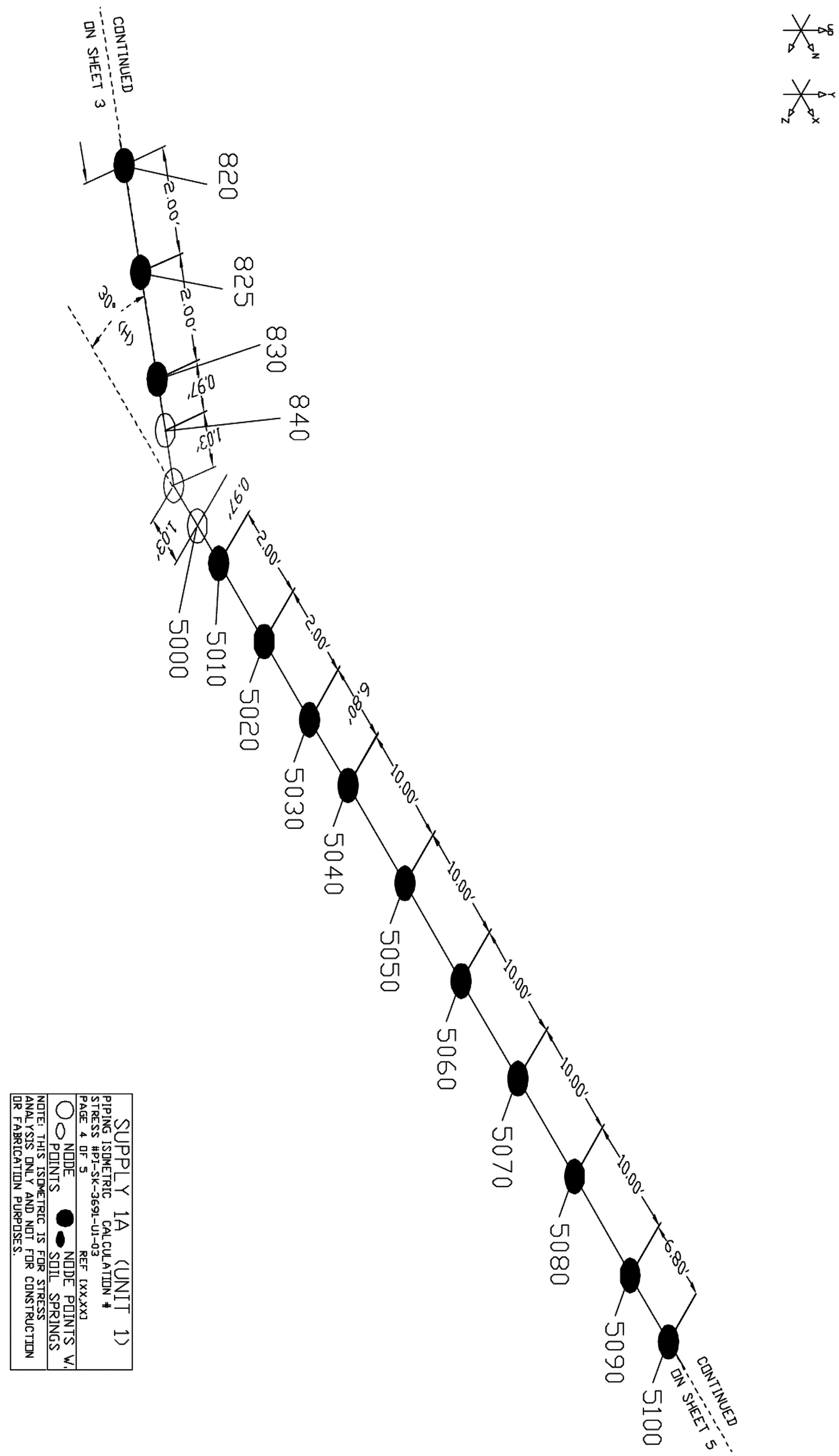




CONTINUED ON SHEET 2
685
690
695
700
705
710
715
720
725
730
735
740
745
750
755
760
765
770
775
780
785
790
795
800
810
820
CONTINUED ON SHEET 4
SUPPLY 1A (UNIT 1)
PIPING ISOMETRIC CALCULATION #
STRESS #PI-SK-3691-U1-03
PAGE 3 OF 5 REF [XXXX]
NODE POINTS
NODE POINTS W. SOIL SPRINGS
NOTE: THIS ISOMETRIC IS FOR STRESS ANALYSIS ONLY AND NOT FOR CONSTRUCTION OR FABRICATION PURPOSES.

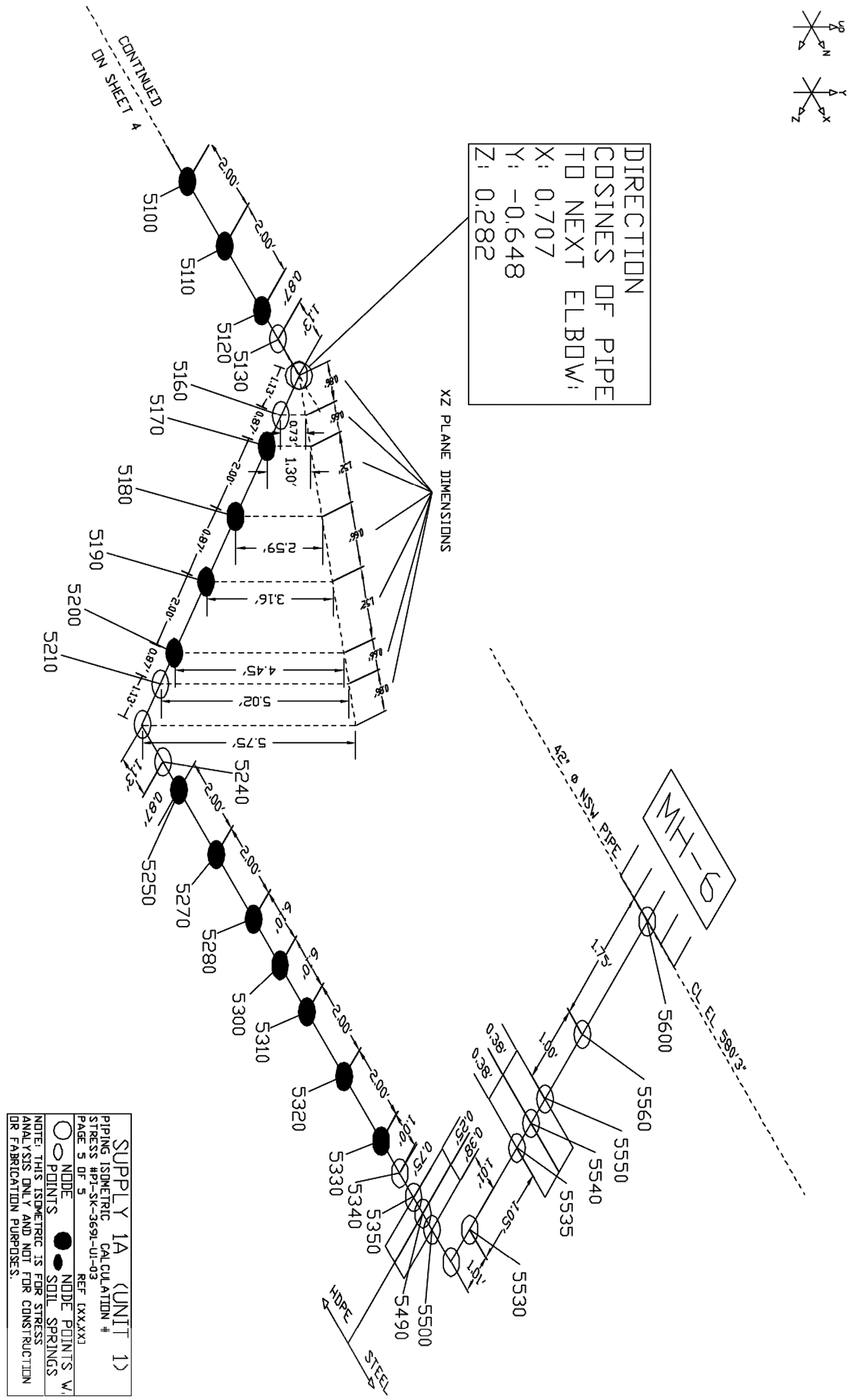
CALCULATION CONTINUATION SHEET

Client	Duke Power Carolinas, LLC	Calculation No.	07Q3691-CAL-003
Project	Catawba Unit # 1 and #2 – Buried HDPE Piping Design and Analysis		
Title	Analysis of Buried HDPE Piping System— Nuclear Service Water (NSW) Supply Line Diesel Generator "1A" Unit 1		
By:	[signature] Date 11/10/08	Chk'd by [signature]	Date 11/11/08



CALCULATION CONTINUATION SHEET

Client	Duke Power Carolinas, LLC	Calculation No.	07Q3691-CAL-003
Project	Catawba Unit # 1 and #2 – Buried HDPE Piping Design and Analysis		
Title	Analysis of Buried HDPE Piping System— Nuclear Service Water (NSW) Supply Line Diesel Generator "1A" Unit 1		
By:	[signature] Date 11/10/08	Chk'd by [signature]	Date 11/11/08



Appendix B

ADLPIPE Input and Output files

Client	Duke Power Carolinas, LLC	Calculation No.	07Q3691-CAL-003
Project	Catawba Unit # 1 and #2 – Buried HDPE Piping Design and Analysis		
Title	Analysis of Buried HDPE Piping System— Nuclear Service Water (NSW) Supply Line Diesel Generator "1A" Unit 1		
By:	[signature] Date 11/10/08	Chk'd by [signature]	Date 11/11/08

INPUT FILE:

```
GE,***********          CATAWBA NUCLEAR STATION          ***********
GE,COOLING WATER SUPPLY LINE FROM 42-IN HEADER 'A' TO D/G BLDG OF UNIT 1
UN,0,0,0,
NOTE,MODEL=supply1a.adi
NO,*******************************************************************
NO,THERE ARE TWO SUPPLY LINES RUNNING TO THE D/G BUILDING OF UNIT 1
NO,THIS IS THE LINE THAT ORIGINATES FROM THE 42-IN SUPPLY HEADER 'A'
NO,*******************************************************************
NO,COORDINATE SYSTEM: +X = NORTH, +Z = EAST, Y = VERTICAL
NO,*******************************************************************
NO,PIPING: 10" AND 12", SCH. 40, Cr-Mo AND CARBON STEEL PIPES,
NO,       12", DR 11, IPS HDPE PIPE,
NO,CONTENTS:
NO,       WATER FILLED, NO INSULATION,
NO,DESIGN CONDITIONS:
NO,       T(AMBIENT) = 55 F, T(DESIGN) = 100 F, P(DESIGN) = 100 PSIG
NO,CODE:   ASME, YEAR 1989,
NO,*******************************************************************
NO,ASSUME PIPE IS ANCHORED AT BOTH ENDS
AN,,100,
RE,,100,1,1,1,1,1,1,
AN,,5600,
RE,,5600,1,1,1,1,1,1,
NO,*******************************************************************
NO,THE FOLLOWING SOIL SPRING STIFFNESS VALUES IN [LB/IN] ARE USED.
NO
NO,                       LENGTH OF PIPE BETWEEN SPRINGS
NO,    SOIL HEIGHT   DIRECTION    ------------------------------
NO,    ABOVE PIPE    OF SPRING    2FT SECTION     10FT SECTION
NO,    ---------------------------------------------------------
NO,       H = 5 FT  LATERAL          3120              15600
NO,                      VERTICAL         12960             64800
NO,                      AXIAL            10200             51000
NO
NO,       H = 7.5 FT     LATERAL          3720              18600
NO,                      VERTICAL         16920             84600
NO,                      AXIAL            14760             73800
NO,
NO,       H = 13.25 FT   LATERAL          4680              23400
NO,                      VERTICAL         25320             126600
NO,                      AXIAL            25320             126600
NO
NO,STIFFNESS VALUES FOR OTHER LENGTHS ARE OBTAINED BY PROPORTION
NO,*******************************************************************
NO
RE,,1140,1,1,1,1,1,1,
RE,,2140,1,1,1,1,1,1,
RE,,3140,1,1,1,1,1,1,
RE,,1145,1,1,1,1,1,1,
RE,,2145,1,1,1,1,1,1,
RE,,3145,1,1,1,1,1,1,
RE,,1150,1,1,1,1,1,1,
RE,,2150,1,1,1,1,1,1,
RE,,3150,1,1,1,1,1,1,
RE,,1155,1,1,1,1,1,1,
RE,,2155,1,1,1,1,1,1,
RE,,3155,1,1,1,1,1,1,
RE,,1160,1,1,1,1,1,1,
RE,,2160,1,1,1,1,1,1,
```

```
RE,,3160,1,1,1,1,1,1,
RE,,1165,1,1,1,1,1,1,
RE,,2165,1,1,1,1,1,1,
RE,,3165,1,1,1,1,1,1,
RE,,1170,1,1,1,1,1,1,
RE,,2170,1,1,1,1,1,1,
RE,,3170,1,1,1,1,1,1,
RE,,1220,1,1,1,1,1,1,
RE,,2220,1,1,1,1,1,1,
RE,,3220,1,1,1,1,1,1,
RE,,1270,1,1,1,1,1,1,
RE,,2270,1,1,1,1,1,1,
RE,,3270,1,1,1,1,1,1,
RE,,1275,1,1,1,1,1,1,
RE,,2275,1,1,1,1,1,1,
RE,,3275,1,1,1,1,1,1,
RE,,1280,1,1,1,1,1,1,
RE,,2280,1,1,1,1,1,1,
RE,,3280,1,1,1,1,1,1,
RE,,1285,1,1,1,1,1,1,
RE,,2285,1,1,1,1,1,1,
RE,,3285,1,1,1,1,1,1,
RE,,1290,1,1,1,1,1,1,
RE,,2290,1,1,1,1,1,1,
RE,,3290,1,1,1,1,1,1,
RE,,1295,1,1,1,1,1,1,
RE,,2295,1,1,1,1,1,1,
RE,,3295,1,1,1,1,1,1,
RE,,1300,1,1,1,1,1,1,
RE,,2300,1,1,1,1,1,1,
RE,,3300,1,1,1,1,1,1,
RE,,1305,1,1,1,1,1,1,
RE,,2305,1,1,1,1,1,1,
RE,,3305,1,1,1,1,1,1,
RE,,1485,1,1,1,1,1,1,
RE,,2485,1,1,1,1,1,1,
RE,,3485,1,1,1,1,1,1,
RE,,1490,1,1,1,1,1,1,
RE,,2490,1,1,1,1,1,1,
RE,,3490,1,1,1,1,1,1,
RE,,1495,1,1,1,1,1,1,
RE,,2495,1,1,1,1,1,1,
RE,,3495,1,1,1,1,1,1,
RE,,1500,1,1,1,1,1,1,
RE,,2500,1,1,1,1,1,1,
RE,,3500,1,1,1,1,1,1,
RE,,1505,1,1,1,1,1,1,
RE,,2505,1,1,1,1,1,1,
RE,,3505,1,1,1,1,1,1,
RE,,1510,1,1,1,1,1,1,
RE,,2510,1,1,1,1,1,1,
RE,,3510,1,1,1,1,1,1,
RE,,1515,1,1,1,1,1,1,
RE,,2515,1,1,1,1,1,1,
RE,,3515,1,1,1,1,1,1,
RE,,1520,1,1,1,1,1,1,
RE,,2520,1,1,1,1,1,1,
RE,,3520,1,1,1,1,1,1,
RE,,1525,1,1,1,1,1,1,
RE,,2525,1,1,1,1,1,1,
RE,,3525,1,1,1,1,1,1,
RE,,1530,1,1,1,1,1,1,
```

RE,,2530,1,1,1,1,1,1,
RE,,3530,1,1,1,1,1,1,
RE,,1535,1,1,1,1,1,1,
RE,,2535,1,1,1,1,1,1,
RE,,3535,1,1,1,1,1,1,
RE,,1540,1,1,1,1,1,1,
RE,,2540,1,1,1,1,1,1,
RE,,3540,1,1,1,1,1,1,
RE,,1545,1,1,1,1,1,1,
RE,,2545,1,1,1,1,1,1,
RE,,3545,1,1,1,1,1,1,
RE,,1580,1,1,1,1,1,1,
RE,,2580,1,1,1,1,1,1,
RE,,3580,1,1,1,1,1,1,
RE,,1585,1,1,1,1,1,1,
RE,,2585,1,1,1,1,1,1,
RE,,3585,1,1,1,1,1,1,
RE,,1590,1,1,1,1,1,1,
RE,,2590,1,1,1,1,1,1,
RE,,3590,1,1,1,1,1,1,
RE,,1675,1,1,1,1,1,1,
RE,,2675,1,1,1,1,1,1,
RE,,3675,1,1,1,1,1,1,
RE,,1680,1,1,1,1,1,1,
RE,,2680,1,1,1,1,1,1,
RE,,3680,1,1,1,1,1,1,
RE,,1685,1,1,1,1,1,1,
RE,,2685,1,1,1,1,1,1,
RE,,3685,1,1,1,1,1,1,
RE,,1690,1,1,1,1,1,1,
RE,,2690,1,1,1,1,1,1,
RE,,3690,1,1,1,1,1,1,
RE,,1695,1,1,1,1,1,1,
RE,,2695,1,1,1,1,1,1,
RE,,3695,1,1,1,1,1,1,
RE,,1700,1,1,1,1,1,1,
RE,,2700,1,1,1,1,1,1,
RE,,3700,1,1,1,1,1,1,
RE,,1705,1,1,1,1,1,1,
RE,,2705,1,1,1,1,1,1,
RE,,3705,1,1,1,1,1,1,
RE,,1710,1,1,1,1,1,1,
RE,,2710,1,1,1,1,1,1,
RE,,3710,1,1,1,1,1,1,
RE,,1715,1,1,1,1,1,1,
RE,,2715,1,1,1,1,1,1,
RE,,3715,1,1,1,1,1,1,
RE,,1720,1,1,1,1,1,1,
RE,,2720,1,1,1,1,1,1,
RE,,3720,1,1,1,1,1,1,
RE,,1725,1,1,1,1,1,1,
RE,,2725,1,1,1,1,1,1,
RE,,3725,1,1,1,1,1,1,
RE,,1730,1,1,1,1,1,1,
RE,,2730,1,1,1,1,1,1,
RE,,3730,1,1,1,1,1,1,
RE,,1735,1,1,1,1,1,1,
RE,,2735,1,1,1,1,1,1,
RE,,3735,1,1,1,1,1,1,
RE,,1740,1,1,1,1,1,1,
RE,,2740,1,1,1,1,1,1,
RE,,3740,1,1,1,1,1,1,

```
RE,,1745,1,1,1,1,1,1,
RE,,2745,1,1,1,1,1,1,
RE,,3745,1,1,1,1,1,1,
RE,,1750,1,1,1,1,1,1,
RE,,2750,1,1,1,1,1,1,
RE,,3750,1,1,1,1,1,1,
RE,,1755,1,1,1,1,1,1,
RE,,2755,1,1,1,1,1,1,
RE,,3755,1,1,1,1,1,1,
RE,,1760,1,1,1,1,1,1,
RE,,2760,1,1,1,1,1,1,
RE,,3760,1,1,1,1,1,1,
RE,,1765,1,1,1,1,1,1,
RE,,2765,1,1,1,1,1,1,
RE,,3765,1,1,1,1,1,1,
RE,,1770,1,1,1,1,1,1,
RE,,2770,1,1,1,1,1,1,
RE,,3770,1,1,1,1,1,1,
RE,,1775,1,1,1,1,1,1,
RE,,2775,1,1,1,1,1,1,
RE,,3775,1,1,1,1,1,1,
RE,,1780,1,1,1,1,1,1,
RE,,2780,1,1,1,1,1,1,
RE,,3780,1,1,1,1,1,1,
RE,,1785,1,1,1,1,1,1,
RE,,2785,1,1,1,1,1,1,
RE,,3785,1,1,1,1,1,1,
RE,,1790,1,1,1,1,1,1,
RE,,2790,1,1,1,1,1,1,
RE,,3790,1,1,1,1,1,1,
RE,,1795,1,1,1,1,1,1,
RE,,2795,1,1,1,1,1,1,
RE,,3795,1,1,1,1,1,1,
RE,,1800,1,1,1,1,1,1,
RE,,2800,1,1,1,1,1,1,
RE,,3800,1,1,1,1,1,1,
RE,,1810,1,1,1,1,1,1,
RE,,2810,1,1,1,1,1,1,
RE,,3810,1,1,1,1,1,1,
RE,,1820,1,1,1,1,1,1,
RE,,2820,1,1,1,1,1,1,
RE,,3820,1,1,1,1,1,1,
RE,,1825,1,1,1,1,1,1,
RE,,2825,1,1,1,1,1,1,
RE,,3825,1,1,1,1,1,1,
RE,,1830,1,1,1,1,1,1,
RE,,2830,1,1,1,1,1,1,
RE,,3830,1,1,1,1,1,1,
RE,,15010,1,1,1,1,1,1,
RE,,25010,1,1,1,1,1,1,
RE,,35010,1,1,1,1,1,1,
RE,,15020,1,1,1,1,1,1,
RE,,25020,1,1,1,1,1,1,
RE,,35020,1,1,1,1,1,1,
RE,,15030,1,1,1,1,1,1,
RE,,25030,1,1,1,1,1,1,
RE,,35030,1,1,1,1,1,1,
RE,,15040,1,1,1,1,1,1,
RE,,25040,1,1,1,1,1,1,
RE,,35040,1,1,1,1,1,1,
RE,,15050,1,1,1,1,1,1,
RE,,25050,1,1,1,1,1,1,
```

```
RE,,35050,1,1,1,1,1,1,
RE,,15060,1,1,1,1,1,1,
RE,,25060,1,1,1,1,1,1,
RE,,35060,1,1,1,1,1,1,
RE,,15070,1,1,1,1,1,1,
RE,,25070,1,1,1,1,1,1,
RE,,35070,1,1,1,1,1,1,
RE,,15080,1,1,1,1,1,1,
RE,,25080,1,1,1,1,1,1,
RE,,35080,1,1,1,1,1,1,
RE,,15090,1,1,1,1,1,1,
RE,,25090,1,1,1,1,1,1,
RE,,35090,1,1,1,1,1,1,
RE,,15100,1,1,1,1,1,1,
RE,,25100,1,1,1,1,1,1,
RE,,35100,1,1,1,1,1,1,
RE,,15110,1,1,1,1,1,1,
RE,,25110,1,1,1,1,1,1,
RE,,35110,1,1,1,1,1,1,
RE,,15120,1,1,1,1,1,1,
RE,,25120,1,1,1,1,1,1,
RE,,35120,1,1,1,1,1,1,
RE,,15170,1,1,1,1,1,1,
RE,,25170,1,1,1,1,1,1,
RE,,35170,1,1,1,1,1,1,
RE,,15180,1,1,1,1,1,1,
RE,,25180,1,1,1,1,1,1,
RE,,35180,1,1,1,1,1,1,
RE,,15190,1,1,1,1,1,1,
RE,,25190,1,1,1,1,1,1,
RE,,35190,1,1,1,1,1,1,
RE,,15200,1,1,1,1,1,1,
RE,,25200,1,1,1,1,1,1,
RE,,35200,1,1,1,1,1,1,
RE,,15250,1,1,1,1,1,1,
RE,,25250,1,1,1,1,1,1,
RE,,35250,1,1,1,1,1,1,
RE,,15270,1,1,1,1,1,1,
RE,,25270,1,1,1,1,1,1,
RE,,35270,1,1,1,1,1,1,
RE,,15280,1,1,1,1,1,1,
RE,,25280,1,1,1,1,1,1,
RE,,35280,1,1,1,1,1,1,
RE,,15300,1,1,1,1,1,1,
RE,,25300,1,1,1,1,1,1,
RE,,35300,1,1,1,1,1,1,
RE,,15310,1,1,1,1,1,1,
RE,,25310,1,1,1,1,1,1,
RE,,35310,1,1,1,1,1,1,
RE,,15320,1,1,1,1,1,1,
RE,,25320,1,1,1,1,1,1,
RE,,35320,1,1,1,1,1,1,
RE,,15330,1,1,1,1,1,1,
RE,,25330,1,1,1,1,1,1,
RE,,35330,1,1,1,1,1,1,
SE,,0,
NO,*******************************************************************
NO,THE PIPING SYSTEM STARTS AT THE SURFACE OF THE D/G BUILDING WALL
NO,WITH A 10-IN Cr-Mo STEEL PIPE THAT IS CONSIDERED ANCHORED AT THE
NO,SURFACE OF THE WALL (NODE PT. 100).
NO
NO,PIPE CENTERLINE IS AT ELEVATION 588'-6"
```

```
NO
NO,A 10X12 STEEL REDUCER, WITH FLANGES WELDED ON ITS ENDS, CONNECTS,
NO,THE 10-IN PIPE TO A 12-IN HDPE PIPE.
NO,*****************************************************************
NO,10-IN, SCH. 40 Cr-Mo STEEL PIPE PROPERTIES:,
NO,    OUTSIDE DIAMETER = 10.75 IN
NO,    WALL THICKNESS = 0.365 IN
NO,    WT(PIPE)= 40.5LB/FT = 3.38 LB/IN
NO,    WT(WATER) = 34.1 LB/FT= 2.84 LB/IN
NO,    WT(PIPE+WATER) = 3.38 + 2.84 = 6.22 LB/IN
NO
NO,PROPERTIES OF PIPE MATERIAL (SB-690/SB-675) AT 70 F:
NO,    E = 28E+06 PSI
NO,    ALPHA = 8.1E-06 IN/IN/F
NO,*****************************************************************
NO
PI,100,105,10.75,0.365,28.0,8.1,.01,6.22,
NO
NO,*****************************************************************
NO,LENGTH OF 10-IN DIAMETER PIPE COMING OUT OF WALL = 20IN = 1.67FT
NO,*****************************************************************
NO
RU,100,105,-1.67,,,
NO
NO,*****************************************************************
NO,ATTACH A 150-LB WELDING NECK (WN) FLANGE TO END OF 10-IN PIPE
NO,AND TO THE 10" SIDE OF REDUCER
NO,FOR 10-IN WN FLANGE (PER LADISH CATALOG):
NO,   TOTAL LENGTH = 4.0 IN = 0.33 FT
NO,   FLANGE THICKNESS = 1.188 IN
NO,   O. D. OF FLANGE = 16 IN
NO,   DIAMETER AT HUB BASE= 12.0 IN
NO,   WALL THICKNESS (MIN) = 0.365 IN
NO,   WEIGHT OF FLANGE= 54 LB -->  UNIT WT = 13.50 LB/IN
NO,   WT(FLANGE+WATER)= 13.50 + 2.84 = 16.3 LB/IN
NO,USE DIAMETER AT HUB BASE AS O.D. FOR MODELING
NO,*****************************************************************
NO
NOTE,IV=WNFL,END=FLG
1V,105,110,-0.33,,,12.0,0.365,16.3,
NOTE,IV=WNFL,BEG=FLG
1V,110,115,-0.33,,,12.0,0.365,16.3,
NO
NO,*****************************************************************
NO,INSTALL A 10X12 STEEL REDUCER.
NO,PER LADISH CATALOG:
NO,     REDUCER LENGTH = 8 IN = 0.67 FT
NO,     REDUCER WEIGHT = 34 LB --> UNIT WT = 4.25 LB/IN
NO,WEIGHT OF WATER:
NO,     FOR 10" PIPE = 34.1 LB/FT = 2.84 LB/IN
NO,     FOR 12" PIPE = 49.0 LB/FT = 4.08 LB/IN
NO,     FOR 10X12 REDUCER = (2.84+4.08)/2 = 3.46 LB/IN
NO,WT (REDUCER+WATER) = 4.25 + 3.46 = 7.7 LB/IN
NO,FOR 12" PIPE: OD = 12.75 IN AND WALL THICKNESS = 0.375 IN
NO,*****************************************************************
NO
RD,115,120,-0.67,,,12.75,0.375,7.7,
NO
NO,*****************************************************************
NO,ATTACH A WELDING NECK (WN) FLANGE TO THE 12-IN SIDE OF REDUCER
NO,FOR 12-IN,150-LB WN FLANGE (PER LADISH CATALOG):,
NO,   TOTAL LENGTH = 4.5 IN = 0.38 FT
```

```
NO,    FLANGE THICKNESS = 1.25 IN
NO,    O. D. OF FLANGE = 19 IN
NO,    DIAMETER AT HUB BASE= 14.375 IN
NO,    WALL THICKNESS (MIN) = 0.375 IN
NO,    WEIGHT OF FLANGE= 88 LB -->  UNIT WT = 19.56 LB/IN
NO,    WT(FLANGE+WATER)= 19.56 + 4.08 = 23.6 LB/IN
NO,USE DIAMETER AT HUB BASE AS O.D. FOR MODELING
NO,*******************************************************************
NO
NOTE,IV=WNFL,END=FLG
1V,120,130,-0.38,,,14.375,0.375,23.6,
SE,,0,
NO
NO,*******************************************************************
NO,                  CHANGE TO 12" HDPE PIPE
NO,*******************************************************************
NO,12-IN, DR 11, HDPE PIPE PROPERTIES:,
NO,     OUTSIDE DIAMETER, OD = 12.75 IN
NO,     MIN.WALL THICKNESS, t = 1.159 IN
NO,     INSIDE DIAMETER, ID = OD - 2t = 10.432 IN
NO,     WT(PIPE) = 18.41 LB/FT = 1.53 LB/IN
NO,     WT(WATER) = 37.04 LB/FT = 3.09 LB/IN
NO,     WT(WATER+PIPE) = 1.53 + 3.09 = 4.62 LB/IN
NO
NO,HDPE PROPERTIES AT 70F AND 50-YEAR DURATION:
NO,     E = 28 KSI
NO,     ALPHA = 90.0E-6 IN/IN/F
NO,*******************************************************************
NO
PI,130,133,12.75,1.159,0.028,90.0,0.01,4.62,
NO
NO,*******************************************************************
NO,INSTALL A FLANGE ADAPTER WITH A STEEL BACKUP RING MOUNTED ON IT
NO
NO,FOR 12-IN, DR 11, IPS HDPE FLANGE ADAPTER (PER ISCO CATALOG):,
NO,      TOTAL LENGTH = 12.0 IN = 1.0 FT
NO,      FLANGE THICKNESS = 1.55 IN
NO,      WEIGHT OF ADAPTER = 24 LB
NO,FOR 12-IN STEEL BACKUP RING (PER ISCO CATALOG):
NO,      THICKNESS = 1.25 IN,     WEIGHT = 24 LB
NO
NO,MODEL ADAPTER AND RING ASSEMBLY AS A PIPE AND FLANGE COMBINATION
NO,FOR FLANGE, USE:,
NO,      LENGTH = 1.55+1.25 = 2.8" -->  LENGTH = 3 IN
NO,      WALL THICKNESS = 1.159 IN
NO,      O.D. OF FLANGE = 15.5 IN
NO,      WEIGHT = WT(RING+ADAPTER) - WT(9" LONG PIPE)
NO,             = 24.0 + 24.0 - 18.4*(9/12) = 34.2 LB
NO       WT(FLANGE+WATER)= (34.2/3)+3.09 = 14.5 LB/IN
NO
NO,FOR PIPE, USE:,
NO,      LENGTH = 12.0 - 3.0 = 9 IN
NO,      WT(PIPE+WATER) = 4.62 LB/IN
NO,*******************************************************************
NO
NOTE,IV=WNFL,BEG=FLG
1V,130,133,-0.25,,,15.5,1.159,14.5,
RU,133,135,-0.75,,,
NO
NO,*******************************************************************
NO,PIPE ORIENTATION: PARALLEL TO X-AXIS
NO
```

```
NO,SINCE PIPE AXIS IS AT ELEVATION 588'-6", HEIGHT OF SOIL (H) FROM,
NO,TOP OF PIPE = 5 FT.  THEREFORE, USE SOIL SPRING STIFFNESS VALUES
NO,OBTAINED FOR H = 5 FT
NO
NO,                SPRING STIFFNESS [LB/IN]
NO,   DIRECTION            ----------------------------
NO,   OF SPRING            2FT SECTION    10FT SECTION
NO,   --------------------------------------------
NO,       LATERAL          3120              15600
NO,       VERTICAL         12960             64800
NO,       AXIAL            10200             51000
NO
NO,START APPLYING SOIL SPRINGS AT 2 FT INTERVALS
NO,LOCATION OF 1ST SPRING SET FROM END OF FLANGE ADAPTER = 1.0FT
NO,*****************************************************************
NO
RU,135,140,-1.0,
SE,,0,
RU,140,1140,1.0,,,
2SP,140,1140,10200,,,
SE,,0,
RU,140,2140,,1.0,,
2SP,140,2140,12960,,,
SE,,0,
RU,140,3140,,,1.0,
2SP,140,3140,3120,,,
SE,,0,
RU,140,145,-2.0,
SE,,0,
RU,145,1145,1.0,,,
2SP,145,1145,10200,,,
SE,,0,
RU,145,2145,,1.0,,
2SP,145,2145,12960,,,
SE,,0,
RU,145,3145,,,1.0,
2SP,145,3145,3120,,,
SE,,0,
RU,145,150,-2.0,
SE,,0,
RU,150,1150,1.0,,,
2SP,150,1150,10200,,,
SE,,0,
RU,150,2150,,1.0,,
2SP,150,2150,12960,,,
SE,,0,
RU,150,3150,,,1.0,
2SP,150,3150,3120,,,
SE,,0,
NO,*****************************************************************
NO,CHANGE SOIL SPRING SPACING FROM 2FT TO 10 FT
NO
NO,REMAINING LENGTH OF PIPE PARALLEL TO X-AXIS= 32.4'-5'-6'= 21.4FT
NO
NO,LENGTH AVAILABLE TO APPLY SPRINGS EVERY 10FT = 21.4'-6.0'-2.5'
NO,                              = 12.9 FT
NO,MODEL THIS AVAILABLE LENGTH WITH TWO SECTIONS AS FOLLOWS:
NO,     12.9 FT = 2 * 6.45 FT
NO,*****************************************************************
NO,EACH OF THE NEXT TWO SECTION ARE 6.45 FT LONG.  SOIL SPRING
NO,STIFFNESS VALUES ARE ADJUSTED (PROPORTIONAL TO SECTION LENGTH)
NO,*****************************************************************
```

```
NO
RU,150,155,-6.45,
SE,,0,
RU,155,1155,1.0,,,
2SP,155,1155,32895,,,
SE,,0,
RU,155,2155,,1.0,,
2SP,155,2155,41796,,,
SE,,0,
RU,155,3155,,,1.0,
2SP,155,3155,10836,,,
SE,,0,
RU,155,160,-6.45,
SE,,0,
RU,160,1160,1.0,,,
2SP,160,1160,32895,,,
SE,,0,
RU,160,2160,,1.0,,
2SP,160,2160,41796,,,
SE,,0,
RU,160,3160,,,1.0,
2SP,160,3160,10836,,,
SE,,0,
NO,*******************************************************************
NO,START APPLYING SOIL SPRINGS AROUND ELBOW AT 2 FT INTERVALS
NO,*******************************************************************
RU,160,165,-2.0,
SE,,0,
RU,165,1165,1.0,,,
2SP,165,1165,10200,,,
SE,,0,
RU,165,2165,,1.0,,
2SP,165,2165,12960,,,
SE,,0,
RU,165,3165,,,1.0,
2SP,165,3165,3120,,,
SE,,0,
RU,165,170,-2.0,
SE,,0,
RU,170,1170,1.0,,,
2SP,170,1170,10200,,,
SE,,0,
RU,170,2170,,1.0,,
2SP,170,2170,12960,,,
SE,,0,
RU,170,3170,,,1.0,
2SP,170,3170,3120,,,
SE,,0,
NO
NO,********************************************************************
NO,NEXT RUN GOES UP TO THE BEGINNING OF 45- DEGREE MITERED ELBOW
NO,LENGTH OF 45-DEG. MITERED ELBOW (SEE BELOW): FC = 1.13 FT
NO,THEREFORE, LENGTH OF NEXT RUN = 2.0'-1.13' = 0.87 FT
NO,*****************************************************************
NO
RU,170,175,-0.87,
NO
NO,*****************************************************************
NO,**********     45 DEGREE IPS HDPE ELBOW     **************
NO,*****************************************************************
NO,THIS IS A 3-SEGMENT MITERED ELBOW.
NO,FOR 12-IN, DR-9, MITERED ELBOW (PER ISCO CATALOG):,
```

```
NO,       OUTSIDE DIAMETER, OD = 12.75 IN
NO,       MIN. WALL THICKNESS, t = 1.417 IN
NO,       INSIDE DIAMETER, ID = OD - 2t = 9.916 IN
NO,       RADIUS, R = 19.5 IN
NO,       LENGTH, FC = 13.5 IN = 1.13 FT
NO,       WT(PIPE) = 21.97 LB/FT = 1.83 LB/IN
NO,WEIGHT OF WATER FOR ID = 9.916 IN:
NO,       WT(WATER)= 33.46 LB/FT = 2.79 LB/IN
NO,WT(PIPE+WATER) = 1.83 + 2.79 = 4.62 LB/IN
NO
NO,SIF AND STRESS INDICES FOR MITERED ELBOW:
NO,       SIF = 2.0       B1 = 0.69          B2 = 1.64
NO
NO,ELBOW STARTS AT PT 175 AND ENDS AT PT 215
NO,******************************************************************
NO
RU,175,180,-1.13,,,
CM,180,190,12.75,1.417,,19.5,11.25,4.62,
IB,180,190,2.0,.69,1.64,
CM,190,200,12.75,1.417,,19.5,22.5,4.62,
IB,190,200,2.0,.69,1.64,
CM,200,210,12.75,1.417,,19.5,,4.62,
IB,200,210,2.0,.69,1.64,
RU,210,215,-0.8,-0.8,,
NO
NO,******************************************************************
NO,PIPE AXIS OF NEXT SECTION MAKES 45 DEGREES (CCW) WITH THE Y-AXIS
NO
NO,PIPE DROPS FROM EL. 588'-6" TO EL. 586'-0"
NO,LENGTH OF PIPING = 2.5'/COS(45)= 3.536' = 42.4 IN < 4FT
NO,APPLY ONLY ONE SET OF SOIL SPRINGS AT (APPROX.) CENTER OF SPAN
NO
NO,A 90-DEGREE ELBOW CHANGES THE PIPING ORIENTATION AT EL.586'-0"
NO
NO,LENGTH OF 90-DEG. MITERED ELBOW (SEE BELOW): FC= 24.9 IN
NO,LENGTH OF STRAIGHT PIPE REQUIRED BETWEEN THE TWO ELBOWS:
NO,           L2 = 42.4-24.9-13.5 = 4.0 IN
NO
NO,NEXT RUN REPRESENTS THE 4" STUB. SOIL SPRINGS WILL BE PLACED AT
NO,END OF THIS STUB (WHICH IS ALSO THE BEGINNING OF 90-DEGREE ELBOW)
NO,USE (APPROX.) SPRING STIFFNESS VALUES OF A 2-FT SPAN.
NO,******************************************************************
NO
RU,215,220,-0.235,-0.235,,
NO
SE,,0,
RU,220,1220,-0.707,-0.707,,
2SP,220,1220,10200,
SE,,0,
RU,220,2220,-0.707,0.707,,
NO,*****************************************************************
NO,PIPE IS INCLINED WITH RESPECT TO VERTICAL AXIS.  THEREFORE
NO,SPRING RATE IN THIS DIRECTION IS COMPUTED FROM VERTICAL (Kv)
NO,AND LATERAL (Kt) SOIL SPRING RATES AS FOLLOWS:
NO,    K = SQRT[(0.707Kv)^2 + (0.707Kt)^2]
NO,    K = SQRT[(0.707*12960)^2 +(0.707*3120)^2] = 9425 LB/IN
NO,*****************************************************************
2SP,220,2220,9425,
SE,,0,
RU,220,3220,,,1.0,
2SP,220,3220,3120,,,
SE,,0,
```

CALCULATION CONTINUATION SHEET

Client	Duke Power Carolinas, LLC	Calculation No.	07Q3691-CAL-003
Project	Catawba Unit # 1 and #2 – Buried HDPE Piping Design and Analysis		
Title	Analysis of Buried HDPE Piping System— Nuclear Service Water (NSW) Supply Line Diesel Generator “1A” Unit 1		
By:	[signature] Date 11/10/08	Chk'd by	[signature] Date 11/11/08

```
NO,*****************************************************************
NO,**********       90 DEGREE IPS HDPE ELBOW       **************
NO,*****************************************************************
NO,THIS IS A 5-SEGMENT MITERED ELBOW.
NO,FOR 12-IN, DR-9, MITERED ELBOW (PER ISCO CATALOG):,
NO,      OUTSIDE DIAMETER, OD = 12.75 IN
NO,      MIN. WALL THICKNESS, t = 1.417 IN
NO,      INSIDE DIAMETER, ID = OD - 2t = 9.916 IN
NO,      RADIUS, R = 19.5 IN
NO,      LENGTH, FC = 24.9 IN = 2.075 FT
NO,      WT(PIPE) = 21.97 LB/FT = 1.83 LB/IN
NO,WEIGHT OF WATER FOR ID = 9.916 IN:
NO,      WT(WATER)= 33.46 LB/FT = 2.79 LB/IN
NO,WT(PIPE+WATER) = 1.83 + 2.79 = 4.62 LB/IN
NO
NO,SIF AND STRESS INDICES FOR MITERED ELBOW:
NO,      SIF = 2.0      B1 = 0.69        B2 = 1.64
NO
NO,ELBOW STARTS AT PT. 220 AND ENDS AT PT. 270
NO,*****************************************************************
NO
RU,220,230,-1.47,-1.47,,
CM,230,235,12.75,1.417,,19.5,11.25,4.62,
IB,230,235,2.0,.69,1.64,
CM,235,240,12.75,1.417,,19.5,22.5,4.62,
IB,235,240,2.0,.69,1.64,
CM,240,245,12.75,1.417,,19.5,22.5,4.62,
IB,240,245,2.0,.69,1.64,
CM,245,250,12.75,1.417,,19.5,22.5,4.62,
IB,245,250,2.0,.69,1.64,
CM,250,260,12.75,1.417,,19.5,,4.62,
IB,250,260,2.0,.69,1.64,
RU,260,270,,,2.075,
NO
NO,*****************************************************************
NO,PIPE AXIS IS NOW PARALLEL TO Z-AXIS,  X IS LATERAL DIRECTION,
NO
NO,TOTAL LENGTH OF PIPING UP TO THE NEXT (60-DEG.) ELBOW = 193.2 FT
NO
NO,LENGTH USED FOR APPLICATION OF SOIL SPRINGS AT 2FT INTERVALS
NO,(AROUND ELBOWS ON EACH END OF PIPING) = 12 FT
NO
NO,LENGTH AVAILABLE TO APPLY SPRINGS AT 10 FT INTERVALS = 181.2 FT
NO,*****************************************************************
NO,SINCE 90-DEG ELBOW LENGTH = 24.9" = 2.075 FT (APPROX.= 2FT),
NO,FOR SIMPLICITY, APPLY FISRT SET OF SOIL SPRINGS AT END OF ELBOW
NO,AND USE STIFFNESS VALUES OBTAINED FOR A 2FT SECTION.
NO,*****************************************************************
NO,
NO,PIPE AXIS IS AT ELEVATION 586'-0"; HENCE, HEIGHT OF SOIL (H) FROM,
NO,TOP OF PIPE = 7.5 FT.  THEREFORE, USE SOIL SOIL SPRING STIFFNESS
NO,VALUES OBTAINED FOR H = 7.5 FT
NO
NO,              SPRING STIFFNESS [LB/IN]
NO,   DIRECTION           ----------------------------
NO,   OF SPRING           2FT SECTION    10FT SECTION
NO,   ---------------------------------------------
NO,      LATERAL          3720             18600
NO,      VERTICAL         16920            84600
NO,      AXIAL            14760            73800
NO
NO,*****************************************************************
```

```
NO,APPLY 1st SET OF SOIL SPRINGS AT END OF 90-DEGREE MITERED ELBOW
NO,******************************************************************
SE,,0,
RU,270,1270,1.0,,,
2SP,270,1270,3720,
SE,,0,
RU,270,2270,,1.0,,
2SP,270,2270,16920,
SE,,0,
RU,270,3270,,,1.0,
2SP,270,3270,14760,
SE,,0,
NO,******************************************************************
NO,FOR NEXT RUN, USE LENGTH = 1.925 FT (INSTEAD OF 2FT)
NO,
NO,APPLY SOIL SPRINGS AT END OF THIS RUN.  USE SPRING STIFFNESS
NO,VALUES OBTAINED FOR A 2 FT SECTION
NO,******************************************************************
NO,
RU,270,275,,,1.925,
SE,,0,
RU,275,1275,1.0,,,
2SP,275,1275,3720,
SE,,0,
RU,275,2275,,1.0,,
2SP,275,2275,16920,
SE,,0,
RU,275,3275,,,1.0,
2SP,275,3275,14760,
SE,,0,
NO,******************************************************************
NO,APPLY 3RD SPRING SET AT END OF NEXT 2FT SECTION
NO,******************************************************************
RU,275,280,,,2.0,
SE,,0,
RU,280,1280,1.0,,,
2SP,280,1280,3720,
SE,,0,
RU,280,2280,,1.0,,
2SP,280,2280,16920,
SE,,0,
RU,280,3280,,,1.0,
2SP,280,3280,14760,
SE,,0,
NO,******************************************************************
NO,CHANGE SOIL SPRING SPACING FROM 2FT TO 10 FT
NO,DIVIDE AVAILABLE LENGTH AS FOLLOWS: 181.2FT = 17*10FT + 2*5.6FT
NO,
NO,******************************************************************
NO,LENGTH OF NEXT SECTION = 5.6 FT.  SOIL SPRING STIFFNESS VALUES
NO,ARE ADJUSTED (PROPORTIONAL TO SECTION LENGTH)
NO,******************************************************************
RU,280,285,,,5.6,
SE,,0,
RU,285,1285,1.0,,,
2SP,285,1285,10416,
SE,,0,
RU,285,2285,,1.0,,
2SP,285,2285,47376,
SE,,0,
RU,285,3285,,,1.0,
2SP,285,3285,41328,
```

```
SE,,0,
NO,*****************************************************************
NO,APPLY SPRINGS EVERY 10FT OVER THE NEXT 170FT OF PIPING SECTION
NO,*****************************************************************
RU,285,290,,,10.0,
SE,,0,
RU,290,1290,1.0,,,
2SP,290,1290,18600,
SE,,0,
RU,290,2290,,1.0,,
2SP,290,2290,84600,
SE,,0,
RU,290,3290,,,1.0,
2SP,290,3290,73800,
SE,,0,
RU,290,295,,,10.0,
SE,,0,
RU,295,1295,1.0,,,
2SP,295,1295,18600,
SE,,0,
RU,295,2295,,1.0,,
2SP,295,2295,84600,
SE,,0,
RU,295,3295,,,1.0,
2SP,295,3295,73800,
SE,,0,
RU,295,300,,,10.0,
SE,,0,
RU,300,1300,1.0,,,
2SP,300,1300,18600,
SE,,0,
RU,300,2300,,1.0,,
2SP,300,2300,84600,
SE,,0,
RU,300,3300,,,1.0,
2SP,300,3300,73800,
SE,,0,
RU,300,305,,,10.0,
SE,,0,
RU,305,1305,1.0,,,
2SP,305,1305,18600,
SE,,0,
RU,305,2305,,1.0,,
2SP,305,2305,84600,
SE,,0,
RU,305,3305,,,1.0,
2SP,305,3305,73800,
SE,,0,
NO,*****************************************************************
NO,NODE NUMBERS BETWEEN 305 AND 485 INTENTIONALLY SKIPPED
NO,*****************************************************************
RU,305,485,,,10.0,
SE,,0,
RU,485,1485,1.0,,,
2SP,485,1485,18600,
SE,,0,
RU,485,2485,,1.0,,
2SP,485,2485,84600,
SE,,0,
RU,485,3485,,,1.0,
2SP,485,3485,73800,
SE,,0,
```

```
RU,485,490,,,10.0,
SE,,0,
RU,490,1490,1.0,,,
2SP,490,1490,18600,
SE,,0,
RU,490,2490,,1.0,,
2SP,490,2490,84600,
SE,,0,
RU,490,3490,,,1.0,
2SP,490,3490,73800,
SE,,0,
RU,490,495,,,10.0,
SE,,0,
RU,495,1495,1.0,,,
2SP,495,1495,18600,
SE,,0,
RU,495,2495,,1.0,,
2SP,495,2495,84600,
SE,,0,
RU,495,3495,,,1.0,
2SP,495,3495,73800,
SE,,0,
RU,495,500,,,10.0,
SE,,0,
RU,500,1500,1.0,,,
2SP,500,1500,18600,
SE,,0,
RU,500,2500,,1.0,,
2SP,500,2500,84600,
SE,,0,
RU,500,3500,,,1.0,
2SP,500,3500,73800,
SE,,0,
RU,500,505,,,10.0,
SE,,0,
RU,505,1505,1.0,,,
2SP,505,1505,18600,
SE,,0,
RU,505,2505,,1.0,,
2SP,505,2505,84600,
SE,,0,
RU,505,3505,,,1.0,
2SP,505,3505,73800,
SE,,0,
RU,505,510,,,10.0,
SE,,0,
RU,510,1510,1.0,,,
2SP,510,1510,18600,
SE,,0,
RU,510,2510,,1.0,,
2SP,510,2510,84600,
SE,,0,
RU,510,3510,,,1.0,
2SP,510,3510,73800,
SE,,0,
RU,510,515,,,10.0,
SE,,0,
RU,515,1515,1.0,,,
2SP,515,1515,18600,
SE,,0,
RU,515,2515,,1.0,,
2SP,515,2515,84600,
```

```
SE,,0,
RU,515,3515,,,1.0,
2SP,515,3515,73800,
SE,,0,
RU,515,520,,,10.0,
SE,,0,
RU,520,1520,1.0,,,
2SP,520,1520,18600,
SE,,0,
RU,520,2520,,1.0,,
2SP,520,2520,84600,
SE,,0,
RU,520,3520,,,1.0,
2SP,520,3520,73800,
SE,,0,
RU,520,525,,,10.0,
SE,,0,
RU,525,1525,1.0,,,
2SP,525,1525,18600,
SE,,0,
RU,525,2525,,1.0,,
2SP,525,2525,84600,
SE,,0,
RU,525,3525,,,1.0,
2SP,525,3525,73800,
SE,,0,
RU,525,530,,,10.0,
SE,,0,
RU,530,1530,1.0,,,
2SP,530,1530,18600,
SE,,0,
RU,530,2530,,1.0,,
2SP,530,2530,84600,
SE,,0,
RU,530,3530,,,1.0,
2SP,530,3530,73800,
SE,,0,
RU,530,535,,,10.0,
SE,,0,
RU,535,1535,1.0,,,
2SP,535,1535,18600,
SE,,0,
RU,535,2535,,1.0,,
2SP,535,2535,84600,
SE,,0,
RU,535,3535,,,1.0,
2SP,535,3535,73800,
SE,,0,
RU,535,540,,,10.0,
SE,,0,
RU,540,1540,1.0,,,
2SP,540,1540,18600,
SE,,0,
RU,540,2540,,1.0,,
2SP,540,2540,84600,
SE,,0,
RU,540,3540,,,1.0,
2SP,540,3540,73800,
SE,,0,
RU,540,545,,,10.0,
SE,,0,
RU,545,1545,1.0,,,
```

```
2SP,545,1545,18600,
SE,,0,
RU,545,2545,,1.0,,
2SP,545,2545,84600,
SE,,0,
RU,545,3545,,,1.0,
2SP,545,3545,73800,
SE,,0,
NO,*****************************************************************
NO,NEXT PIPING SECTION IS 5.6 FT LONG.  SOIL SPRING STIFFNESS
NO,VALUES ARE ADJUSTED (PROPORTIONAL TO SECTION LENGTH)
NO,*****************************************************************
NO
RU,545,580,,,5.6,
SE,,0,
RU,580,1580,1.0,,,
2SP,580,1580,10416,
SE,,0,
RU,580,2580,,1.0,,
2SP,580,2580,47376,
SE,,0,
RU,580,3580,,,1.0,
2SP,580,3580,41328,
SE,,0,
NO,*****************************************************************
NO,CHANGE SPACING OF SOIL SPRINGS TO 2 FT (AROUND 60-DEGREE ELBOW)
NO,*****************************************************************
RU,580,585,,,2.0,
SE,,0,
RU,585,1585,1.0,,,
2SP,585,1585,3720,
SE,,0,
RU,585,2585,,1.0,,
2SP,585,2585,16920,
SE,,0,
RU,585,3585,,,1.0,
2SP,585,3585,14760,
SE,,0,
RU,585,590,,,2.0,
SE,,0,
RU,590,1590,1.0,,,
2SP,590,1590,3720,
SE,,0,
RU,590,2590,,1.0,,
2SP,590,2590,16920,
SE,,0,
RU,590,3590,,,1.0,
2SP,590,3590,14760,
SE,,0,
NO,*****************************************************************
NO,NEXT RUN GOES UP TO THE BEGINNING OF 60-DEG. MITERED ELBOW
NO,LENGTH OF 60-DEG.ELBOW (SEE BELOW BELOW) = 20.4IN = 1.7 FT
NO,THEREFORE, LENGTH OF NEXT RUN = 2.0 - 1.7 = 0.3 FT
NO,*****************************************************************
NO
RU,590,600,,,0.3,
NO
NO,*****************************************************************
NO,**********      60 DEGREE IPS HDPE ELBOW       **************
NO,*****************************************************************
NO,THIS IS A 12-IN, DR 9, 5-SEGMENT MITERED ELBOW.  THIS IS NOT A,
NO,COMMONLY AVAILABLE STANDARD COMPONENT.  THE FOLLOWING DIMENSIONS
```

```
NO,ARE USED TO MODEL THE ELBOW:
NO,      OUTSIDE DIAMETER, OD = 12.75 IN
NO,      MIN. WALL THICKNESS, t = 1.417 IN
NO,      INSIDE DIAMETER, ID = OD - 2t = 9.916 IN
NO,      RADIUS, R = 25.9 IN
NO,      LENGTH, FC = 20.4 IN = 1.7 FT
NO,      WT(PIPE) = 21.97 LB/FT = 1.83 LB/IN
NO,WEIGHT OF WATER FOR ID = 9.916 IN:
NO,      WT(WATER)= 33.46 LB/FT = 2.79 LB/IN
NO,WT(PIPE+WATER) = 1.83 + 2.79 = 4.62 LB/IN
NO
NO,SIF AND STRESS INDICES FOR MITERED ELBOW:
NO,      SIF = 2.0      B1 = 0.69         B2 = 1.64
NO
NO,ELBOW STARTS AT NODE PT. 600 AND ENDS AT NODE PT. 640
NO,*****************************************************************
NO
RU,600,605,,,1.7,
CM,605,610,12.75,1.417,,25.9,7.5,4.62,
IB,605,610,2.0,0.69,1.64,
CM,610,615,12.75,1.417,,25.9,15.0,4.62,
IB,610,615,2.0,0.69,1.64,
CM,615,620,12.75,1.417,,25.9,15.0,4.62,
IB,615,620,2.0,0.69,1.64,
CM,620,625,12.75,1.417,,25.9,15.0,4.62,
IB,620,625,2.0,0.69,1.64,
CM,625,630,12.75,1.417,,25.9,,4.62,
IB,625,630,2.0,0.69,1.64,
RU,630,640,1.4722,,0.85,
NO
NO,*****************************************************************
NO,PIPE AXIS OF NEXT SECTION MAKES 60 DEGREES (CCW) WITH Z-AXIS
NO
NO,TOTAL LENGTH OF PIPING UP TO NEXT (30-DEG.) ELBOW = 260.5 FT
NO
NO,APPLY SOIL SPRINGS AT 2FT INTERVALS AROUND ELBOWS (TOTAL= 12 FT)
NO,AND AT 10FT INTERVALS OVER REMAINING SECTION (260.5-12= 248.5FT)
NO,*****************************************************************
NO,START APPLYING SOIL SPRINGS AT 2FT INTERVALS
NO,LOCATION OF 1ST SPRING SET FROM END OF ELBOW= 2.0-1.7 = 0.3 FT
NO,*****************************************************************
NO
RU,640,675,0.2598,,0.15,
SE,,0,
RU,675,1675,0.866,,0.5,
2SP,675,1675,14760,
SE,,0,
RU,675,2675,,1.0,,
2SP,675,2675,16920,
SE,,0,
RU,675,3675,0.5,,-0.866,
2SP,675,3675,3720,
SE,,0,
RU,675,680,1.732,,1.0,
SE,,0,
RU,680,1680,0.866,,0.5,
2SP,680,1680,14760,
SE,,0,
RU,680,2680,,1.0,,
2SP,680,2680,16920,
SE,,0,
RU,680,3680,0.5,,-0.866,
```

```
2SP,680,3680,3720,
SE,,0,
RU,680,685,1.732,,1.0,
SE,,0,
RU,685,1685,0.866,,0.5,
2SP,685,1685,14760,
SE,,0,
RU,685,2685,,1.0,,
2SP,685,2685,16920,
SE,,0,
RU,685,3685,0.5,,-0.866,
2SP,685,3685,3720,
SE,,0,
NO,******************************************************************
NO,CHANGE SOIL SPRING SPACING FROM 2FT TO 10 FT
NO,DIVIDE AVAILABLE LENGTH AS FOLLOWS: 248.5 FT= 23*10FT + 2*9.25FT
NO,******************************************************************
NO
NO,******************************************************************
NO,LENGTH OF NEXT SECTION = 9.25 FT.  SOIL SPRING STIFFNESS VALUES
NO,ARE ADJUSTED (PROPORTIONAL TO SECTION LENGTH)
NO,******************************************************************
NO
RU,685,690,8.0105,,4.625,
SE,,0,
RU,690,1690,0.866,,0.5,
2SP,690,1690,68265,
SE,,0,
RU,690,2690,,1.0,,
2SP,690,2690,78255,
SE,,0,
RU,690,3690,0.5,,-0.866,
2SP,690,3690,17205,
SE,,0,
NO,******************************************************************
NO,APPLY SPRINGS AT 10FT INTERVALS OVER THE NEXT 230 FT SECTION
NO,******************************************************************
RU,690,695,8.66,,5.0,
SE,,0,
RU,695,1695,0.866,,0.5,
2SP,695,1695,73800,
SE,,0,
RU,695,2695,,1.0,,
2SP,695,2695,84600,
SE,,0,
RU,695,3695,0.5,,-0.866,
2SP,695,3695,18600,
SE,,0,
RU,695,700,8.66,,5.0,
SE,,0,
RU,700,1700,0.866,,0.5,
2SP,700,1700,73800,
SE,,0,
RU,700,2700,,1.0,,
2SP,700,2700,84600,
SE,,0,
RU,700,3700,0.5,,-0.866,
2SP,700,3700,18600,
SE,,0,
RU,700,705,8.66,,5.0,
SE,,0,
RU,705,1705,0.866,,0.5,
```

```
2SP,705,1705,73800,
SE,,0,
RU,705,2705,,1.0,,
2SP,705,2705,84600,
SE,,0,
RU,705,3705,0.5,,-0.866,
2SP,705,3705,18600,
SE,,0,
RU,705,710,8.66,,5.0,
SE,,0,
RU,710,1710,0.866,,0.5,
2SP,710,1710,73800,
SE,,0,
RU,710,2710,,1.0,,
2SP,710,2710,84600,
SE,,0,
RU,710,3710,0.5,,-0.866,
2SP,710,3710,18600,
SE,,0,
RU,710,715,8.66,,5.0,
SE,,0,
RU,715,1715,0.866,,0.5,
2SP,715,1715,73800,
SE,,0,
RU,715,2715,,1.0,,
2SP,715,2715,84600,
SE,,0,
RU,715,3715,0.5,,-0.866,
2SP,715,3715,18600,
SE,,0,
RU,715,720,8.66,,5.0,
SE,,0,
RU,720,1720,0.866,,0.5,
2SP,720,1720,73800,
SE,,0,
RU,720,2720,,1.0,,
2SP,720,2720,84600,
SE,,0,
RU,720,3720,0.5,,-0.866,
2SP,720,3720,18600,
SE,,0,
RU,720,725,8.66,,5.0,
SE,,0,
RU,725,1725,0.866,,0.5,
2SP,725,1725,73800,
SE,,0,
RU,725,2725,,1.0,,
2SP,725,2725,84600,
SE,,0,
RU,725,3725,0.5,,-0.866,
2SP,725,3725,18600,
SE,,0,
RU,725,730,8.66,,5.0,
SE,,0,
RU,730,1730,0.866,,0.5,
2SP,730,1730,73800,
SE,,0,
RU,730,2730,,1.0,,
2SP,730,2730,84600,
SE,,0,
RU,730,3730,0.5,,-0.866,
2SP,730,3730,18600,
```

```
SE,,0,
RU,730,735,8.66,,5.0,
SE,,0,
RU,735,1735,0.866,,0.5,
2SP,735,1735,73800,
SE,,0,
RU,735,2735,,1.0,,
2SP,735,2735,84600,
SE,,0,
RU,735,3735,0.5,,-0.866,
2SP,735,3735,18600,
SE,,0,
RU,735,740,8.66,,5.0,
SE,,0,
RU,740,1740,0.866,,0.5,
2SP,740,1740,73800,
SE,,0,
RU,740,2740,,1.0,,
2SP,740,2740,84600,
SE,,0,
RU,740,3740,0.5,,-0.866,
2SP,740,3740,18600,
SE,,0,
RU,740,745,8.66,,5.0,
SE,,0,
RU,745,1745,0.866,,0.5,
2SP,745,1745,73800,
SE,,0,
RU,745,2745,,1.0,,
2SP,745,2745,84600,
SE,,0,
RU,745,3745,0.5,,-0.866,
2SP,745,3745,18600,
SE,,0,
RU,745,750,8.66,,5.0,
SE,,0,
RU,750,1750,0.866,,0.5,
2SP,750,1750,73800,
SE,,0,
RU,750,2750,,1.0,,
2SP,750,2750,84600,
SE,,0,
RU,750,3750,0.5,,-0.866,
2SP,750,3750,18600,
SE,,0,
RU,750,755,8.66,,5.0,
SE,,0,
RU,755,1755,0.866,,0.5,
2SP,755,1755,73800,
SE,,0,
RU,755,2755,,1.0,,
2SP,755,2755,84600,
SE,,0,
RU,755,3755,0.5,,-0.866,
2SP,755,3755,18600,
SE,,0,
RU,755,760,8.66,,5.0,
SE,,0,
RU,760,1760,0.866,,0.5,
2SP,760,1760,73800,
SE,,0,
RU,760,2760,,1.0,,
```

```
2SP,760,2760,84600,
SE,,0,
RU,760,3760,0.5,,-0.866,
2SP,760,3760,18600,
SE,,0,
RU,760,765,8.66,,5.0,
SE,,0,
RU,765,1765,0.866,,0.5,
2SP,765,1765,73800,
SE,,0,
RU,765,2765,,1.0,,
2SP,765,2765,84600,
SE,,0,
RU,765,3765,0.5,,-0.866,
2SP,765,3765,18600,
SE,,0,
RU,765,770,8.66,,5.0,
SE,,0,
RU,770,1770,0.866,,0.5,
2SP,770,1770,73800,
SE,,0,
RU,770,2770,,1.0,,
2SP,770,2770,84600,
SE,,0,
RU,770,3770,0.5,,-0.866,
2SP,770,3770,18600,
SE,,0,
RU,770,775,8.66,,5.0,
SE,,0,
RU,775,1775,0.866,,0.5,
2SP,775,1775,73800,
SE,,0,
RU,775,2775,,1.0,,
2SP,775,2775,84600,
SE,,0,
RU,775,3775,0.5,,-0.866,
2SP,775,3775,18600,
SE,,0,
RU,775,780,8.66,,5.0,
SE,,0,
RU,780,1780,0.866,,0.5,
2SP,780,1780,73800,
SE,,0,
RU,780,2780,,1.0,,
2SP,780,2780,84600,
SE,,0,
RU,780,3780,0.5,,-0.866,
2SP,780,3780,18600,
SE,,0,
RU,780,785,8.66,,5.0,
SE,,0,
RU,785,1785,0.866,,0.5,
2SP,785,1785,73800,
SE,,0,
RU,785,2785,,1.0,,
2SP,785,2785,84600,
SE,,0,
RU,785,3785,0.5,,-0.866,
2SP,785,3785,18600,
SE,,0,
RU,785,790,8.66,,5.0,
SE,,0,
```

```
RU,790,1790,0.866,,0.5,
2SP,790,1790,73800,
SE,,0,
RU,790,2790,,1.0,,
2SP,790,2790,84600,
SE,,0,
RU,790,3790,0.5,,-0.866,
2SP,790,3790,18600,
SE,,0,
RU,790,795,8.66,,5.0,
SE,,0,
RU,795,1795,0.866,,0.5,
2SP,795,1795,73800,
SE,,0,
RU,795,2795,,1.0,,
2SP,795,2795,84600,
SE,,0,
RU,795,3795,0.5,,-0.866,
2SP,795,3795,18600,
SE,,0,
RU,795,800,8.66,,5.0,
SE,,0,
RU,800,1800,0.866,,0.5,
2SP,800,1800,73800,
SE,,0,
RU,800,2800,,1.0,,
2SP,800,2800,84600,
SE,,0,
RU,800,3800,0.5,,-0.866,
2SP,800,3800,18600,
SE,,0,
RU,800,810,8.66,,5.0,
SE,,0,
RU,810,1810,0.866,,0.5,
2SP,810,1810,73800,
SE,,0,
RU,810,2810,,1.0,,
2SP,810,2810,84600,
SE,,0,
RU,810,3810,0.5,,-0.866,
2SP,810,3810,18600,
SE,,0,
NO,*******************************************************************
NO,NEXT PIPING SECTION IS 9.25 FT LONG.  SOIL SPRING STIFFNESS
NO,VALUES ARE ADJUSTED (PROPORTIONAL TO SECTION LENGTH).
NO,*******************************************************************
NO
RU,810,820,8.0105,,4.625,
SE,,,0,
RU,820,1820,0.866,,0.5,
2SP,820,1820,68265,
SE,,0,
RU,820,2820,,1.0,,
2SP,820,2820,78255,
SE,,0,
RU,820,3820,0.5,,-0.866,
2SP,820,3820,17205,
SE,,0,
NO,******************************************************************
NO,APPLY SOIL SPRINGS AT 2 FT INTERVALS (AROUND 30-DEG. ELBOW)
NO,******************************************************************
RU,820,825,1.732,,1.0,
```

```
SE,,0,
RU,825,1825,0.866,,0.5,
2SP,825,1825,14760,
SE,,0,
RU,825,2825,,1.0,,
2SP,825,2825,16920,
SE,,0,
RU,825,3825,0.5,,-0.866,
2SP,825,3825,3720,
SE,,0,
RU,825,830,1.732,,1.0,
SE,,0,
RU,830,1830,0.866,,0.5,
2SP,830,1830,14760,
SE,,0,
RU,830,2830,,1.0,,
2SP,830,2830,16920,
SE,,0,
RU,830,3830,0.5,,-0.866,
2SP,830,3830,3720,
SE,,0,
NO,*****************************************************************
NO,NEXT RUN GOES UP TO THE BEGINNING OF 30-DEG. MITERED ELBOW
NO,LENGTH OF ELBOW (SEE BELOW) = 12.4 IN = 1.03 FT
NO,THEREFORE, LENGTH OF NEXT RUN = 2.0 - 1.03 = 0.97 FT
NO,USE: SIN(30) = 0.5  AND COS(30) = 0.866
NO,*****************************************************************
NO
RU,830,840,0.84002,,0.485,
NO
NO,*****************************************************************
NO,**********       30 DEGREE IPS HDPE ELBOW       **************
NO,*****************************************************************
NO,THIS IS A 12-IN, DR 9, 3-SEGMENT MITERED ELBOW.  THIS IS NOT A,
NO,COMMONLY AVAILABLE STANDARD COMPONENT.  THE FOLLOWING DIMENSIONS
NO,ARE USED TO MODEL THE ELBOW:
NO,       OUTSIDE DIAMETER, OD = 12.75 IN
NO,       MIN. WALL THICKNESS, t = 1.417 IN
NO,       INSIDE DIAMETER, ID = OD - 2t = 9.916 IN
NO,       RADIUS, R = 25.9 IN
NO,       LENGTH, FC = 12.4 IN = 1.03 FT
NO,       WT(PIPE) = 21.97 LB/FT = 1.83 LB/IN
NO,WEIGHT OF WATER FOR ID = 9.916 IN:
NO,       WT(WATER)= 33.46 LB/FT = 2.79 LB/IN
NO,WT(PIPE+WATER) = 1.83 + 2.79 = 4.62 LB/IN
NO
NO,SIF AND STRESS INDICES FOR MITERED ELBOW:
NO,       SIF = 2.0       B1 = 0.69         B2 = 1.64
NO
NO,ELBOW STARTS AT NODE PT. 840 AND ENDS AT NODE PT. 5000
NO,*****************************************************************
NO
RU,840,850,0.89198,,0.515,
CM,850,860,12.75,1.417,,25.9,7.5,4.62,
IB,850,860,2.0,0.69,1.64,
CM,860,870,12.75,1.417,,25.9,15.0,4.62,
IB,860,870,2.0,0.69,1.64,
CM,870,880,12.75,1.417,,25.9,,4.62,
IB,870,880,2.0,0.69,1.64,
RU,880,5000,1.03,,,
NO
NO,*****************************************************************
```

```
NO,PIPE AXIS OF NEXT SECTION IS PARALLEL TO THE X-AXIS
NO,*****************************************************************
NO,LENGTH OF PIPING PARALLEL TO X-AXIS = 75.6 FT
NO
NO,APPLY SOIL SPRINGS AT 2FT INTERVALS AROUND 30-DEGREE ELBOW
NO,LOCATION OF 1ST SPRING SET = 2.0'-1.03'= 0.97' FROM END OF ELBOW
NO,*****************************************************************
NO
RU,5000,5010,0.97,,,
SE,,0,
RU,5010,15010,1.0,,,
2SP,5010,15010,14760,,,
SE,,0,
RU,5010,25010,,1.0,,
2SP,5010,25010,16920,,,
SE,,0,
RU,5010,35010,,,1.0,
2SP,5010,35010,3720,,,
SE,,0,
RU,5010,5020,2.0,,,
SE,,0,
RU,5020,15020,1.0,,,
2SP,5020,15020,14760,,,
SE,,0,
RU,5020,25020,,1.0,,
2SP,5020,25020,16920,,,
SE,,0,
RU,5020,35020,,,1.0,
2SP,5020,35020,3720,,,
SE,,0,
RU,5020,5030,2.0,,,
SE,,0,
RU,5030,15030,1.0,,,
2SP,5030,15030,14760,,,
SE,,0,
RU,5030,25030,,1.0,,
2SP,5030,25030,16920,,,
SE,,0,
RU,5030,35030,,,1.0,
2SP,5030,35030,3720,
SE,,0,
NO,*****************************************************************
NO,CHANGE SOIL SPRING SPACING FROM 2 FT TO 10 FT
NO,AVAILABLE LENGTH = 75.6 FT - 12 FT = 63.6 FT
NO,DIVIDE THIS LENGTH AS FOLLOWS: 63.6FT = 5*10FT + 2*6.8FT
NO,*****************************************************************
NO
NO,*****************************************************************
NO,LENGTH OF NEXT PIPING SECTION = 6.8 FT.  SOIL SPRING STIFFNESS
NO,VALUES ARE ADJUSTED (PROPORTIONAL TO SECTION LENGTH).
NO,*****************************************************************
RU,5030,5040,6.8,,,
SE,,0,
RU,5040,15040,1.0,,,
2SP,5040,15040,50184,,,
SE,,0,
RU,5040,25040,,1.0,,
2SP,5040,25040,57528,,,
SE,,0,
RU,5040,35040,,,1.0,
2SP,5040,35040,12648,
SE,,0,
```

```
NO,*****************************************************************
NO,APPLY SPRINGS AT 10FT INTERVALS OVER THE NEXT 50 FT SECTION
NO,*****************************************************************
RU,5040,5050,10.0,,,
SE,,0,
RU,5050,15050,1.0,,,
2SP,5050,15050,73800,,,
SE,,0,
RU,5050,25050,,1.0,,
2SP,5050,25050,84600,
SE,,0,
RU,5050,35050,,,1.0,
2SP,5050,35050,18600,
SE,,0,
RU,5050,5060,10.0,,,
SE,,0,
RU,5060,15060,1.0,,,
2SP,5060,15060,73800,,,
SE,,0,
RU,5060,25060,,1.0,,
2SP,5060,25060,84600,,,
SE,,0,
RU,5060,35060,,,1.0,
2SP,5060,35060,18600,
SE,,0,
RU,5060,5070,10.0,,,
SE,,0,
RU,5070,15070,1.0,,,
2SP,5070,15070,73800,,,
SE,,0,
RU,5070,25070,,1.0,,
2SP,5070,25070,84600,,,
SE,,0,
RU,5070,35070,,,1.0,
2SP,5070,35070,18600,
SE,,0,
RU,5070,5080,10.0,,,
SE,,0,
RU,5080,15080,1.0,,,
2SP,5080,15080,73800,,,
SE,,0,
RU,5080,25080,,1.0,,
2SP,5080,25080,84600,,,
SE,,0,
RU,5080,35080,,,1.0,
2SP,5080,35080,18600,
SE,,0,
RU,5080,5090,10.0,,,
SE,,0,
RU,5090,15090,1.0,,,
2SP,5090,15090,73800,,,
SE,,0,
RU,5090,25090,,1.0,,
2SP,5090,25090,84600,,,
SE,,0,
RU,5090,35090,,,1.0,
2SP,5090,35090,18600,
SE,,0,
NO,*****************************************************************
NO,LENGTH OF NEXT PIPING SECTION = 6.8 FT.  SOIL SPRING STIFFNESS
NO,VALUES ARE ADJUSTED (PROPORTIONAL TO SECTION LENGTH)
NO,*****************************************************************
```

```
NO
RU,5090,5100,6.8,,,
SE,,0,
RU,5100,15100,1.0,,,
2SP,5100,15100,50184,,,
SE,,0,
RU,5100,25100,,1.0,,
2SP,5100,25100,57528,,,
SE,,0,
RU,5100,35100,,,1.0,
2SP,5100,35100,12648,
SE,,0,
NO,*********************************************************************
NO,START APPLYING SOIL SPRINGS AT 2 FT INTERVALS
NO,*********************************************************************
RU,5100,5110,2.0,,,
SE,,0,
RU,5110,15110,1.0,,,
2SP,5110,15110,14760,,,
SE,,0,
RU,5110,25110,,1.0,,
2SP,5110,25110,16920,,,
SE,,0,
RU,5110,35110,,,1.0,
2SP,5110,35110,3720,,,
SE,,0,
RU,5110,5120,2.0,,,
SE,,0,
RU,5120,15120,1.0,,,
2SP,5120,15120,14760,,,
SE,,0,
RU,5120,25120,,1.0,,
2SP,5120,25120,16920,,,
SE,,0,
RU,5120,35120,,,1.0,
2SP,5120,35120,3720,,,
SE,,0,
NO,*********************************************************************
NO,NEXT RUN GOES UP TO THE BEGINNING OF 45- DEGREE MITERED ELBOW
NO,LENGTH OF 45-DEG. MITERED ELBOW (SEE BELOW): FC = 1.13 FT
NO,THEREFORE, LENGTH OF NEXT RUN = 2.0'-1.13' = 0.87 FT
NO,*****************************************************************
NO
RU,5120,5130,0.87,,,
NO
NO,*****************************************************************
NO,**********        45 DEGREE IPS HDPE ELBOW        **************
NO,*****************************************************************
NO,THIS IS A 3-SEGMENT MITERED ELBOW.  ITS PROPERTIES ARE AS LISTED
NO,EARLIER.
NO
NO,PIPE ELEVATION = 586'-0"
NO
NO,ELBOW STARTS AT PT. 5130 AND ENDS AT PT. 5160
NO,*****************************************************************
NO
RU,5130,5135,1.13,,,
CM,5135,5140,12.75,1.417,,19.5,11.25,4.62,
IB,5135,5140,2.0,.69,1.64,
CM,5140,5145,12.75,1.417,,19.5,22.5,4.62,
IB,5140,5145,2.0,.69,1.64,
CM,5145,5150,12.75,1.417,,19.5,,4.62,
```

```
IB,5145,5150,2.0,.69,1.64,
NO
NO,*****************************************************************
NO,THE STRAIGHT PIPES THAT ARE PARALLEL TO X-AXIS AND CONNECTED BY
NO,THE TWO 45-DEGREE MITERED ELBOWS ARE AT DIFFERENET ELEVATIONS
NO,(ONE AT EL.586'-0" AND THE OTHER AT 580'-3")
NO
NO,THEREFORE, DISTANCE IN Y-DIRECTION (Ly) BETWEEN THE TWO STRAIGHT,
NO,PIPES IS OBTAINED AS FOLLOWS: Ly = 580'-3"-586'-0" = -5.75 FT
NO
NO,DISTANCE BETWEEN THOSE SAME PIPES IN Z-DIRECTION: Lz = 2.50 FT
NO
NO,Let Lyz = Perpendicular distance between pipes
NO,        Lyz = SQRT(2.50^2+5.75^2)= 6.27 FT
NO
NO,DISTANCE IN X-DIRECTION (Lx) BETWEEN THE ENDS OF SAME PIPES:
NO,        Lx = Lyz = 6.27 FT
NO
NO,Distance between centers of the two elbows connecting the pipes:
NO,        L = Lyz/COS(45) = 8.87 FT
NO
NO,Direction cosines of line connecting the two 45-degree elbows:
NO,      X-DIRECTION = COS(45) = 0.707
NO,      Y-DIRECTION = -5.75/8.87 = -0.648
NO,      Z-DIRECTION = 2.50/8.87 = 0.282
NO
NO,Direction cosines of line perpedicular to and in same plane with
NO,The above line are:
NO
NO,      X-DIRECTION = COS(45) = 0.707
NO,      Y-DIRECTION = COS(45)*(5.75/6.27) = 0.648
NO,      Z-DIRECTION = -COS(45)*(2.50/6.27) = -0.282
NO
NO,Direction cosines of line perpendicular to plane containing the
NO,Above two lines are:
NO
NO,      X-DIRECTION = COS(90) = 0.0
NO,      Y-DIRECTION = 2.50/6.27 = 0.399
NO,      Z-DIRECTION = 5.75/6.27 = 0.917
NO
NO,SINCE TOTAL LENGTH OF THIS PIPING SECTION = 8.87 FT < 12 FT, ALL
NO,SOIL SPRINGS WILL BE APPLIED AT 2 FT (OR LESS) INTERVALS
NO
NO,DIVIDE 8.87 FT AS: 8.87' = 2.0' + 2.0' + 0.87' + 2.0' + 2.0'
NO
NO,NEXT RUN GOES TO END OF 1st ELBOW. (LENGTH OF ELBOW = 1.13FT)
NO,          delta X = 0.707*1.13 = 0.79891
NO,          delta Y = -0.648*1.13 = -0.73224
NO,          delta Z = 0.282*1.13 = 0.31866
NO,*****************************************************************
NO
RU,5150,5160,0.79891,-0.73224,0.31866,
NO
NO,*****************************************************************
NO
NO,LOCATION OF 1ST SET OF SPRINGS FROM END OF ELBOW= 2'-1.13'=0.87'
NO
NO,*****************************************************************
RU,5160,5170,0.61509,-0.56376,0.24534,
SE,,0,
RU,5170,15170,0.707,-0.648,0.282,
2SP,5170,15170,14760,,,
```

```
SE,,0,
RU,5170,25170,,0.399,0.917,
NO,***************************************************************
NO,SPRING RATE IN THIS DIRECTION IS OBTAINED FROM VERTICAL (Kv)
NO,AND LATERAL (Kt) SOIL SPRING RATES AS FOLLOWS:
NO,
NO,K = SQRT[(0.399 Kv)^2 + (0.917 Kt)^2]
NO,K = SQRT[(0.399*16920)^2 + (0.917*3720)^2] = 7564 LB/IN
NO,***************************************************************
2SP,5170,25170,7564,,,
SE,,0,
RU,5170,35170,0.707,0.648,-0.282,
2SP,5170,35170,3720,,,
SE,,0,
NO,***************************************************************
NO,THE 2ND SET OF SPRINGS IS APPLIED AT END OF NEXT 2FT SECTION
NO,STIFFNESS DIRECTIONS AND VALUES ARE SAME AS PRECEDING SECTION
NO,***************************************************************
NO
RU,5170,5180,1.414,-1.296,0.564,
SE,,0,
RU,5180,15180,0.707,-0.648,0.282,
2SP,5180,15180,14760,,,
SE,,0,
RU,5180,25180,,0.399,0.917,
2SP,5180,25180,7564,,,
SE,,0,
RU,5180,35180,0.707,0.648,-0.282,
2SP,5180,35180,3720,,,
SE,,0,
NO,*****************************************************************
NO,LENGTH OF NEXT PIPING SECTION = 0.87 FT.  SOIL SPRING STIFFNESS
NO,DIRECTIONS ARE SAME AS PRECEDING SECTION; HOWEVER, VALUES ARE,
NO,ADJUSTED (PROPORTIONAL TO SECTION LENGTH)
NO,*****************************************************************
NO
RU,5180,5190,0.61509,-0.56376,0.24534,
SE,,0,
RU,5190,15190,0.707,-0.648,0.282,
2SP,5190,15190,6421,,,
SE,,0,
RU,5190,25190,,0.399,0.917,
2SP,5190,25190,3290,,,
SE,,0,
RU,5190,35190,0.707,0.648,-0.282,
2SP,5190,35190,1618,,,
SE,,0,
NO,*****************************************************************
NO,SPRING SPACING IS NOW 2 FT.  SPRING STIFFNESS DIRECTIONS AND
NO,VALUES ARE SAME AS PRECEDING 2FT SECTIONS
NO,*****************************************************************
NO
RU,5190,5200,1.414,-1.296,0.564,
SE,,0,
RU,5200,15200,0.707,-0.648,0.282,
2SP,5200,15200,14760,,,
SE,,0,
RU,5200,25200,,0.399,0.917,
2SP,5200,25200,7564,,,
SE,,0,
RU,5200,35200,0.707,0.648,-0.282,
2SP,5200,35200,3720,,,
```

CALCULATION CONTINUATION SHEET

Client	Duke Power Carolinas, LLC	Calculation No.	07Q3691-CAL-003
Project	Catawba Unit # 1 and #2 – Buried HDPE Piping Design and Analysis		
Title	Analysis of Buried HDPE Piping System— Nuclear Service Water (NSW) Supply Line Diesel Generator "1A" Unit 1		
By: [signature]	Date 11/10/08	Chk'd by [signature]	Date 11/11/08

```
SE,,0,
NO,*****************************************************************
NO,NEXT RUN GOES TO THE BEGINNING OF 2ND 45-DEGREE MITERED ELBOW
NO,LENGTH OF ELBOW (SEE BELOW) = 13.5 IN = 1.13 FT
NO,THEREFORE, LENGTH OF RUN = 2.0 - 1.13 = 0.87 FT
NO,RECALL THAT DIRECTION COSINES ARE: X-DIRECTION = 0.707
NO,                               Y-DIRECTION = -0.648
NO,                               Z-DIRECTION = 0.282
NO,*****************************************************************
NO
RU,5200,5210,0.61509,-0.56376,0.24534,
NO
NO,*****************************************************************
NO,**********       45 DEGREE IPS HDPE ELBOW       **************
NO,*****************************************************************
NO,THIS IS A 3-SEGMENT MITERED ELBOW.  ITS PROPERTIES ARE AS LISTED
NO,EARLIER.
NO
NO,MTTERED ELBOW STARTS AT PT. 5210 AND ENDS AT PT 5240
NO,*****************************************************************
NO
RU,5210,5220,0.79891,-0.73224,0.31866,
CM,5220,5225,12.75,1.417,,19.5,11.25,4.62,
IB,5220,5225,2.0,.69,1.64,
CM,5225,5230,12.75,1.417,,19.5,22.5,4.62,
IB,5225,5230,2.0,.69,1.64,
CM,5230,5235,12.75,1.417,,19.5,,4.62,
IB,5230,5235,2.0,.69,1.64,
RU,5235,5240,1.13,,,
NO
NO,*****************************************************************
NO,AXIS OF PIPING IS NOW PARALLEL TO X-AXIS
NO
NO,PIPE CENTERLINE IS AT ELEVATION 580'-3".  HEIGHT OF SOIL ABOVE
NO,TOP OF PIPE = 13.25 FT.  THEREFORE, USE SPRING STIFFNESS VALUES
NO,OBTAINED FOR H = 13.25 FT.
NO
NO,                  SPRING STIFFNESS [LB/IN]
NO,    DIRECTION               -----------------------------
NO,    OF SPRING               2FT SECTION     10FT SECTION
NO,    ---------------------------------------------
NO,
NO,        LATERAL             4680                 23400
NO,        VERTICAL            25320                126600
NO,        AXIAL               25320                126600
NO
NO,TOTAL LENGTH PIPING PARALLEL TO X-AXIS = 31.8 FT
NO,       LENGTH OF STEEL FLANGE = 4.5 IN
NO,       LENGTH OF SHORT-RADIUS, 90-DEG.ELBOW = 12 IN
NO,       TOTAL LENGTH OF STEEL COMPONENTS = 16.5 IN = 1.38 FT
NO,THEREFORE, LENGTH OF HDPE PIPE = 31.8-1.38-6.27 = 24.2 FT
NO
NO,APPLY SOIL SPRINGS AS FOLLOWS:
NO,  AT FT INTERVALS NEAR ELBOW AND HDPE/STEEL INTERFACE (OVER 6FT
NO,  LENGTH ON EACH END)
NO,  AT 6.1 FT INTERVALS FOR THE REMAINING 12.2 FT MIDDLE SECTION
NO,*****************************************************************
NO,LOCATION OF 1ST SET OF SPRINGS FROM END OF ELBOW= 2'-1.13'=0.87'
NO,*****************************************************************
NO
RU,5240,5250,0.87,,,
SE,,0,
```

```
RU,5250,15250,1.0,,,
2SP,5250,15250,25320,,,
SE,,0,
RU,5250,25250,,1.0,,
2SP,5250,25250,25320,,,
SE,,0,
RU,5250,35250,,,1.0,
2SP,5250,35250,4680,,,
SE,,0,
RU,5250,5270,2.0,,,
SE,,0,
RU,5270,15270,1.0,,,
2SP,5270,15270,25320,,,
SE,,0,
RU,5270,25270,,1.0,,
2SP,5270,25270,25320,,,
SE,,0,
RU,5270,35270,,,1.0,
2SP,5270,35270,4680,,,
SE,,0,
RU,5270,5280,2.0,,,
SE,,0,
RU,5280,15280,1.0,,,
2SP,5280,15280,25320,,,
SE,,0,
RU,5280,25280,,1.0,,
2SP,5280,25280,25320,,,
SE,,0,
RU,5280,35280,,,1.0,
2SP,5280,35280,4680,,,
SE,,0,
NO,*****************************************************************
NO,LENGTH OF NEXT SECTION = 6.1 FT.  SOIL SPRING STIFFNESS VALUES
NO,ARE ADJUSTED (PROPORTIONAL TO SECTION LENGTH)
NO,*****************************************************************
NO
RU,5280,5300,6.1,,,
SE,,0,
RU,5300,15300,1.0,,,
2SP,5300,15300,77226,,,
SE,,0,
RU,5300,25300,,1.0,,
2SP,5300,25300,77226,,,
SE,,0,
RU,5300,35300,,,1.0,
2SP,5300,35300,14274,,,
SE,,0,
NO,*****************************************************************
NO,LENGTH OF NEXT SECTION = 6.1 FT.  SOIL SPRING STIFFNESS VALUES
NO,ARE ADJUSTED (PROPORTIONAL TO SECTION LENGTH)
NO,*****************************************************************
NO
RU,5300,5310,6.1,,
SE,,0,
RU,5310,15310,1.0,,,
2SP,5310,15310,77226,,,
SE,,0,
RU,5310,25310,,1.0,,
2SP,5310,25310,77226,,,
SE,,0,
RU,5310,35310,,,1.0,
2SP,5310,35310,14274,
```

```
SE,,0,
NO,*****************************************************************
NO,START APPLYING SOIL SPRINGS AT 2FT INTERVALS
NO,*****************************************************************
RU,5310,5320,2.0,,,
SE,,0,
RU,5320,15320,1.0,,,
2SP,5320,15320,25320,,,
SE,,0,
RU,5320,25320,,1.0,,
2SP,5320,25320,25320,,,
SE,,0,
RU,5320,35320,,,1.0,
2SP,5320,35320,4680,,,
SE,,0,
RU,5320,5330,2.0,,,
SE,,0,
RU,5330,15330,1.0,,,
2SP,5330,15330,25320,,,
SE,,0,
RU,5330,25330,,1.0,,
2SP,5330,25330,25320,,,
SE,,0,
RU,5330,35330,,,1.0,
2SP,5330,35330,4680,,,
SE,,0,
NO,*****************************************************************
NO,NEXT 2FT SECTION CONTAINS FLANGE ADAPTER AND STEEL BACKUP RING
NO
NO,NEXT RUN (LENGTH = 1.0FT) GOES UP TO BEGINNING OF FLANGE ADAPTER
NO,*****************************************************************
NO
RU,5330,5340,1.0,,,
NO
NO,INSTALL A FLANGE ADAPTER WITH A STEEL BACKUP RING MOUNTED ON IT
NO
NO,FOR 12-IN, DR 11, IPS HDPE FLANGE ADAPTER (PER ISCO CATALOG):,
NO,     TOTAL LENGTH = 12.0 IN = 1.0 FT
NO,     FLANGE THICKNESS = 1.55 IN
NO,     WEIGHT OF ADAPTER = 24 LB
NO,FOR 12-IN STEEL BACKUP RING (PER ISCO CATALOG):
NO,     THICKNESS = 1.25 IN,     WEIGHT = 24 LB
NO
NO,MODEL ADAPTER AND RING ASSEMBLY AS A PIPE AND FLANGE COMBINATION
NO,FOR FLANGE, USE:,
NO,     LENGTH = 1.55+1.25 = 2.8" -->  LENGTH = 3 IN
NO,     WALL THICKNESS = 1.159 IN
NO,     O.D. OF FLANGE = 15.5 IN
NO,     WEIGHT = WT(RING+ADAPTER) - WT(9" LONG PIPE)
NO,          = 24.0 + 24.0 - 18.4*(9/12) = 34.2 LB
NO      WT(FLANGE+WATER)= (34.2/3)+3.09 = 14.5 LB/IN
NO
NO,FOR PIPE, USE:,
NO,     LENGTH = 12.0 - 3.0 = 9 IN
NO,     WT(PIPE+WATER) = 4.62 LB/IN
NO,*****************************************************************
NO
RU,5340,5350,0.75,,,
NOTE,IV=WNFL,END=FLG
1V,5350,5490,0.25,,,15.5,1.159,14.5,
SE,,0,
NO,*****************************************************************
```

CALCULATION CONTINUATION SHEET

Client	Duke Power Carolinas, LLC	Calculation No.	07Q3691-CAL-003
Project	Catawba Unit # 1 and #2 – Buried HDPE Piping Design and Analysis		
Title	Analysis of Buried HDPE Piping System— Nuclear Service Water (NSW) Supply Line Diesel Generator "1A" Unit 1		
By:	[signature] Date 11/10/08	Chk'd by [signature]	Date 11/11/08

```
NO,                    CHANGE TO STEEL PIPE
NO,*******************************************************************
NO,12-IN, SCH. 40 Cr-Mo STEEL PIPE PROPERTIES:,
NO,    OUTSIDE DIAMETER = 12.75 IN
NO,    WALL THICKNESS = 0.375 IN
NO,    WT(PIPE)= 49.6 LB/FT = 4.13 LB/IN
NO,    WT(WATER) = 49.0 LB/FT= 4.08 LB/IN
NO,    WT(PIPE+WATER) = (49.6+49.0)/12 = 8.22 LB/IN
NO,*******************************************************************
NO
PI,5490,5500,12.75,0.375,28.0,8.1,0.01,8.22,
NO
NO,*******************************************************************
NO,INSTALL A 90-DEGREE ELBOW WITH A FLANGE WELDED ON ONE END
NO,*******************************************************************
NO,FOR 12-IN SHORT RADIUS 90-DEG. ELBOW (BASED ON LADISH CATALOG):
NO,     LENGTH = 12 IN               T = 0.375 IN
NO,     RADIUS = 12 IN               WT(ELBOW)= 80 LB
NO,     WT(ELBOW+WATER)= 129.0 LB/FT = 10.75 LB/IN
NO
NO,FOR 12-IN,150-LB WN FLANGE (PER LADISH CATALOG):,
NO,    TOTAL LENGTH = 4.5 IN = 0.38 FT
NO,    FLANGE THICKNESS = 1.25 IN
NO,    O. D. OF FLANGE = 19 IN
NO,    DIAMETER AT HUB BASE= 14.375 IN
NO,    WALL THICKNESS (MIN) = 0.375 IN
NO,    WEIGHT OF FLANGE= 88 LB -->  UNIT WT = 19.56 LB/IN
NO,    WT(FLANGE+WATER)= 19.56 + 4.08 = 23.6 LB/IN
NO,USE DIAMETER AT HUB BASE AS O.D. FOR MODELING
NO,*******************************************************************
NO
NOTE,IV=WNFL,BEG=FLG
1V,5490,5500,0.38,,,14.375,0.375,23.6,
RU,5500,5510,1.01,,,
EL,5510,5520,12.75,0.375,,12.0,,10.75,
RU,5520,5530,,,-1.01,
NO
NO,*******************************************************************
NO,WELD 1.05FT (12.6 IN) LONG Cr-Mo PIPE TO END OF 90-DEGREE ELBOW.
NO,PIPE HAS A 150-LB FLANGE WELDED TO ITS OTHER END.
NO,*******************************************************************
NO
RU,5530,5535,,,-1.05,
NOTE,IV=WNFL,END=FLG
1V,5535,5540,,,-0.38,14.375,0.375,23.6,
SE,,0,
NO
NO,*******************************************************************
NO,PIPE MATERIAL CHANGES FROM Cr-Mo TO SA-106 GR. B CARBON STEEL
NO,*******************************************************************
NO
PI,5540,5550,12.75,0.375,27.9,6.07,0.01,8.22,
NO
NO,*******************************************************************
NO,INSTALL A 1.0 FT LONG, 12-IN PIPE WITH A FLANGE WELDED ON ONE END,
NO,OTHER END OF THE PIPE WILL BE WELDED TO THE 42-IN SUPPLY HEADER 'A'
NO,*******************************************************************
NO
NOTE,IV=WNFL,BEG=FLG
1V,5540,5550,,,-0.38,14.375,0.375,23.6,
RU,5550,5560,,,-1.0,
NO
```

```
NO,*******************************************************************
NO,42-IN DIAMETER PIPE PROPERTIES:
NO,   OD = 42 IN = 3.5 FT              WALL THICKNESS = 0.500 IN
NO,   WT(PIPE) = 221.6LB/FT              WT(WATER) = 571.7LB/FT
NO,   WT(PIPE+WATER)= 66.1LB/IN
NO,*******************************************************************
NO,A WELDOLET IS USED BETWEEN 12-IN PIPE AND 42-IN HEADER.  APPLY
NO,SIF=4.87 FOR WELDOLET AT THE JUNCTION POINT (CENTER OF 42-IN PIPE)
NO,*******************************************************************
NO
SE,,0,
RU,5560,5600,,,-1.75,
CH,5560,5600,42.,0.500,,,,66.1,
JB,5560,5600,4.87,
NO
EN,,0
EX
NO
NO,****************************** END OF RUN *************************
NO
EXECUTE
NO,*************************** DEADWEIGHT ANALYSIS *****************************
NO,LOADING CASE NO. 10
NO,CODE= ASME, YEAR = 1989, CLASS = 3
NO,FOR 1989 ASME CODE, CLASS 3 ANALYSIS = CLASS 2 ANALYSIS
NO,DESIGN PRESSURE = 100 PSI, PEAK PRESSURE = 75 PSI
NO,SA-106 GRADE B CARBON STEEL PROPERTIES:
NO,      Sc = 15000 PSI             Sh = 15000 PSI
NO,      Sy = 35000 PSI             POISSON RATIO = 0.3
NO,      Ec = 27.9E+06 PSI
NO,HDPE 50-YEAR DURATION PROPERTIES:
NO,      Sc = 800 PSI               Sh = 800 PSI
NO,      Sy = 2500 PSI              POISSON RATIO = 0.45
NO,      Ec = 0.028E+06 PSI
NO,SB-690/SB-675 Cr-Mo STEEL PROPERTIES:
NO,      Sc = 23100 PSI             Sh = 22200 PSI
NO,      Sy = 45000 PSI             POISSON RATIO = 0.3
NO,      Ec = 28E+06 PSI
NO
CL,,,3.0,1989,1,
CO,3,1,10,100,75,23100,22200,
MA,,,45000,,0.3,,,28.0,
CL,130,133,3.0,100,75,800,800,
MA,130,133,2500,,0.45,,,0.028,
CL,5490,5500,3.0,100,75,23100,22200,
MA,5490,5500,45000,,0.3,,,28.0,
CL,5540,5550,3.0,100,75,15000,15000,
MA,5540,5550,35000,,0.3,,,27.9,
DEADWEIGHT,,,,-1,,
XP,-27,20,
EN,,,
NO
EXECUTE
NO,*************** THERMAL ANALYSIS AT MIN TEMP = 32 F, LEVEL A ***************
NO,LOADING CASE NO. 21
NO,Delta T = 32 F - 55 F = -23 F
NO,PROPERTIES OF HDPE, Cr-Mo AND CARBON STEEL REMAIN SAME AS FOR DW CASE,
NO
CL,,,3.0,1989,1,
CO,3,0,21,100,75,23100,22200,
MA,,,45000,,0.3,,,28.0,
CL,130,133,3.0,100,75,800,800,
```

```
MA,130,133,2500,,0.45,,,0.028,
CL,5490,5500,3.0,100,75,23100,22200,
MA,5490,5500,45000,,0.3,,,28.0,
CL,5540,5550,3.0,100,75,15000,15000,
MA,5540,5550,35000,,0.3,,,27.9,
CH,100,105,10.75,0.365,28.0,8.1,-23.,6.22,
CH,130,133,12.75,1.159,0.028,90.,-23.,4.62,
CH,5490,5500,12.75,0.375,28.0,8.1,-23.,8.22,
CH,5540,5550,12.75,0.375,27.9,6.07,-23,8.22,
TH,,0,
EN,,,
EXECUTE
NO,*************** THERMAL ANALYSIS AT MAX TEMP = 100 F
NO,LOADING CASE NO. 22
NO,Delta T = 100 F - 55 F = 45 F
NO,CARBON STEEL AND Cr-Mo STEEL PROPERTIES ARE SAME AS DEADWEIGHT CASE
NO
NO,HDPE 50-YEAR DURATION PROPERTIES:
NO,      Sc = 800 PSI              Sh = 620 PSI
NO,      Sy = 2500 PSI             POISSON RATIO = 0.45
NO,      Ec = 0.023E+06 PSI
CL,,,3.0,1989,1,
CO,3,0,22,100,75,23100,22200,
MA,,,45000,,0.3,,,28.0,
CL,130,133,3.0,100,75,800,620,
MA,130,133,2500,,0.45,,,0.023,
CL,5490,5500,3.0,100,75,23100,22200,
MA,5490,5500,45000,,0.3,,,28.0,
CL,5540,5550,3.0,100,75,15000,15000,
MA,5540,5550,35000,,0.3,,,27.9,
CH,100,105,10.75,0.365,28.0,8.1,45,6.22,
CH,130,133,12.75,1.159,0.023,90.,45,4.62,
CH,5490,5500,12.75,0.375,28.0,8.1,45,8.22,
CH,5540,5550,12.75,0.375,27.9,6.07,45,8.22,
TH,,0,
EN,,,
EXECUTE
NO,*************** THERMAL ANALYSIS AT MIN TEMP = 32 F, LEVEL B ***************
NO,LOADING CASE NO. 23
NO,DELTA T=32 F - 55 F = -23F
NO,CARBON STEEL AND Cr-Mo STEEL PROPERTIES ARE SAME AS DEADWEIGHT CASE
NO,HDPE 10 YEAR DURATION PROPERTIES
NO,      Sc=840 PSI                Sh=840 PSI
NO,      Sy=2500 PSI               POISSON RATIO=0.45
NO,      Ec=0.032E+6 PSI
CL,,,3.0,1989,1,
CO,3,0,23,100,75,23100,22200,
MA,,,45000,,0.3,,,28.0,
CL,130,133,3.0,100,75,840,840,
MA,130,133,2500,,0.45,,,0.032,
CL,5490,5500,3.0,100,75,23100,22200,
MA,5490,5500,45000,,0.3,,,28.0,
CL,5540,5550,3.0,100,75,15000,15000,
MA,5540,5550,35000,,0.3,,,27.9,
CH,100,105,10.75,0.365,28.0,8.1,-23,6.22,
CH,130,133,12.75,1.159,0.032,90,-23,4.62,
CH,5490,5500,12.75,0.375,28.0,8.1,-23,8.22,
CH,5540,5550,12.75,0.375,27.9,6.07,-23,8.22,
TH,,0,
EN,,,
EXECUTE
NO,*************** THERMAL ANALYSIS AT MAX TEMP = 100 F
```

```
NO,LOADING CASE NO. 24
NO,DELTA T = 100 F - 55 F = 45 F
NO,CARBON STEEL AND Cr.-Mo STEEL PROPERTIES ARE SAME AS DEADWEIGHT CASE
NO,HDPE 10 YEAR DURATION PROPERTIES
NO,     Sc=840 PSI              Sh=620 PSI
NO,     Sy=2500 PSI              POISSON RATIO=0.45
NO,     Ec=0.026E+6 PSI
CL,,,3.0,1989,1,
CO,3,0,24,100,75,23100,22200,
MA,,,45000,,0.3,,,28.0,
CL,130,133,3.0,100,75,840,620,
MA,130,133,2500,,0.45,,,0.026,
CL,5490,5500,3.0,100,75,23100,22200,
MA,5490,5500,45000,,0.3,,,28.0,
CL,5540,5550,3.0,100,75,15000,15000,
MA,5540,5550,35000,,0.3,,,27.9,
CH,100,105,10.75,0.365,28.0,8.1,45,6.22,
CH,130,133,12.75,1.159,0.026,90,45,4.62,
CH,5490,5500,12.75,0.375,28.0,8.1,45,8.22,
CH,5540,5550,12.75,0.375,27.9,6.07,45,8.22,
TH,,0,
EN,,,
NO
EXECUTE
NO,************** THERMAL ANALYSIS AT MIN TEMP = 32 F, LEVEL C/D **************
NO,LOADING CASE NO. 25
NO,DELTA T = 32 F - 55 F = -23 F
NO,CARBON STEEL AND Cr.-Mo STEEL PROPERTIES ARE SAME AS DEADWEIGHT CASE
NO,HDPE 1000 HOUR DURATION PROPERTIES
NO,     Sc=840 PSI              Sh=840 PSI
NO,     Sy=2500 PSI              POISSON RATIO=0.45
NO,     Ec=0.044E+6 PSI
CL,,,3.0,1989,1,
CO,3,0,25,100,75,23100,22200,
MA,,,45000,,0.3,,,28.0,
CL,130,133,3.0,100,75,840,840,
MA,130,133,2500,,0.45,,,0.044,
CL,5490,5500,3.0,100,75,23100,22200,
MA,5490,5500,45000,,0.3,,,28.0,
CL,5540,5550,3.0,100,75,15000,15000,
MA,5540,5550,35000,,0.3,,,27.9,
CH,100,105,10.75,0.365,28.0,8.1,-23,6.22,
CH,130,133,12.75,1.159,0.044,90,-23,4.62,
CH,5490,5500,12.75,0.375,28.0,8.1,-23,8.22,
CH,5540,5550,12.75,0.375,27.9,6.07,-23,8.22,
TH,,0,
EN,,,
NO
EXECUTE
NO,************** THERMAL ANALYSIS AT MAX TEMP = 100 F
NO,LOADING CASE NO. 26
NO,DELTA T = 100 F - 55 F = 45 F
NO,CARBON STEEL AND Cr-Mo STEEL PROPERTIES ARE SAME AS DW CASE
NO,HDPE 1000 HR DURATION PROPERTIES
NO,     Sc=840 PSI              Sh=620 PSI
NO,     Sy=2500 PSI              POISSON RATIO=0.45
NO,     Ec=0.036+6 PSI
CL,,,3.0,1989,1,
CO,3,0,26,100,75,23100,22200,
MA,,,45000,,0.3,,,28.0,
CL,130,133,3.0,100,75,840,620,
MA,130,133,2500,,0.45,,,0.036,
```

```
CL,5490,5500,3.0,100,75,23100,22200,
MA,5490,5500,45000,,0.3,,,28.0,
CL,5540,5550,3.0,100,75,15000,15000,
MA,5540,5550,35000,,0.3,,,27.9,
CH,100,105,10.75,0.365,28.0,8.1,45,6.22,
CH,130,133,12.75,1.159,0.036,90,45,4.62,
CH,5490,5500,12.75,0.375,28.0,8.1,45,8.22,
CH,5540,5550,12.75,0.375,27.9,6.07,45,8.22,
TH,,0,
EN,,,
EXECUTE
NO,*************** THERMAL ANALYSIS AT T = 32 F, PSEUDO-SEISMIC ***************
NO,LOADING CASE NO. 30
NO,Delta T = 10 F
NO,CARBON STEEL AND Cr.-Mo STEEL PROPERTIES ARE SAME AS DEADWEIGHT CASE
NO
NO,**** FOR HDPE, USE SHORT-TERM (< 10 HRS) ELASTIC MODULUS VALUE:,
NO,     Sc = 1200 PSI          Sh = 1200 PSI
NO,     Sy = 2500 PSI          POISSON RATIO = 0.35
NO,     Ec = 0.110E+06 PSI
CL,,,3.0,1989,1,
CO,3,0,30,100,75,23100,22200,
MA,,,45000,,0.3,,,28.0,
CL,130,133,3.0,100,75,1200,1200,
MA,130,133,2500,,0.35,,,0.110,
CL,5490,5500,3.0,100,75,23100,22200,
MA,5490,5500,45000,,0.3,,,28.0,
CL,5540,5550,3.0,100,75,15000,15000,
MA,5540,5550,35000,,0.3,,,27.9,
CH,100,105,10.75,0.365,28.0,8.1,10.,6.22,
CH,130,133,12.75,1.159,0.110,90.,10.,4.62,
CH,5490,5500,12.75,0.375,28.0,8.1,10.,8.22,
CH,5540,5550,12.75,0.375,27.9,6.07,10,8.22,
TH,,0,
EN,,0,
NO
EXECUTE
NO,*****************  COMBINE LOAD CASES 21 AND 22, LEVEL A  ******************,
NO,METHOD OF LOAD COMBINATION = ABSOLUTE VALUE OF RANGE
NO,LOADING CASE NO. 27
CL,,,3.0,1989,3,
NE,7,,21,22,,,,27,
OU,4,,27,
EN,,0,
EXECUTE
NO,*****************  COMBINE LOAD CASES 23 AND 24, LEVEL B  ******************,
NO,METHOD OF LOAD COMBINATION = ABSOLUTE VALUE OF RANGE
NO,LOADING CASE NO. 28
CL,,,3.0,1989,3,
NE,7,,23,24,,,,28,
OU,4,,28,
EN,,0,
EXECUTE
NO,*****************  COMBINE LOAD CASES 25 AND 26, LEVEL C/D  *****************,
NO,METHOD OF LOAD COMBINATION = ABSOLUTE VALUE OF RANGE
NO,LOADING CASE NO. 29
CL,,,3.0,1989,3,
NE,7,,25,26,,,,29,
OU,4,,29,
EN,,0,
EXECUTE
NO,************** COMPUTE ABSOLUTE RANGE FOR LOAD CASE 30 (SEISMIC) **************
```

```
NO,THESE LOADS REPRESENT SSE SEISMIC LOAD RANGES
NO,METHOD OF COMPUTING = ABSOLUTE LOAD CASE 30 + ABSOLUTE LOAD CASE 30
NO,LOADING CASE NO. 31
CL,,,3.0,1989,3,
NE,3,,30,30,,,,31,
OU,4,,31,
EN,,0,
EXECUTE
NO,*************** DIVIDE ABSOLUTE RANGE OF LOAD CASE 30 BY 1.875  ***************
NO,THESE LOADS REPRESENT OBE SEISMIC LOAD RANGES
NO,METHOD OF COMPUTING = FACTORING --> 0.5333*LOAD CASE 31
NO,LOADING CASE NO. 32
CL,,,3.0,1989,3,
NE,8,,31,0.5333,,,,32,
OU,4,,32,
EN,,0,
EXECUTE
NO,****************  COMBINE THERMAL AND OBE LOADS: LEVEL B   ********************
NO,METHOD OF COMBINATION = ADD ABSOLUTE VALUES OF EACH LOAD
NO,LOAD CASE NO. 40 -- USE THERMAL LOADS OBTAINED AT MINIMUM TEMP. (LOAD CASE 21)
NO,LOAD CASE NO. 41 -- USE THERMAL LOADS OBTAINED AT MAXIMUM TEMP. (LOAD CASE 22)
CL,,,3.0,1989,3,
NE,3,,21,32,,,,40
NE,3,,22,32,,,,41
OU,1,,40,
OU,1,,41,
EN,,0,
EXECUTE
NO,****** SEARCH FOR HIGHEST LOADS FROM LOAD CASES 27, 40, AND 41: LEVEL B *******
NO,LOAD CASE NO. 45
CL,,,3.0,1989,3,
NE,9,,27,40,41,,,45
OU,1,,45,
EN,,0,
EXECUTE
NO,*****************    GENERATE STRESS REPORT: LEVEL A    ***********************
CL,,,3.0,1989,1,
EQUATION,8,,10
EQUATION,9,,10
EQUATION,10,,,27
EN,,0,
EXECUTE
NO,********************    GENERATE STRESS REPORT: LEVEL B    ********************
CL,,,3.0,1989,2,
EQUATION,8,,10
EQUATION,9,,10
EQUATION,10,,,45
EN,,0,
EXECUTE
NO,******************    GENERATE STRESS REPORT: LEVEL C/D    ********************
CL,,,3.0,1989,4,
EQUATION,10,,,31
EN,,0,
```

OUTPUT FILE:

Output on CD-Rom