JAMES R MORRIS
Vice President

Catawba Nuclear Station
4800 Concord Road / CN01VP
York, SC 29745-9635

803 831 4251
803 831 3221 fax

June 21, 2007

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Subject: Duke Power Company LLC d/b/a Duke Energy Carolinas, LLC (Duke)
Catawba Nuclear Station, Units 1 and 2
Docket Numbers 50-413 and 50-414
Request for Relief Number 06-CN-003
Use of Polyethylene Material in Nuclear Safety Related Piping Applications

References:
1. Letter from Duke to NRC, same subject, dated October 26, 2006.
2. Requests for Additional Information (RAIs), provided electronically to Duke, dated March 6, 2007.

The Reference 1 letter supported a proposed alternative of utilizing polyethylene material in lieu of steel material in piping associated with the emergency diesel generator jacket water coolers and other nuclear safety related piping applications. The NRC provided RAIs in conjunction with this submittal via the Reference 2 transmittal.

The attachment to this letter constitutes Duke's response to these RAIs. The format of the response is to restate each NRC question, followed by our response.

Duke is requesting NRC review and approval of this request for alternative by July 31, 2007.

There are no regulatory commitments contained in this letter or its attachment.

If you have any questions concerning this material, please call L.J. Rudy at (803) 831-3084.

Very truly yours,

James R. Morris

LJR/s

Attachment

xc (with attachment):

W.D. Travers, Regional Administrator
U.S. Nuclear Regulatory Commission, Region II
Atlanta Federal Center
61 Forsyth St., SW, Suite 23T85
Atlanta, GA 30303

A.T. Sabisch, Senior Resident Inspector
U.S. Nuclear Regulatory Commission
Catawba Nuclear Station

J.F. Stang, Jr., Senior Project Manager (addressee only)
U.S. Nuclear Regulatory Commission
Mail Stop 8-H4A
Washington, D.C. 20555-0001

bxc (with attachment):

R.D. Hart
L.J. Rudy
K.E. Nicholson
D.L. Ward
E.W. McElroy
M.L. Arey, Jr.
S.S. Lefler, Jr.
M.J. Ferlisi
M.A. Pyne
R.N. McGill
Document Control File 801.01
RGC File
NCMPA-1
NCEMC
PMPA
SREC
ELL-EC050

Attachment

Response to NRC Requests for Additional Information (RAIs)

RAIs from Piping and NDE Branch, Division of Component Integrity:

REQUEST FOR ADDITIONAL INFORMATION
REQUEST FOR RELIEF NO. 06-CN-003
DUKE POWER COMPANY, LLC
CATAWBA NUCLEAR STATION, UNITS 1 AND 2
DOCKET NOS 50-413 AND 50-414

In the submittal dated October 26, 2006, Duke Power Company, LLC, (the licensee) proposed using polyethylene (PE) pipe for buried Class 3 applications in lieu of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Class 3 metal pipe. The PE pipe segments will be butt fused together and nondestructively examined (NDE). The Nuclear Regulatory Commission (NRC) staff has reviewed the NDE inspection criteria in the proposed alternative. To continue the review, the NRC staff requests the following additional information.

1. In Section 6000, the proposed alternative provides criteria for leak tightness verification. The criteria is a hydrostatic test performed at 150% of the design pressure. Discuss the value derived from the hydrostatic test that supports or validates the structural integrity determinations of the fused joints. Provide the details and calculations to support the conclusions.

Duke Response:

The test pressure of 150% of the design pressure was chosen based on the following:

- The ASME B31.1, B31.3, and B31.8 Codes reviewed found the test pressure of 150% of the design pressure is used,
- In ASTM F-2164 *Field Leak Test of PE Pipe*, 150% of the design pressure is used within the gas and water industries, and
- The United States Department of Transportation (DOT) requires a test pressure of 150% of the design pressure per 49 CFR Part 192.513 for gas transmission PE piping.

The pressure test is the oldest quality test/examination that can be used on a pressure boundary to establish a level of reliability not to leak. When water is used as the test medium the pressure test becomes a hydrostatic test. Depending how the hydrostatic test is performed, the following attributes can be achieved; a measure of reliability of the pressure boundary not to leak, mechanical stress relief of the component being tested, and the proof test used for the determination of the maximum working pressure of a component.

A great deal of research was undertaken to determine and select how to properly hydrostatically test a PE piping system; this includes the test pressure and the test method used. The alternate pressure test proposed in the Relief Request (-6000) far exceeds the pressure test enclosed in ASME Boiler and Pressure Vessel Code, Section III ND.

The test pressure of 150% of the design pressure is 20% greater than the test pressure required in Section III ND (125%).

The test method selected is documented in ASTM F-2164. The requirements of the leak test have been incorporated into the Relief Request. The test uses a test pressure equal to 150% of the design pressure. This test is a standard industry test used by both the gas and water industries and meets the requirements set forth in the DOT 49 CFR. The test is actually the combination of two pressure test methodologies, the visual inspection of fused joints and static pressure drop test (5% change in pressure over one hour) on the portion of piping being tested. The PE piping being tested is required to pass both methodologies.

This test method again exceeds the method enclosed in Section III ND.

The proposed hydrostatic leak test should not be confused with a pressure proof test. The pressure proof test is required when a pressure component is designed by rules. The proof test is used to determine the maximum working pressure of a pressure component. Using the requirements discussed in ASME Section VIII, Division 1, UG-101 Proof Test, the component is subjected to 400% to 500% of the proposed maximum working pressure. During and/or after being subjected to this high pressure, the component is evaluated for detrimental effects on its structural integrity. For obvious reasons a pressure proof test will not be run on any of the installed PE piping.

The primary purpose of performing the hydrostatic leak test is to identify any leakage from the PE pressure boundary. However, the hydrostatic leak test will expose the fused joints to a pressure 50% greater than the design pressure. This additional pressure reduces the risk of a fused joint failure occurring during system operation that is usually operating below the design pressure.

In conclusion, the standard industry practice for many years has been to hydrostatically (leak) test piping systems to 150% of the design pressure. This is the same practice used before today's NDE methods were incorporated into the construction effort. When compared to other industries (e.g., commercial aviation which tests to only 110%), the hydrostatic (leak) test provides an adequate design margin.

2. In Section 5000, the proposed alternative provides acceptance criteria for determining PE fused joint soundness. The acceptance criteria is a combination of a visual examination and a review of the fused joint fabrication parameters recorded on a data logger (records time, temperature, and pressure used to fabricate the fused joint). The (quality assurance) personnel performing the visual examinations are supervised independently of the (maintenance) personnel performing the fused joint fabrication process. It is not clear if the personnel reviewing the data logger data are also independent of the personnel involved in the fused joint fabrication process. (a) Discuss the independence of the personnel reviewing the data logger data from the personnel making the fused joint. (b) Discuss the interface between the personnel reviewing the data logger data and the personnel performing the visual examination. (c) Discuss the signing-off on the acceptability of the review of the data logger data. (d) Discuss the timeliness requirements for data logger data review with respect to the repair or replacement activity.

Duke Response (a), (b), (c), (d):

All activities associated with this Relief Request will be performed under the Catawba Nuclear Station (CNS) Quality Assurance Program, which is based on 10 CFR 50 Appendix B. Within the CNS Quality Assurance Manual, separation between the Maintenance Group and the Quality Group is required. The current plan is to train both the Maintenance Group (fusing machine operators) and the Quality Group (VT-1 examiners) in the correct operation of the fusion equipment. This is to ensure equal skill levels in both groups and requires about 36-40 hours of training. This training will include how to review data logger documentation.

Since the data logger and visual inspections are both required for each fusion joint they can be performed in either order. The review can be done by the same VT-1 examiner. The work sequence will be controlled and documented by QA hold points as it is performed. When it is determined that a fused joint is rejected, it will be cut out. All data will be reviewed prior to placing the system in service.

3. In Section 5000, the proposed alternative is requiring a visual testing (VT) examination on the outside surface of the fused joint. The VT examination is an alternative for the 1998 Edition through 2000 Addenda to Section III of the ASME Code-required surface examination. However, the proposed alternative was silent on performing the Code-required, ND-2557(b)(3), surface examination of all accessible internal surfaces. (a) Provide a discussion on the VT examination that will be used to examine internal surfaces. (b) For inaccessible internal surfaces, discuss the technical evaluation supporting the determinations and provide a discussion on supplementing the VT examination with alternate NDE methods.

Duke Response (a):

The reference to ND-2557(b)(3) is not the appropriate examination requirement since it is applicable to tubular product materials and surface examination methods (MT and PT) are not appropriate for PE pipe.

The parent paragraph ND-2550, EXAMINATION AND REPAIR OF SEAMLESS AND WELDED (WITHOUT FILLER METAL) TUBULAR PRODUCTS AND FITTINGS refers to metallic standards contained in Section II Parts A and B. When the specific paragraph ND-2557(b)(3) is reviewed:

> (3) When surface examination is required all external and all accessible internal surfaces shall be examined except bolt holes and threads.

The document requiring the surface examination is the product standard (ASTM) contained in Section II. A surface examination would only be performed when required by the metallic product standard. The Relief Request (-2210 (b)) requires that PE material be procured from qualified material suppliers using the ASTM standards identified in Supplement 2, and is outside the scope of Section III, ND-2000.

As an example, using Supplement 2 of the Relief Request for the procurement of PE pipe, two ASTM specifications would be used. The first, ASTM D-3350-05 *Standard Specification for Polyethylene Plastics Pipe and Fittings Material*, would be used to specify the PE material physical properties and the tests required to ensure the physical properties are achieved. The second, ASTM D-3035-03a *Standard Specification for Polyethylene (PE) (DR-PR) Based on*

Controlled Outside Diameter, would specify the requirements for the pipe dimensions, labeling/marking, and testing of the pipe product. The testing required would be ring tensile test, burst testing, and sustained pressure test.

In addition, several common seamless metallic pipe standards (SA-106 and SA-312) were reviewed and neither required a surface examination. As a point of interest, the SA-106 standard required only a visual examination of the external pipe surface, similar to the PE requirements. Also, a review of the PE pipe industry standard practices found an inside diameter examination was not required or performed.

Duke Response (b):

Other industries have been fusing and installing HDPE pipe for more than 20 years and based on their experience, it was decided to follow their inspection strategy of using visual inspection of the joints. A recent magazine article entitled "Insuring PE Pipe Integrity" in Pipeline and Gas Technology, March 2006 issue, NYSEARCH reported on their evaluation of NDE techniques for assessing PE joint integrity. They noted that visual inspection is currently practiced today. They evaluated three other techniques, ultrasonic phased array, microwave, and the weld zone inspection method - a laser based technique. Although promising results were achieved, none of the techniques reliably detected all the flaws of interest during blind demonstrations. The Electric Power Research Institute also evaluated the microwave technique and an ultrasonic time of flight diffraction (TOFD) technique and reported those results in EPRI report 1011628 2006, *Technical Support for Proposed Polyethylene Pipe Code Case,* EPRI, Palo Alto, CA. Demonstrations were performed on blind mockups and most of the flaws were detected. The mockups did not include joints with cold fusion flaws. A literature search revealed that NDE experts do not seem to agree on the detectability of cold fusion. EPRI recently received a pipe joint with cold fusion and the detection is currently being evaluated. There is no benefit to supplement VT with other NDE methods based on their current reliability and current industry practice.

4. NUREG/CR-6860, "An Assessment of Visual Testing," discusses the effects of different variables on the effectiveness in detecting cracks with visual examinations. Although the NUREG only considered remote visual examination techniques, many of the variables are applicable to direct visual examinations. The ASME Code visual examinations are for

detecting specific plant defects. In Subsection 5400 of the proposal, VT personnel receive 32 hours of training in the recognition of specific surface indications that are associated with unsound fused joints. Indication recognition is subjective and varies with VT examiners. The process for establishing uniform minimum examiner skills is through performance demonstrations. The proposal is silent on establishing uniform minimum examiner skills. (a) Discuss the process that will be used to establish uniform minimum examiner skills in the recognition of unacceptable fused joint surface indications and configurations. (b) If a performance demonstration is used, discuss the minimum number of acceptable and unacceptable fused joints in the test set. (c) Discuss the specifics of the PE pipe (i.e., diameter, wall-thickness, shape) used in the test set.

Duke Response (a):

Paragraph -5400 has two different training requirements, 32 additional hours for a Certificate Holder and 16 hours for an Owner's VT-1 visual examiners. These times were considered to be sufficient to train VT personnel to perform the required examinations on PE fused joints. The following training outline details how the Catawba Nuclear Station (CNS) PE team will meet the training requirements for visual examiners.

In order to enhance the production process, the fusion machine operators and visual examiners will receive the same training (about 36-40 hours of training), and this training will include as a minimum:

(1) Butt fusion joining
- Principles of fusion
- Straight/coiled pipes, service lines, main lines, etc.
- Components: pipes, flange adapters saddle fittings, other fittings
- Butt fusion equipment: manual, semi-automatic, and automatic machines
- Joint preparation: cleaning, rounding, alignment, facing, etc.
- Butt fusion cycle: pressure, time and temperature relationships, diagrams
- Failure modes: understanding and avoiding possible mistakes

- Test methods: visual examination, high speed tensile-impact test, bending test, hydrostatic test, data log recording/evaluation, etc.

(2) The trainee fusion operator should be familiar with the butt fusion joining technique and procedure (FPS) by making a sufficient number of butt fusion joints. In some cases, the fusion technique may vary slightly according to diameter, material, or other factors. In such cases, the trainee fusion operator should also be made familiar with the various techniques.

(3) The trainee should start by making a butt joint between two pipes, and should then learn to make butt fusion joints with pipes and fittings such as tees, reducers, etc.

(4) The trainee should learn how to detect and avoid typical fusion defects.

(5) The trainee should learn how to assess the quality of a butt fusion joint by doing a visual examination of the butt fusion joint and comparing it to the visual guidelines published in the pipe manufacturer's heat fusion joining procedure booklet. The trainee should also compare the data log record to the FPS to ensure the proper parameters and procedures were followed in the butt fusion process.

This training will be given to qualified Level II and III, VT-1 visual examiners, who will be using procedures for PE pipe developed under the CNS Quality Assurance Plan. There will be two parts to the visual examination, data logger review and visual inspection of the PE joint. Both parts will be performed by the visual examiner. Review of the data logger record (record of fusion machine operator's actions) is objective in nature, while the visual inspection of the PE joint is subjective in nature.

Detrimental indication recognition of the fusion bead on the outer pipe surface is a subjective process and varies with the VT examiners. The training discussed above will reduce this variance between examiners and will increase the reliability of the examinations. Visual recognition and indication comparisons shall be performed, using ASTM F2620-06 *Standard Practice for*

Heat Fusion Joining of Polyethylene Pipe and Fittings and vendor visual training aids on PE joints. The visual examination of the PE joint will be procedurally controlled. If there is a question on acceptability, the PE joint shall be cut out.

The training requirements above were developed during development of the ASME Code Case N-755. The project team requested Duke personnel to perform a visual examination of 12 to 15 fused joints on non-safety service water piping at CNS. The personnel applied acceptance criteria being developed for Code Case N-755. The individual performing the visual examinations was a welding engineer with a background in the PE piping project at CNS. When discussing the results of the examination, it became evident that having complete knowledge of the fusing process and equipment would greatly improve the overall quality of the project. The Code Case N-755 project team then developed requirements that the visual examiners will be given the same training as the fusion machine operators.

Duke Response (b):

Performance demonstration (PD) will not be used. There is not an adequate experience base to support PD use with PE material. It took more than 10 years of research and development to produce the PD methodology for the ultrasonic examination method currently in ASME Section XI. During the approval of Code Case N-755, ASME Section XI, SubGroup Nondestructive Examination agreed that exceeding the training requirements of Section XI, Appendix VI, Qualification of Personnel for Visual Examination, provides adequate guidelines for the qualification of visual examination personnel for PE pipe.

Duke Response (c):

Performance demonstration will not be used; therefore, there will be no standard set of samples. Samples with outer surface indications used for training aids can be any size. Per QF 340, test joints shall use 6 inch NPS minimum for fusion machine operator training (for testing and visual examination).

5. A visual examination of PE fused joints provide anecdotal information about joint integrity. A literature search of nondestructive examination methods identified the inability for visual examinations to detect volumetric flaws, such as: porosity, foreign material, lack-of-fusion (cold fusion) and non-visible lack-of-penetration and cracks. (a) Discuss the probability of volumetric flaws escaping detection during

the visual examination of field fused joints along with supporting data. (b) Discuss the failure mechanisms of the different volumetric fused joint flaws: include shape/size and type of failure (i.e., brittle, yield, pitted, slow, fast, local, running). (c) Discuss the origin and acceptability (i.e., size, configuration, through-wall location) of volumetric flaws by flaw types common to PE fused joints.

Duke Response:

The response to questions (a), (b), and (c) is presented in the following table and notes.

Flaw Descriptions and Failure Mechanisms of Flaws in Polyethylene Fused Joints

Flaw Description	Failure Mechanism	Type of Failure	Flaw Origin	Detection Probability by Visual Inspection	Flaw Acceptable to Joint Performance
Contaminants (Note 1)	Cracking (Slow Crack Growth)	Slow (Brittle)	• Shavings in joint during fusing process	Low	No
			• Dirt in joint during fusing process	Low	No
			• Moisture in joint during fusing process	Low	No
			• Oil in joint during fusing process	Low	No
Contaminants (Note 2)	Through Joint Leakage	Fast or Slow (Leak)	• Embedded particles provide a through wall leak path	High	No
Cold Fused Joint (Note 3)	Separation of Joint	Fast (Brittle)	• Application of pressure during heat cycle	High	No
			• Inadequate heater plate temperature	High	No
			• Excessive heater plate temperature	Low	No
			• Inadequate soak time in heat cycle	Low	No
			• Excessive joining pressure	Low	No
			• Inadequate joining pressure	High	No
			• Inadequate cooling time	Low	No

Notes for flaw description and failure description:

(1) Contaminants for this category are either particles or liquids introduced into the joint during the joining process that are not easily visible. Possible contaminants in the joint include dirt, sand, dust, water, grease, and oils. Solid contaminants could range in size from microscopic particles up to particles nearly the size of the pipe wall

thickness. Contaminants could be located at any location in the fused joint wall. It is possible that contaminants could be pushed out of the joint with the viscous material that forms the fusion bead and then have no effect on joint performance but still be detectable by visual inspection. However, contaminants that remain in the area of the fused joint between the pipe ends could form voids (porosity) in the completed polyethylene piping joint. These voids could form initiation sites for slow crack growth that ultimately could lead to cracking and eventual brittle failure as cracking becomes great enough to result in rapid loss of piping pressure integrity and structural integrity.

Contamination is always a concern when making a butt fusion joint. That is why the joining procedure requires pipe ends to be faced to mechanical stops to ensure that virgin material is exposed and any oxidation and/or contamination that might be present on the pipe faces is removed. After the facing operation the operator removes shavings produced by the facing operation and inspects the pipe ends to make sure the pipe ends were completely faced off and there are no gaps, voids, or foreign matter on the pipe faces. If there are voids in the pipe face, that is a pipe quality problem which is almost unheard of. If voids in the pipe face are detected by the visual inspection, the job must be stopped and the problem evaluated by the pipe manufacturer. If there is any foreign matter on the pipe end surfaces, it can be brushed away with a clean cotton cloth before the heating operation. These are usually loose shavings from the facing operation. The pipe ends are then brought together and the alignment checked. After the pipe ends are adjusted, the pipes are left together to prevent any dust or contamination on the pipe ends.

The time between the facing operation and the heating operation is usually about 10-30 seconds. In that time, the heater is checked to make sure it is at the proper temperature and the pipe faces are cleaned with a clean cotton cloth. This is done for every joint before the heating operation. Once the heater is ready, the fusion machine operator opens the carriage and the heater is installed between the pipe ends. The fusion machine operator quickly moves the carriage closed, trapping the heater between the pipe ends and starts the heating process. This all takes about 5-10 seconds. Unless it is an extremely windy, dusty day, the amount of dust that could possibly get between the heater and the pipe ends in that timeframe is negligible. If the weather forecast is for rain or snow or if it is an extremely windy, dusty day, the fusion procedure requires that the fusion machine and operator be enclosed in a shelter to protect the operator, fusion machine, and the pipe ends from contamination and the elements.

During the heating process, the pipe ends remain against the heater so no contamination can possibly enter the joint area. When the heating process is complete, the carriage is opened just enough to remove the heater plate. The carriage is closed to bring the pipe ends together at the fusion pressure. This open/close time varies somewhat depending on the pipe size. On pipe sizes up to 8 inches, this time is about 3-4 seconds; for 24 inch pipe, the time is about 5-10 seconds. This is the only other time that dirt and dust can contaminate the pipe ends. If some dust gets on the pipe ends at this time, the fusion process pushes it to the bead area and out of the interface.

(2) Contaminants for this category are larger particles that depending on size, number of particles, and location in the fused joint, could produce a through wall leak. Larger contaminants located near the outer wall of the pipe could be visible during visual inspection following the joining process. Larger contaminants located near the inner part of the joint pipe or underneath the surface of the joint would not be detectable by visual examination of the completed joint. It is also possible that particles in the formed bead after joining would be detectable by visual inspection. Depending on size, number of particles, and orientation, these contaminants could produce a localized through wall leak path and be detected by visual inspection and during hydrotest.

(3) A cold fused joint may occur when one or more of the fusing process parameters are outside of the range of parameters allowed by the fusing procedure. Fusing plate temperature, time of heating, joining pressure, and allowable cooling period are process parameters controlled by the joining procedure to make a fused joint.

6. ASME Section III and Section XI have crack and metallurgical flaw acceptance criteria (based on size, configuration, and through-wall location) for metal components and piping that are commonly used to maintain the reactor coolant pressure boundary. (a) Provide the volumetric flaw acceptance

criteria for PE pipe (i.e., size, configuration, and through-wall location). (b) Discuss the assumptions, if any, used for calculating pipe failure and flaw growth to pipe failure for the different types of volumetric flaws that are common to PE pipe.

Duke Response (a):

Currently there is no accepted standard industry practice for the volumetric examination of a fused PE joint; thus, no acceptance criteria exist.

The Electric Power Research Institute (EPRI) performed a study of volumetric methods and none were found to provide reliable detection of all the flaws of interest, particularly for cold fusion flaws. This point is confirmed by other research organizations, including the British Welding Institute and NYSEARCH. EPRI and Duke have evaluated ultrasonic TOFD, ultrasonic phase array, and microwave techniques. A copy of the EPRI report 1011628 has been made available to the NRC for review.

Section XI does not require volumetric examination or surface examination of Class 3 components.

ANSI/ASME B31.1 contains requirements for PE pipe but does not include volumetric examination or volumetric acceptance criteria.

The sentence also includes the words "reactor coolant pressure boundary" which seems to infer that a safety classification of ASME Class 1 is to be used. The proposed PE system is an ASME Class 3 system. There are differences between Class 1 and Class 3 required NDE methods. For example, a Class 1 welded joint would require both a volumetric and a surface examination. Class 3 welded joints require a volumetric or surface examination. This difference in requirements is based on safety; Class 1 is higher than Class 3 and more NDE is required for Class 1. Class 3 also allows additional methods of component joining that are not allowed in Class 1 construction.

One of the additional joining methods in Class 3 construction is the brazed joint. This joint cannot be examined by a volumetric or a surface examination. It is required to be examined only by a visual examination (ND-5275). This visual examination provides a precedent for the visual examination of a PE joint as required by Section -5000 of the Relief Request.

A literature search has been conducted to determine the acceptance criteria used by other users of PE pipe. The only available criterion that was found was for visual inspections. Other industries that use PE pipe do not typically employ volumetric methods and they do not use surface examination methods.

Duke Response (b):

Reliable volumetric techniques are not currently available, so there is no need to perform such calculations. As the industry obtains more experience with HDPE and as reliable volumetric techniques are developed, the need to perform such calculations would be evaluated. Since the PE system is ASME Class 3, it would not be subjected to any volumetric testing under a Section XI Program, making flaw evaluation unnecessary.

RAIs from Mechanical and Civil and Engineering Branch (EMCB), Division of Engineering:

Catawba Nuclear Stations Units 1 and 2 - Request for Relief Number 06-CN-003
(Use of Polyethylene Material in Nuclear Safety Related Buried Piping Applications)
Duke Power Company: Docket Nos. 50-413 and 50-414

Request for Additional Information (RAI)

I. Background:

When the Relief Request package was submitted by Duke on October 26, 2006, the proposed ASME code case N-755 was still in the development phase. Subsequently, the code case was passed with NRC voting negative as there are some concerns pertaining to the safety with the 10% flaw and Slow Crack Growth (SCG) issue. The High Density Polyethylene (HDPE) material, used in the evaluations contained in the relief request, is PE3408, while the final recommended HDPE material in the code case is PE4710 as the suitable material for use at 140°F.

References used in the review:
1. Catawba Request for Relief (06-CN-003) package which also includes the draft code case, and EPRI Report 1013549
2. Handbook of Polyethylene Pipe, Plastics Pipe Institute
3. Performance Pipe Engineering Manual (Bulletin PP 900), Chevron Phillips Chemical Company
4. Plastic Pipe: Burst and Fatigue Testing of PVC and HDPE Pipe, WRC Bulletin 445
5. PE Joint Alignment, FEA, G. Antacki

II. Request for Additional Information (RAI):

RAI-01:
The HDPE material (section 2110 b of p. 6) and the mechanical properties such as short term (table 3035-3 of p. 17) and long term (table 3021-1 of p. 12) allowable stresses, Elastic Modulus (table 3031-3 of p. 14), allowable alternating stress amplitude of 1100 psi (section 3042.2 of p. 19 & section 3051 of p. 20) for fatigue or cyclic loading applications) used in the relief request package are based on PE3408, while the final recommended HDPE material in the draft code case is PE4710 as the only suitable grade of PE material for use at 140°F. Please provide the following information.

(a) In the light of this development, what is the HDPE material Duke intends to use? (b) Please provide for the HDPE material (if PE4710) the corresponding mechanical properties (S, Salt, E) for various time durations (short term & long term) and temperatures. (c) As necessary, revise all of the evaluations in the relief request accordingly, and resubmit for staff review.

Duke Response (a):

Duke intends to use PE 4710 material for this relief request.

Duke Response (b):

Material properties used in the relief request submittal are applicable for the PE 4710 material as well as for PE 3408 as supported by the following information:

- Plastics Pipe Institute Publication TR-4/2007a lists the Hydrostatic Design Basis and Hydrostatic Design Stress for polyethylene piping materials. Table 1.A.13 of TR-4/2007a lists the Hydrostatic Design Basis for 4710 material and this table states that 4710 materials listed in the table also meet the requirements for a PE 3408 material per ASTM D3350-02a.

- Some of the material furnished to Duke as PE 3408 and presently installed at Catawba in the non-safety service water system complies with requirements for both PE 4710 and PE 3408 material. These materials were procured as 3408 material but actually meet requirements for both 3408 and 4710 materials and are marked "PE3408/4710 PE100". The allowable stress values used in both the relief request and Code Case N-755 are based on the lower mechanical properties that are required for PE 3408. The analyses presented in the relief request use the lower allowable stress values based on PE 3408 material and these analyses are conservative for use of PE 4710. The sample analyses apply for both PE 3408 and PE 4710. PE 4710 has improved resistance to slow crack growth compared to PE 3408 as confirmed by test requirements of ASTM D 3350.

- The comparison provided by Dudley Burwell, ISCo Industries, dated August 21, 2006 (attached) shows that polyethylene material once rated as PE 3408 can now be called PE 4710.

- Testing summarized by EPRI Report 1013479 supports the use of material properties used in both the relief request and Code Case N-755. Further testing is being conducted for PE 4710 piping under direction by EPRI as outlined by the attached schedule. However, Duke does not intend to use these test results to develop higher allowable stress values for the polyethylene material addressed by this relief request.

Duke Response (c):

It is not necessary to revise all evaluations and resubmit for staff review since the relief request requires use of polyethylene material with minimum material properties of PE 3408. PE 4710 material complies with requirements of this paragraph, since PE 4710 material properties meet or exceed PE 3408 material properties. The sample analyses presented in the relief request will be developed into a design calculation during project implementation and the analyses will be revised to reference only PE 4710 material. Material properties used in both the relief request and Code Case N-755 are conservatively based on material properties of PE 3408.

RAI-02:
10% Allowable Flaw Issue (Section 2910 a of p. 8)
Since this Request for Relief is for safety related applications, and there are some safety related concerns pertaining to the PE piping material, NRC is looking for more test data and analytical or experimental results. The specific items for additional information are listed below.

There is a need for Slow Crack Growth data on PE4710 type resins with additional verification experiments on both new and degraded piping to settle the 10% allowable flaw depth issue.

There is a question on whether the combination of large diameter piping, elevated temperatures, and allowable flaw sizes (10% of the wall thickness) could lead to premature leaks or failures in PE piping due to Slow Crack Growth.

(a) Test data with respect to Slow Crack Growth (SCG) Rate (related to long term brittle fracture) for specific (diameters & plastic material PE4710 proposed in the code case) polyethylene pipes with 10% sharp & blunt scratches to justify 50 yr life expectancy for temperatures of up to 140°F is required. The test data may include scratched as well as unscratched pipes with internal pressure as well as mechanical loadings as applicable.

If there is no existing test data to establish that indentations of up to 10% of the wall thickness (axial flaws) is currently available, new test data needs to be generated and provided to the NRC for review.

(b) As there is no reliable volumetric inspection method currently available for PE material, visual inspection is proposed in section 2910 a of p. 8 for the fusion buttweld joints for polyethylene pipe. SCG test data for PE4710 polyethylene pipe showing acceptability of circumferential flaws of up to 10% wall thickness (such as those due to inclusions, cold fusion area of a fused joint) is needed for staff review to justify 50 yr life expectancy for temperatures of up to 140°F.

Duke Response (a):

Presently there is insufficient test data to support the allowance of scratches with a depth of up to 10% of the scratch depth for extended service life for all pipe sizes and all design temperatures. Testing is being planned under ASME direction to provide this data and support the 10% scratch depth allowance of Code Case N-755. However, this testing cannot be completed in a time frame that will support the Catawba schedule for replacement of piping addressed in this relief request. The general 10% scratch depth allowance will be replaced with a smaller scratch depth allowance based on test data presented in *Experimental Determination of Allowable Crack Depths in Polyethylene Pipes Subjected to Internal Pressure Loading* (authored by D.A. McKee, C.H. Popelar, and C.J. Kuhlman of the Southwest Research Institute; N. Brown of the University of Pennsylvania; and M.M. Mamoun of the Gas Research Institute). This test data included pressure testing of 4 inch, SDR 11 pipe with a 10% scratch depth of 0.041 inches. This

test data will be used to support the following allowances on scratch depth:

- Piping $\leq$ 4 inch NPS with an SDR $\geq$ 11 will have a scratch depth allowance of no more than 10% of the nominal wall thickness.
- Piping $\leq$ 4 inch NPS with an SDR < 11 will have a scratch depth allowance of the smaller of either 10% of the nominal wall thickness or 0.041 inches.
- Piping > 4 inch NPS will have a scratch depth allowance of the smaller of either 10% of the nominal wall thickness or 0.041 inches.

Unacceptable scratches or unacceptable damage to polyethylene piping under the scope of this relief request will be resolved by:

1. Either cutting out and replacing the damaged section of pipe, or
2. Removing scratches or damage by blending and then verifying that the remaining material thickness meets all design requirements. Any piping section with any damage exceeding 10% of the nominal wall thickness shall be cut out and replaced.

The requirements of this provision are consistent with requirements of ASME Boiler and Pressure Vessel Code paragraph ND-2558 for metallic materials and will be as follows:

Surface defects shall be removed by grinding or machining in accordance with the following requirements:

(a) The depression after defect elimination is blended uniformly into the surrounding surface with a maximum taper not to exceed 3:1 (ratio of width to height).
(b) After defect elimination, the area will be examined by visual examination to ensure that the defect has been removed.
(c) If the elimination of the defect reduces the thickness of the section below the minimum required design thickness, the section of piping containing the defect shall be cut out and replaced.

These requirements replace paragraph 2920 of the relief request.

Duke Response (b):

Flaws such as inclusions and cold fusion are unacceptable in polyethylene piping fused joints. As correctly stated in the RAI, currently there is not a reliable volumetric examination method for examination of polyethylene piping and fused joints. The Catawba relief request and Code Case N-755 have addressed the issue of flaws in fused joints by requiring fusion process controls that will provide a very high confidence level that flaws are not incorporated into the fused joints. The relief request and Code Case N-755 requirements for the joining process are based on requirements of ASTM F2620-06 *Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings*. Extensive testing was performed by the Plastics Pipe Institute in the development of this standard to establish limits on the essential parameters for making a fused joint to ensure defects are not incorporated into the joints. These tests are documented in Plastics Pipe Institute Publication TR-33/2005, *Generic Butt Fusion Joining Procedure for Field Joining of Polyethylene Pipe*. Fusion joints were made using all combinations of pressure and temperature parameters permitted by the procedure. In addition, fusion joints were made using heater plate temperatures 25 degrees F above and 25 degrees F below the temperature specified by the procedure. Also, fusion joints were made using interfacial pressures 10 psi above and 10 psi below the pressure specified by the procedure. All of the fusion joints (including those made under the extended parameters) passed every test conducted. These tests included tensile testing, quick burst testing, and high speed tensile impact testing.

Additional confidence that the joint has been properly fused without flaws is further established by requiring that the essential joining parameters (fusion temperature, fusion pressure, and time of pressure application) are permanently recorded. Personnel making fusion joints will be trained and qualified in accordance with requirements of the relief request and Code Case N-755. Assurance that foreign material will not be introduced into the fused joint will be addressed by procedure requirements. Joints will be made inside a protective enclosure when environmental factors could introduce contaminants or moisture into the joint. A visual inspection of the bead profile of the completed fused joint is performed to assure compliance with requirements of the relief request and Code Case. Finally, the hydrotest is a final quality check of the soundness of the fused joint.

Fused joints made in accordance with these requirements provide very high confidence that joints are free of any detrimental flaws.

RAI-03:
There is no evaluation presented for the flanged joint interface between metallic piping and polyethylene piping (addressed in sections 2330 & 4520) for acceptability of the differential seismic movements, differential settlements, and other mechanical loads. Figures 4520-1 of p. 26 & Fig. 3647-1 of p. C25 show an abrupt change on the inside surface at the interface. These flange joints are to be considered as non-standard flanges, because of the presence of PE flange adapter and metallic backing ring, and abrupt step like change on the inside surface. Such non-standard flange joints require a detailed evaluation similar to Appendix-XI of ASME Code section III. In addition, the factors of safety chosen for polyethylene piping are less (for levels A&B) than for metallic piping. Please provide an evaluation of the flanged joints per paragraphs ND-3647.1 & ND-3658.1 of the code.

Duke Response:

HDPE flanges were tested to leakage as part of the ongoing EPRI test program. The results of these tests are summarized in the Interim EPRI Report Number 1014902. The tests show that with adequate bolt preload, the flange's capacity is greater than that of the attached pipe. That is, if the stresses on the fusion butt joints connecting the flange adapter to the pipe meet the Code Case limits, then the moment transmitted to the flanged joint will be below that which is necessary to cause flange leakage. It should be further noted that, in conducting these comparisons, no SIF or stress index was applied to the stresses at the weld location. Therefore, these are the nominal stresses which represent the upper bound load or stress that could exist at the fusion joint between the pipe and the flange adapter. This approach would also result in the highest possible load

that would be permitted at the flange and still conform to the Code requirements at the safe-end weld. This is consistent with the requirements of the current Code Case in Section 3022.3 and 4510(e). Based on the results of this testing and the appropriate bolt torque, the flange leakage capacity will be greater than the capacity of the attached pipe. Therefore, specific analysis and design requirements for the HDPE flange to steel flange connection is not warranted or required.

RAI-04:
Please provide justification related to the following items.

(a) The basis for allowable seismic strain limits listed in Table A-1 of Supplement 3 (p. 36), and allowable pipe bending radius of ≥ 30xDo in section 4510 (p. 25).

(b) The basis for allowable limits for ring deflection percentage (table 3031-1 of p. 14). PPI handbook (chapter 6, page 215, table 2-11) lists these as safe allowable values. However, are these values good for PE3408 & PE4710 materials also?

(c) Also, clarify and correct the nomenclature that Ω and Ω_{max} (section 3031 of p. 13) are not ring deflections per se as stated in section 3031, but, a ratio of ring deflection to mean diameter of the pipe.

(d) Is the justification for the offset or surface mismatch limit of 10% thickness (section 4421.2 of p. 24) based on G. Antacki's FEA results? To determine the peak stress effects at the abrupt step type change in the geometry due to the offset, it does not appear that the FEM mesh is reasonably fine enough locally. It seems like the FE mesh size is of the same size throughout the model. This needs confirmation using a finer mesh.

(e) Provide the basis for long term and short term Poisson's ratio values listed in sections 3010 (p. 11); 3033.2 (p. 16); 3042.1 (p. 18). EPRI report 1013459 as well as Performance Pipe Engineering Manual (Bulletin PP900) lists the Poisson ratio values, but no justification is provided.

Duke Response (a):

The seismic strain limit in Table A-1 is calculated from the standard manufacturers HDPE pipe curvature, given that ε =

R/ρ (radius of pipe/curvature). The factor k = 1.33 applies for level B (k = 1.1) and C and D (k = 1.33) in accordance with Table 3035-2, (page 17 of the relief request).

DR	ρ	ε
< 9	20 D	(D/2)/(20D) = 0.025
9 to 13.5	25 D	(D/2)/(25D) = 0.020
13.5 to 21	27 D	(D/2)/(27D) = 0.019
> 21	30 D	(D/2)/(30D) = 0.017

The allowable pipe bending radius of $\geq$ 30 times the pipe outside diameter is an installation tolerance based on the experience of Catawba in installing polyethylene piping in non-safety service and recognition of the elastic properties of polyethylene piping.

Duke Response (b):

The design rules of the PPI Handbook, Chapter 6, Design of Polyethylene Piping Systems, apply to HDPE pipe, including PE 3408 and PE 4710.

Duke Response (c):

The comment is correct, while Ω is commonly referred to as ring deflection, it is the vertical downward ring deflection of the cross section divided by the mean diameter of the pipe (as defined in the PPI Handbook, Chapter 6, Design of Polyethylene Piping Systems).

Duke Response (d):

G. Antaki's analysis was used to address the effect of 10% mismatch or offset in the fused joint.

An analysis (attached) with 10 elements through-thickness (double the original 5) yields similar results to the previous analysis.

No offset (theoretical) Maximum stress	10% offset (5 elements) von Mises stress	10% offset (10 elements) von Mises stress
Tension = 10 psi	10.7 psi	10.6 psi
Shear + Bend'g = 10 psi + 541 psi	536 psi	565 psi

Duke Response (e):

According to "Principles of Polymer Engineering" by N.G. McCrum, C.P. Buckley, and C.B. Bucknall, Oxford Science Publications, Oxford University Press, 1988, p 347, Poisson's ratio for plastics lies between 0.35 and 0.42. Polyethylene has both crystalline and amorphous regions and the ratio will vary in these regions. For a highly drawn crystalline region, a value of 0.4 was reported by I.M. Ward, "Mechanical Properties of Solid Polymers", 2nd Edition, John Wiley and Sons, 1985 p 271.

EPRI report 1013549 recommended a short term Poisson's ratio of .35 and a long term ratio of .45. These recommendations were based on the recommendations given in the CP Chem, "*Performance of Pipe Engineering Manual*", Book 2, Chapter 7, page 104. The Plastic Pipe Institute, "*Handbook of Polyethylene Pipe*", makes the same recommendation for Poisson's ratio on page 430. Further, on page 75 of "*Handbook of Polyethylene Pipe*", a Poisson's ratio of .4 to .45 is recommended. This recommendation is based on data in the "*Handbook of Plastics and Elastomer's*", by Charles Harper, (McGraw Hill, 1975). Rosato, D.V., et. al., in "Designing with Plastics and Composites", (page 143 Table 3-2), VanNorstrand/Rienhold, copyright 1991 and in "Concise Encyclopedia of Plastics", (page 201), Klyver Academic Publishers, copyright 2002 recommend a value of .2 to .4 for Poisson's ratio.

As discussed in the referenced publications Poisson's Ratio is a secondary factor in design and analysis of HDPE piping systems. It does not have a controlling effect on the overall piping system design, qualification, or function. Considering the above discussion and references, the Poisson's ratio values used in the Code Case are reasonable and are based on industry recommendations, experience, and judgment.

RAI-05:

(a) Why is t_{min} defined twice and differently here in section 3021.1 of p. 12? Please correct by deleting one of them as appropriate.

(b) Tables A-2, A-3, & A-4 of pages A-6 & A-7: Units are not listed for temperature. Include units for temperature in row 1 of the table as °F. The units listed for α are incorrect. Correct the units for α from in/°F to in/in/°F. In table A-4 of p. A-7, what is N? Should it be Poisson's ratio (ν) as shown in table A-3?

(c) Table 5-1 of p. 5-2: row 5-1(c): Temperature is incorrect. Is this 30-Year Life rather than temperature? Also, the third set of temperatures in the first column listed as 400°F, 600°F, 700°F, 1000°F, 1200°F, 1400°F seem to be incorrect by a factor of ten. Shouldn't they be corrected to 40°F, 60°F, 70°F, 100°F, 120°F, 140°F?

(d) Table A-12, Appendix A of p. A-28: Why is the F_a for load case 31 at node# 2377 is much smaller than 0.5 (F_a of load case 32)?

(e) Table 3113-1 of Appendix C p. C-19: What are P_T & F? These are not defined. Is F the Flood Load FL & P_T the Transportation Load?

(f) Table 3654-1 of Appendix C p. C-23: What is 18/t in column #1? Is this the dimension ratio D/t?

(g) Fig. 3-2 title of p. 3-6: Why is reference [6] used instead of [7]?

(h) Reference 7 of p. 7-1: Why is WRC bulletin No. 433 used here? It does not deal with HDPE pipe. WRC bulletin No. 445 deals with HDPE piping.

Duke Response (a):

The term t_{min} is defined as the pressure design thickness. The line with "t_{min} = maximum pressure design thickness, in." should be deleted from page 12 of the Duke Relief Request.

Duke Response (b):

(1) The units of temperature, (°F) should be added in Table A-2, A-3, and A-4 of the relief request.

(2) The units of α should be changed to in/in/°F in Tables A-2, A-3, and A-4 of the relief request.

(3) N should be changed to υ (Poisson's Ratio) in Table A-4 of the relief request.

Duke Response (c):

This comment is in reference to EPRI Report 1013549 which has been published by EPRI.

Yes, the table header for 5-1(c) should be 30 year life. Yes, the correct temperatures are 40°F, 60°F, 70°F, 100°F, 120°F, and 140°F.

Duke contacted EPRI and requested revision of the report when the report is next revised.

Duke Response (d):

For Load Case 32, an incorrect, conservative number was transposed from the ADLPIPE program output. The F_a for Load Case 32 should have been 472 lbs, which is approximately 2 x 241 lbs, the F_a for Load Case 31. No revision is necessary.

Duke Response (e):

Table 3113-1 contained typographical errors. Flood and transportation loads are both considered primary loads, therefore P_T should be corrected to P_t (as previously defined). F should be changed to F_L, also as previously defined. This information is based on EPRI Document No. 1013549, Appendix A, page A-17, Table 3113-1 and revision is at the discretion of EPRI.

Duke Response (f):

The correct term is D/t or SDR.

Duke Response (g):

This comment is in reference to EPRI Report 1013549 which has been published by EPRI.

This is a typographical error. The correct reference is [7].

Duke contacted EPRI and requested revision of the report when the report is next revised.

Duke Response (h):

This comment is in reference to EPRI Report 1013549 which has been published by EPRI.

This is a typographical error. The correct report number is "WRC Bulletin No. 445."

Duke contacted EPRI and requested revision of the report when the report is next revised.

RAI-06:
As described in section 2.5 (p. 2-5) of EPRI Report 1013549, the proposed factors of safety chosen for polyethylene piping are less (for levels A & B) than for metallic piping used for ASME section III safety related class 3 applications. Hence, some conservatism and safety margins need to be maintained for HDPE piping. In the light of this background, please provide justification related to the following items.

(a) Table 3042.2-1 of p. 19 lists stress intensification factor for fusion butt joint as 1.0 and for miter bend as 2.0, while p. 5-17 of EPRI report recommends 2.0 & 3.0 respectively. Why are the EPRI recommended interim values not used?

(b) (i)Section 3042.3 (page 19): The allowable alternating stress amplitude for cyclic or fatigue loading listed here for thermal expansion evaluation of buried HDPE piping is 1100 psi. This is based on a very limited bending fatigue test data of 7 specimens (does not meet ASME Section III code requirements) of PE3408 material at slow rates (short term) at room temperature as shown on Fig. 3-2 of p. 3-6 of the EPRI report. It is inappropriate to use 1100 psi directly without accounting for time duration and temperature effects. Since this 1100 psi allowable is short term room temperature value for PE3407 material, why isn't this magnitude factored down by the ratio of modulii of Elasticity: (E for 50 yr at 140°F/E for 1000 hr at 70°F) to account for long term duration and temperature effect?

For buried piping thermal expansion evaluations:
For PE3408 for 50 yr 140°F: Allowable Salt = 1100 (12000/44000) = 300 psi (not 1100 psi as shown in section 3042.3 p. 19).

(ii)Section 3051 (page 20): Similarly for buried piping seismic evaluations using equivalent Thermal approach (by converting soil strain due to seismic wave passage into an equivalent temperature rise): For PE3408 for seismic 140°F short term: Allowable Salt = 1100 (18000/44000) = 450 psi (not 1100 psi as shown in section 3051 p. 20).

The allowable salt value of 1100 psi used in Appendix A section 3042 of p. A-30 & A-31, A-40 & A-41 for thermal, and section 3050 of p. A-31, A-41 for seismic should be corrected as appropriate.

Is the bending fatigue data being developed for PE4710 material, which will be used in your application? Please submit the data for NRC review.

(c) How is 1000 psi allowable stress established for circumferential compressive stress in section 3032? This should correspond to the allowable stress for 50 yr at 140°F for level A & short term allowable stress at 140°F for levels B, C, D. (For example it is only 400 psi for level A & k(630) psi for occasional levels B, C, D for PE3408 material, where k is service level factor.)

(d) Appendix A, section A2.8 items 9 (a) & (c) of p. A-15 and A-16: Why are load cases 24 & 31 and 24 & 32 combined using SRSS rather than Absolute Sum? Provide justification for combining by SRSS rather than Absolute Sum for seismic results for buried pipe (i)done as equivalent thermal & (ii)seismic from response spectra of above ground piping with null spectra for buried piping.

Duke Response (a):

The original EPRI report assumed straight pipe and butt fusion joints would be tested separately and would have separate Stress Intensification Factors (SIF) assigned to them. However, subsequently it was decided to conduct the testing consistent with the approach used by Markl in the original SIF testing of steel piping in the 1950s. A fatigue stress-strain curve for fusion butt joints will be developed from this testing which will serve as the basis of all future SIF development. Based on these tests, a fusion joint will be assigned an SIF of 1.0 and the corresponding cycle to failure curve provided. With this approach, a

fusion joint can be used anywhere in a HDPE piping system without any special regard for SIF or location.

Therefore the correct SIFs are i = 1.0 for fusion butt joints and i = 2.0 for 5 segment miter bends.

Duke Response (b)(i):

Interim EPRI Progress Report 1014902 provides results of extensive fatigue tests of 4 inch butt fusion joints and expands fatigue data beyond the limited data presented in EPRI Report 1013549.

The secant modulus for HDPE decreases with time at constant applied load as discussed in Section 3.3 of EPRI Report 1013549. However, the short term modulus of elasticity is not altered significantly (< 10%) by pre-straining. This phenomenon is similar to high temperature creep in steel piping. The major source of this creep behavior in HDPE is pressure, which is a primary non-self limiting load in HDPE piping systems. This failure mode is primary stress creep rupture. For the buried HDPE, the thermal stresses are displacement induced, self limiting stresses, and as such are secondary stresses. Secondary stresses are self relieving and as such do not have the constant load necessary to produce a creep rupture failure. If the stresses are maintained below the elastic limit the main concern is fatigue failure due to repeated heatup and cooldown (cycling).

The fatigue tests reported in EPRI Progress Report 1014902 were displacement (strain) controlled tests and the resulting stress capacities were based on the actual modulus of elasticity the specimen was experiencing while under load. Two sets of data were provided: one set with the elastic modulus that existed during the initial load cycle and one set with the lower bound modulus that is experienced after a prolonged period of cycling at 1 Hz. In the test data, the failures are based on the load and modulus that pipe experienced under load. The effect of modulus reduction as a function of time at load is accounted for by using the accurate modulus in the structural analysis to determine the correct applied load. Once this is done, it is not necessary and it is overly conservative to also reduce the capacities determined from actual tests by the elastic modulus for a given load.

The change in thermal stress occurs when the temperature of the pipe changes. This change in temperature and resulting thermal stress will occur in a very short time frame (less than one hour). Therefore, change in load and resulting cyclic secondary stress is a short term duration load. If a short term duration load occurs in conjunction with a long term duration load, the short term load will experience the short term elastic modulus, rather than the reduced modulus of the long term load.

This effect was verified by the aging tests that were conducted in EPRI Report 1013479. In these tests, tensile specimens were aged for 72 hours with a constant pre-stress of 2000 psi (25,000 microstrain) and at a temperature of 160°F. The resulting specimens were subjected to short term tensile testing and showed no marked change in the short term tensile capacities or elastic modulus.

Therefore, the cyclic change in thermal stress will occur at the short term modulus and should be compared to cyclic test data based on a comparable short term modulus.

The main concern with elastic modulus is the determination of the appropriate value to be used in the structural analysis of the piping system. The analysis is used to determine the loads and stresses in the piping system. Depending on the type of load and analysis method, the use of an inappropriate elastic modulus can under-predict or over-predict the loads on the piping systems.

Therefore, by selecting the appropriate elastic modulus for use in the structural analysis to determine the forces, loads, and displacements (strains), the resulting cyclic thermal stresses can be directly correlated to the test data and no adjustments for elastic modulus creep efforts need to be made in the fatigue capacity data.

Duke Response (b)(ii):

For the buried HDPE, the seismic stresses are displacement induced and as such are secondary stresses and the main concern is fatigue failure similar to that expected from cyclic thermal stresses. The modulus of elasticity for HDPE decreases with time at load as discussed in Section 3.3 of EPRI Report 1013549. This phenomenon is similar to high temperature creep in steel piping. The major source of this creep behavior in HDPE is pressure, which is a primary non-self limiting load in HDPE piping systems. However, this effect is only experienced by the long duration load that is the originator of the creep effect. If a short term duration load occurs in conjunction with a long term duration load, the short term load will experience the short elastic modulus, rather than the reduced modulus of the long term load.

This effect was verified by the aging tests that were conducted in EPRI Report 1013479. In these tests, tensile specimens were aged for 72 hours with a constant pre-stress of 2000 psi (25,000 microstrain) and at a temperature of 160°F. The resulting specimens were subjected to short term tensile testing and showed no marked change in the short term tensile capacities or elastic modulus.

Therefore, since the seismic loads are short term events, the seismic stress should be developed using a short term elastic modulus and compared to the fatigue capacities developed in the EPRI Progress Report.

The Interim EPRI Progress Report 1014902 provides the results of extensive fatigue tests of 4 inch butt fusion joints at 140°F and 160°F. This data is available for review by contacting EPRI. The testing is based on material certified as PE 3408/3608 which will have properties that are essentially the same as or less than those of PE 4710. Therefore, the data is conservative relative to the Code Case.

It should be noted that for a design basis of 7000 or fewer cycles, the test results of the EPRI report envelop the 1100 psi cyclic stress range in the Code Case with a margin of at least 2 for all temperatures reported. The design basis number of cycles for the Catawba service water supply is a maximum of 7000 cycles.

Duke Response (c):

For elevated temperature service the allowable compressive stress in the sidewall is to be reduced to the allowable stress at temperature. The commentary developed for 3032 for *Code Case N-755 Design Commentary and Example,* May 23, 2006 addressed this issue as follows:

The sidewall stress equation is from the PPI Handbook (and is also explained in the following publications: (a) Buried

Pipe Design by A.P. Moser, (b) American Lifelines Alliance Design Guide for Buried Steel Pipe, (c) WRC Bulletin 425 A Review of Methods for the Analysis of Buried Pressure Pipe). The allowable stress is also from the PPI Handbook, for compressive stress in HDPE 3408. For elevated temperature service the allowable stress is to be reduced using the same reduction factors as for HDS, down to 0.5 x 1000 psi = 500 psi at 140°F.

$$\sigma_{sw} = \frac{(480+500)\times 11}{2\times 144} = 37 \le 1000\,\text{psi} \rightarrow \text{OK}$$

Duke Response (d):

The inter-modal and inter-spatial combination by SRSS is consistent with the methodology put forth in Regulatory Guide 1.92 Revision 1, February 1976, and Non-Mandatory Appendix N (Section N-1223.1) of Section III of the ASME Boiler and Pressure Vessel Code, and NUREG-1061, Volume 3 and 4.

There are two spectral groups considered in the Multiple Input Response Spectra analysis. The first group is for the above ground steel piping and the second group is for the buried steel and HDPE piping. The buried pipe responds to seismic ground waves upon their arrival at the site and this is a displacement response similar to seismic anchor motion. The above ground response is a building filtered in-structure response to ground wave input at the building basement. This above piping response is an inertial response. There will be a time delay between the above ground and the building filtered response. Considering these factors the combination of inter-group responses by SRSS is based on the recommendations of WRC Bulletin 352 and NUREG-1061, Volume 4. The SRSS of inter-group responses was accepted by the USNRC for use in the Advanced Boiling Water Reactor (NUREG-1503, Section 3.9.2 and 3.12.3.3).

Enclosures to this RAI Response

1. August 21, 2006 ISCo Industries Letter
2. Finite Element Analysis for Evaluation of 10% Joint Offset/Mismatch
3. EPRI Planned Testing Schedule for 2007
4. Qualifications of RAI Respondents
5. Revised Pages for Request for Relief 06-CN-003

Enclosure 1

August 21, 2006 ISCo Industries Letter

ISCO INDUSTRIES

3435 Stanwood Blvd
Huntsville, Alabama 35811
1 800 345 4726 ext 6720

August 21, 2006

Steve Lefler
Duke Energy
Nuclear Power
526 S Church
Charlotte, NC 28202
Mail code ec07c

Reference: Tracing the Roots of PE 4710 to PE 3408

Dear Steve:

As we discussed, there are strong connections between PE 3808 and PE 4710. The best method to compare these HDPE resin types is to use ASTM D 3350-02 and the current version D 3350-05.

Duke Power has used Performance Pipe and Phillips Driscopipe as their primary supplier. The Driscopipe 1000 became Drisplex 4100 when Chevron merged its Plexco HDPE pipe operation with Phillips Driscopipe. The cell classification for the HDPE pipe supplied by both Plexco and Phillips was PE 345464C. See attachment, "Performance Pipe Data Sheet".

Typical Physical Properties of PE 3408 with a cell classification of 345464C

PROPERTY		SPECIFICATION	UNIT	NOMINAL VALUE
Material Designation		PPI / ASTM		PE3408
Cell Classification		ASTM D 3350-02		345464C
Density	(3)	ASTM D 1505	g/cm3	0.941 to .955*
Melt Index	(4)	ASTM D 1238	gm/ 10 min	0.05 to .15*
Flexural Modulus	(5)	ASTM D 790	psi	110,000 to 160,000
Tensile Strength	(4)	ASTM D 638	psi	3,200 to 3,500
Slow Crack Growth				
ESCR	(4)	ASTM D 1693	hours in 100% igepal	>5,000
PENT	(6)	ASTM F 1473	hours	>100
HDB @ 73 deg F	(4)	ASTM D 1693	psi	1,600
UV Stabilizer	(C)	ASTM D 1603	%C	2.5%

* This is the base resin density range. The addition of carbon black increases density. Typical black pipe densities range from .955 to .96.

- It is easier to extrude thick wall pipe will a low melt index. Resins with different (lower) melt indexes are used to make larger pipes with thicker walls.

The table above provides topical physical properties for high density polyethylene resin with a cell classification as noted. This resin also is designated as a PE 3408 material. The letters "PE" designates the material as being polyethylene. The first number designates the density cell class of the material. The second number designates the slow crack growth cell class of the material as per ASTM D 1693.

A high density polyethylene material –**PE**- with a density of 0.941 to .955 g/cc is a cell class 3, and an ESCR, condition C, of greater than 600 hours – cell class 4, is a grade **PE34.**

The Plastic Pipe Institute has augmented the grade designation form ASTM D 3350 to include the Hydrostatic Design Stress (HDS) by adding two digits to the material's grade. The Hydrostatic Design Stress is the maximum long-term stress that material can be subjected to after applying the maximum design factor. For resins made prior to 2006, the design factor was 0.5 to establish the Hydrostatic Design Basis (HDB). For the new bimodal PE4710 resins, the design factor is 0.63 because of the superior toughness and higher slow crack growth resistance. By truncating the standard HDS in hundreds, the PPI has adopted the use of **04** for 400 psi HDS, **06** for 630 psi HDS, **08** for 800 psi HDS and **10** for 1000 psi HDS.

In summary, the pipe supplied to you first as Driscopipe 1000 and later as Drisplex 4100 was also classified PE 3408. The physical properties to be PE 3408 are;

Density in the range .941 to .955	3
Slow crack growth of 600 hours minimum	4
Hydrostatic design Stress of 800 psi	08

Please note that the cell classification is based on a different slow crack growth test. The PE 3408 is based on ESCR testing. The cell classification is based on the PENT test.

By 2002, virtually all HDPE resins never failed the ESCR test. The letters stand for Environmental Stress Crack Test. This test was conducted by exposing tensile bars with scratch or cut to a strong detergent at 80 C. Since most samples never failed, it was time for another test!

The PENT test is conducted at 80 C as well. A molded sample or a section of pipe is notched to 20% of its thickness. The sample is then placed in tension and time is measured to failure. The six (6) designation indicates that the sample failed in 100 hours or more.

In December 2005, ASTM approved changes to ASTM D 3350-05. The physical properties of various cell classifications changed. See attachments "D 3350-02 Table with cells" and "D 3350-05 cell table". There are three changes that are important:

Density- For cell classification "3" the standard range of density was from .941 to .955 g/cm. The new range for "3" is .940 to .947.

For resins with a density of .947 to .955 the cell classification is "4".

Slow Crack Growth- The Cell classifications for **ESCR** test have not changed. A cell classification of 1-4 provides a measure of ESCR resistance.

For the **PENT** test, the following are used:

"4" indicates 10 hours to fail
"5" indicates 30 hours to fail
"6" indicates 100 hours to fail- under 3350-02, this would be "4"
"7" indicates 500 hours or more to fail

Hydrostatic Strength – The designation "4" still indicates a hydrostatic design basis of 1600 psi. Both ASTM D 3350 -02 and D 3350 -05 provide for Minimum Required Strength based on ISO 12162. A rating of five (5) indicates MRS of 1160 psi and a rating of six (6) indicates 1450 psi. An MRS rating of 1450 psi is approximately equal to 1,000 psi HDB using the ASTM methods with a service factor of 0.63.

The key change in the Hydrostatic Strength is allowing a service factor of 0.63 rather than a service factor of 0.5 used in the past.

The cell classification of PE 345464C has the same physical properties under both ASTM D 3350-02 and ASTM D 3350-05. The PPI/ASTM designation does change. Because of the increased number of cells related to slow crack growth, a resin that was designated as PE 3408 is now a PE 3608. In ASTM D 3350-02, a PENT rating of 100 hours was designated with "4". Under ASTM D 3350-05, it is designated with "6", What are the physical properties of PE 445574C?

Typical Physical Properties of PE 4710 with a cell classification of 445574C

PROPERTY		SPECIFICATION	UNIT	NOMINAL VALUE
Material Designation		PPI / ASTM		PE4710
Cell Classification		ASTM D 3350-05		445574C
Density	(4)	ASTM D 1505	g/cm3	0.947-.955
Melt Index	(4)	ASTM D 1238	gm/ 10 min	<.15
Flexural Modulus	(5)	ASTM D 790	psi	110,000 to 160,000
Tensile Strength	(5)	ASTM D 638	psi	3,500 to 4,000
Slow Crack Growth				
ESCR		ASTM D 1693	hours in 100% igepal	no failure
PENT	(7)	ASTM F 1473	hours	>500 hours
HDB @ 73 deg F	(4)	ASTM D 1693	psi	1,600
MRS		ISO 12162	psi	1450
UV Stabilizer	(C)	ASTM D 1603	%C	2.5%

The yellow highlighted values indicate the density, PENT test and hydrostatic design ratings. The service factor of 0.63 is understood for PE 4710 materials.

How do the physical properties of a PE 3408 resin and a PE 4710 resin compare?

To answer this question, the physical properties of a DOW Chemical resin have been used. Below are the physical properties of DOW DGDA-2490 NT high density polyethylene resin. Printed 2001. This resin was called a PE 3408 in 2001 and is now a PE 4710 resin.

PROPERTY		SPECIFICATION	UNIT	NOMINAL VALUE
Material Designation		PPI / ASTM		PE3408
Cell Classification		ASTM D 3350-02		346566C
Density	(3)	ASTM D 1505	g/cm3	0.949
Melt Index	(4)	ASTM D 1238	gm/ 10 min	0.08
Flexural Modulus	(6)	ASTM D 790	psi	170,000
Tensile Strength	(5)	ASTM D 638	psi	3,600
Slow Crack Growth				
ESCR		ASTM D 1693	hours in 100% igepal	>5,000
PENT	(6)	ASTM F 1473	hours	6,000
HDB @ 73 deg F		ASTM D 1693	psi	1,600
MRS	(6)	ISO 12162	psi	1,450
UV Stabilizer	(C)	ASTM D 1603	%C	2.5%

The attachment,"DGDA-2490 TDS 305-02866" shows the physical properties published by DOW. The product was listed in PPI's TR-4 as a PE 3408 resin. The cell classification shown on the Data sheet shows a Cell Classification of PE 346566. A cell classification of PE 346564 is also correct. This product was sold as both a PE 3408 and an ISO PE 100.

In June 2006, a new data sheet was created for the current resin. The resin is now called CONTINUUM DGDA – 2490 NT (See attachment.)

PROPERTY		SPECIFICATION	UNIT	NOMINAL VALUE
Material Designation		PPI / ASTM		PE4710
Cell Classification		ASTM D 3350-05		445574C
Density	(4)	ASTM D 1505	g/cm3	0.949
Melt Index	(4)	ASTM D 1238	gm/ 10 min	0.08
Flexural Modulus	(5)	ASTM D 790	psi	150,000
Tensile Strength	(5)	ASTM D 638	psi	3,600
Slow Crack Growth				
ESCR		ASTM D 1693	hours in 100% igepal	>5,000
PENT	(7)	ASTM F 1473	hours	10.000
HDB @ 73 deg F	(4)	ASTM D 1693	psi	1,600
UV Stabilizer	(C)	ASTM D 1603	%C	2.5%

When we compare the DOW resin DGDA-2490 NT, a product rated as a PE 3408 in June 2001 to Drisplex 4100 and the current resin, CONTINUUM DGDA-2490 NT rate as PE 4710, we find the following:

	DOW	Drisplex 4100	CONTINUUM
	PE 3408	PE3408	PE 4710
Density is the same	.949	.941	.949
Melt Index is the same	.08	.10	.08
Flexural Modulus is lower	170,000	110,000	150,000
Tensile is the same	3,600	3,200	3,600
ESCR	equal	equal	equal
PENT is higher	6,000	100	10,000
HDB same	1,600	1,600	1,600
UV Stabilizer	same	same	same
Service factor	0.5	0.5	0.63

1. The data shows that the DOW resins have a higher density. The higher density normally provides a higher tensile and higher flexural modulus. Both products do have higher properties than the Drisplex 4100.
2. The melt index of all three resins is close. This means that all be easily fuse together. The same extrusion equipment can be used to make HDPE pipe with all three resins.
3. The PENT test is a measure of slow crack growth. Both DOW resins offer much greater resistance to slow crack growth.
4. The basic molecules of carbon and hydrogen are the same. The HDB has not changed.
5. The UV stabilizer is still the same.
6. Since the PE 4710 resins are stronger and less prone to slow crack growth failures, less safety factor is needed. A service factor of 0.63 can be used.

It is my opinion that the above comparison shows that a designation of PE 3408 and a designation of PE 4710 do not indicate a great difference. The above comparison shows that the physical properties of a resin once rated as PE 3408 can now be called a PE 4710. A big part of the number difference is the changes in ASTM D 3350-05. The new PE4710 resins provide greater resistance to slow crack growth which increases the safety factor. Since the plan is to continue to use a service factor of 0.5 with PE 4710 pipe, the safety factors are increased even more.

Steve, call me if you have any questions.

Sincerely,

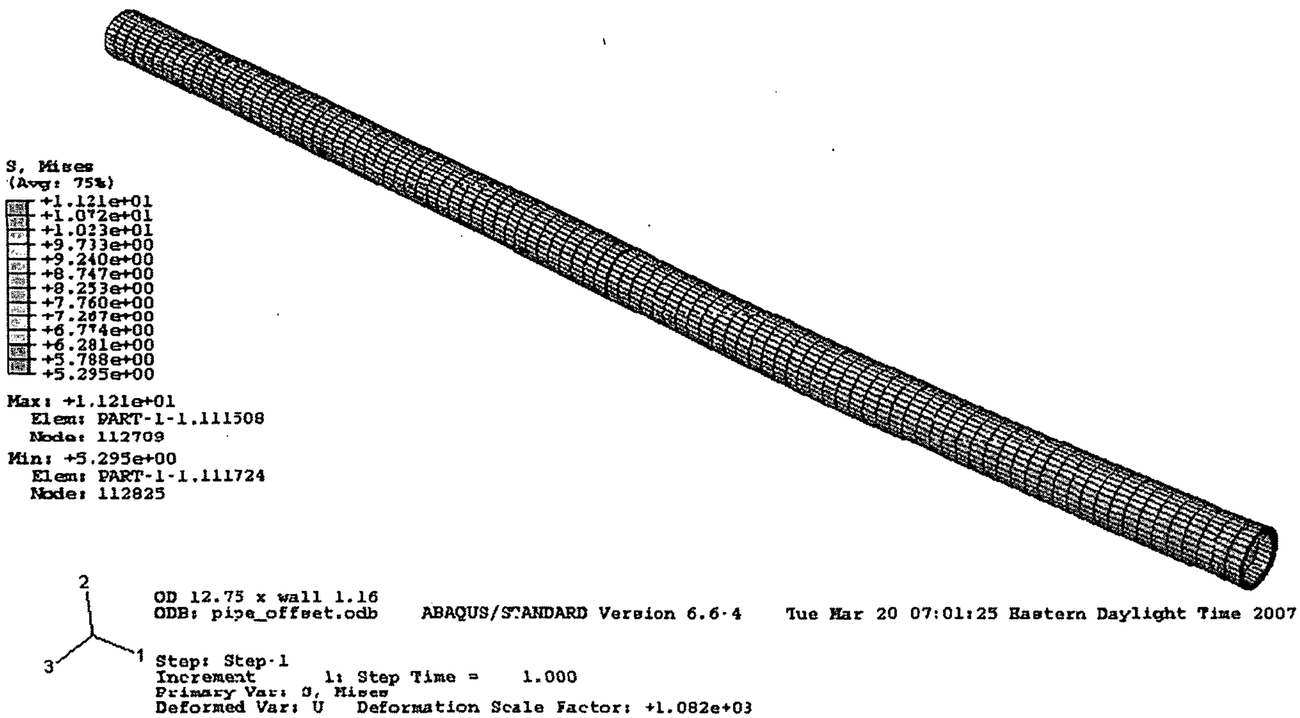
Dudley Burwell

Dudley Burwell
Vice President

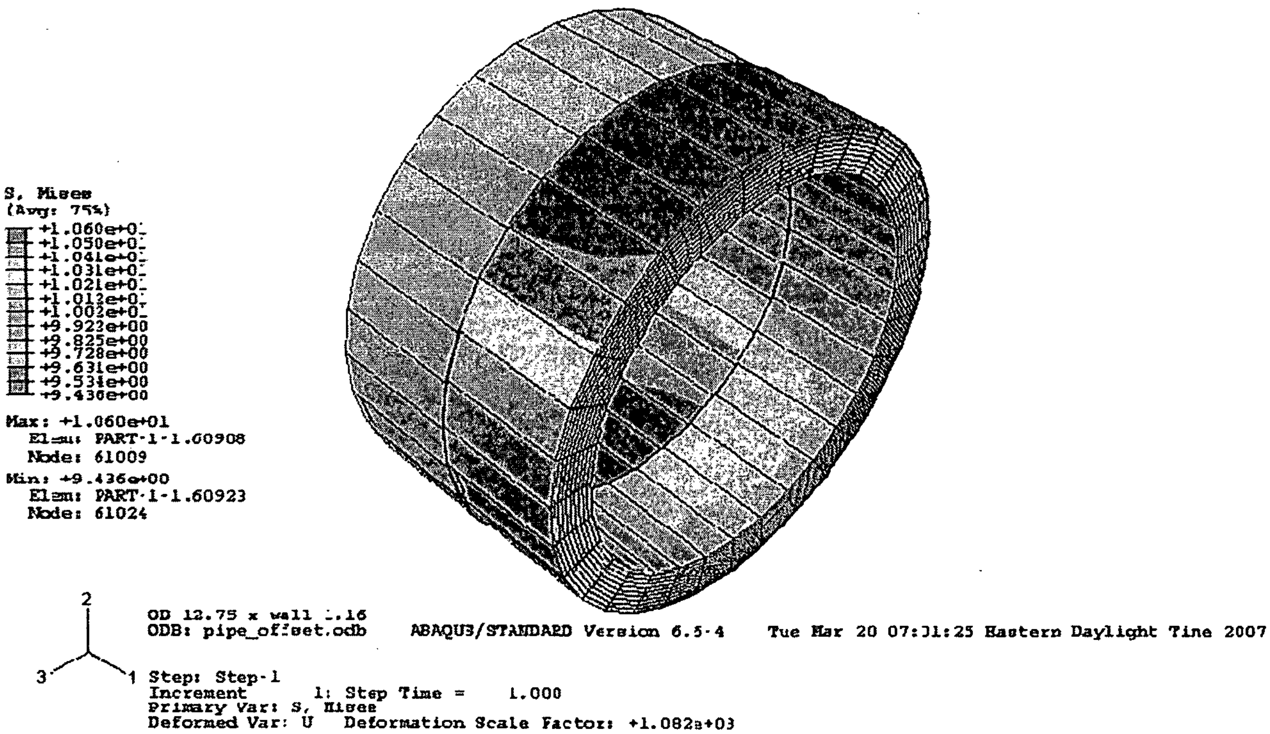
Enclosure 2

Finite Element Analysis for Evaluation of 10% Joint Offset/Mismatch

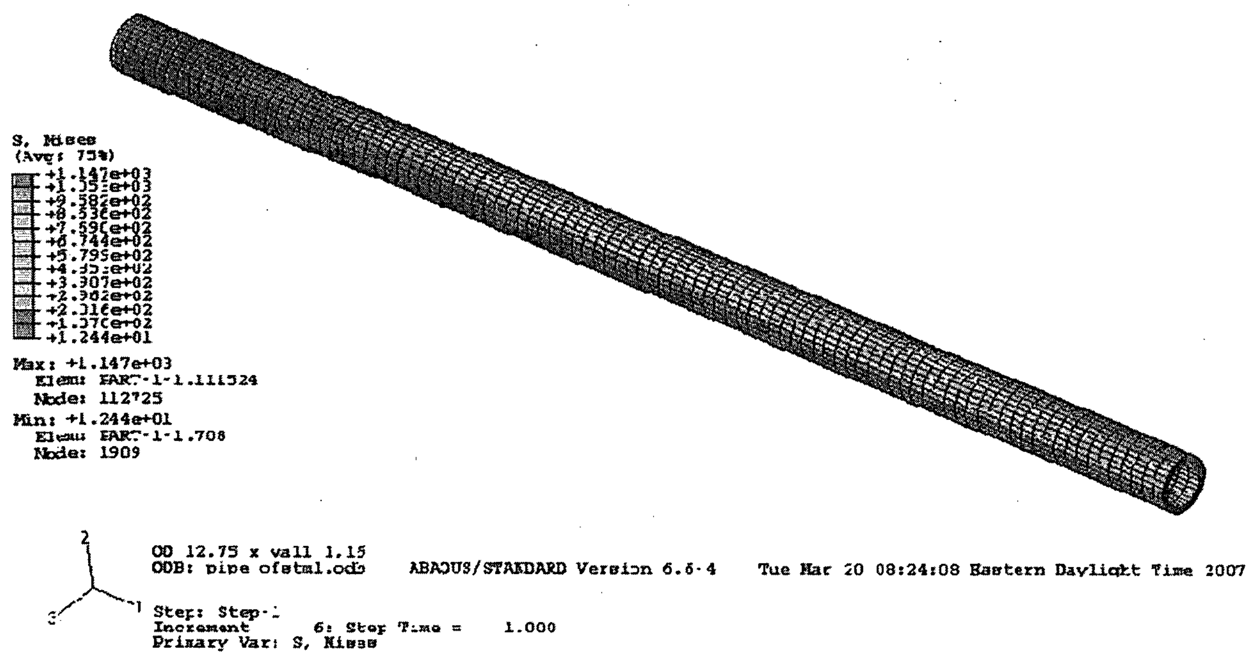
OD 12.75" x wall 1.16" E = 110 ksi, Nu = 0.4, Sy = 1300 psi
Length = 2 x 144" = 24 ft, Joint Offset 0.1" radial at mid section
10 Elements through wall
Tension = 10 psi at one end, other end fixed



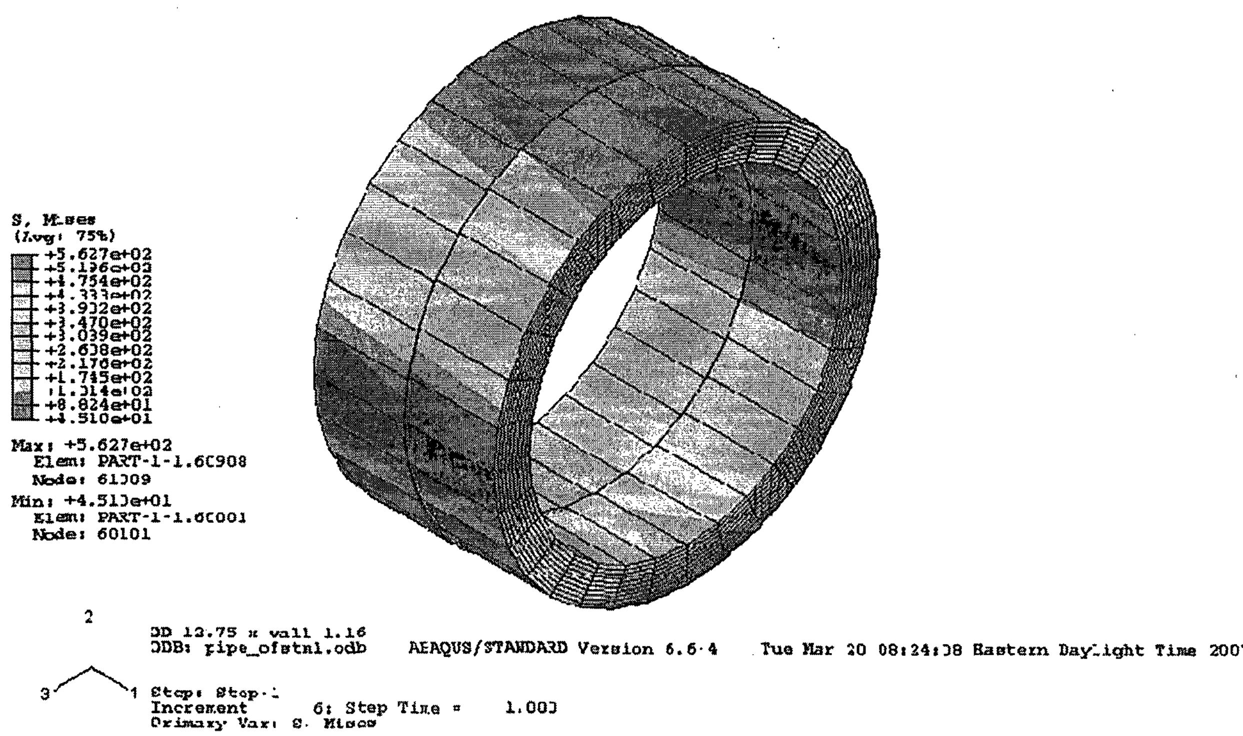
OD 12.75" x wall 1.16" E = 110 ksi, Nu = 0.4, Sy = 1300 psi
Length = 2 x 144" = 24 ft, Joint Offset 0.1" radial at mid section
10 Elements through wall
Tension = 10 psi at one end, other end fixed
Stresses at Offset region



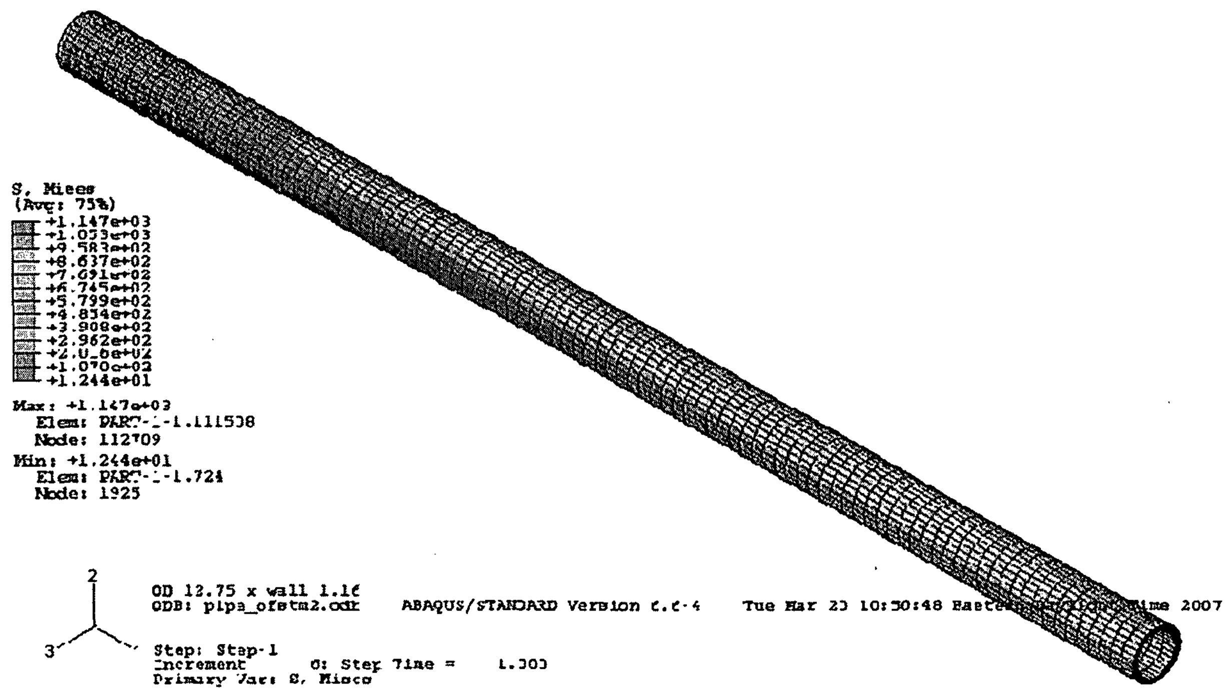
OD 12.75" x wall 1.16" E = 110 ksi, Nu = 0.4, Sy = 1300 psi
Length = 2 x 144" = 24 ft, Joint Offset 0.1" radial at mid section
10 Elements through wall
Bending 10 psi lateral at one end (Force in -2 direction), other end fixed



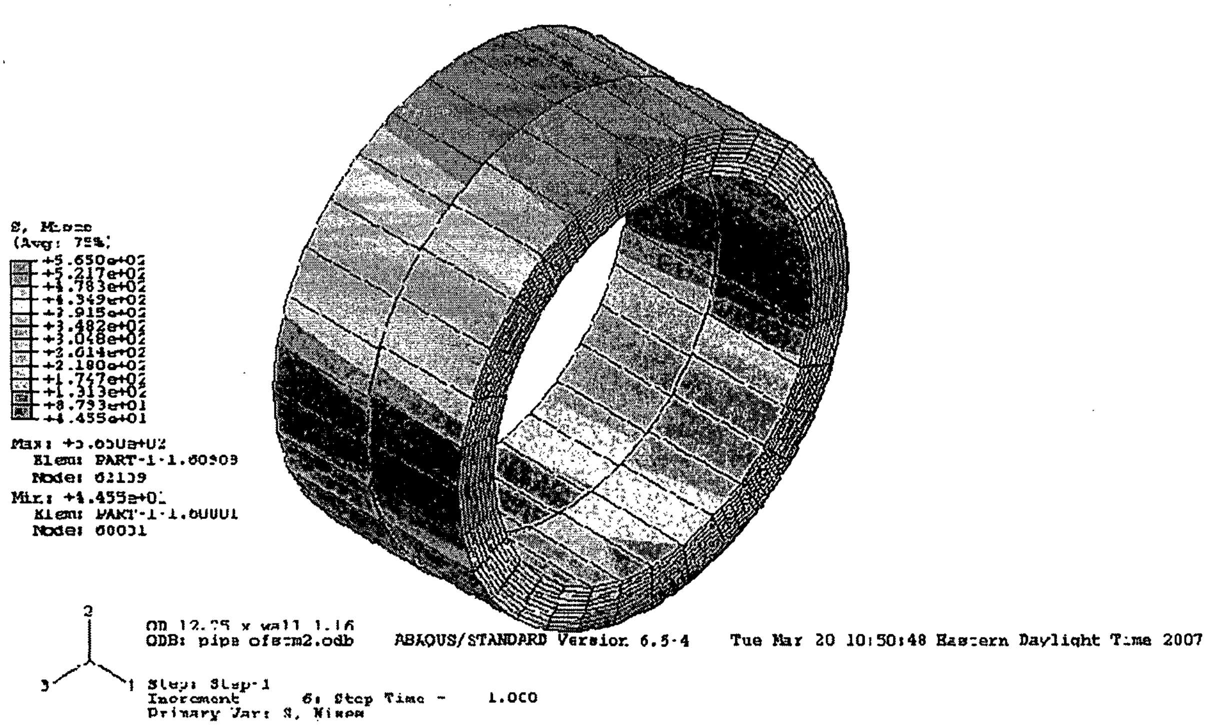
Stresses at Offset Region



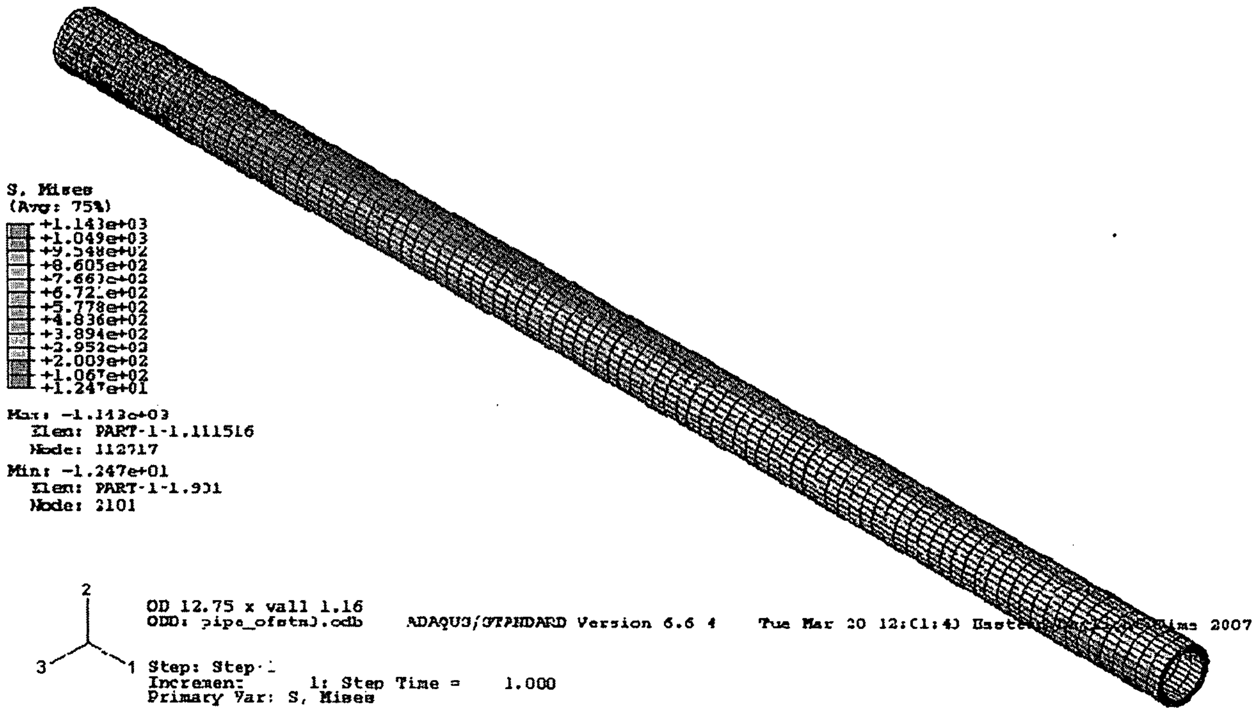
OD 12.75" x wall 1.16" E = 110 ksi, Nu = 0.4, Sy = 1300 psi
Length = 2 x 144" = 24 ft, Joint Offset 0.1" radial at mid section
10 Elements through wall
Bending 10 psi lateral at one end (force in +2 direction), other end fixed



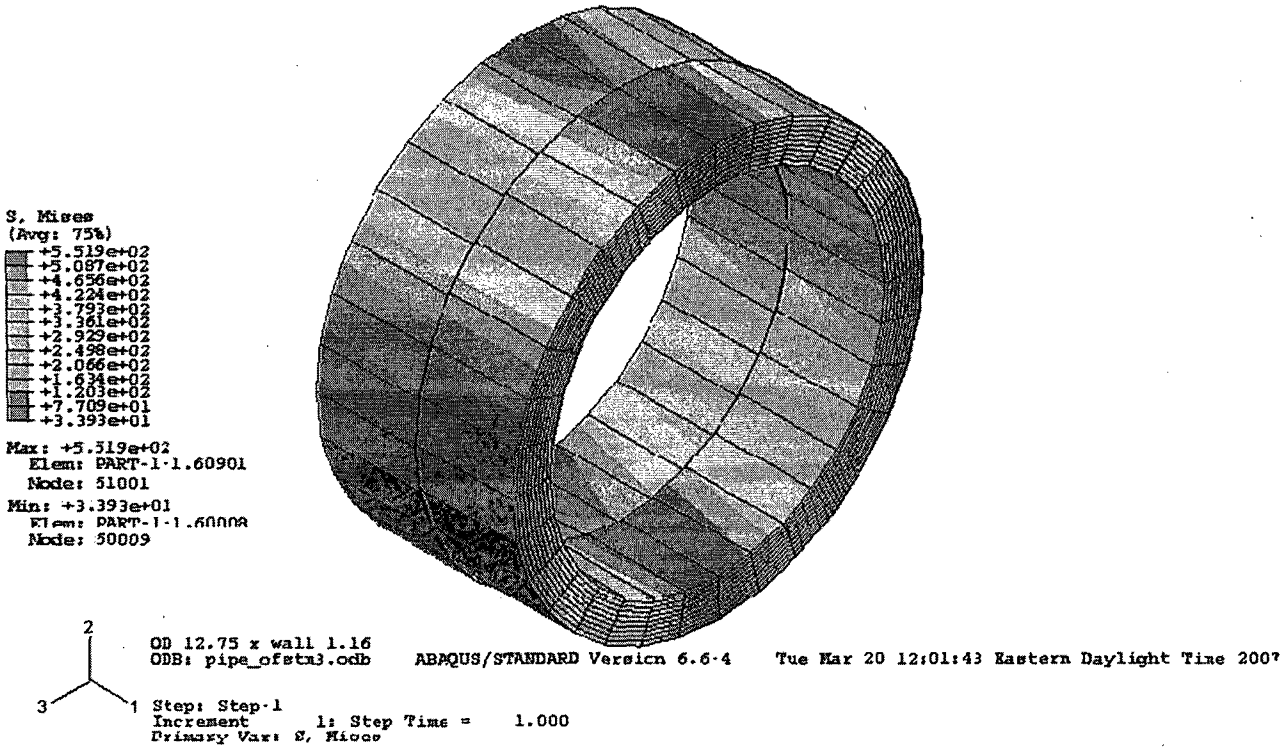
Stresses at Offset Region



OD 12.75" x wall 1.16" E = 110 ksi, Nu = 0.4, Sy = 1300 psi
Length = 2 x 144" = 24 ft, Joint Offset 0.1" radial at mid section
10 Elements through wall
Bending 10 psi lateral at one end (force in +3 direction), other end fixed



Stresses at Offset Region


S, Mises
(Avg: 75%)
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+5.087e+02
+4.656e+02
+4.224e+02
+3.793e+02
+3.361e+02
+2.929e+02
+2.498e+02
+2.066e+02
+1.634e+02
+1.203e+02
+7.709e+01
+3.393e+01
Max: +5.519e+02
Elem: PART-1-1.60901
Node: 51001
Min: +3.393e+01
Node: 50009
2
3
1
OD 12.75 x wall 1.16
ODB: pipe_ofstm3.odb
ABAQUS/STANDARD Version 6.6-4
Tue Mar 20 12:01:43 Eastern Daylight Time 2007
Step: Step-1
Increment 1: Step Time = 1.000

Enclosure 3

EPRI Planned Testing Schedule for 2007

Summary of EPRI January 2007 HDPE Testing Proposals

Task Currently Approved for 07 Funding

Task 1: Slow Crack Growth associated with Code allowable of 10% scratch depth (4710)
(Fund only if PPI task force unable to resolve issue)

- Proposed method using PENT tensile test per ASTM F1473 to meet schedule and cost considerations

Task 3: Full range of stress-strain properties for 4710

- Test at 40F, 70F, 140F, and 160F, axial and hoop directions, new and thermally aged materials, with 5 replicas (80 tests)

Task 4: Fatique curves of 4710

- Test 4" pipe with butt fusion weld per ASME
- Test at 40F, 70F, 140F, and 160F, 5 displacement amplitudes, with 4 replicas (80 tests)

Task 5: SIFs and FF for 5-mitered bend using 4710

- Use 4" pipe at 70F
- Test in-plane and out-of-plane directions, 3 displacement amplitudes, with 4 replicas (24 tests)

Task moved from 07 to 08 Plan to allow for Slow Crack Growth Testing

Task 2: Long Term Creep Rupture Tests for 4710

- Industry has only limited data for 4710 at high temperature (>100F)
- Use 4" pressurized specimens, follow ASTM D2837-04
- Measure time to failure at minimum of 18 pressure-time points/temperature
- Test at 104F, 140F, and 160F (72 tests)
- Should provide sufficient data to complete allowable stress table in CC N-755 (values for >20 years and > 120F are listed as in development)
- May well provide data to justify higher stress allowables and use at temperatures >140F

Proposed 2008 Activities

Task1: Develop SIFs and FFs for other commonly used fittings
(Includes electro-fusion coupling testing)

Enclosure 4

Qualifications of RAI Respondents

Persons from which Assistance is Requested to Answer RAI's for CN Relief Request for Use of Polyethylene Piping

NRC Branch	RAI No.	Brief description of RAI Topic	Primary Responder	Secondary Responder (s)
EMCB	01	Identify HDPE material to be used	Steve Lefler	
	02 a	Address 10% scratch depth and additional testing	Steve Lefler	
	b	Address defects in fused joint and SCG	Steve Lefler	
	03	Qualification of flanged joints	Tim Adams	
	04 a	Basis for allowable seismic strain limits & basis for 30 pipe D bend	Tim Adams	George Antaki
	b	Basis for allowable limits for ring deflection	George Antaki	D Burwell, Adams
	c	Clarify nomenclature	Tim Adams	
	d	Analyze joint offset using a finer mesh	George Antaki	
	e	Provide basis for Poisson's ratio	Tim Adams	Larry Petroff
	05 a	t min defined twice	Ernie McElroy	
	b	Units not listed for temperature	Tim Adams	
	c	EPRI Report	Tim Adams	
	d	Appendix A question for load case 31	Tim Adams	
	e	Appendix C , (page 19), P_t and F not defined	Tim Adams	
	f	Appendix C, (page 23) What is 18/t in column 1?	Tim Adams	
	g	EPRI Report	Tim Adams	
	h	EPRI Report	Tim Adams	
	06 a	SIF factor for fusion joint	Tim Adams	
	b i	Allowable alternating stress amplitude, consideration for E at temp.	Tim Adams	George Antaki
	b ii	Consideration of E correction for thermal approach	Tim Adams	George Antaki
	c	How is 1000 psi allowable stress established in section 3032	George Antaki	
	d	Combination method for load cases	Tim Adams	
Piping/NDE	1.	Discuss hydrotest value for validating integrity of fused joints	Frank Schaaf	Antaki, Adams
	2.	Discuss interfaces/responsibilities for examination & data log review	Ernie McElroy	Frank Schaaf
	3.	Address VT exam of inside surfaces	Frank Schaaf	
		Discuss supplementing VT exam with alternate methods	Jack Spanner	
	4.	Discuss process to establish min. examiner skills	Ernie McElroy	F.Schaaf/J.Spanner
	5.	Discuss probability of flaws and failure mechanisms in joint flaws	Jim Craig	S. Lefler
	6.	Provide volumetric flaw acceptance criteria for PE pipe	Frank Schaaf	Jack Spanner

Catawba RAI Responses

Statement of Qualifications of Respondent

Person: Larry Petroff
Company: Performance Pipe
Title: Technical Service Specialist
Qualifications (Experience, industry committee involvement, educational background, etc. as applicable to RAI responses) I am a civil engineer and have worked with plastic pipe since 1970. I have been employed by Performance Pipe for almost 27 years. I am a member of ASTM, AWWA, and ASCE as well as past chairman for the PPI M&I division. I have written a number of technical papers on polyethylene pipe and am actively involved in the codes and standards writing process. I graduated from the University of Arkansas at Little Rock and hold masters degrees from the University of Arkansas in Engineering and from Georgia Tech (geotechnical).
Specific RAI Reference if desired: Poisson Ratio
Signature / Date Larry Petroff Larry Petroff, April 27, 2007

Catawba RAI Responses
Statement of Qualifications of Respondent

Jack Spanner
Electric Power Research Institute
Program Manager, NDE Technology Transfer
Qualifications: Jack Spanner is a Program Manager in the NDE program area of the Nuclear Sector. His current research activities focus on inspection and codification of polyethylene piping installation requirements, development of reactor vessel head penetration nozzle nondestructive examination qualification, thin film phased array search units, eddy current examination of lead sheathed distribution cable, ASME code activities, reactor vessel internals inspection for license renewal, and film-less radiography. Mr. Spanner joined EPRI in 1993 as a Manager, Advanced NDE Technology. Provide project management for nuclear related NDE contracted project work. Projects have been related to digital radiography, guided wave UT inspection, laser generated UT, neural networks, solid state RT, Risk Informed Inspection, phosphor plate RT, semi-automatic scanners, NDE modeling, computer based training, synthetic environment training, NDE Workforce Study, and Performance Demonstration Initiative. He has participated in ASME code activities for more than twenty years and is a member of ASME SC XI. He is chairman of Sub-Group-NDE and is the Principal Level III for EPRI. Before joining EPRI, Mr. Spanner worked at Pacific Gas and Electric company for thirteen years. He progressed from NDE engineer to the Senior NDE Engineer and managed the company's NDE group which consisted of six management personnel and twelve technicians. Also designated the Corporate Level III for Radiographic, Visual, Ultrasonic, Eddy Current, Liquid Penetrant, and Magnetic Particle NDE methods. The group was responsible for developing and qualifying NDE procedures, and providing examination services of power plant components. Provided training, personnel certification, consulting, NDE related RD&D, and represented company interests on ASME Code and EPRI committees. While at PG&E helped initiate and represented the Company at the Performance Demonstration Initiative Steering Committee and was elected chairman from August 1991 until December 1992. Mr. Spanner received a M.S. in Welding Engineering from Ohio State University, Columbus, OH in 1979 and a B.S. in Physical Metallurgy from Washington State University, Pullman, WA in 1974. He also completed 9 hours of graduate credit in welding engineering at Rensselaer Polytechnic Institute, Troy, NY and 3 hours of credit in Fracture Mechanics at Union College, Schenectady, NY while serving as a Lieutenant in the Army at Watervliet Aresenal in New York.
Specific RAI Reference if desired
Signature / Date; Jack Spanner / **May 4, 2007**

George Antaki, PE
Antaki
5.2.07
133 River Birch Road
Aiken, SC 29803
Tel. 803-649-5510
Fax 803-648-2528
antaki@aol.com

1989-2007

- Manager, Equipment Analysis and Testing, Structural Mechanics, Savannah River Site, Aiken, SC.
- Manage a group of engineers responsible for structural analysis and equipment qualification, including stress analysis, seismic qualification, finite element analysis, heat transfer and steady state and transient fluid flow analysis.
- Operations, maintenance and construction support, including vessel and relief valve inspection and fitness-for-service (run-or-repair) programs.
- Chairman of Site Piping & Valves Technical Committee, responsible for materials, design, construction and maintenance of site-wide metallic and non-metallic piping systems, utility and process piping systems, in accordance with ASME B31, AWWA codes and standards.
- Structural failure and accident analysis, safety analysis, field investigations of abnormal conditions: vibration, waterhammer, over-pressure, impulsive and impact loads, instability and failure, of systems, equipment and components.
- Responsible for implementation of the ASME code for pressure vessels and piping systems, including materials, design, fabrication and welding, non-destructive examination, and pressure and leak testing.
- Responsible for the development and implementation of Risk-Based Inspection (RBI) program for steam and non-steam process systems and pressure vessels, including risk-ranking, inspection planning (ultrasonic, radiography, pulsed eddy current, digital radiography, remote visual), inspections, analysis of results, run-or-repair decisions (API 579, ASME XI, NBIC, etc.).
- Chairman, Site Pressure Equipment Protection Committee, responsible for vessel and system pressure integrity, vessel and relief valve inspection program site-wide, including valve shop, test and inspection trending, and optimization of inspection program; technical, schedule, and budgetary coordination and implementation among approximately 15 operating facilities.
- Selection and sizing of pressure relief devices, thermo-hydraulic analysis.

1975-1989

- Westinghouse, Water Reactors Division (Brussels, 1975-1978, Pittsburgh, PA, 1978-1989).
- Design and stress analysis of nuclear power plant reactor internals, ASME III, manufacturing follow, and plant installation. Power plant pipe design and qualification, as-built, hot functional testing, utility support technical services, equipment qualification.

Committee Memberships:

- Fellow, American Society of Mechanical Engineers
- Member, ASME Post-Construction Executive Committee
- Member, ASME Subcommittee on Repair and Testing
- Member, ASME III Qualification of Mechanical Equipment (QME)
- Member, PVRC Subcommittee Dynamic Analysis
- Vice-Chair, ASME B31 Mechanical Design Technical Committee
- Co-chair of Joint ASME-ASCE Task Group on Design of Buried Steel Pipe, published by American Lifelines Alliance, www.americanlifelinesalliance.org.
- Vice-Chair Joint API-ASME Task Group Fitness-for-Service (API 579)
- Past-member (1991-2005) ASME III Working Group Piping Design
- Past-Chair Joint ASME-IEEE Committee on application of SQUG in ASME and IEEE
- Author, Draft Standard ASME B31E Seismic Design and Qualification of Piping Systems, under ballot within ASME B31

Textbooks
- Piping & Pipeline Engineering, textbook, published by Dekker.
- Fitness-for-Service and Integrity of Piping, Vessels and Tanks, McGraw-Hill

Publications
- WRC Bulletin 425, A Review of Methods for the Analysis of Buried Pressure Piping, September, 1997.
- WRC Bulletin 446, Design and Repair of Buried Pipe, November, 1999.
- Brookhaven National Laboratory, Seismic Design and Evaluation Guidelines for the Department of Energy High-Level Waste Storage Tanks and Appurtenances, October, 1995, co-author of Chapter 7, Underground Piping and Conduits, and author of Appendix I, Example Seismic Analysis of an Underground Double-Containment Piping System. Support of Los Alamos National Laboratory staff in review of contractor design and qualification of seismically qualified Safety Class HDPE underground fire water loop, including material and construction specifications.
- Other publications and ASME PVP papers on design and integrity of mechanical equipment and piping, risk-based inspections.
- American Lifelines Alliance (ALA) reports on (a) seismic qualification of piping systems, (b) buried steel pipe, (c) seismic qualification of active mechanical equipment.

Instructor:
- ASME Course PD-077 Failure and Failure Prevention of Vessels, Boilers and Rotating Equipment.
- ASME Course PD-394 Seismic Design and Retrofit of Equipment and Piping.
- ASME Course PD-398 Operation, Maintenance and Repair of Piping Systems.
- International courses on ASME B31 for piping and pipelines, API 579-580-581 risk-based inspections and fitness-for-service.

Consulting:

- American Lifelines Alliance, Guidelines for Seismic Design of Piping Systems.
- American Lifelines Alliance, Guidelines for Seismic Evaluation of Mechanical equipment (testing, analysis, earthquake experience).
- Seismic Design Criteria for Trans-Alaska Pipeline System (TAPS).
- Consult to Department of Energy and Operating Contractors in support of DOE complex-wide structural qualification and structural integrity issues, including Los Alamos National Laboratory project for the design and construction of a safety-class buried HDPE fire loop, Pantex facility for seismic retrofit, Hanford for seismic qualification, Los Alamos National Laboratory for stress analysis and qualification of impulsively loaded vessels.
- EPRI, bibliography research and design equations for the integrity analysis of buried polyethylene pipe.

Education:

- 1975, Engineering, State University of Liege, Belgium.
- 1985, Masters, Mechanical Engineering, Carnegie-Mellon University

STERLING

REFRIGERATION CORP
648 HOLT ROAD
WEBSTER, NY 14580
585.872.0809

April 25, 2007

Mr. Steve Lefler, Jr
Principal Engineer
Duke Power
526 South Church Street
Charlotte, NC 28202

Subject: Expert Qualifications for Catawba Nuclear Station Relief Request for PE pipe, NRC "Request for Additional Information" (RAI)

Dear Steve:

The requested certificate is enclosed and supporting personal resume attached.

Catawba RAI Responses
Statement of Qualifications of Respondent

Person: Frank J. Schaaf, Jr
Company: Sterling Refrigeration Corp
Title: Consultant
Qualifications (Experience, industry committee involvement, educational background, etc. as applicable to RAI responses) Basic Background see attached resume. For specific PE experience: Served as the Project Manager for the development and one of the principal authors of ASME, Code Case N-755, **Use of Polyethylene (PE) Plastic Pipe for Section III, Division 1, Construction and Section XI Repair/Replacement Activities.**
Specific RAI Reference if desired: NDE 1, 2, 3, 4, 6
Signature / Date: *Frank J Schaaf, Jr* (Electronic) 24 April 2007

If there are questions please call me.

Sincerely,

Frank J Schaaf, Jr (Electronic)

Frank J. Schaaf, Jr
Sterling Refrigeration Corp
Consultant

Attachment; Schaaf resume

EXPERIENCE

2003 to **Sterling Refrigeration Corporation**

Upon retirement, setup company for nuclear consulting with the focus on ASME, Boiler and Pressure Vessel Code work, Transmission and Inspection Maintenance (TIMS) support, and mechanical root cause analysis.

1989 to 2002 **Rochester Gas and Electric**

Materials Laboratory Engineer

Performs mechanical testing of materials for composition and root cause analysis for failures. Wrote laboratory operations Quality Assurance manual to support nuclear assignments, also wrote the ASME Section IX welding program used in both nuclear and fossil fuel stations. Specialize in mechanical failures in both mechanical and electric components.

Served as the Project Manager for the Electrical Structure Inspection Program (ESIP). This includes the supervision of two inspection teams, selection, implementation, and maintenance of the Transmission Inspection and Maintenance System (TIMS).

Senior Staff Engineer

Provide consulting to different nuclear departments within the company. Also served as the Technical Coordinator for the Safety Review and Audit Board, with the responsibility of making it more effective.

Developed Ginna's Third Interval pressure testing program. This included writing five ASME Code Cases to support the program and industry.

Director, Technical Assessment of Nine Mile II

Provided reviews of the technical issues involved with the operation of Nine Mile Point II. After three months the department was dissolved and replaced with a co-owner company.

1986 to 1989 **Nebraska Public Power District**

Project Engineer

Nuclear Overview Group - Group was formed by the Vice-President Nuclear, it consisted of a past Division Manager of Nuclear Operations and myself. The group reported to the Vice-President Nuclear. The group charter was review of the overall operation of the Nuclear Division and to make recommendations for improvements to the Vice-President.

Served on the Safety Review and Audit Board (SRAB), which oversees/reviews all nuclear safety issues. The Board reported to the Vice-President Nuclear.

Served on the following committees:

BWR Owners' Group
SCRAM Frequency Reduction - Vice-Chairman for Maintenance
BWR Systems Improvement - Chairman

BWR Owners' Group (EPRI for Intergranular Stress Cracking Corrosion (IGSCC)
Technical Advisory Committee (TAC) - Member

Catawba RAI Responses
Statement of Qualifications of Respondent

Person: Dudley Burwell
Company: ISCO Industries LLC
Title: Vice President Corporate Quality
Qualifications Education: BS in Chemistry & MBA University of Alabama Work experience: DuPont- Engineered Plastics 1969 to 1974 NIPAK- Regional Sales Manager for HDPE Pipe 1974 to 1979 Fluid Controls, Inc. President & Owner HDPE Pipe distributor 1979 to 1999 ISCO Industries LLC; Technical Director 1999 to 2006; VP of Corp Quality 2006 to present Technical Associations: Director of the International Association of Plastic Distributors 1995 to 2002 Plastic Pipe Institute 2002 to present ASTM 2001 to present ASME Special Working Group on Polyethylene Pipe Patent: HDPE dual containment piping system
Specific RAI Reference if desired
Signature / Date Dudley Burwell 4/24/2007

Statement of Qualifications of Respondent

Person: Timothy M. Adams	
Company: Stevenson and Associates, Suite 200, 9217 Midwest Ave., Cleveland, Ohio, 44125	
Title: Chief Mechanical Engineer; General Manager, Cleveland Office; Senior Partner	

Qualifications:

EDUCATION:
MS Mechanical Engineering, University of Pittsburgh, 1985
BS Mechanical Engineering, Summa Cum Laude, University of Pittsburgh, 1977

EXPERIENCE:
Mr. Adams is the Corporate Chief Mechanical Engineer and the General Manager of the Stevenson and Associates Cleveland Office. He has over 29 years experience in the design of Pressure Retaining Components to Section III and Section VIII of the ASME Boiler and Pressure Vessel Code and the B31 series Codes. In addition, to his general management responsibilities, Mr. Adams is responsible for: project management; and provision of technical consulting and design work in the areas of design/analysis of piping systems; pressure vessels/tanks; mechanical equipment; structures; and application of Industry Consensus Codes and Standards for the electric power generation; petrochemical; and, process industries and DOE nuclear waste processing facilities. Mr. Adams is an expert in the application of experience based and traditional qualification techniques to the seismic evaluation of piping systems (above ground, buried, etc.) valves, component equipment and supports.

PUBLICATIONS:
Authored and co-authored over 40 technical publications in the Mechanical Engineering field.

PROFESSIONAL ACTIVITIES:
Member, American Society of Mechanical Engineers (ASME); Member, American Welding Society (AWS); Member, American Society for Non-Destructive Testing (ASNT); Member, ASME BPVC III, Div. 1, Subgroup on Design; Member, ASME BPVC III, Div. 1, Working Group on Piping Design; Member, ASME BPVC III, Div.1, Working Group on Design Methods; Member, ASME BPVC III, Div.1, Working Group on Probabilistic Methods; Member, ASME BPVC III, Div.3, Working Group on Containment Design; Member, ASME BPVC Project Team on Seismic Issues and Member ASME BPVC Section III, Division 1, Special Working Group on Polyethylene Pipe; Member, ASME Main Committee on the Qualification of Mechanical Equipment in Nuclear Power Plants (ASME-QME); Member, ASME QME Subcommittee on General Requirements (QME-SCGR); Chairman, ASME QME Subgroup on Dynamic Qualification (QME-SDQ); Member Joint ASME/ASCE Special Task Group Buried Piping Design; ASME Alternate Representative to Building Seismic Safety Council (BSSC)

Jim Craig, P.E.
Industry Relations Manager
McElroy Manufacturing, Inc.

I am the Industry Relations Manager for McElroy Manufacturing, Inc. in Tulsa, OK and was formerly the National Sales Manager and Director of Research and Development at McElroy. I have been involved in the design of plastic pipe fusion equipment, training for those products and the development of industry standards for PE heat fusion for the last 34 years.

I received my Bachelor of Science degree in 1968, am a registered Mechanical Engineer in the state of Oklahoma and also a Certified Fluid Power Engineer. I am the Chairman of the ASTM F17.20 Joining Sub-Committee, past Chairman of the PPI Municipal and Industrial Division and am a past Chairman of the Mid-Continent Section of the American Society of Mechanical Engineers.

I was the chairman of the task groups that developed the PPI Generic Butt Fusion Procedure for Polyethylene Pipe TR-33 and the PPI Generic Saddle Fusion Procedure for Polyethylene Pipe TR-41. I have since developed an ASTM document F2620 that incorporates these PPI procedures in ASTM.

I have recently developed two documents at PPI that address questions by the water industry about how to repair HDPE (TN-35) and how to connect HDPE pipe to existing water systems (TN-36). I have been involved with the development of our fusion training program at McElroy and have done fusion training for contractors, engineers, pipe manufacturers, and other end users for the last 20 years.

Jim Craig, P.E.

Enclosure 5

Revised Pages for Request for Relief 06-CN-003

Revised Relief Request Pages

RAI	Paragraph or Table	Page
02 (EMCB)	Paragraph 2920	9
05a (EMCB)	Table 3021.1	12
05b (EMCB)	Table A-2	A-6
05b (EMCB)	Table A-3	A-6
05b (EMCB)	Table A-4	A-7
05e (EMCB)	Table 3113-1	C-19
05f (EMCB)	Table 3654-1	C-23

-2920 Repair of Material

Scratches within the following limits are acceptable:

- Piping ≤ 4 inch NPS with an SDR ≥ 11 will have a scratch depth allowance of no more than 10 percent of the nominal wall thickness.
- Piping ≤ 4 inch NPS with an SDR < 11 will have a scratch depth allowance of the smaller of either 10 percent of the nominal wall thickness or 0.041 inches.
- Piping > 4 inch NPS will have a scratch depth allowance of the smaller of either 10 percent of the nominal wall thickness or 0.041 inches.

Scratches in excess of the acceptable limits and other damage will be resolved by:

a) Cutting out and replacing the damaged section of pipe or
b) Removing damage by blending and then verifying that the remaining material thickness meets all design requirements. Surface defects shall be removed by grinding or machining in accordance with the following requirements:
    1) The depression after defect elimination is blended uniformly into the surrounding surface with a maximum taper not to exceed 3:1 (ratio of width to height).
    2) After defect elimination, the area will be examined by visual examination to ensure that the defect has been removed.
    3) If the elimination of the defect reduces the thickness of the section below the minimum required design thickness, the section of piping containing the defect shall be cut out and replaced.
c) Any piping section with any damage exceeding 10% of the nominal wall thickness shall be cut out and replaced.

(g) Seismic wave passage and, permanent seismic soil movement and building anchor motions, for seismic design in accordance with paragraph 3050.

(h) Ground movement caused by thermal expansion and contraction in accordance with paragraph 3042.

-3021 Pressure Design of Pipe

-3021.1 Minimum Required Wall Thickness. The minimum required wall thickness of straight sections of pipe for pressure design shall be determined by

$$t_{design} = t_{min} + c$$

t_{design} = minimum required wall thickness, in
c = the sum of mechanical allowances and erosion allowance, in

$$t_{min} = P\, D / (2S + P)$$

t_{min} = pressure design thickness, in
P = Piping system internal Design Pressure (gage) at the specified Design Temperature, both being specified in the Piping Design Specification. This pressure does not include the consideration of pressure surge, psi
D = pipe outside diameter, in
S = Design Stress, psi, per Table 3021-1

Table 3021-1 Design Stress S for PE (psi)

Temperature (°F)	Load Duration (years) 50 yrs
≤70	800
100	620
120	520
140	400

-3021.2 Allowable Service Level Surge Pressures. The sum of the maximum anticipated operating pressure plus the maximum anticipated Level B pressure surge shall be no greater than 1.5 times the piping system Design Pressure (see paragraph 3021.1). The sum of the maximum anticipated operating pressure plus the maximum anticipated Level C and D pressure surge shall be no greater than 2 times the piping system Design Pressure (see paragraph 3021.1).

-3022 Pressure Design of Joints and Fittings

-3022.1 Polyethylene pipe shall be joined using the butt fusion process. All connections to metallic piping shall be flanged joints.

The following properties, E and α, were taken from a previous version of ASME BPVC, and allowable stresses for the carbon steel were taken from the ASME BPVC, Section II, Part D (1989 Edition).

Table A-2
A-106 Carbon Steel Properties – All Load Cases

Temp	38 °F	80 °F	89 °F	100 °F	
α	5.99E-6	6.09E-6	6.12E-6	6.14E-6	in/in/° F
E	28	27.9	27.9	27.8	ksi
S_m	20,000	20,000	20,000	20,000	psi
S_y	35,000	35,000	35,000	35,000	psi
S	17100	17100	17100	17100	17100
ΔT	-32	10	19	30	° F

The properties for the PE piping are taken from the values presented in section 3000 of the Relief Request. The values for the modulus E are found in Table 3031-3, Poisson's ratio in Section 3042.1, the allowable long term stresses in Table 3021-1, and the allowable short term stresses in Table 3035-3. The coefficient of thermal expansion, α_t, that is used is typical for polyethylene piping and is 9×10^{-5} in/in/^{0}F. It is noted that the PE properties vary with the load case, as the load duration varies from short term to 50 years. A load duration of 50 years is used for deadweight and thermal stress analyses and short term duration for OBE, SSE and the equivalent thermal strain analysis.

Table A-3
PE Properties - 50 Year Load Duration - Load Cases 10, 21, 22, 23

Temperature	38 °F	70 °F	89 °F	100 °F	
α	90 E-6	90 E-6	90 E-6	90 E-6	in/in/° F
E	39	28	25	23	ksi
S	960	800	670	600	psi
v	0.45	0.45	0.45	0.45	in/in
ΔT	-32	0	19	30	° F

Table A-4
PE Properties - Short Term Load Duration – Load cases 24, 31, 32

Temperature	70 °F	80 °F	
A	90 E-6	90 E-6	in/in/° F
E	115	107	ksi
S(1)	1200	1110	psi
v	0.35	0.35	in/in
ΔT	0	10	°F

(1) The short term allowable stresses are taken from the Draft proposed ASME code case N-755, Table 3035-3

A2.2 Transition from Steel to PE Pipe

There is a transition from 10" steel pipe to 12" PE pipe at the 42" header and from PE back to steel pipe before the pipe enters the diesel building. The carbon steel piping is cut and a reducer is butt welded to the pipe to change the nominal diameter from 10" to 12". Then a 12" 150-lb ANSI B16.5 steel weld neck flange is installed. On the PE side, a flange adapter is fused to the PE pipe. A special back-up ring is slipped over the PE flange adapter. This back-up ring has the same bolt pattern as the 150 lb ANSI B16.5 steel flange.

The carbon steel components of this transition are modeled using the Laddish catalog standard dimensions. The PE pipe is modeled based on the dimensions given in manufacturer's catalogs, in this case Independent Pipe Products. The pipe properties were changed at the transition to PE and again at the transition back to carbon steel.

A2.3 Modeling of PE Elbows

The piping routing includes 45°, 90° and 30° PE elbows. These elbows are modeled as mitered bends. The 90° mitered bend has 5 segments, the 45° mitered bend 3 segments and the 30 ° miter bend is modeled as two segments of a 45° mitered bend. The 45° and 30° mitered bends are assumed to consist of 2 or 3 equal segments. The 90° mitered bend is modeled according to the manufacturer's catalog specifications.

The following sketch shows how the miter bend angles for the 90° mitered bend are determined:

Table 3111-1: Elastic Moduli for Pipe Fabricated from PE 3408

Load Duration	*Elastic Modulus†, 1000 psi (MPa), at Temperature, °F (°C)*							
	-20 (-29)	*0 (-18)*	*40 (4)*	*60 (16)*	*73 (23)*	*100 (38)*	*120 (49)*	*140 (60)*
Short-Term	**300.0 (2069)**	**260.0 (1793)**	**170.0 (1172)**	**130.0 (896)**	**110.0 (758)**	**100.0 (690)**	**65.0 (448)**	**50.0 (345)**
10 h	**140.8 (971)**	**122.0 (841)**	**79.8 (550)**	**61.0 (421)**	**57.5 (396)**	**46.9 (323)**	**30.5 (210)**	**23.5 (162)**
100 h	**125.4 (865)**	**108.7 (749)**	**71.0 (490)**	**54.3 (374)**	**51.2 (353)**	**41.8 (288)**	**27.2 (188)**	**20.9 (144)**
1000 h	**107.0 (738)**	**92.8 (640)**	**60.7 (419)**	**46.4 (320)**	**43.7 (301)**	**35.7 (246)**	**23.2 (160)**	**17.8 (123)**
1 y	**93.0 (641)**	**80.6 (556)**	**52.7 (363)**	**40.3 (278)**	**38.0 (262)**	**31.0 (214)**	**20.2 (139)**	**15.5 (107)**
10 y	**77.4 (534)**	**67.1 (463)**	**43.9 (303)**	**33.5 (231)**	**31.6 (218)**	**25.8 (178)**	**16.8 (116)**	**12.9 (89)**
50 y	**69.1 (476)**	**59.9 (413)**	**39.1 (270)**	**29.9 (206)**	**28.2 (194)**	**23.0 (159)**	**15.0 (103)**	**11.5 (79)**

† Typical values based on ASTM D 638 testing of molded plaque material specimens.

Table 3113-1 – Suggested Load Combinations and Assigned Service Levels

	Primary	Cyclic Secondary	Non-cyclic Secondary
Design	**P + W′**		
Level A	**P + W′ + P_t**	T_L+F_LH	S_L
Level B	**P + W′ + P_t**	T_L + *OBE-W+OBE-W_{nb}*	None
Level C	**P + W′ + P_t + F_L**	T_L (extreme up to 140° F)	None
Level D	None	T_L (faulted > 140° F) *SSE-W + SSE-D*	None

17. Table 3654-1: B_1 and B_2 for Miter Bends			
18. D/t	Nom OD	B1 PE	B2 PE
7	10.75	0.69	1.38
7	12.75	0.69	1.38
7	14.00	0.69	1.38
9	10.75	0.69	1.64
9	12.75	0.69	1.64
9	14.00	0.69	1.64
11	10.75	0.69	1.91
11	12.75	0.69	1.91
11	14.00	0.69	1.91
13.5	10.75	0.69	2.21
13.5	12.75	0.69	2.21
13.5	14.00	0.69	2.21

Table 3681-1: Reaction Modulus E' for Various Soils and Soil Conditions (lb/in^2)				
Soil Type	Dumped	Proctor < 85%	85%<Proctor<95%	Proctor > 95%
Very Fine Grain	50	200	400	1000
Fine Grain	100	400	1000	2000
Coarse Grain	200	1000	2000	3000

Table 3681-2: Constant A_t in Equation (3) & (4)	
Bedding Angle Degrees	A_t
0	0.294
15	0.234
30	0.189
45	0.157
60	0.138