Calvert Cliffs Nuclear Power Plant

1650 Calvert Cliffs Parkway
Lusby, Maryland 20657

CENG
a joint venture of
Constellation Energy
eDF

CALVERT CLIFFS
NUCLEAR POWER PLANT

January 17, 2013

U. S. Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: Document Control Desk

SUBJECT: Calvert Cliffs Nuclear Power Plant
Unit Nos. 1 & 2; Docket Nos. 50-317 & 50-518
Proposed Alternative for Mitigation of Buried Saltwater Piping Degradation (RR-ISI-04-08)

During future refueling outages Calvert Cliffs Nuclear Power Plant, LLC (Calvert Cliffs) will be conducting required inspections of our buried Saltwater System piping on both Calvert Cliffs Unit 1 and Unit 2. The buried Saltwater System piping for both units are American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section XI, Inservice Inspection Class 3 systems. In case any of these future inspections identify defects requiring repair it is prudent that Calvert Cliffs submit a proposed alternative repair (RR-ISI-04-08) for Nuclear Regulatory Commission approval. The proposed alternative repair request is contained in Attachment (1). Since much of the Saltwater System piping runs beneath our turbine building floor, replacement of the buried Saltwater System piping would be a hardship or unusual difficulty without a compensating increase in the level of quality and safety, therefore the proposed alternative repair is submitted for approval in accordance with 10 CFR 50.55a(a)(3)(ii). This proposed alternative would be applicable to the repairs of future defects identified in buried portions of our Saltwater System piping throughout the Fourth Ten Year Inservice Inspection Interval.

Calvert Cliffs requests that you complete approval of this alternative repair by August 30, 2013. However, Calvert Cliffs will conduct inspection of Unit 2 Saltwater System buried piping during its upcoming refueling outage that starts in February 2013. Should this inspection identify the need for this alternative repair, the Nuclear Regulatory Commission will be contacted for an expedited approval.

A047
NRR

Should you have questions regarding this matter, please contact Mr. Douglas E. Lauver at (410) 495-5219.

Very truly yours,

James J. Stanley
Manager – Engineering Services

JJS/KLG/bjd

Attachment: (1) Proposed Alternative for Mitigation of Buried Saltwater Piping Degradation (RR-ISI-04-08)
Enclosure: 1 Evaluation of Repair Sleeve Assemblies, Calculation 11-2357-C-003

cc: N. S. Morgan, NRC
W. M. Dean, NRC
Resident Inspector, NRC
S. Gray, DNR

ATTACHMENT (1)

PROPOSED ALTERNATIVE FOR MITIGATION OF BURIED SALTWATER PIPING DEGRADATION (RR-ISI-04-08)

Calvert Cliffs Nuclear Power Plant, LLC

January 17, 2013

10 CFR 50.55a Request ISI-04-08, Proposed Alternative In Accordance with 10 CFR 50.55a(a)(3)(ii)

1. ASME Code Component(s) Affected

30 and 36 inch Inservice Inspection (ISI) Class 3 Buried Saltwater System ductile cast iron piping for Calvert Cliffs Units 1 and 2.

2. Applicable Code Edition and Addenda

American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI, 2004 Edition, no Addenda. The original "Code of Construction" of the affected components is United States of America Standards (USAS) B31.1, 1967 Edition as supplemented by the requirements of American National Standards Institute (ANSI) A21.1-1967/American Water Works Association (AWWA) C101-67 and ANSI A21.50-1976 (AWWA C150-1976).

3. Applicable Code Requirement

American Society of Mechanical Engineers Code, Section XI, Subarticle IWA-4300. Allowable activities under IWA-4000 for Class 3 piping involve either weld repairs or replacement. Weld repair is not possible because this buried Saltwater System piping is ductile cast iron piping. Replacement of the buried piping is a hardship that poses unusual difficulty without a compensating increase in quality and safety over the proposed alternative repair. It is recognized that the proposed alternative repair would fall under the provisions of IWA-4340, whose use is prohibited by 10 CFR 50.55a(b)(2)(xxv). However, the proposed alternative repair is significantly more comprehensive than the provisions provided by IWA-4340.

4. Reason for Request

Calvert Cliffs routinely monitors and inspects Saltwater System components in accordance with the requirements of Generic Letter (GL) 89-13, Service Water Problems Affecting Safety Related Equipment. Calvert Cliffs is currently increasing the level of inspections of buried portions of the system consistent with Nuclear Energy Institute (NEI)-09-14, Guidelines for the Management of Underground Piping and Tanks. During the February 2013 refueling outage, Calvert Cliffs will inspect buried sections of Unit 2's 30 and 36 inch Saltwater System piping. The intent of these inspections is to supplement visual inspections that routinely occur from the inner diameter (ID) of the piping to determine if there are areas where internal or external degradation is occurring and have not been identified utilizing current inspection methodologies. Calvert Cliffs will utilize a technology known as Broadband Electromagnetic (BEM) examination to perform these inspections of the piping. This inspection technology will identify potential areas of deterioration that when found can be further identified by nondestructive examination (NDE) methods to provide a more definitive characterization of the flaw.

At this time Calvert Cliffs has no reason to suspect that any conditions exist that do not meet the minimum wall thickness as defined in the design basis calculations of record for the 30 and 36 inch buried Saltwater System piping. However, it is prudent that a method to repair defects in the piping be identified in advance of any inspections, in the event deteriorated conditions are identified.

It should be noted that much of the buried Saltwater System piping to be inspected runs under the 3 feet thick steel reinforced concrete base mat of the Turbine Building. The base mat supports numerous equipment and components that are located directly above the path of the buried piping. In addition there are no welded type repair technologies that can be applied to ductile cast iron piping that are allowed by the original codes of construction USAS B31.1-1967, ANSI A21.1-1967 (AWWA C101-67) and ANSI A21.50-1976 (AWWA C150-1976), or ASME Code Section XI repair rules. As such the only alternatives to eliminate a defect are via direct replacement of the affected component or a mechanical repair.

The reason for this proposed alternative repair is to allow the use of a mechanical repair system to restore pressure boundary integrity for degraded conditions found during inspections. The specific limitations of the repair systems will be governed by conditions identified and those limitations discussed in Section 7.0 below. In general the proposed mechanical repair system will be utilized only for localized degradation in the piping. The direct replacement of this piping to correct relatively minor localized conditions is considered overly burdensome and costly and does not result in a compensating increase in the system's overall level of quality and safety when compared to the proposed mechanical repair alternative.

5. Component Scope

The scope of the repair alternative is limited to the buried sections of the 30 and 36 inch Saltwater System ductile cast iron piping. As such, this proposed repair alternative is not applicable for use on any gray cast iron section of the Saltwater System piping.

6. Burden Caused by Compliance

There are no approved methods or new technologies that provide an adequate method to weld ductile cast iron piping without adversely affecting the integrity of the base metal. The ductile cast iron Saltwater System is a bell and spigot pipe with fittings that connect to compress the joint gasket. This consists of a loose flange or gland that is slid over the spigot section of the pipe prior to insertion into the bell. Once inserted into the joint, bolting is installed between the gland and the integrally cast flange on the bell section of piping. The bolting is then tightened to seat the "V" wedge type gasket and thus provide a leak tight joint. Figure 1 below provides the general configuration of an ANSI/AWWA A21.10/C110 style joint.

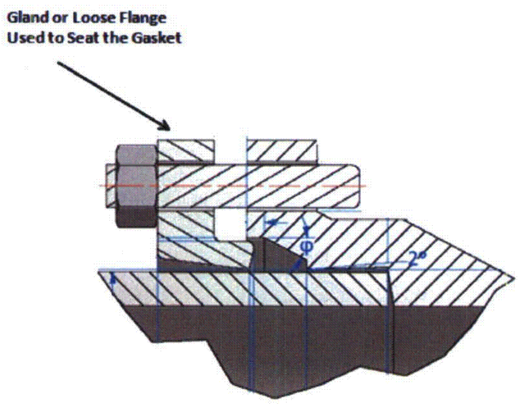


Figure 1

Repairs and modifications to ductile cast iron pipe must use similar methods of mechanical compression for connectivity. In some cases threaded joints may also be utilized.

The planned comprehensive inspection of the buried Saltwater System piping is being performed by Calvert Cliffs to assess and ensure the long-term integrity of the pipe. During previous internal inspections of the piping, areas of missing or deteriorated cement mortar liner have been identified and the mortar lining repaired. Areas where base metal deterioration has been noted have been minor and have not fallen below minimum wall thickness criteria. At this time Calvert Cliffs has no reason to believe that the integrity or reliability of the buried piping has been compromised. Nor are we aware of any specific areas that may be subject to accelerated degradation due to saltwater corrosion or areas of high stress concentration that could be prone to cracking or fracture. Regarding external corrosion of the pipe there is a protective coating on the piping outer diameter (OD) and this generally provides a barrier from external corrosion. The external condition of the buried piping is passive and is only exposed to low chloride level groundwater. Therefore, the potential for deterioration on the pipe OD is considered to be negligible. Operating experience of this piping under similar conditions at older power stations has demonstrated good performance over many years.

The examinations to be performed utilizing BEM technology will provide a qualitative assessment of the cross-sectional pipe wall. This exam will identify potential areas of degradation that when found can be further characterized by localized NDE methods. This intensity of examinations to be performed on the pipe is greater than that required during the original construction. There are no baseline comparisons available and original manufacturing defects may be identified that are inherent and acceptable to this type of piping material.

The construction cost, impact on outage duration, and operational challenges to replace a portion of the buried Saltwater System piping during an outage are substantial. The physical proximity of the Saltwater System piping and the constraints encumbered by interferences located in the Turbine Building make replacement very challenging. Furthermore, since the Saltwater System is the ultimate heat sink, and replacement would affect both trains of that system it will likely require a full reactor core offload, aligning the unaffected unit to provide cooling to the spent fuel pool and establishing abnormal plant configurations for an extended period of time. Industry experience has shown that the type of degradation usually found in saltwater piping (external or internal) is localized pitting.

Considering the hardship and unusual considerations of a replacement, the proposed repair alternative described and as limited by the constraints below will preserve the structural integrity of the buried Saltwater System piping to an acceptable level of quality and safety.

7. Proposed Alternative and Basis for Use

Description of Repair/Replacement

The repair/replacement alternative (Figure 2) is a sleeve assembly primarily consisting of a pressure retaining backing plate, an internal rubber gasket and four retaining bands.

The backing plate is made of AL6XN (UNS N08367), a single sheet of 16 gauge sheet metal 14" wide and designed to enclose the entire inside circumference of the 30" and 36" size pipe. It is placed directly over the degraded area on the inner diameter of the pipe to restore pressure boundary integrity.

The rubber gasket is made of Ethylene Propylene Diene Monomer (EPDM). It is factory vulcanized to form one continuous piece and designed to fit the piping inner surface. The gasket is 0.3" thick and about 20" long. The ends of the gasket have grooved ribs. It is placed over the backing plate completely enclosing the entire backing plate and extends beyond each end of the backing plate.

The retaining bands are also made of AL6XN (UNS N08367), 2" wide and 0.1875" thick and ring shaped. Two retaining bands are placed on each end of the gasket and two near the middle where the backing plate is located. To keep the backing plate and the gasket in place and held tightly against the pipe, the retaining bands are radially expanded by a hydraulic expander. The retaining bands are locked in place by wedges also made of AL6XN material. The two end retaining bands compress the groove ends of the gasket against the pipe inner circumference and provide a leak tight seal to prevent water intrusion past the gasket. The two middle retaining bands secure the backing plate in place.

The Saltwater System underground piping has 1/4" cement coating on the inside surface. Prior to installation of the sleeve, the cement coating of the degraded area and its surrounding area will be removed and repaired with an approved sealant. To prevent galvanic corrosion, the outer surface of the backing plate will be wraped with a 1/8" thick rubber gasket so that the stainless steel backing plate does not come in direct contact with ductile cast iron piping. Should water leak under the outer stainless steel retaining bands, it is possible, although unlikely, to have crevice corroison. Therefore, periodic inspections will be performed by disassemblying the sleeve assembly and checking for any detoriotion of the retaining bands, signs of leakage past the gasket, or any other degradation.

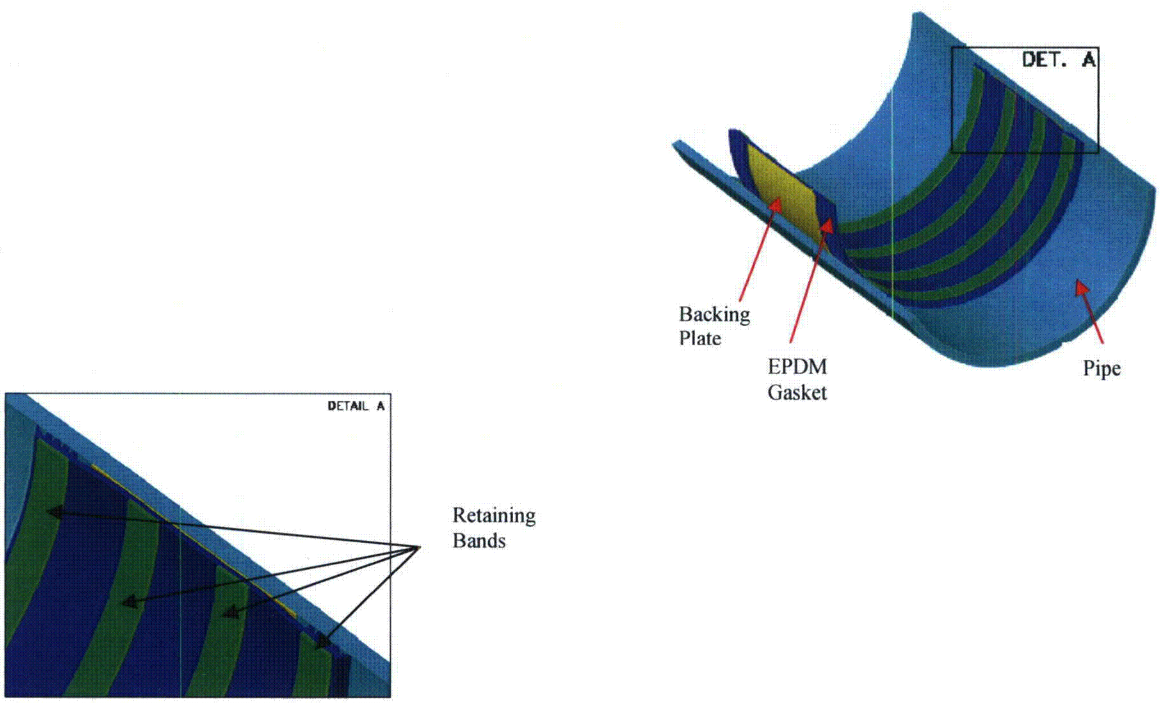


Figure 2

This repair system has been designed consistent with the requirements of the original codes of construction (ANSI B31.1, 1967 Edition). The design calculation (Enclosure 1) qualifies the repair sleeve assembly for the loads applied during installation and operation. The calculation addresses the following:

1) The repair sleeve assembly is capable of restoring pressure boundary of localized pipe wall thinning that can be contained within a 3" diameter area.
2) The friction force created by the retaining bands between the repair assembly and the pipe is significantly larger than the hydrodynamic force of the flowing fluid and seismic loads, and will prevent it from being dislodged.
3) The host pipe can withstand the pressure exerted by the retaining bands during installation, the system design pressure, and the pressure due to thermal expansion/contraction of the retaining bands.

The design calculation determines the following:

1) Contact pressure between the retaining bands, EPDM elastomer seal and the pipe
2) Hoop stresses in the host pipe due to retaining band loads
3) Compressive stress in the retaining band
4) Minimum wall thickness required by the host pipe based on resultant forces of retaining bands
5) Thermal effects on the forces in the retaining band
6) The minimum contact force between the seal assembly and the pipe wall
7) Hydrodynamic loads on the seal assembly for all design basis flow conditions to ensure it stays in place
8) Seismic loads on the sleeve assembly
9) Abnormal loading condition
10) Maximum allowable through wall hole size on the pipe
11) Thermal cycles for the retaining bands and the gasket.

Table 1 below provides a summary of the results from the design calculation.

Table 1

Calculation Results Summary Table for Ductile Iron Pipe

	30 inch Ductile Iron	36 inch Ductile Iron
Maximum compressive stress of yield stress at installation in retaining band	$\frac{\sigma_{c\_chk}}{S_y} = 46.5\cdot\%$	$\frac{\sigma_{c\_chk}}{S_y} = 46.5\cdot\%$
Required minimum wall thickness of the host pipe to support sleeve assemblies	$t_{DI\_30min} = 0.326\cdot in$	$t_{DI\_36min} = 0.348\cdot in$
Minimum friction force available between the sleeve and the pipe wall to resist seismic and hydrualic loads follows	$F_{fS\_DI30} = 9112\cdot lbf$	$F_{fS\_DI36} = 9192\cdot lbf$
Hydrodynamic load on the assembly with an impact of 2	$F_{HYD\_30} = 236\cdot lbf$	$F_{HYD\_36} = 139\cdot lbf$
Hydrodynamic load on the assembly with an impact of 2 at sleeve invert condition	$F_{HYD\_ab\_30} = 305\cdot lbf$	$F_{HYD\_ab\_36} = 186\cdot lbf$
Axial direction seismic acceleration required to dislodge sleeve assembly	$A_{S\_DI30} = 82.8\cdot g$	$A_{S\_DI36} = 83.6\cdot g$
Alternating stress due to thermal fatigue	$S_{ALT\_DI30} = 1941\cdot psi$	$S_{ALT\_DI36} = 1959\cdot psi$
Maximum flaw size at operating pressure	$d_{flaw} := 3.09in$	$d_{flaw} = 3.09\cdot in$

Results:

The calculation demonstrates this repair provides a mechanism to restore pressure boundary integrity by utilizing the reinforcing plate as the new pressure boundary for a locally degraded section of the piping.

This proposed repair system will be applied in cases where degradation has resulted in saltwater piping wall thickness falling below minimum design wall thickness values and is the result of corrosion initiated on the interior diameter of the saltwater piping. This proposed repair system will not be used in cases of discovered cracking or on corrosion that initiated on the external diameter of the saltwater piping. Should either of those cases be discovered, additional analysis would be performed and a separate proposed repair alternative would have to be submitted.

Reconciliation

The original code of construction for the subject piping to be repaired is USAS B31.1, 1967 Edition. However the guidelines provided by USAS B31.1 provide little guidance in the design of ductile cast iron piping. This code does allow ANSI/AWWA C115/A21.15 to be used as an alternative for ductile cast iron. The calculation of record for this piping utilizes design guidelines provided by the

Ductile Iron Pipe Research Association that is consistent with the requirements of ANSI/AWWA C115/A21.15.

As a basis for design, AWWA Manual M11 "Design of Steel Piping" was used in assessing pressure boundary integrity load conditions. This code is consistent with the calculation of record that qualified the piping for its design basis conditions. This design code is consistent with the original codes of construction utilized in the design of the system. USAS B31.10-1967, the overall code of construction, provides no direct guidance for the design of buried piping and in this case defaults to AWWA requirements by inference.

Key attributes of the proposed repair system include:

1) High Strength ASME SB-688 (AL6XN) material is utilized for all load carrying components.
2) ASME SB-688 is resistant to corrosion attack due to submersion in saltwater.
3) There is no welding required for installation.
4) There are no adverse affects to the systems hydraulic capacity.
5) Installation of the repair system will be performed with controlled procedures.
6) The repair system can easily be removed to allow inspection and monitoring of the deteriorated area.

The ASME Section XI, Appendix IX provides rules for the use of mechanical clamping devices and it is implied that these type mechanisms would be externally applied. However, the code does not consider modifications to non-steel piping systems currently in use in the nuclear fleet, for safety-related buried piping, such as Pre-Stressed Concrete Cylinder Pipe or ductile cast iron. The ductile cast iron piping utilized at Calvert Cliffs is currently not recognized by ASME Sections II, III, or XI and thus the owner must rely on guidance for repair and replacement activities from the original code of construction.

The style of the repair system to be used is similar to the compression style mechanical joints already in use in the piping system. The ASME Section XI addresses mechanical clamping devices. Mechanical clamps require that they be designed to resist the internal pressure by overcoming forces acting on the device. Components of a clamping device are subject to tensile forces as a result of pressure. The proposed repair system components are subject to more favorable compressive loads as internal pressures increases. The proposed repair system is not considered a clamp and is therefore not considered subject to the rules of ASME XI, Appendix IX.

The following provides a summary of the proposed repair systems:

1) The materials utilized in the repair system are non-corrosive when exposed to the saltwater in the Saltwater System.
2) The maximum size of the degraded area including projected growth will fit within a 3 inch diameter area.
3) No additional supports are required for the repair system. The component to be utilized relies only on the ductile cast iron piping for structural and pressure integrity.
4) The repair system has been designed for pressure boundary integrity only. The remaining non-degraded ductile cast iron pipe maintains full design structural capacity of the piping system.

5) The repair system utilized considers all design basis loading requirements including seismic and ensures that it will continue to perform its intended function during all those type of events.
   a) The repair system design was evaluated for a design pressure of 50 psig and was assessed to consider the effect of prying actions due to system maximum flow. All stress levels were less than the allowable for Level A Service Limits.
6) The repair system to be utilized is designed in such a manner so as not to damage or adversely affect the existing ductile cast iron piping.
7) The intended use of the repair system is to repair localized degraded areas in the piping and is not designed to transmit longitudinal loads or a full circumferential severance of the piping.
8) When degradation is identified in the ductile cast iron pipe it will be characterized to ascertain whether the degradation is ID or OD initiated and the characterization will be considered in the projected degradation growth.
9) The evaluations conducted for this repair were completed in accordance with the original code of construction for the buried ductile cast iron Saltwater System piping, USAS B31.1, 1967 Edition as supplemented by the requirements of ANSI A21.1-1967 (AWWA C101-67) and ANSI A21.50-1976 (AWWA C150-1976).
10) The repair system will be installed in a piping that is continuously supported and the additional weight does not increase bending in the ductile cast iron pipe.
11) Any degradation identified that is due to erosion or corrosion of the thickness of the material at the load transfer area will be determined and checked against design criteria.
12) The constraining effects of the repair system have also been considered and there are no adverse effects from the installation of the repair system on the ductile cast iron pipe.

The internal mechanical seal (i.e., EPDM Rubber & Retaining Bands), upon which this design is based on, has been utilized as a corrosion barrier in numerous Class 3 systems throughout the industry for many years. These seals have ensured that the host pipe, in the area where they are installed, are isolated from the effects of the process fluid corrosive effects.

The installation of this proposed alternative repair is considered to arrest the growth of the corrosion since it will completely seal the degraded area from the corrosive fluid (saltwater). Calvert Cliffs will disassemble the first installed repair system and inspect the degraded area after two operating cycles. This inspection will include:

- A check of the retaining bands and backing ring for corrosion
- A check of the liner under the sleeve for wetness
- A check for any damage of the liner

The results from this inspection will then be used to determine if any change in the periodicity of this action is warranted. In case of multiple installations, only one of the proposed repair systems will be disassembled while the rest will be visually inspected every other refueling outage during conduct of our current preventive maintenance task to inspect Saltwater System piping.

All degradation identified will be assessed on a case by case basis. Depending on the defect size the pressure plate may be altered to provide adequate strength to account for degradation outside of the design basis calculation. Appropriate changes will be made to the calculation to reconcile any changes to the pressure plate dimensions. Defects where the repair system is utilized will be characterized and projections on growth will be provided to ensure that the defect will be contained within the specified limits of the repair system. Subsequent inspections frequencies of the encapsulated degraded area will also be determined. Monitoring of the size of the degradation will be performed as required.

8. CONCLUSION

The installation of the proposed repair system provides a method to repair defects in buried Saltwater System piping that is not irreversible and allows the long-term monitoring of the degradation area. The pressure boundary capacity of the repair system has been demonstrated by analysis and corrosion resistant components have been utilized to eliminate the potential for degradation. As discussed in Section 7.0 the manner of repair and connectivity to the piping system is consistent with the methods utilized at pipe joints. The AL6XN material utilized in this repair ensures high resistance to saltwater corrosion and has been utilized in similar applications at other plants with no signs of deterioration. In addition this type of repair system has been demonstrated to function in service over ten years without issue.

Based on the above, Calvert Cliffs believes that the proposed repair system, when installed within the limitations of the design constraints, provides a reliable repair method that is consistent with the original code of construction. Also because the repair system can be easily removed and reinstalled it will allow for long-term monitoring of the defect condition as required and this capability addresses those concerns identified in 10 CFR 50.55a(b)(2)(xxv). These requirements are applicable to the repairs of future defects identified in buried portions of our 30 and 36 inch ISI Class 3, Saltwater System piping.

ENCLOSURE 1

Evaluation of Repair Sleeve Assemblies, Calculation 11-2357-C-003

Calvert Cliffs Nuclear Power Plant, LLC
January 17, 2013

Evaluation of Repair Sleeve Assemblies

Calculation No. 11-2357-C-003
Revision 4
Volume 1 of 1

Prepared for:

Constellation Energy
Calvert Cliffs Nuclear Power Plant

March, 2012

altran
SOLUTIONS

NEW YORK / PHILADELPHIA · BOSTON
ATLANTA · BALTIMORE · SAN FRANCISCO

altran

Report Record

Calculation No.: 11-2357-C-003 Rev. No.: 4 Sheet No. 2

QA Status: Quality Grade ☒, Commercial Grade ☐, Other ☐ Total Sheets: 52

Title: Evaluation of Repair Sleeve Assemblies

Client: Constellation Energy Facility: Calvert Cliffs Nuclear Power Plant

Revision Description: Complete revision to incorporate changes in response to owner's comments. Removed references to gray cast iron pipe, which is out of scope.

Computer runs are identified on a Computer File Index : Yes ☐ N/A ☒

Error reports are evaluated by: Date:

Computer use is affected by error notices. No ☐, Yes ☐ (if yes, attach explanation)

Originator(s)	Date	Verifier(s)	Date
Hui Lu, Ph. D.	3/9/2012	Al Chock	3/9/2012

Verification: Verification is performed in accordance with EOP 3.4 as indicated below

☒ Design review as documented on the following sheet or

☐ Alternate calculation as documented in attachment or

☐ Qualification testing as documented in attachment or

APPROVAL FOR RELEASE:

PROJECT MANAGER: Robert W. Hammelmann Date: 3/12/2012

Report Record

altran Calculation No.: 11-2357-C-003 Rev. No.: 0 Sheet No. 2A

QA Status: Quality Grade ☒, Commercial Grade ☐, Other ☐ Total Sheets: 44

Title: Evaluation of Repair Sleeve Assemblies

Client: Constellation Energy **Facility:** Calvert Cliffs Nuclear Power Plant

Revision Description: Original issue.

SUPERSEDED

Computer runs are identified on a Computer File Index Yes ☐ N/A ☒

Error reports are evaluated by: Date:

Computer use is affected by error notices. No ☐ Yes ☒ (If yes, attach explanation)

Originator(s)	Date	Verifier(s)	Date
Hui Lu, Ph. D.	12/28/2011	William Mcbrine, P. E.	12/28/11

Verification: Verification is performed in accordance with EOP 3.4 as indicated below

☒ Design review as documented on the following sheet or

☐ Alternate calculation as documented in attachment or

☐ Qualification testing as documented in attachment or

APPROVAL FOR RELEASE:

PROJECT MANAGER: Robert W. Hammelmann Date: 04 JAN 12

Report Record

altran Calculation No.: 11-2357-C-003 Rev. No.: 1 Sheet No. 2B

QA Status: Quality Grade ☒, Commercial Grade ☐, Other ☐ Total Sheets: 46

Title: Evaluation of Repair Sleeve Assemblies

Client: Constellation Energy Facility: Calvert Cliffs Nuclear Power Plant

Revision Description: Revised to add section 4.6.4 (sheet 35A); Modified conclusions and reference (sheet 41, 42 and 44). Updated sheets 6, 7, 10, 11, 24, 30, 33 and 34 due to customer comments. Also replaced cover sheet, report record (pg 2), verification sheet (pg 3), revision description (pg 4).

Computer runs are identified on a Computer File Index : Yes ☐ N/A ☒

Error reports are evaluated by: Date:

Computer use is affected by error notices. No ☐ Yes ☐ (If yes, attach explanation)

SUPERSEDED

Originator(s)	Date	Verifier(s)	Date
Yu Gan, Ph. D.	1/26/2012	Alfred W. Chock	1/26/12
Elena Wapner	1/26/2012	Robert Hammelmann	01/26/12

Verification: Verification is performed in accordance with EOP 3.4 as indicated below

☒ Design review as documented on the following sheet or

☐ Alternate calculation as documented in attachment or

☐ Qualification testing as documented in attachment or

APPROVAL FOR RELEASE:

PROJECT MANAGER: Robert W. Hammelmann Date: 01/26/12

Report Record

altran Calculation No.: 11-2357-C-003 Rev. No.: 2 Sheet No. 2C

QA Status: Quality Grade ☒, Commercial Grade ☐, Other ☐ Total Sheets: ~~46~~ 47

Title: Evaluation of Repair Sleeve Assemblies

Client: Constellation Energy Facility: Calvert Cliffs Nuclear Power Plant

Revision Description: Revised hoop stress and minimum wall thickness calculations to include system design pressure. Added CCNPP Civil and Structural documentation to allowable seismic axial acceleration calculation. Cleaned up calculation.

Computer runs are identified on a Computer File Index : Yes ☐ N/A ☒

Error reports are evaluated by: Date:

Computer use is affected by error notices. No ☐, Yes ☐ (if yes, attach explanation)

Originator(s)	Date	Verifier(s)	Date
Elena Wapner	2/15/12	Robert Hammelmann	2/15/12

SUPERSEDED

Verification: Verification is performed in accordance with EOP 3.4 as indicated below

☒ Design review as documented on the following sheet or

☐ Alternate calculation as documented in attachment or

☐ Qualification testing as documented in attachment or

APPROVAL FOR RELEASE:

PROJECT MANAGER: Robert W. Hammelmann Date: 2/15/12

Report Record

altran Calculation No.: 11-2357-C-003 Rev. No.: 3 Sheet No. 2 D

QA Status: Quality Grade ☒, Commercial Grade ☐, Other ☐ Total Sheets: 48

Title: Evaluation of Repair Sleeve Assemblies

Client: Constellation Energy Facility: Calvert Cliffs Nuclear Power Plant

Revision Description: Revised hoop stress and minimum wall thickness calculations using max install pressure instead of long term contact pressure. Revised S_h.

SUPERSEDED

Computer runs are identified on a Computer File Index: Yes ☐ N/A ☒

Error reports are evaluated by: Date:

Computer use is affected by error notices. No ☒ Yes ☐ (if yes, attach explanation)

Originator(s)	Date	Verifier(s)	Date
Elena Wapner	2/17/12	Robert Hammelmann	2/17/12

Verification: Verification is performed in accordance with EOP 3.4 as indicated below

☒ Design review as documented on the following sheet or

☐ Alternate calculation as documented in attachment or

☐ Qualification testing as documented in attachment or

APPROVAL FOR RELEASE:

PROJECT MANAGER: Robert W. Hammelmann Date: 2/17/12

altran

Verification

Calc. No. 11-2357-C-003 Rev. 4 Sheet 3

Verification Considerations (in accordance with EOP 3.4)

		Initials
1.	The inputs come from an appropriate and controlled source, and are clearly referenced.	JC
2.	The inputs from uncontrolled sources or assumptions are properly justified and documented.	JC
3.	The inputs or assumptions that are not adequately justified are identified for later confirmation.	JC
4.	Design, analysis, testing, examination, and acceptance criteria are specified and complied with.	JC
5.	Appropriate interface control was administered during the process of this report.	—
6.	The computer programs used are authorized for use and/or properly verified.	—
7.	Applicable codes, standards, or regulatory requirements are properly specified and complied with.	JC
8.	The specified tests and examinations were performed by personnel with appropriate qualifications.	—
9.	All tests and examinations were performed in accordance with written procedures.	—
10	Specimens are controlled by identification number and their traceability is maintained.	—
11	The calibration of instrumentation is acceptable and properly recorded.	—
12	The instruments that are used are recorded by name and identification number.	—
13	The report is neat and legible and suitable for reproduction.	JC
14	The formatting and technical requirements of applicable procedures are complied with.	JC
15	Critical numerical computations have been checked in detail.	JC
16	The endorsements of all originators and verifiers have been properly recorded.	JC
17	Appropriate construction, operation, and/or maintenance considerations have been considered.	—
18	The conclusions satisfy stated objectives, and they are consistent with the input.	JC
19	All material specified are compatible with their service environment.	JC
20	Procedural requirements for report revisions and subsequent reviews are complied with.	JC

Clarify significant comments:

All comments are resolved and incorporated into the report except as noted here:

[signature]	3/9/2012	[signature]	3/9/2012
Originator's Concurrence	Date	Verifier's Concurrence	Date

Revision Description

Rev. No.	Revision Description
0	Original issue.
1	Revised to add section 4.6.4 (sheet 35A); Modified conclusions and reference (sheet 41, 42 and 44). Updated sheets 6, 7, 10, 11, 24, 30, 33 and 34 due to customer comments. Also replaced cover sheet, report record (pg 2), verification sheet (pg 3), revision description (pg 4).
2	Revised hoop stress and minimum wall thickness calculations to include system design pressure. Added CCNPP Civil and Structural documentation to allowable seismic axial acceleration calculation. Cleaned up calculation.
3	Revised hoop stress and minimum wall thickness calculations using max install pressure instead of long term contact pressure. Revised S_h. Minimum contact pressure calculations were revised to neglect, and not subtract, the design pressure. Updated sections include: 3.4, 4.1.5 & 4.1.6, 4.2.1 & 4.2.2, 4.3.2, 4.4.2 & 4.6.4. All conclusions updated with revised values.
4	Complete revision to incorporate changes in response to owner's comments. Removed references to gray cast iron pipe, which is out of scope.

TABLE OF CONTENTS

Cover Page 1
Report Record 2
Verification 3
Revision Description 4
Table of Contents 5

1.0 INTRODUCTION 6
1.1 Background 6
1.2 Purpose 6

2.0 ASSUMPTIONS AND IPUT 7
2.1 Assumptions 7
2.2 Input 8

3.0 DESIGN CRITERIA 11

4.0 METHODOLOGY 11
4.1 Loads on the Sleeve Retaining Bands at Installation 11
4.2 Compute the Thermal Effects on the Forces in the Retaining Band 15
4.3 Calculation of Hydrodynamic Load 18
4.4 Check of the Sleeve Under Seismic Loads 23
4.5 Check of Seal for Abnormal Loading Condition 24
4.6 Check Backing Plate 28
4.7 Cyclic Fatigue 29

5.0 CONCLUSION 30

6.0 REFERENCES 33

ATTACHMENTS

Attachment A Design Sketches
Attachment B Miscellaneous Information
Attachment C Email Correspondence
Attachment D Miscellaneous Calvert Cliffs Documents

Evaluation of Repair Sleeve Assemblies

1.0 Introduction

1.1 Background

Calvert Cliffs Nuclear Power Plant (CCNPP) has safety related salt water supply piping in-service for over 35 years. In February 2012, there will be a comprehensive inspection of the piping utilizing a technology that will provide a cross-sectional assessment of the pipe wall.Plant management has requested that a repair method must be in place in the event that a defect(s) are encountered that exceed the minimum design basis requirements. As the pipe material is composed of ductile iron/gray cast iron, a welded repair is not possible. Therefore, the plan is to develop a non-welded mechanical repair, installed internally and can be completed within the existing service water header outage window. [Ref.1]

Altran has developed a repair method that provides structural and pressure boundary integrity for all design basis loading conditions. This repair system consists of an EPDM internal gasket, four (4) AL6XN retaining bands and pressure/structural overlapped load plate (non-welded AL6XN) as depicted in Attachment A.

The mechanical sleeve system is comprised of a rubber gasket that is factory sized and molded to fit the inside diameter of the pipe to be refurbished. A sheet of UNS N08367 stainless steel (AL6XN) is placed between the gasket and the inside pipe wall as a backing plate and act as pressure/structural load barrier. The entire assembly is held in place by a series of four (4) AL6XN bands that are expanded against the sleeve causing it to bear tight against the inside of the pipe.

The rubber gasket material is Ethylene Propylene Diamine Monomer (EPDM) manufactured in compliance with ASTM-D3900, D3568 and is designated as M4AA710A13B13C12Z1Z2Z3 per ASTM-D2000 [Ref. 2]. The gasket is factory vulcanized to form one continuous piece. The ends of each gasket have grooved ribs which become compressible sealing points against the inside of the pipe. The sleeves are thus secured in place by the circumferential pressure exerted by the stainless steel retaining bands, which are hydraulically expanded and held in position by wedges made from the same material.

The backing plate is a single sheet of 16 gauge (.0598") UNS N08367 sheet metal 14" wide enclosing the entire inside circumference of the 30" or 36" Pipe [Ref 3]. After the backing plate has been placed over the degraded area, the balance of the mechanical sleeve assembly will be installed over the backing plate. Four (4) AL6XN bands will be used per sleeve assembly. For each assembly two bands will be installed at each end of the rubber gasket and two to secure the backing plate in position.

The sleeve, which is held in place with retaining bands, has ribs that contact the inside of the pipe to be repaired. As loads are transferred from the metal retaining bands to the sealing ribs, these restraining members control the cold flow of the elastomeric material so that the gasket remains in contact with the pipe to create a seal. The position of the "inside" bands assure a secure fit for the backing plate. The strength and resilience of the sleeve assembly will provide a durable and reliable protective shield inside the pipe against the erosive effects of water flowing at varying rates.

1.2 Purpose

The purpose of this calculation is to
1) qualify the internal mechanical sleeve assembly as a contingent repair for the safety related service water supply piping at the Calvert Cliffs Nuclear Power Plant. The loading conditions considered include installation, seismic (SSE), pipe movement, fatigue and normal operation. The assembly will be qualified for one abnormal loading condition, in which the upstream band is lost. Further, the backing plate has been reviewed to assess its effect on pressure boundary enhancement,
2) calculated the maximum flaw size based on the qualification.

2.0 Assumptions and Input

2.1 Assumptions

1. The system design temperature is assumed to be 32 °F to 95 °F.;

2. The minimum fluid inlet temperature is assumed to be 32 °F

3. The coefficient of friction between the sleeve and the pipe wall is assumed to be:

   $\mu := 0.32$ This is based on a rubber belt on steel [Ref. 4, Table 12.2]

4. An impact factor of 2 was applied to the hydrodynamic loads to account for the rapid increase in Service Water supply flow during an accident, as shown in Section 4.3 and 4.5.

5. It is assumed that during the abnormal operating condition, the upstream retaining band will be lost and the sleeve will fold back on itself.

6. The weight of the sleeve assembly is assumed to be 110 lbf.

7. Poisson's ration for AL-6XN is assumed to be 0.3.

8. Retaining bands on backing plate will be placed on a non-degraded area adjacent to the corrosion area.

9. DELETED

10. A maximum of long term stress relaxation of EPDM gasket is assumed to be 12%. During the repair sleeve installation, two expansions of retaining band to the hydraulic pressure will be made. After a minimum of 30 minutes holding following the first expansion, the EPDM gasket is assumed to have made the majority part of long term stress relaxation. [Ref. 2]

11. Ground water pressure on the outer diameter is assumed to be negligible.

12. The expansion pressure of hydraulic expander at the installation is assumed to be at the range of 2800-3500 psi, with an expansion cylinder bore diameter of 1.69 in. 3500 psi is the maximum pressure defined at the installation procedure [Ref. 10]. 2800 psi is an administrative low limit assigned by Altran (a conservative value used to ensure a minimum amount of "grip" for the gasket / pipe interface).

13. The installation temperature is assumed to be 70 °F.

14. This calculation qualifies the contingency repair method for ductile iron pipe only (Pipe/Service Class LC-2).

15. The postulate degraded condition for the calculation is a circular flaw.

16. Qualification assumes removal of the cement mortar lining in the area of the contingency repair prior to installation. Exposed ductile iron pipe surfaces shall be coated with Belzona, as a corrosion inhibitor in accordance with Spec. M-600, Class LC [Ref. 21].

17. The density of the material fill is assumed to be 120 lb/ft^3 (from Ref. 3).

18. This qualification assumes that the seam of the backing plate is located on the other side of the circular flaw.

2.2 Input

2.2.1 System Piping Parameters - Pipe Specification for 30"/36" Pipes

	30in	36in	
Pipe Outside Diameter	$D_{po\_30} := 32.00in$	$D_{po\_36} := 38.30in$	[Ref.19]
Pipe Wall Thickness	$t_{p\_30} := 0.550in$	$t_{p\_36} := 0.630in$	[Ref.19]

Pipe Inside Diameter

$$D_{pi\_30} := D_{po\_30} - 2t_{p\_30} \qquad D_{pi\_36} := D_{po\_36} - 2t_{p\_36}$$

$$D_{pi\_30} = 30.90 \cdot in \qquad D_{pi\_36} = 37.04 \cdot in$$

Piping Buried Location	$H_{max\_30} := 11.4ft$	$H_{max\_36} := 11.7ft$	[Ref.3]
Earth Weight above Buried Pipe	$W_{earth} := 120 \frac{lbf}{ft^3}$		[Ref.3]

Pipe Materials

Ductile Iron : Class LC, USAS A21.51-1981[24]. Material ASTM A377, Joint Class 4 [16-18]

	32 °F	95 °F
Mean Coefficient of Thermal Expansion	$\alpha_{DI_0} := 6.2 \cdot 10^{-6} \cdot \frac{in}{in \cdot F}$	$\alpha_{DI_1} := 6.2 \cdot 10^{-6} \cdot \frac{in}{in \cdot F}$

[Ref.19], Attachment B

Written in vector form
$$\alpha_{DI} = \begin{pmatrix} 6.2 \times 10^{-6} \\ 6.2 \times 10^{-6} \end{pmatrix} \cdot \frac{in}{in \cdot F}$$

Yield Stress

$S_{y\_DI} := 42000psi$ [Ref. 23]

2.2.2 System Design Parameters

Design Pressure $P_d := 50psi$ [Ref.17]

Design Temperature Range (32 °F to 95 °F), Therefore the ΔT is:

The assumed installation temperature is 70 °F, Assumption 13. [Ref.17]

ΔT = 32 °F - 70 °F = -38 °F

ΔT = 95 °F - 70 °F = 25 °F

$$\Delta T_{sw} := \begin{pmatrix} -38 \\ 25 \end{pmatrix} \cdot F$$

Maximum System Flow Rate

$q_{sys} := 40000 \frac{gal}{min}$ [Ref.22], Attachment C

$W_{hs} := 110 \cdot lbf$ The weight of the sleeve assembly as assumed. Assumption 6.

$\mu_{f\_70F} := 0.658 \cdot 10^{-3} \cdot \frac{lb}{ft \cdot sec}$ This is the absolute viscosity of water at 70 °F, [Ref. 7]

$\rho_{wtr\_70F} := 62.3 \cdot \frac{lb}{ft^3}$ This is the density water at 70 °F, [Ref. 7]

2.2.3 Internal Sleeve Parameters [Ref. 2, Attachment A].

EPDM Gasket Thickness	$t_{ws} := 0.300in$		[Ref. 8], Attachment A
EPDM Gasket Length	$L_{ws} := 19.79in$		[Ref. 8], Attachment A
Retaining Band Thickness	$t_{rb} := 0.1875in$		[Ref. 2], Attachment A
Retaining Band Width	$w_{rb} := 2.0in$		[Ref. 2], Attachment A
Retaining Band Outside Diameter	$D_{rbo\_30} := D_{pi\_30} - 2t_{ws}$	$D_{rbo\_30} = 30.30 \cdot in$	
	$D_{rbo\_36} := D_{pi\_36} - 2t_{ws}$	$D_{rbo\_36} = 36.44 \cdot in$	
Thickness of the Push Tab	$t_{pt} := t_{rb}$	$t_{pt} = 0.1875 \cdot in$	
Thickness of the Backing Plate (16 gauge)	$thk_{back} := 0.0598in$		Attachment A

2.2.4 Retaining Band and Backing Plate Material Properties

Materials: AL-6XN (UNS N08367), ASTM B688 **[Ref. 2, Attachment A]**

Yield Strength $S_y := 45000\text{psi}$ [Ref. 20]

$S_u := 100000\text{psi}$ [Ref. 20]

$S_h := \min\left(\frac{2}{3}\cdot S_y, \frac{1}{4}S_u\right)$ $S_h = 25000\cdot\text{psi}$

	32 °F	95 °F
Mean Coefficient of Thermal Expansion	$\alpha_{rb_0} := 8.5\cdot 10^{-6}\frac{\text{in}}{\text{in}\cdot\text{F}}$	$\alpha_{rb_1} := 8.5\cdot 10^{-6}\frac{\text{in}}{\text{in}\cdot\text{F}}$

[Ref. 6], Attachment B

Written in vector form $\alpha_{rb} = \begin{pmatrix} 8.5\times 10^{-6} \\ 8.5\times 10^{-6} \end{pmatrix}\cdot\frac{\text{in}}{\text{in}\cdot\text{F}}$

Modulus of Elasticity $E_{rb} := 28.3\cdot 10^{6}\cdot\text{psi}$ [Ref.6], Attachment B

Poisson's Ratio $\nu := 0.3$ Assumption 7

2.2.5 Hydraulic Expander Parameters

Expansion Pressure (gage). This is pressure applied by the hydraulic expander to each of the 4 retaining bands.

$HP_i := \begin{array}{|c|} \hline 2800\cdot\text{psi} \\ \hline 3500\cdot\text{psi} \\ \hline \end{array}$ Minimum Assumption 12; Maximum [Ref.10]

Expansion Cylinder Bore, Standard Enerpac #RC 104 Expander $b := 1.69\text{in}$ Assumption 12, Attachment C

3.0 Design Criteria

1. **USA Standard (USAS) B31.1, *Power Piping*, 1967 [5].**

2. **ANSI A21.50, *American National Standard for the Thickness Design of Ductile-Iron Pipe*, 1967, 1976 [23].**

4.0 Methodology

This calculation qualifies the sleeve assemblies for loads applied during installation and operation. The analysis uses methods of classical mechanics. In addition, the applied hoop stress caused by the retaining bands on the host pipe was qualified. This calculation will also determine if the retaining bands are sufficient to hold the sleeve in place and qualify the backing plate that will repair the defect. This calculation will also determine if the retaining bands shall be sufficient for the 50 psig design pressure of the Service Water (SW) cooling system. In addition, the calculation will determine the maximum diameter of a postulated circular flaw in the ductile iron pipe based on the ability of the AL6XN backing plate to resist the internal pressure load.

4.1 Loads on the Sleeve Retaining Bands at Installation

The AL6XN retaining bands are installed using a hydraulic expansion device to press the band tight against the sleeve. During installation, a force is applied in opposite directions to each push tab at the break in the band.

This force causes a compressive stress in the band and induces the required contact pressure onto the sleeve. Once the retaining band is expanded to the required hydraulic pressure, a wedge is installed below the long push tab. The hydraulic pressure is then released. After a minimum of 30 minutes, a second expansion of the retaining band is performed to the expansion tool hydraulic pressure. The abutting edges of the retaining band press against the wedge maintaining the band and the wedge in compression. The forces in the retaining band cause it to conform to the shape of the host pipe.

4.1.1 Method for Computing Forces and Stresses in the Retaining Bands

The hydraulic expander applies a compressive force to the retaining band at installation, and the area of the force applied on is the cross sectional area of the retaining band . This force causes a compressive stress that may be calculated via:

$$f_c = \frac{\text{Force}}{\text{Area}}$$

$$f_c = \frac{CB}{t_{rb} \cdot w_{rb}} \qquad \text{Eq. (1)}$$

Where:

f_c = Compressive Stress (psi)

CB = Compressive Force Due to Hydraulic Expander (lbf)

t_{rb} = Thickness of Retaining Band (in)

w_{rb} = Width of Retaining Band (in)

In addition, the compressive stress in the band is related to the pressure imposed by the band on the pipe Pcontact using the hoop stress equation

$$f_c = \frac{P_{contact} \cdot D_{rb}}{2 \cdot t_{rb}} \qquad \text{Eq. (2)}$$

Substituting Eq. 2 for f_c in Eq.1, then solving for $P_{contact}$

$$P_{contact} = \frac{2}{D_{rbo} \cdot w_{rb}} CB \qquad \text{Eq. (3)}$$

Where:

D_{rbo} = Retaining Band Outside Diameter (in)

$P_{contact}$ = Contact Pressure (psi)

w_{rb} = Width of Retaining Band (in) = 2.00 in.

CB = Compressive Force Due to Hydraulic Expander (lbf)

4.1.2 Calculation of the Compressive Force in the Retaining Band at Installation

The sleeve retaining bands are installed using the standard #RC104 expander with a 1.69" diameter hydraulic cylinder. The compressive force on the retaining band during installation, CB, is:

$$CB_i := \left(\frac{\pi}{4} \cdot b^2\right) \cdot HP_i$$

[Reference to Section 2.2.5]

CB is the hoop force imposed on the retaining band by the hydraulic cylinder during installation.

$b = 1.69 \cdot in$

This is the expansion cylinder bore.

$$CB = \begin{pmatrix} 6281 \\ 7851 \end{pmatrix} \cdot lbf$$

Force on band due to minimum hydraulic expander pressure (2800psi)

Force on band due to minimum hydraulic expander pressure (3500psi)

4.1.3 Calculation of Contact Pressure Between the Retaining Bands, EPDM Elastomer Gasket and the Pipe

The contact pressure, $P_{contact}$, at installation is calculated using Eq. 3:

For 30 inch Host Pipe

$$P_{contact\_30} := \frac{2CB}{w_{rb} \cdot D_{rbo\_30}}$$

$$P_{contact\_30} = \begin{pmatrix} 207 \\ 259 \end{pmatrix} \cdot psi \qquad \begin{matrix} \text{Minimum} \\ \text{Maximum} \end{matrix}$$

The long term contact pressure is based on a maximum compression stress relaxation of 12%, (assumption 10).

$$P_{contactLT\_30} := (1 - 12\%) \cdot P_{contact\_30}$$

$$P_{contactLT\_30} = \begin{pmatrix} 182 \\ 228 \end{pmatrix} \cdot psi \qquad \begin{matrix} \text{Minimum} \\ \text{Maximum} \end{matrix}$$

For 36 inch Host Pipe

$$P_{contact\_36} := \frac{2CB}{w_{rb} \cdot D_{rbo\_36}}$$

$$P_{contact\_36} = \begin{pmatrix} 172 \\ 215 \end{pmatrix} \cdot psi \qquad \begin{matrix} \text{Minimum} \\ \text{Maximum} \end{matrix}$$

The long term contact pressure is based on a maximum compression stress relaxation of 12%

$$P_{contactLT\_36} := (1 - 12\%) \cdot P_{contact\_36}$$

$$P_{contactLT\_36} = \begin{pmatrix} 152 \\ 190 \end{pmatrix} \cdot psi \qquad \begin{matrix} \text{Minimum} \\ \text{Maximum} \end{matrix}$$

4.1.4 Check of Compressive Stress in the Retaining Band

The compressive stress corresponding to the maximum hydraulic expansion pressure is:

$$\sigma_{c\_chk} := \frac{\cdot CB_1}{t_{rb} \cdot w_{rb}}$$

$\sigma_{c\_chk} = 20936 \cdot psi$ Maximum compressive stress in retaining band at installation

$\frac{\sigma_{c\_chk}}{S_h} = 83.7 \cdot \%$ of allowable stress [sheet 10]

4.1.5 Determine the Host Pipe Minimum Wall Thickness

The host pipe minimum wall thickness to sustain sleeve assembly loading is determined from ANSI A21.50-1976, Section 50-2.2 Step 2 "Design for Internal Pressure" [Ref. 23]. $t_{min}=(P_{total}*D_{pipe})/(2*S_{y\_pipe})$

<u>For 30 inch Ductile Iron Host Pipe</u>

$$t_{DI\_30min} := \frac{2\left(P_{contact\_30_1} + P_d + 100psi + P_{TH1\_DI30}\right) \cdot D_{po\_30}}{2 \cdot \left(S_{y\_DI}\right)}$$

$t_{DI\_30min} = 0.326 \cdot in$ This is the minimum host pipe wall thickness for sleeve loading. The host pipe is 30" with a design wall thickness of 0.550 inches.

<u>For 36 inch Ductile Iron Host Pipe</u>

$$t_{DI\_36min} := \frac{2\left(P_{contact\_36_1} + P_d + 100psi + P_{TH1\_DI36}\right) \cdot D_{po\_36}}{2 \cdot \left(S_{y\_DI}\right)}$$

$t_{DI\_36min} = 0.348 \cdot in$ This is the minimum host pipe wall thickness for sleeve loading. The host pipe is 36" with a design wall thickness of 0.630 inches.

4.2 Compute the Thermal Effects on the Forces in the Retaining Band

4.2.1 Calculation of Thermal Expansion/Compression in the Retaining Bands

Thermal expansion/contraction in the circumferential direction = Δx (assuming that the EPDM is fully compressed). This is the difference in expansion between the degraded ductile iron pipe and the AL6XN band.

This calculation is repeated for the hot and cold thermal expansion moduli and the contraction and expansion from 70F to the minimum and maximum operating temperatures in the system. Refer to section 3.2)

For Ductile Iron 30 inch pipe

$$\Delta x_{cold\_DI30} := \alpha_{rb_0} \cdot \pi \cdot D_{rbo\_30} \cdot \Delta T_{sw} - \alpha_{DI_0} \cdot \pi \cdot D_{pi\_30} \cdot \Delta T_{sw}$$

$$\alpha_{rb} = \begin{pmatrix} 8.5 \times 10^{-6} \\ 8.5 \times 10^{-6} \end{pmatrix} \cdot \frac{1}{F} \qquad \alpha_{DI} = \begin{pmatrix} 6.2 \times 10^{-6} \\ 6.2 \times 10^{-6} \end{pmatrix} \cdot \frac{1}{F}$$

$$\Delta x_{cold\_DI30} = \begin{pmatrix} -0.0079 \\ 0.0052 \end{pmatrix} \cdot in$$

Contraction, ΔT=-38 °F
Expansion, ΔT=+25 °F

$$\Delta x_{hot\_DI30} := \alpha_{rb_1} \cdot \pi \cdot D_{rbo\_30} \cdot \Delta T_{sw} - \alpha_{DI_1} \cdot \pi \cdot D_{pi\_30} \cdot \Delta T_{sw}$$

$$\Delta x_{hot\_DI30} = \begin{pmatrix} -0.0079 \\ 0.0052 \end{pmatrix} \cdot in$$

Contraction, ΔT=-38 °F
Expansion, ΔT=+25 °F

The thermal strain in the retaining band is:

$$\varepsilon_{thm\_DI30} := \frac{\Delta x_{cold\_DI30}}{\pi \cdot D_{rbo\_30}}$$

The cold condition produces a slightly greater strain. This difference is negligible.

$$\varepsilon_{thm\_DI30} = \begin{pmatrix} -8.27 \times 10^{-5} \\ 5.44 \times 10^{-5} \end{pmatrix}$$

Contraction
Expansion

Thermal stress σ_{TH} in the retaining band due to relative circumferential expansion/contraction of the AL6XN retaining bands with respect to the pipe resulting from the temperature changes defined in Section 3.2 is:

$$\sigma_{TH\_DI30} := \varepsilon_{thm\_DI30} \cdot E_{rb} \qquad \sigma_{TH\_DI30} = \begin{pmatrix} -2341 \\ 1540 \end{pmatrix} \cdot psi$$

Contraction
Expansion

where σ_{TH_DI30} = thermal stress, $E_{rb} = 2.83 \times 10^{7} \cdot psi$

Compressive force in the retaining bands due to relative thermal expansion/contraction:

$C_{TH\_DI30} := \sigma_{TH\_DI30} \cdot t_{rb} \cdot w_{rb}$ $\quad C_{TH\_DI30} = \begin{pmatrix} -878 \\ 578 \end{pmatrix} \cdot lbf$ Contraction / Expansion

The change in contact pressure between the sleeve and the pipe wall due to thermal effects is:

$$P_{TH\_DI30} := \frac{2 \cdot C_{TH\_DI30}}{w_{rb} \cdot D_{rbo\_30}} \qquad P_{TH\_DI30} = \begin{pmatrix} -29 \\ 19 \end{pmatrix} \cdot psi$$

$$P_{TH1m\_DI30} := \max(P_{TH\_DI30}) \qquad P_{TH1m\_DI30} = 19 \cdot psi$$

$P_{TH1\_DI30} \equiv 19\ psi$ **Note: this is a forced identity and should be checked with each calculation that $P_{TH1} = P_{TH1m}$ This value is used above for the Long term operational hoop stress.**

The minimum contact pressure between the sleeve and the pipe wall can be computed using the minimum long term contact pressure and the effects of thermal contraction neglecting the design pressure. This pressure will conservatively compute the friction force holding the sleeve in place that will be compared to the hydrodynamic forces acting to dislodge the sleeve.

$P_{contactLT\_30_0} = 182 \cdot psi$ Sheet 13

$$P_{min\_DI30} := P_{contactLT\_30_0} + P_{TH\_DI30_0}$$

$$P_{min\_DI30} = 153 \cdot psi$$

<u>For Ductile Iron 36 inch pipe</u>

$$\Delta x_{cold\_DI36} := \alpha_{rb_0} \cdot \pi \cdot D_{rbo\_36} \cdot \Delta T_{sw} - \alpha_{DI_0} \cdot \pi \cdot D_{pi\_36} \cdot \Delta T_{sw} \qquad \alpha_{rb} = \begin{pmatrix} 8.5 \times 10^{-6} \\ 8.5 \times 10^{-6} \end{pmatrix} \cdot \frac{1}{F}$$

$\Delta x_{cold\_DI36} = \begin{pmatrix} -0.0096 \\ 0.0063 \end{pmatrix} \cdot in$ Contraction / Expansion $\quad \alpha_{DI} = \begin{pmatrix} 6.2 \times 10^{-6} \\ 6.2 \times 10^{-6} \end{pmatrix} \cdot \frac{1}{F}$

$$\Delta x_{hot\_DI36} := \alpha_{rb_1} \cdot \pi \cdot D_{rbo\_36} \cdot \Delta T_{sw} - \alpha_{DI_1} \cdot \pi \cdot D_{pi\_36} \cdot \Delta T_{sw}$$

$\Delta x_{hot\_DI36} = \begin{pmatrix} -0.0096 \\ 0.0063 \end{pmatrix} \cdot in$ Contraction / Expansion

The thermal strain in the retaining band is:

$$\varepsilon_{thm\_DI36} := \frac{\Delta x_{cold\_DI36}}{\pi \cdot D_{rbo\_36}}$$

The cold condition produces a slightly greater strain. This difference is negligible.

$$\varepsilon_{thm\_DI36} = \begin{pmatrix} -8.35 \times 10^{-5} \\ 5.49 \times 10^{-5} \end{pmatrix} \quad \begin{matrix} \text{Contraction} \\ \text{Expansion} \end{matrix}$$

Thermal stress σ_{TH} in the retaining band due to relative circumferential expansion/contraction of the AL6XN retaining bands with respect to the pipe resulting from the temperature changes defined in Section 3.1 is:

$$\sigma_{TH\_DI36} := \varepsilon_{thm\_DI36} \cdot E_{rb} \qquad \sigma_{TH\_DI36} = \begin{pmatrix} -2364 \\ 1555 \end{pmatrix} \cdot psi \quad \begin{matrix} \text{Contraction} \\ \text{Expansion} \end{matrix}$$

Compressive force in the retaining bands due to relative thermal expansion/contraction:

$$C_{TH\_DI36} := \sigma_{TH\_DI36} \cdot t_{rb} \cdot w_{rb} \qquad C_{TH\_DI36} = \begin{pmatrix} -886 \\ 583 \end{pmatrix} \cdot lbf \quad \begin{matrix} \text{Contraction} \\ \text{Expansion} \end{matrix}$$

The change in contact pressure between the sleeve and the pipe wall due to thermal effects is:

$$P_{TH\_DI36} := \frac{2 \cdot C_{TH\_DI36}}{w_{rb} \cdot D_{rbo\_36}} \qquad P_{TH\_DI36} = \begin{pmatrix} -24 \\ 16 \end{pmatrix} \cdot psi$$

$$P_{TH1m\_DI36} := \max(P_{TH\_DI36}) \qquad P_{TH1m\_DI36} = 16 \cdot psi$$

$$P_{TH1\_DI36} \equiv 16psi$$

Note: this is a forced identity and should be checked with each calculation that $P_{TH1} = P_{TH1m}$ This value is used above for the Long term operational hoop stress.

The minimum contact pressure between the sleeve and the pipe wall can be computed using the minimum long term contact pressure and the effects of thermal contraction neglecting the design pressure. This pressure will conservatively compute the friction force holding the sleeve in place that will be compared to the hydrodynamic forces acting to dislodge the sleeve.

$$P_{contactLT\_36_0} = 152 \cdot psi$$

Sheet 13

$$P_{min\_DI36} := P_{contactLT\_36_0} + P_{TH\_DI36_0}$$

$$P_{min\_DI36} = 127 \cdot psi$$

4.2.2 Calculation of Minimum Friction Force Between the Sleeve and the Pipe Wall.

The contact force between the sleeve and the pipe wall at each retaining band is:

For Ductile Iron

30 inch Host Pipe

$P_{min\_DI30} = 153 \cdot psi$ Sheet 16

$w_{rb} = 2.00 \cdot in$ $D_{rbo\_30} = 30.30 \cdot in$ Sheet 9

$F_{cmin\_DI30} := P_{min\_DI30} \cdot w_{rb} \cdot \pi \cdot D_{rbo\_30}$ $F_{cmin\_DI30} = 29212 \cdot lbf$

The minimum friction force is:

$F_{fmin\_DI30} := \mu \cdot F_{cmin\_DI30}$ $F_{fmin\_DI30} = 9348 \cdot lbf$

36 inch Host Pipe

$P_{min\_DI36} = 127 \cdot psi$ Sheet 17

$w_{rb} = 2.00 \cdot in$ $D_{rbo\_36} = 36.44 \cdot in$ Sheet 9

$F_{cmin\_DI36} := P_{min\_DI36} \cdot w_{rb} \cdot \pi \cdot D_{rbo\_36}$ $F_{cmin\_DI36} = 29159 \cdot lbf$

The minimum friction force is:

$F_{fmin\_DI36} := \mu \cdot F_{cmin\_DI36}$ $F_{fmin\_DI36} = 9331 \cdot lbf$

4.3 Calculation of Hydrodynamic Load

The sleeve is held in place by four retaining bands, located at both ends and adjacent to the corrosion area location. The bands are forced against the sleeve via a hydraulic expander, and a wedge is set into the open gap to hold the retaining band against the sleeve/pipe. The retaining band expansion induces a uniform compressive pressure on the sleeve elastomer. This pressure creates a longitudinal friction force between the elastomer and the pipe. The longitudinal hydrodynamic shear force generated by the fluid flow across the sleeve assembly is opposed by the longitudinal friction force. The minimum friction force is computed in Section 4.2.2.

4.3.1 Hydrodynamic Load

For 30 inch Pipe

The pipe inside diameter is:

$D_{pi\_30} = 30.90 \cdot in$ [Ref. Sect. 2.1]

Conservatively taken as the pipe ID less the sum of the thickness of the sleeves retaining bands and push tab,

$D_{O\_30} := D_{pi\_30} - 2(t_{ws} + t_{rb} + t_{pt})$ The sleeve thickness is based on a layer of gasket material, the retaining band, and the push tab. Attachment A.

where, t_{ws}=thickness of gasket = 0.300 in [Ref. Sect. 2.2.3, sheet 9]

t_{rb}=thickness of retaining band = 0.1875 in [Ref. Sect. 2.2.3, sheet 9]

t_{pt}=thickness of push tab = 0.1875 in [Ref. Sect. 2.2.3, sheet 9]

$D_{O\_30} = 29.55 \cdot in$

The average flow velocity in the orifice is:

$$V_{orif\_30} := \frac{q_{sys}}{\left(\frac{\pi}{4}\right)\cdot\left(D_{O\_30}\right)^2} \qquad V_{orif\_30} = 18.7 \cdot \frac{ft}{sec}$$

where, q_{sys}=40000 gpm [Ref. 22], Attachment C

The average inflow velocity based on the pipe area is:

$$V_{pipe\_30} := \frac{q_{sys}}{\left(\frac{\pi}{4}\right)\cdot\left(D_{pi\_30}\right)^2} \qquad V_{pipe\_30} = 17.1 \cdot \frac{ft}{sec}$$

Determine the Reynolds number for the pipe:

$$Re_{pipe\_30} := \frac{\rho_{wtr\_70F} \cdot V_{pipe\_30} \cdot D_{pi\_30}}{\mu_{f\_70F}}$$

$$Re_{pipe\_30} = 4.172 \times 10^6$$

The pressure drop across the sleeve will be calculated by treating it as a thick edged orifice, per [Ref 11, page 87] Attachment B, with a sleeve length of

$$L_{ws} = 19.79 \cdot in$$

$F_{O\_30} := \frac{\pi}{4} \cdot \left(D_{O\_30}\right)^2$ cross sectional area of the orifice. $F_{pi\_30} := \frac{\pi}{4} \cdot \left(D_{pi\_30}\right)^2$ Cross-sectional area of the pipe.

$\frac{F_{O\_30}}{F_{pi\_30}} = 0.915$ Use this ratio for the abscissa of the table in Diagram 4-15, [Ref 11].

$D_{h\_30} := 4 \cdot \frac{F_{O\_30}}{\pi \cdot D_{O\_30}}$ The hydraulic diameter of the orifice

$D_{h\_30} = 29.55 \cdot in$

$L_{ovrD\_30} := \frac{L_{ws}}{D_{h\_30}}$ This is the L/D ratio that is used in the ordinate of the table in Diagram 4-15, [Ref 11].

$L_{ovrD\_30} = 0.67$ Note that in diagram 4-12 and 4-15 (as presented in Attachment B), Ko (the hydraulic loss) is represented by the variable ζ.

From figure in diagram 4-12 of [Ref 11] τ is found from L_{ovrD}.

$\tau\_30 := 0.672$ From figure in diagram 4-12 of [Ref 11] τ is found from L_{ab}.

Hydraulic loss for sleeve, represented as a thick edged orifice

$$K_{o\_30} := 0.5\left(1-\frac{F_{O\_30}}{F_{pi\_30}}\right)+\left(1-\frac{F_{O\_30}}{F_{pi\_30}}\right)^2+\tau\_30\cdot\sqrt{1-\frac{F_{O\_30}}{F_{pi\_30}}}\cdot\left(1-\frac{F_{O\_30}}{F_{pi\_30}}\right)$$ [Ref. 11 diagram 4-15]

$$K_{o\_30} = 0.067$$

To determine the pressure drop across the sleeve assembly, certain fluid properties are necessary. The viscosity and density of water at 70 deg F is:

$\mu_{f\_70F} = 6.58\times10^{-4}\cdot\frac{lb}{ft\cdot sec}$ $\rho_{wtr\_70F} = 62.3\cdot\frac{lb}{ft^3}$ $\nu_{wtr\_70F} := \frac{\mu_{f\_70F}}{\rho_{wtr\_70F}}$ [Ref 12, T 3.3.3 & T 6.1.6]

The total pressure drop across the sleeve is

$$\Delta P\_30 := \rho_{wtr\_70F}\cdot K_{o\_30}\cdot\frac{V_{orif\_30}^{\ 2}}{2} \qquad \Delta P\_30 = 0.157\cdot psi$$

The hydrodynamic drag on the sleeve assembly is therefore:

$$F_{drag\_30} := \Delta P\_30\cdot\pi\cdot\frac{(D_{pi\_30})^2}{4} \qquad F_{drag\_30} = 118\cdot lbf$$

Since the flow rate increases rapidly in the event of an accident, an impact factor (dynamic load factor) of 2 will be applied to the hydrodynamic loads: (See assumption 4)

$$F_{HYD\_30} := F_{drag\_30}\cdot 2 \qquad F_{HYD\_30} = 236\cdot lbf$$

The hydrodynamic load is much lower than the minimum friction force between the sleeve and pipe, see sec. 4.2.2. Therefore the 30-inch repair is acceptable for hydrodynamic loads.

For 36 inch Pipe

The pipe inside diameter is:

$$D_{pi\_36} = 37.04 \cdot in$$

The diameter of the orifice (here the term orifice means the ID of the in place retaining ring) is:

$$t_f := t_{ws} + t_{rb} + t_{pt}$$

The sleeve thickness is based on a layer of gasket material, the retaining band, and the push tab.

$$t_f = 0.675 \cdot in$$

$$D_{O\_36} := D_{pi\_36} - 2t_f$$

$$D_{O\_36} = 35.69 \cdot in$$

The average flow velocity in the orifice is:

$$V_{orif\_36} := \frac{q_{sys}}{\left(\frac{\pi}{4}\right) \cdot \left(D_{O\_36}\right)^2} \qquad V_{orif\_36} = 12.8 \cdot \frac{ft}{sec}$$

The average inflow velocity based on the pipe area is:

$$V_{pipe\_36} := \frac{q_{sys}}{\left(\frac{\pi}{4}\right) \cdot \left(D_{pi\_36}\right)^2} \qquad V_{pipe\_36} = 11.9 \cdot \frac{ft}{sec}$$

Determine the Reynolds number for the pipe:

$$Re_{pipe\_36} := \frac{\rho_{wtr\_70F} \cdot V_{pipe\_36} \cdot D_{pi\_36}}{\mu_{f\_70F}}$$

$$Re_{pipe\_36} = 3.481 \times 10^6$$

The pressure drop across the sleeve will be calculated by treating it as a thick edged orifice, per [Ref 11, page 87], with a sleeve length of

$$L_{ws} = 19.79 \cdot in$$

$F_{O\_36} := \frac{\pi}{4} \cdot \left(D_{O\_36}\right)^2$ cross sectional area of the orifice.

$F_{pi\_36} := \frac{\pi}{4} \cdot \left(D_{pi\_36}\right)^2$ Cross-sectional area of the pipe.

$\frac{F_{O\_36}}{F_{pi\_36}} = 0.928$ Use this ratio for the abscissa of the table in Diagram 4-15, [Ref 11].

$D_{h\_36} := 4 \cdot \frac{F_{O\_36}}{\pi \cdot D_{O\_36}}$ The hydraulic diameter of the orifice

$D_{h\_36} = 35.69 \cdot in$

$L_{ovrD\_36} := \frac{L_{ws}}{D_{h\_36}}$ This is the L/D ratio that is used in the ordinate of the table in Diagram 4-15, [13].

$L_{ovrD\_36} = 0.554$

From figure in diagram 4-12 of [Ref 11] τ is found from L_{ovrD}.

$\tau\_36 := 0.900$ From figure in diagram 4-12 of [Ref 11] τ is found from L_{ab}.

Hydraulic loss for sleeve, represented as a thick edged orifice

$$K_{o\_36} := 0.5\left(1 - \frac{F_{O\_36}}{F_{pi\_36}}\right) + \left(1 - \frac{F_{O\_36}}{F_{pi\_36}}\right)^2 + \tau\_36 \cdot \sqrt{1 - \frac{F_{O\_36}}{F_{pi\_36}}} \cdot \left(1 - \frac{F_{O\_36}}{F_{pi\_36}}\right)$$ [Ref. 11] diagram 4-15

$K_{o\_36} = 0.058$

To determine the pressure drop across the sleeve assembly, certain fluid properties are necessary. The viscosity and density of water at 70 deg F is:

$\mu_{f\_70F} = 6.58 \times 10^{-4} \cdot \frac{lb}{ft \cdot sec}$ $\rho_{wtr\_70F} = 62.3 \cdot \frac{lb}{ft^3}$ $\nu_{wtr\_70F} := \frac{\mu_{f\_70F}}{\rho_{wtr\_70F}}$ [Ref 12, T 3.3.3 & T 6.1.6]

The total pressure drop across the sleeve is

$\Delta P\_36 := \rho_{wtr\_70F} \cdot K_{o\_36} \cdot \frac{V_{orif\_36}^2}{2}$ $\Delta P\_36 = 0.064 \cdot psi$

The hydrodynamic drag on the sleeve assembly is therefore:

$F_{drag\_36} := \Delta P\_36 \cdot \pi \cdot \frac{(D_{pi\_36})^2}{4}$ $F_{drag\_36} = 69 \cdot lbf$

Since the flow rate increases rapidly in the event of an accident, an impact factor (dynamic load factor) of 2 will be applied to the hydrodynamic loads: (See assumption 4)

$F_{HYD\_36} := F_{drag\_36} \cdot 2$ $F_{HYD\_36} = 139 \cdot lbf$

The hydrodynamic load is much lower than the minimum friction force between the sleeve and pipe, see sec. 4.2.2. Therefore the 36-inch repair is acceptable for hydrodynamic loads.

4.3.2 Check Hydrodynamic Loads Against Friction Force

For 30 inch Ductile Iron Pipe

$$\frac{F_{fmin\_DI30}}{F_{HYD\_30}} = 39.6 \qquad >>1$$

Therefore the sleeve will not be dislodged by flow induced forces.

For 36 inch Ductile Iron Pipe

$$\frac{F_{fmin\_DI36}}{F_{HYD\_36}} = 67.3 \qquad >>1$$

Therefore the sleeve will not be dislodged by flow induced forces.

4.4 Check of the Sleeve Under Seismic Loads

The seismic load required to cause the sleeve to slip axially within the pipe during a seismic event is calculated below.

4.4.1 Friction Force Available to Resist Seismic Loading

The friction force available to resist the seismic load: F_{fS_DI} is calculated by subtracting the hydrodynamic load: F_{HYD} from the minimum friction force: F_{fmin_DI}.

For 30 inch Ductile Iron Pipe

$$F_{fmin\_DI30} = 9348 \cdot lbf$$

$$F_{fS\_DI30} := F_{fmin\_DI30} - F_{HYD\_30} \qquad F_{fS\_DI30} = 9112 \cdot lbf$$

For 36 inch Ductile Iron Pipe

$$F_{fmin\_DI36} = 9331 \cdot lbf$$

$$F_{fS\_DI36} := F_{fmin\_DI36} - F_{HYD\_36} \qquad F_{fS\_DI36} = 9192 \cdot lbf$$

4.4.2 Allowable Sleeve Seismic Axial Acceleration

The allowable local acceleration at the sleeve is a function of the weight of the sleeve and the friction force available to resist the movement. A= F/m

For 30 inch Ductile Iron Pipe

$W_{hs} = 110 \cdot lbf$ sheet 9

$$A_{S\_DI30} := \frac{F_{fS\_DI30}}{\frac{W_{hs}}{g}} \qquad A_{S\_DI30} = 82.8 \cdot g$$

For 36 inch Ductile Iron Pipe

$$A_{S\_DI36} := \frac{F_{fS\_DI36}}{\frac{W_{hs}}{g}} \qquad A_{S\_DI36} = 83.6 \cdot g$$

These calculated allowable accelerations are greater than the maximum ground accelerations required for Class I structures in the design basis, CCNPP "Civil and Structural Design Criteria", Reference 15.

4.5 Check of Sleeve for Abnormal Loading Condition

The abnormal configuration is assumed to occur if some of the retaining bands were to fail leaving the sleeve held in place by only one band. The worst case event would occur if one or more of the upstram bands failed, resulting in the sleeve folding back over the remaining downstream band. This would result in an increase in hydrodynamic drag with the potential for the sleeve to become dislodged and clog the pipe. The calculation conservatively assumes that the friction force from a single retaining band resists the hydrodynamic forces.

This condition is determined by first finding the hydraulic load.

For 30 inch Pipe

The pipe inside diameter is:

$$D_{pi\_30} = 30.9 \cdot in$$

The diameter of the orifice created by the folded over sleeve is:

$$t_{fold} := 2t_{ws} + t_{rb} + t_{pt}$$

$$t_{fold} = 0.975 \cdot in$$

The folded over sleeve thickness is based on 2 layers of gasket material, the retaining band, and the push tab.

$$D_{ab\_30} := D_{pi\_30} - 2t_{fold} \qquad D_{ab\_30} = 28.95 \cdot in$$

$F_{ab\_30} := \frac{\pi}{4}\cdot(D_{ab\_30})^2$ $\quad F_{pi\_30} = 749.906\cdot in^2$ Cross-sectional areas of the folded section and the pipe.

$D_{hab\_30} := 4\cdot\frac{F_{ab\_30}}{\pi D_{ab\_30}}$ $\quad D_{hab\_30} = 28.95\cdot in$ Hydraulic Diameter of the folded section.

$L_{ab\_30} := \frac{L_{ws}}{D_{hab\_30}}$ $\quad L_{ab\_30} = 0.684$

$\tau_{ab\_30} := 0.6384$ From figure in diagram 4-12 of [Ref 11] τ is found from L_{ab}.

Hydraulic loss for sleeve, represented as a thick edged orifice [Ref 11]
Check applicability of formula:

check1 := if($L_{ab\_30} > 0.015$,"formula applicable","out of bounds") check1 = "formula applicable"

check2 := if($Re_{pipe\_30} > 10^5$,"formula applicable","out of bounds") check2 = "formula applicable"

$$Kab_{o\_30} := 0.5\cdot\left(1-\frac{F_{ab\_30}}{F_{pi\_30}}\right)+\left(1-\frac{F_{ab\_30}}{F_{pi\_30}}\right)^2+\tau_{ab\_30}\cdot\sqrt{1-\frac{F_{ab\_30}}{F_{pi\_30}}}\cdot\left(1-\frac{F_{ab\_30}}{F_{pi\_30}}\right)$$

$Kab_{o\_30} = 0.103$

The pressure drop across the sleeve in the folded over condition is therefore:

$\Delta P_{ab\_30} := \rho_{wtr\_70F}\cdot Kab_{o\_30}\cdot\frac{V_{pipe\_30}^2}{2}$ $\quad \Delta P_{ab\_30} = 0.203\cdot psi$

The hydrodynamic drag on the sleeve for the abnormal condition is therefore:

$F_{HYD\_ab\_30} := 2\cdot\Delta P_{ab\_30}\cdot\pi\cdot\frac{D_{pi\_30}^2}{4}$ $\quad F_{HYD\_ab\_30} = 305\cdot lbf$ Including an impact factor of 2.

The hydrodynamic load of is much lower than the minimum friction force between the sleeve and pipe, see sec. 4.2.2. Therefore the 30-inch repair is acceptable for abnormal hydrodynamic loads.

For 36 inch Pipe

The pipe inside diameter is:

$$D_{pi\_36} = 37.04 \cdot in$$

The diameter of the orifice created by the folded over sleeve is:

$$t_{fold} := 2t_{ws} + t_{rb} + t_{pt}$$

$$t_{fold} = 0.975 \cdot in$$

The folded over sleeve thickness is based on 2 layers of gasket material, the retaining band, and the push tab.

$$D_{ab\_36} := D_{pi\_36} - 2t_{fold} \qquad D_{ab\_36} = 35.09 \cdot in$$

$$F_{ab\_36} := \frac{\pi}{4} \cdot \left(D_{ab\_36}\right)^2 \qquad F_{pi\_36} = 1.078 \times 10^3 \cdot in^2$$

Cross-sectional areas of the folded section and the pipe.

$$D_{hab\_36} := 4 \cdot \frac{F_{ab\_36}}{\pi D_{ab\_36}} \qquad D_{hab\_36} = 35.09 \cdot in$$

Hydraulic Diameter of the folded section.

$$L_{ab\_36} := \frac{L_{ws}}{D_{hab\_36}} \qquad L_{ab\_36} = 0.564$$

$$\tau_{ab\_36} := 0.8764$$

From figure in diagram 4-12 of [Ref 11] τ is found from L_{ab}.

Hydraulic loss for sleeve, represented as a thick edged orifice [Ref 11]
Check applicability of formula:

$$check1 := if\left(L_{ab\_36} > 0.015, \text{"formula applicable"}, \text{"out of bounds"}\right) \qquad check1 = \text{"formula applicable"}$$

$$check2 := if\left(Re_{pipe\_36} > 10^5, \text{"formula applicable"}, \text{"out of bounds"}\right) \qquad check2 = \text{"formula applicable"}$$

$$Kab_{o\_36} := 0.5 \cdot \left(1 - \frac{F_{ab\_36}}{F_{pi\_36}}\right) + \left(1 - \frac{F_{ab\_36}}{F_{pi\_36}}\right)^2 + \tau_{ab\_36} \cdot \sqrt{1 - \frac{F_{ab\_36}}{F_{pi\_36}}} \cdot \left(1 - \frac{F_{ab\_36}}{F_{pi\_36}}\right)$$

$$Kab_{o\_36} = 0.091$$

The pressure drop across the sleeve in the folded over condition is therefore:

$$\Delta P_{ab\_36} := \rho_{wtr\_70F} \cdot Kab_{o\_36} \cdot \frac{V_{pipe\_36}^{2}}{2} \qquad \Delta P_{ab\_36} = 0.086 \cdot psi$$

The hydrodynamic drag on the sleeve for the abnormal condition is therefore:

$$F_{HYD\_ab\_36} := 2 \cdot \Delta P_{ab\_36} \cdot \pi \cdot \frac{D_{pi\_36}^{2}}{4} \qquad F_{HYD\_ab\_36} = 186 \cdot lbf$$

Including an impact factor of 2.

The hydrodynamic load of is much lower than the minimum friction force between the sleeve and pipe, see sec. 4.2.2. Therefore the 36-inch repair is acceptable for abnormal hydrodynamic loads.

<u>For 30 inch Ductile Iron Pipe</u>

$$\frac{F_{fmin\_DI30}}{F_{HYD\_ab\_30}} = 30.6$$ >>1 no slippage will occur during system operation with the sleeve folded over.

<u>For 36 inch Ductile Iron Pipe</u>

$$\frac{F_{fmin\_DI36}}{F_{HYD\_ab\_36}} = 50.1$$ >>1 no slippage will occur during system operation with the sleeve folded over.

4.6 Check Backing Plate

4.6.1 Critical flaw size calculated via membrane stress

In as much as the backing plate extends beyond the edge of the flaw and is fixed by the retaining bands and operating pressure of the system, it is reasonable to treat the reinforcement as a fixed support. Using calculation of the critical flaw size in this manner yields the following result:

$$M_c = \frac{P_d \cdot d_{flaw}^2 \cdot (1 + \nu)}{16 \cdot 4} = 1.016 d_{flaw}^2 \qquad M_r = \frac{-P_d \cdot d_{flaw}^2}{8 \cdot 4} = -1.563 d_{flaw}^2$$

Therefore, $\sigma_{max} = \frac{6 \cdot M_r}{thk_{back}^2} = 2622.45 d_{flaw}^2$

for $\sigma_{max} < S_h$ it is required that, $d_{flaw} < \sqrt{\frac{S_h}{2622.45}} = 3.09in$

The critical flaw size is: $d_{flaw} := 3.09in$

4.7 Cyclic Fatigue

The Stainless Steel type AL6XN retaining bands were evaluated due to the thermal fatigue over the design temperature range of the system (Section 3.1)

For 30 inch Ductile Iron Pipe

$$\text{Stress\_Range\_DI30} := \sigma_{TH\_DI30_1} - \sigma_{TH\_DI30_0} \qquad \text{Stress\_Range\_DI30} = 3882 \cdot psi$$

$$S_{ALT\_DI30} := \frac{\sigma_{TH\_DI30_1} - \sigma_{TH\_DI30_0}}{2} \qquad S_{ALT\_DI30} = 1941 \cdot psi$$

Per inspection of the design fatigue curve (Fig. I-9.2.1 Ref.13), the number of cycles for

$S_{ALT\_DI30} = 1941 \cdot psi$ **is well above 10,000 cycles**

For 36 inch Ductile Iron Pipe

$$\text{Stress\_Range\_DI36} := \sigma_{TH\_DI36_1} - \sigma_{TH\_DI36_0} \qquad \text{Stress\_Range\_DI36} = 3919 \cdot psi$$

$$S_{ALT\_DI36} := \frac{\sigma_{TH\_DI36_1} - \sigma_{TH\_DI36_0}}{2} \qquad S_{ALT\_DI36} = 1959 \cdot psi$$

Per inspection of the design fatigue curve (Fig. I-9.2.1 Ref.13), the number of cycles for

$S_{ALT\_DI36} = 1959 \cdot psi$ **is well above 10,000 cycles**

Similarly the pressure cyclic range of 25 psi will induce negligible stress in the components and thus is also well within the Design Fatigue curve.

The EPDM rubber has an elongation of 350% per ASTM 412. This elongation of a non metallic material as well as its characteristic for high longevity due to its flexibility provide for the rubber gasket to have a fatigue life greater than the 10,000 cycles.

5.0 Conclusion:

This evaluation of the proposed sleeve assemblies indicates that the assemblies are acceptable for installation in the Calvert Cliffs Nuclear power station Service Water system noting the assumptions stated. Also one retaining band is capable of resisting hydrodynamic drag loads therefore 4 retaining bands are very conservative. The following summarize the results of the calculation.

- the maximum compressive stress at the installation in the retaining band is:

$$\sigma_{c\_chk} = 20936 \cdot psi$$

This is $\frac{\sigma_{c\_chk}}{S_h} = 83.7 \cdot \%$ of allowable stress

- The required minimum wall thickness of the host pipe to support sleeve assemblies, The host pipe is either 30" with a wall thickness of 0.55 inches or 36" with a wall thickness of 0.63 inches.

For 30/36 inch Ductile Iron Host Pipe

$$t_{DI\_30min} = 0.326 \cdot in$$

$$t_{DI\_36min} = 0.348 \cdot in$$

- The minimum friction force available force between the sleeve and the pipe wall to resist seismic and hydrualic loads follows. Note that this conservatively considers only one of the four retaining bands.

For 30 inch Ductile Iron Pipe

$$F_{fS\_DI30} = 9112 \cdot lbf$$

For 36 inch Ductile Iron Pipe

$$F_{fS\_DI36} = 9192 \cdot lbf$$

- For maximum system flow conditions, the hydrodynamic load on the assembly, including an impact of 2, is:

For 30 inch Pipe

$$F_{HYD\_30} = 236 \cdot lbf$$

For 36 inch Pipe

$$F_{HYD\_36} = 139 \cdot lbf$$

- If the sleeve inverts, the hydrodynamic load on the sleeve assembly for this abnormal condition is:

For 30 inch Ductile Iron Pipe

$$F_{HYD\_ab\_30} = 305 \cdot lbf$$

$$\frac{F_{fmin\_DI30}}{F_{HYD\_ab\_30}} = 30.6$$

For 36 inch Ductile Iron Pipe

$$F_{HYD\_ab\_36} = 186 \cdot lbf$$

$$\frac{F_{fmin\_DI36}}{F_{HYD\_ab\_36}} = 50.1$$

Therefore, since the hydrodynamic load on the sleeve assemblies is significantly less than the friction force between the sleeve and the pipe. The sleeve will remain stationary for the evaluated scenarios.

Note that this conservatively considers only one of the four retaining bands.

- The axial direction seismic acceleration required to dislodge the sleeve assembly is:

$A_{S\_DI30} = 82.8 \cdot g$ $\quad$ $A_{S\_DI36} = 83.6 \cdot g$

This is significantly greater than common peak spectra accelerations. Therefore the assembly is seismically acceptable.

- The EPDM rubber gasket and retaining bands can withstand 10,000 cyclic movements.

$Elongation := 350 \cdot \%$ At this elongation 10,000 cycles is not limiting ref ASTM D-412.

$S_{ALT\_DI30} = 1941 \cdot psi$ $\quad$ $S_{ALT\_DI36} = 1959 \cdot psi$

This alternating stress is well below the endurance limit [Ref. 13]

Calculation Results Summary Table for Ductile Iron Pipe

	30 inch Ductile Iron	36 inch Ductile Iron
Maximum compressive stress of yield stress at installation in retaining band	$\frac{\sigma_{c\_chk}}{S_y} = 46.5 \cdot \%$	$\frac{\sigma_{c\_chk}}{S_y} = 46.5 \cdot \%$
Required minimum wall thickness of the host pipe to support sleeve assemblies	$t_{DI\_30min} = 0.326 \cdot in$	$t_{DI\_36min} = 0.348 \cdot in$
Minimum friction force available between the sleeve and the pipe wall to resist seismic and hydrualic loads follows	$F_{fS\_DI30} = 9112 \cdot lbf$	$F_{fS\_DI36} = 9192 \cdot lbf$
Hydrodynamic load on the assembly with an impact of 2	$F_{HYD\_30} = 236 \cdot lbf$	$F_{HYD\_36} = 139 \cdot lbf$
Hydrodynamic load on the assembly with an impact of 2 at sleeve invert condition	$F_{HYD\_ab\_30} = 305 \cdot lbf$	$F_{HYD\_ab\_36} = 186 \cdot lbf$
Axial direction seismic acceleration required to dislodge sleeve assembly	$A_{S\_DI30} = 82.8 \cdot g$	$A_{S\_DI36} = 83.6 \cdot g$
Alternating stress due to thermal fatigue	$S_{ALT\_DI30} = 1941 \cdot psi$	$S_{ALT\_DI36} = 1959 \cdot psi$
Maximum flaw size at operating pressure	$d_{flaw} := 3.09in$	$d_{flaw} = 3.09 \cdot in$

6.0 References

1. Altran Solutions Proposal No. P11-2357-00 Final Rev-1, "Contingent Repairs for the 30 Inch and 36 Inch Diameter Ductile Iron Pipe for the Safety Related Service Water System", September 27, 2011.

2. HydraTech Engineered Products, Typical Circumferential Cross Section, Drawing No. HT-STD-06A. (see Attachment A).

3. Calvert Cliffs Nuclear Power Plant, "Minimum Wall Thickness for Salt Water System Underground Piping Per AWWA Code", Cal. No. C-92-98, May 11, 1992.

4. M. Lindeburg, *Mechanical Engineering Reference Manual, 8th Edition*, 1990.

5. USAS B31.1 *Power Piping Code*, 1967.

6. RathGibson, Physical Properties of 6XN Alloys in the Annealed Condition at -20°F to +100°F, http://www.rathgibson.com/products_by_alloy/super_austenitic/6xn.aspx. (see Attachment B).

7. F. Kreith, *Principles of Heat Transfer, 2nd ed.,* Scranton Pa., International Textbook Co, 1965.

8. HydraTech Engineered Products, Hydratite Double Wide Seal, Drawing No. HT-STD-03. (see Attachment A)

9. Email conversation, From Mike Fox [mailto:mike.fox@hydratechllc.com] to Hammelmann Robert, Subject: RE: Hydraulic loading during installation., November 30, 2011 4:35 PM. (see Attachment C)

10. Altran Solutions Installation Procedure No. 11-2357-P-004 Rev. 1, "Installation Procedure For 30" and 36" Diameter Internal Sleeve Piping Repair Systems", December 2011.

11. Erwin Fried and I.E. Idelchick, *Flow Resistance: A Design Guide for Engineers, 2nd Edition*, Pages 87 and 85, 1989. (see Attachment B)

12. *Marks Standard Handbook of Mechanical Engineers*, McGraw Hill, 10th Edition, 1996.

13. ASME Section III, Appendices I, Figure I-9.2.1., Design Fatigue curve,1989.

14. W.C. Young, and R.G. Budynas, *Roark's Formulas for Stress and Strain, 7th Edition*, McGraw-Hill, 2002.

15. Calvert Cliffs Nuclear Power Plant, "Civil and Structural Design Criteria", ES-005, Rev 0.

16. CCNPP, "Specification for Salt Water System Pipe and Fittings", Spec. 6750-M-265, Rev. 3. Bechtel, 1969-11-21.

17. CCNPP, "M-601 Piping Class Summary Sheets", BG&E Document 92769, Rev. 49. (see Attachment D)

18. CCNPP, "Saltwater System", *Calvert Cliffs UFSAR*, Section 9.5.2.3, Rev. 37.

19. CIPRA, *Cast Iron Pipe Research Association (CIPRA) Guide to Installation of Ductile Iron Pipe,*1972. (see Attachment B)

20. ASTM Standard B 688 - 96 (Reapproved 2004), Standard Specification for Chromium-Nickel-Molybdenum-Iron (UNS N08366 and UNSN08367) Plate, Sheet, and Strip, 2004.

21. CCNPP, "M-600 Piping Class Summary Sheets", BG&E Document 92767-A, Rev. 44.

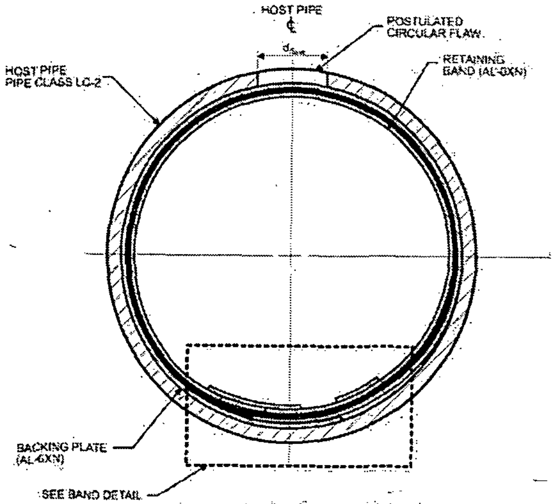
22. Email from E. Hussain (CENG) to R. Hammelmann (Altran) dated 2012-02-21, 15:53, Subject: "FW: Important message from Constellation Energy".

23. ANSI A21.50, *American National Standard for the Thickness Design of Ductile-Iron Pipe*, 1967, 1976.

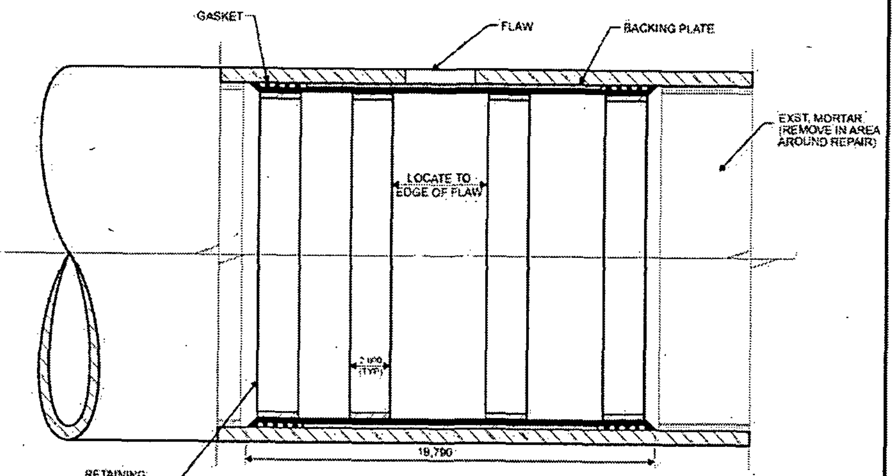
24. ANSI A21.51, *American National Standard for Ductile-Iron Pipe, Centrifugally Cast*, 1981.

ATTACHMENT A

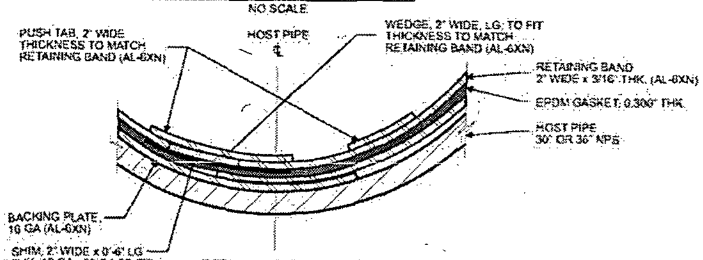
Design Sketches



CIRCUMFERENTIAL CROSS SECTION
NO SCALE



LONGITUDINAL CROSS SECTION
NO SCALE



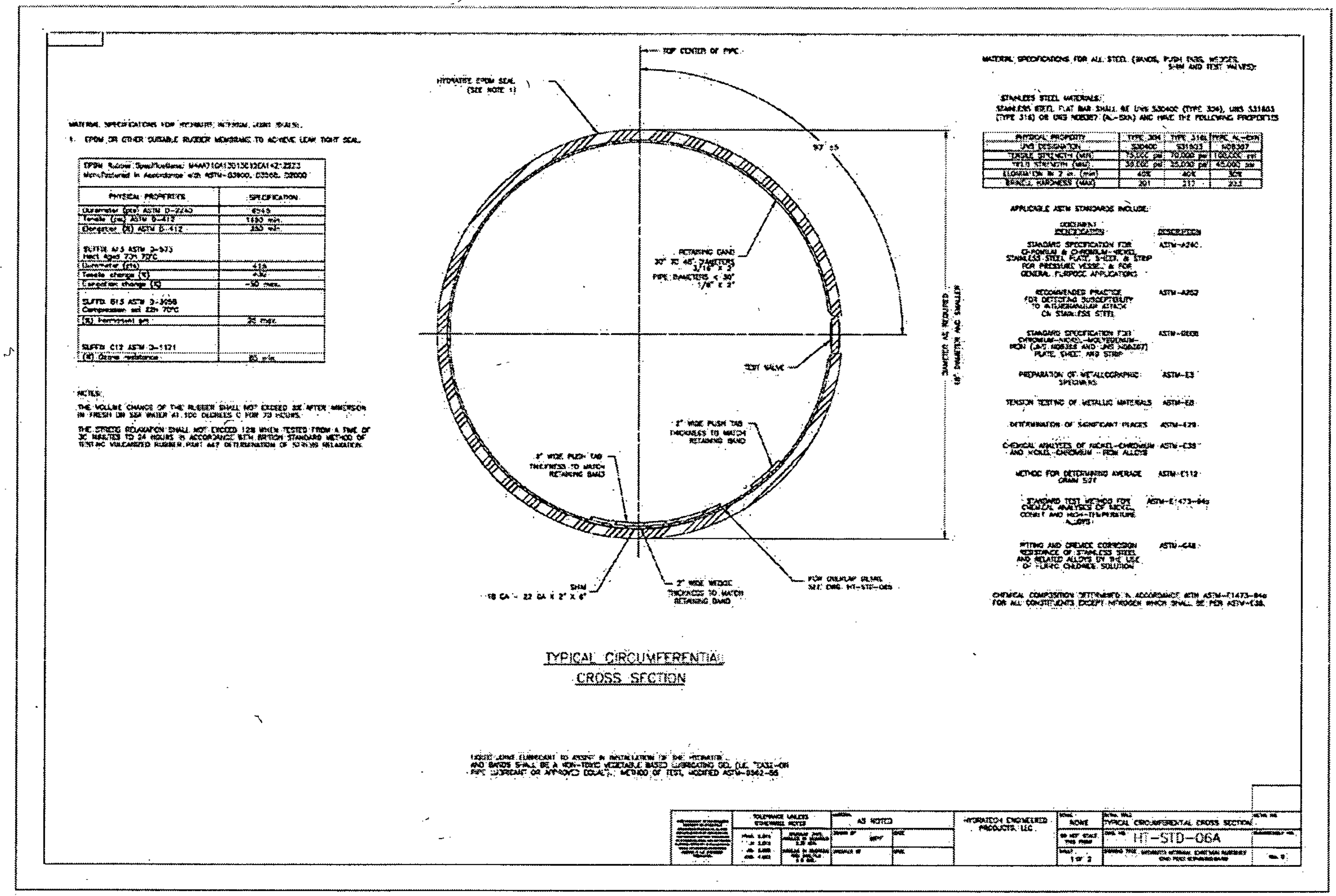
RETAINING BAND DETAIL
NO SCALE

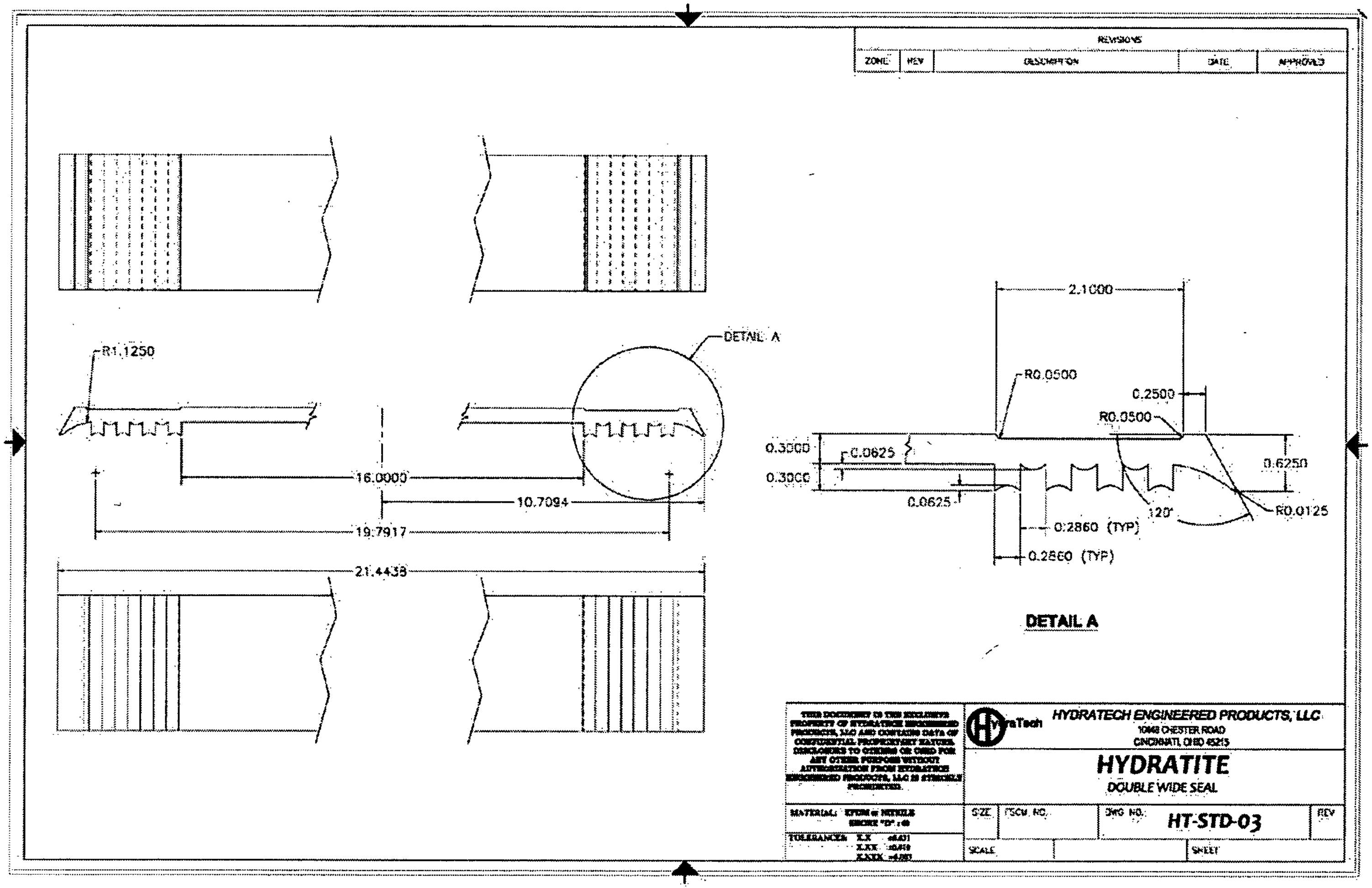
HOST PIPE OD	32.00"	38.30"
HOST PIPE WALL THICKNESS	0.55"	0.63"
RETAINING BAND OD	29.80"	35.94"
RETAINING BAND THICKNESS	0.1875"	
GASKET LENGTH	19.79"	
GASKET THICKNESS	0.300"	

NOTES:

1. FOR VERIFICATION OF CRITICAL DIMENSIONS ONLY.
2. WORK WITH CALCULATION 11-2357-C-001
3. BACKING PLATE OVERLAP SHOULD BE LOCATED ON OPPOSITE SIDE OF THE HOST PIPE FROM THE FLAW.

altran	CLIENT	TITLE	DRAWING NO.	SHEET OF	REV.
	CALVERT CLIFFS NPP	INTERNAL SLEEVE REPAIR SYSTEM	11-2357-C-001, M-1	1 1	0


TOP CENTER OF PIPE
TEST VALVE
TYPICAL CIRCUMFERENTIAL CROSS SECTION
AS NOTED
NONE
HT-STD-06A


REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
R1.1250
DETAIL A
16.0000
10.7094
19.7917
21.4438
2.1000
R0.0500
0.2500
R0.0500
0.3000
0.3000
0.0625
0.0625
0.6250
120°
R0.0125
0.2860 (TYP)
0.2860 (TYP)
DETAIL A
HYDRATECH ENGINEERED PRODUCTS, LLC
CINCINNATI, OHIO 45215
HYDRATITE
DOUBLE WIDE SEAL
SIZE
FSCM NO.
DWG NO.
HT-STD-03
REV
SCALE
SHEET

ATTACHMENT B

Miscellaneous Information

RathGibson

make the connection

Home : Products by Alloy : Super Austentic : 6-Moly : 6XN

6XN

Physical Properties of 6XN Alloys in the Annealed Condition at -20°F to +100°F

			Tensile Strength			Yield Strength								
Alloy	UNS Designation	Spec.	psi	MPa	ksi	psi	MPa	ksi	Elongation in 2 in. (min.) %	Grain Size Req.	Max. Hardness	Modulus of Elasticity ($x10^6$ psi)	Mean Coefficient of Thermal Expansion (IN./IN./°F x 10^{-6})	Thermal Conductivity (BTU-in/ft^2-h-°F)
6XN	N08367	B675	100,000	690	100	45,000	310	45	30	—	—	28.3	8.5	116

Figure 1. AL6XN Material Mean Coefficient of Thermal Expasion from RathGibson. (Reference 6: http://www.rathgibson.com/products_by_alloy/super_austenitic/6xn.aspx)

Standard Dimensions and Weights of Mechanical-Joint Ductile-Iron Pipe (contd.)

Size, *in.*	Thickness Class	Thickness *in.*	OD* *in.*	Wt. of Barrel Per Ft *lb*	Wt. of Bell† *lb*	18-Ft Laying Length Wt. Per Lgth.‡ *lb*	18-Ft Laying Length Avg. Wt. Per Ft§ *lb*	20-Ft Laying Length Wt. Per Lgth.‡ *lb*	20-Ft Laying Length Avg. Wt. Per Ft§ *lb*
18	1	0.38	19.50	69.8	111	1,365	76.0	1,505	75.4
18	2	0.41	19.50	75.2	111	1,465	81.4	1,615	80.8
18	3	0.44	19.50	80.6	111	1,560	86.8	1,725	86.2
18	4	0.47	19.50	86.0	111	1,660	92.2	1,830	91.6
18	5	0.50	19.50	91.3	111	1,755	97.5	1,935	96.8
18	6	0.53	19.50	96.7	111	1,850	102.9	2,045	102.2
20	1	0.39	21.60	79.5	131	1,560	86.8	1,720	86.0
20	2	0.42	21.60	85.5	131	1,670	92.8	1,840	92.0
20	3	0.45	21.60	91.5	131	1,780	98.8	1,960	98.0
20	4	0.48	21.60	97.5	131	1,885	104.8	2,080	104.0
20	5	0.51	21.60	103.4	131	1,990	110.7	2,200	110.0
20	6	0.54	21.60	109.3	131	2,100	116.6	2,315	115.8
24	1	0.41	25.80	100.1	174	1,975	109.8	2,175	108.8
24	2	0.44	25.80	107.3	174	2,105	117.0	2,320	116.0
24	3	0.47	25.80	114.4	174	2,235	124.1	2,460	123.1
24	4	0.50	25.80	121.6	174	2,365	131.3	2,605	130.3
24	5	0.53	25.80	128.8	174	2,490	138.5	2,750	137.5
24	6	0.56	25.80	135.9	174	2,620	145.6	2,890	144.6
30	1	0.43	32.00	130.5	216	2,565	142.5	2,825	144.3
30	2	0.47	32.00	142.5	216	2,780	154.5	3,065	153.3
30	3	0.51	32.00	154.4	216	2,995	166.4	3,305	165.2
30	4	0.55	32.00	166.3	216	3,210	178.3	3,540	177.1
30	5	0.59	32.00	178.2	216	3,425	190.2	3,780	189.0
30	6	0.63	32.00	190.0	216	3,635	202.0	4,015	200.8
36	1	0.48	38.30	174.5	310	3,450	191.7	3,800	190.0
36	2	0.53	38.30	192.4	310	3,775	209.6	4,160	207.9
36	3	0.58	38.30	210.3	310	4,095	227.5	4,515	225.8
36	4	0.63	38.30	228.1	310	4,415	245.3	4,870	243.6
36	5	0.68	38.30	245.9	310	4,735	263.1	5,250	261.4
36	6	0.73	38.30	263.7	310	5,055	280.9	5,585	279.2
42	1	0.53	44.50	224.0	405			4,885	244.2
42	2	0.59	44.50	249.1	405			5,385	269.4
42	3	0.65	44.50	274.0	405			5,885	294.2
42	4	0.71	44.50	298.9	405			6,385	319.2
42	5	0.77	44.50	323.7	405			6,880	344.0
42	6	0.83	44.50	348.4	405			7,375	368.6
48	1	0.58	50.80	280.0	505			6,105	305.2
48	2	0.65	50.80	313.4	505			6,775	338.6
48	3	0.72	50.80	346.6	505			7,435	371.8
48	4	0.79	50.80	379.8	505			8,100	405.0
48	5	0.86	50.80	412.9	505			8,765	438.2
48	6	0.93	50.80	445.9	505			9,425	471.2

* Tolerances of OD of spigot end: 3–12 in., ±0.06 in.; 14–24 in., +0.05 in., −0.08 in.; 30–48 in., +0.08 in., −0.06 in.

† The mechanical joint bell for 30–48-in. sizes of ductile-iron pipe have thicknesses different from those shown in ANSI A21.11 (AWWA C111), which are based on gray-iron pipe. These reduced thicknesses provide a lighter weight bell, which is compatible with the wall thicknesses of ductile-iron pipe. The internal socket dimensions, bolt circle, and bolt holes of the redesigned bell remain identical to those specified in A21.11 (AWWA C111) to assure interchangeability of the joint.

‡ Including bell; calculated weight of pipe rounded off to nearest 5 lb.

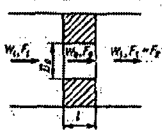
§ Including bell; average weight per foot, based on calculated weight of pipe before rounding.

76

Figure 2. Standard Dimensions and Weights of Mechanical-Joint Ductile-Iron Pipe from Cast Iron Pipe Research Association (Birmingham, AL).

Thick-edged orifice ($l/D_h > 0.015$) in a straight tube (channel); $\mathrm{Re} = w_0 D_h/\nu > 10^4$ [13, 14]

Diagram 4-15



$$D_h = \frac{4F_0}{\Pi_0}$$

$$\zeta_1 = \frac{\Delta p}{\rho w_1^2/2} \approx \left[\left(0.5 + \tau\sqrt{1 - \frac{F_0}{F_1}}\right)\left(1 - \frac{F_0}{F_1}\right) + \left(1 - \frac{F_0}{F_1}\right)^2 + \lambda \frac{l}{D_h}\right]\left(\frac{F_1}{F_0}\right)^2 = \left(\zeta_0 + \lambda \frac{l}{D_h}\right)\left(\frac{F_1}{F_0}\right)^2$$

where $\tau = f(l/D_h)$, see the table below or graph a of Diagram 4-12;

$$\zeta_0 = 0.5\left(1 - \frac{F_0}{F_1}\right) + \left(1 - \frac{F_0}{F_1}\right)^2 + \tau\sqrt{1 - \frac{F_0}{F_1}}\left(1 - \frac{F_0}{F_1}\right);$$ for λ

see Chapter 2 at $\lambda = 0.02$ for the values of $\zeta_1 = f(l/D_h\, F_0/F_1)$ see the graph

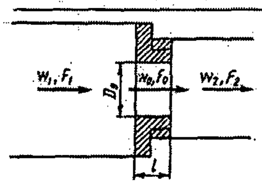
Values of ζ

$\frac{l}{D_h}$	τ	F_0/F_1														
		0.02	0.04	0.06	0.08	0.10	0.15	0.20	0.25	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.0
0	1.35	7000	1670	730	400	245	96.0	51.5	30.0	18.2	8.25	4.00	2.00	0.97	0.42	0.13	0
0.2	1.22	6600	1600	687	374	230	94.0	48.0	28.0	17.4	7.70	3.75	1.87	0.91	0.40	0.13	0.01
0.4	1.10	6310	1530	660	356	221	89.0	46.0	26.5	16.6	7.40	3.60	1.80	0.88	0.39	0.13	0.01
0.6	0.84	5700	1380	590	322	199	81.0	42.0	24.0	15.0	6.60	3.20	1.60	0.80	0.36	0.12	0.01
0.8	0.42	4680	1130	486	264	164	66.0	34.0	19.6	12.2	5.50	2.70	1.34	0.66	0.31	0.11	0.02
1.0	0.24	4260	1030	443	240	149	60.0	31.0	17.8	11.1	5.00	2.40	1.20	0.61	0.29	0.11	0.02
1.4	0.10	3930	950	408	221	137	55.6	28.4	16.4	10.3	4.60	2.25	1.15	0.58	0.28	0.11	0.03
2.0	0.02	3770	910	391	212	134	53.0	27.4	15.8	9.90	4.40	2.20	1.13	0.58	0.28	0.12	0.04
3.0	0	3765	913	392	214	132	53.5	27.5	15.9	10.0	4.50	2.24	1.17	0.61	0.31	0.15	0.06
4.0	0	3775	930	400	215	132	53.8	27.7	16.2	10.0	4.60	2.25	1.20	0.64	0.35	0.16	0.08
5.0	0	3850	936	400	220	133	55.5	28.5	16.5	10.5	4.75	2.40	1.28	0.69	0.37	0.20	0.10
6.0	0	3870	940	400	222	133	55.8	28.5	16.6	10.5	4.80	2.42	1.32	0.70	0.40	0.21	0.12
7.0	0	4000	950	405	230	135	55.9	29.0	17.0	10.9	5.00	2.50	1.38	0.74	0.43	0.23	0.14
8.0	0	4000	965	410	236	137	56.0	30.0	17.2	11.2	5.10	2.58	1.45	0.78	0.45	0.25	0.16
9.0	0	4080	985	420	240	140	57.0	30.0	17.4	11.4	5.30	2.62	1.50	0.80	0.50	0.28	0.18
10	0	4110	1000	430	245	146	59.7	31.0	18.2	11.5	5.40	2.80	1.57	0.89	0.53	0.32	0.20

Figure 3. Coefficient of Fluid Resistance (pressure loss coefficient) in Thick-edged Orifice in a Straight Tube, Reference 11.

Thick-edged orifice ($l/D_h > 0.015$) installed in a transition section; $\mathrm{Re} = w_0 D_h/\nu > 10^5$ [13, 14]

Diagram 4-12



$$D_h = \frac{4F_0}{\Pi_0}$$

$$\zeta = \frac{\Delta p}{\rho w_0^2/2} \approx 0.05\left(1 - \frac{F_0}{F_1}\right) + \left(1 - \frac{F_0}{F_2}\right)^2 + \tau\sqrt{1 - \frac{F_0}{F_2}} \times \left(1 - \frac{F_0}{F_2}\right) + \lambda\frac{l}{D_h} = \zeta_0 + \lambda\frac{l}{D_h}$$

where $\tau = f(l/D_h)$; for λ see Chapter 2

$\frac{l}{D_h}$	0	0.2	0.4	0.6	0.8
τ	1.35	1.22	1.10	0.84	0.42
$\frac{l}{D_h}$	1.0	1.2	1.6	2.0	2.4
τ	0.24	0.16	0.07	0.02	0

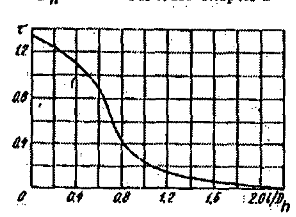


Figure 4. Coefficient of Fluid Resistance (pressure loss coefficient) in Thick-edged Orifice Installed in a Transition Section, Reference 11.

Excerpt from CIPRA, Guide to Installation of Ductile Iron Pipe, Cast Iron Pipe Research Assn, Oakbrook, IL 1972 (Reference 19)

USEFUL INFORMATION

WEIGHTS OF DUCTILE IRON PIPE AND CONTAINED WATER

Pipe Size In.	Weight-lb./ft. (Push-on Joint)	
	Pipe (Wp)*	Water (Ww)#
3	10	3
4	13	6
6	21	12
8	30	22
10	39	34
12	49	49
14	56	67
16	65	88
18	75	110
20	86	136
24	109	196
30	139	307
36	185	422
42	237	601
48	296	785
54	371	993

*Based on Class 2 push-on joint ductile iron pipe in 20 ft. lengths.

#Based on nominal pipe size.

USEFUL INFORMATION

LINEAR EXPANSION OF CUTILE IRON PIPE

The coefficient of linear expansion of ductile iron may be taken as 0.0000062 per degree Fahrenheit. The expansion or contraction in inches that will take place in a line of given length with various temperature changes is shown in the following table:

Temp. Difference °F	LENGTH OF LINE IN FEET			
	100	500	1000	5280
5	0.037	0.19	0.37	1.96
10	0.014	0.37	0.74	3.93
20	0.149	0.74	0.15	7.86
30	0.223	1.12	2.23	11.78
40	0.298	1.49	2.98	15.71
50	0.372	1.86	3.72	19.64
60	0.446	2.23	4.46	23.57
70	0.520	2.60	5.20	27.50
80	0.595	2.98	5.95	31.43
90	0.670	3.35	6.70	35.35
100	0.744	3.72	7.44	39.28
120	0.893	4.46	8.93	47.14
150	1.116	5.58	11.16	58.92

72

Figure 5. Excerpt from CIPRA, Guide to Installation of Ductile Iron Pipe, Cast Iron Pipe Research Association, Oakbrook, IL, 1972, (Reference 19).

ATTACHMENT C

Email Correspondence

From: Mike Fox [mailto:mike.fox@hydratechllc.com]
Sent: Wednesday, November 30, 2011 4:35 PM
To: Hammelmann Robert
Subject: RE: Hydraulic loading during installation

Robert,

The recommended expander pressure is 3500 psi (for both sizes)

The cylinder bore size is 1.69" (typical expander). We do have a smaller expander with 1.00" cylinder

Based on the 1.69" cylinder and 3500 psi, the imposed pressure on pipe is estimated as follows:

Contact pressure on I.D of pipe for 30.4" = 260 psi
Contact pressure on I.D of pipe for 36.54" = 215 psi

Compression force on retaining band = 7850 psi

Michael Fox
HydraTech Engineered Products
Office: 513.827.9169
Mobile: 513.404.9701

Chock Alfred

From:	Hussain, Emran M <Emran.Hussain@cengllc.com>
Sent:	Tuesday, February 21, 2012 3:53 PM
To:	Hammelmann Robert
Cc:	Drake, Andre S
Subject:	FW: Important message from Constellation Energy
Attachments:	Document.pdf
Categories:	Blue Category

Bob,
1. For pressure, use Document 92769, rev. 49.2. Flow Rate use UFSAR rev. 43; Pump flow rate 2 x 20,000 gpm = 40,000 gpm which is slightly higher than your number.

Emran

-----Original Message-----
From: PRT4293 [mailto:PRT4293@ceg.corp.net]
Sent: Tuesday, February 21, 2012 3:50 PM
To: Hussain, Emran M
Subject: Important message from Constellation Energy

Please open the attached document. This document was digitally sent to you using an HP Digital Sending device.

ATTACHMENT D

Miscellaneous Calvert Cliffs Documents

CLASS & SERVICE NO.	SERVICE DESCRIPTION	DESIGN RATING		SERVICE CONDITIONS NORMAL		MAXIMUM		CURRENT CLASS FOR ASME XI PER REG GUIDE 1.26	ORIGINAL DESIGN CODE AND CLASS
		PSIG	°F	PSIG	°F	PSIG	°F		
LC-1	Plumbing and sanitary drains (underground outside building to treatment plant)	25	100					Non-Class	B31.1
LC-2	Salt Water system (underground)	50	95 *Note 110, 115*				*Note 110, 115*	Class III	B31.1
LC-3	Waste process effluent to circulating water discharge (underground)	60	130					Non-Class	B31.1
LC-4	Sewage treatment plant pump discharge	50	110	15	80			Non-Class	B31.1
LC-5	13.8 KV regulator pit drains	Atm.	100	Atm.	100			Non-Class	B31.1

NORMS Phantom Doc ID: 92769LC	M-601 Piping Class Summary Sheets Sheet No.: LC-1	Calvert Cliffs Unit 1 & 2 Constellation Nuclear

Figure 5. Calvert Cliffs M-601 Piping Class Summary Sheet No. LC-1 for Salt Water System (underground) Design Rating.