#### FEEDER GRAYLOC HUB LOCAL ALLOWABLE THICKNESS - AN APPLICATION OF FFSG APPENDIX E LEVEL 2 EVALUATION

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#### ABSTRACT

Flow assisted corrosion (FAC) caused the highest rates of wall loss at outlet feeder pipes in the regions close to the Grayloc end fittings. In the past, almost all stress analyses on reduced thickness, above or below pressure based value, were conducted based on ASME III Code compliance.

However, above assessments were feeders specific in nature and time consuming. For a large scale planned outage, more than several hundreds outlet feeder baseline and repeat inspections may be conducted. There is a reasonable risk that a number of feeders may be found with a wall thickness at or below the pressure based thickness. It is possible that unanticipated results from the inspection could extend the outage duration due to the need to perform unplanned stress analyses to demonstrate the fitness for service of the feeder pipes.

To be effective to prevent outage delay it is necessary to conduct a generic feeder structural integrity assessment prior to the start of the outage. FFSG Appendix E (**Reference 1**) provides acceptance criteria and evaluation procedure for assessing local thinning near the Grayloc region for thickness below pressure based value. The structural evaluation procedure in Appendix E is not feeder specific in such a preventive assessment could provide predetermined acceptable thickness limits to be compared with inspection data. The acceptable thickness limits shall result in significant reduction of feeder disposition time.

#### **1.0 INTRODUCTION**

In CANDU nuclear power plant, feeder pipes carry heavy water to and from the reactor fuel channels to remove heat produced by the fission of uranium fuel. The feeder pipes connect the inlet and outlet headers to the reactor core. The number of feeder pipes is in the range of 760 to 960 for various types of CANDU designs. The feeders are made of SA106 Grade B carbon steel. Feeder piping is designed to Class 1 piping requirements of the ASME Boiler and Pressure Vessel Code, Section III, Subsection NB and CSA Standards. In general, bends closest to the fuel channel connections represent the most critically stressed sections of feeder pipes. Severe wall loss due to FAC has been found in CANDU stations, the wall thickness reduction could be as high as the half of nominal wall values.

The thickness assessment is carried out to show whether or not the analyzed wall thickness values with excessive local thinning at the Grayloc would meet the Code requirements. The majority of feeder structural integrity assessments were based on ASME Section III, NB class 1 piping code (**Reference 2**) and CSA N289.3 for seismic requirements.

The procedures in ASME SEC III are developed for design analysis for new components, rather than for the in-service assessment for degraded feeder piping systems. The analysis rules and methods used in new component design by nature are overly conservative for in-service evaluation of feeder thinning. Feeders are inspected in accordance with the CSA Standards CAN/CSA-N285.4. When a detected wall thinning or a flaw does not satisfy the criteria of acceptance by examination in N285.4, the CSA code allows a fitness-for-service assessment to determine the acceptability for continue operation. FFSG provides the unique set of assessment rules with the consideration of feeder fabrication, design, configuration and degrade mechanisms. The assessment will be used to justify continued operation of feeders in degraded condition.

Appendix E of FFSG was developed to evaluate thinned region in feeder piping. It follows the methodologies of ASME Section XI. The evaluation procedures maintain the design intent margins of Section III. There are three levels of evaluation for internal pressure loading and pressure coincidence with bending moment respectively. Level 1 refers to ASME III NB-3640 and NB-3650 assessments. But it is not suitable when a local thickness is below the pressure base value. Level 3 is finite element based approach, including elastic, limited load and plastic-collapse analyses.

Level 2 evaluation consists of a set of closed form rules which were developed with the first principle and verified by extensive finite element modeling. It provides an easy-to-use and conservative tool for the fast disposition of adverse inspection results. This paper is to provide a proactive measure to develop a set of acceptable local thickness for piping section next to the feeder Grayloc hub, thus inspection results can be compared and be dispositioned. It would reduce the potential risk of outage delay due to adverse feeder thickness.

### 2.0 LEVEL 2 ASSESSMENT METHOD

The evaluation procedure is as per Article E-2 of FFSG Appendix E and shown in **Figure 1**. Level 2 evaluation on internal pressure and bending moment coincident with internal pressure were carried out in this paper.

### 2.1 Level 2 Structural Evaluation for Thinned Region for Internal Pressure Loading

The design pressure based minimum thickness  $(t_{min}^{sp})$  of NB-3641 is limited by hoop stress under internal pressure:

$$t_{\min}^{sp} = \frac{PD_o}{2(S_m + Py)},$$
(1)

where P – Internal Design Pressure,  $D_o$  – Outside diameter of feeder ( $R_o=D_o/2$ ),  $S_m$  – Y = 0.4

The minimum value of acceptable thickness for local thinning shall be greater than or equal to  $0.75 t_{min}^{sp}$  regardless the acceptance of the assessment, as limited by the line-in-granite rule in FFSG.

In Appendix E, a local thinning region is defined when a local wall thickness is less than the evaluation of wall thickness,  $t_{eval}$ , which is defined as 1.10  $t_{min}^{sp}$  or 1.13  $t_{min}^{sp}$ .  $L_{m(t)}$  is the circumferential extent of thickness less than  $t_{eval}$ .  $L_{m(a)}$  is the circumferential extent of thickness less than  $t_{eval}$ .  $L_{m(a)}$ , as shown in **Figure 2**. The separation distance for multiple local regions is  $2.5(R_{eval}t_{eval})^{0.5}$ , where  $R_{eval} = R_o - t_{eval}/2$ . Once multiple thinning regions are detected, the proximity rules should be checked against the separation distance, then the combination of thinning regions or single separate region can be evaluated accordingly. The acceptable thickness obtained in this paper is suitable for both combined and single thinning region.

The geometry characterization of thinning region is defined as  $(R_{min}t_{min})^{0.5}$ , where  $R_{min} (= R_o - t_{min}/2)$  is the mean radius of the piping item. There are three classifications of local thinned region geometry based on axial and circumferential extent. The allowable local wall thickness  $t_{aloc}$  is calculated using formulas or empirical curves defined in each category.

(a) *Limited Circumferential Extent (LC)*: when the circumferential extent,  $L_{m(t)}$ , of the local thinned region predicted to be less than  $t_{eval}$  does not exceed  $R_{min}t_{min}$ )<sup>0.5</sup>.

For a straight pipe, the ratio of  $t_{aloc}/t_{min}^{sp}$  can be calculated using following formula:

$t_{aloc}/t_{min}^{sp} = 0.75$	for $L_{m(a)}/(R_{min} t_{min}^{sp})^{0.5} < 2.75$	
$t_{aloc}/t_{min}^{sp} = 0.046*(x - 2.75) + 0.75$	for $2.75 \le x = L_{m(a)} / (R_{min} t_{min}^{sp})^{0.5} \le 6.0$ (2)	2)
$t_{aloc}/t_{min}^{sp}=0.9$	for $L_{m(a)}/(R_{min} t_{min}^{sp})^{0.5} > 6.0$	

(b) *Limited Axial and Circumferential Extent (LAC)*: when the maximum extent,  $L_{m(t)}$ , of local wall thickness predicted to be less than  $t_{eval}$  is less than or equal to  $2.65(R_{min}t_{min})^{0.5}$ .

For a straight pipe or bend, the ratio of  $t_{aloc}/t_{min}^{sp}$  is the maximum value of following three requirements:

(i). Protection against pressure blowout:

$$\frac{t_{aloc}}{t_{min}^{sp}} = 0.353 L_m \left(\frac{1}{R_{min} t_{min}^{sp}}\right)^{1/2}$$
(3)

(ii). Satisfy reinforcement requirement:

$$\frac{t_{aloc}}{t_{min}^{sp}} = 1 - 1.5 \frac{(R_{min} t_{min}^{sp})^{1/2}}{L} (\frac{t}{t_{min}^{sp}} - 1)$$
(4)

(iii). Line-in-Granite of FFSG for local thinning:

$$t_{aloc}/t_{min}^{sp} = 0.75$$
 (5)

(c) Unlimited Circumferential Extent (UC): when the circumferential extent,  $L_{m(t)}$ , of the local thinned region predicted to be less than  $t_{eval}$  exceeds to  $(R_{\min}t_{\min})^{0.5}$ .

For a straight pipe, the ratio of  $t_{aloc}/t_{min}^{sp}$  can be calculated using following formula:

$$t_{aloc}/t_{min}^{sp} = 0.75$$
 for  $x = L_{m(a)}/(R_{min}t_{min})^{0.5} < 0.725$ 

#### 2.2 Level 2 Structural Evaluation for Thinned Region for Applied Bending Moment and Coincident Internal Pressure Loading

The structure integrity is evaluated for membrane plus bending axial stress and membrane axial stress respectively. The geometry characterization of the circumferential cross-section of the straight pipe section of feeder pipe is illustrated in Figure 3. In this figure, the pipe original or nominal wall thickness t<sub>nom</sub> is assumed to have been uniformly thinned on the inside surface by FAC to a wall thickness t<sub>1</sub> (or t in equations below). The local thinning is characterized as having a uniform wall thickness  $t_2$  and a circumferential extent 2 $\theta$ . The depth of local thinning is  $a = t_1$   $t_2$ 

#### 2.2.1 **Membrane plus Bending Axial Stress**

For each ASME III Level A, B C, and D loading under evaluation, the following criterion shall be satisfied:

$$\sigma_b^p \le \frac{1}{SF_b} (\sigma_b^c - \sigma_b^s) - \sigma_m^{p^*} (1 - \frac{1}{SF_m})$$
(7)

where SF<sub>b</sub> - structural factor on primary bending moment

SF<sub>m</sub> - structural factor on internal pressure or primary axial force

#### The nominal bending axial stress $\sigma_b^c$ at net-section collapse (i).

$$\sigma_{\rm b}^{\rm c} = \frac{{\sf M}_{\rm nsc}{\sf R}_0}{{\sf I}} \tag{8}$$

Bending moment corresponding to a state of net-section collapse of a straight section  $(M_{nsc})$  is calculated as following:

Short thinning region: for thinned region not penetrating the compressive region of the (a). cross section such that  $\theta + \beta \le \pi$ , the bending moment at net-section is given by

$$M_{nsc} = M_{o} \left\{ \sin\beta - \frac{1}{2} [1 - (1 + \alpha \frac{a}{D})^{2} (1 - \frac{a}{t})] \sin\theta \right\}$$
(9)  
where
$$\beta = \frac{\pi}{2} \left\{ 1 - \frac{\theta}{\pi} \frac{a}{t} \left[ 1 - \alpha \frac{t}{D} (1 - \frac{a}{t}) \right] - \left( \frac{P^{*}}{P_{o}} + \frac{F_{p}}{F_{o}} \right) \right\},$$

 $F_{p}$  – Primary axial force,  $\alpha = 1$ 

(b). Long thinning region: for thinned region penetrating the compressive region of the cross section such that  $\theta + \beta > \pi$ , the bending moment at net-section is given by

$$M_{nsc} = M_{o} \left\{ (1 + \alpha \frac{a}{D})^{2} (1 - \frac{a}{t}) \sin \beta - \frac{1}{2} [1 - (1 + \alpha \frac{a}{D})^{2} (1 - \frac{a}{t})] \sin \theta \right\}$$
(10)  
where 
$$\beta = \frac{\frac{\pi}{2} \left\{ 1 - (2 - \frac{\theta}{\pi}) \frac{a}{t} \left[ 1 - \alpha \frac{t}{D} (1 - \frac{a}{t}) \right] - (\frac{P^{*}}{P_{o}} + \frac{F_{p}}{F_{o}}) \right\}}{1 - \frac{a}{t} [1 - \alpha \frac{t}{D} (1 - \frac{a}{t})]}$$

t

and 
$$P_o = 4\sigma_f \frac{\frac{t}{D}}{(1-\frac{t}{D})^2}$$
,  $F_o = \pi D t \sigma_f$ ,  $M_o = D^2 t \sigma_f$ ,  $\lambda = 2\alpha (1+\alpha) \frac{\frac{t}{D}}{(1-\frac{t}{D})^2}$ 

$$P^{*} = P\left\{1 + \lambda \frac{\theta}{\pi} \frac{a}{t} \left[1 - \frac{t}{D} (1 - \frac{a}{t})\right]\right\}$$

mean diameter :  $D = D_o - t$ , flow stress :  $\sigma_f = \frac{\sigma_y + \sigma_u}{2}$ , inside area :  $A_i = \frac{\pi}{4}(D - t)^2$ 

The nominal primary and secondary bending axial stress  $\sigma_b^p$  and  $\sigma_b^s$  in the straight pipe (ii). section due to applied primary and secondary bending moment M<sub>p</sub> and M<sub>s</sub> are given by

$$\sigma_b^p = \frac{M_p R_0}{I}, \qquad \sigma_b^s = \frac{M_s R_0}{I}$$

$$I = \frac{\pi}{4} (R_o^4 - R_i^4)$$
(11)

The effective applied nominal primary membrane axial stress  $\sigma_m^{p^*}$  due to pressure, axial (iii). force is calculated by

$$\sigma_{\rm m}^{\rm p^{\star}} = \frac{{\rm P}^{\star}{\rm A}_{\rm i} + {\rm F}_{\rm p}}{\pi {\rm D} t} \tag{12}$$

#### 2.2.2 **Membrane Axial Stress**

For each ASME III Level A, B C, and D loading under evaluation, the following criterion shall be satisfied

$$\sigma_{\rm m}^{\rm p^{\rm c}} \le \frac{\sigma_{\rm m}^{\rm c}}{{\sf SF}_{\rm m}} \tag{13}$$

where the nominal membrane axial stress  $\sigma_m^{\ c}$  at net-section collapse with zero coincident bending stress is calculated by

 $\sigma_m^c$ 

$$\sigma_{m}^{c} = \sigma_{f} \left\{ 1 - \frac{\theta}{\pi} \frac{a}{t} \left[ 1 - \alpha \frac{t}{D} (1 - \frac{a}{t}) \right] - \frac{2}{\pi} \Phi \right\}$$
  
where  $\Phi = \sin^{-1} \left\{ \frac{1}{2} [1 - (1 + \alpha \frac{a}{D})^{2} (1 - \frac{a}{t})] \sin \theta \right\}$ 

(14)

#### 3.0 **DARLINGTON FEEDER INPUT DATA**

This section is to establish the various input parameters required to perform the structural integrity assessments of a postulated local thinning region below pressure based value in the vicinity of the Grayloc weld of Darlington outlet feeder pipes.

#### 3.1 **Feeder Pipe Geometric Data**

There are only two bend sizes of outlet feeder pipe at DNGS: 2" NPS and 2.5" NPS.

2" NPS feeders:	
$D_0 = 60.325 \text{ mm}$	outside diameter
$t_{nom} = 5.537 \text{ mm}$	nominal wall thickness
$t_{min} = 2.757 \text{ mm}$	pressure based thickness
$0.75* t_{min} = 2.07 mm$	FFSG line-in-granite value

2.5" NPS feeders:	
$D_0 = 73.025 \text{ mm}$	outside diameter
$t_{nom} = 7.010 \text{ mm}$	nominal wall thickness
$t_{min} = 3.338 \text{ mm}$	pressure based thickness
$0.75^* t_{min} = 2.50 \text{ mm}$	FFSG line-in-granite value

There are 22 types of feeder bends for all 480 Darlington outlet feeders. Bend type is categorized by feeder's size, bend radius, angle, straight pipe length, and etc. It is noted that the maximum and minimum length of the straight pipe is 45.5 and 3.1 mm respectively.

#### 3.2 **Application of Inspection Thickness Data**

The 6-probe pack is used by the Inspection Organization to measure wall thickness adjacent the Grayloc weld. The 6-pack is a 6-transducer array and can be manually moved by the operator in the circumferential direction while keeping the 6-pack abutting the weld cap. An encoder allows the collected data to be synchronized with circumferential position. It can measure the thickness of the pipe material in a zone bounded by the edge of the weld cap to a distance 15 mm from the edge of the weld cap. The inspection is to cover the full circumference of the pipe where access and contact conditions permit. The numbering and offset in axial and circumferential offsets are listed in Table 1. From the table, the closest measured thickness next to the Grayloc weld is 2.5 mm. Past experience indicates that local thinning rarely extends beyond 15 mm away from the weld cap.

#### 3.3 Loading Condition and Material Properties

#### **3.3.1** Design Condition

The design conditions are as per Darlington design specification:

Outlet feeder design temperature: 318.33 °C

Outlet feeder design internal pressure: 11.275 MPa(g)

#### **3.3.2 Operating Condition**

The maximum transient pressures under ASME III Level A, B, and C conditions are following (there is no Level D loading in feeders):

Outlet feeder maximum Level A pressure:11.26 MPa(g)Outlet feeder maximum Level B pressure:12.09 MPa(g)Outlet feeder maximum Level C pressure:13.60 MPa(g)

The enveloped primary and secondary loads are summarized from the previous OPG feeder Darlington stress analysis and are given in **Table 2**.

#### **3.3.3** Material Properties

The feeder pipe is procured to the SA-106 Grade B material specification. The material properties used in the local thinning assessment are code specified values at the design temperature of 318.33 °C. It should be noted that the Darlington feeder CMTRs report much higher values both for yield tensile and ultimate tensile strength. Thus the use of code value is conservative.

$\sigma_m = 119.18 \text{ MPa}$	Class 1 allowable stress intensity
$\sigma_y = 178.23 \text{ MPa}$	Specified yield tensile strength
$\sigma_u = 413.7 \text{ MPa}$	Specified ultimate tensile strength

#### 4.0 ASSESSMENT RESULTS

Using closed-form equations in given in **Section 2.1 and 2.2** or article E.5 of Appendix E. The *Operational Assessments* are performed for the end-of-evaluation-period outlet feeder thickness to demonstrate that the feeders are fit for continue service. The allowable thickness obtained in this assessment should be compared to the predicted thickness or the inspection thickness minus the thinning rate times the EFPY value of the next planned outage when the feeder is going to be replaced.

The evaluation thickness  $t_{eval}$  equal to 3.03 mm for LC and UC and 3.12 mm for LAC mm for 2 inch feeder, the respective values for 2.5 inch feeder are 3.67 mm and 3.77 mm. Once the inspected or predicted thickness is found to be below  $t_{min}$ , the allowable local thickness assessment has to be initiated. However, the size of local thinning is determined by the evaluation thickness of  $t_{eval}$ , rather than  $t_{min}$ .

#### 4.1 Allowable Thickness Assessment by Internal Pressure Loading

The applicability of the evaluation is dependent on the axial and circumferential extents of the local thinning regions of the two different sizes feeders: 2" and 2.5". The detailed calculations are carried out in **Table 3** and are shown in **Figure 4** for 2" feeder. The results are summarized in **Table 4** and **Table 5** for 2" and 2.5" feeders respectively.

A thinning extent could fall into two classification regions when  $L_m/(R_{min}t_{min})^{0.5} < 2.65$ , i.e. LC or LAC, UC or LAC, depending on the value of  $L_{m(t)}/(R_{min}t_{min})^{0.5}$ , the minimum value of  $t_{aloc}$  from two classification calculations is taken as the final acceptable value.

As shown in two tables, if the axial thinning extent is less than 6 mm regardless of circumferential extent, or the circumferential extent is less than 15° and the axial extent is less than 15 mm, the allowable thickness is 0.75  $t_{min}$  or the "line-in-granite" of FFSG for local thinning.

If the axial extent exceeds 20 mm and circumferential extent exceeds  $20^{\circ}$ , the allowable thickness is approximately 0.90 t<sub>min</sub> and becomes independent of thinning extent.

#### 4.2 Allowable Thickness Assessment under Moment Loading with Coincident Internal Pressure Loading

In this assessment, the uniform thickness  $t_1$  (or t used in equations in **Section 2.0** is the  $t_{eval}$  or higher, while local thinning thickness  $t_2$  ( $t_2 = t_1 - a$ ) is the minimum allowable thickness of 0.75  $t_{min}$  or higher values obtained in **Section 4.1** from the internal pressure evaluation. Since it is unlikely that surrounding wall thickness is uniformly thinned to  $t_{eval}$  around the local region ( $t_2$ ), thus the calculation is very conservative.

As shown in **Table 6**, the local thickness is taken as of 0.75  $t_{min}$  or 2.07 mm, the surrounding thickness is assumed as  $t_{eval}$  or 1.13 $t_{min}$  of 3.11 mm. For the circumferential extent up to  $2\theta = 20^{\circ}$ , both membrane plus bending axial, and membrane axial stresses meet the Appendix E criteria. When the circumferential extent exceeds 20°, the membrane plus bending axial stress fails to meet the requirements. In order to meet the requirements, either  $t_1$  or  $t_2$  has to be increased, as shown in **Table 7 and 8**.

### 5.0 APPLICATION EXAMPLE

An example is illustrated in this section to show the application of the assessment methodology as well as the direct use of the result tables obtained in the **Section 4.1** and **4.2**.

Darlington feeder J24E of Unit 2 was identified to have a predicted below pressure based thickness local thinning area before the scheduled outage. A detailed NB-3200 stress analysis was performed and demonstrated that the ASME III code compliance is met for the local thinning (**Reference 3**). The same thinning parameters are used here for the demonstration of Level 2 evaluation of FFSG Appendix E.

## 5.1 Predicted Thickness

The predicted minimum and average thicknesses are shown in Table 9.

D2J24E is a 2" feeder,  $t_{min} = 2.757 \text{ mm}$  $t_{eval} = 3.03 \text{ or } 3.12 \text{ mm} (3.12 \text{ mm is used to be conservative to estimate the thinning size})$ 

As shown in **Table 9**, the axial length where the thickness below  $t_{eval}$  3.12 mm (not  $t_{min}$ ) is between the Grayloc weld to Probe 3 or 8.75 mm (2.5+2.5+2.5+2.5/2, i.e. 3  $\frac{1}{2}$  probe distance).

The circumferential thickness distribution is shown in **Figure 5**. The circumferential length of local thinning, where the thickness is less than 3.12 mm, is 40 mm long. The thickness at the extrados region is below  $t_{eval}$  of 3.12 mm but higher than  $t_{min}$  of 2.757 mm, thus it is not defined as a local thinning region and therefore no assessment is required. In the distance of  $2.5(R_{eval}t_{eval})^{0.5}$  of 23.6 mm range, there is no another region where the thickness is below 3.12 mm. Thus this local thinning can be characterized as a single local thinning region.

In summary: the size of local thinning region:

- axial thinning extent  $L_{m(a)} = 8.75$  mm.
- circumferential extent  $L_{m(t)} = 38.2 \text{ mm}$

(40 mm is the circumferential length measured from the outside diameter, it has to be converted to the circumferential length calculated from the mean radius,  $40*R_{min}/R_o = 40*28.78/30.163 = 38.2$  mm)

- target allowable thickness  $t_{aloc} = 2.54 \text{ mm}$
- surrounding thickness  $t_{avg} = 3.47$  mm (conservatively assumed as the average thickness at probe 1)

### 5.2 Allowable Local Thickness for J24E

### 5.2.1 Assessment by Calculation

Assessment on internal pressure loading is performed in **Table 10** using the local thinning size identified above. The minimum allowable thickness is 2.23 mm. Assessment on bending moment coincident with internal pressure loading is performed in **Table 11**. The minimum allowable thickness is 2.09 mm. Thus the minimum allowable local thickness is the maximum value of two values, i.e. 2.23 mm. It is below the target thickness of 2.54 mm.

In summary, the predicted thickness meets FFSG Appendix E local thinning requirements and the reactor can operate up to the end of evaluation period.

### 5.2.2 Assessment by Result Tables

Applying the thinning size and surrounding thickness to the generic allowable thickness for 2 inch feeder in **Table 4**, the minimum acceptable thickness is approximately 2.29 mm, which is

below the target thickness of 2.54 mm. Thus the local thinning is compliant to FFSG Appendix E requirements.

#### 6.0 CONCLUSIONS

Level 2 evaluation provides an easy-to-use and conservative tool for the fast disposition of adverse inspection results. The allowable thicknesses developed in this paper can be used for the disposition of inspected or predicted below pressure base thickness in the vicinity of the Grayloc. It would reduce the potential risk of outage delay due to adverse feeder thickness.

#### 7.0 ACKNOWLEDGEMENT

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#### 8.0 **REFERENCES**

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1653

261

1580

Transducer #	Axial Offset (mm)	Circumferential offset (mm)	Incidence Degree	Distance relative the Weld Edge (mm)
1	0	3.0	normal	2.5
2	2.5	0.0	normal	5
3	5	-3.0	normal	7.5
4	7.5	0.0	normal	10
5	10	-3.0	normal	12.5
6	12.5	3.0	normal	15

	Table 1	Transducer	Numbering	and Location	for the 6-Pack
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## Table 2 Enveloped Primary and Secondary Loads for All Darlington Outlet Feeders

2 inch feeders		
Level A, B Loads	F <sub>res</sub> (N)	M <sub>res</sub> (N-m)
DWT (Deadweight)	921	223
THM (Thermal)		
Fixed short feeders	1223	1147
Free short feeders	1630	1630
Long feeders (assume free)	1451	730
Level C (Seismic) Loads		
Seismic Anchor Movement (EAM)	497	187
Seismic Inertia (EEM)	1324	831
2.5 inch feeders		
Level A, B Loads	F <sub>res</sub> (N)	M <sub>res</sub> (N-m)
DWT (Deadweight)	1124	398
THM (Thermal)		
Fixed short feeders	2003	1692
Free short feeders	2655	2785

2402

Seismic Anchor Movement (EAM)688Seismic Inertia (EEM)2580

Note: Forces and Moments are obtained at the Grayloc sealed face.

Long feeders (assume free) Level C (Seismic) Loads

## Table 3 Allowable Thickness under Internal Pressure Loading for 2.0 inch Feeders Imputs Darlington 2 light Feeders

Design pressure	PD	11.3	MPa										
Nominal outside diameter	Do	60.325	mm										
Design stress intensity	S <sub>m</sub> @318 °C	119.1	MPa										
Outside Radius	$R_o = D_o/2$	30.163	mm										
Geometry Characterization	ı												
Pressure based thickness for SP	$t_{min}^{SP} = P_D D_o / [2(S_m + yP_D)]$	2.757	mm										
Evaluation Wall at Grayloc	$t_{eval} = 1.10 t_{min}^{SP} (LC, UC)$ $t_{eval} = 1.13 t_{min}^{SP} (LAC)$	3.03 3.12	=> The inspected or	predicted thickne	sses are require	ed to compa	ared to t <sub>er</sub>	al instead	of $t_{\min}$				
Mean Evaluated Radius	$R_{eval} = R_o - t_{eval}/2 (LC, UC)$ $R_{eval} = R_o - t_{eval}/2 (LAC)$	28.65	=> Radius at the at	surrounding regio	n								
	2.5(R*t) <sup>1/2</sup> (LC UC)	23.30											
Minimum Length for	2.0(11eval (eval) (20,00)	20.00	=> The wall thicknes	s in the material s	urrounding the	local thinne	d region	shall be g	greater th	an or equa	al to t <sub>eval</sub>	from this minimum d	istance.
surrounding material t > t <sub>eval</sub>	2.5(R <sub>eval</sub> *t <sub>eval</sub> ) <sup>1/2</sup> (LAC)	23.60			-		-						
Mean Inside Radius	$R_{min} = R_o - t_{min}/2$	28.78	=> Mean radius at lo	cal thinning regior	n								
Characterized size	(R <sub>min</sub> *t <sub>min</sub> ) <sup>1/2</sup>	8.91	=> Thinning region of	haracteristic dime	nsion								
Classification of Local Thi	nning Region												
Classification	Extent of	Thinning Less Th	an t <sub>eval</sub>	Lm				Formulas	to calcu	ate allowa	ble thick	ness	
(a) Limited Circumferential		17			$t_{aloc}/t_{min} = 0.75$	5						for Lm(a) /Rmintmin)0.5	< 2.75
Extent (LC):	Circumferential extent, L <sub>r</sub>	$m(t) \leq (R_{\min}t_{\min})^{1/2}$	where t <t<sub>eval</t<sub>	8.91		C*/ 0 75	0 75				600	v = 1 (D + )0.5	> 0.75
					$l_{aloc}/l_{min} = 0.04$	10 (X -2.75	) + 0.75				101	$x = L_{m(a)}/R_{min}L_{min}$	> 2.75
(b) Limited Axial and					t <sub>aloc</sub> /t <sub>min</sub> ≥ 0.35	53L <sub>m</sub> [1/(t <sub>mir</sub>	<sup>sp</sup> R <sub>min</sub> <sup>sp</sup>	] <sup>0.5</sup>					
(b) Limited Axial and Circumferential Extent	Maximum extent I < 2	65 (P. t.) <sup>1/2</sup>	where t <t .<="" td=""><td>23.61</td><td colspan="8"><math>t_{1}/t_{2} &gt; 1 = 1.5(R_{1}, t_{1})^{0.5}(t_{1}, t_{1}, t_{2})/t_{1}</math></td></t>	23.61	$t_{1}/t_{2} > 1 = 1.5(R_{1}, t_{1})^{0.5}(t_{1}, t_{1}, t_{2})/t_{1}$								
(LAC):	Maximum extent, Em = 2.	00 (Reminemin)	20.01	taloc (min = 1 = 1.0(1/min/min/) (leval / lmin = 1)/Lm taloc oquus to the maximum timee values									
. ,					t <sub>aloc</sub> /t <sub>min</sub> = 0.75	5							
					$t_{alcc}/t_{min} = 0.75$ for $L_{m(a)}/R_{min}t_{min}$ <sup>0.5</sup> < 0.725								
(c) Unlimited Circumferential	Oissurgfassatist sutsat. I	× (D + )1/2		8.01 + # = 0.007.4 $(0.0242)^3$ 0.6769.2 $(0.0699)$ 0.0261 for 0.725 for 1.00 $(0.010)$									
Extent (UC):	Circumferential extent, L <sub>r</sub>	$m(t) > (R_{min}t_{min})$ (	where t <t<sub>eval</t<sub>	0.91	$t_{aloo}/t_{min} = -0.028/x + 0.2243x^{-} + 0.6768x^{-} + 0.9688x + 0.3251 \text{ for } 0.725 < x=L_{m(a)}/R_{min}t_{min})^{6.5} < 2.5$								
					$t_{aloc}/t_{min} = 0.9$							for L <sub>m(a)</sub> /R <sub>min</sub> t <sub>min</sub> )	<sup>0.5</sup> > 2.5
1													
Maximum Axial Extent L <sub>m(a)</sub>	6.0 mm												
$L_{m(a)}/(R_{min}t_{min})^{1/2}$	0.67												
								1	LAC				
circumferential thinning angle (deg)	arch length (mm) Lmth	L <sub>m</sub> =	L <sub>m</sub>	1	Geometry	LC					UC	t <sub>aloc</sub> /t <sub>min</sub> sp	Results by Thinning
	<b>0</b> - ( ) m(g)	$(L_{m(a)}^{2}+L_{m(t)}^{2})^{1/2}$	/2.65(R <sub>min</sub> <sup>sp</sup> t <sub>min</sub> <sup>sp</sup> ) <sup>1/2</sup>	-m(t) (1 4min4min7	Classification		(a)	(b)	(C)	Max (a,b,c)		Min(LC,LAC,UC)	Classification
	2.51	6.50	0.276	0.2		0.750	0.259	0 722	0.750	0.750	n/n	0.750	10
10	5.02	7.83	0.331	0.6	LC or LAC	0.750	0.310	0.778	0.750	0.778	n/a	0.750	LC
15	7.54	9.63	0.408	0.8	LC or LAC	0.750	0.382	0.820	0.750	0.820	n/a	0.750	LC
20	10.05	11.70	0.496	1.1	UC or LAC	n/a	0.464	0.852	0.750	0.852	0.750	0.750	UC
25	12.56	13.92	0.590	1.4	UC or LAC	n/a	0.552	0.875	0.750	0.875	0.750	0.750	UC
35	17.58	18.58	0.787	20	UC or LAC	n/a	0.043	0.893	0.750	0.893	0.750	0.750	UC
40	20.09	20.97	0.888	2.3	UC or LAC	n/a	0.831	0.917	0.750	0.917	0.750	0.750	UC
45	22.61	23.39	0.991	2.5	UC or LAC	n/a	0.927	0.926	0.750	0.927	0.750	0.750	UC
55	27.63	28.27	1.198	3.1	UC	n/a	n/a	n/a	n/a	n/a	0.750	0.750	UC
90	30.14	30.73	1.302	3.4	UC	n/a	n/a	n/a	n/a	n/a	0.750	0.750	UC
180	90.43	90.63	3.839	10.2	UC	n/a	n/a	n/a	n/a	n/a	0.750	0.750	UC
270	135.64	135.77	5.751	15.2	UC	n/a	n/a	n/a	n/a	n/a	0.750	0.750	UC
360	180.85	180.95	7.665	20.3	UC	n/a	n/a	n/a	n/a	n/a	0.750	0.750	UC

## Table 4Summary of Allowable Thickness under Internal Pressure Loading<br/>for 2" Feeder

2" feeder		Adiacont Wall														
Circumferential Thinning Extent L <sub>m(t)</sub>	6	8	10	15	20	Thickness										
angle (degree)		t <sub>aloc</sub> (mm)														
5 - 15		2.07 2.15														
20						2 3.12										
45	2.07	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.20			
60	60		2.29	2.42	2.48	> 3 5										
75	2.	20				≥ 5.5										
90		2.37														

# Table 5Summary of Allowable Thickness under Internal Pressure Loading<br/>for 2.5" Feeder

2.5" feeder		Maximum Axial Extent L <sub>m(a)</sub> (mm)							
Circumferential Thinning Extent L <sub>m(t)</sub>	6	8	10	15	20	Wall Thickness			
angle (degree)		t <sub>aloc</sub> (mm)							
15		2.50							
20						2 3.77			
45	2.50	2.50	2.67						
60			2.01	2.87	2.95	> 1 31			
75	2.	67				2 4.51			
90		2.84							

## Table 6Allowable Thickness under Bending Moment and Pressure for 2" Feeder

Inputs		Darlington 2 inc	h Feeders															
Design pressure		PD			11.3	MPa												
Nominal outside		Do			60.3	mm												
Nominal thickness		t			5 54	mm												
Design stress intensi	ity	σ <sub>m</sub>			119.1	MPa												
Yield strength		σ,			178.23	MPa												
Ultimate tensile stren	ngth	σu			413.7	MPa												
Flow stress	_	$\sigma_{\rm f}$			295.97	MPa												
Since the local thinni	ing is	within the short se	ction of straight p	pipe, all calculation	ns are based o	on a straight pipe a	assumption.											
Nominal outside radi	us	R.	$R_o = D_o/2$		30.15	mm												
Nominal inside radius	s	R	$R_{I} = R_{o} - t_{nom}$		24.61	mm												
thickness for SP		$t_{min}^{SP} = P_D D_o / [2(\sigma_r)]$	n+Py)]		2.756	mm												
Evaluation Wall at		$t_{eval}$ = 1.10 $t_{min}^{SP}$	(LC, UC)		3.03	mm												
Grayloc		$t_{eval}$ = 1.13 $t_{min}^{SP}$	(LAC)		3.11	mm												
Mean Diameter at t <sub>mi</sub>	in	$D = D_o - t_{min}$			57.5	at local thinning re	egion											
Characterized size		(R <sub>min</sub> *t <sub>min</sub> ) <sup>1/2</sup>	(1.0.110)		8.9 20 62	mm												
Mean Evaluated Rad	dius	$R_{eval} = R_0 - t_{eval}/2$ $R_{eval} = R_0 - t_{eval}/2$	(LC,0C) (LAC)		28.03	at surrounding reg	gion											
Location of thinning		α α	( )		1	inside surface thir	nning											
		Enveloped Lo	ads (2 inch)	Resultant	Load	Primary L	oad	Seconda	ry Load									
		DM/T (Data	dura (abd)	F <sub>res</sub> (kN)	M <sub>res</sub> (kN-m)	F <sub>p</sub>	M <sub>p</sub>	Fs	Ms									
		THM (Dea	iermal)	1.63	1.63	0.921	0.223	- 1.63	- 1.63	-								
		EAM (Seismic	Anchor Mvt)	0.497	0.187	-	-	0.497	0.187									
1		EEM (Seisn	nic Inertia)	1.324	0.831	1.324	0.831	-	-	]								
			primary loads		Secon	dary loads		structural facto	rs	effective In:	ad components	(not used)						
Load Case		Р	F <sub>p</sub>	Mp	Fs	Ms	SFm	SFb	SFe	P <sub>eff</sub>	Feff	M <sub>eff</sub>						
Level A/B		12.1 MPa	0.921 kN	0.223 kN·m	1.6 kN	1.630 kN·m	2.7	2.3	1.0	32.59 MPa	4.12 MPa	2.14 MPa						
Level C		12.1 MPa	1.324 kN	0.831 kN·m	0.5 kN	0.187 kN·m	1.8	1.6	1.0	21.73 MPa	2.88 MPa	1.52 MPa						
Case	No.				Cha	aracterization of Fe	eder Local T	ninning					· ·	Net-section Chara	cterized Collap	se Param	ieters	
		t <sub>2</sub> (0.75t <sub>min</sub> )	t <sub>1</sub> / t <sub>min</sub>	adjacent t <sub>1</sub>	Ri	depth a	20	PDA	mean D	t <sub>1</sub> /D	a/t <sub>1</sub>	a/D	P.	F.	Mo	λ	P*	θ/π
1		2.07	1.13	3.11	27.04	1.05	10°	41.82%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN·m	3.01 MPa	0.24	12.10	0.028
	2	2.07	1.13	3.11	27.04	1.05	20°	42.35%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN·m	3.01 MPa	0.24	12.12	0.056
	3	2.07	1.13	3.11	27.04	1.05	45°	43.67%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN·m	3.01 MPa	0.24	12.19	0.125
	4	2.07	1.13	3.11	27.04	1.05	60°	44.47%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN·m	3.01 MPa	0.24	12.23	0.167
	5	2.07	1.13	3.11	27.04	1.05	75°	45.26%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN·m	3.01 MPa	0.24	12.27	0.208
Level A/B	6	2.07	1.13	3.11	27.04	1.05	90°	46.05%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN·m	3.01 MPa	0.24	12.31	0.250
	7	2.07	1.13	3.11	27.04	1.05	135°	48.43%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN·m	3.01 MPa	0.24	12.43	0.375
	8	2.07	1.13	3.11	27.04	1.05	180°	50.81%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN·m	3.01 MPa	0.24	12.55	0.500
	9	2.07	1.13	3.11	27.04	1.05	235°	53.72%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN·m	3.01 MPa	0.24	12.69	0.653
	10	2.07	1.13	3.11	27.04	1.05	270°	55.57%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN·m	3.01 MPa	0.24	12.78	0.750
	11	2.07	1.13	3.11	27.04	1.05	360°	60.32%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN·m	3.01 MPa	0.24	13.02	1.000
	1	2.07	1.13	3.11	27.04	1.05	10°	41.82%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN·m	3.01 MPa	0.24	12.10	0.028
	2	2.07	1.13	3.11	27.04	1.05	20°	42.35%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN·m	3.01 MPa	0.24	12.12	0.056
	3	2.07	1.13	3.11	27.04	1.05	45°	43.67%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN·m	3.01 MPa	0.24	12.19	0.125
	4	2.07	1.13	3.11	27.04	1.05	60°	44.47%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN·m	3.01 MPa	0.24	12.23	0.167
	5	2.07	1.13	3.11	27.04	1.05	75°	45.26%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN·m	3.01 MPa	0.24	12.27	0.208
	6	2.07	1.13	3.11	27.04	1.05	90°	46.05%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN·m	3.01 MPa	0.24	12.31	0.250
Level C	7	2.07	1.13	3.11	27.04	1.05	135°	48.43%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN·m	3.01 MPa	0.24	12.43	0.375
	8	2.07	1.13	3.11	27.04	1.05	180°	50.81%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN·m	3.01 MPa	0.24	12.55	0.500
1	9	2.07	1.13	3.11	27.04	1.05	235°	53.72%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN·m	3.01 MPa	0.24	12.69	0.653
1	10	2.07	1.13	3.11	27.04	1.05	270°	55.57%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN·m	3.01 MPa	0.24	12.78	0.750
	11	2.07	1.13	3.11	27.04	1.05	360°	60.32%	57.19	0.05	0.336	0.018	72.1 MPa	165.59 kN∙m	3.01 MPa	0.24	13.02	1.000
Case (Continue)	No.		Net-Section	Collapse Bending	Moment			M	embrane Plu	s Bending Axial	Stresses, and M	embrane Axial	Stress		Str	uctural Ev	aluation	
		β/π	check a/t, θ/π	flaw type	β/π	M <sub>nsc</sub> /M <sub>o</sub>	A,		σ <sub>m</sub> <sup>-p.</sup>	σ <sub>b</sub> <sup>p</sup>	σ <sub>b</sub> s	Φ	σ <sub>m</sub> °	σ <sub>b</sub> <sup>c</sup>	Mem + Be	nding	Mem	Axial
1	1	0.404	ok	short	0.404	0.941	2296.3	2.29E+05	51.29	29.31	214.24	0.01	290.74	372.89	0.96	pass	0.48	pass
	2	0.399	ok	short	0.399	0.923	2296.3	2.29E+05	51.40	29.31	214.24	0.03	285.53	365.77	0.98	pass	0.49	pass
1	3	0.388	ok	short	0.388	0.879	2296.3	2.29E+05	51.67	29.31	214.24	0.06	2/2.73	348.07	1.02	FAIL	0.51	pass
1	4	0.380	ok	short	0.380	0.852	2296.3	2.29E+05	51.84	29.31	214.24	80.0	265.28	337.71	1.05	FAIL	0.53	pass
	5	0.373	ok	short	0.373	0.827	2296.3	2.29E+05	52.00	29.31	214.24	0.10	258.07	327.70	1.08	FAIL	0.54	pass
Level A/B	6	0.366	ok	short	0.366	0.803	2296.3	2.29E+05	52.16	29.31	214.24	0.11	251.17	318.15	1.11	FAIL	0.56	pass
	7	0.345	ok	short	0.345	0.740	2296.3	2.29E+05	52.65	29.31	214.24	0.14	232.76	293.28	1.19	FAIL	0.61	pass
1	8	0.324	ok	short	0.324	0.696	2296.3	2.29E+05	53.14	29.31	214.24	0.16	218.51	275.57	1.26	FAIL	0.66	pass
1	9	0.299	ok	short	0.299	0.668	2296.3	2.29E+05	53.74	29.31	214.24	0.14	207.21	264.64	1.31	FAIL	0.70	pass
	10	0.282	ok	long	0.297	0.664	2296.3	2.29E+05	54.12	29.31	214.24	0.11	203.21	263.00	1.31	FAIL	0.72	pass
	11	0.240	ok	long	0.355	0.618	2296.3	2.29E+05	55.10	29.31	214.24	0.00	200.03	244.87	1.40	FAIL	0.74	pass
1	1	0.406	ok	short	0.406	0.943	2296.3	2.29E+05	52.01	109.23	24.58	0.01	290.74	373.70	0.95	pass	0.48	pass
1	2	0.401	ok	short	0.401	0.925	2296.3	2.29E+05	52.12	109.23	24.58	0.03	285.53	366.62	0.96	pass	0.49	pass
	3	0.390	ok	short	0.390	0.881	2296.3	2.29E+05	52.39	109.23	24.58	0.06	272.73	349.01	1.01	FAIL	0.52	pass
1	4	0.383	ok	short	0.383	0.855	2296.3	2.29E+05	52.56	109.23	24.58	0.08	265.28	338.71	1.03	FAIL	0.53	pass
1.	5	0.376	ok	short	0.376	0.830	2296.3	2.29E+05	52.72	109.23	24.58	0.10	258.07	328.75	1.06	FAIL	0.55	pass
Level C	6	0.369	ok	short	0.369	0.806	2296.3	2.29E+05	52.88	109.23	24.58	0.11	251.17	319.26	1.09	FAIL	0.57	pass
1	7	0.348	ok	short	0.348	0.743	2296.3	2.29E+05	53.37	109.23	24.58	0.14	232.76	294.56	1.17	FAIL	0.62	pass
1	8	0.326	ok	short	0.326	0.699	2296.3	2.29E+05	53.86	109.23	24.58	0.16	218.51	277.00	1.24	FAIL	0.67	pass
1	9	0.301	ok	short	0.301	0.672	2296.3	2.29E+05	54.46	109.23	24.58	0.14	207.21	266.26	1.28	FAIL	0.71	pass
1	10	0.284	ok	long	0.301	0.668	2296.3	2.29E+05	54.84	109.23	24.58	0.11	203.21	264.65	1.29	FAIL	0.73	pass
1	11	0.242	ok	long	0.358	0.621	2296.3	2.29E+05	55.82	109.23	24.58	0.00	200.03	246.08	1.38	FAIL	0.75	pass

Table 7	Revised Allowable Local Thickness under Bending Moment and
	Pressure for 2" Feeder

Casa	No	Characterization of Feeder Local Thinning												Net-section Characterized Collapse Parameters					
Case	INU.	t <sub>2</sub> (0.75t <sub>min</sub> )	t <sub>1</sub> / t <sub>min</sub>	adjacent t <sub>1</sub>	Ri	depth a	20	PDA	mean D	t <sub>1</sub> /D	a/t <sub>1</sub>	a/D	Po	Fo	Mo	λ	P*	θ/π	
	3	2.07	1.27	3.50	26.65	1.43	45°	37.70%	56.80	0.06	0.409	0.025	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.24	0.125	
	4	2.07	1.27	3.50	26.65	1.43	60°	38.78%	56.80	0.06	0.409	0.025	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.29	0.167	
	5	2.20	1.27	3.50	26.65	1.30	75°	39.32%	56.80	0.06	0.370	0.023	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.32	0.208	
Level A/B	6	2.37	1.27	3.50	26.65	1.13	90°	39.54%	56.80	0.06	0.323	0.020	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.33	0.250	
	7	2.67	1.27	3.50	26.65	0.83	135°	40.00%	56.80	0.06	0.236	0.015	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.36	0.375	
	8	2.76	1.27	3.50	26.65	0.74	180°	41.10%	56.80	0.06	0.213	0.013	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.41	0.500	
	9	2.76	1.27	3.50	26.65	0.74	235°	43.12%	56.80	0.06	0.213	0.013	82.8 MPa	184.85 kN∙m	3.34 MPa	0.28	12.52	0.653	
	10	2.76	1.27	3.50	26.65	0.74	270°	44.41%	56.80	0.06	0.213	0.013	82.8 MPa	184.85 kN∙m	3.34 MPa	0.28	12.58	0.750	
	11	2.76	1.27	3.50	26.65	0.74	360°	47.72%	56.80	0.06	0.213	0.013	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.75	1.000	
	3	2.07	1.27	3.50	26.65	1.43	45°	37.70%	56.80	0.06	0.409	0.025	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.24	0.125	
	4	2.07	1.27	3.50	26.65	1.43	60°	38.78%	56.80	0.06	0.409	0.025	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.29	0.167	
	5	2.20	1.27	3.50	26.65	1.30	75°	39.32%	56.80	0.06	0.370	0.023	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.32	0.208	
	6	2.37	1.27	3.50	26.65	1.13	90°	39.54%	56.80	0.06	0.323	0.020	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.33	0.250	
Level C	7	2.67	1.27	3.50	26.65	0.83	135°	40.00%	56.80	0.06	0.236	0.015	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.36	0.375	
2010/0	8	2.76	1.27	3.50	26.65	0.74	180°	41.10%	56.80	0.06	0.213	0.013	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.41	0.500	
	9	2.76	1.27	3.50	26.65	0.74	235°	43.12%	56.80	0.06	0.213	0.013	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.52	0.653	
	10	2.76	1.27	3.50	26.65	0.74	270°	44.41%	56.80	0.06	0.213	0.013	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.58	0.750	
	11	2.76	1.27	3.50	26.65	0.74	360°	47.72%	56.80	0.06	0.213	0.013	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.75	1.000	
Case (Castinue)	Ne		Net-Section	Collapse Bending I	Moment			м	embrane Plu	s Bending Axial S	Stresses, and M	embrane Axial	Stress		Str	uctural Ev	raluation		
Case (Continue)	No.	β/π	Net-Section check a/t, θ/π	Collapse Bending I	Moment β/π	M <sub>nsc</sub> /M <sub>o</sub>	A,	M	embrane Plu σ <sub>m</sub> <sup>p*</sup>	s Bending Axial S	Stresses, and M	embrane Axial Φ	Stress	σ <sub>b</sub> °	Str Mem + Be	uctural Ev	raluation Mem	Axial	
Case (Continue)	No.	β/π 0.395	Net-Section check a/t, θ/π ok	Collapse Bending I flaw type short	Moment β/π 0.395	M <sub>nsc</sub> /M <sub>o</sub> 0.873	A <sub>i</sub> 2231.2	M 2.53E+05	embrane Plu σ <sub>m</sub> <sup>p*</sup> 45.19	s Bending Axial S σ <sub>b</sub> <sup>p</sup> 26.59	Stresses, and M σ <sub>b</sub> <sup>s</sup> 194.38	embrane Axial Ф 0.07	Stress $\sigma_m^c$ 267.68	σ <sub>b</sub> <sup>c</sup> 347.97	Str Mem + Be 0.93	uctural Ev Inding	valuation Mem 0.46	Axial pass	
Case (Continue)	No. 3	β/π 0.395 0.386	Net-Section check a/t, θ/π ok ok	Collapse Bending I flaw type short short	Moment β/π 0.395 0.386	M <sub>nsc</sub> /M <sub>o</sub> 0.873 0.842	A <sub>i</sub> 2231.2 2231.2	I 2.53E+05 2.53E+05	embrane Plu: σ <sub>m</sub> <sup>p*</sup> 45.19 45.39	s Bending Axial S σ <sub>b</sub> <sup>p</sup> 26.59 26.59	Stresses, and M σ <sub>b</sub> <sup>s</sup> 194.38 194.38	embrane Axial Ф 0.07 0.09	Stress σ <sub>m</sub> <sup>c</sup> 267.68 258.61	σ <sub>b</sub> ° 347.97 335.48	Str Mem + Be 0.93 0.96	uctural Ev inding pass pass	Valuation Mem 0.46 0.47	Axial pass pass	
Case (Continue)	No. 3 4 5	β/π 0.395 0.386 0.382	Net-Section check a/t, θ/π ok ok ok	Collapse Bending I flaw type short short short	Moment β/π 0.395 0.386 0.382	M <sub>nsc</sub> /M <sub>o</sub> 0.873 0.842 0.828	A, 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05	embrane Plu: σ <sub>m</sub> <sup>p*</sup> 45.19 45.39 45.49	s Bending Axial 5 σ <sub>b</sub> <sup>p</sup> 26.59 26.59 26.59	Stresses, and M σ <sub>b</sub> <sup>s</sup> 194.38 194.38 194.38	embrane Axial 0.07 0.09 0.10	Stress σ <sub>m</sub> <sup>c</sup> 267.68 258.61 254.44	σ <sub>b</sub> <sup>c</sup> 347.97 335.48 329.96	Str Mem + Be 0.93 0.96 0.98	uctural Ev inding pass pass pass	/aluation Mem 0.46 0.47 0.48	Axial pass pass pass	
Case (Continue)	No 3 4 5 6	β/π 0.395 0.386 0.382 0.380	Net-Section check a/t, θ/π ok ok ok ok	Collapse Bending I flaw type short short short short	Moment β/π 0.395 0.386 0.382 0.380	M <sub>nsc</sub> /M <sub>o</sub> 0.873 0.842 0.828 0.825	A, 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plu: <u></u> <u></u>	s Bending Axial 3 σ <sub>b</sub> <sup>p</sup> 26.59 26.59 26.59 26.59	Stresses, and M σ <sub>b</sub> <sup>\$</sup> 194.38 194.38 194.38 194.38 194.38	embrane Axial 0.07 0.09 0.10 0.10	Stress σ <sub>m</sub> <sup>c</sup> 267.68 258.61 254.44 253.35	σ <sub>b</sub> ° 347.97 335.48 329.96 328.90	Str Mem + Be 0.93 0.96 0.98 0.98	nding pass pass pass pass pass	Valuation Mem 0.46 0.47 0.48 0.49	Axial pass pass pass pass	
Case (Continue)	No. 3 4 5 6 7	β/π 0.395 0.386 0.382 0.380 0.376	Net-Section check a/t, θ/m ok ok ok ok ok	Collapse Bending I flaw type short short short short short short	Woment β/π 0.395 0.386 0.382 0.380 0.376	M <sub>nsc</sub> /M <sub>o</sub> 0.873 0.842 0.828 0.825 0.825	A, 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plu:	s Bending Axial 3 0, p 26.59 26.59 26.59 26.59 26.59 26.59 26.59	Stresses, and M           σ <sub>b</sub> *           194.38           194.38           194.38           194.38           194.38           194.38           194.38           194.38	Φ 0.07 0.09 0.10 0.10 0.10	Stress σ <sup>m</sup> <sup>c</sup> 267.68 258.61 254.44 253.35 252.34	σ <sub>b</sub> <sup>c</sup> 347.97 335.48 329.96 328.90 329.47	Str Mem + Be 0.93 0.96 0.98 0.98 0.98	nding pass pass pass pass pass pass	Mem 0.46 0.47 0.48 0.49 0.49	Axial pass pass pass pass pass	
Case (Continue)	No. 3 4 5 6 7 8	<ul> <li>β/π</li> <li>0.395</li> <li>0.386</li> <li>0.382</li> <li>0.380</li> <li>0.376</li> <li>0.368</li> </ul>	Net-Section check a/t, θ/π ok ok ok ok ok	Collapse Bending I flaw type short short short short short short short	Woment β/π 0.395 0.386 0.382 0.380 0.376 0.368	M <sub>nsc</sub> /M <sub>o</sub> 0.873 0.842 0.828 0.825 0.825 0.827 0.819	A, 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plu:	s Bending Axial 8 σ <sub>b</sub> <sup>p</sup> 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59	Stresses, and M <u> </u>	Φ 0.07 0.09 0.10 0.10 0.10 0.10 0.10	Stress $\sigma_m^c$ 267.68           258.61           254.44           253.35           252.34           247.93	σ <sub>6</sub> <sup>c</sup> 347.97 335.48 329.96 328.90 329.47 326.34	Str Mem + Be 0.93 0.96 0.98 0.98 0.98 0.99	pass pass pass pass pass pass pass pass	Mem 0.46 0.47 0.48 0.49 0.49 0.49 0.50	Axial pass pass pass pass pass pass	
Case (Continue)	No 3 4 5 6 7 8 9	β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.352	Net-Section check a/t, 8/m ok ok ok ok ok ok	Collapse Bending I flaw type Short Short Short Short Short Short Iong	Woment β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.353	M <sub>rsc</sub> /M <sub>o</sub> 0.873 0.842 0.828 0.825 0.825 0.827 0.819 0.808	A, 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plu:	s Bending Axial S	Stresses, and M orb <sup>5</sup> 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38	Φ           0.07           0.09           0.10           0.10           0.10           0.10           0.10           0.10	Stress $\sigma_m^c$ 267.68           258.61           254.44           253.35           252.34           247.93           240.83	σ <sub>b</sub> <sup>c</sup> 347.97 335.48 329.96 328.90 329.47 326.34 322.09	Str           0.93           0.96           0.98           0.98           0.98           0.98           0.98           0.98           0.98           0.98	pass pass pass pass pass pass pass pass	valuation Mem 0.46 0.47 0.48 0.49 0.49 0.49 0.50 0.52	Axial pass pass pass pass pass pass pass	
Case (Continue)	No. 3 4 5 6 7 8 9 10	β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.352 0.341	Net-Section check a/t, θ/π ok ok ok ok ok ok ok	Collapse Bending I flaw type short short short short short long long	Moment β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.353 0.364	M <sub>nsc</sub> /M <sub>o</sub> 0.873 0.842 0.828 0.825 0.827 0.819 0.808 0.804	A, 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plu:	s Bending Axial S σ <sub>b</sub> <sup>p</sup> 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59	Stresses, and M 0,5 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38	Φ           0.07           0.09           0.10           0.10           0.10           0.10           0.10           0.10           0.10           0.10           0.10           0.10	Stress σm <sup>c</sup> 267.68 258.61 254.44 253.35 252.34 247.93 240.83 238.27	σ <sub>b</sub> <sup>c</sup> 347.97           335.48           329.96           328.90           329.47           326.34           322.09           320.36	Str           Mem + Be           0.93           0.96           0.98           0.98           0.98           0.98           0.99           1.00           1.01	pass pass pass pass pass pass pass pass	valuation Mem 0.46 0.47 0.48 0.49 0.49 0.50 0.52 0.53	Axial pass pass pass pass pass pass pass pa	
Case (Continue)	No. 3 4 5 6 7 8 9 10 11	β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.352 0.341 0.315	Net-Section check a/t, 8/m ok ok ok ok ok ok ok ok	Collapse Bending I flaw type short short short short short ong long long	Woment β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.353 0.364 0.395	M <sub>nsc</sub> /M <sub>o</sub> 0.873 0.842 0.828 0.825 0.827 0.819 0.808 0.804 0.764	A 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plu: <u> </u>	s Bending Axial 3 <b>c</b> <sub>b</sub> <sup>p</sup> 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59	Stresses, and M 0,5 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38	embrane Axial	Stress           omc           267.68           258.61           254.44           253.35           252.34           247.93           240.83           238.27           236.10	σ <sub>6</sub> ° 347.97 335.48 329.96 328.90 329.47 326.34 322.09 320.36 304.68	Str           Mem + Be           0.93           0.96           0.98           0.98           0.98           0.99           1.00           1.01	pass pass pass pass pass pass pass FAIL FAIL	Mem           0.46           0.47           0.48           0.49           0.50           0.52           0.53	Axial pass pass pass pass pass pass pass pa	
Case (Continue)	No. 3 4 5 6 7 8 9 10 11 3	β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.352 0.341 0.315 0.397	Net-Section check a/t, 8/m ok ok ok ok ok ok ok ok ok	Collapse Bending I flaw type short short short short short long long long short	Voment β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.353 0.364 0.395 0.397	M <sub>rsc</sub> /M <sub>o</sub> 0.873 0.842 0.828 0.825 0.827 0.819 0.808 0.808 0.804 0.764 0.875	A 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plui <u> </u>	s Bending Axial 3 <b>o</b> <sub>b</sub> <sup>o</sup> 26.59	Stresses, and Mr <b>o</b> <sub>b</sub> * 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 22.30	embrane Axial Ф 0.07 0.09 0.10 0.10 0.10 0.10 0.09 0.07 0.00 0.07	Stress           om <sup>o</sup> 267.68           258.61           254.44           253.35           252.34           247.93           240.83           238.27           236.10           267.68	0,6° 347.97 335.48 329.96 328.90 329.47 326.34 322.09 320.36 304.68 348.76	Str Mem + Be 0.93 0.96 0.98 0.98 0.99 1.00 1.01 1.06 0.92	pass pass pass pass pass pass pass pass	Mem           0.46           0.47           0.48           0.49           0.50           0.52           0.53           0.54	Axial pass pass pass pass pass pass pass pa	
Case (Continue)	No 3 4 5 6 7 8 9 10 11 11 3 4	<ul> <li>β/π</li> <li>0.395</li> <li>0.386</li> <li>0.382</li> <li>0.380</li> <li>0.376</li> <li>0.368</li> <li>0.352</li> <li>0.341</li> <li>0.315</li> <li>0.397</li> <li>0.388</li> </ul>	Net-Section check alt, 6/π ok ok ok ok ok ok ok ok ok	Collapse Bending flaw type short short short short short long long long short short	Voment β/π 0.395 0.386 0.382 0.380 0.376 0.363 0.353 0.364 0.395 0.397 0.388	M <sub>nsc</sub> /M <sub>o</sub> 0.873 0.842 0.828 0.825 0.827 0.819 0.808 0.804 0.764 0.875 0.844	A 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plui <u> </u>	s Bending Axial 3 or, <sup>b</sup> 26.59 29.10 99.10	Open         Open           0p. <sup>5</sup> 194.38           194.38         194.38           194.38         194.38           194.38         194.38           194.38         194.38           194.38         194.38           194.38         194.38           194.38         194.38           194.38         194.38           194.38         194.38           194.38         194.38           192.30         22.30	embrane Axial Ф 0.07 0.09 0.10 0.10 0.10 0.09 0.07 0.00 0.07 0.09	Stress           0m <sup>c</sup> 267.68           258.61           254.44           253.35           252.34           240.83           238.27           236.10           267.68           258.61	σ <sub>6</sub> <sup>c</sup> 347.97           335.48           329.96           328.90           329.47           326.34           322.09           320.36           304.68           348.76           336.34	Str Mem + Be 0.93 0.96 0.98 0.98 0.98 0.99 1.00 1.01 1.06 0.92 0.95	pass pass pass pass pass pass pass pass	valuation Mem 0.46 0.47 0.48 0.49 0.50 0.52 0.53 0.54 0.46 0.48	Axial pass pass pass pass pass pass pass pa	
Case (Continue)	No 3 4 5 6 7 7 8 9 10 11 11 3 4 5	<ul> <li>β/π</li> <li>0.395</li> <li>0.386</li> <li>0.382</li> <li>0.380</li> <li>0.376</li> <li>0.368</li> <li>0.352</li> <li>0.341</li> <li>0.315</li> <li>0.397</li> <li>0.388</li> <li>0.384</li> </ul>	Net-Section check a/t, 8/m ok ok ok ok ok ok ok ok ok ok	Collapse Bending flaw type short short short short long long long short short short short	Voment β/π 0.395 0.386 0.382 0.380 0.376 0.363 0.353 0.364 0.395 0.397 0.388 0.384	M <sub>rsc</sub> /M <sub>o</sub> 0.873 0.842 0.828 0.825 0.827 0.819 0.808 0.804 0.764 0.875 0.844 0.830	A 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plux <u> <u> </u> </u>	s Bending Axial S <b>0</b> , <sup>p</sup> 26.59 20.10 29.10 99.10 99.10 99.10	Stresses, and M object 22, 30 Stresses, and M 194.38 194.3	embrane Axial Ф 0.07 0.09 0.10 0.10 0.10 0.09 0.07 0.00 0.07 0.09 0.10	Stress           om <sup>c</sup> 267.68           258.61           254.44           253.35           252.34           247.93           248.83           238.27           236.10           267.68           256.61           254.44	σ <sub>b</sub> <sup>c</sup> 347.97           335.48           329.96           328.90           329.47           326.34           322.09           320.36           304.68           348.76           330.85	Str Mem + Be 0.93 0.96 0.98 0.98 0.98 1.00 1.01 1.06 0.92 0.95 0.96	pass pass pass pass pass pass pass pass	valuation Mem 0.46 0.47 0.48 0.49 0.50 0.52 0.53 0.54 0.46 0.48 0.49	Axial pass pass pass pass pass pass pass pa	
Case (Continue)	No 3 4 5 6 7 7 8 9 10 11 11 3 4 5 6	β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.352 0.341 0.315 0.397 0.388 0.384 0.382	Net-Section check all, 8/m ok ok ok ok ok ok ok ok ok ok	Collapse Bending I flaw type short short short short long long long short short short short short	Voment β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.353 0.364 0.395 0.395 0.395 0.388 0.388 0.384 0.384	M <sub>nec</sub> /M <sub>0</sub> 0.873 0.842 0.828 0.825 0.827 0.819 0.808 0.804 0.764 0.875 0.844 0.830 0.828	A 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plux <u> <u> </u> </u>	s Bending Axial 1 object 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 99.10 99.10 99.10 99.10	Stresses, and M observed for the second sec	embrane Axial	Stress           om <sup>c</sup> 267.68           258.61           254.44           253.35           252.34           247.93           240.83           238.27           236.10           267.68           258.61           254.44	0,6 347.97 335.48 329.96 328.90 329.47 326.34 322.09 320.36 320.36 348.76 336.34 330.85 329.81	Str Mem + Be 0.93 0.96 0.98 0.98 0.98 0.99 1.00 1.01 1.06 0.92 0.95 0.96 0.97	pass pass pass pass pass pass pass pass	Mem           0.46           0.47           0.48           0.49           0.50           0.52           0.53           0.54           0.48           0.49	Axial pass pass pass pass pass pass pass pa	
Case (Continue)	No 3 4 5 6 7 8 9 10 11 3 4 5 6 7 7	β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.352 0.341 0.315 0.397 0.388 0.384 0.384 0.384 0.378	Net-Section check alt, Bht ok ok ok ok ok ok ok ok ok ok ok ok ok	Collapse Bending 1 flaw type short short short short long long long short short short short short short	β/π           0.395           0.386           0.382           0.380           0.376           0.363           0.364           0.395           0.395           0.388           0.388           0.388           0.382           0.382	M <sub>Med</sub> M <sub>0</sub> 0.873 0.842 0.828 0.827 0.819 0.808 0.808 0.808 0.808 0.764 0.875 0.844 0.875 0.844 0.830 0.828 0.829	A 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plu: $\sigma_m^{F'}$ 45.19 45.39 45.49 45.49 45.53 45.61 45.81 46.19 46.42 47.04 46.42 47.04 46.03 46.13 46.17 46.26	s Bending Akal 18 og. <sup>p</sup> 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 99.10 99.10 99.10 99.10	Stresses, and M 0,5 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 22.30 22.30 22.30	Avial         Avial           Φ         0.07           0.09         0.10           0.10         0.10           0.10         0.00           0.07         0.09           0.07         0.09           0.07         0.09           0.07         0.09           0.10         0.10           0.10         0.10	Stress           om <sup>6</sup> 267.68           258.61           254.44           253.35           252.34           247.93           240.83           238.27           236.10           255.45           255.45           253.45           253.45           254.44	op           347.97           335.48           329.96           328.47           326.34           322.09           320.46           348.76           336.34           330.85           329.81           330.40	Str Mem + Be 0.93 0.96 0.98 0.98 0.98 1.00 1.01 1.01 1.06 0.92 0.95 0.96	pass pass pass pass pass pass pass FAIL FAIL FAIL pass pass pass pass	Mem           0.46           0.47           0.48           0.49           0.50           0.52           0.53           0.54           0.46           0.49           0.49           0.50           0.52           0.53           0.54           0.46           0.49           0.49	Axial pass pass pass pass pass pass pass pa	
Case (Continue) Level A/B	No 3 4 5 6 7 8 9 10 11 11 3 4 5 6 6 7 8	β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.352 0.341 0.315 0.397 0.388 0.384 0.382 0.384 0.382 0.370	Net-Section check all, B/m ok ok ok ok ok ok ok ok ok ok ok ok ok	Collapse Bending I flaw type short short short short short long long long short short short short short short short short	β/π           0.395           0.386           0.386           0.380           0.376           0.363           0.364           0.395           0.388           0.384           0.384           0.384           0.378           0.378	M <sub>med</sub> M <sub>o</sub> 0.873 0.824 0.825 0.825 0.827 0.819 0.804 0.804 0.804 0.804 0.804 0.844 0.830 0.828 0.828 0.829	A 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plu orm <sup>p</sup> 45.19 45.39 45.39 45.49 45.53 45.61 45.81 46.19 46.42 47.04 45.83 46.03 46.13 46.13 46.13 46.26 46.46	s Bending Axial 13 0,8 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 99.10 99.10 99.10 99.10 99.10	Stresses, and M           0s           194.38           194.38           194.38           194.38           194.38           194.38           194.38           194.38           194.38           194.38           194.38           194.38           194.38           22.30           22.30           22.30           22.30           22.30           22.30           22.30	Φ         0.07           0.09         0.10           0.10         0.10           0.10         0.00           0.00         0.00           0.00         0.07           0.00         0.07           0.00         0.07           0.00         0.07           0.00         0.07           0.00         0.07           0.00         0.10           0.10         0.10           0.10         0.10	Stress $\sigma_m^c$ 267.68           258.61           254.44           253.35           252.34           240.83           238.27           236.10           267.68           258.61           254.44           253.35           238.27           236.10           267.68           258.61           252.34           252.34           247.93	o.5           347.97           335.48           329.96           328.90           329.47           326.34           320.36           348.76           336.34           330.85           329.81           330.45	Str Mem + Be 0.93 0.96 0.98 0.98 0.98 0.99 1.00 1.01 1.01 1.06 0.92 0.95 0.95 0.97	pass pass pass pass pass pass pass FAIL FAIL FAIL pass pass pass pass pass	Mem           0.46           0.47           0.48           0.49           0.52           0.53           0.54           0.48           0.49           0.52           0.53           0.54           0.48           0.49           0.49           0.51	Axial pass pass pass pass pass pass pass pa	
Case (Continue) Level A/B	No 3 4 5 6 7 8 9 9 10 11 11 3 4 5 6 6 7 8 9 9	β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.352 0.341 0.315 0.397 0.388 0.382 0.384 0.382 0.378 0.370 0.354	Net-Section ohe chait, Brm ok ok ok ok ok ok ok ok ok ok ok ok ok	Collapse Bending 1 flaw type short short short short short long long long short short short short short short short short long	Voment β/π 0.395 0.386 0.382 0.380 0.368 0.368 0.368 0.364 0.395 0.395 0.384 0.382 0.384 0.382 0.382 0.378 0.378 0.378	M <sub>Hef</sub> /M <sub>o</sub> 0.873 0.842 0.825 0.825 0.827 0.819 0.804 0.804 0.804 0.804 0.804 0.875 0.840 0.830 0.828 0.829 0.829 0.811	A 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.55E+05 2.5	embrane Plu: <b>a</b> m <sup>P</sup> <b>45.19</b> <b>45.39</b> <b>45.49</b> <b>45.53</b> <b>45.61</b> <b>45.81</b> <b>46.14</b> <b>46.42</b> <b>46.43</b> <b>46.13</b> <b>46.17</b> <b>46.26</b> <b>46.46</b> <b>46.83</b>	s Bending Akial 's or,p <sup>9</sup> 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 99.10 99.10 99.10 99.10	Stresses, and M o,5 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 22.30 22.30 22.30 22.30	embrane Axial 0.07 0.09 0.10 0.10 0.10 0.10 0.09 0.07 0.00 0.07 0.00 0.07 0.09 0.10 0.10 0.10 0.10 0.10 0.09 0.10 0.09 0.07 0.09 0.01 0.09 0.10 0.10 0.09 0.10 0.09 0.10 0.09 0.10 0.09 0.10 0.09 0.10 0.09 0.10 0.09 0.09 0.10 0.09 0.09 0.00 0.09 0.00 0.09 0.00 0.09 0.00 0.09 0.00 0.09 0.00 0.09 0.00 0.09 0.00 0.09 0.07 0.09 0.09 0.07 0.09 0.07 0.09 0.07 0.09 0.07 0.09 0.07 0.09 0.07 0.09 0.07 0.09 0.07 0.00 0.07 0.00 0.07 0.00 0.07 0.00 0.07 0.00 0.07 0.00 0.07 0.00 0.07 0.00 0.07 0.00 0.07 0.00 0.01 0.09 0.10 0.00 0.07 0.00 0.01 0.00 0.01 0.00 0.01 0.00 0.01 0.00 0.07 0.00 0.01 0.00 0.01 0.00 0.01 0.00 0.01 0.00 0.01 0.00 0.01 0.00 0.0	Jump           om           267.68           258.61           254.44           253.35           252.34           247.93           240.83           238.27           236.10           267.68           256.61           256.61           254.44           253.35           252.34           247.93           247.93           247.93           247.93           240.83	op           347.97           335.48           329.96           329.47           326.34           320.36           320.36           304.68           346.76           336.34           330.85           329.81           330.40           327.34	Str Mem + Be 0.93 0.96 0.98 0.98 0.98 0.99 1.00 1.01 1.06 0.92 0.95 0.96 0.97 0.96 0.97 0.99	pass pass pass pass pass pass pass FAIL FAIL pass pass pass pass pass	Mem           0.46           0.47           0.48           0.49           0.50           0.52           0.53           0.54           0.48           0.49           0.49           0.50           0.52           0.53           0.54           0.49           0.49           0.49           0.49           0.51           0.53	Axial pass pass pass pass pass pass pass pa	
Case (Continue) Level A/B	No	β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.352 0.341 0.315 0.397 0.388 0.384 0.384 0.384 0.382 0.378 0.370 0.354 0.354 0.354	Net-Section check alt, Bht ok ok ok ok ok ok ok ok ok ok ok ok ok	Collapse Bending I flaw type short short short short iong long long iong short short short short short long long long long long long long long	Voment β/π 0.395 0.386 0.382 0.380 0.368 0.368 0.368 0.364 0.395 0.364 0.395 0.388 0.388 0.388 0.384 0.382 0.378 0.378 0.375 0.365 0.367	M <sub>med</sub> M <sub>o</sub> 0.873 0.842 0.828 0.827 0.819 0.808 0.804 0.764 0.875 0.844 0.875 0.844 0.875 0.828 0.829 0.829 0.821 0.821 0.821 0.821	A 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.55E+05 2.5	embrane Plut	s Bending Akal 3 or, p 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 99.10 99.10 99.10 99.10 99.10 99.10 99.10	Stresses, and M o, 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 22.30 22.30 22.30 22.30 22.30 22.30 22.30 22.30 22.30	embrane Axial 0.07 0.09 0.10 0.10 0.10 0.10 0.09 0.07 0.00 0.07 0.00 0.10 0.10 0.10 0.10 0.10 0.09 0.10 0.09 0.07 0.09 0.07	Stress           267.68           258.61           254.44           253.35           252.34           247.93           240.83           238.27           236.10           257.44           258.61           258.61           254.44           253.35           252.34           254.44           253.35           252.34           240.83           238.27	06°           347.97           335.48           329.96           328.90           328.47           326.34           320.36           320.36           320.36           336.48           346.68           346.76           336.84           330.85           329.81           330.40           327.34           323.20           321.38	Str Mem + Be 0.93 0.96 0.98 0.99 1.00 1.01 1.01 1.06 0.99 0.95 0.96 0.97 0.96 0.97 0.96 0.99 0.99	uctural Exit pass pass pass pass pass FAIL FAIL pass pass pass pass pass pass pass	Mem           0.46           0.47           0.48           0.49           0.50           0.52           0.53           0.54           0.48           0.49           0.51           0.53           0.53	Axial pass pass pass pass pass pass pass pa	

Table .8	Allowable Local Thickness under Bending Moment and Pressure for 2"
	Feeder with Revised Surrounding Thickness

Conn	No	Characterization of Feeder Local Thinning											Net-section Characterized Collapse Parameters					
Case	INU.	t <sub>2</sub> (0.75t <sub>min</sub> )	t <sub>1</sub> / t <sub>min</sub>	adjacent t <sub>1</sub>	Ri	depth a	20	PDA	mean D	t <sub>1</sub> /D	a/t <sub>1</sub>	a/D	Po	F。	Mo	λ	P*	θ/π
	3	2.07	1.27	3.50	26.65	1.43	45°	37.70%	56.80	0.06	0.409	0.025	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.24	0.125
	4	2.07	1.27	3.50	26.65	1.43	60°	38.78%	56.80	0.06	0.409	0.025	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.29	0.167
	5	2.20	1.27	3.50	26.65	1.30	75°	39.32%	56.80	0.06	0.370	0.023	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.32	0.208
	6	2.37	1.27	3.50	26.65	1.13	90°	39.54%	56.80	0.06	0.323	0.020	82.8 MPa	184.85 kN∙m	3.34 MPa	0.28	12.33	0.250
Level A/B	7	2.67	1.27	3.50	26.65	0.83	135°	40.00%	56.80	0.06	0.236	0.015	82.8 MPa	184.85 kN∙m	3.34 MPa	0.28	12.36	0.375
	8	2.76	1.27	3.50	26.65	0.74	180°	41.10%	56.80	0.06	0.213	0.013	82.8 MPa	184.85 kN∙m	3.34 MPa	0.28	12.41	0.500
	9	2.76	1.27	3.50	26.65	0.74	235°	43.12%	56.80	0.06	0.213	0.013	82.8 MPa	184.85 kN∙m	3.34 MPa	0.28	12.52	0.653
	10	2.76	1.27	3.50	26.65	0.74	270°	44.41%	56.80	0.06	0.213	0.013	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.58	0.750
	11	2.76	1.27	3.50	26.65	0.74	360°	47.72%	56.80	0.06	0.213	0.013	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.75	1.000
	3	2.07	1.27	3.50	26.65	1.43	45°	37.70%	56.80	0.06	0.409	0.025	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.24	0.125
	4	2.07	1.27	3.50	26.65	1.43	60°	38.78%	56.80	0.06	0.409	0.025	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.29	0.167
	5	2.20	1.27	3.50	26.65	1.30	75°	39.32%	56.80	0.06	0.370	0.023	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.32	0.208
	6	2.37	1.27	3.50	26.65	1.13	90°	39.54%	56.80	0.06	0.323	0.020	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.33	0.250
Level C	7	2.67	1.27	3.50	26.65	0.83	135°	40.00%	56.80	0.06	0.236	0.015	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.36	0.375
2010.0	8	2.76	1.27	3.50	26.65	0.74	180°	41.10%	56.80	0.06	0.213	0.013	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.41	0.500
	9	2.76	1.27	3.50	26.65	0.74	235°	43.12%	56.80	0.06	0.213	0.013	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.52	0.653
	10	2.76	1.27	3.50	26.65	0.74	270°	44.41%	56.80	0.06	0.213	0.013	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.58	0.750
	11	2.76	1.27	3.50	26.65	0.74	360°	47.72%	56.80	0.06	0.213	0.013	82.8 MPa	184.85 kN·m	3.34 MPa	0.28	12.75	1.000
0			Net-Section	Collapse Bending I	Moment			м	embrane Plu	s Bending Axial	Stresses, and M	embrane Axial	Stress		Stri	uctural Ev	aluation	
Case (Continue)	No.	β/π	Net-Section check a/t, θ/π	Collapse Bending I flaw type	Moment β/π	M <sub>nsc</sub> /M <sub>o</sub>	Ai	M	embrane Plu: σ <sub>m</sub> <sup>p*</sup>	s Bending Axial	Stresses, and M	embrane Axial	Stress	σ <sub>b</sub> <sup>c</sup>	Stri Mem + Be	uctural Ev	valuation Mem	Axial
Case (Continue)	No.	β/π 0.395	Net-Section check a/t, θ/π ok	Collapse Bending I flaw type short	Moment β/π 0.395	M <sub>nsc</sub> /M <sub>o</sub> 0.873	A <sub>i</sub> 2231.2	M 2.53E+05	embrane Plu $\sigma_m^{p^*}$ 45.19	s Bending Axial σ <sub>b</sub> <sup>p</sup> 26.59	Stresses, and M $\sigma_b^s$ 194.38	embrane Axial Ф 0.07	Stress $\sigma_m^c$ 267.68	σ <sub>b</sub> <sup>c</sup> 347.97	Stri Mem + Be 0.93	uctural Ev nding pass	Valuation Mem 0.46	Axial pass
Case (Continue)	No. 3 4	β/π 0.395 0.386	Net-Section check a/t, θ/π ok ok	Collapse Bending I flaw type short short	Moment β/π 0.395 0.386	M <sub>nsc</sub> /M <sub>o</sub> 0.873 0.842	A <sub>i</sub> 2231.2 2231.2	M 2.53E+05 2.53E+05	embrane Plu σ <sub>m</sub> <sup>p*</sup> 45.19 45.39	s Bending Axial 3 σ <sub>b</sub> <sup>p</sup> 26.59 26.59	Stresses, and M σ <sub>b</sub> <sup>s</sup> 194.38 194.38	embrane Axial Ф 0.07 0.09	Stress σ <sub>m</sub> <sup>c</sup> 267.68 258.61	σ <sub>b</sub> ° 347.97 335.48	Stri Mem + Be 0.93 0.96	nding pass pass	Mem 0.46 0.47	Axial pass pass
Case (Continue)	No. 3 4 5	β/π 0.395 0.386 0.382	Net-Section check a/t, θ/π ok ok ok	Collapse Bending I flaw type short short short	Woment β/π 0.395 0.386 0.382	M <sub>nsc</sub> /M <sub>o</sub> 0.873 0.842 0.828	A <sub>i</sub> 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05	embrane Plu: σ <sub>m</sub> <sup>p*</sup> 45.19 45.39 45.49	s Bending Axial 3 σ <sub>b</sub> <sup>p</sup> 26.59 26.59 26.59	Stresses, and M σ <sub>b</sub> <sup>s</sup> 194.38 194.38 194.38	embrane Axial Ф 0.07 0.09 0.10	Stress σ <sub>m</sub> <sup>c</sup> 267.68 258.61 254.44	σ <sub>b</sub> ° 347.97 335.48 329.96	Stri Mem + Be 0.93 0.96 0.98	nding pass pass pass pass	Mem 0.46 0.47 0.48	Axial pass pass pass
Case (Continue)	No. 3 4 5 6	β/π 0.395 0.386 0.382 0.380	Net-Section check a/t, θ/π ok ok ok ok	Collapse Bending I flaw type short short short short	Moment β/π 0.395 0.386 0.382 0.380	M <sub>nsc</sub> /M <sub>o</sub> 0.873 0.842 0.828 0.825	A, 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plu: σ <sub>m</sub> <sup>p*</sup> 45.19 45.39 45.49 45.53	s Bending Axial 3 σ <sub>b</sub> <sup>p</sup> 26.59 26.59 26.59 26.59	Stresses, and M σ <sub>b</sub> <sup>s</sup> 194.38 194.38 194.38 194.38	embrane Axial 0.07 0.09 0.10 0.10	Stress σ <sub>m</sub> <sup>c</sup> 267.68 258.61 254.44 253.35	σ <sub>b</sub> <sup>c</sup> 347.97 335.48 329.96 328.90	Stri Mem + Be 0.93 0.96 0.98 0.98	nding pass pass pass pass pass	Valuation Mem 0.46 0.47 0.48 0.49	Axial pass pass pass pass
Case (Continue)	No. 3 4 5 6 7	β/π 0.395 0.386 0.382 0.380 0.376	Net-Section check a/t, θ/π ok ok ok ok ok	Collapse Bending I flaw type short short short short short	Moment β/π 0.395 0.386 0.382 0.380 0.376	M <sub>nsc</sub> /M <sub>o</sub> 0.873 0.842 0.828 0.825 0.825	A, 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plu: σ <sub>m</sub> <sup>p*</sup> 45.19 45.39 45.49 45.53 45.61	s Bending Axial 3	Stresses, and M	емbrane Axial Ф 0.07 0.09 0.10 0.10 0.10	Stress σ <sup>°</sup> <sub>m</sub> <sup>c</sup> 267.68 258.61 254.44 253.35 252.34	σ <sub>b</sub> <sup>c</sup> 347.97           335.48           329.96           328.90           329.47	Stra Mem + Be 0.93 0.96 0.98 0.98 0.98	nding pass pass pass pass pass pass	Mem 0.46 0.47 0.48 0.49 0.49	Axial pass pass pass pass pass
Case (Continue)	No	<ul> <li>β/π</li> <li>0.395</li> <li>0.386</li> <li>0.382</li> <li>0.380</li> <li>0.376</li> <li>0.368</li> </ul>	Net-Section check a/t, θ/π ok ok ok ok ok	Collapse Bending I flaw type short short short short short short	Woment β/π 0.395 0.386 0.382 0.380 0.376 0.368	M <sub>nsc</sub> /M <sub>c</sub> 0.873 0.842 0.828 0.825 0.825 0.827 0.819	A 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plu: σ <sub>m</sub> <sup>p*</sup> 45.19 45.39 45.49 45.53 45.61 45.81	s Bending Axial : σ <sub>b</sub> <sup>p</sup> 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59	Stresses, and M	емbrane Axial Ф 0.07 0.09 0.10 0.10 0.10 0.10	Stress σm <sup>c</sup> 267.68 258.61 254.44 253.35 252.34 247.93	σ <sub>b</sub> <sup>c</sup> 347.97           335.48           329.96           328.90           329.47           326.34	Stri           Mem + Be           0.93           0.96           0.98           0.98           0.98           0.98           0.98	nding pass pass pass pass pass pass pass	valuation Mem 0.46 0.47 0.48 0.49 0.49 0.49 0.50	Axial pass pass pass pass pass pass
Case (Continue)	No	β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.352	Net-Section check a/t, θ/m ok ok ok ok ok ok	Collapse Bending I flaw type short short short short short short long	Woment β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.353	M <sub>nsc</sub> /M <sub>o</sub> 0.873 0.842 0.828 0.825 0.825 0.827 0.819 0.808	A, 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plu:	s Bending Axial 3 σ <sub>b</sub> <sup>p</sup> 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59	Stresses, and M 0,5 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38	емbrane Axial Ф 0.07 0.09 0.10 0.10 0.10 0.10 0.10 0.09	Stress           σm <sup>c</sup> 267.68           258.61           253.35           252.34           247.93           240.83	σ <sub>b</sub> <sup>c</sup> 347.97 335.48 329.96 328.90 329.47 326.34 322.09	Stri           Mem + Be           0.93           0.96           0.98           0.98           0.98           0.99           1.00	nding pass pass pass pass pass pass pass pas	valuation Mem 0.46 0.47 0.48 0.49 0.49 0.50 0.50	Axial pass pass pass pass pass pass pass
Case (Continue)	No	β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.352 0.341	Net-Section check a/t, 8/m ok ok ok ok ok ok ok	Collapse Bending I flaw type short short short short short iong long	Woment β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.353 0.364	Mnse/Mo 0.873 0.842 0.828 0.825 0.825 0.827 0.819 0.808 0.804	A, 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plu:	s Bending Axial 3 <b>o</b> <sub>b</sub> <sup>p</sup> 26.59	Stresses, and M 0,5 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38	Φ           0.07           0.09           0.10           0.10           0.10           0.10           0.10           0.10           0.10           0.10	Stress           om <sup>c</sup> 267.68           258.61           254.44           253.35           252.34           247.93           240.83           238.27	σb <sup>c</sup> 347.97           335.48           329.96           328.90           329.47           326.34           322.09           320.36	Str           Mem + Be           0.93           0.96           0.98           0.98           0.98           0.98           0.99           1.00           1.01	nding pass pass pass pass pass pass FAIL FAIL	Mem           0.46           0.47           0.48           0.49           0.50           0.52           0.53	Axial pass pass pass pass pass pass pass pa
Case (Continue)	No	β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.352 0.341 0.315	Net-Section check a/t, 8/π ok ok ok ok ok ok ok	Collapse Bending I flaw type short short short short short long long long	Woment β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.353 0.364 0.395	Mnse/Mo 0.873 0.842 0.828 0.825 0.827 0.819 0.808 0.804 0.764	A 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plu: <u> </u>	s Bending Axial 1 orb <sup>p</sup> 26.59 26.	Stresses, and M ob <sup>5</sup> 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38	Φ           0.07           0.09           0.10           0.10           0.10           0.10           0.10           0.10           0.10           0.10           0.10           0.10           0.10           0.10           0.10           0.10           0.10           0.09           0.07           0.00	Stress           om <sup>c</sup> 267.68           258.61           254.44           253.35           252.34           247.93           240.83           238.27           236.10	σ <sub>b</sub> <sup>c</sup> 347.97           335.48           329.96           328.90           329.47           326.34           322.09           320.36           304.68	Str           Mem + Be           0.93           0.96           0.98           0.98           0.98           0.99           1.00           1.01	nding pass pass pass pass pass pass FAIL FAIL FAIL	Aluation Mem 0.46 0.47 0.48 0.49 0.49 0.50 0.52 0.53 0.54	Axial pass pass pass pass pass pass pass pa
Case (Continue)	No	β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.352 0.341 0.315 0.397	Net-Section           check a/t, 8/π           ok           ok	Collapse Bending I flaw type short short short short short long long long short	Moment β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.353 0.364 0.395 0.397	Mnac/Mo 0.873 0.842 0.828 0.825 0.827 0.819 0.808 0.804 0.764 0.875	A 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plu: <u> </u>	s Bending Axial 1 <b>o</b> <sub>b</sub> <sup>p</sup> 26.59	Stresses, and M ob <sup>5</sup> 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 22.30	embrane Axial	Stress           om <sup>c</sup> 267.68           258.61           254.44           253.35           252.34           247.93           240.83           238.27           236.10           267.68	σ <sub>b</sub> ° 347.97 335.48 329.96 328.90 329.47 326.34 322.09 320.36 304.68 348.76	Stn Mem + Be 0.93 0.96 0.98 0.98 0.98 0.99 1.00 1.01 1.00 1.01 0.92	nding pass pass pass pass pass pass FAIL FAIL FAIL pass	Aluation Mem 0.46 0.47 0.48 0.49 0.49 0.50 0.52 0.53 0.54 0.46	Axial pass pass pass pass pass pass pass pa
Case (Continue)	No 3 3 4 5 6 7 7 8 9 9 10 11 11 3 4	β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.352 0.341 0.315 0.397 0.388	Net-Section ok ok ok ok ok ok ok ok ok ok	Collapse Bending I flaw type short short short short long long long short short	Voment β/π 0.395 0.386 0.386 0.380 0.380 0.376 0.368 0.353 0.364 0.395 0.397 0.388	M <sub>rss</sub> /M <sub>o</sub> 0.873 0.842 0.828 0.825 0.827 0.819 0.808 0.804 0.764 0.875 0.844	A 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plu: <u> </u>	a Bending Axial 3 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	Stresses, and M obs 5 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 22.30 22.30	embrane Axial	Stress $\sigma_m^c$ 267.68           258.61           254.44           252.34           247.93           240.83           238.27           236.10           267.68           258.61	σ <sub>b</sub> <sup>c</sup> 347.97           335.48           329.96           328.90           329.47           326.34           322.09           320.36           304.68           348.76           336.34	Stin Mem + Be 0.93 0.96 0.98 0.98 0.99 1.00 1.01 1.01 1.06 0.92 0.95	nding pass pass pass pass pass pass FAIL FAIL pass pass	Mem           0.46           0.47           0.48           0.49           0.50           0.52           0.53           0.54           0.46	Axial pass pass pass pass pass pass pass pa
Case (Continue)	No. 3 4 5 6 7 7 8 9 10 11 11 3 3 4 5	β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.352 0.341 0.315 0.397 0.388 0.384	Net-Section check a/t, 8/m ok ok ok ok ok ok ok ok ok ok	Collapse Bending I flaw type short short short short long long long short short short	Woment β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.353 0.364 0.397 0.397 0.388 0.384	Mnss/Ms 0.873 0.842 0.828 0.825 0.827 0.819 0.808 0.804 0.764 0.875 0.844 0.830	A 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plu <b>G</b> m <sup>P</sup> 45.19 45.39 45.49 45.61 45.61 45.61 45.81 46.19 46.42 47.04 45.83 46.03 46.13	s Bending Axial 1 observed and a set of the	Stresses, and M	Φ           0.07           0.09           0.10           0.10           0.10           0.10           0.07           0.09           0.07           0.09           0.07           0.09           0.07           0.09           0.10	Stress           om <sup>c</sup> 267.68           256.61           254.44           253.35           252.34           247.93           248.27           236.10           267.68           258.61           255.34	σ <sub>b</sub> °           347.97           335.48           329.96           328.90           329.47           322.09           320.36           304.68           348.76           330.85	Strn Mem + Be 0.93 0.96 0.98 0.98 0.99 1.00 1.01 1.00 1.00 1.00 1.00 2.095 0.96	nding pass pass pass pass pass pass FAIL FAIL pass pass pass	Mem           0.46           0.47           0.48           0.49           0.50           0.52           0.53           0.54           0.46           0.48	Axial pass pass pass pass pass pass pass pa
Case (Continue)	No	β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.352 0.341 0.315 0.397 0.388 0.384 0.382	Net-Section check a/t, 6/m ok ok ok ok ok ok ok ok ok ok ok	Collapse Bending I flaw type short short short short short long long long short short short short short	40ment β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.353 0.364 0.397 0.388 0.397 0.388 0.384 0.382	Mnsc/Mo 0.873 0.842 0.828 0.825 0.827 0.819 0.808 0.804 0.764 0.875 0.844 0.830 0.828	A 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plu: σ_m <sup>p</sup> 45.19 45.49 45.49 45.53 45.61 45.81 46.19 46.42 47.04 45.83 46.03 46.13 46.17	s Bending Axial 's or, <sup>p</sup> 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 92.0 99.10 99.10 99.10	Stresses, and M           σ <sub>5</sub> <sup>6</sup> 194.38           194.38           194.38           194.38           194.38           194.38           194.38           194.38           194.38           194.38           194.38           22.30           22.30           22.30           22.30	O         O           0.07         0.09           0.10         0.10           0.10         0.10           0.009         0.07           0.09         0.07           0.09         0.07           0.09         0.10	Stress           om <sup>c</sup> 267.68           258.61           254.44           253.35           252.34           247.93           240.83           238.27           236.10           267.68           256.61           254.44	op           347.97           335.48           329.96           328.90           328.34           320.36           304.68           348.76           330.85           329.81	Strn Mem + Be 0.93 0.96 0.98 0.98 0.99 1.00 1.01 1.00 0.92 0.95 0.96 0.97	nding pass pass pass pass pass pass FAIL FAIL pass pass pass pass pass	Mem           0.46           0.47           0.48           0.49           0.50           0.52           0.53           0.54           0.46           0.49	Axial pass pass pass pass pass pass pass pa
Case (Continue)	No	β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.352 0.341 0.315 0.397 0.388 0.384 0.384 0.382 0.378	Nei-Section check at, 8/m ok ok ok ok ok ok ok ok ok ok ok ok ok	Collapse Bending I flaw type short short short short short long long long short short short short short	Voment β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.353 0.364 0.395 0.397 0.388 0.397 0.388 0.382 0.382 0.378	M <sub>Heal</sub> /M <sub>0</sub> 0.873 0.842 0.828 0.825 0.827 0.819 0.808 0.804 0.808 0.804 0.804 0.875 0.844 0.875 0.844 0.828 0.828	A 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	embrane Plui	Bending Avail 3           op           26.59           26.59           26.59           26.59           26.59           26.59           26.59           26.59           26.59           26.59           26.59           26.59           26.59           26.59           26.59           26.59           99.10           99.10           99.10           99.10           99.10	Stresses, and M 96 97 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 22.30 22.30 22.30 22.30	Φ           0.07           0.09           0.10           0.10           0.10           0.10           0.00           0.00           0.07           0.09           0.10           0.10           0.07           0.09           0.07           0.00           0.07           0.09           0.10           0.10           0.10           0.10	Ome         Ome           267.68         267.68           258.61         254.44           253.35         252.34           247.93         240.83           238.27         236.10           267.68         258.61           254.44         253.35	α, 6           347.97           335.48           329.96           329.47           326.30           322.09           320.47           320.34           320.35           347.97           320.36           320.36           320.36           320.36           320.37           330.48           330.40	Stm Mem + Be 0.93 0.96 0.98 0.98 0.99 1.00 1.01 1.01 1.06 0.92 0.95 0.96 0.97	nding pass pass pass pass pass pass FAIL FAIL pass pass pass pass pass	Mem           0.46           0.47           0.48           0.49           0.50           0.52           0.53           0.54           0.46           0.48           0.49	Axial pass pass pass pass pass pass pass pa
Case (Continue) Level A/B	No	β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.352 0.341 0.315 0.397 0.388 0.384 0.382 0.384 0.382 0.370	Net-Section check alt, B/m ok ok ok ok ok ok ok ok ok ok ok ok ok	Collapse Bending I flaw type short short short short long long long short short short short short short short short	β/π         0.395           0.386         0.382           0.380         0.376           0.368         0.353           0.364         0.395           0.395         0.388           0.384         0.382           0.384         0.378           0.378         0.378	Mme/Mg 0.873 0.842 0.825 0.825 0.827 0.819 0.804 0.804 0.804 0.804 0.864 0.844 0.830 0.828 0.828 0.822	A 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05 2.53E+05	and the second	Bending Axial 13 <b>c</b> <sub>b</sub> <sup>9</sup> 26.59 26.59 26.59 26.59 26.59 26.59 26.59 26.59 99.10 99.10 99.10 99.10 99.10	Stresses, and M           05           194.38           194.38           194.38           194.38           194.38           194.38           194.38           194.38           194.38           194.38           194.38           194.38           194.38           22.30           22.30           22.30           22.30           22.30           22.30           22.30           22.30	Φ           0.07           0.09           0.10           0.10           0.10           0.00           0.07           0.09           0.07           0.09           0.07           0.09           0.07           0.09           0.07           0.09           0.10           0.10           0.10           0.10           0.10	Stress           om <sup>6</sup> 267.68           258.61           253.55           252.34           247.93           248.03           238.10           267.68           258.61           236.10           267.68           258.61           256.44           253.35           258.41           253.35           252.34           247.93	06           347.97           335.48           329.96           328.90           328.47           326.34           320.36           304.68           348.76           336.34           330.85           329.81           332.34	Strint + Be 0.93 0.96 0.98 0.98 0.99 1.00 1.01 1.00 1.01 1.06 0.92 0.95 0.96 0.97	nding pass pass pass pass pass pass pass FAIL FAIL Pass pass pass pass pass	Mem           0.46           0.47           0.48           0.49           0.50           0.52           0.53           0.54           0.46           0.49           0.50           0.52           0.53           0.54           0.46           0.49           0.49           0.51	Axial pass pass pass pass pass pass pass pa
Case (Continue) Level A/B	No 3 4 5 6 7 8 9 10 11 11 3 4 5 6 7 8 9 9 10 11 11 3 4 5 6 7 8 9 9 10 10 11 11 11 11 11 11 11 11	β/π 0.395 0.386 0.380 0.380 0.376 0.368 0.352 0.341 0.315 0.397 0.388 0.384 0.384 0.382 0.378 0.370 0.354	Net-Section check at, B/m ok ok ok ok ok ok ok ok ok ok ok ok ok	Collapse Bending I flaw type short short short short short long long long short short short short short short short long	β/π           0.395           0.386           0.386           0.386           0.380           0.380           0.363           0.364           0.397           0.388           0.384           0.382           0.397           0.388           0.384           0.382           0.370           0.355	M <sub>med</sub> /M <sub>0</sub> 0.873 0.842 0.825 0.825 0.827 0.819 0.804 0.764 0.804 0.875 0.830 0.828 0.829 0.821 0.811	A 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2 2231.2	M 2.53E+05 2.55E+05 2.5	embrane Plu $\sigma_m^{P'}$ 45.19           45.39           45.49           45.61           45.81           46.42           47.04           45.83           46.03           46.13           46.26           46.46           46.46	Bending Axial 3 0, b 26,59 26,59 26,59 26,59 26,59 26,59 26,59 26,59 26,59 26,59 26,59 99,10 99,10 99,10 99,10 99,10 99,10 99,10	Stresses, and M object 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 22.30 22.30 22.30 22.30 22.30 22.30 22.30	Φ           0.07           0.09           0.10           0.10           0.10           0.10           0.10           0.10           0.07           0.09           0.10           0.10           0.10           0.10           0.07           0.09           0.10           0.10           0.10           0.10           0.10           0.10           0.10	Stress 267.68 258.61 254.44 253.35 252.34 247.93 240.83 238.27 236.10 267.68 258.61 254.44 253.35 254.44 253.35 252.34 247.93 240.83	06 <sup>6</sup> 347.97           335.48           329.96           329.97           326.34           320.36           320.36           304.68           336.34           336.34           336.34           330.45           329.81           330.40           327.34           323.20	Stm + Be 0.93 0.96 0.98 0.98 0.99 1.00 1.01 1.00 1.01 1.00 0.92 0.95 0.96 0.97 0.99	nding pass pass pass pass pass pass pass FAIL FAIL pass pass pass pass pass pass	Mem           0.46           0.47           0.48           0.49           0.50           0.52           0.53           0.54           0.48           0.49           0.51           0.53	Axial pass pass pass pass pass pass pass pa
Case (Continue) Level A/B	No. 3 4 5 6 7 8 9 9 10 10 11 11 3 4 4 5 6 6 7 8 9 9 9 9 9 9 9 10	β/π 0.395 0.386 0.382 0.380 0.376 0.368 0.362 0.341 0.397 0.388 0.397 0.388 0.384 0.384 0.384 0.370 0.370 0.354 0.343	Net-Section check at, 6/m ok ok ok ok ok ok ok ok ok ok ok ok ok	Collapse Bending I flaw type short short short short long long long short short short short short short short long long long long long long long long	Voment β/π 0.395 0.386 0.382 0.382 0.376 0.368 0.364 0.395 0.397 0.388 0.397 0.388 0.397 0.388 0.397 0.388 0.378 0.375 0.367	Mme/Ma 0.873 0.828 0.828 0.825 0.827 0.827 0.808 0.804 0.764 0.875 0.844 0.875 0.844 0.830 0.828 0.829 0.821 0.821 0.810	A 2231.2	M 2.53E+05 2.55E+05 2.5	embrane Plu $\sigma_m^P$ 45.19           45.39           45.49           45.61           45.81           46.42           47.04           45.83           46.17           46.26           46.42           46.13           46.17           46.83           47.07	Bendling Axial 3           op         2           26.59         2         5.59           26.59         2         5.59           26.59         2         5.59           26.59         2         5.59           26.59         2         6.59           99.10         99.10         99.10           99.10         99.10         99.10           99.10         99.10         99.10           99.10         99.10         99.10           99.10         99.10         10	Stresses, and M <b>c</b> <sub>b</sub> <sup>5</sup> 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 194.38 22.30 22.30 22.30 22.30 22.30 22.30 22.30 22.30	Φ           0.07           0.09           0.10           0.10           0.10           0.10           0.10           0.10           0.07           0.09           0.07           0.09           0.07           0.09           0.10           0.10           0.10           0.10           0.10           0.10           0.10           0.10           0.10           0.10           0.09           0.07	Stress           om <sup>c</sup> 267.68           258.61           253.35           253.35           252.34           240.83           238.27           236.10           267.68           258.41           253.35           252.34           254.44           253.35           254.43           254.44           253.35           252.34           254.43           253.35           252.34           240.83           238.27	op         c           347.97         335.48           329.96         329.96           328.90         328.34           322.09         320.36           304.68         336.34           330.36         329.31           330.41         320.36           330.34         329.31           330.40         327.34           322.33         321.38	Strint + Be 0.93 0.96 0.98 0.99 0.99 1.00 1.01 1.06 0.92 0.95 0.97 0.96 0.97 0.96 0.99 0.99 0.99 0.99	nding pass pass pass pass pass FAIL pass pass pass pass pass pass pass pas	Advaluation           0.46           0.47           0.48           0.49           0.50           0.53           0.54           0.46           0.49           0.50           0.53           0.54           0.49           0.49           0.49           0.49           0.49           0.49           0.49           0.51           0.53           0.53	Axial           pass           pass

## Table 9J24E Minimum and Average Wall Thickness of at 6 Probe Locations (mm)

Probe #	Probe 1	Probe 2	Probe 3	Probe 4	Probe 5	Probe 6
min thickness	2.54	2.80	2.86	3.48	3.45	3.63
avg thickness	3.47	3.58	3.70	3.82	3.88	4.00

## Table 10 J24E Allowable Local Minimum Thickness under Pressure Loading

Maximum Axial Extent L <sub>m(a)</sub>	8.75 mm												
$L_{m(a)}/(R_{min}t_{min}^{sp})^{1/2}$	0.98												
circumferential thinning angle (deg)	arch length (mm) $L_{m(t)}$	$L_m = (L_{m(a)}^2 + L_{m(t)}^2)^{1/2}$	$L_{m}$ /2.65 $(R_{min}^{sp}t_{min}^{sp})^{1/2}$	$\frac{L_{m(t)}}{/(R_{min}t_{min}^{sp})^{1/2}}$	Geometry Classification	LC	(a)	(b)	LAC (c)	C Max (a,b,c)	UC	t <sub>aloc</sub> /t <sub>min</sub> <sup>sp</sup> Min(LC,LAC,UC)	t <sub>aloc</sub>
76	38.2	39.17	1.661	4.3	UC	n/a	n/a	n/a	n/a	n/a	0.810	0.810	2.23

# Table 11 Allowable Local Minimum Thickness under Bending Moment Coincident with Pressure Loading for J24E

Casa	NIa	Characterization of Feeder Local Thinning											Net-section Characterized Collapse Parameters						
Case	140.	t <sub>2</sub> (0.75t <sub>min</sub> )	t <sub>1</sub> / t <sub>min</sub>	adjacent t <sub>1</sub>	Ri	depth a	20	PDA	mean D	t <sub>1</sub> /D	a/t <sub>1</sub>	a/D	P <sub>0</sub>	Fo	Mo	λ	P*	θ/π	
Level A/B	1	2.09	1.26	3.47	26.68	1.38	76°	40.20%	56.83	0.06	0.397	0.024	82.1 MPa	183.48 kN·m	3.32 MPa	0.28	12.34	0.211	
Level C	1	2.09	1.26	3.47	26.68	1.38	76°	40.20%	56.83	0.06	0.397	0.024	82.1 MPa	183.48 kN·m	3.32 MPa	0.28	12.34	0.211	
			Net-Section	Collapse Bending I	Membrane Plus Bending Axial Stresses, and Membrane Axi						l Stress		Structural Evaluation						
Case (Continue)	NO.	β/π	check a/t, θ/π	flaw type	β/π	M <sub>nsc</sub> /M <sub>o</sub>	Ai	I	$\sigma_m^{p^*}$	$\sigma_b^p$	$\sigma_b^s$	Φ	$\sigma_m^c$	σb <sup>c</sup>	Mem + Be	ending	Mem	Axial	
Level A/B	1	0.378	ok	short	0.378	0.814	2235.8	2.51E+05	45.99	26.77	195.65	0.11	250.74	324.21	1.00	pass	0.50	pass	
Level C	1	0.380	ok	short	0.380	0.816	2235.8	2.51E+05	46.64	99.74	22.45	0.11	250.74	325.14	0.98	pass	0.50	pass	





Figure 2

Illustration of Local Thinned Region







# Figure 4Ratio of Allowable Local Thickness versus Pressure Based Minimum<br/>Thickness for a Straight Pipe Section of a 2 Inch Feeder Pipe



#### Figure 5 Predicted Thickness Profile for D2J24E near the Grayloc at D1021