Constellation

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RS-22-085

10 CFR 50.90

January 12, 2023

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555-0001

LaSalle County Station, Units 1 and 2
Renewed Facility Operating License Nos. NPF-11 and NPF-18
NRC Docket Nos. 50-373 and 50-374

Subject: Application to Revise Design Basis to Allow Use of Plastic Section Properties in Lower Downcomer Braces Analysis

In accordance with 10 CFR 50.90, "Application for amendment of license, construction permit, or early site permit," Constellation Energy Generation, LLC (CEG) is submitting a license amendment request for LaSalle County Station, Units 1 and 2 (LSCS) to revise the Updated Final Safety Analysis Report (UFSAR) to allow the use of plastic section properties in analysis of the lower downcomer braces.

The request is subdivided as follows:

- Attachment 1 provides a description and evaluation of the proposed change.
- Attachment 2 provides a markup of the affected UFSAR pages.
- Attachment 3 provides design calculation documents for information only.

A pre-application meeting with the NRC was held on November 10, 2022, to provide a summary of the proposed license amendment request, ensure a common understanding of the proposed change and scope of the planned submittal, summarize supporting analyses and activities that have been performed, and to obtain NRC feedback prior to formal submittal. NRC feedback has been incorporated into Attachment 1.

The proposed changes have been reviewed by the LSCS Plant Operations Review Committee in accordance with the CEG Quality Assurance Program.

The attachment to this letter provides a description and assessment of the proposed changes.

Approval of the proposed amendment is requested by January 31, 2024. Site implementation will occur within 30 days of NRC approval.

In accordance with 10 CFR 50.91, a copy of this application, with attachments, is being provided to the designated State Officials.

There are no regulatory commitments contained within this letter. Should you have any questions concerning this letter, please contact Mr. Jason Taken at (630) 657-3660.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 12th day of January, 2023.

Respectfully,

Lueshen, Kevin

Digitally signed by Lueshen, Kevin
Date: 2023.01.12 14:33:10 -06'00'

Kevin Lueshen
Sr. Manager – Licensing
Constellation Energy Generation, LLC

Attachment 1: Description and Assessment
Attachment 2: UFSAR Markup
Attachment 3: Design Bases Calculations (for information only)

cc: NRC Regional Administrator, Region III
NRC Senior Resident Inspector – LaSalle County Station
NRC Project Managers – LaSalle Station
Illinois Emergency Management Agency – Division of Nuclear Safety

**ATTACHMENT 1**

LaSalle County Station, Units 1 and 2
Renewed Facility Operating License Nos. NPF-11 and NPF-18
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**Description and Assessment**

**ATTACHMENT 1**
**Description and Assessment**

**Subject:** Application to Revise Design Basis to Allow Use of Plastic Section Properties in Lower Downcomer Braces Analysis

**ATTACHMENT 1**
**Description and Assessment**

## 1.0 SUMMARY DESCRIPTION

In accordance with 10 CFR 50.90, "Application for amendment of license, construction permit, or early site permit," Constellation Energy Generation, LLC (CEG) is submitting a license amendment request for LaSalle County Station, Units 1 and 2 (LSCS) to revise the Updated Final Safety Analysis Report (UFSAR) to allow the use of plastic section properties in analysis of the lower downcomer braces.

## 2.0 DETAILED DESCRIPTION

During interface with the Nuclear Regulatory Commission on a non-conforming condition related to the pool swell profile, it was identified that analyses 187, 187K, and Rev. 0 of L-002547 utilize plastic section modulus, contrary to station licensing commitments (Reference 9). Calculations 187 and 187K are being revised to point to Calculation L-002547, Revision 0A (see Attachment 3) which contains updated evaluations for the upper downcomer bracing members, lower downcomer bracing members, and lower downcomer bracing gusset plates connecting the brace member to the downcomer.

The suppression chamber vent system consists of 98 downcomer pipes open to the drywell and submerged below the water level of the suppression pool, providing a flow path for uncondensed steam into the water. These downcomers function as the path for pressure suppression of steam, liquid and gases released in the drywell during a Loss of Coolant Accident (LOCA). Each downcomer has a 23.5-inch internal diameter. The downcomers project 6 inches above the drywell floor to prevent flooding from a broken line. This ensures complete quenching of the steam as it exits the downcomer pipes. Each vent pipe opening is shielded by a 1-inch-thick steel deflector plate to prevent overloading any single vent pipe by direct flow from a pipe break to that particular vent.

The downcomers in the suppression pool have been braced at elevation 721 feet, well above the pool swell impact zone, to reduce the pool dynamic loads transmitted to the drywell floor. Additional bracing (Lower Downcomer Braces) for the downcomers is installed at elevation 697 feet to support the downcomers against bounding submerged structures loads. The downcomer vents are subjected to static and dynamic loads due to normal, upset, emergency, and faulted plant conditions.

The downcomer bracing system consists of inner and outer rings which brace the inner and outer downcomers, respectively. Both the inner and outer rings consist of upper bracing and lower bracing. The upper bracing members are built-up I shapes while the lower bracing members are 8" diameter XXS pipe sections.

The proposed changes do not affect how any systems are operated or controlled. The use of the plastic section modulus is limited to the lower downcomer bracing members and the lower downcomer gusset plate sections.

## 3.0 TECHNICAL EVALUATION

### 3.1 Background

Calculation L-002547, Revision 0A provides design basis analyses for the upper and lower downcomer braces and lower downcomer brace gusset plate sections. The scope of the calculation was to re-evaluate the downcomer bracing members and gusset plate section based on the bounding loads. For the upper downcomer bracing members, elastic section properties are used, consistent with the current licensing basis. However, for the lower downcomer bracing members and the lower downcomer gusset plate sections, the design basis allowables (AISC 7th Edition) are exceeded in (3) modeled braces when using elastic section modulus. Therefore, the plastic section modulus is used to evaluate all lower downcomer bracing members and the lower downcomer gusset plate sections. No changes are required for the upper downcomer braces. The plastic sections modulus applies only to the lower downcomer braces and lower downcomer gusset plate sections.

### 3.2 Methodology

The loads on the downcomer vents are put into the PIPSYS model to determine the moments and axial loads at a joint. The most heavily-loaded member is determined by comparing every member/node which has a maximum axial force or bending moment due to any of the loading cases previously mentioned. To the results of the PIPSYS run, the drag load on the brace itself is added.

Procedure Summary:

a) Calculate moments due to drag loads on lower ring bracing members.
b) Determine maximum moments and axial loads on lower bracing from the PIPSYS model results.
c) Calculate stresses on lower bracing member.
d) Design connection of lower bracing to Pedestal and downcomer vent, and connection to Containment wall.
e) Reassess downcomer vent.
f) Reassess upper bracing member.

Figures 3.1 through 3.3 below show an overview of the downcomer bracing systems and the PIPSYS models used to analyze them. Additionally, as shown in the figures below, the PIPSYS models for the inner and outer rings only consist of about one quarter of the full downcomer bracing system. These partial models provide design basis analysis for the full downcomer bracing system in the existing calculations. It is considered that the output for the partial models remains bounding for the entire downcomer bracing system. The output from the PIPSYS analyses is used in the evaluation of the downcomers and bracing.

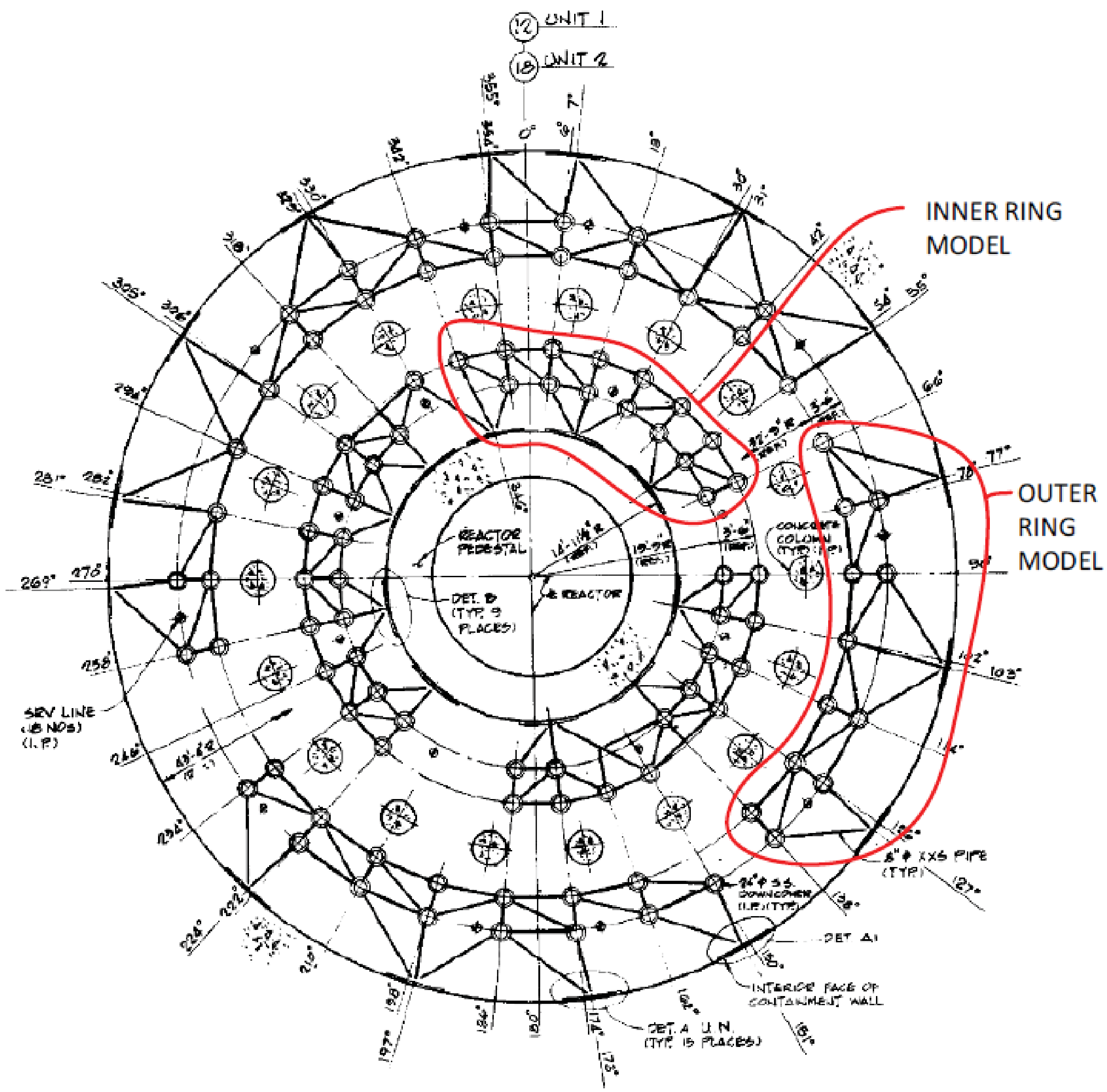


Figure 3.1: Overview of Downcomer Bracing

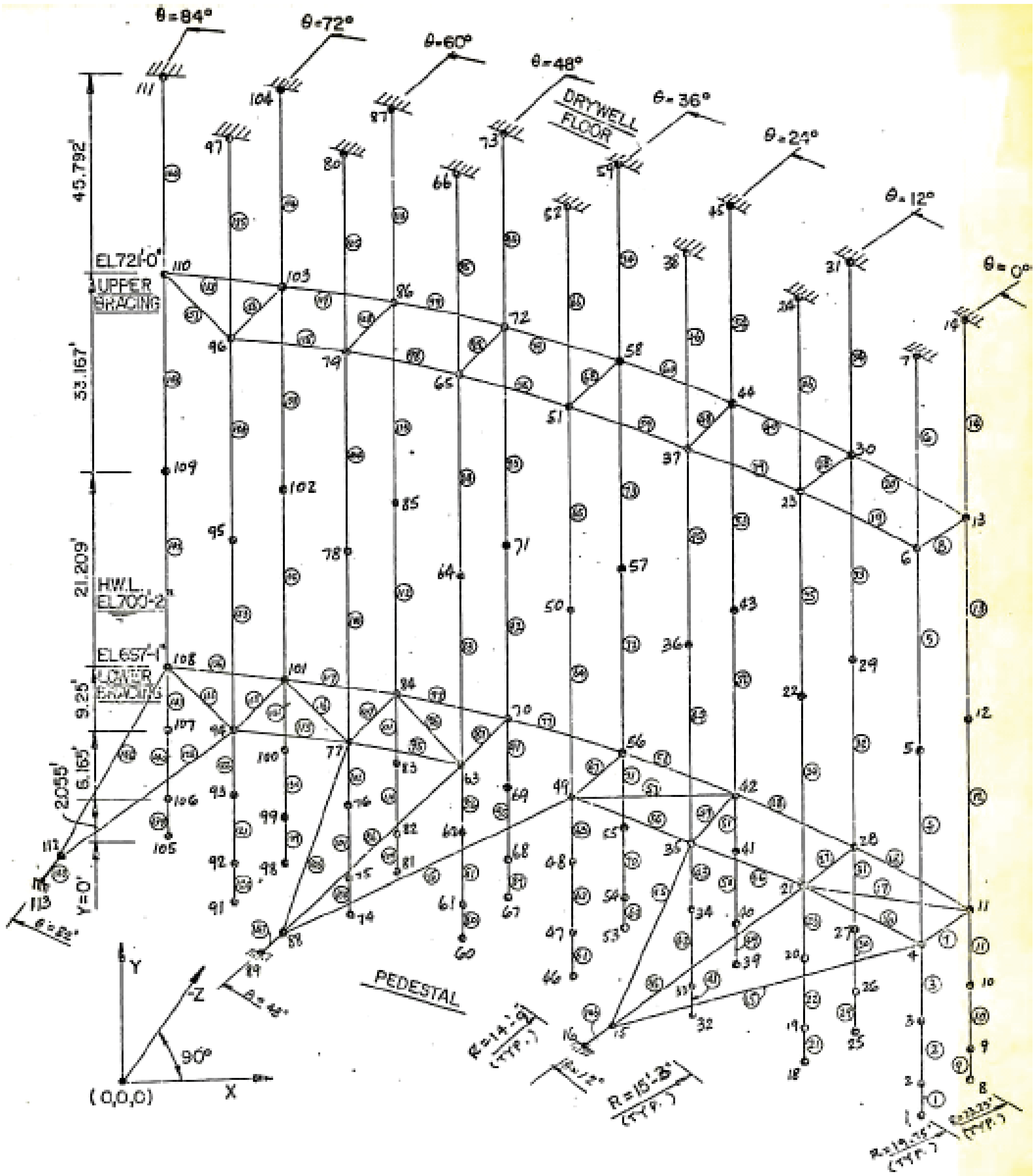


Figure 3.2: Downcomer Bracing Model, Inner Rings 1 & 2

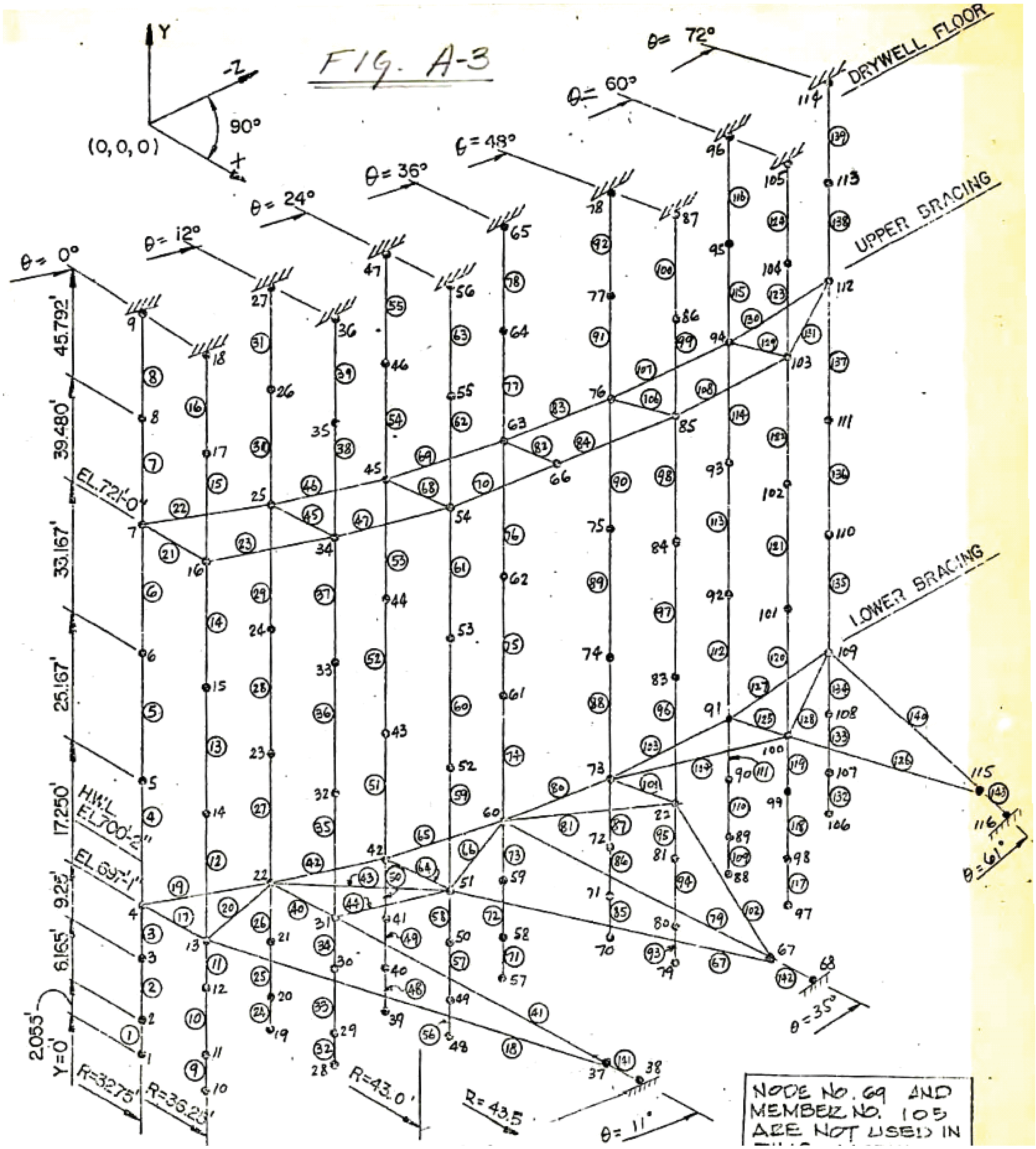


Figure 3.3: Downcomer Bracing Model, Outer Rings 3 & 4

This evaluation considers that the same members judged to be critical in Calc. L-002547, Rev. 0 remain critical. Therefore, only the members evaluated in Calc. L-002547 Rev. 0 are evaluated in Rev. 0A. Consistent with the existing analyses for the upper bracing members, an enveloping analysis is performed. In this evaluation, the upper bracing members are analyzed using elastic section properties, as required by LaSalle's original licensing basis. The lower downcomer bracing members and the gusset plate section are evaluated using plastic section properties.

### 3.3 Evaluation of Downcomer Bracing and Gusset Plate Sections

The Downcomer braces and gusset plate sections are evaluated for controlling load combinations consisting of abnormal/extreme environmental loads. The loading on these members is obtained from the PIPSYS analysis.

Conservatively, the evaluation considers a true envelope of the loads for the upper bracing members. In other words, the maximum force/moment of all upper bracing members for each case are considered to act concurrently.

Stresses are evaluated as follows:

a) Upper Downcomer Braces: Elastic section properties are used, consistent with the current licensing basis.
b) Lower Downcomer Braces and Lower Downcomer Brace Gusset Sections: Plastic Section properties are used.

### 3.4 Load Combinations

Controlling load combinations for lower bracing members and gusset plate sections consist of abnormal/extreme environmental loads. Load combinations 7-1, 7-2 and 7-3 below were considered, where:

S = Allowable stress
D = Dead loads
$T_a$ = Accident temperature load
LOCA = Loss of Coolant Accident loads
SRV = Safety/Relief valve load
$E_{ss}$ = Safe shutdown earthquake

Station Blackout cases (SBO) and Small Line Break LOCA cases S1 and S2:
7-1. $S \geq D + T_a + SRV + E_{ss}$
LOCA line break cases L3, I1b, and I2b:
7-2. $S \geq D + T_a + \gamma^*SRV + LOCA + E_{ss}$
LOCA line break cases L1, L2, I1a, I2a, and S3:
7-3. $S \geq D + T_a + \gamma^*SRV + LOCA + E_{ss}$

### 3.5 Plastic Section Properties Justification

Controlling load combinations for the lower bracing members and gusset plate sections consist of abnormal/extreme environmental loads similar to other high energy load combinations.

High energy line breaks are discussed in Section 3.6 of the UFSAR. The discussion in this section focuses on the design of pipe whip restraints and in Table 3.6-6 acceptance criteria are provided. This table shows that the energy absorbing portions of the pipe whip restraints are allowed to go plastic, thereby absorbing energy.

Support steel for the VR Exhaust plenum walls for the Abnormal, Abnormal/Severe Environmental and Abnormal/Extreme Environmental load cases are discussed in section 3.C.5 of the UFSAR. They are designed to AISC allowables stresses increased by a factor of 1.6, however, in cases where this allowable cannot be met, the section in question can fully develop its plastic moment (Utilize plastic section modulus).

The stresses in the lower downcomer braces and lower downcomer gussets plate sections were limited to American Institute of Steel Construction (AISC) allowable stresses increased by a factor of 1.6. The maximum stresses for each were determined to be greater than elastic allowables. For the lower downcomer braces and lower downcomer gussets plate sections the stresses cause formation of a plastic hinge and the behavior is no longer elastic. Therefore, they were qualified using the plastic section modulus methodology. The computed stresses considering elastic behavior are still less than the steel ultimate strength and the calculated stresses using plastic section modulus methodology are less than the yield stress.

The downcomers function as the path for pressure suppression of steam, liquid and gases released in the drywell during a Loss of Coolant Accident (LOCA). Once Reactor Pressure Vessel (RPV) depressurization has been completed, the energy addition to the primary containment through the SRVs will be within the capacity of the containment vent, even if the SRV discharges are uncovered. Maintaining the RPV depressurized then takes priority and primary containment pressure may be controlled by venting. Therefore, second order analysis of the post blowdown deformed shape of the downcomer braces and gusset plate sections is not required.

### 3.6 Potential for Structural Changes

Based on the evaluations performed on the downcomer braces and lower downcomer brace gusset plate sections, it is currently concluded that no structural modifications will be required.

### 3.7 Comparison to Other Plants

LaSalle Station has reviewed the UFSAR/FSAR of other Constellation stations relative to the use of plastic section properties for structural steel members for comparison. Below in Figures 3.4 and 3.5 are excerpts from the Dresden and Quad Cities Station UFSAR, respectively.

Structural Steel Members

| Stress | Design Limit |
|---|---|
| Bending | 1.6* AISC allowable based on plastic section modulus with stresses not to exceed 0.95 *Fy. For this to be used, the section should satisfy the compact section criteria and lateral bracing requirements of the AISC Code. AISC LRFD Specification may be consulted to obtain further clarifications. |
| Axial | 1.6* AISC allowable not <0.95*Fy |
| Shear | $0.95*Fy/(3)^{1/2}=0.548*Fy$ |

**Figure 3.4: Dresden UFSAR Section 3.9.3.3.4.2**

QUAD CITIES — UFSAR

Structural Steel Members

| Stress | Design Limit |
|---|---|
| Bending | 1.6 * AISC allowable based on plastic section modulus with stresses not to exceed 0.95 * Fy. For this to be used the section should satisfy the compact section criteria and lateral bracing requirements of the AISC Code. AISC LRFD Specification may be consulted to obtain further clarifications. |
| Axial | 1.6 * AISC allowable not < 0.95* Fy |
| Shear | $0.95*Fy / (3)^{1/2} = 0.548 * Fy$ |

**Figure 3.5: Quad Cities UFSAR Section 3.9.3.1.3.4.2**

As identified above, both Dresden and Quad Cities Station allow for the use of plastic section modulus in the design of Main Steam Piping Supports (High Energy Systems).

## 4.0 REGULATORY EVALUATION

### 4.1 Applicable Regulatory Requirements

10 CFR 50, Appendix A, "General Design Criteria for Nuclear Power Plants," Criterion 16, "Containment Design," requires that reactor containment and associated systems shall be provided to establish an essentially leak-tight barrier against the uncontrolled release of radioactivity to the environment and to assure that the containment design conditions important to safety are not exceeded for as long as postulated accident conditions require.

10 CFR 50, Appendix A, "General Design Criteria for Nuclear Power Plants," Criterion 50, 'Containment design basis," requires that the reactor containment structure, including access

openings, penetrations, and the containment heat removal system shall be designed so that the containment structure and its internal compartments can accommodate, without exceeding the design leakage rate and with sufficient margin, the calculated pressure and temperature conditions resulting from any loss-of-coolant accident. This margin shall reflect consideration of (1) the effects of potential energy sources which have not been included in the determination of the peak conditions, such as energy in steam generators and as required by § 50.44 energy from metal-water and other chemical reactions that may result from degradation but not total failure of emergency core cooling functioning, (2) the limited experience and experimental data available for defining accident phenomena and containment responses, and (3) the conservatism of the calculational model and input parameters.

10 CFR 50.59 allows licensees to make changes to the plant as described in the UFSAR only if the changes do not result in a malfunction of a structure, system, or component important to safety with a different result than any previously evaluated in the UFSAR. As discussed in Section 3.0 above, the proposed change results in a departure from a method of evaluation described in the UFSAR used in establishing the design bases or in the safety analyses.

### 4.2 No Significant Hazards Consideration Analysis

In accordance with 10 CFR 50.90, "Application for amendment of license, construction permit, or early site permit," Constellation Energy Generation, LLC (CEG) is submitting a license amendment request for LaSalle County Station, Units 1 and 2 (LSCS) to revise the Updated Final Safety Analysis Report (UFSAR) to allow the use of plastic section properties in analysis of the lower downcomer braces.

CEG has evaluated whether a significant hazards consideration is involved with the proposed amendment(s) by focusing on the three standards set forth in 10 CFR 50.92, "Issuance of amendment," as discussed below:

1. **Does the proposed amendment involve a significant increase in the probability or consequences of an accident previously evaluated?**

   **Response: No**

   The proposed change revises the LSCS UFSAR to allow the use of plastic section properties in analyses of the lower downcomer braces. The proposed changes do not affect plant operations or any design function. No physical plant changes are being made, so there is no change to the probability or consequence of any accident.

   Therefore, the proposed change does not involve a significant increase in the probability or consequences of an accident previously evaluated.

2. **Does the proposed amendment create the possibility of a new or different kind of accident from any previously evaluated?**

   **Response: No**

   The proposed changes do not create the possibility of a new or different kind of accident from any accident previously evaluated because they do not involve the addition of any new components or systems. The proposed changes do not alter the design function of components or systems that could initiate a new or different kind of accident. The proposed changes do not alter how components or systems are controlled or utilized. The methodology does not require any physical changes to the plant; therefore, no new accidents could be introduced.

No credible new failure mechanisms, malfunctions, or accident initiators not considered in the design and licensing bases are introduced. The proposed change does not invalidate assumptions made in the safety analysis.

Therefore, the proposed change does not create the possibility of a new or different kind of accident from any previously evaluated.

3. **Does the proposed amendment involve a significant reduction in a margin of safety?**

   **Response: No**

   The changes revising the LSCS UFSAR to allow the use of plastic section properties in analyses of the lower downcomer braces do not represent a significant change in a margin of safety. The lower downcomer braces were originally designed elastically to the American Institute of Steel Construction's (AISC) "Steel Construction Manual – 7th Edition" allowable stresses times a factor of 1.6. In the reassessment of these members, plastic section properties are allowed for abnormal/extreme environmental load cases. It is appropriate to consider them similar to high-energy line break systems that allow plastic section properties to be utilized and will maintain their integrity as they absorb energy.

   The proposed change does not adversely affect existing plant safety margins or the reliability of the equipment assumed to operate in the safety analysis. As such, there are no changes being made to safety analysis assumptions, safety limits, or limiting safety system settings that would adversely affect plant safety as a result of the proposed change.

   Therefore, the proposed change does not involve a significant reduction in a margin of safety.

Based on the above, CEG concludes that the proposed change presents no significant hazards consideration under the standards set forth in 10 CFR 50.92(c), and, accordingly, a finding of "no significant hazards consideration" is justified.

4.3 Conclusion

In conclusion, based on the considerations discussed above, (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public.

## 5.0 ENVIRONMENTAL EVALUATION

The proposed change would not change a requirement with respect to installation or use of a facility component located within the restricted area, as defined in 10 CFR 20, or would change an inspection or surveillance requirement. The proposed change does not involve (i) a significant hazards consideration, (ii) a significant change in the types or significant increase in the amounts of any effluents that may be released offsite, or (iii) a significant increase in individual or cumulative occupational radiation exposure. Accordingly, the proposed change meets the eligibility criterion for categorical exclusion set forth in 10 CFR 51.22(c)(9).

Therefore, pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment need be prepared in connection with the proposed change.

## 6.0 REFERENCES


1. AISC Manual of Steel Construction, 7th Edition
2. LaSalle Updated Final Safety Analysis Report, Rev. 025
3. Dresden Updated Final Safety Analysis Report, Rev. 014
4. Quad Cities Updated Final Safety Analysis Report, Rev. 016
5. Calculation L-002547, “ASSESSMENT OF CONTAINMENT WALL, BASEMAT, LINER, REACTOR PEDESTAL, DOWNCOMER BRACING, DRYWELL FLR, SUPP. POOL CO., FOR 105% PWR UPRATE”, Rev. 0A
6. Calculation 187, “DESIGN DOWNCOMER BRACING EL697'1", Rev. 1A
7. Calculation 187K, “ASSESSMENT DOWNCOMER BRACING SYS LOADS”, Rev. 0A
8. "Request for License Amendment to revise the basis for evaluation of VR Exhaust Plenum Masonry Walls for LaSalle Units 1 and 2," dated May 5, 1999 (ML20206J692)
9. Integrated Inspection Report 373/374/2017004, dated 2/13/18

**ATTACHMENT 2**

LaSalle County Station, Units 1 and 2
Renewed Facility Operating License Nos. NPF-11 and NPF-18
NRC Docket Nos. 50-373 and 50-374

**UFSAR Markup**

Proposed Change:

Revise section, delete text with strikethrough and add the following text at bullet point b.

The allowable stresses for the downcomer bracing are:

1. The AISC allowables, for load combinations 1, 2, and 3 of Table 4.1-1.

2. 1.6 times AISC allowables based on elastic** section modulus, but no greater than 0.95 fy, for load combinations 4, 4A, 5, 5A, 6, 7 and 7A.

   **Lower downcomer braces and gusset plate sections may utilize plastic section modulus for load cases 7 and 7A.

Refer to DAR section 5.3.3.4 for the downcomer bracing applicable codes.

3.8.3.2.4 Reactor Pedestal

a. 1 through 10;

b. 16 through 19;

c. 21, 22, and 24; and

d. 27 through 29.

3.8.3.2.5 Reactor Shield

a. 3 through 5, 8 through 10;

b. 12, 16 through 19, 24; and

c. 27 through 29.

3.8.3.2.6 Platforms, Galleries and Downcomer Bracings

a. 12, 16 through 19, and 24;

b. ~~refer to DAR Section 5.3.3.4 for the downcomer bracing applicable codes.~~

3.8.3.3 Loads and Loading Combinations

The drywell floor and the reactor pedestal were initially designed using the loads, load combinations, and load factors listed and discussed in Tables 3.8-3 and 3.8-8 respectively. However, as required by the NRC, the final design was modified to incorporate SRV discharge and postulated LOCA loads as discussed in Reference 1. The loads and loading combinations for the drywell floor are in compliance with Article CC-3000 of the ASME B&PV Code, Section III, Division 2, to the extent discussed in Subsection 3.8.1.3.

The loads and loading combinations for the reactor pedestal comply with the sections of ACI-349, which are based on ACI-318.

The drywell floor and the reactor pedestal are designed for the following pressures:

a. full pressure: 45 psig in the drywell and the suppression chamber;

b. partial pressure large: 45 psig in the drywell and 20 psig in the suppression chamber; and

**ATTACHMENT 3**

LaSalle County Station, Units 1 and 2
Renewed Facility Operating License Nos. NPF-11 and NPF-18
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**Design Bases Calculations**

**(for information only)**

## Design Analysis Cover Sheet Form
Page 1

| | | | |
|---|---|---|---|
| **Design Analysis** | | **Last Page No.** [6] 100 | |
| **Analysis No.:** [1] | L-002547 | **Revision:** [2] 0A | Major ☐ Minor ☒ |
| **Title:** [3] | Assessment of Containment Wall, Basemat, Liner, Reactor Pedestal, Downcomer Bracing, Drywell Floor, and Suppression Pool Columns for 105% Power Uprate | | |
| **EC No.:** [4] | 634630 | **Revision:** [5] 0 | |

| | | **Component(s):** [14] | |
|---|---|---|---|
| **Station(s):** [7] | LAS | | |
| **Unit No.:** [8] | 1 & 2 | | |
| **Discipline:** [9] | STDC | | |
| **Descrip. Code/Keyword:** [10] | S02 | | |
| **Safety/QA Class:** [11] | SR | | |
| **System Code:** [12] | MS | | |
| **Structure:** [13] | RB | | |

**CONTROLLED DOCUMENT REFERENCES** [15]

| Document No.: | From/To | Document No.: | From/To |
|---|---|---|---|
| Calc. 187 | From | Calc 187K | From |
| ~~Calc. L-002547~~ RJS 12/7/22 | From | | |
| | | | |
| | | | |

**Is this Design Analysis Safeguards Information?** [16] Yes ☐ No ☒ If yes, see SY-AA-101-106

**Does this Design Analysis contain Unverified Assumptions?** [17] Yes ☐ No ☒ If yes, ATI/AR#:

**This Design Analysis SUPERCEDES:** [18] N/A **in its entirety.**

**Description of Revision** (list changed pages when all pages of original analysis were not changed): [19]
Minor revision 0A assesses the feasbility of qualifying the downcomer bracing members using the elastic section modulus, consistent with the current licensing commitment. If not feasible, the analysis is updated to use the plastic section modulus in support of a License Amendment Request.

**Preparer:** [20] See Page 1.1 (Print Name) ______ (Sign Name) ______ (Date)

**Method of Review:** [21] **Detailed Review** ☒ **Alternate Calculations (attached)** ☐ **Testing** ☐

**Reviewer:** [22] See Page 1.1 (Print Name) ______ (Sign Name) ______ (Date)

**Review Notes:** [23] Independent review ☒ Peer review ☐

(For External Analyses Only)

**External Approver:** [24] K. Ata (Print Name) [signature] (Sign Name) 10/11/2021 (Date)

**Exelon Reviewer:** [25] Robert Stubblefield (Print Name) [signature] (Sign Name) 11/30/22 (Date)

**Independent 3rd Party Review Reqd?** [26] Yes ☐ No ☒

**Exelon Approver:** [27] JAMES PATTERSON (Print Name) [signature] (Sign Name) 11/30/22 (Date)

## List of Preparers and Reviewers

**Section(s):** 1.0-6.2

| | Print Name | Sign Name | Date |
|---|---|---|---|
| **Prepared by:** | G. Frazee | [signature] | 10/11/2021 |
| **Prepared by:** | A. Blomquist | [signature] | 10/11/2021 |
| **Reviewed by:** | S. G. Kwon | [signature] | 10/11/2021 |

**Method of Review:** ☒ Detailed ☐ Alternate ☐ Test

**Section(s):** 7.0-7.2.6.4, 8.0-8.2

| | Print Name | Sign Name | Date |
|---|---|---|---|
| **Prepared by:** | G. Frazee | [signature] | 10/11/2021 |
| **Reviewed by:** | A. Blomquist | [signature] | 10/11/2021 |

**Method of Review:** ☒ Detailed ☐ Alternate ☐ Test

**Section(s):** 7.3-7.4.4

| | Print Name | Sign Name | Date |
|---|---|---|---|
| **Prepared by:** | A. Blomquist | [signature] | 10/11/2021 |
| **Reviewed by:** | G. Frazee | [signature] | 10/11/2021 |

**Method of Review:** ☒ Detailed ☐ Alternate ☐ Test

**ATTACHMENT 2**
**Owner's Acceptance Review Checklist for External Design Analyses**
**Page 1 of 3**

**Design Analysis No.: L-002547** **Rev: 0A** **Page 1.2**
**Contract #: 00597084** **Release #: 00722**

| No | Question | Instructions and Guidance | Yes / No / N/A |
|---|---|---|---|
| 1 | Do assumptions have sufficient documented rationale? | All Assumptions should be stated in clear terms with enough justification to confirm that the assumption is conservative.<br><br>For example, 1) the exact value of a particular parameter may not be known or that parameter may be known to vary over the range of conditions covered by the Calculation. It is appropriate to represent or bound the parameter with an assumed value. 2) The predicted performance of a specific piece of equipment in lieu of actual test data. It is appropriate to use the documented opinion/position of a recognized expert on that equipment to represent predicted equipment performance.<br>Consideration should also be given as to any qualification testing that may be needed to validate the Assumptions. Ask yourself, would you provide more justification if you were performing this analysis? **If** yes, the rationale is likely incomplete. | ☒ Yes ☐ No ☐ N/A |
| 2 | Are assumptions compatible with the way the plant is operated and with the licensing basis? | Ensure the documentation for source and rationale for the assumption supports the way the plant is currently or will be operated post change and they are not in conflict with any design parameters. If the Analysis purpose is to establish a new licensing basis, this question can be answered yes, if the assumption supports that new basis. | ☒ Yes ☐ No ☐ N/A |
| 3 | Do all unverified assumptions have a tracking and closure mechanism in place? | **If** there are unverified assumptions without a tracking mechanism indicated, **then** create the tracking item either through an ATI or a work order attached to the implementing WO. Due dates for these actions need to support verification prior to the analysis becoming operational or the resultant plant change being op authorized. | ☐ Yes ☐ No ☒ N/A |
| 4 | Do the design inputs have sufficient rationale? | The origin of the input, or the source should be identified and be readily retrievable within Exelon's documentation system. If not, then the source should be attached to the analysis. Ask yourself, would you provide more justification if you were performing this analysis? **If** yes, the rationale is likely incomplete. | ☒ Yes ☐ No ☐ N/A |
| 5 | Are design inputs correct and reasonable with critical parameters identified, if appropriate? | The expectation is that an Exelon Engineer should be able to clearly understand which input parameters are critical to the outcome of the analysis. That is, what is the impact of a change in the parameter to the results of the analysis? If the impact is large, then that parameter is critical. | ☒ Yes ☐ No ☐ N/A |
| 6 | Are design inputs compatible with the way the plant is operated and with the licensing basis? | Ensure the documentation for source and rationale for the inputs supports the way the plant is currently or will be operated post change and they are not in conflict with any design parameters. | ☒ Yes ☐ No ☐ N/A |

**ATTACHMENT 2**
**Owner's Acceptance Review Checklist for External Design Analyses**
**Page 2 of 3**

**Design Analysis No.: L-002547** **Rev: 0A** **Page 1.3**

| No | Question | Instructions and Guidance | Yes / No / N/A |
|---|---|---|---|
| 7 | Are Engineering Judgments clearly documented and justified? | See Section 2.13 in CC-AA-309 for the attributes that are sufficient to justify Engineering Judgment. Ask yourself, would you provide more justification if you were performing this analysis? **If** yes, the rationale is likely incomplete. | ☒ ☐ ☐ |
| 8 | Are Engineering Judgments compatible with the way the plant is operated and with the licensing basis? | Ensure the justification for the engineering judgment supports the way the plant is currently or will be operated post change and is not in conflict with any design parameters. **If** the Analysis purpose is to establish a new licensing basis, **then** this question can be answered yes, if the judgment supports that new basis. | ☒ ☐ ☐ |
| 9 | Do the results and conclusions satisfy the purpose and objective of the Design Analysis? | Why was the analysis being performed? Does the stated purpose match the expectation from Exelon on the proposed application of the results? **If** yes, **then** the analysis meets the needs of the contract. | ☒ ☐ ☐ |
| 10 | Are the results and conclusions compatible with the way the plant is operated and with the licensing basis? | Make sure that the results support the UFSAR defined system design and operating conditions, or they support a proposed change to those conditions. If the analysis supports a change, are all of the other changing documents included on the cover sheet as impacted documents? | ☒ ☐ ☐ |
| 11 | Have any limitations on the use of the results been identified and transmitted to the appropriate organizations? | Does the analysis support a temporary condition or procedure change? Make sure that any other documents needing to be updated are included and clearly delineated in the design analysis. Make sure that the cover sheet includes the other documents where the results of this analysis provide the input. | ☐ ☐ ☒ |
| 12 | Have margin impacts been identified and documented appropriately for any negative impacts (Reference ER-AA-2007)? | Make sure that the impacts to margin are clearly shown within the body of the analysis. If the analysis results in reduced margins ensure that this has been appropriately dispositioned in the EC being used to issue the analysis. | ☐ ☐ ☒ |
| 13 | Does the Design Analysis include the applicable design basis documentation? | Are there sufficient documents included to support the sources of input, and other reference material that is not readily retrievable in Exelon controlled Documents? | ☒ ☐ ☐ |
| 14 | Have all affected design analyses been documented on the Affected Documents List (ADL) for the associated Configuration Change? | Determine if sufficient searches have been performed to identify any related analyses that need to be revised along with the base analysis. It may be necessary to perform some basic searches to validate this. | ☒ ☐ ☐ |
| 15 | Do the sources of inputs **and** analysis methodology used meet committed technical and regulatory requirements? | Compare any referenced codes and standards to the current design basis and ensure that any differences are reconciled. If the input sources **or** analysis methodology are based on an out-of-date methodology or code, additional reconciliation may be required if the site has since committed to a more recent code | ☒ ☐ ☐ |

**ATTACHMENT 2**
**Owner's Acceptance Review Checklist for External Design Analyses**
**Page 3 of 3**

**Design Analysis No.: L-002547** **Rev: 0A** **Page 1.4**

| No | Question | Instructions and Guidance | Yes / No / N/A |
|---|---|---|---|
| 16 | Have vendor supporting technical documents and references (including GE DRFs) been reviewed when necessary? | Based on the risk assessment performed during the pre-job brief for the analysis (per HU-AA-1212), ensure that sufficient reviews of any supporting documents not provided with the final analysis are performed. | ☒ Yes ☐ No ☐ N/A |
| 17 | Do operational limits support assumptions and inputs? | Ensure the Tech Specs, Operating Procedures, etc. contain operational limits that support the analysis assumptions and inputs. | ☐ Yes ☐ No ☒ N/A |
| 18. | List the critical characteristics of the product, and validate those critical characteristics. | | |

Create an SFMS entry as required by CC-AA-4008. SFMS Number: 72938

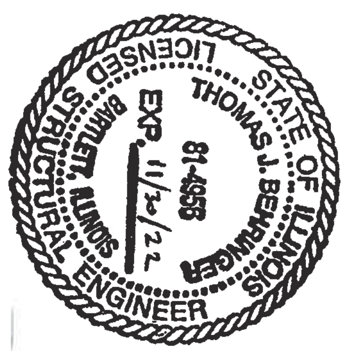
**Licensed Engineer Certification Page**
**Page 1 of 1**

**CERTIFICATION OF CALCULATION NUMBER(s): L-002547, Revision 0A**

I certify that the Calculation(s) listed above was prepared by me or under my personal supervision or developed in conjunction with the use of accepted engineering standards and that I am a Licensed Structural Engineer under the laws of the State of Illinois.

Certified by: ______________________ Date: 10/11/2021

**Seal Below**




**Expires:** 11/30/22

Sargent & Lundy LLC Illinois Department of Professional Regulation Registration Number is: 184-000106

## TABLE OF CONTENTS

# 1.0 BACKGROUND, PURPOSE & SCOPE

## 1.1 BACKGROUND

During Exelon's interface with the NRC on a non-conforming condition related to the pool swell profile, it was identified that analyses 187 (Ref. 3a), 187K (Ref. 3b), and Rev. 0 of L-002547 (Ref. 3c) utilize plastic section modulus, contrary to station licensing commitments. See IR No. 04091810.

Note that Rev. 0 of Calc. L-002547 (Ref. 3c) is the major calculation revision corresponding to this minor revision. Throughout this minor revision Rev. 0 of Calc. L-002547 will be referred to as "Calc. L-002547." This analysis is in support of EC 634630.

## 1.2 PURPOSE

The purpose of this minor revision is to provide a bounding evaluation for the upper and lower downcomer brace members and lower downcomer brace gusset plate section used at some connections to the downcomers and to re-evaluate these items to bring the analysis into alignment with current station licensing commitments. As part of this effort, it was identified that incorrect bounding loads were considered in the latest analyses of the upper and lower bracing members in Calc. L-002547 (Ref. 3c). The refined analysis considering the correct bounding loads and using the elastic section modulus determined the stresses exceed the DB allowables. Therefore, Exelon is pursuing a License Amendment Request (LAR) via Licensing Action LI-21-0215 to allow for the use of plastic section modulus for the lower downcomer bracing and gusset plate section.

Based on the above, the purpose of this minor revision is to re-evaluate the lower downcomer bracing and gusset plate section using plastic section modulus in support of the LAR. The upper downcomer bracing members are evaluated using elastic section properties, consistent with the current licensing basis.

## 1.3 SCOPE

The scope of this minor revision is to re-evaluate the downcomer bracing members and gusset plate section based on the bounding loads. For the upper downcomer bracing members, elastic section properties are used, consistent with the current licensing basis. For the lower downcomer bracing members and the gusset plate section, plastic section modulus is used in support of the LAR.

## 2.0 DESIGN INPUTS

$ORIGIN \equiv 1$ Starting ordinal for matrix operations

1. Lower Downcomer Braces:

The lower downcomer bracing system (Elevation 697'-1") is shown on Dwg. S-797 (Ref. 2a) and the bracing members are described in Section 5.3.3.1 of the Mark II Design Analysis Report (DAR) (Ref. 1c). As shown in Ref. 2b, the lower braces are 8" XXS pipe conforming to ASTM A618 Type II.

A corrosion allowance was originally made for the braces per Section 2.5 of Calc. 187 (Ref. 3a). The corrosion allowance only considered a design life of 40 years. Operating licenses for LaSalle Units 1 and 2 have been renewed resulting in an extended operating life of 60 years. Based on discussion with Exelon on 5/18/2020, the reduction in thickness for an operating life of 40 years is to be used herein.

$red_{corr} := 1\frac{mil}{yr}$ Corrosion reduction (Ref. 3a, Section 2.5)

$D_{in.nom} := 6.875in$ Nominal inner diameter of 8" XXS pipe (Ref. 3a, Section 2.5)

$D_{out.nom} := 8.625in$ Nominal outer diameter of 8" XXS pipe (Ref. 3a, Section 2.5)

$D_{out.corr} := D_{out.nom} - 2\cdot red_{corr}\cdot(40yr) = 8.545\ in$ Reduced outer diameter to account for corrosion over operating life

$I_{lb} := 152in^4$ Moment of inertia of 8" XXS pipe, allowing for corrosion (Ref. 3a, Section 2.5)

$S_{lb} := 35.58in^3$ Elastic section modulus of 8" XXS pipe, allowing for corrosion (Ref. 3a, Section 2.5)

$Z_{lb} := \frac{D_{out.corr}^{\ 3}}{6} - \frac{D_{in.nom}^{\ 3}}{6} = 49.83\ in^3$ Plastic section modulus of 8" XXS pipe, allowing for corrosion (Ref. 4a, page 6-27)

$A_{lb} := 20.23in^2$ Cross-sectional area of 8" XXS pipe, allowing for corrosion (Ref. 3a, Section 2.5)

Material properties for the braces are given below. Since the maximum temperature considered for the Suppression Pool is 212°F per Calc. L-002547 (Ref. 3c), the yield stress of the material does not need to be reduced per Table X.1 of Ref. 4b.

$F_{y.A618} := 50ksi$ Yield strength of ASTM A618, Type II pipe (Ref. 6a, Table 2)

2. Upper Downcomer Braces:

The upper downcomer bracing members (Elevation 721'-0") are described in Section 5.3.3.1 and Figure 5.3-1 of the DAR (Ref. 1c) and in Refs. 2c and 2d. A portion of Ref. 2d is reproduced below for reference showing the dimensions of the brace web and flanges.

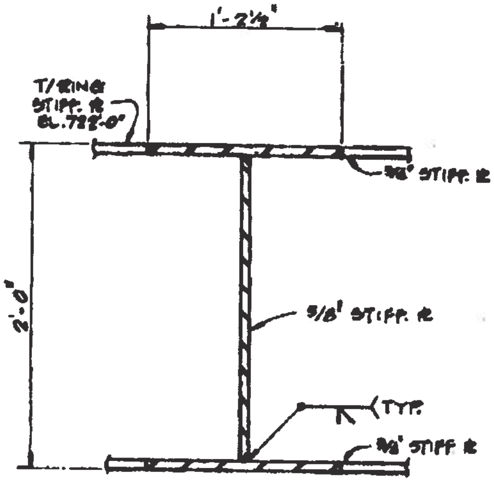



**Figure 2.1-1:** Upper Downcomer Bracing Plate Dimensions (Ref. 2d)

Section 2.10.2 of Ref. 3a calculates the section properties for the upper brace members.

$A_{t.ub} := 35.81in^2$ Total area of cross section

$S_{x.ub} := 294.47in^3$ Elastic section modulus of major axis bending

$S_{y.ub} := 52.63in^3$ Elastic section modulus for minor axis bending

As discussed in Ref. 1c, the upper braces are made from ASTM A-572 Grade 50 steel. Material properties for the upper braces are shown below. As noted in Design Input #1, the yield stress of the material does not need to be reduced for the design temperatures considered.

$F_{y.A572} := 50ksi$ Yield stress of ASTM A572 Gr 50 (Ref. 6b, Table 3)

3. Lower Downcomer Brace Gusset Plate:

Some of the lower downcomer brace vent connections utilize gusset plates as shown in Detail E and Detail H on Dwg. S798 (Ref. 2b). Note that on page 2 of Section 2.8.2 of Calc. 187 (Ref. 3a), it is stated that this gusset plate configuration is not used on any single brace-to-downcomer connections and is only used in some locations where more than one brace connects to one horizontal gusset plate on the downcomer (see Figure 2.1-2). Section 7-7 on Ref. 2b shows the gusset plate configuration which has been reproduced in Figure 2.1-2. Although the 2 and 3 brace to vent connections use a single horizontal gusset plate, the effective section properties are considered to be the same as the single brace to vent connection. This is consistent with the existing evaluations as stated on page 3 of Section 2.8.2 of Calc. 187 (Ref. 3a).

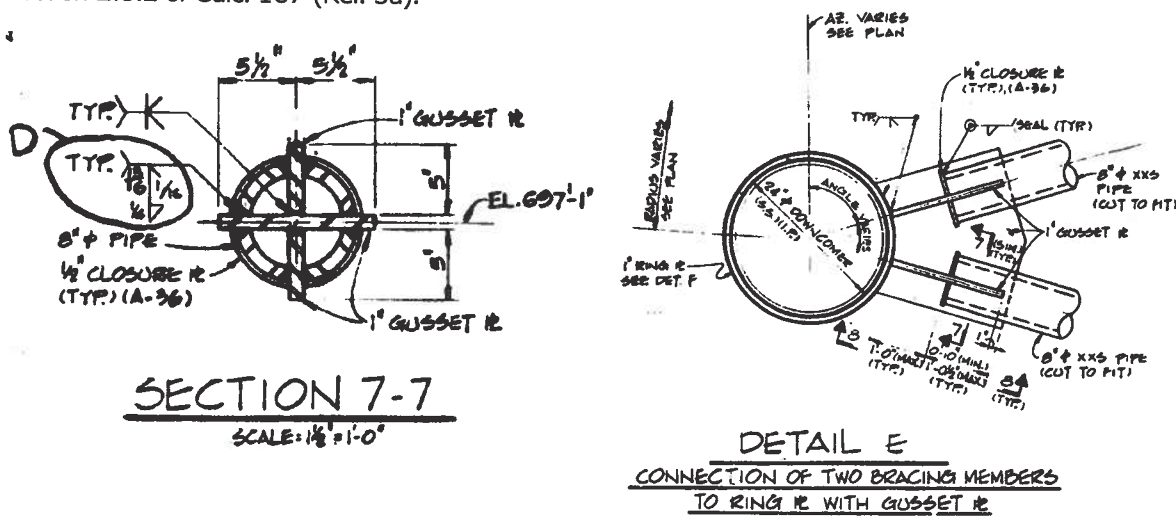



**Figure 2.1-2:** Lower Downcomer Gusset Plate Dimensions (Ref. 2b)

The properties of the plus shaped gusset section are calculated on page 1 of Section 2.8.2 of Calc. 187 (Ref. 3a). However, the properties given there did not take the reduction in plate dimensions to account for corrosion that was considered for the lower bracing members. Considering, the gusset plates are submerged like the lower bracing members, the section properties are recalculated considering the same reduction for corrosion used for the lower bracing members.

$t_{gp} := 1in - 2\cdot red_{corr}\cdot(40yr) = 0.92\,in$ — Thickness of gusset plates

$w_{gp} := 11in - 2\cdot red_{corr}\cdot(40yr) = 10.92\,in$ — Width of gusset plates in each direction

$A_{gp} := (2\cdot w_{gp} - t_{gp})\cdot t_{gp} = 19.25\,in^2$ — Area of effective gusset section

$$S_{gp} := \left[\frac{(w_{gp} - t_{gp})\cdot t_{gp}^{\,3}}{12} + \frac{t_{gp}\cdot w_{gp}^{\,3}}{12}\right]\cdot(0.5\cdot w_{gp})^{-1} = 18.4\,in^3$$

Elastic section modulus of effective gusset section

$$Z_{gp} := \frac{(w_{gp} - t_{gp})\cdot t_{gp}^{\,2}}{4} + \frac{t_{gp}\cdot w_{gp}^{\,2}}{4} = 29.54\,in^3$$

Plastic section modulus of effective gusset section

Per Dwg. S-797 (Ref. 2a) all plates shall be ASTM A588 (Ref. 6c) Lukens Fineline U.N. As noted in Design Input #1, the yield strength of the material does not need to be reduced for the design temperatures considered.

$F_{y.A588} := 50ksi$ — Yield strength for gusset plate material per Table 2 in ASTM A588 (Ref. 6c)

4. Thermal load increase factors:

Calc. L-002547 (Ref. 3c) accounts for the 105% power uprate, which only increases the accident thermal loading on the braces. Thermal loads from Calculation 187 (Ref. 3a) and Calculation 187K (Ref. 3b) are factored based on the design basis accident temperatures and the accident temperatures associated with the 105% power uprate. The same factors from Ref. 3c are used in this evaluation to increase the applicable thermal loads on the braces for the 190°F and 212°F accident temperature cases. Ref. 3c qualified the 150°F cases through engineering judgment so did not determine an increase factor for this temperature. However, since plastic section properties were used in the evaluations that the engineering judgment is based on, the bracing members are evaluated for the 150°F cases. An increase factor for the 150°F temperature is determined following the same methodology presented in Ref. 3c.

$IF_{150} := \frac{(150 - 70)\Delta°F}{(146 - 70)\Delta°F} = 1.05$ — Thermal load increase factor for 150°F accident temperature (Ref. 3c, Section 7)

$IF_{190} := 1.58$ — Thermal load increase factor for 190°F accident temperature (Ref. 3c, Section 7)

$IF_{212} := 1.87$ — Thermal load increase factor for 212°F accident temperature (Ref. 3c, Section 7)

5. As-built eccentricities for lower bracing members:

Section 3.4 of Calc. 187 (Ref. 3a) evaluates the lower bracing members for nonconformances with installation tolerances, which results in eccentricity between the brace centerline and the connection workpoint. This eccentricity results in additional moment on the brace members.

The PIPSYS models used to determine brace loads are partial models meant to bound all brace members. Therefore, the critical model members that are evaluated correspond to multiple installed brace members. Only the eccentricity for the modeled members that are critical are considered. The critical members are considered to remain the same as those evaluated in Section 7.3 of Calc. L-002547 (Ref. 3c). Section 3.4, Pages 48-51 of Ref. 3a provide the as-installed eccentricities, which are summarized on the following page.

$e_{lb.86.h} := 0.70in$ Max horizontal eccentricity for inner ring model member 86 (no vertical eccentricity exists) (Unit 1 CBI brace 52)

$e_{lb.126i.h} := 0.75in$ Max horizontal eccentricity for inner ring model member 126 (no vertical eccentricity exists) (Unit 1 CBI brace 52) (Unit 1 CBI brace 14)

$e_{lb.47} := 0.0in$ Max eccentricity for inner ring model member 47 (No eccentricities)

$e_{lb.57.h} := 3.20in$ Max horizontal eccentricity for inner ring model member 57 (no vertical eccentricity exists) (Unit 1 CBI brace 52) (Unit 1 CBI brace 3)

$e_{lb.7} := 0.06in$ Max eccentricity for inner ring model member 7 (Unit 1 CBI brace 20)

$e_{lb.75.h} := 0.70in$ Max horizontal eccentricity for inner ring model member 75 (no vertical eccentricity exists) (Unit 1 CBI brace 52) (Unit 2 CBI brace 2)

$e_{lb.104} := 0.0in$ Max eccentricity for outer ring model member 104 (No eccentricities)

$e_{lb.126o} := 0.0in$ Max eccentricity for outer ring model member 126 (No eccentricities)

$e_{lb.40} := 0.25in$ Max eccentricity for outer ring model member 40 (Unit 1 CBI brace 40)

$e_{lb.41} := 0.65in$ Max eccentricity for outer ring model member 41 (Unit 1 CBI brace 59)

$e_{lb.67} := 1.06in$ Max eccentricity for outer ring model member 67 (Unit 1 CBI brace 35)

$e_{lb.101} := 0.0in$ Max eccentricity for outer ring model member 101 (No eccentricities)

## 3.0 ASSUMPTIONS & ENGINEERING CONSIDERATIONS

There are no unverified assumptions used in the preparation of this analysis.

Minor engineering judgments, where used, are identified and substantiated.

## 4.0 REFERENCES


1. LaSalle Station Documents
   a. UFSAR, Rev. 24.
   b. DS-SE-01-LS, Rev. 8, "Structural Department Project Design Criteria."
   c. Mark II Design Analysis Report, Rev. 10.

2. LaSalle Station Drawings
   a. S-797, Rev. E, "Reactor Containment - Downcomer Bracing Plans, Sections & Details."
   b. S-798, Rev. D, "Reactor Containment - Downcomer Bracing Section & Details."
   c. S-869, Rev. D, "Reactor Containment Downcomer Bracing Plan & Details."
   d. S-870, Rev. B, "Reactor Containment Downcomer Bracing Sections & Details."

3. LaSalle Station Calculations
   a. 187, Rev. 1, "Design of Downcomer Bracing El. 697'-1"."
   b. 187K, Rev. 0, "Assessment of Downcomer Bracing System for NUREG Lateral Chugging Loads."
   c. L-002547, Rev. 0, "Assessment of Containment Wall, Basemat, Liner, Reactor Pedestal, Downcomer Bracing, Drywell Floor, and Suppression Pool Columns for 105% Power Uprate.
   d. L-001799, Rev. 0, "Assessment of Containment Wall, Base Mat, Liner, Reactor Pedestal, Downcomer Bracing, Drywell Floor and Suppression Pool Columns for Suppression Pool Temperature Increase."
   e. 187B, Rev. 0, "Downcomer Bracing System Analysis with Additional Bracing at El. 697'-1" (Microfiche)."

4. American Institute of Steel Construction
   a. Steel Construction Manual, 7th Edition.
   b. Design Guide 19, "Fire Resistance of Structural Steel Framing."

5. American Society of Mechanical Engineers
   a. Boiler & Pressure Vessel Code, Section III, Division 1, Subsection NC, "Class 2 Components," 1977 Edition.
   b. Cases of ASME Boiler and Pressure Vessel Code, Case N-71-7 (1644-7), "Additional Material for Component Supports, Section III, Division 1, Subsection NF Class 1, 2, 3, and MC Component Supports."

6. ASTM International
   a. ASTM A618-74, "Hot-Formed Welded and Seamless High-Strength Low-Allow Structural Tubing."
   b. ASTM A572-75, "High-Strength Low-Alloy Columbium-Vanadium Steels of structural Quality."
   c. ASTM A588-81, "High-Strength Low-Alloy Structural Steel with 50 ksi Minimum Yield Point to 4 in. Thick."

7. Not Used.

8. US Nuclear Regulatory Commission
   a. NUREG-0808, "MARK II Containment Program Load Evaluation and Acceptance Criteria."
   b. NUREG-0800, Section 3.6.2, Rev. 1, "Determination of Rupture Locations and Dynamic Effects Associated with the Postulated Rupture of Piping."

## 5.0 IDENTIFICATION OF COMPUTER PROGRAMS

Listed below are the computer programs that have been used in the development of this calculation. All software listed is validated per Sargent & Lundy Software Verification & Validation procedures, which meet 10 CFR 50 Appendix B quality assurance requirements. The software has been accessed from the LAN by the following PC numbers:

- PL10996 (G. Frazee)
- PL12327 (A. Blomquist)

### 5.1 MATHCAD v15.0 M050 (S&L PROGRAM NO. 03.7.548-15_M050)

*Mathcad* Version 15 is a Windows-based, general purpose calculation package with built-in mathematical functions, operators, units, and constants that can be used to perform calculations.

# 6.0 METHODOLOGY & ACCEPTANCE CRITERIA

## 6.1 METHODOLOGY

Methodology for evaluating the downcomer braces in the existing design basis evaluations is described in Calc. 187 (Ref. 3a), Section 1.3, and is followed unless noted otherwise. Excerpts are repeated below for reference:

*The loads on the downcomer vents...are put into the PIPSYS model to determine the moments and axial loads at a joint. The most heavily-loaded member is determined by comparing every member/node which has a maximum axial force or bending moment due to any of the loading cases previously mentioned. To the results of the PIPSYS run, the drag load on the brace itself is added.*

*Procedure Summary:*

*a. Calculate moments due to drag loads on lower ring bracing members.*
*b. Determine maximum moments and axial loads on lower bracing from the PIPSYS model results.*
*c. Calculate stresses on lower bracing member.*
*d. Design connection of lower bracing to Pedestal and downcomer vent, and connection to Containment wall.*
*e. Reassess downcomer vent.*
*f. Reassess upper bracing member.*

Figures 6.1-1 through 6.1-3 show an overview of the downcomer bracing systems and the PIPSYS models used to analyze them.

The downcomer bracing system consists of inner and outer rings which brace the inner and outer downcomers, respectively. Both the inner and outer rings consist of upper bracing (EL 721'-0") and lower bracing (EL. 697'-11"). The upper bracing members are built-up I shapes while the lower bracing members are 8" diameter XXS pipe sections.

As shown in Figure 6.1-1, the PIPSYS models for the inner and outer rings only consist of about one quarter of the full downcomer bracing system. These partial models provide design basis analysis for the full downcomer bracing system in the existing calculations. It is considered that the output for the partial models remains bounding for the entire downcomer bracing system.

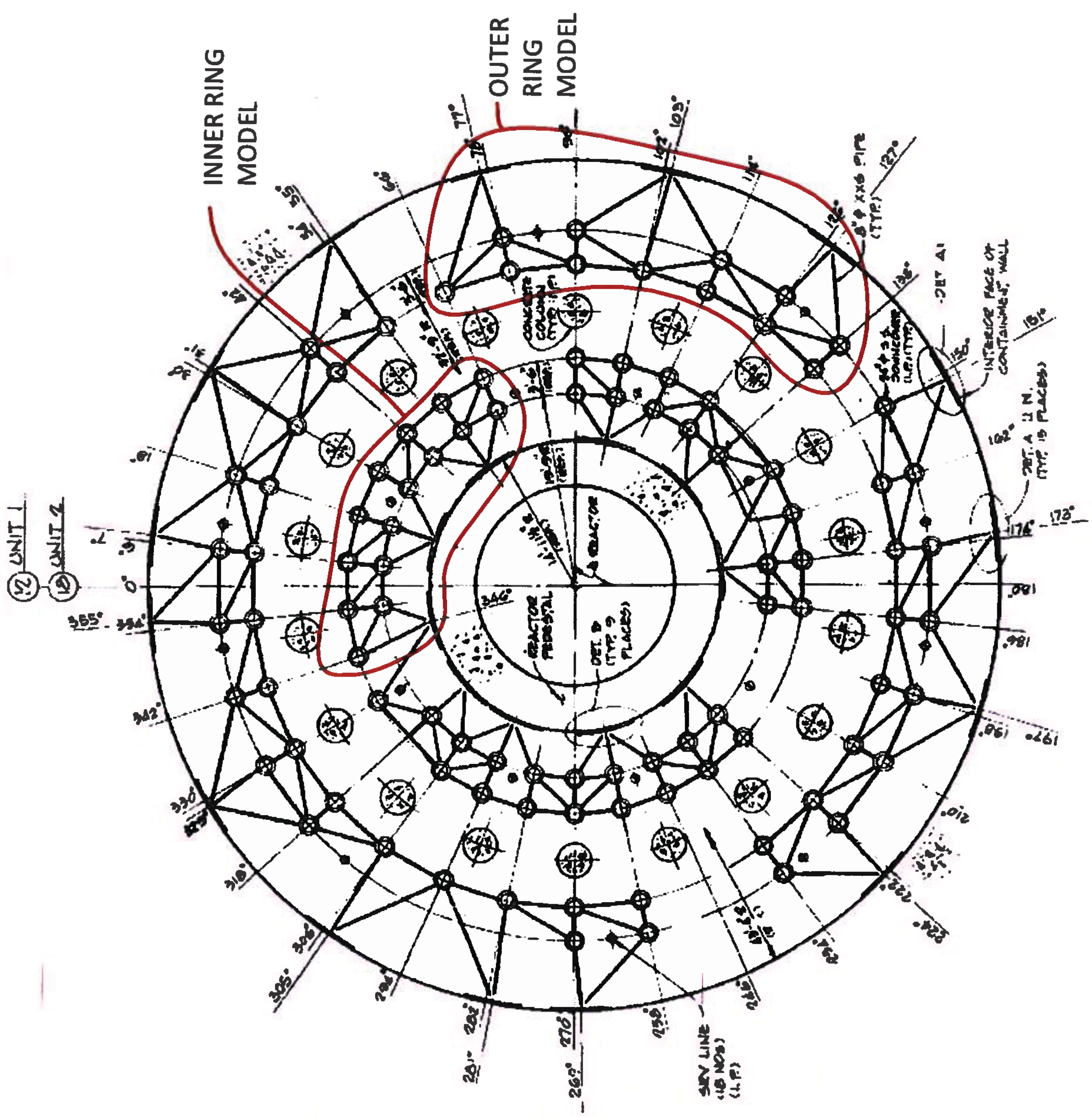



**Figure 6.1-1:** Overview of Downcomer Bracing (Ref. 2a; Ref. 3a, Section 2.1)

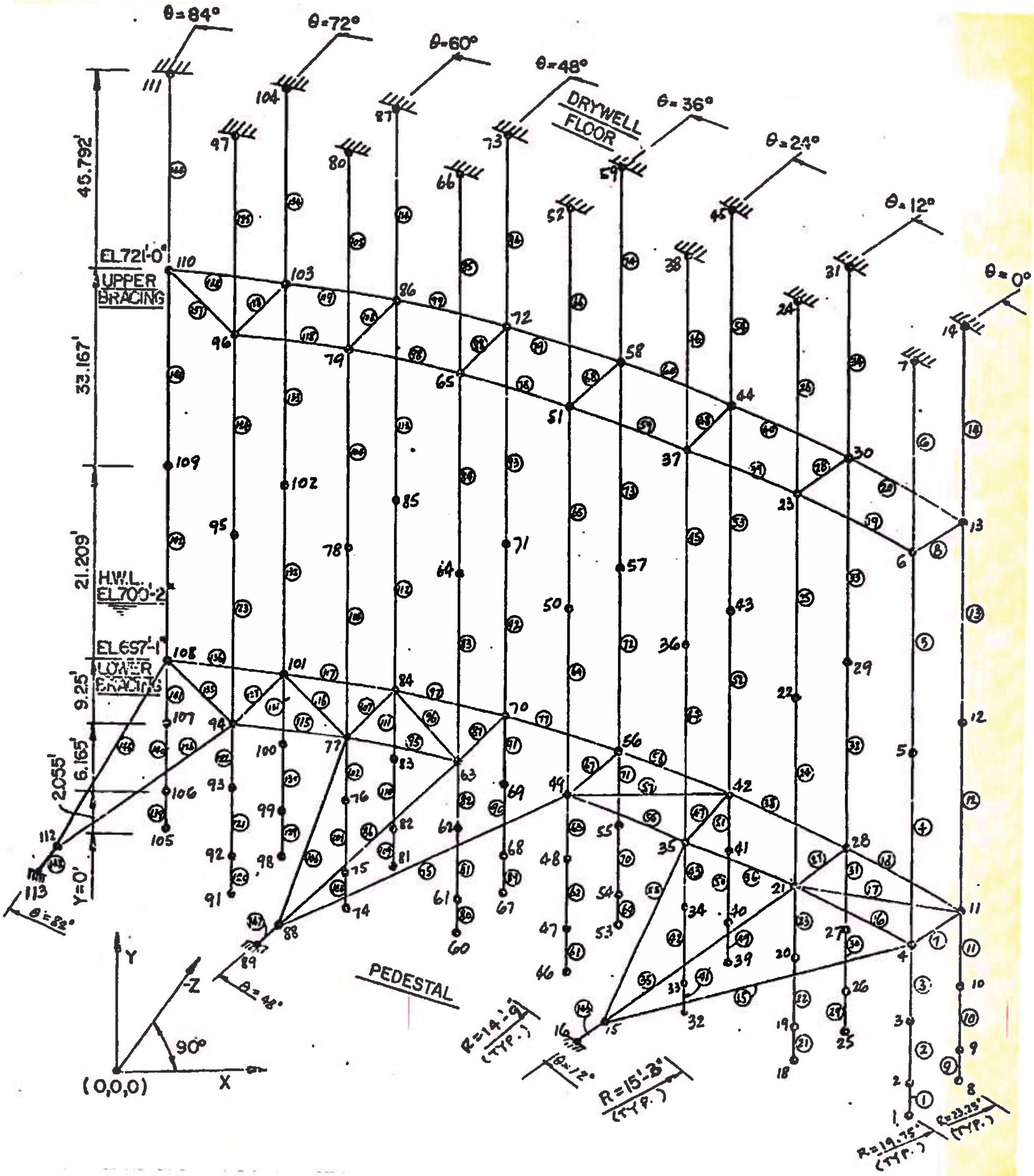



**Figure 6.1-2:** Downcomer Bracing Model, Inner Rings 1 & 2 (Ref. 3a, Section 2.1)

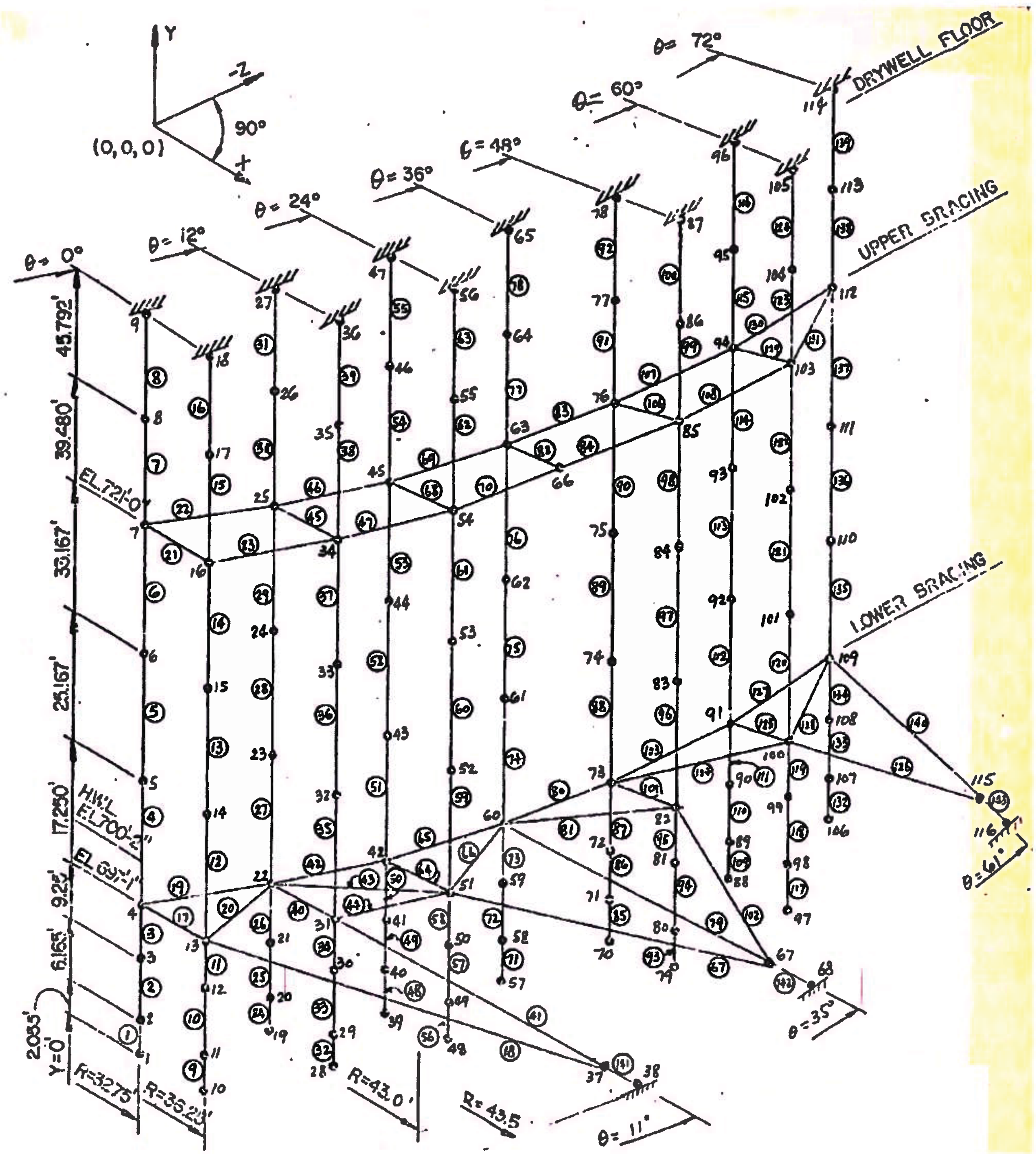



**Figure 6.1-3:** Downcomer Bracing Model, Outer Rings 3 & 4 (Ref. 3a, Section 2.1)

The output from the PIPSYS analyses is used in the evaluation of the downcomers and bracing. Section 2 of Calc. 187 (Ref. 3a) performed the original design basis evaluations for the bracing. Section 3.4 of Calc. 187 re-evaluates the bracing for as-built conditions that include nonconformances with erection tolerances. These as-built conditions result in eccentricity between the centerline of the brace member and the connection work points which induces additional moment on the members. Section 4.0 of Calc. 187 re-evaluates the bracing for updated PIPSYS model runs and resulting brace loads. Throughout the original design basis evaluation, plastic section properties are considered for the lower bracing members when the use of elastic section modulus is not successful in qualifying the member. The upper bracing members are qualified through elastic analysis.

Calculation 187K (Ref. 3b) re-evaluates the downcomer bracing for revised Loss-Of-Coolant Accident (LOCA) Chugging load conditions specified in NUREG-0808 (Ref. 8a). Only the LOCA Chugging Lateral loads are changed as a result of this analysis (LOCA Chugging Drag loads remain the same as in Calc. 187). The downcomer braces were evaluated in Section 6 of Ref. 3b, and the plastic section modulus is used in the existing qualification of the lower bracing. The upper bracing members, however, are qualified through elastic analysis.

Calculation L-002547 (Ref. 3c) determines the governing loading condition (Calc. 187 or Calc. 187K loads) for the members and factors up the corresponding thermal loads to account for the 105% power uprate. The bracing members/nodes determined to be critical in Calculations 187 (Ref. 3a) and 187K (Ref. 3b) were subsequently considered to be critical in the power uprate evaluations in Calc. L-002547. The lower bracing members were qualified using plastic section modulus. The upper bracing members were qualified through using elastic section modulus. However, through review of the Calc. 187 and Calc. 187K loads, it was determined that Calc. L-002547 incorrectly identified the controlling loads for both the upper and lower bracing members. Therefore, they need to be re-evaluated using the correct bounding loads.

This evaluation considers that the same members judged to be critical in Calc. L-002547 (Ref. 3c) remain critical. Therefore, only the members evaluated in Calc. L-002547 are evaluated in this evaluation. Consistent with the existing analyses for the upper bracing members, an enveloping analysis is performed. In this evaluation, the upper bracing members are analyzed using elastic section properties, as required by LaSalle's original licensing basis. The lower downcomer bracing members and the gusset plate section are evaluated using plastic section properties, as allowed per Licensing Action LI-21-0215.

For each critical member, the loads from Calc. 187 (Ref. 3a) and Calc. 187K (Ref. 3b) are compared to determine which are governing. Consistent with Calc. L-002547 (Ref. 3c), the thermal loads are factored to account for the increased power uprate accident temperatures and combined with these governing loads following the load combinations outlined in Section 6.1.2.

The technical approaches utilized in Calc. L-002547 are used in this evaluation unless stated otherwise.

### *6.1.1 Governing Loads*

As discussed above, Section 7 of Calc. L-002547 (Ref. 3c) determines whether Calc. 187 (Ref. 3a) or Calc. 187K (Ref. 3b) provides the governing loads. Calc. L-002547 did this by comparing the controlling margin factors from each calculation, which is not always appropriate since different approaches/methods were used in determining the margin factors. Review of the loads from the two calculations shows that the governing loads were incorrectly determined for both the upper and lower bracing members.

Consistent with the existing evaluations in Ref. 3a, Ref. 3b, and Ref. 3c, the lateral plus drag chugging loads are considered governing over other LOCA loads.

#### 6.1.1.1 Governing Loads for Lower Bracing Members

Section 7 of Calc. L-002547 determines that the original design basis evaluations in Calc. 187 (Ref. 3a) control for the lower bracing members. This is not correct for all of the critical lower bracing members that are evaluated in Calc. L-002547. Review of the loads from Calc. 187 and Calc. 187K shows that for some of the critical members, the loads in Calc. 187K are governing and should have been used in the evaluation. For each of the critical lower bracing members evaluated in Calc. L-002547, the loads in Calcs. 187 and 187K are compared to determine which are controlling.

#### 6.1.1.2 Governing Loads for Upper Bracing Members

Calcs. 187 and 187K each perform a single evaluation for the upper bracing members using enveloping loads from all upper bracing members. Section 7 of Calc. L-002547 determines that the original design basis evaluation in Calc. 187 (Ref. 3a) controls for the upper bracing members. The incorrect margin factor in Calc. 187 is referenced and review of the loads from Calcs. 187 and 187K shows that the loads in Calc. 187K are governing and should have been used. For the enveloping evaluation of the upper bracing members, the loads in Calcs. 187 and 187K are reviewed to determine which are controlling.

#### 6.1.1.3 Governing Loads for Lower Bracing Gusset Plate Section

Calculation L-002547 (Ref. 3c) evaluates normal stresses in the lower downcomer bracing gusset plate section using plastic section modulus. Review of the evaluation in Section 7.4 of Ref. 3c shows that it determined the loads considered in Section 2.8.2 of Calc. 187 (Ref. 3a) to control by comparison of the governing margin factors in Calc. 187 (Ref. 3a) and Calc. 187K (Ref. 3b). However, the governing evaluation in Section 6.3 of Calc. 187K (Ref. 3b) considered a reduction in moment based on actual member length while the governing evaluation in Section 2.8.2 of Calc. 187 (Ref. 3a) did not. Therefore, the margin factors cannot be compared to determine the controlling loads. For the lower bracing gusset plate section, the evaluations in Calcs. 187 and 187K are reviewed to determine the controlling loads.

### 6.1.2 Governing Load Combinations

Sections 4.5 and 4.7 of Calculation 187 (Ref. 3a) evaluate the lower and upper bracing members for governing normal loading conditions (load combination 3) and governing abnormal loading conditions (load combination 7/7a), respectively, as defined in Table 4.3-2 of Ref. 1c. Review of Table 4.3-2 of Ref. 1c confirms that these load combinations govern for the normal and abnormal loading conditions.

Calculation 187K (Ref. 3b) addresses changes in LOCA chugging loads which are only included in abnormal load combinations and, therefore, only evaluates for load combination 7/7a.

Calculation L-002547 (Ref. 3c) evaluates for the loading impact due to the 105% power uprate. Per Ref. 3c, the 105% power uprate only affects accident suppression pool temperature and therefore the accident thermal load on the downcomer braces. Therefore, Ref. 3c does not address normal operating load conditions and only evaluates for load combination 7/7a.

As indicated in the Background section of Ref. 3c, an operating suppression pool temperature of 90°F was initially considered in the existing evaluations but the correct operating temperature is 105°F (see Section 1 of Ref. 3c). The impact of this increase in operating temperature is assessed in Calculation L-001799 (Ref. 3d), and the bracing members are qualified for normal operating conditions. Note that the evaluations in Calculation 187 (Ref. 3a) for normal operating conditions (load combination 3) conservatively use thermal loads due to the (at the time) accident temperature of 146°F.

Review of Sections 4.5 and 4.7 of calculation 187 (Ref. 3a) shows that elastic section modulus was used to qualify the lower and upper braces for normal operating conditions (load combination 3). Since plastic section modulus was not used and the 105% power uprate only impacts accident temperature, the evaluations of the lower and upper bracing members for normal conditions (load combination 3) in Ref. 3a and Ref. 3d are still valid.

Therefore, the bracing members are only evaluated for the governing abnormal loading conditions (load combination 7/7a) in this calculation. Table 1 from Ref. 3c is provided for reference below in Table 6.1-1 which outlines the applicable combinations of LOCA and Safety/Relief Valve (SRV) loading along with the corresponding accident suppression pool temperature.

**Table 6.1-1:** Refined LOCA Load Definition (Ref. 3c, Table 1)

**Table 1: Refined LOCA Load Definition[1]**

| Plant Condition[2] | Case Number | 1. LOCA Loading Phenomena: Other[3] | 1. LOCA Loading Phenomena: Chugging | 2. SRV Loading Phenomenon: All | 2. SRV Loading Phenomenon: ADS | 2. SRV Loading Phenomenon: Asym | 2. SRV Loading Phenomenon: Single | Maximum Pool Temp (Deg. F) |
|---|---|---|---|---|---|---|---|---|
| DBA-LOCA | L1 | X | | | | | X | 150 |
| | L2 | | X | | | | X | 150 |
| | L3 | | X | | | | | 190 |
| IBA-LOCA | I1a | | X | | X | | | 150 |
| | I1b | | X | | X[4] | | | 190 |
| | I2a | | X | | | X | | 150 |
| | I2b | | X | | | X[4] | | 190 |
| SBA-LOCA | S1 | | | | X | | | 212 |
| | S2 | | | | | X | | 212 |
| | S3 | | X | | X[5] | X[5] | | 150 |
| SBO | SBO1 | | | | X | | | 212 |
| | SBO2 | | | | | X | | 212 |

**Table 1 Notes:**

1) Other loads (dead loads (D), live loads (L), safe shutdown earthquake ($E_{ss}$), LOCA pressure loads ($P_A$, $P_B$), etc.) are as identified in DAR Tables 4.1-1, 4.3-1, 4.3-2, 5.3-1, and 5.3-2 [Ref. 3].

2) For this table, DBA-LOCA is defined as a LOCA which will depressurize the reactor rapidly such that chugging, pool temperatures > 150°F, and SRV loading cannot occur simultaneously, SBA-LOCA is defined as breaks which do not depressurize the reactor (i.e., the HPCS system can be used to maintain fluid inventory), and IBA-LOCA is defined as all break sizes between these two extremes.

3) Other LOCA loading phenomena include those loads early in the transient which occur at lower pool temperatures. These include downcomer water jet clearing, downcomer charging air bubble, pool swell, fall back, and Condensation Oscillation (CO). These loads all occur at pool temperatures below 150°F, though not necessarily simultaneously.

4) SRV loading for Cases I1b and I2b is reduced by a factor which is a function of RPV pressure. By superimposing plant response for the various LOCA transients [see Section 6.4 of Ref. 7], the factor becomes a function of pool temperature. See Figure 1.

5) Apply either ADS or asymmetric SRV loads, but not both simultaneously.

### 6.1.2.1 Load Combinations for Lower Bracing Members and Gusset Plate Section

Section 7 of Calc. L-002547 (Ref. 3c) considers two combinations of loads for the lower downcomer bracing which both fall under load combination 7/7a. These two combinations are outlined in Step 3 of the Evaluation Approach in Section 3 of Ref. 3c. These same two load combinations are considered in this evaluation, consistent with the latest existing analysis.

Load combinations 7-1 and 7-2 below were considered in Calc. L-002547 (Ref. 3c), where:

| | | |
|---|---|---|
| S | = | Allowable stress |
| D | = | Dead loads |
| $T_a$ | = | Accident temperature load |
| LOCA | = | Loss of Coolant Accident loads |
| SRV | = | Safety/Relief valve load |
| $E_{ss}$ | = | Safe shutdown earthquake |

1. Station Blackout cases (SBO) and Small Line Break LOCA cases S1 and S2:

7-1. $S \geq D + T_a + SRV + E_{ss}$

This combination bounds the SBO cases and Small Line Break LOCA cases S1 and S2 shown in Table 6.1-1. These cases do not experience LOCA loading phenomena and occur with an accident pool temperature of 212°F.

2. LOCA line break cases L3, I1b, and I2b:

7-2. $S \geq D + T_a + \gamma * SRV + LOCA + E_{ss}$

This combination bounds the cases which have an accident pool temperature of 190°F (L3, I1b, and I2b) as shown in Table 6.1-1. As outlined in Step 3b of the Methodology in Calc. L-002547, 40% of the SRV loads are considered in combination with 100% of the LOCA loads. This reduction in SRV loading is based on Fig. 1 in Calc. L-002547, which relates the SRV load scale factor to suppression pool temperature when combined with LOCA chugging loads.

$\gamma_{SRV.72} := 0.40$ SRV reduction factor at 190°F

Step 3b of the Methodology in Calc. L-002547 states that by engineering judgment the above load combination (7-2) envelops all other LOCA line break cases (L1, L2, I1a, I2a, and S3) because the increase in accident temperature to 150°F from 146°F (considered in Ref. 3a and Ref. 3b) is negligibly small. However, some of the existing lower downcomer bracing evaluations for an accident temperature of 146°F considered plastic sections properties. Therefore, the existing evaluations at 146°F cannot be used to state that the braces are acceptable for the 150°F cases and an additional load combination (7-3) is necessary to be checked.

3. LOCA line break cases L1, L2, I1a, I2a, and S3:

7-3. $S \geq D + T_a + \gamma * SRV + LOCA + E_{ss}$

This combination bounds the cases having an accident pool temperature of 150°F (L3, I1b, and I2b) as shown in Table 6.1-1. Note that when considered with 100% of the LOCA load there is no reduction in SRV loading at 150°F per Fig. 1 in Calc. L-002547, which relates the SRV load scale factor to suppression pool temperature when combined with LOCA chugging loads. However, per Ref. 3b, Section 6.0, page 1, Step 4 in the procedure states that SRV load may be reduced by 20% for resonant sequential symmetric discharge (RSSD) and by 30% for single valve subsequent actuation (SVSA) for load cases with lower temperatures (146°F; also applied for 150°F).

$\gamma_{RSSD} := 0.80$ SRV-RSSD reduction factor

$\gamma_{SVSA} := 0.70$ SRV-SVSA reduction factor

### 6.1.2.2 Load Combinations for Upper Bracing Members

Section 7.2 of Calc. L-002547 (Ref. 3c) evaluates the upper downcomer braces using the total axial load and moments taken from Calc. 187 (Ref. 3a). As previously discussed, Calc. L-002547 incorrectly identified that the enveloping loads from Calc. 187 controlled. Review of Calc. 187K (Ref. 3b) shows that the enveloping loads from that calculation control and LC #7 is considered to govern. The same combination is considered to govern in this evaluation. Since a single enveloping evaluation is performed for the upper downcomer braces, the 212°F thermal load is considered with the full SRV and LOCA loads to bound all potential load combinations.

$$S \geq D + T_a + SRV + LOCA + E_{ss} + SNUB$$

where

| | | |
|---|---|---|
| S | = | Allowable stress |
| D | = | Dead loads |
| $T_a$ | = | Accident temperature load |
| LOCA | = | Loss of Coolant Accident loads (Chugging lateral and drag loads) |
| SRV | = | Safety/Relief valve load (reaction from downcomer pipe plus SRV support on upper brace) |
| $E_{ss}$ | = | Safe shutdown earthquake |
| SNUB | = | Snubber support load |

Consistent with Calc. L-002547 (and Calc. 187K), only normal stress on the upper bracing members is evaluated. Review of Sections 2.10 and 4.7 of Calc. 187 shows that other stress checks have substantial margin.

### 6.1.3 As-Built Conditions

Section 3.4 of Calc. 187 (Ref. 3a) evaluates the lower downcomer bracing for nonconformity to erection tolerances and determines that the member eccentricities are acceptable by using the plastic section modulus. Subsequent evaluations of the lower bracing in Section 4 of Calc. 187, Calc. 187K (Ref. 3b), and Calc. L-002547 (Ref. 3c) do not account for the as-built eccentricities, which increase moment on the members.

The evaluation of the lower bracing members in this calculation accounts for the additional moment due to these eccentricities. Section 3.4 of Calc. 187 lists the as-built eccentricity for each lower bracing member, which have been reproduced in Design Input #5. As previously discussed, the existing analyses only modeled a single quadrant of the downcomer bracing system and considered it represents the whole system. The modeled brace members therefore represent multiple installed brace members. Section 3.4 of Calc. 187 lists the eccentricity for each actual brace member and the corresponding modeled member.

The evaluations performed in the existing calculations and this refined analysis are for the critical brace members in the single quadrant model. Therefore, for each critical member, the maximum eccentricity listed in Section 3.4 of Calc. 187 for the actual members represented by that modeled member is used to determine the additional moment. The additional moment is determined by multiplying the total axial load in the member by the maximum total eccentricity and is then added to total moment on the member.

### *6.1.4 Refinements in Evaluation*

#### 6.1.4.1 Refinement of Lower Bracing Member Analysis

Refinement of the lower bracing members is required to account for as-built eccentricities and use correct bounding loads. To reduce conservatism in the evaluation of the lower bracing members, the following refinements are made:

- Determine directionality of moments to reduce total moments when load cases act in opposing directions. Currently, the resultant moments (vector sum of moments about the member primary axes) from each load are combined via absolute sum, instead of the moments about the primary axes for each load being added separately and then combined by vector sum.

- Use AISC Design Guide 19 (Ref. 4b) yield stress at elevated temperatures (discussed in Design Input #2)

- Use a 10% increase in yield stress to account for dynamic loading (discussed in Section 6.2)

#### 6.1.4.2 Refinement of Upper Bracing Member Analysis

Due to incorrect bounding loads being used in Calc. L-002547 (Ref. 3c), the upper bracing members must be re-evaluated using the correct bounding loads.

As previously discussed, enveloping loads for all upper bracing members are used to perform a single governing evaluation. The only refinements used in evaluation of the upper bracing members are as follows:

- Use AISC Design Guide 19 (Ref. 4b) yield stress at elevated temperatures (discussed in Design Input #2)

- Use a 10% increase in yield stress to account for dynamic loading (discussed in Section 6.2)

## 6.2 ACCEPTANCE CRITERIA

Consistent with Ref. 3a, Section 1.0 (and Ref. 1b, Section 4.2.k and Table 7.2-4), structural steel members are designed using the elastic design provisions of the AISC 1969 "Specification for the Design, Fabrication & Erection of Structural Steel for Buildings," as presented in Ref. 4a, Part 5. However, for the lower downcomer braces and gusset plate section, Licensing Action LI-21-0215 allows the use of plastic section properties.

As previously discussed, LC #7 controls for the bracing members based on the existing analyses and is considered in this evaluation. The allowable stresses for this LC (abnormal extreme environmental) are defined per Table 4.3-2 of the LaSalle DAR (Ref. 1c) and are provided below:

$S_7$ = 1.6*AISC allowable not to exceed $0.95F_y$

Consistent with the existing evaluations, the maximum allowable stress of $0.95F_y$ is applicable to axial tension and bending, as well as axial compression. Section 1.7 of Calc. 187 (Ref. 3a) states that an allowable stress of $0.95F_y$ is acceptable for axial compression loads since the loads are dynamic in nature and last only a short time.

Additionally, per SRP Section 3.6.2 (Ref. 8b), Subsection III.2.a, a 10% increase of the minimum specified design yield strength may be used in the analysis to account for strain rate effects under dynamic loading. This increase is considered for the axial and bending allowables only.

Increased allowable bending stress of lower downcomer braces (Ref. 4a, Part 5, Section 1.5.1.4.5):

$$F_{b.LB} := 1.1\,\min\left[1.6\left(0.60F_{y.A618}\right), 0.95\cdot F_{y.A618}\right] = 52.25\cdot ksi$$

Increased allowable axial stress of lower downcomer braces (Ref. 4a, Part 5, Section 1.5.1.1):

$$F_{a.LB} := 1.1\,\min\left[1.6\left(0.60\cdot F_{y.A618}\right), 0.95\cdot F_{y.A618}\right] = 52.25\cdot ksi$$

Increased allowable bending stress of upper downcomer braces (Ref. 4a, Part 5, Section 1.5.1.4.5):

$$F_{b.UB} := 1.1\,\min\left[1.6\left(0.60F_{y.A572}\right), 0.95\cdot F_{y.A572}\right] = 52.25\cdot ksi$$

Increased allowable axial stress of upper downcomer braces (Ref. 4a, Part 5, Section 1.5.1.1):

$$F_{a.UB} := 1.1\,\min\left[1.6\left(0.60\cdot F_{y.A572}\right), 0.95\cdot F_{y.A572}\right] = 52.25\cdot ksi$$

Increased allowable bending/axial stress of gusset plate section (Ref. 4a, Part 5, Sections 1.5.1.1 and 1.5.1.4.5):

$$F_{ba.gp} := 1.1\cdot\min\left[1.6\left(0.60\cdot F_{y.A588}\right), 0.95\cdot F_{y.A588}\right] = 52.25\cdot ksi$$

# 7.0 NUMERICAL ANALYSIS

## 7.1 LOWER DOWNCOMER BRACING, INNER RING

For the 105% power uprate, the thermal load is increased based on the elevated Suppression Pool temperature. All other loads remain the same. Per Ref. 3a, Section 4.5 and Ref. 3c, Section 7.3.2.1, the following members were previously qualified and are re-analyzed herein:

- Member 126 / Node 94
- Member 75 / Node 49
- Member 86 / Node 63
- Member 7 / Node 11
- Member 57 / Node 49
- Member 47 / Node 35

### *7.1.1 Member 126 / Node 94*

#### 7.1.1.1 Determine Current Design Loading

Ref. 3a, Section 4.5 and Ref. 3b, Section 6.2.1 identify Member 126 as a critical lower bracing member for the Inner Ring bracing. Loads on the member are identified below. The loads are taken as the maximum from Ref. 3a, Section 4.5, pages 4 & 8b or Ref. 3b, Section 6.2.1, page 4 unless noted otherwise.

$F_{a.DL} := 0\text{kip}$ $\quad M_{R.DL} := 0.02\text{ft}\cdot\text{kip}$ Axial load and moment due to dead load

$F_{a.Th.146} := 53.11\text{kip}$ Axial load due to thermal load, 146°F (Ref. 3a, Section 4.5, page 4)

$$M_{B.Th.146} := \begin{pmatrix} 8134 \\ -2866 \end{pmatrix}\text{ft}\cdot\text{lbf} \qquad \begin{pmatrix} \text{"Node 112"} \\ \text{"Node 94"} \end{pmatrix}$$

$$M_{C.Th.146} := \begin{pmatrix} 34789 \\ 78237 \end{pmatrix}\text{ft}\cdot\text{lbf} \qquad \begin{pmatrix} \text{"Node 112"} \\ \text{"Node 94"} \end{pmatrix}$$

Moment components due to thermal load, 146°F (Ref. 3e, PIPSYS Run 374PCG, Section D, page 1-11)

$F_{a.SVSA} := 34.69\text{kip}$ Axial load due to SRV-SVSA (Ref. 3a, Section 4.5, page 3)

$M_{B.SVSA} := 5.800\text{ft}\cdot\text{kip}$

$M_{C.SVSA} := 8.673\text{ft}\cdot\text{kip}$

Moment components for SRV-SVSA (Ref. 3a, Section 4.12.1, page 14)

$F_{a.RSSD} := 39.76kip$ — Axial load due to SRV-RSSD (Ref. 3a, Section 4.5, page 3)

$M_{R.RSSD} := 9.15ft \cdot kip$ — Resultant moment for SRV-RSSD (Ref. 3a, Section 4.5, page 3)

$F_{a.LOCA} := \max(24.64, 46.458) \cdot kip + 105.19kip = 151.65 \cdot kip$ — Axial load due to LOCA (Ref. 3a, Section 4.5, page 4; Ref. 3b, Section 6.2.1, page 4)

$M_{B.LOCA.lat.db} := 2.129ft \cdot kip$

$M_{C.LOCA.lat.db} := 5.292ft \cdot kip$

Moment components for LOCA chugging lateral load case, design basis (Ref. 3e, PIPSYS Run 643PCG, Section D, page 1-11)

$M_{B.LOCA.drag.db} := 15.199ft \cdot kip$

$M_{C.LOCA.drag.db} := 9.728ft \cdot kip$

Moment components for LOCA chugging drag load case, design basis (Ref. 3e, PIPSYS Run A853YW, Section I, page 12-38)

$M_{B.LOCA.lat.0808} := 2.130ft \cdot kip$

$M_{C.LOCA.lat.0808} := 25.689ft \cdot kip$

Moment components for LOCA chugging lateral load case, NUREG-0808 (Ref. 3b, Section 4.0, page 10)

The enveloping moment components for LOCA lateral + drag are determined below.

$$M_{B.LOCA} := \max\left(M_{B.LOCA.lat.db}, M_{B.LOCA.lat.0808}\right) + M_{B.LOCA.drag.db}$$

$$M_{B.LOCA} = 17.33 \cdot ft \cdot kip$$

$$M_{C.LOCA} := \max\left(M_{C.LOCA.lat.db}, M_{C.LOCA.lat.0808}\right) + M_{C.LOCA.drag.db}$$

$$M_{C.LOCA} = 35.42 \cdot ft \cdot kip$$

$F_{a.DRAG} := 0kip$ $\quad M_{R.DRAG} := 1.50ft \cdot kip$ — Axial load and moment due to bracing drag (SVSA or RSSD + Chugging) (Ref. 3a, Section 4.5, page 4)

$F_{a.Ess} := 0kip$ $\quad M_{R.Ess} := 2.64ft \cdot kip$ — Axial load and moment due to seismic (Ref. 3a, Section 4.5, page 4)

The thermal moment for the brace can be reduced by considering the actual length of the member since the PIPSYS analysis output is given at the working points of the analytical members (not the actual member ends) and the thermal moment gradient along the length of the member is known.

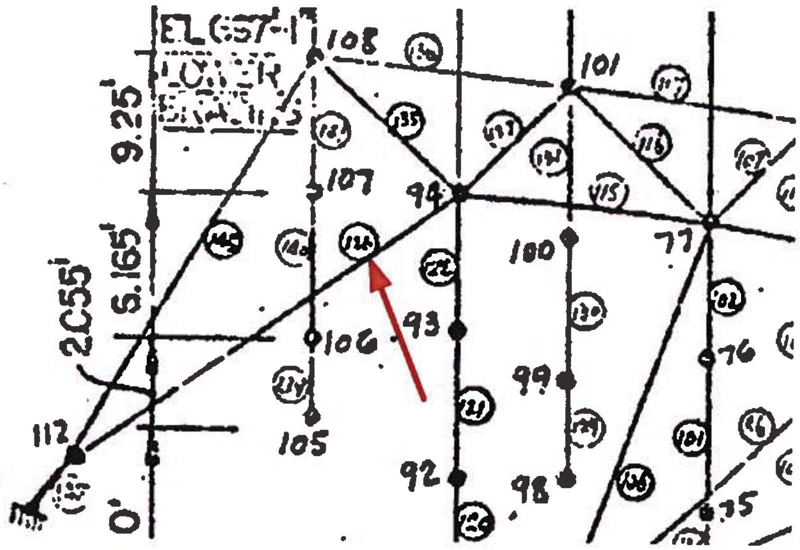



**Figure 7.1.1.1-1:** Member 126 Location in PIPSYS Model (Ref. 3a, Section 2.1, page 2)

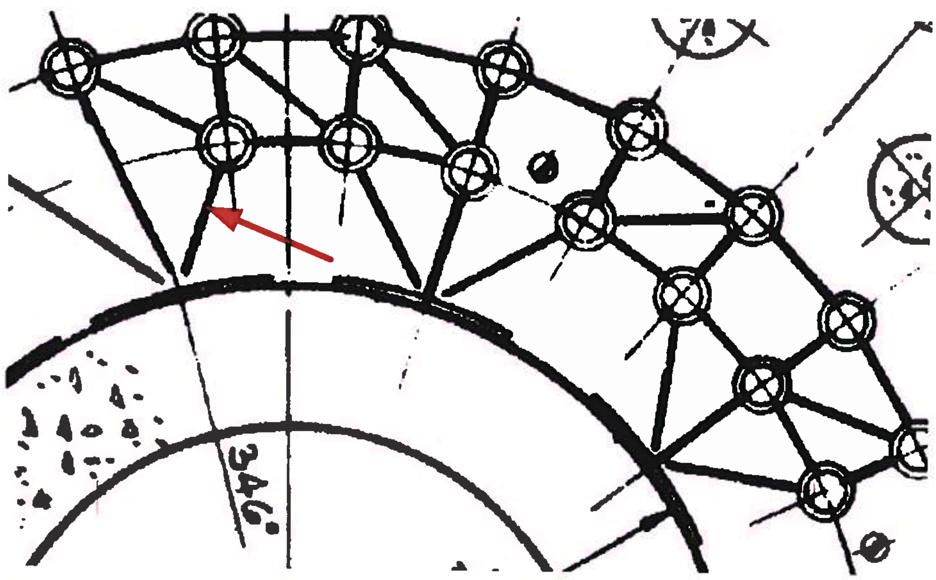



**Figure 7.1.1.1-2:** Member 126 Location in Installed Configuration (Ref. 2a)

The node-to-node length of this member is determined based on the measurements in Ref. 2a.

$r_1 := 14ft + 11\frac{1}{2}in$ $\quad r_2 := 19ft + 9in$ Radius to Pedestal wall and downcomer

X- and Y-coordinates of the downcomers to which Member 126 attaches:

$$x_{DC} := \begin{pmatrix} -r_1 \cdot \sin(360deg - 346deg) \\ -r_2 \cdot \sin(360deg - 354deg) \end{pmatrix} = \begin{pmatrix} -3.62 \\ -2.06 \end{pmatrix} \cdot ft \qquad y_{DC} := \begin{pmatrix} r_1 \cdot \cos(360deg - 346deg) \\ r_2 \cdot \cos(360deg - 354deg) \end{pmatrix} = \begin{pmatrix} 14.51 \\ 19.64 \end{pmatrix} \cdot ft$$

$$L_{nn} := \sqrt{\left(x_{DC_2} - x_{DC_1}\right)^2 + \left(y_{DC_2} - y_{DC_1}\right)^2} = 5.36 \cdot ft$$ Node-to-node length of Member 126

$$L_{crit} := L_{nn} - \frac{24in}{2} = 4.36 \cdot ft$$ Length to critical section of Member 126, at outer face of downcomer

Since the thermal moment gradient is known, pro-rate to find the thermal moment components at the face of the downcomer.

$$M_{B.Th.146} := \left| linterp\left[\begin{pmatrix} 0 \\ L_{nn} \end{pmatrix}, M_{B.Th.146}, L_{crit}\right] \right| = 0.81 \cdot ft \cdot kip$$

$$M_{C.Th.146} := \left| linterp\left[\begin{pmatrix} 0 \\ L_{nn} \end{pmatrix}, M_{C.Th.146}, L_{crit}\right] \right| = 70.13 \cdot ft \cdot kip$$

Moment components due to thermal load at 146°F, linearly pro-rated to determine moment at face of downcomer

Per Design Input #5, Member 126 was installed out of tolerance in the horizontal direction, thus additional moment needs to be added for the eccentricity.

$e_{lb.126i.h} = 0.75\ in$ Maximum horizontal eccentricity of a CBI brace number equivalent to Member 126 (previously specified)

### 7.1.1.2 Evaluate Load Combination 7-1

$F_{a.Th.212} := IF_{212} \cdot F_{a.Th.146} = 99.32 \cdot kip$

$M_{B.Th.212} := IF_{212} \cdot M_{B.Th.146} = 1.52 \cdot ft \cdot kip$

$M_{C.Th.212} := IF_{212} \cdot M_{C.Th.146} = 131.14 \cdot ft \cdot kip$

Axial load and moment components due to thermal load, prorated for 212°F

Design axial load on brace, SVSA and RSSD determined separately, Load Combination 7-1:

$F_{a.SVSA.71} := F_{a.DL} + F_{a.Th.212} + F_{a.SVSA} + F_{a.DRAG} + F_{a.Ess} = 134.01 \cdot kip$

$F_{a.RSSD.71} := F_{a.DL} + F_{a.Th.212} + F_{a.RSSD} + F_{a.DRAG} + F_{a.Ess} = 139.08 \cdot kip$

Design moment on brace, SVSA, Load Combination 7-1:

$M_{B.SVSA.71} := M_{B.Th.212} + M_{B.SVSA} + e_{lb.126i.h} \cdot F_{a.SVSA.71} = 15.7 \cdot ft \cdot kip$

$M_{C.SVSA.71} := M_{C.Th.212} + M_{C.SVSA} = 139.81 \cdot ft \cdot kip$

$M_{R.SVSA.71} := \sqrt{M_{B.SVSA.71}^2 + M_{C.SVSA.71}^2} + M_{R.DL} + M_{R.DRAG} + M_{R.Ess} = 144.85 \cdot ft \cdot kip$

Design moment on brace, RSSD, Load Combination 7-1:

$M_{B.RSSD.71} := M_{B.Th.212} + e_{lb.126i.h} \cdot F_{a.RSSD.71} = 10.21 \cdot ft \cdot kip$

$M_{C.RSSD.71} := M_{C.Th.212} = 131.14 \cdot ft \cdot kip$

$M_{R.RSSD.71} := \sqrt{M_{B.RSSD.71}^2 + M_{C.RSSD.71}^2} + M_{R.RSSD} + M_{R.DL} + M_{R.DRAG} + M_{R.Ess}$

$M_{R.RSSD.71} = 144.85 \cdot ft \cdot kip$

As shown, RSSD controls.

$f_{a.126.ir.71} := \frac{F_{a.RSSD.71}}{A_{lb}} = 6.87 \cdot ksi$ Axial stress on brace, Load Combination 7-1

$f_{b.126.ir.71} := \frac{M_{R.RSSD.71}}{Z_{lb}} = 34.88 \cdot ksi$ Bending stress on brace, Load Combination 7-1

$IC_{126.ir.LC71} := \frac{f_{a.126.ir.71}}{F_{a.LB}} + \frac{f_{b.126.ir.71}}{F_{b.LB}} = 0.80$ Interaction coefficient for Member 126, Load Combination 7-1

$MF_{126.ir.LC71} := \frac{1}{IC_{126.ir.LC71}} = 1.25$ Margin factor for Member 126, Load Combination 7-1

### 7.1.1.3 Evaluate Load Combination 7-2

$F_{a.Th.190} := IF_{190} \cdot F_{a.Th.146} = 83.91 \cdot kip$

$M_{B.Th.190} := IF_{190} \cdot M_{B.Th.146} = 1.28 \cdot ft \cdot kip$

$M_{C.Th.190} := IF_{190} \cdot M_{C.Th.146} = 110.8 \cdot ft \cdot kip$

Axial load and moment components due to thermal load, prorated for 190°F

SRV loads are reduced to 40% of the full load per Section 6.1.2.1. RSSD controls per the previous section.

Design axial load on brace, Load Combination 7-2:

$$F_{a.tot.72} := F_{a.DL} + F_{a.Th.190} + \gamma_{SRV.72} F_{a.RSSD} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 251.47 \cdot kip$$

Design moment on brace, Load Combination 7-2:

$$M_{B.72} := M_{B.Th.190} + M_{B.LOCA} + e_{lb.126i.h} \cdot F_{a.tot.72} = 34.33 \cdot ft \cdot kip$$

$$M_{C.72} := M_{C.Th.190} + M_{C.LOCA} = 146.22 \cdot ft \cdot kip$$

$$M_{R.tot.72} := \sqrt{M_{B.72}^2 + M_{C.72}^2} + \gamma_{SRV.72} M_{R.RSSD} + M_{R.DL} + M_{R.DRAG} + M_{R.Ess} = 158.02 \cdot ft \cdot kip$$

$$f_{a.126.ir.72} := \frac{F_{a.tot.72}}{A_{lb}} = 12.43 \cdot ksi$$

Axial stress on brace, Load Combination 7-2

$$f_{b.126.ir.72} := \frac{M_{R.tot.72}}{Z_{lb}} = 38.05 \cdot ksi$$

Bending stress on brace, Load Combination 7-2

$$IC_{126.ir.LC72} := \frac{f_{a.126.ir.72}}{F_{a.LB}} + \frac{f_{b.126.ir.72}}{F_{b.LB}} = 0.97$$

Interaction coefficient for Member 126, Load Combination 7-2

$$MF_{126.ir.LC72} := \frac{1}{IC_{126.ir.LC72}} = 1.03$$

Margin factor for Member 126, Load Combination 7-2

### 7.1.1.4 Evaluate Load Combination 7-3

$F_{a.Th.150} := IF_{150} \cdot F_{a.Th.146} = 55.91 \cdot kip$

$M_{B.Th.150} := IF_{150} \cdot M_{B.Th.146} = 0.86 \cdot ft \cdot kip$

$M_{C.Th.150} := IF_{150} \cdot M_{C.Th.146} = 73.82 \cdot ft \cdot kip$

Axial load and moment components due to thermal load, prorated for 150°F

SRV loads are reduced per Section 6.1.2.1.

Design axial load on brace, Load Combination 7-3:

$$F_{a.SVSA.150} := F_{a.DL} + F_{a.Th.150} + \gamma_{SVSA} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 231.84 \cdot kip$$

$$F_{a.RSSD.150} := F_{a.DL} + F_{a.Th.150} + \gamma_{RSSD} F_{a.RSSD} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 239.36 \cdot kip$$

Design moment on brace, 150°F temperature case, with SRV-SVSA:

$$M_{B.SVSA.150} := M_{B.Th.150} + \left(\gamma_{SVSA} M_{B.SVSA} + M_{B.LOCA}\right) \cdots + e_{lb.126i.h} \cdot F_{a.SVSA.150} = 36.73 \cdot ft \cdot kip$$

$$M_{C.SVSA.150} := M_{C.Th.150} + \left(\gamma_{SVSA} M_{C.SVSA} + M_{C.LOCA}\right) = 115.31 \cdot ft \cdot kip$$

$$M_{R.SVSA.150} := \sqrt{M_{B.SVSA.150}^2 + M_{C.SVSA.150}^2} + M_{R.DL} + M_{R.DRAG} + M_{R.Ess} = 125.18 \cdot ft \cdot kip$$

Design moment on brace, 150°F temperature case, with SRV-RSSD:

$$M_{B.RSSD.150} := M_{B.Th.150} + M_{B.LOCA} \cdots + e_{lb.126i.h} \cdot F_{a.RSSD.150} = 33.14 \cdot ft \cdot kip$$

$$M_{C.RSSD.150} := M_{C.Th.150} + M_{C.LOCA} = 109.24 \cdot ft \cdot kip$$

$$M_{R.RSSD.150} := \sqrt{M_{B.RSSD.150}^2 + M_{C.RSSD.150}^2} + \gamma_{RSSD} M_{R.RSSD} \cdots + M_{R.DL} + M_{R.DRAG} + M_{R.Ess} = 125.63 \cdot ft \cdot kip$$

As shown, RSSD controls.

$$f_{a.126.ir.73} := \frac{F_{a.RSSD.150}}{A_{lb}} = 11.83 \cdot ksi$$

Axial stress on brace, Load Combination 7-3

$$f_{b.126.ir.73} := \frac{M_{R.RSSD.150}}{Z_{lb}} = 30.26 \cdot ksi$$

Bending stress on brace, Load Combination 7-3

$$IC_{126.ir.LC73} := \frac{f_{a.126.ir.73}}{F_{a.LB}} + \frac{f_{b.126.ir.73}}{F_{b.LB}} = 0.81$$

Interaction coefficient for Member 126, Load Combination 7-3

$$MF_{126.ir.LC73} := \frac{1}{IC_{126.ir.LC73}} = 1.24$$

Margin factor for Member 126, Load Combination 7-3

## 7.1.2 *Member 75 / Node 49*

### 7.1.2.1 Determine Current Design Loading

Ref. 3a, Section 4.5 and Ref. 3b, Section 6.2.1 identify Member 75 as a critical lower bracing member for the Inner Ring bracing. Loads on the member are identified below.

$F_{a.DL} := 0kip$ $\quad M_{R.DL} := 0.078ft\cdot kip$ — Axial load and moment due to dead load (Ref. 3a, Section 4.5, page 4)

$F_{a.Th.146} := 20.92kip$ — Axial load due to thermal load, 146°F

$M_{B.Th.146} := \begin{pmatrix} -9806 \\ -10966 \end{pmatrix} ft\cdot lbf \quad \begin{pmatrix} \text{"Node 88"} \\ \text{"Node 49"} \end{pmatrix}$

$M_{C.Th.146} := \begin{pmatrix} 17956 \\ 64093 \end{pmatrix} ft\cdot lbf \quad \begin{pmatrix} \text{"Node 88"} \\ \text{"Node 49"} \end{pmatrix}$

Moment components due to thermal load, 146°F (Ref. 3e, PIPSYS Run 374PCG, Section D, page 1-8)

Per Ref. 3a, Section 4.5, page 3, SVSA controls over RSSD.

$F_{a.SVSA} := 48.08kip$ — Axial load due to SRV-SVSA (Ref. 3a, Section 4.5, page 4)

$M_{B.SVSA} := 8.515ft\cdot kip$

$M_{C.SVSA} := 18.847ft\cdot kip$

Moment components for SRV-SVSA load case (Ref. 3a, Section 4.12.1, page 14)

$F_{a.LOCA} := \max(45.61, 48.922)\cdot kip + 115.60kip = 164.52\cdot kip$ — Axial load due to LOCA (Ref. 3a, Section 4.5, page 4; Ref. 3b, Section 6.2.1, page 4)

$M_{B.LOCA.lat.db} := 0.505ft\cdot kip$

$M_{C.LOCA.lat.db} := 12.037ft\cdot kip$

Moment components for LOCA chugging lateral load case, design basis (Ref. 3e, PIPSYS Run ID 643PCG, Section D, page 1-8)

$M_{R.LOCA.lat.0808} := 22.755ft\cdot kip$ — Resultant moment for LOCA chugging lateral load case, NUREG-0808 (Ref. 3b, Section 6.2.1, page 4)

$M_{B.LOCA.drag.db} := 21.579ft\cdot kip$

$M_{C.LOCA.drag.db} := 14.326ft\cdot kip$

Moment components for LOCA chugging drag load case, design basis (Ref. 3e, PIPSYS Run A853YW, Section I, page 12-35)

By observation, the NUREG-0808 lateral chugging loads control.

$F_{a.DRAG} := 0kip$ $M_{R.DRAG} := 1.50ft \cdot kip$ Axial load and moment due to bracing drag (SVSA or RSSD + Chugging) (Ref. 3a, Section 4.5, page 4)

$F_{a.Ess} := 0kip$ $M_{R.Ess} := 3.55ft \cdot kip$ Axial load and moment due to seismic (Ref. 3a, Section 4.5, page 4)

The thermal moment for the brace can be reduced by considering the actual length of the member since the PIPSYS analysis output is given at the working points of the analytical members (not the actual member ends) and the thermal moment gradient along the length of the member is known.

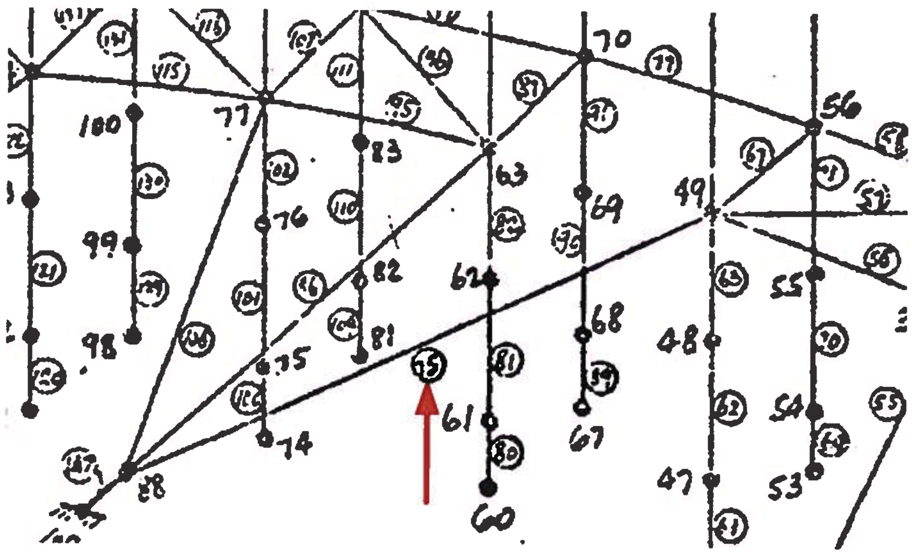


**Figure 7.1.2.1-1:** Member 75 Location in PIPSYS Model (Ref. 3a, Section 2.1, page 2)

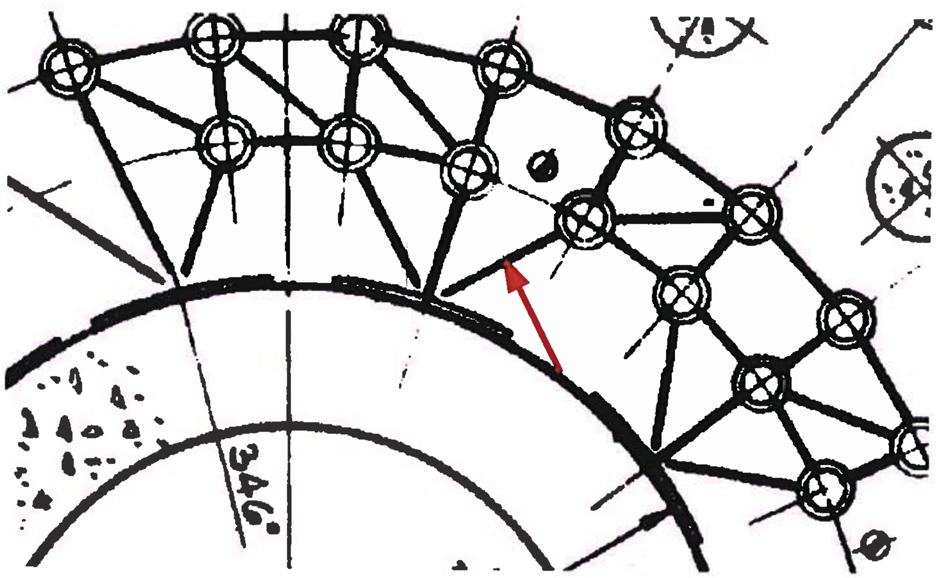


**Figure 7.1.2.1-2:** Member 75 Location in Installed Configuration (Ref. 2a)

The node-to-node length of this member is determined based on the measurements in Ref. 2a.

$r_1 := 14\text{ft} + 11\frac{1}{2}\text{in}$ $\quad r_2 := 19\text{ft} + 9\text{in}$ Radii to working points

X- and Y-coordinates of the working points to which Member 75 attaches:

$$x_{DC} := \begin{pmatrix} r_1 \cdot \cos(90\text{deg} - 18\text{deg}) \\ r_2 \cdot \cos(90\text{deg} - 30\text{deg}) \end{pmatrix} = \begin{pmatrix} 4.62 \\ 9.87 \end{pmatrix} \cdot \text{ft} \qquad y_{DC} := \begin{pmatrix} r_1 \cdot \sin(90\text{deg} - 18\text{deg}) \\ r_2 \cdot \sin(90\text{deg} - 30\text{deg}) \end{pmatrix} = \begin{pmatrix} 14.23 \\ 17.1 \end{pmatrix} \cdot \text{ft}$$

$$L_{nn} := \sqrt{\left(x_{DC_2} - x_{DC_1}\right)^2 + \left(y_{DC_2} - y_{DC_1}\right)^2} = 5.99 \cdot \text{ft}$$ Node-to-node length of Member 75

$$L_{crit} := L_{nn} - \frac{24\text{in}}{2} = 4.99 \cdot \text{ft}$$ Length to critical section of Member 75, at outer face of downcomer

Since the thermal moment gradient is known, pro-rate to find the thermal moment components at the face of the downcomer.

$$M_{B.Th.146} := \left| \text{linterp}\left[\begin{pmatrix} 0 \\ L_{nn} \end{pmatrix}, M_{B.Th.146}, L_{crit}\right] \right| = 10.77 \cdot \text{ft} \cdot \text{kip}$$

$$M_{C.Th.146} := \left| \text{linterp}\left[\begin{pmatrix} 0 \\ L_{nn} \end{pmatrix}, M_{C.Th.146}, L_{crit}\right] \right| = 56.39 \cdot \text{ft} \cdot \text{kip}$$

Moment components due to thermal load at 146°F, linearly pro-rated to determine moment at face of downcomer

Per Design Input #5, Member 75 was installed out of tolerance in the horizontal direction, thus additional moment needs to be added for the eccentricity.

$e_{lb.75.h} = 0.70\text{ in}$ Maximum eccentricity of a CBI brace number equivalent to Member 75 (previously specified)

### 7.1.2.2 Evaluate Load Combination 7-1

$F_{a.Th.212} := IF_{212} \cdot F_{a.Th.146} = 39.12 \cdot kip$

$M_{B.Th.212} := IF_{212} \cdot M_{B.Th.146} = 20.14 \cdot ft \cdot kip$

$M_{C.Th.212} := IF_{212} \cdot M_{C.Th.146} = 105.45 \cdot ft \cdot kip$

Axial load and moment components due to thermal load, prorated for 212°F

Design axial load on brace, Load Combination 7-1:

$F_{a.tot.71} := F_{a.DL} + F_{a.Th.212} + F_{a.SVSA} + F_{a.DRAG} + F_{a.Ess} = 87.2 \cdot kip$

Design moment on brace, Load Combination 7-1:

$M_{B.71} := M_{B.Th.212} + M_{B.SVSA} + e_{lb.75.h} \cdot F_{a.tot.71} = 33.75 \cdot ft \cdot kip$

$M_{C.71} := M_{C.Th.212} + M_{C.SVSA} = 124.3 \cdot ft \cdot kip$

$M_{R.tot.71} := \sqrt{M_{B.71}^2 + M_{C.71}^2} + M_{R.DL} + M_{R.DRAG} + M_{R.Ess} = 133.92 \cdot ft \cdot kip$

$f_{a.75.ir.71} := \frac{F_{a.tot.71}}{A_{lb}} = 4.31 \cdot ksi$

Axial stress on brace, Load Combination 7-1

$f_{b.75.ir.71} := \frac{M_{R.tot.71}}{Z_{lb}} = 32.25 \cdot ksi$

Bending stress on brace, Load Combination 7-1

$IC_{75.ir.LC71} := \frac{f_{a.75.ir.71}}{F_{a.LB}} + \frac{f_{b.75.ir.71}}{F_{b.LB}} = 0.70$

Interaction coefficient for Member 75, Load Combination 7-1

$MF_{75.ir.LC71} := \frac{1}{IC_{75.ir.LC71}} = 1.43$

Margin factor for Member 75, Load Combination 7-1

### 7.1.2.3 Evaluate Load Combination 7-2

$F_{a.Th.190} := IF_{190} \cdot F_{a.Th.146} = 33.05 \cdot kip$

$M_{B.Th.190} := IF_{190} \cdot M_{B.Th.146} = 17.02 \cdot ft \cdot kip$

$M_{C.Th.190} := IF_{190} \cdot M_{C.Th.146} = 89.1 \cdot ft \cdot kip$

Axial load and moment components due to thermal load, prorated for 190°F

SRV loads are reduced to 40% of the full load per Section 6.1.2.1.

Design axial load on brace, Load Combination 7-2:

$$F_{a.tot.72} := F_{a.DL} + F_{a.Th.190} + \gamma_{SRV.72} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 216.81 \cdot kip$$

Design moment on brace, Load Combination 7-2:

$$M_{B.72} := M_{B.Th.190} + \gamma_{SRV.72} M_{B.SVSA} + M_{B.LOCA.drag.db} + e_{lb.75.h} \cdot F_{a.tot.72} = 54.65 \cdot ft \cdot kip$$

$$M_{C.72} := M_{C.Th.190} + \gamma_{SRV.72} M_{C.SVSA} + M_{C.LOCA.drag.db} = 110.96 \cdot ft \cdot kip$$

$$M_{R.tot.72} := \sqrt{M_{B.72}^2 + M_{C.72}^2} + M_{R.LOCA.lat.0808} + M_{R.DL} + M_{R.DRAG} + M_{R.Ess} = 151.57 \cdot ft \cdot kip$$

$$f_{a.75.ir.72} := \frac{F_{a.tot.72}}{A_{lb}} = 10.72 \cdot ksi$$

Axial stress on brace, Load Combination 7-2

$$f_{b.75.ir.72} := \frac{M_{R.tot.72}}{Z_{lb}} = 36.5 \cdot ksi$$

Bending stress on brace, Load Combination 7-2

$$IC_{75.ir.LC72} := \frac{f_{a.75.ir.72}}{F_{a.LB}} + \frac{f_{b.75.ir.72}}{F_{b.LB}} = 0.90$$

Interaction coefficient for Member 75, Load Combination 7-2

$$MF_{75.ir.LC72} := \frac{1}{IC_{75.ir.LC72}} = 1.11$$

Margin factor for Member 75, Load Combination 7-2

### 7.1.2.4 Evaluate Load Combination 7-3

$F_{a.Th.150} := IF_{150} \cdot F_{a.Th.146} = 22.02 \cdot kip$

$M_{B.Th.150} := IF_{150} \cdot M_{B.Th.146} = 11.34 \cdot ft \cdot kip$

$M_{C.Th.150} := IF_{150} \cdot M_{C.Th.146} = 59.36 \cdot ft \cdot kip$

Axial load and moment components due to thermal load, prorated for 150°F

SRV loads are reduced per Section 6.1.2.1.

Design axial load on brace, Load Combination 7-3:

$F_{a.SVSA.150} := F_{a.DL} + F_{a.Th.150} + \gamma_{SVSA} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 220.2 \cdot kip$

Design moment on brace, 150°F temperature case, with SRV-SVSA:

$$M_{B.SVSA.150} := M_{B.Th.150} + \gamma_{SVSA} M_{B.SVSA} + M_{B.LOCA.drag.db} \cdots + e_{lb.75.h} \cdot F_{a.SVSA.150} = 51.72 \cdot ft \cdot kip$$

$$M_{C.SVSA.150} := M_{C.Th.150} + \gamma_{SVSA} M_{C.SVSA} + M_{C.LOCA.drag.db} = 86.88 \cdot ft \cdot kip$$

$$M_{R.SVSA.150} := \sqrt{M_{B.SVSA.150}^2 + M_{C.SVSA.150}^2} + \begin{pmatrix} M_{R.DL} \cdots \\ + M_{R.DRAG} \cdots \\ + M_{R.Ess} \cdots \\ + M_{R.LOCA.lat.0808} \end{pmatrix} = 128.99 \cdot ft \cdot kip$$

$$f_{a.75.ir.73} := \frac{F_{a.SVSA.150}}{A_{lb}} = 10.88 \cdot ksi$$

Axial stress on brace, Load Combination 7-3

$$f_{b.75.ir.73} := \frac{M_{R.SVSA.150}}{Z_{lb}} = 31.06 \cdot ksi$$

Bending stress on brace, Load Combination 7-3

$$IC_{75.ir.LC73} := \frac{f_{a.75.ir.73}}{F_{a.LB}} + \frac{f_{b.75.ir.73}}{F_{b.LB}} = 0.80$$

Interaction coefficient for Member 75, Load Combination 7-3

$$MF_{75.ir.LC73} := \frac{1}{IC_{75.ir.LC73}} = 1.25$$

Margin factor for Member 75, Load Combination 7-3

## 7.1.3 Member 86 / Node 63

### 7.1.3.1 Determine Current Design Loading

Ref. 3a, Section 4.5 and Ref. 3b, Section 6.2.1 identify Member 86 as the critical lower bracing member for the Inner Ring bracing. Loads on the member are identified below.

$F_{a.DL} := 0kip$ $\quad M_{R.DL} := 0.015 ft \cdot kip$ — Axial load and moment due to dead load (Ref. 3a, Section 4.5, page 4)

$F_{a.Th.146} := 22kip$ — Axial load due to thermal load, 146°F (Ref. 3a, Section 4.5, page 4)

$$M_{B.Th.146} := \begin{pmatrix} 2668 \\ 1813 \end{pmatrix} ft \cdot lbf \quad \begin{pmatrix} \text{"Node 88"} \\ \text{"Node 63"} \end{pmatrix}$$

$$M_{C.Th.146} := \begin{pmatrix} 4559 \\ 88671 \end{pmatrix} ft \cdot lbf \quad \begin{pmatrix} \text{"Node 88"} \\ \text{"Node 63"} \end{pmatrix}$$

Moment components due to thermal load, 146°F (Ref. 3e, PIPSYS Run 374PCG, Section D, page 1-8)

Per Ref. 3a, Section 4.5, page 3, SVSA controls over RSSD.

$F_{a.SVSA} := 22.412kip$ — Axial load due to SRV-SVSA

Moment components for SRV-SVSA load case, design basis (Ref. 3e, PIPSYS Run ID 595YW, Section I, page 4-25 and PIPSYS Run ID 596YW, Section I, page 5-24):

$$M_{B.SVSA} := (1.757 + 3.352) ft \cdot kip = 5.11 \cdot ft \cdot kip$$

$$M_{C.SVSA} := (3.632 + 18.206) ft \cdot kip = 21.84 \cdot ft \cdot kip$$

$F_{a.LOCA} := \max(4.40, 60.481) \cdot kip + 38.85kip = 99.33 \cdot kip$ — Axial load due to LOCA (Ref. 3a, Section 4.5, page 4; Ref. 3b, Section 6.2.1, page 4)

$M_{B.LOCA.lat.db} := 1.12 ft \cdot kip$

$M_{C.LOCA.lat.db} := 4.098 ft \cdot kip$

Moment components for LOCA chugging lateral load case, design basis (Ref. 3e, PIPSYS Run ID 643PCG, Section D, page 1-8)

$M_{B.LOCA.lat.0808} := 1.621 ft \cdot kip$

$M_{C.LOCA.lat.0808} := 30.372 ft \cdot kip$

Moment components for LOCA chugging lateral load case, NUREG-0808 (Ref. 3b, Section 4.0, page 4)

$M_{R.LOCA.drag.db} := 29.07 ft \cdot kip$ — Resultant moment for LOCA chugging drag load case, design basis (Ref. 3b, Section 6.2.1, page 4)

By observation, the NUREG-0808 lateral chugging loads control.

| | | |
|---|---|---|
| $F_{a.DRAG} := 0kip$ | $M_{R.DRAG} := 1.11ft \cdot kip$ | Axial load and moment due to bracing drag (SVSA or RSSD + Chugging) (Ref. 3a, Section 4.5, page 4) |
| $F_{a.Ess} := 0kip$ | $M_{R.Ess} := 3.02ft \cdot kip$ | Axial load and moment due to seismic (Ref. 3a, Section 4.5, page 4) |

The thermal moment for the brace can be reduced by considering the actual length of the member since the PIPSYS analysis output is given at the working points of the analytical members (not the actual member ends) and the thermal moment gradient along the length of the member is known.

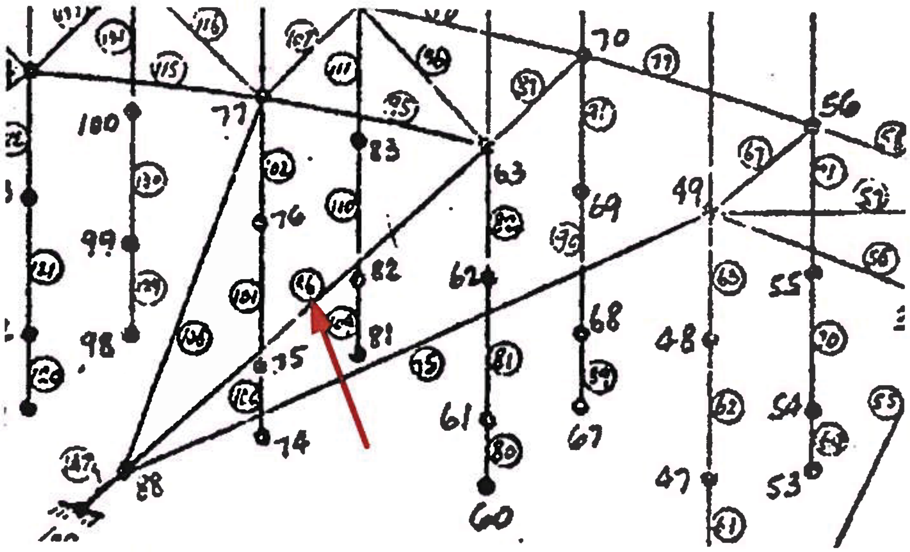



**Figure 7.1.3.1-1:** Member 86 Location in PIPSYS Model (Ref. 3a, Section 2.1, page 2)

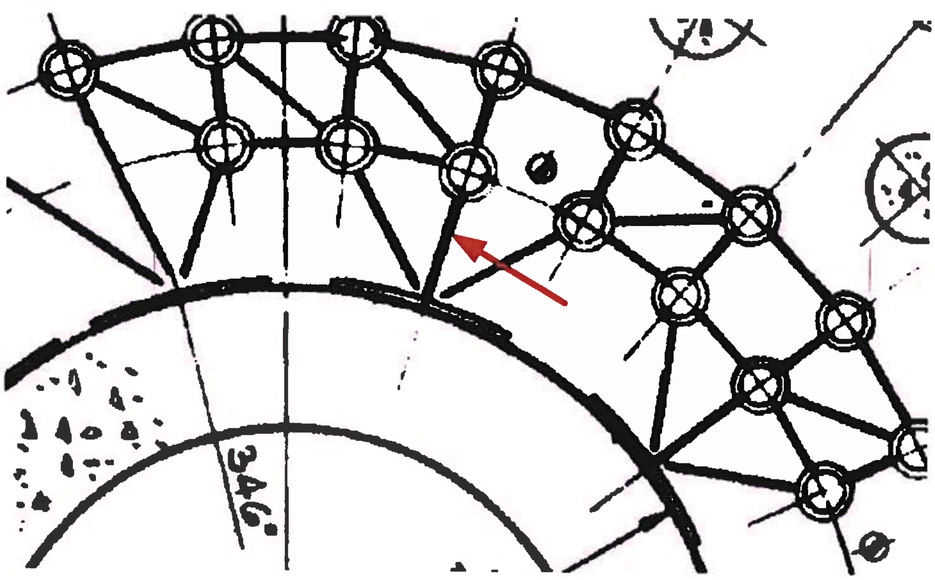



**Figure 7.1.3.1-2:** Member 86 Location in Installed Configuration (Ref. 2a)

The node-to-node length of this member is determined based on the measurements in Ref. 2a.

$r_1 := 14ft + 11\frac{1}{2}in$ $\quad r_2 := 19ft + 9in$ — Radii to working points

$L_{nn} := r_2 - r_1 = 4.79 \cdot ft$ — Node-to-node length of Member 86

$L_{crit} := L_{nn} - \frac{24in}{2} = 3.79 \cdot ft$ — Length to critical section of Member 86, at outer face of downcomer

Since the thermal moment gradient is known, pro-rate to find the thermal moment components at the face of the downcomer.

$M_{B.Th.146} := \left| \text{linterp}\left[\begin{pmatrix} 0 \\ L_{nn} \end{pmatrix}, M_{B.Th.146}, L_{crit}\right] \right| = 1.99 \cdot ft \cdot kip$

$M_{C.Th.146} := \left| \text{linterp}\left[\begin{pmatrix} 0 \\ L_{nn} \end{pmatrix}, M_{C.Th.146}, L_{crit}\right] \right| = 71.12 \cdot ft \cdot kip$

Moment components due to thermal load at 146°F, linearly pro-rated to determine moment at face of downcomer

Per Design Input #5, Member 86 was installed out of tolerance in the horizontal direction, thus additional moment needs to be added for the eccentricity.

$e_{lb.86.h} = 0.70\ in$ — Maximum eccentricity of a CBI brace number equivalent to Member 86 (previously specified)

### 7.1.3.2 Evaluate Load Combination 7-1

$F_{a.Th.212} := IF_{212} \cdot F_{a.Th.146} = 41.14 \cdot kip$

$M_{B.Th.212} := IF_{212} \cdot M_{B.Th.146} = 3.72 \cdot ft \cdot kip$

$M_{C.Th.212} := IF_{212} \cdot M_{C.Th.146} = 132.99 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 212°F

Design axial load on brace, Load Combination 7-1:

$F_{a.tot.71} := F_{a.DL} + F_{a.Th.212} + F_{a.SVSA} + F_{a.DRAG} + F_{a.Ess} = 63.55 \cdot kip$

Design moment on brace, Load Combination 7-1:

$M_{B.71} := M_{B.Th.212} + M_{B.SVSA} + e_{lb.86.h} \cdot F_{a.tot.71} = 12.54 \cdot ft \cdot kip$

$M_{C.71} := M_{C.Th.212} + M_{C.SVSA} = 154.83 \cdot ft \cdot kip$

$M_{R.tot.71} := \sqrt{M_{B.71}^2 + M_{C.71}^2} + M_{R.DL} + M_{R.DRAG} + M_{R.Ess} = 159.48 \cdot ft \cdot kip$

$f_{a.86.ir.71} := \frac{F_{a.tot.71}}{A_{lb}} = 3.14 \cdot ksi$

Axial stress on brace, Load Combination 7-1

$f_{b.86.ir.71} := \frac{M_{R.tot.71}}{Z_{lb}} = 38.41 \cdot ksi$

Bending stress on brace, Load Combination 7-1

$IC_{86.ir.LC71} := \frac{f_{a.86.ir.71}}{F_{a.LB}} + \frac{f_{b.86.ir.71}}{F_{b.LB}} = 0.80$

Interaction coefficient for Member 86, Load Combination 7-1

$MF_{86.ir.LC71} := \frac{1}{IC_{86.ir.LC71}} = 1.26$

Margin factor for Member 86, Load Combination 7-1

### 7.1.3.3 Evaluate Load Combination 7-2

$F_{a.Th.190} := IF_{190} \cdot F_{a.Th.146} = 34.76 \cdot kip$

$M_{B.Th.190} := IF_{190} \cdot M_{B.Th.146} = 3.15 \cdot ft \cdot kip$

$M_{C.Th.190} := IF_{190} \cdot M_{C.Th.146} = 112.37 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 190°F

SRV loads are reduced to 40% of the full load per Section 6.1.2.1.

Design axial load on brace, Load Combination 7-2:

$F_{a.tot.72} := F_{a.DL} + F_{a.Th.190} + \gamma_{SRV.72} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 143.06 \cdot kip$

Design moment on brace, Load Combination 7-2:

$M_{B.72} := M_{B.Th.190} + \gamma_{SRV.72} \cdot M_{B.SVSA} + M_{B.LOCA.lat.0808} + e_{lb.86.h} \cdot F_{a.tot.72} = 15.16 \cdot ft \cdot kip$

$M_{C.72} := M_{C.Th.190} + \gamma_{SRV.72} \cdot M_{C.SVSA} + M_{C.LOCA.lat.0808} = 151.47 \cdot ft \cdot kip$

$$M_{R.tot.72} := \sqrt{M_{B.72}^2 + M_{C.72}^2} + \begin{pmatrix} M_{R.DL} \cdots \\ + M_{R.DRAG} + M_{R.Ess} \cdots \\ + M_{R.LOCA.drag.db} \end{pmatrix} = 185.44 \cdot ft \cdot kip$$

$f_{a.86.ir.72} := \dfrac{F_{a.tot.72}}{A_{lb}} = 7.07 \cdot ksi$ Axial stress on brace, Load Combination 7-2

$f_{b.86.ir.72} := \dfrac{M_{R.tot.72}}{Z_{lb}} = 44.66 \cdot ksi$ Bending stress on brace, Load Combination 7-2

$IC_{86.ir.LC72} := \dfrac{f_{a.86.ir.72}}{F_{a.LB}} + \dfrac{f_{b.86.ir.72}}{F_{b.LB}} = 0.99$ Interaction coefficient for Member 86, Load Combination 7-2

$MF_{86.ir.LC72} := \dfrac{1}{IC_{86.ir.LC72}} = 1.01$ Margin factor for Member 86, Load Combination 7-2

### 7.1.3.4 Evaluate Load Combination 7-3

$F_{a.Th.150} := IF_{150} \cdot F_{a.Th.146} = 23.16 \cdot kip$

$M_{B.Th.150} := IF_{150} \cdot M_{B.Th.146} = 2.1 \cdot ft \cdot kip$

$M_{C.Th.150} := IF_{150} \cdot M_{C.Th.146} = 74.86 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 150°F

SRV loads are reduced per Section 6.1.2.1.

Design axial load on brace, Load Combination 7-3:

$F_{a.SVSA.150} := F_{a.DL} + F_{a.Th.150} + \gamma_{SVSA} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 138.18 \cdot kip$

Design moment on brace, 150°F temperature case, with SRV-SVSA:

$M_{B.150} := M_{B.Th.150} + \gamma_{SVSA} \cdot M_{B.SVSA} + M_{B.LOCA.lat.0808} + e_{lb.86.h} \cdot F_{a.SVSA.150} = 15.35 \cdot ft \cdot kip$

$M_{C.150} := M_{C.Th.150} + \gamma_{SVSA} \cdot M_{C.SVSA} + M_{C.LOCA.lat.0808} = 120.52 \cdot ft \cdot kip$

$$M_{R.tot.150} := \sqrt{M_{B.150}^2 + M_{C.150}^2} + \left(M_{R.DL} \cdots + M_{R.DRAG} + M_{R.Ess} \cdots + M_{R.LOCA.drag.db}\right) = 154.71 \cdot ft \cdot kip$$

$f_{a.86.ir.73} := \dfrac{F_{a.SVSA.150}}{A_{lb}} = 6.83 \cdot ksi$

Axial stress on brace, Load Combination 7-3

$f_{b.86.ir.73} := \dfrac{M_{R.SVSA.150}}{Z_{lb}} = 31.06 \cdot ksi$

Bending stress on brace, Load Combination 7-3

$IC_{86.ir.LC73} := \dfrac{f_{a.86.ir.73}}{F_{a.LB}} + \dfrac{f_{b.86.ir.73}}{F_{b.LB}} = 0.73$

Interaction coefficient for Member 86, Load Combination 7-3

$MF_{86.ir.LC73} := \dfrac{1}{IC_{86.ir.LC73}} = 1.38$

Margin factor for Member 86, Load Combination 7-3

## 7.1.4 *Member 7 / Node 11*

### 7.1.4.1 Determine Current Design Loading

Ref. 3a, Section 4.5 and Ref. 3b, Section 6.2.1 identify Member 7 as a critical lower bracing member for the Inner Ring bracing. Loads on the member are identified below.

$F_{a.DL} := 0kip$ $M_{R.DL} := 0.015ft \cdot kip$ Axial load and moment due to dead load (Ref. 3a, Section 4.5, page 4)

$F_{a.Th.146} := 7.57kip$ $M_{R.Th.146} := 2.79ft \cdot kip$ Axial load and moment due to thermal load, 146°F (Ref. 3a, Section 4.5, page 4)

Per Ref. 3a, Section 4.5, page 3, SVSA controls over RSSD.

$F_{a.SVSA} := 16.97kip$ $M_{R.SVSA} := 27.53ft \cdot kip$ Axial load and moment due to SRV-SVSA (Ref. 3a, Section 4.5, page 3)

$F_{a.LOCA} := \max(14.58, 27.732) \cdot kip + 12.22kip = 39.95 \cdot kip$ Axial load due to LOCA (Ref. 3a, Section 4.5, page 4; Ref. 3b, Section 6.2.1, page 3)

Moment load due to LOCA (Ref. 3a, Section 4.5, page 4; Ref. 3b, Section 6.2.1, page 3)

$M_{R.LOCA} := \max(22.52, 11.211)\, ft \cdot kip + 38.44ft \cdot kip = 60.96 \cdot ft \cdot kip$

$F_{a.DRAG} := 0kip$ $M_{R.DRAG} := 0.29ft \cdot kip$ Axial load and moment due to bracing drag (SVSA or RSSD + Chugging) (Ref. 3a, Section 4.5, page 4)

$F_{a.Ess} := 0kip$ $M_{R.Ess} := 3.02ft \cdot kip$ Axial load and moment due to seismic (Ref. 3a, Section 4.5, page 4)

Per Design Input #5, Member 7 was installed out of tolerance, thus additional moment needs to be added for the eccentricity.

$e_{lb.7} = 0.06\,in$ Maximum eccentricity of a CBI brace number equivalent to Member 7 (previously specified)

### 7.1.4.2 Evaluate Load Combination 7-1

$F_{a.Th.212} := IF_{212} \cdot F_{a.Th.146} = 14.16 \cdot kip$

$M_{R.Th.212} := IF_{212} \cdot M_{R.Th.146} = 5.22 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 212°F

Design axial load on brace, Load Combination 7-1:

$F_{a.tot.71} := F_{a.DL} + F_{a.Th.212} + F_{a.SVSA} + F_{a.DRAG} + F_{a.Ess} = 31.13 \cdot kip$

Design moment on brace, Load Combination 7-1:

$M_{R.tot.71} := M_{R.DL} + M_{R.Th.212} + M_{R.SVSA} + M_{R.DRAG} + M_{R.Ess} = 36.07 \cdot ft \cdot kip$

$$f_{a.7.ir.71} := \frac{F_{a.tot.71}}{A_{lb}} = 1.54 \cdot ksi$$

Axial stress on brace, Load Combination 7-1

$$f_{b.7.ir.71} := \frac{M_{R.tot.71} + F_{a.tot.71} \cdot e_{lb.7}}{Z_{lb}} = 8.72 \cdot ksi$$

Bending stress on brace, Load Combination 7-1

$$IC_{7.ir.LC71} := \frac{f_{a.7.ir.71}}{F_{a.LB}} + \frac{f_{b.7.ir.71}}{F_{b.LB}} = 0.20$$

Interaction coefficient for Member 7, Load Combination 7-1

$$MF_{7.ir.LC71} := \frac{1}{IC_{7.ir.LC71}} = 5.09$$

Margin factor for Member 7, Load Combination 7-1

### 7.1.4.3 Evaluate Load Combination 7-2

$F_{a.Th.190} := IF_{190} \cdot F_{a.Th.146} = 11.96 \cdot kip$

$M_{R.Th.190} := IF_{190} \cdot M_{R.Th.146} = 4.41 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 190°F

SRV loads are reduced to 40% of the full load per Section 6.1.2.1.

Design axial load on brace, Load Combination 7-2:

$$F_{a.tot.72} := F_{a.DL} + F_{a.Th.190} + \gamma_{SRV.72} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 58.7 \cdot kip$$

Design moment on brace, Load Combination 7-2:

$$M_{R.tot.72} := M_{R.DL} + M_{R.Th.190} + \gamma_{SRV.72} M_{R.SVSA} + M_{R.LOCA} + M_{R.DRAG} + M_{R.Ess} = 79.71 \cdot ft \cdot kip$$

$$f_{a.7.ir.72} := \frac{F_{a.tot.72}}{A_{lb}} = 2.9 \cdot ksi$$

Axial stress on brace, Load Combination 7-2

$$f_{b.7.ir.72} := \frac{M_{R.tot.72} + F_{a.tot.72} \cdot e_{lb.7}}{Z_{lb}} = 19.27 \cdot ksi$$

Bending stress on brace, Load Combination 7-2

$$IC_{7.ir.LC72} := \frac{f_{a.7.ir.72}}{F_{a.LB}} + \frac{f_{b.7.ir.72}}{F_{b.LB}} = 0.42$$

Interaction coefficient for Member 7, Load Combination 7-2

$$MF_{7.ir.LC72} := \frac{1}{IC_{7.ir.LC72}} = 2.36$$

Margin factor for Member 7, Load Combination 7-2

### 7.1.4.4 Evaluate Load Combination 7-3

$F_{a.Th.150} := IF_{150} \cdot F_{a.Th.146} = 7.97 \cdot kip$

$M_{R.Th.150} := IF_{150} \cdot M_{R.Th.146} = 2.94 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 150°F

SRV loads are reduced per Section 6.1.2.1.

Design axial load on brace, Load Combination 7-3:

$$F_{a.SVSA.150} := F_{a.DL} + F_{a.Th.150} + \gamma_{SVSA} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 59.8 \cdot kip$$

Design moment on brace, 150°F temperature case, with SRV-SVSA:

$$M_{R.SVSA.150} := M_{R.DL} + M_{R.Th.150} + \gamma_{SVSA} M_{R.SVSA} + M_{R.LOCA} + M_{R.DRAG} + M_{R.Ess} = 86.49 \cdot ft \cdot kip$$

$f_{a.7.ir.73} := \frac{F_{a.SVSA.150}}{A_{lb}} = 2.96 \cdot ksi$ — Axial stress on brace, Load Combination 7-3

$f_{b.7.ir.73} := \frac{M_{R.SVSA.150} + F_{a.SVSA.150} \cdot e_{lb.7}}{Z_{lb}} = 20.9 \cdot ksi$ — Bending stress on brace, Load Combination 7-3

$IC_{7.ir.LC73} := \frac{f_{a.7.ir.73}}{F_{a.LB}} + \frac{f_{b.7.ir.73}}{F_{b.LB}} = 0.46$ — Interaction coefficient for Member 7, Load Combination 7-3

$MF_{7.ir.LC73} := \frac{1}{IC_{7.ir.LC73}} = 2.19$ — Margin factor for Member 7, Load Combination 7-3

## 7.1.5 Member 57 / Node 49

### 7.1.5.1 Determine Current Design Loading

Ref. 3a, Section 4.5 and Ref. 3b, Section 6.2.1 identify Member 57 as a critical lower bracing member for the Inner Ring bracing. Loads on the member are identified below.

$F_{a.DL} := 0kip$ $M_{R.DL} := 0.097ft \cdot kip$ Axial load and moment due to dead load (Ref. 3a, Section 4.5, page 4)

$F_{a.Th.146} := 32.41kip$ Axial load due to thermal load, 146°F (Ref. 3a, Section 4.5, page 4)

$M_{B.Th.146} := \begin{pmatrix} -370 \\ 2030 \end{pmatrix} ft \cdot lbf$ $\begin{pmatrix} \text{"Node 42"} \\ \text{"Node 49"} \end{pmatrix}$

$M_{C.Th.146} := \begin{pmatrix} 965 \\ 7482 \end{pmatrix} ft \cdot lbf$ $\begin{pmatrix} \text{"Node 42"} \\ \text{"Node 49"} \end{pmatrix}$

Moment components due to thermal load, 146°F (Ref. 3e, PIPSYS Run 374PCG, Section D, page 1-6)

$F_{a.SVSA} := 43.06kip$ Axial load due to SRV-SVSA (Ref. 3a, Section 4.5, page 3)

Moment components for SRV-SVSA load case, design basis (Ref. 3e, PIPSYS Run ID 595YW, Section I, page 4-23 and PIPSYS Run ID 596YW, Section I, page 5-22):

$M_{B.SVSA} := (1.137 + 0.749) ft \cdot kip = 1.89 \cdot ft \cdot kip$

$M_{C.SVSA} := (12.039 + 1.715) ft \cdot kip = 13.75 \cdot ft \cdot kip$

$F_{a.RSSD} := 46.03kip$

$M_{R.RSSD} := 9.28ft \cdot kip$

Axial load and moment due to SRV-RSSD (Ref. 3a, Section 4.5, page 3)

$F_{a.LOCA} := \max(41.58, 10.710) \cdot kip + 135.16kip = 176.74 \cdot kip$ Axial load due to LOCA (Ref. 3a, Section 4.5, page 4; Ref. 3b, Section 6.2.1, page 3)

$M_{B.LOCA.lat.db} := 0.678ft \cdot kip$

$M_{C.LOCA.lat.db} := 13.8ft \cdot kip$

Moment components for LOCA chugging lateral load case, design basis (Ref. 3e, PIPSYS Run ID 643PCG, Section D, page 1-6)

$M_{R.LOCA.lat.0808} := 12.093ft \cdot kip$ Resultant moment for LOCA chugging lateral load case, NUREG-0808 (Ref. 3b, Section 6.2.1, page 3)

The design basis LOCA chugging lateral moment controls by observation.

$M_{B.LOCA.drag.db} := 4.711ft \cdot kip$

$M_{C.LOCA.drag.db} := 18.817ft \cdot kip$

Moment components for LOCA chugging drag load case, design basis (Ref. 3e, PIPSYS Run A853YW, Section I, page 12-34)

| | | |
|---|---|---|
| $F_{a.DRAG} := 0\text{kip}$ | $M_{R.DRAG} := 1.86\text{ft}\cdot\text{kip}$ | Axial load and moment due to bracing drag (SVSA or RSSD + Chugging) (Ref. 3a, Section 4.5, page 4) |
| $F_{a.Ess} := 0\text{kip}$ | $M_{R.Ess} := 3.28\text{ft}\cdot\text{kip}$ | Axial load and moment due to seismic (Ref. 3a, Section 4.5, page 4) |

The thermal moment for the brace can be reduced by considering the actual length of the member since the PIPSYS analysis output is given at the working points of the analytical members (not the actual member ends) and the thermal moment gradient along the length of the member is known.

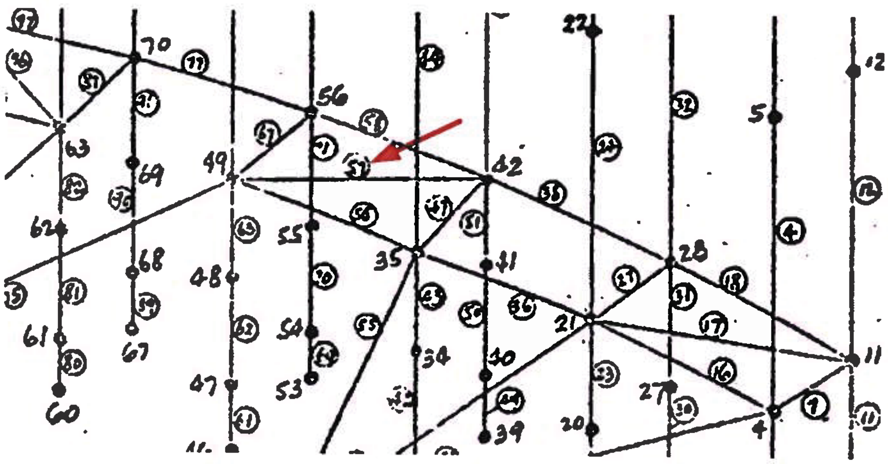


**Figure 7.1.5.1-1:** Member 57 Location in PIPSYS Model (Ref. 3a, Section 2.1, page 2)

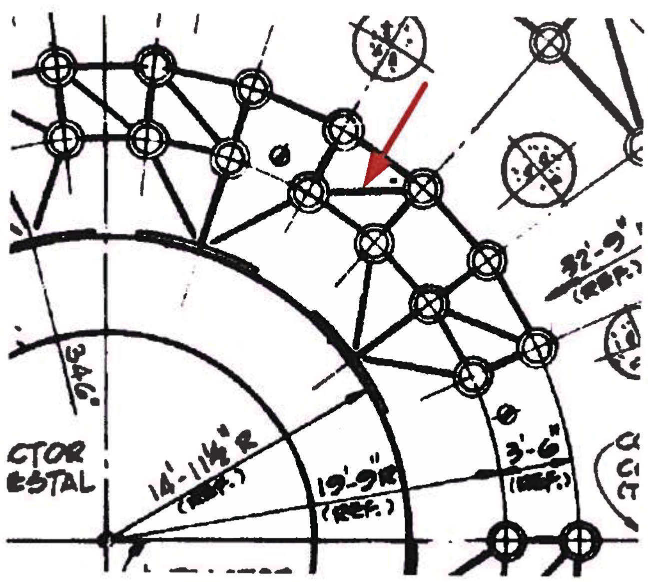


**Figure 7.1.5.1-2:** Member 57 Location in Installed Configuration (Ref. 2a)

The node-to-node length of this member is determined based on the measurements in Ref. 2a.

$r_1 := 19ft + 9in$ $\qquad r_2 := r_1 + (3ft + 6in)$ Radii to downcomers

X- and Y-coordinates of the downcomers to which Member 57 attaches:

$$x_{DC} := \begin{pmatrix} r_1 \cdot \cos(90deg - 30deg) \\ r_2 \cdot \cos(90deg - 42deg) \end{pmatrix} = \begin{pmatrix} 9.87 \\ 15.56 \end{pmatrix} \cdot ft \qquad y_{DC} := \begin{pmatrix} r_1 \cdot \sin(90deg - 30deg) \\ r_2 \cdot \sin(90deg - 42deg) \end{pmatrix} = \begin{pmatrix} 17.1 \\ 17.28 \end{pmatrix} \cdot ft$$

$$L_{nn} := \sqrt{\left(x_{DC_2} - x_{DC_1}\right)^2 + \left(y_{DC_2} - y_{DC_1}\right)^2} = 5.68 \cdot ft$$ Node-to-node length of Member 57

$$L_{crit} := L_{nn} - \frac{24in}{2} = 4.68 \cdot ft$$ Length to critical section of Member 57, at outer face of downcomer

Since the thermal moment gradient is known, pro-rate to find the thermal moment components at the face of the downcomer.

$$M_{B.Th.146} := \left| \text{linterp}\left[\begin{pmatrix} 0 \\ L_{nn} \end{pmatrix}, M_{B.Th.146}, L_{crit}\right] \right| = 1.61 \cdot ft \cdot kip$$

$$M_{C.Th.146} := \left| \text{linterp}\left[\begin{pmatrix} 0 \\ L_{nn} \end{pmatrix}, M_{C.Th.146}, L_{crit}\right] \right| = 6.34 \cdot ft \cdot kip$$

Moment components due to thermal load at 146°F, linearly pro-rated to determine moment at face of downcomer

$$M_{R.Th.146} := \sqrt{M_{B.Th.146}^2 + M_{C.Th.146}^2} = 6.54 \cdot ft \cdot kip$$ Resultant thermal moment at 146°F

Per Design Input #5, Member 57 was installed out of tolerance in the horizontal direction, thus additional moment needs to be added for the eccentricity.

$e_{lb.57.h} = 3.2\ in$ Maximum eccentricity of a CBI brace number equivalent to Member 57 (previously specified)

### 7.1.5.2 Evaluate Load Combination 7-1

$F_{a.Th.212} := IF_{212} \cdot F_{a.Th.146} = 60.61 \cdot kip$

$M_{R.Th.212} := IF_{212} \cdot M_{R.Th.146} = 12.22 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 212°F

Design axial load on brace, Load Combination 7-1:

$F_{a.SVSA.71} := F_{a.DL} + F_{a.Th.212} + F_{a.SVSA} + F_{a.DRAG} + F_{a.Ess} = 103.67 \cdot kip$

$F_{a.RSSD.71} := F_{a.DL} + F_{a.Th.212} + F_{a.RSSD} + F_{a.DRAG} + F_{a.Ess} = 106.64 \cdot kip$

Design moment on brace, Load Combination 7-1:

$M_{R.SVSA.71} := M_{R.DL} + M_{R.Th.212} + \sqrt{M_{B.SVSA}^2 + M_{C.SVSA}^2} + M_{R.DRAG} + M_{R.Ess} = 31.34 \cdot ft \cdot kip$

$M_{R.RSSD.71} := M_{R.DL} + M_{R.Th.212} + M_{R.RSSD} + M_{R.DRAG} + M_{R.Ess} = 26.74 \cdot ft \cdot kip$

$f_{a.57.ir.SVSA.71} := \frac{F_{a.SVSA.71}}{A_{lb}} = 5.12 \cdot ksi$

Axial stress on brace, Load Combination 7-1, with SRV-SVSA

$f_{b.57.ir.SVSA.71} := \frac{M_{R.SVSA.71} + F_{a.SVSA.71} \cdot e_{lb.57.h}}{Z_{lb}} = 14.21 \cdot ksi$

Bending stress on brace, Load Combination 7-1, with SRV-SVSA

$IC_{57.ir.SVSA.LC71} := \frac{f_{a.57.ir.SVSA.71}}{F_{a.LB}} + \frac{f_{b.57.ir.SVSA.71}}{F_{b.LB}} = 0.37$

Interaction coefficient for Member 57, Load Combination 7-1, with SRV-SVSA

$f_{a.57.ir.RSSD.71} := \frac{F_{a.RSSD.71}}{A_{lb}} = 5.27 \cdot ksi$

Axial stress on brace, Load Combination 7-1, with SRV-RSSD

$f_{b.57.ir.RSSD.71} := \frac{M_{R.RSSD.71} + F_{a.RSSD.71} \cdot e_{lb.57.h}}{Z_{lb}} = 13.29 \cdot ksi$

Bending stress on brace, Load Combination 7-1, with SRV-RSSD

$IC_{57.ir.RSSD.LC71} := \frac{f_{a.57.ir.RSSD.71}}{F_{a.LB}} + \frac{f_{b.57.ir.RSSD.71}}{F_{b.LB}} = 0.36$

Interaction coefficient for Member 57, Load Combination 7-1, with SRV-RSSD

$IC_{57.ir.LC71} := \max\left(IC_{57.ir.SVSA.LC71}, IC_{57.ir.RSSD.LC71}\right) = 0.37$

Maximum interaction coefficient for Member 57, Load Combination 7-1

$MF_{57.ir.LC71} := \frac{1}{IC_{57.ir.LC71}} = 2.70$

Margin factor for Member 57, Load Combination 7-1

### 7.1.5.3 Evaluate Load Combination 7-2

$F_{a.Th.190} := IF_{190} \cdot F_{a.Th.146} = 51.21 \cdot kip$

$M_{B.Th.190} := IF_{190} \cdot M_{B.Th.146} = 2.54 \cdot ft \cdot kip$

$M_{C.Th.190} := IF_{190} \cdot M_{C.Th.146} = 10.01 \cdot ft \cdot kip$

Axial load and moment components due to thermal load, prorated for 190°F

SRV loads are reduced to 40% of the full load per Section 6.1.2.1. Per the previous section, SVSA controls.

Design axial load on brace, Load Combination 7-2:

$$F_{a.tot.72} := F_{a.DL} + F_{a.Th.190} + \gamma_{SRV.72} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 245.17 \cdot kip$$

Design moment on brace, Load Combination 7-2:

$$M_{B.72} := M_{B.Th.190} + M_{B.LOCA.lat.db} + M_{B.LOCA.drag.db} + \gamma_{SRV.72} \cdot M_{B.SVSA} \cdots + e_{lb.57.h} \cdot F_{a.tot.72} = 74.06 \cdot ft \cdot kip$$

$$M_{C.72} := M_{C.Th.190} + M_{C.LOCA.lat.db} + M_{C.LOCA.drag.db} + \gamma_{SRV.72} \cdot M_{C.SVSA} = 48.13 \cdot ft \cdot kip$$

$$M_{R.tot.72} := M_{R.DL} + \sqrt{M_{B.72}^2 + M_{C.72}^2} + M_{R.DRAG} + M_{R.Ess} = 93.56 \cdot ft \cdot kip$$

$f_{a.57.ir.72} := \dfrac{F_{a.tot.72}}{A_{lb}} = 12.12 \cdot ksi$ — Axial stress on brace, Load Combination 7-2

$f_{b.57.ir.72} := \dfrac{M_{R.tot.72}}{Z_{lb}} = 22.53 \cdot ksi$ — Bending stress on brace, Load Combination 7-2

$IC_{57.ir.LC72} := \dfrac{f_{a.57.ir.72}}{F_{a.LB}} + \dfrac{f_{b.57.ir.72}}{F_{b.LB}} = 0.66$ — Interaction coefficient for Member 57, Load Combination 7-2

$MF_{57.ir.LC72} := \dfrac{1}{IC_{57.ir.LC72}} = 1.51$ — Margin factor for Member 57, Load Combination 7-2

### 7.1.5.4 Evaluate Load Combination 7-3

$F_{a.Th.150} := IF_{150} \cdot F_{a.Th.146} = 34.12 \cdot kip$

$M_{B.Th.150} := IF_{150} \cdot M_{B.Th.146} = 1.69 \cdot ft \cdot kip$

$M_{C.Th.150} := IF_{150} \cdot M_{C.Th.146} = 6.67 \cdot ft \cdot kip$

Axial load and moment components due to thermal load, prorated for 150°F

SRV loads are reduced per Section 6.1.2.1. Both SVSA and RSSD are checked since the loads are similar.

Design axial load on brace, Load Combination 7-3:

$$F_{a.SVSA.150} := F_{a.DL} + F_{a.Th.150} + \gamma_{SVSA} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 241 \cdot kip$$

$$F_{a.RSSD.150} := F_{a.DL} + F_{a.Th.150} + \gamma_{RSSD} F_{a.RSSD} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 247.68 \cdot kip$$

$$M_{B.73} := M_{B.Th.150} + M_{B.LOCA.lat.db} + M_{B.LOCA.drag.db} = 7.08 \cdot ft \cdot kip$$

$$M_{C.73} := M_{C.Th.150} + M_{C.LOCA.lat.db} + M_{C.LOCA.drag.db} = 39.29 \cdot ft \cdot kip$$

Design moment on brace, 150°F temperature case, with SRV-SVSA:

$$M_{R.SVSA.150} := M_{R.DL} + \sqrt{\left(M_{B.73} + \gamma_{SVSA} M_{B.SVSA} + e_{lb.57.h} \cdot F_{a.SVSA.150}\right)^2 \ldots + \left(M_{C.73} + \gamma_{SVSA} M_{C.SVSA}\right)^2} \ldots + M_{R.DRAG} + M_{R.Ess} = 92.83 \cdot ft \cdot kip$$

Design moment on brace, 150°F temperature case, with SRV-RSSD:

$$M_{R.RSSD.150} := M_{R.DL} + \gamma_{RSSD} M_{R.RSSD} + \sqrt{\left(M_{B.73} + e_{lb.57.h} \cdot F_{a.RSSD.150}\right)^2 + M_{C.73}^{\ 2}} \ldots + M_{R.DRAG} + M_{R.Ess} = 95.67 \cdot ft \cdot kip$$

$$f_{a.57.ir.SVSA.73} := \frac{F_{a.SVSA.150}}{A_{lb}} = 11.91 \cdot ksi$$

Axial stress on brace, Load Combination 7-3, with SRV-SVSA

$$f_{b.57.ir.SVSA.73} := \frac{M_{R.SVSA.150}}{Z_{lb}} = 22.36 \cdot ksi$$

Bending stress on brace, Load Combination 7-3, with SRV-SVSA

$$IC_{57.ir.SVSA.LC73} := \frac{f_{a.57.ir.SVSA.73}}{F_{a.LB}} + \frac{f_{b.57.ir.SVSA.73}}{F_{b.LB}} = 0.66$$

Interaction coefficient for Member 57, Load Combination 7-3, with SRV-SVSA

$$f_{a.57.ir.RSSD.73} := \frac{F_{a.RSSD.150}}{A_{lb}} = 12.24 \cdot ksi$$

Axial stress on brace, Load Combination 7-3, with SRV-RSSD

$$f_{b.57.ir.RSSD.73} := \frac{M_{R.RSSD.150}}{Z_{lb}} = 23.04 \cdot ksi$$

Bending stress on brace, Load Combination 7-3, with SRV-RSSD

$$IC_{57.ir.RSSD.LC73} := \frac{f_{a.57.ir.RSSD.73}}{F_{a.LB}} + \frac{f_{b.57.ir.RSSD.73}}{F_{b.LB}} = 0.68$$

Interaction coefficient for Member 57, Load Combination 7-3, with SRV-RSSD

$$IC_{57.ir.LC73} := \max\left(IC_{57.ir.SVSA.LC73}, IC_{57.ir.RSSD.LC73}\right) = 0.68$$

Maximum interaction coefficient for Member 57, Load Combination 7-3

$$MF_{57.ir.LC73} := \frac{1}{IC_{57.ir.LC73}} = 1.48$$

Margin factor for Member 57, Load Combination 7-3

## *7.1.6 Member 47 / Node 35*

### 7.1.6.1 Determine Current Design Loading

Ref. 3a, Section 4.5 and Ref. 3b, Section 6.2.1 identify Member 47 as a critical lower bracing member for the Inner Ring bracing. Loads on the member are identified below.

$F_{a.DL} := 0kip$ $M_{R.DL} := 0.015ft \cdot kip$ Axial load and moment due to dead load (Ref. 3a, Section 4.5, page 4)

$F_{a.Th.146} := 22.34kip$ $M_{R.Th.146} := 15.87ft \cdot kip$ Axial load and moment due to thermal load, 146°F (Ref. 3a, Section 4.5, page 4)

$F_{a.SVSA} := 26.01kip$ $M_{R.SVSA} := 11.11ft \cdot kip$ Axial load and moment due to SRV-SVSA (Ref. 3a, Section 4.5, page 3)

$F_{a.RSSD} := 32.47kip$ $M_{R.RSSD} := 11.48ft \cdot kip$ Axial load and moment due to SRV-RSSD (Ref. 3a, Section 4.5, page 3)

$F_{a.LOCA} := \max(24.62, 21.320) \cdot kip + 105.39kip = 130.01 \cdot kip$ Axial load due to LOCA (Ref. 3a, Section 4.5, page 4; Ref. 3b, Section 6.2.1, page 3)

Moment load due to LOCA (Ref. 3a, Section 4.5, page 4; Ref. 3b, Section 6.2.1, page 3):

$M_{R.LOCA} := \max(14.56, 3.330) \cdot ft \cdot kip + 48.79ft \cdot kip = 63.35 \cdot ft \cdot kip$

$F_{a.DRAG} := 0kip$ $M_{R.DRAG} := 0.29ft \cdot kip$ Axial load and moment due to bracing drag (SVSA or RSSD + Chugging) (Ref. 3a, Section 4.5, page 4)

$F_{a.Ess} := 0kip$ $M_{R.Ess} := 3.02ft \cdot kip$ Axial load and moment due to seismic (Ref. 3a, Section 4.5, page 4)

Per Design Input #5, Member 47 was installed within tolerance, thus no additional moment needs to be added for the eccentricity.

$e_{lb.47} = 0 \cdot in$ Maximum eccentricity of a CBI brace number equivalent to Member 47 (previously specified)

### 7.1.6.2 Evaluate Load Combination 7-1

$F_{a.Th.212} := IF_{212} \cdot F_{a.Th.146} = 41.78 \cdot kip$

$M_{R.Th.212} := IF_{212} \cdot M_{R.Th.146} = 29.68 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 212°F

Design axial load on brace, Load Combination 7-1:

$F_{a.tot.71} := F_{a.DL} + F_{a.Th.212} + F_{a.RSSD} + F_{a.DRAG} + F_{a.Ess} = 74.25 \cdot kip$

Design moment on brace, Load Combination 7-1:

$M_{R.tot.71} := M_{R.DL} + M_{R.Th.212} + M_{R.RSSD} + M_{R.DRAG} + M_{R.Ess} = 44.48 \cdot ft \cdot kip$

$f_{a.47.ir.71} := \frac{F_{a.tot.71}}{A_{lb}} = 3.67 \cdot ksi$

Axial stress on brace, Load Combination 7-1

$f_{b.47.ir.71} := \frac{M_{R.tot.71}}{Z_{lb}} = 10.71 \cdot ksi$

Bending stress on brace, Load Combination 7-1

$IC_{47.ir.LC71} := \frac{f_{a.47.ir.71}}{F_{a.LB}} + \frac{f_{b.47.ir.71}}{F_{b.LB}} = 0.28$

Interaction coefficient for Member 47, Load Combination 7-1

$MF_{47.ir.LC71} := \frac{1}{IC_{47.ir.LC71}} = 3.63$

Margin factor for Member 47, Load Combination 7-1

### 7.1.6.3 Evaluate Load Combination 7-2

$F_{a.Th.190} := IF_{190} \cdot F_{a.Th.146} = 35.3 \cdot kip$

$M_{R.Th.190} := IF_{190} \cdot M_{R.Th.146} = 25.07 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 190°F

SRV loads are reduced to 40% of the full load per Section 6.1.2.1.

Design axial load on brace, Load Combination 7-2:

$$F_{a.tot.72} := F_{a.DL} + F_{a.Th.190} + \gamma_{SRV.72} F_{a.RSSD} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 178.3 \cdot kip$$

Design moment on brace, Load Combination 7-2:

$$M_{R.tot.72} := M_{R.DL} + M_{R.Th.190} + \gamma_{SRV.72} M_{R.RSSD} + M_{R.LOCA} + M_{R.DRAG} + M_{R.Ess} = 96.34 \cdot ft \cdot kip$$

$f_{a.47.ir.72} := \dfrac{F_{a.tot.72}}{A_{lb}} = 8.81 \cdot ksi$ — Axial stress on brace, Load Combination 7-2

$f_{b.47.ir.72} := \dfrac{M_{R.tot.72}}{Z_{lb}} = 23.2 \cdot ksi$ — Bending stress on brace, Load Combination 7-2

$IC_{47.ir.LC72} := \dfrac{f_{a.47.ir.72}}{F_{a.LB}} + \dfrac{f_{b.47.ir.72}}{F_{b.LB}} = 0.61$ — Interaction coefficient for Member 47, Load Combination 7-2

$MF_{47.ir.LC72} := \dfrac{1}{IC_{47.ir.LC72}} = 1.63$ — Margin factor for Member 47, Load Combination 7-2

### 7.1.6.4 Evaluate Load Combination 7-3

$F_{a.Th.150} := IF_{150} \cdot F_{a.Th.146} = 23.52 \cdot kip$

$M_{R.Th.150} := IF_{150} \cdot M_{R.Th.146} = 16.71 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 150°F

SRV loads are reduced per Section 6.1.2.1.

Design axial load on brace, Load Combination 7-3:

$$F_{a.SVSA.150} := F_{a.DL} + F_{a.Th.150} + \gamma_{SVSA} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 171.73 \cdot kip$$

$$F_{a.RSSD.150} := F_{a.DL} + F_{a.Th.150} + \gamma_{RSSD} F_{a.RSSD} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 179.5 \cdot kip$$

Design moment on brace, 150°F temperature case, with SRV-SVSA:

$$M_{R.SVSA.150} := M_{R.DL} + M_{R.Th.150} + \gamma_{SVSA} M_{R.SVSA} + M_{R.LOCA} + M_{R.DRAG} + M_{R.Ess} = 91.16 \cdot ft \cdot kip$$

Design moment on brace, 150°F temperature case, with SRV-RSSD:

$$M_{R.RSSD.150} := M_{R.DL} + M_{R.Th.150} + \gamma_{RSSD} M_{R.RSSD} + M_{R.LOCA} + M_{R.DRAG} + M_{R.Ess} = 92.56 \cdot ft \cdot kip$$

As shown, RSSD controls.

$$f_{a.47.ir.73} := \frac{F_{a.RSSD.150}}{A_{lb}} = 8.87 \cdot ksi$$

Axial stress on brace, Load Combination 7-3

$$f_{b.47.ir.73} := \frac{M_{R.RSSD.150}}{Z_{lb}} = 22.29 \cdot ksi$$

Bending stress on brace, Load Combination 7-3

$$IC_{47.ir.LC73} := \frac{f_{a.47.ir.73}}{F_{a.LB}} + \frac{f_{b.47.ir.73}}{F_{b.LB}} = 0.60$$

Interaction coefficient for Member 47, Load Combination 7-3

$$MF_{47.ir.LC73} := \frac{1}{IC_{47.ir.LC73}} = 1.68$$

Margin factor for Member 47, Load Combination 7-3

## 7.2 LOWER DOWNCOMER BRACING, OUTER RING

For the 105% power uprate, the thermal load is increased based on the elevated Suppression Pool temperature. All other loads remain the same. Per Ref. 3a, Section 4.5 and Ref. 3c, Section 7.3.2.2, the following members were previously qualified and are re-analyzed herein:

- Member 126 / Node 100
- Member 41 / Node 31
- Member 101 / Node 73
- Member 104 / Node 100
- Member 40 / Node 22
- Member 67 / Node 51

### *7.2.1 Member 126 / Node 100*

#### 7.2.1.1 Determine Current Design Loading

Ref. 3a, Section 4.5 and Ref. 3b, Section 6.2.2 identify Member 126 as a critical lower bracing member for the Outer Ring bracing. Loads on the member are identified below. The loads are taken as the maximum from Ref. 3a, Section 4.5, page 5 or Ref. 3b, Section 6.2.2, page 2. RSSD does not control for SRV loading per Ref. 3a, Section 4.5, page 5.

$F_{a.DL} := 0kip$ $M_{R.DL} := 0.165ft \cdot kip$ Axial load and moment due to dead load

$F_{a.Th.146} := 62.3kip$ $M_{R.Th.146} := 56.95ft \cdot kip$ Axial load and moment due to thermal load, 146°F

$F_{a.SVSA} := 35.92kip$ $M_{R.SVSA} := 7.323ft \cdot kip$ Axial load and moment due to SRV-SVSA

$F_{a.LOCA} := \max(49.81, 45.33) \cdot kip + 35.34kip = 85.15 \cdot kip$ Axial load due to LOCA

$M_{R.LOCA} := \max(13.82, 8.33) \cdot ft \cdot kip + 11.13ft \cdot kip = 24.95 \cdot ft \cdot kip$ Moment due to LOCA

$F_{a.DRAG} := 0kip$ $M_{R.DRAG} := 1.64ft \cdot kip$ Axial load and moment due to bracing drag (SVSA or RSSD + Chugging)

$F_{a.Ess} := 0kip$ $M_{R.Ess} := 2.67ft \cdot kip$ Axial load and moment due to seismic

Per Design Input #5, Member 126 was installed within tolerance, thus no additional moment needs to be added for the eccentricity.

$e_{lb.126o} = 0 \cdot in$ Maximum eccentricity of a CBI brace number equivalent to Member 126 (previously specified)

### 7.2.1.2 Evaluate Load Combination 7-1

$F_{a.Th.212} := IF_{212} \cdot F_{a.Th.146} = 116.5 \cdot kip$

$M_{R.Th.212} := IF_{212} \cdot M_{R.Th.146} = 106.5 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 212°F

Design axial load on brace, Load Combination 7-1:

$F_{a.tot.71} := F_{a.DL} + F_{a.Th.212} + F_{a.SVSA} + F_{a.DRAG} + F_{a.Ess} = 152.42 \cdot kip$

Design moment on brace, Load Combination 7-1:

$M_{R.tot.71} := M_{R.Th.212} + M_{R.SVSA} + M_{R.DL} + M_{R.DRAG} + M_{R.Ess} = 118.29 \cdot ft \cdot kip$

$f_{a.126.or.71} := \frac{F_{a.tot.71}}{A_{lb}} = 7.53 \cdot ksi$ Axial stress on brace, Load Combination 7-1

$f_{b.126.or.71} := \frac{M_{R.tot.71}}{Z_{lb}} = 28.49 \cdot ksi$ Bending stress on brace, Load Combination 7-1

$IC_{126.or.LC71} := \frac{f_{a.126.or.71}}{F_{a.LB}} + \frac{f_{b.126.or.71}}{F_{b.LB}} = 0.69$ Interaction coefficient for Member 126, Load Combination 7-1

$MF_{126.or.LC71} := \frac{1}{IC_{126.or.LC71}} = 1.45$ Margin factor for Member 126, Load Combination 7-1

### 7.2.1.3 Evaluate Load Combination 7-2

$F_{a.Th.190} := IF_{190} \cdot F_{a.Th.146} = 98.43 \cdot kip$

$M_{R.Th.190} := IF_{190} \cdot M_{R.Th.146} = 89.98 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 190°F

SRV loads are reduced to 40% of the full load per Section 6.1.2.1.

Design axial load on brace, Load Combination 7-2:

$$F_{a.tot.72} := F_{a.DL} + F_{a.Th.190} + \gamma_{SRV.72} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 197.95 \cdot kip$$

Design moment on brace, Load Combination 7-2:

$$M_{R.tot.72} := M_{R.Th.190} + \gamma_{SRV.72} M_{R.SVSA} + M_{R.LOCA} + M_{R.DL} + M_{R.DRAG} + M_{R.Ess} = 122.34 \cdot ft \cdot kip$$

$$f_{a.126.or.72} := \frac{F_{a.tot.72}}{A_{lb}} = 9.79 \cdot ksi$$

Axial stress on brace, Load Combination 7-2

$$f_{b.126.or.72} := \frac{M_{R.tot.72}}{Z_{lb}} = 29.46 \cdot ksi$$

Bending stress on brace, Load Combination 7-2

$$IC_{126.or.LC72} := \frac{f_{a.126.or.72}}{F_{a.LB}} + \frac{f_{b.126.or.72}}{F_{b.LB}} = 0.75$$

Interaction coefficient for Member 126, Load Combination 7-2

$$MF_{126.or.LC72} := \frac{1}{IC_{126.or.LC72}} = 1.33$$

Margin factor for Member 126, Load Combination 7-2

### 7.2.1.4 Evaluate Load Combination 7-3

$F_{a.Th.150} := IF_{150} \cdot F_{a.Th.146} = 65.58 \cdot kip$

$M_{R.Th.150} := IF_{150} \cdot M_{R.Th.146} = 59.95 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 150°F

SRV loads are reduced per Section 6.1.2.1.

Design axial load on brace, Load Combination 7-3:

$$F_{a.tot.73} := F_{a.DL} + F_{a.Th.150} + \gamma_{SVSA} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 175.87 \cdot kip$$

Design moment on brace, Load Combination 7-3:

$$M_{R.tot.73} := M_{R.Th.150} + \gamma_{SVSA} M_{R.SVSA} + M_{R.LOCA} + M_{R.DL} + M_{R.DRAG} + M_{R.Ess} = 94.5 \cdot ft \cdot kip$$

$f_{a.126.or.73} := \dfrac{F_{a.tot.73}}{A_{lb}} = 8.69 \cdot ksi$ — Axial stress on brace, Load Combination 7-3

$f_{b.126.or.73} := \dfrac{M_{R.tot.73}}{Z_{lb}} = 22.76 \cdot ksi$ — Bending stress on brace, Load Combination 7-3

$IC_{126.or.LC73} := \dfrac{f_{a.126.or.73}}{F_{a.LB}} + \dfrac{f_{b.126.or.73}}{F_{b.LB}} = 0.60$ — Interaction coefficient for Member 126, Load Combination 7-3

$MF_{126.or.LC73} := \dfrac{1}{IC_{126.or.LC73}} = 1.66$ — Margin factor for Member 126, Load Combination 7-3

## *7.2.2 Member 41 / Node 31*

### 7.2.2.1 Determine Current Design Loading

Ref. 3a, Section 4.5 and Ref. 3b, Section 6.2.2 identify Member 41 as a critical lower bracing member for the Outer Ring bracing. Loads on the member are identified below. The loads are taken as the maximum from Ref. 3a, Section 4.5, page 5 or Ref. 3b, Section 6.2.2, page 3. RSSD does not control for SRV loading per Ref. 3a, Section 4.5, page 5.

$F_{a.DL} := 0kip$ $M_{R.DL} := 0.165ft \cdot kip$ Axial load and moment due to dead load

$F_{a.Th.146} := 39.01kip$ $M_{R.Th.146} := 61.33ft \cdot kip$ Axial load and moment due to thermal load, 146°F

$F_{a.SVSA} := 30.698kip$ $M_{R.SVSA} := 9.907ft \cdot kip$ Axial load and moment due to SRV-SVSA

Note that Ref 3b, Section 6.2.2, page 3 misidentifies the controlling axial force and moment for LOCA lateral chugging. See Ref. 3b, Section 6.2.2, page 1 for the controlling values.

$F_{a.LOCA} := \max(53.26, 54.180) \cdot kip + 28.21kip = 82.39 \cdot kip$ Axial load due to LOCA

$M_{R.LOCA} := \max(14.74, 23.699) \cdot ft \cdot kip + 12.01ft \cdot kip = 35.71 \cdot ft \cdot kip$ Moment due to LOCA

$F_{a.DRAG} := 0kip$ $M_{R.DRAG} := 1.64ft \cdot kip$ Axial load and moment due to bracing drag (SVSA or RSSD + Chugging)

$F_{a.Ess} := 0kip$ $M_{R.Ess} := 2.2ft \cdot kip$ Axial load and moment due to seismic

Per Design Input #5, Member 41 was installed out of tolerance, thus additional moment needs to be added for the eccentricity.

$e_{lb.41} = 0.65\ in$ Maximum eccentricity of a CBI brace number equivalent to Member 41 (previously specified)

### 7.2.2.2 Evaluate Load Combination 7-1

$F_{a.Th.212} := IF_{212} \cdot F_{a.Th.146} = 72.95 \cdot kip$

$M_{R.Th.212} := IF_{212} \cdot M_{R.Th.146} = 114.69 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 212°F

Design axial load on brace, Load Combination 7-1:

$F_{a.tot.71} := F_{a.DL} + F_{a.Th.212} + F_{a.SVSA} + F_{a.DRAG} + F_{a.Ess} = 103.65 \cdot kip$

Design moment on brace, Load Combination 7-1:

$M_{R.tot.71} := M_{R.Th.212} + M_{R.SVSA} + M_{R.DL} + M_{R.DRAG} + M_{R.Ess} = 128.6 \cdot ft \cdot kip$

$f_{a.41.or.71} := \frac{F_{a.tot.71}}{A_{lb}} = 5.12 \cdot ksi$ Axial stress on brace, Load Combination 7-1

$f_{b.41.or.71} := \frac{M_{R.tot.71} + F_{a.tot.71} \cdot e_{lb.41}}{Z_{lb}} = 32.32 \cdot ksi$ Bending stress on brace, Load Combination 7-1

$IC_{41.or.LC71} := \frac{f_{a.41.or.71}}{F_{a.LB}} + \frac{f_{b.41.or.71}}{F_{b.LB}} = 0.72$ Interaction coefficient for Member 41, Load Combination 7-1

$MF_{41.or.LC71} := \frac{1}{IC_{41.or.LC71}} = 1.40$ Margin factor for Member 41, Load Combination 7-1

### 7.2.2.3 Evaluate Load Combination 7-2

$F_{a.Th.190} := IF_{190} \cdot F_{a.Th.146} = 61.64 \cdot kip$

$M_{R.Th.190} := IF_{190} \cdot M_{R.Th.146} = 96.9 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 190°F

SRV loads are reduced to 40% of the full load per Section 6.1.2.1.

Design axial load on brace, Load Combination 7-2:

$$F_{a.tot.72} := F_{a.DL} + F_{a.Th.190} + \gamma_{SRV.72} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 156.31 \cdot kip$$

Design moment on brace, Load Combination 7-2:

$$M_{R.tot.72} := M_{R.Th.190} + \gamma_{SRV.72} M_{R.SVSA} + M_{R.LOCA} + M_{R.DL} + M_{R.DRAG} + M_{R.Ess} = 140.58 \cdot ft \cdot kip$$

$$f_{a.41.or.72} := \frac{F_{a.tot.72}}{A_{lb}} = 7.73 \cdot ksi$$

Axial stress on brace, Load Combination 7-2

$$f_{b.41.or.72} := \frac{M_{R.tot.72} + F_{a.tot.72} \cdot e_{lb.41}}{Z_{lb}} = 35.89 \cdot ksi$$

Bending stress on brace, Load Combination 7-2

$$IC_{41.or.LC72} := \frac{f_{a.41.or.72}}{F_{a.LB}} + \frac{f_{b.41.or.72}}{F_{b.LB}} = 0.83$$

Interaction coefficient for Member 41, Load Combination 7-2

$$MF_{41.or.LC72} := \frac{1}{IC_{41.or.LC72}} = 1.20$$

Margin factor for Member 41, Load Combination 7-2

### 7.2.2.4 Evaluate Load Combination 7-3

$F_{a.Th.150} := IF_{150} \cdot F_{a.Th.146} = 41.06 \cdot kip$

$M_{R.Th.150} := IF_{150} \cdot M_{R.Th.146} = 64.56 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 150°F

SRV loads are reduced per Section 6.1.2.1.

Design axial load on brace, Load Combination 7-3:

$$F_{a.tot.73} := F_{a.DL} + F_{a.Th.150} + \gamma_{SVSA} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 144.94 \cdot kip$$

Design moment on brace, Load Combination 7-3:

$$M_{R.tot.73} := M_{R.Th.150} + \gamma_{SVSA} M_{R.SVSA} + M_{R.LOCA} + M_{R.DL} + M_{R.DRAG} + M_{R.Ess} = 111.21 \cdot ft \cdot kip$$

$f_{a.41.or.73} := \dfrac{F_{a.tot.73}}{A_{lb}} = 7.16 \cdot ksi$ — Axial stress on brace, Load Combination 7-3

$f_{b.41.or.73} := \dfrac{M_{R.tot.73}}{Z_{lb}} = 26.78 \cdot ksi$ — Bending stress on brace, Load Combination 7-3

$IC_{41.or.LC73} := \dfrac{f_{a.41.or.73}}{F_{a.LB}} + \dfrac{f_{b.41.or.73}}{F_{b.LB}} = 0.65$ — Interaction coefficient for Member 41, Load Combination 7-3

$MF_{41.or.LC73} := \dfrac{1}{IC_{41.or.LC73}} = 1.54$ — Margin factor for Member 41, Load Combination 7-3

## *7.2.3 Member 101 / Node 73*

### 7.2.3.1 Determine Current Design Loading

Ref. 3a, Section 4.5 and Ref. 3b, Section 6.2.2 identify Member 101 as a critical lower bracing member for the Outer Ring bracing. Loads on the member are identified below. The loads are taken as the maximum from Ref. 3a, Section 4.5, page 6 or Ref. 3b, Section 6.2.2, page 4. RSSD does not control for SRV loading per Ref. 3a, Section 4.5, page 5.

$F_{a.DL} := 0\text{kip}$ $M_{R.DL} := 0.01\text{ft}\cdot\text{kip}$ Axial load and moment due to dead load

$F_{a.Th.146} := 21.28\text{kip}$ $M_{R.Th.146} := 7.30\text{ft}\cdot\text{kip}$ Axial load and moment due to thermal load, 146°F

$F_{a.SVSA} := 13.49\text{kip}$ $M_{R.SVSA} := 29.20\text{ft}\cdot\text{kip}$ Axial load and moment due to SRV-SVSA

$F_{a.LOCA} := \max(23.18, 30.49)\cdot\text{kip} + 18.87\text{kip} = 49.36\cdot\text{kip}$ Axial load due to LOCA

$M_{R.LOCA} := \max(11.49, 36.46)\cdot\text{ft}\cdot\text{kip} + 29.01\text{ft}\cdot\text{kip} = 65.47\cdot\text{ft}\cdot\text{kip}$ Moment due to LOCA

$F_{a.DRAG} := 0\text{kip}$ $M_{R.DRAG} := 0.15\text{ft}\cdot\text{kip}$ Axial load and moment due to bracing drag (SVSA or RSSD + Chugging)

$F_{a.Ess} := 0\text{kip}$ $M_{R.Ess} := 5.47\text{ft}\cdot\text{kip}$ Axial load and moment due to seismic

Per Design Input #5, Member 101 was not installed out of tolerance, thus no additional moment needs to be added for the eccentricity.

$e_{lb.101} = 0\cdot\text{in}$ Maximum eccentricity of a CBI brace number equivalent to Member 101 (previously specified)

### 7.2.3.2 Evaluate Load Combination 7-1

$F_{a.Th.212} := IF_{212} \cdot F_{a.Th.146} = 39.79 \cdot kip$

$M_{R.Th.212} := IF_{212} \cdot M_{R.Th.146} = 13.65 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 212°F

Design axial load on brace, Load Combination 7-1:

$F_{a.tot.71} := F_{a.DL} + F_{a.Th.212} + F_{a.SVSA} + F_{a.DRAG} + F_{a.Ess} = 53.28 \cdot kip$

Design moment on brace, Load Combination 7-1:

$M_{R.tot.71} := M_{R.DL} + M_{R.Th.212} + M_{R.SVSA} + M_{R.DRAG} + M_{R.Ess} = 48.48 \cdot ft \cdot kip$

$$f_{a.101.or.71} := \frac{F_{a.tot.71}}{A_{lb}} = 2.63 \cdot ksi$$

Axial stress on brace, Load Combination 7-1

$$f_{b.101.or.71} := \frac{M_{R.tot.71}}{Z_{lb}} = 11.68 \cdot ksi$$

Bending stress on brace, Load Combination 7-1

$$IC_{101.or.LC71} := \frac{f_{a.101.or.71}}{F_{a.LB}} + \frac{f_{b.101.or.71}}{F_{b.LB}} = 0.27$$

Interaction coefficient for Member 101, Load Combination 7-1

$$MF_{101.or.LC71} := \frac{1}{IC_{101.or.LC71}} = 3.65$$

Margin factor for Member 101, Load Combination 7-1

### 7.2.3.3 Evaluate Load Combination 7-2

$F_{a.Th.190} := IF_{190} \cdot F_{a.Th.146} = 33.62 \cdot kip$

$M_{R.Th.190} := IF_{190} \cdot M_{R.Th.146} = 11.53 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 190°F

SRV loads are reduced to 40% of the full load per Section 6.1.2.1.

Design axial load on brace, Load Combination 7-2:

$$F_{a.tot.72} := F_{a.DL} + F_{a.Th.190} + \gamma_{SRV.72} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 88.38 \cdot kip$$

Design moment on brace, Load Combination 7-2:

$$M_{R.tot.72} := M_{R.DL} + M_{R.Th.190} + \gamma_{SRV.72} M_{R.SVSA} + M_{R.LOCA} + M_{R.DRAG} + M_{R.Ess} = 94.31 \cdot ft \cdot kip$$

$$f_{a.101.or.72} := \frac{F_{a.tot.72}}{A_{lb}} = 4.37 \cdot ksi$$

Axial stress on brace, Load Combination 7-2

$$f_{b.101.or.72} := \frac{M_{R.tot.72}}{Z_{lb}} = 22.71 \cdot ksi$$

Bending stress on brace, Load Combination 7-2

$$IC_{101.or.LC72} := \frac{f_{a.101.or.72}}{F_{a.LB}} + \frac{f_{b.101.or.72}}{F_{b.LB}} = 0.52$$

Interaction coefficient for Member 101, Load Combination 7-2

$$MF_{101.or.LC72} := \frac{1}{IC_{101.or.LC72}} = 1.93$$

Margin factor for Member 101, Load Combination 7-2

### 7.2.3.4 Evaluate Load Combination 7-3

$F_{a.Th.150} := IF_{150} \cdot F_{a.Th.146} = 22.4 \cdot kip$

$M_{R.Th.150} := IF_{150} \cdot M_{R.Th.146} = 7.68 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 150°F

SRV loads are reduced per Section 6.1.2.1.

Design axial load on brace, Load Combination 7-3:

$$F_{a.tot.73} := F_{a.DL} + F_{a.Th.150} + \gamma_{SVSA} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 81.2 \cdot kip$$

Design moment on brace, Load Combination 7-3:

$$M_{R.tot.73} := M_{R.DL} + M_{R.Th.150} + \gamma_{SVSA} M_{R.SVSA} + M_{R.LOCA} + M_{R.DRAG} + M_{R.Ess} = 99.22 \cdot ft \cdot kip$$

$$f_{a.101.or.73} := \frac{F_{a.tot.73}}{A_{lb}} = 4.01 \cdot ksi$$

Axial stress on brace, Load Combination 7-3

$$f_{b.101.or.73} := \frac{M_{R.tot.73}}{Z_{lb}} = 23.9 \cdot ksi$$

Bending stress on brace, Load Combination 7-3

$$IC_{101.or.LC73} := \frac{f_{a.101.or.73}}{F_{a.LB}} + \frac{f_{b.101.or.73}}{F_{b.LB}} = 0.53$$

Interaction coefficient for Member 101, Load Combination 7-3

$$MF_{101.or.LC73} := \frac{1}{IC_{101.or.LC73}} = 1.87$$

Margin factor for Member 101, Load Combination 7-3

## *7.2.4 Member 104 / Node 100*

### 7.2.4.1 Determine Current Design Loading

Ref. 3a, Section 4.5 and Ref. 3b, Section 6.2.2 identify Member 104 as a critical lower bracing member for the Outer Ring bracing. Loads on the member are identified below. The loads are taken as the maximum from Ref. 3a, Section 4.5, page 5 or Ref. 3b, Section 6.2.2, page 2. RSSD does not control for SRV loading per Ref. 3a, Section 4.5, page 5.

$F_{a.DL} := 0kip$ $M_{R.DL} := 0.127ft \cdot kip$ Axial load and moment due to dead load

$F_{a.Th.146} := 65.5kip$ $M_{R.Th.146} := 6.21ft \cdot kip$ Axial load and moment due to thermal load, 146°F

$F_{a.SVSA} := 24.92kip$ $M_{R.SVSA} := 9.19ft \cdot kip$ Axial load and moment due to SRV-SVSA

$F_{a.LOCA} := \max(40.31, 17.45) \cdot kip + 37.08kip = 77.39 \cdot kip$ Axial load due to LOCA

$M_{R.LOCA} := \max(20.94, 2.29) \cdot ft \cdot kip + 12.18ft \cdot kip = 33.12 \cdot ft \cdot kip$ Moment due to LOCA

$F_{a.DRAG} := 0kip$ $M_{R.DRAG} := 1.27ft \cdot kip$ Axial load and moment due to bracing drag (SVSA or RSSD + Chugging)

$F_{a.Ess} := 0kip$ $M_{R.Ess} := 2.93ft \cdot kip$ Axial load and moment due to seismic

Per Design Input #5, Member 104 was installed within tolerance, thus no additional moment needs to be added for the eccentricity.

$e_{lb.104} = 0$ Maximum eccentricity of a CBI brace number equivalent to Member 104 (previously specified)

### 7.2.4.2 Evaluate Load Combination 7-1

$F_{a.Th.212} := IF_{212} \cdot F_{a.Th.146} = 122.49 \cdot kip$

$M_{R.Th.212} := IF_{212} \cdot M_{R.Th.146} = 11.61 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 212°F

Design axial load on brace, Load Combination 7-1:

$F_{a.tot.71} := F_{a.DL} + F_{a.Th.212} + F_{a.SVSA} + F_{a.DRAG} + F_{a.Ess} = 147.41 \cdot kip$

Design moment on brace, Load Combination 7-1:

$M_{R.tot.71} := M_{R.DL} + M_{R.Th.212} + M_{R.SVSA} + M_{R.DRAG} + M_{R.Ess} = 25.13 \cdot ft \cdot kip$

$f_{a.104.or.71} := \dfrac{F_{a.tot.71}}{A_{lb}} = 7.29 \cdot ksi$ Axial stress on brace, Load Combination 7-1

$f_{b.104.or.71} := \dfrac{M_{R.tot.71}}{Z_{lb}} = 6.05 \cdot ksi$ Bending stress on brace, Load Combination 7-1

$IC_{104.or.LC71} := \dfrac{f_{a.104.or.71}}{F_{a.LB}} + \dfrac{f_{b.104.or.71}}{F_{b.LB}} = 0.26$ Interaction coefficient for Member 104, Load Combination 7-1

$MF_{104.or.LC71} := \dfrac{1}{IC_{104.or.LC71}} = 3.92$ Margin factor for Member 104, Load Combination 7-1

### 7.2.4.3 Evaluate Load Combination 7-2

$F_{a.Th.190} := IF_{190} \cdot F_{a.Th.146} = 103.49 \cdot kip$

$M_{R.Th.190} := IF_{190} \cdot M_{R.Th.146} = 9.81 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 190°F

SRV loads are reduced to 40% of the full load per Section 6.1.2.1.

Design axial load on brace, Load Combination 7-2:

$$F_{a.tot.72} := F_{a.DL} + F_{a.Th.190} + \gamma_{SRV.72} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 190.85 \cdot kip$$

Design moment on brace, Load Combination 7-2:

$$M_{R.tot.72} := M_{R.DL} + M_{R.Th.190} + \gamma_{SRV.72} M_{R.SVSA} + M_{R.LOCA} + M_{R.DRAG} + M_{R.Ess} = 50.93 \cdot ft \cdot kip$$

$$f_{a.104.or.72} := \frac{F_{a.tot.72}}{A_{lb}} = 9.43 \cdot ksi$$

Axial stress on brace, Load Combination 7-2

$$f_{b.104.or.72} := \frac{M_{R.tot.72}}{Z_{lb}} = 12.27 \cdot ksi$$

Bending stress on brace, Load Combination 7-2

$$IC_{104.or.LC72} := \frac{f_{a.104.or.72}}{F_{a.LB}} + \frac{f_{b.104.or.72}}{F_{b.LB}} = 0.42$$

Interaction coefficient for Member 104, Load Combination 7-2

$$MF_{104.or.LC72} := \frac{1}{IC_{104.or.LC72}} = 2.41$$

Margin factor for Member 104, Load Combination 7-2

### 7.2.4.4 Evaluate Load Combination 7-3

$F_{a.Th.150} := IF_{150} \cdot F_{a.Th.146} = 68.95 \cdot kip$

$M_{R.Th.150} := IF_{150} \cdot M_{R.Th.146} = 6.54 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 150°F

SRV loads are reduced per Section 6.1.2.1.

Design axial load on brace, Load Combination 7-3:

$$F_{a.tot.73} := F_{a.DL} + F_{a.Th.150} + \gamma_{SVSA} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 163.78 \cdot kip$$

Design moment on brace, Load Combination 7-3:

$$M_{R.tot.73} := M_{R.DL} + M_{R.Th.150} + \gamma_{SVSA} M_{R.SVSA} + M_{R.LOCA} + M_{R.DRAG} + M_{R.Ess} = 50.42 \cdot ft \cdot kip$$

$$f_{a.104.or.73} := \frac{F_{a.tot.73}}{A_{lb}} = 8.1 \cdot ksi$$

Axial stress on brace, Load Combination 7-3

$$f_{b.104.or.73} := \frac{M_{R.tot.73}}{Z_{lb}} = 12.14 \cdot ksi$$

Bending stress on brace, Load Combination 7-3

$$IC_{104.or.LC73} := \frac{f_{a.104.or.73}}{F_{a.LB}} + \frac{f_{b.104.or.73}}{F_{b.LB}} = 0.39$$

Interaction coefficient for Member 104, Load Combination 7-3

$$MF_{104.or.LC73} := \frac{1}{IC_{104.or.LC73}} = 2.58$$

Margin factor for Member 104, Load Combination 7-3

## *7.2.5 Member 40 / Node 22*

### 7.2.5.1 Determine Current Design Loading

Ref. 3a, Section 4.5 and Ref. 3b, Section 6.2.2 identify Member 40 as a critical lower bracing member for the Outer Ring bracing. Loads on the member are identified below. The loads are taken as the maximum from Ref. 3a, Section 4.5, page 5 or Ref. 3b, Section 6.2.2, page 2. RSSD does not control for SRV loading per Ref. 3a, Section 4.5, page 5.

$F_{a.DL} := 0\text{kip}$  $M_{R.DL} := 0.015\text{ft}\cdot\text{kip}$  Axial load and moment due to dead load

$F_{a.Th.146} := 29.20\text{kip}$  $M_{R.Th.146} := 11.25\text{ft}\cdot\text{kip}$  Axial load and moment due to thermal load, 146°F

$F_{a.SVSA} := 19.47\text{kip}$  $M_{R.SVSA} := 31.20\text{ft}\cdot\text{kip}$  Axial load and moment due to SRV-SVSA

$F_{a.LOCA} := \max(41.14, 23.0)\cdot\text{kip} + 25.00\text{kip} = 66.14\cdot\text{kip}$  Axial load due to LOCA

$M_{R.LOCA} := \max(24.58, 15.66)\cdot\text{ft}\cdot\text{kip} + 28.18\text{ft}\cdot\text{kip} = 52.76\cdot\text{ft}\cdot\text{kip}$  Moment due to LOCA

$F_{a.DRAG} := 0\text{kip}$  $M_{R.DRAG} := 0.15\text{ft}\cdot\text{kip}$  Axial load and moment due to bracing drag (SVSA or RSSD + Chugging)

$F_{a.Ess} := 0\text{kip}$  $M_{R.Ess} := 5.47\text{ft}\cdot\text{kip}$  Axial load and moment due to seismic

Per Design Input #5, Member 40 was installed out of tolerance, thus additional moment needs to be added for the eccentricity.

$e_{lb.40} = 0.25\text{ in}$  Maximum eccentricity of a CBI brace number equivalent to Member 40 (previously specified)

### 7.2.5.2 Evaluate Load Combination 7-1

$F_{a.Th.212} := IF_{212} \cdot F_{a.Th.146} = 54.6 \cdot kip$

$M_{R.Th.212} := IF_{212} \cdot M_{R.Th.146} = 21.04 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 212°F

Design axial load on brace, Load Combination 7-1:

$F_{a.tot.71} := F_{a.DL} + F_{a.Th.212} + F_{a.SVSA} + F_{a.DRAG} + F_{a.Ess} = 74.07 \cdot kip$

Design moment on brace, Load Combination 7-1:

$M_{R.tot.71} := M_{R.DL} + M_{R.Th.212} + M_{R.SVSA} + M_{R.DRAG} + M_{R.Ess} = 57.87 \cdot ft \cdot kip$

$f_{a.40.or.71} := \frac{F_{a.tot.71}}{A_{lb}} = 3.66 \cdot ksi$

Axial stress on brace, Load Combination 7-1

$f_{b.40.or.71} := \frac{M_{R.tot.71} + F_{a.tot.71} \cdot e_{lb.40}}{Z_{lb}} = 14.31 \cdot ksi$

Bending stress on brace, Load Combination 7-1

$IC_{40.or.LC71} := \frac{f_{a.40.or.71}}{F_{a.LB}} + \frac{f_{b.40.or.71}}{F_{b.LB}} = 0.34$

Interaction coefficient for Member 40, Load Combination 7-1

$MF_{40.or.LC71} := \frac{1}{IC_{40.or.LC71}} = 2.91$

Margin factor for Member 40, Load Combination 7-1

### 7.2.5.3 Evaluate Load Combination 7-2

$F_{a.Th.190} := IF_{190} \cdot F_{a.Th.146} = 46.14 \cdot kip$

$M_{R.Th.190} := IF_{190} \cdot M_{R.Th.146} = 17.78 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 190°F

SRV loads are reduced to 40% of the full load per Section 6.1.2.1.

Design axial load on brace, Load Combination 7-2:

$$F_{a.tot.72} := F_{a.DL} + F_{a.Th.190} + \gamma_{SRV.72} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 120.06 \cdot kip$$

Design moment on brace, Load Combination 7-2:

$$M_{R.tot.72} := M_{R.DL} + M_{R.Th.190} + \gamma_{SRV.72} M_{R.SVSA} + M_{R.LOCA} + M_{R.DRAG} + M_{R.Ess} = 88.65 \cdot ft \cdot kip$$

$$f_{a.40.or.72} := \frac{F_{a.tot.72}}{A_{lb}} = 5.93 \cdot ksi$$

Axial stress on brace, Load Combination 7-2

$$f_{b.40.or.72} := \frac{M_{R.tot.72} + F_{a.tot.72} \cdot e_{lb.40}}{Z_{lb}} = 21.95 \cdot ksi$$

Bending stress on brace, Load Combination 7-2

$$IC_{40.or.LC72} := \frac{f_{a.40.or.72}}{F_{a.LB}} + \frac{f_{b.40.or.72}}{F_{b.LB}} = 0.53$$

Interaction coefficient for Member 40, Load Combination 7-2

$$MF_{40.or.LC72} := \frac{1}{IC_{40.or.LC72}} = 1.87$$

Margin factor for Member 40, Load Combination 7-2

### 7.2.5.4 Evaluate Load Combination 7-3

$F_{a.Th.150} := IF_{150} \cdot F_{a.Th.146} = 30.74 \cdot kip$

$M_{R.Th.150} := IF_{150} \cdot M_{R.Th.146} = 11.84 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 150°F

SRV loads are reduced per Section 6.1.2.1.

Design axial load on brace, Load Combination 7-3:

$$F_{a.tot.73} := F_{a.DL} + F_{a.Th.150} + \gamma_{SVSA} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 110.51 \cdot kip$$

Design moment on brace, Load Combination 7-3:

$$M_{R.tot.73} := M_{R.DL} + M_{R.Th.150} + \gamma_{SVSA} M_{R.SVSA} + M_{R.LOCA} + M_{R.DRAG} + M_{R.Ess} = 92.08 \cdot ft \cdot kip$$

$$f_{a.40.or.73} := \frac{F_{a.tot.73}}{A_{lb}} = 5.46 \cdot ksi$$

Axial stress on brace, Load Combination 7-3

$$f_{b.40.or.73} := \frac{M_{R.tot.73}}{Z_{lb}} = 22.17 \cdot ksi$$

Bending stress on brace, Load Combination 7-3

$$IC_{40.or.LC73} := \frac{f_{a.40.or.73}}{F_{a.LB}} + \frac{f_{b.40.or.73}}{F_{b.LB}} = 0.53$$

Interaction coefficient for Member 40, Load Combination 7-3

$$MF_{40.or.LC73} := \frac{1}{IC_{40.or.LC73}} = 1.89$$

Margin factor for Member 40, Load Combination 7-3

## *7.2.6 Member 67 / Node 51*

### 7.2.6.1 Determine Current Design Loading

Ref. 3a, Section 4.5 and Ref. 3b, Section 6.2.2 identify Member 67 as a critical lower bracing member for the Outer Ring bracing. Loads on the member are identified below. The loads are taken as the maximum from Ref. 3a, Section 4.5, page 6 or Ref. 3b, Section 6.2.2, page 4. RSSD does not control for SRV loading per Ref. 3a, Section 4.5, page 5.

$F_{a.DL} := 0\text{kip}$ $\quad M_{R.DL} := 0.38\text{ft}\cdot\text{kip}$ Axial load and moment due to dead load

$F_{a.Th.146} := 27.40\text{kip}$ $\quad M_{R.Th.146} := 28.90\text{ft}\cdot\text{kip}$ Axial load and moment due to thermal load, 146°F

$F_{a.SVSA} := 13.71\text{kip}$ $\quad M_{R.SVSA} := 4.52\text{ft}\cdot\text{kip}$ Axial load and moment due to SRV-SVSA

$F_{a.LOCA} := \max(42.12, 21.28)\cdot\text{kip} + 50.18\text{kip} = 92.3\cdot\text{kip}$ Axial load due to LOCA

$M_{R.LOCA} := \max(6.16, 1.97)\cdot\text{ft}\cdot\text{kip} + 7.64\text{ft}\cdot\text{kip} = 13.8\cdot\text{ft}\cdot\text{kip}$ Moment due to LOCA

$F_{a.DRAG} := 0\text{kip}$ $\quad M_{R.DRAG} := 3.84\text{ft}\cdot\text{kip}$ Axial load and moment due to bracing drag (SVSA or RSSD + Chugging)

$F_{a.Ess} := 0\text{kip}$ $\quad M_{R.Ess} := 1.93\text{ft}\cdot\text{kip}$ Axial load and moment due to seismic

Per Design Input #5, Member 67 was installed out of tolerance, thus additional moment needs to be added for the eccentricity.

$e_{lb.67} = 1.06\,\text{in}$ Maximum eccentricity of a CBI brace number equivalent to Member 67 (previously specified)

### 7.2.6.2 Evaluate Load Combination 7-1

$F_{a.Th.212} := IF_{212} \cdot F_{a.Th.146} = 51.24 \cdot kip$

$M_{R.Th.212} := IF_{212} \cdot M_{R.Th.146} = 54.04 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 212°F

Design axial load on brace, Load Combination 7-1:

$F_{a.tot.71} := F_{a.DL} + F_{a.Th.212} + F_{a.SVSA} + F_{a.DRAG} + F_{a.Ess} = 64.95 \cdot kip$

Design moment on brace, Load Combination 7-1:

$M_{R.tot.71} := M_{R.Th.212} + M_{R.SVSA} + M_{R.DL} + M_{R.DRAG} + M_{R.Ess} = 64.71 \cdot ft \cdot kip$

$$f_{a.67.or.71} := \frac{F_{a.tot.71}}{A_{lb}} = 3.21 \cdot ksi$$

Axial stress on brace, Load Combination 7-1

$$f_{b.67.or.71} := \frac{M_{R.tot.71} + F_{a.tot.71} \cdot e_{lb.67}}{Z_{lb}} = 16.97 \cdot ksi$$

Bending stress on brace, Load Combination 7-1

$$IC_{67.or.LC71} := \frac{f_{a.67.or.71}}{F_{a.LB}} + \frac{f_{b.67.or.71}}{F_{b.LB}} = 0.39$$

Interaction coefficient for Member 67, Load Combination 7-1

$$MF_{67.or.LC71} := \frac{1}{IC_{67.or.LC71}} = 2.59$$

Margin factor for Member 67, Load Combination 7-1

### 7.2.6.3 Evaluate Load Combination 7-2

$F_{a.Th.190} := IF_{190} \cdot F_{a.Th.146} = 43.29 \cdot kip$

$M_{R.Th.190} := IF_{190} \cdot M_{R.Th.146} = 45.66 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 190°F

SRV loads are reduced to 40% of the full load per Section 6.1.2.1.

Design axial load on brace, Load Combination 7-2:

$$F_{a.tot.72} := F_{a.DL} + F_{a.Th.190} + \gamma_{SRV.72} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 141.08 \cdot kip$$

Design moment on brace, Load Combination 7-2:

$$M_{R.tot.72} := M_{R.Th.190} + \gamma_{SRV.72} M_{R.SVSA} + M_{R.LOCA} + M_{R.DL} + M_{R.DRAG} + M_{R.Ess} = 67.42 \cdot ft \cdot kip$$

$$f_{a.67.or.72} := \frac{F_{a.tot.72}}{A_{lb}} = 6.97 \cdot ksi$$

Axial stress on brace, Load Combination 7-2

$$f_{b.67.or.72} := \frac{M_{R.tot.72} + F_{a.tot.72} \cdot e_{lb.67}}{Z_{lb}} = 19.24 \cdot ksi$$

Bending stress on brace, Load Combination 7-2

$$IC_{67.or.LC72} := \frac{f_{a.67.or.72}}{F_{a.LB}} + \frac{f_{b.67.or.72}}{F_{b.LB}} = 0.50$$

Interaction coefficient for Member 67, Load Combination 7-2

$$MF_{67.or.LC72} := \frac{1}{IC_{67.or.LC72}} = 1.99$$

Margin factor for Member 67, Load Combination 7-2

### 7.2.6.4 Evaluate Load Combination 7-3

$F_{a.Th.150} := IF_{150} \cdot F_{a.Th.146} = 28.84 \cdot kip$

$M_{R.Th.150} := IF_{150} \cdot M_{R.Th.146} = 30.42 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 150°F

SRV loads are reduced per Section 6.1.2.1.

Design axial load on brace, Load Combination 7-3:

$$F_{a.tot.73} := F_{a.DL} + F_{a.Th.150} + \gamma_{SVSA} F_{a.SVSA} + F_{a.LOCA} + F_{a.DRAG} + F_{a.Ess} = 130.74 \cdot kip$$

Design moment on brace, Load Combination 7-3:

$$M_{R.tot.73} := M_{R.Th.150} + \gamma_{SVSA} M_{R.SVSA} + M_{R.LOCA} + M_{R.DL} + M_{R.DRAG} + M_{R.Ess} = 53.54 \cdot ft \cdot kip$$

$$f_{a.67.or.73} := \frac{F_{a.tot.73}}{A_{lb}} = 6.46 \cdot ksi$$

Axial stress on brace, Load Combination 7-3

$$f_{b.67.or.73} := \frac{M_{R.tot.73}}{Z_{lb}} = 12.89 \cdot ksi$$

Bending stress on brace, Load Combination 7-3

$$IC_{67.or.LC73} := \frac{f_{a.67.or.73}}{F_{a.LB}} + \frac{f_{b.67.or.73}}{F_{b.LB}} = 0.37$$

Interaction coefficient for Member 67, Load Combination 7-3

$$MF_{67.or.LC73} := \frac{1}{IC_{67.or.LC73}} = 2.70$$

Margin factor for Member 67, Load Combination 7-3

## 7.3 UPPER DOWNCOMER RING BRACING

Existing evaluation of the upper bracing members incorrectly identified that the loads in Calculation 187 (Ref. 3a) govern for LOCA lateral chugging. Review of Calculation 187K (Ref. 3b) shows that the loads in that calculation are governing. Review of the two calculations (Section 4.7 in Calc. 187 and Section 6.4 in Calc. 187K) shows that all loads are the same except for the lateral chugging loads.

### *7.3.1 Determine Current Design Loading*

The latest loads in each of these calculations are summarized below to clearly identify the controlling loads. As determined in Calc. 187 (Ref. 3a) and used in subsequent evaluations in Calc. 187K (Ref. 3b) and L-002547 (Ref. 3c), the LOCA chugging loads bound the other LOCA loads.

The existing evaluations consider a true envelope of the loads for the upper bracing members. In other words, the maximum force/moment of all upper bracing members for each case are considered to act concurrently. This same conservative approach is considered in this evaluation.

All forces and moments due to load cases other than lateral chugging loads:

Axial loads per Section 4.7 of Ref. 3a and Section 6.4 of Ref. 3b:

$F_{A.TH.146} := 32.7kip$ Axial load due to accident thermal (146 °F)

$F_{A.SRV.SVSA} := 7.74kip$ Axial load due to SRV SVSA load load

$F_{A.CHUG.DRAG} := 12.10kip$ Axial load due to chugging drag load

$F_{A.SRV.SPPT} := 60.65kip$ Axial load due to SRV support load

Minor axis bending moments per Section 4.7 of Ref. 3a and Section 6.4 of Ref. 3b:

$M_{B.TH.146} := 7.3kip\cdot ft$ Minor axis bending due to accident thermal (146 °F)

$M_{B.SRV.SVSA} := 5.07kip\cdot ft$ Minor axis bending due to SRV SVSA load

$M_{B.CHUG.DRAG} := 7.14kip\cdot ft$ Minor axis bending due to chugging drag

$M_{B.SEIS} := 2.74kip\cdot ft$ Minor axis bending due to seismic

$M_{B.SRV.SPPT} := 62.46kip\cdot ft$ Minor axis bending due to SRV support load

Major axis bending moments per Section 4.7 of Ref. 3a and Section 6.4 of Ref. 3b:

$M_{C.TH.146} := 70.8 kip \cdot ft$ Major axis bending due to accident thermal (146 °F)

$M_{C.SRV.SVSA} := 38.45 kip \cdot ft$ Major axis bending due to SRV SVSA load

$M_{C.CHUG.DRAG} := 64.21 kip \cdot ft$ Major axis bending due to chugging drag

$M_{C.SEIS} := 2.88 kip \cdot ft$ Major axis bending due to seismic

$M_{C.DEAD} := 0.38 kip \cdot ft$ Major axis bending due to dead load

$M_{C.SNUB} := 97.94 kip \cdot ft$ Major axis bending due to snubber support load

$M_{C.SRV.SPPT} := 99.70 kip \cdot ft$ Major axis bending due to SRV support load

Forces and moments due to lateral chugging loads:

Calculation 187 loads (Section 4.7 of Ref. 3a):

$F_{A.CHUG.LAT.187} := 3.14 kip$ Axial load due to lateral chugging

$M_{B.CHUG.LAT.187} := 3.5 kip \cdot ft$ Minor axis bending due to lateral chugging

$M_{C.CHUG.LAT.187} := 25.0 kip \cdot ft$ Major axis bending due to lateral chugging

Calculation 187K loads (Section 6.4 of Ref. 3b):

$F_{A.CHUG.LAT.187K} := 16.62 kip$ Axial load due to lateral chugging

$M_{B.CHUG.LAT.187K} := 13.265 kip \cdot ft$ Minor axis bending due to lateral chugging

$M_{C.CHUG.LAT.187K} := 55.628 kip \cdot ft$ Major axis bending due to lateral chugging

Governing lateral chugging forces and moments:

$$F_{A.CHUG.LAT} := \max\left(\begin{pmatrix} F_{A.CHUG.LAT.187K} \\ F_{A.CHUG.LAT.187} \end{pmatrix}\right) = 16.62 \cdot kip$$

Governing axial load due to lateral chugging

$$M_{B.CHUG.LAT} := \max\left(\begin{pmatrix} M_{B.CHUG.LAT.187K} \\ M_{B.CHUG.LAT.187} \end{pmatrix}\right) = 13.27 \cdot kip \cdot ft$$

Governing minor axis bending due to lateral chugging

$$M_{C.CHUG.LAT} := \max\left(\begin{pmatrix} M_{C.CHUG.LAT.187K} \\ M_{C.CHUG.LAT.187} \end{pmatrix}\right) = 55.63 \cdot kip \cdot ft$$

Governing major axis bending due to lateral chugging

## *7.3.2 Evaluate Braces*

The upper bracing is evaluated for a 212°F accident temperature. This accident temperature along with no reduction in SRV loading is used to conservatively bound all LOCA cases provided in Table 6.1-1. Per Table 6.1-1, the maximum temperature for the plant conditions in which both LOCA and SRV occur is 190°F. Therefore, considering the 212°F accident temperature simultaneously with both SRV and LOCA loads is conservative. In addition, the 60% reduction in SRV loading at temperatures equal to or greater than 190°F is conservatively not considered to bound the 150°F LOCA cases.

### *212°F Accident Temperature*

Additional load due to thermal increase for 105% power uprate. Only the thermal loads are increased.

$$IF_{212} = 1.87$$

Increase factor on thermal loads for increase to 212°F accident temperature

Design axial load on brace, 212°F temperature case:

$$F_{A.212} := IF_{212} \cdot F_{A.TH.146} \cdots + \left(F_{A.SRV.SVSA} + F_{A.SRV.SPPT}\right) + \left(F_{A.CHUG.DRAG} + F_{A.CHUG.LAT}\right) = 158.26 \cdot kip$$

Design minor axis moment on brace, 212°F temperature case:

$$M_{B.212} := IF_{212} \cdot M_{B.TH.146} + M_{B.SEIS} \cdots + \left(M_{B.SRV.SVSA} + M_{B.SRV.SPPT}\right) + \left(M_{B.CHUG.DRAG} + M_{B.CHUG.LAT}\right) = 104.33 \cdot ft \cdot kip$$

Design major axis moment on brace, 212°F temperature case:

$$M_{C.212} := IF_{212} \cdot M_{C.TH.146} + M_{C.DEAD} + M_{C.SEIS} + M_{C.SNUB} \cdots + \left(M_{C.SRV.SVSA} + M_{C.SRV.SPPT}\right) + \left(M_{C.CHUG.DRAG} + M_{C.CHUG.LAT}\right) = 491.58 \cdot ft \cdot kip$$

$$f_{A.212} := \frac{F_{A.212}}{A_{t.ub}} = 4.42 \cdot ksi$$

Axial stress on brace, 212°F temperature case

$$f_{B.212} := \frac{M_{B.212}}{S_{y.ub}} = 23.79 \cdot ksi$$

Minor axis bending stress on brace, 212°F temperature case

$$f_{C.212} := \frac{M_{C.212}}{S_{x.ub}} = 20.03 \cdot ksi$$

Major axis bending stress on brace, 212°F temperature case

$$IC_{UB.212} := \frac{f_{A.212}}{F_{a.UB}} + \frac{f_{B.212}}{F_{b.UB}} + \frac{f_{C.212}}{F_{b.UB}} = 0.92$$

Interaction coefficient for Upper Bracing, 212°F temperature case

$$MF_{UB.212} := \frac{1}{IC_{UB.212}} = 1.08$$

Margin factor for Upper Bracing, 212°F temperature case

## 7.4 LOWER DOWNCOMER BRACING GUSSET PLATE SECTION

Consistent with Calc. L-002547 (Ref. 3c), it is considered that the critical members determined in Calc. 187 (Ref. 3a) and in Calc. 187K (Ref. 3b), remain bounding when thermal loads are increased.

Calc. 187K determined that different members controlled when the revised lateral chugging loads are considered. Review of the loads for the inner and outer ring critical gusset plate evaluations in Calc. 187 Section 2.8.2 (Ref. 3a) and Calc. 187K Section 6.3 (Ref. 3b) shows that the loads for the inner ring gusset plate evaluation in Calc. 187K are governing (Member 145 / Node 108). In addition, the inner ring loads from Calc. 187K have larger thermal moments which will be more greatly affected by the 105% power uprate.

Therefore, the gusset plate evaluation considers the loading from the inner ring evaluation (Member 145 / Node 108) in Calc. 187K Section 6.3 (Ref. 3b).

### *7.4.1 Determine Current Design Loading*

Axial forces and moments for inner ring (Member 145 / Node 108) per Calc. 187K (Section 6.3 of Ref. 3b) unless otherwise noted:

$F_{A.Th.146.gp} := 21.84 \cdot kip$ Axial load due to thermal

$M_{Th.146.gp} := \begin{pmatrix} -13610 \\ 24931 \end{pmatrix} ft \cdot lbf$ $\begin{pmatrix} \text{"Node 112"} \\ \text{"Node 108"} \end{pmatrix}$ Moment at each end of member due to thermal load, 146°F (Ref. 3e, PIPSYS Run 374PCG, Section D, page 1-13)

$F_{A.chug.lat.gp} := 61.14 \cdot kip$ Axial load due to lateral chugging

$M_{chug.lat.gp} := 21.36 \cdot kip \cdot ft$ Moment due to lateral chugging

$F_{A.chug.drag.gp} := 13.69 \cdot kip$ Axial load due to chugging drag

$M_{chug.drag.gp} := 17.58 \cdot kip \cdot ft$ Moment due to chugging drag

$F_{A.RSSD.gp} := 10.05 \cdot kip$ Axial load due to SRV-RSSD

$M_{RSSD.gp} := 9.24 \cdot kip \cdot ft$ Moment due to SRV-RSSD

$F_{A.SVSA.gp} := 8.98 \cdot kip$ Axial load due to SRV-SVSA

$M_{SVSA.gp} := 3.69 \cdot kip \cdot ft$ Moment due to SRV-SVSA

By inspection RSSD loads control over SVSA loads.

$F_{A.RSSD.DRAG.gp} := 2.85 \cdot kip$ Axial load due to SRV-RSSD drag

$M_{RSSD.DRAG.gp} := 2.66 \cdot kip \cdot ft$ Moment due to SRV-RSSD drag

The controlling inner ring loads per Calc. 187K (Ref. 3b) are evaluated using the same three (3) load combinations considered for the lower bracing members as outlined in Section 6.1.2.1.

Due to the shape of the cross section, the horizontal ($M_B$) or vertical ($M_C$) moments will result in the largest stress at the extreme fibers, not the resultant of the two. The section has the same bending capacity in each direction, so the governing moment between the horizontal and vertical directions is considered. Review of Section 6.3 of Calc. 187K (Ref. 3b) shows that the governing moment for Member 145 corresponds to the total vertical moment ($M_C$). The horizontal moments ($M_B$) are substantially smaller. Review of the as-built eccentricities in Section 3.4 of Calc. 187 (Ref. 3a) shows that all CBI brace members represented by PIPSYS model member 145 only have horizontal as-built eccentricities. The largest of which is 0.82 inches. Therefore, the as-built eccentricities corresponding to member 145 will not increase the critical vertical moment on the gusset section. The horizontal eccentricity will not result in the horizontal moment governing based on comparison of the horizontal and vertical moments.

The thermal moment for the brace can be reduced by considering the actual length of the member since the PIPSYS analysis output is given at the working points of the analytical members (not the actual member ends) and the thermal moment gradient along the length of the member is known.

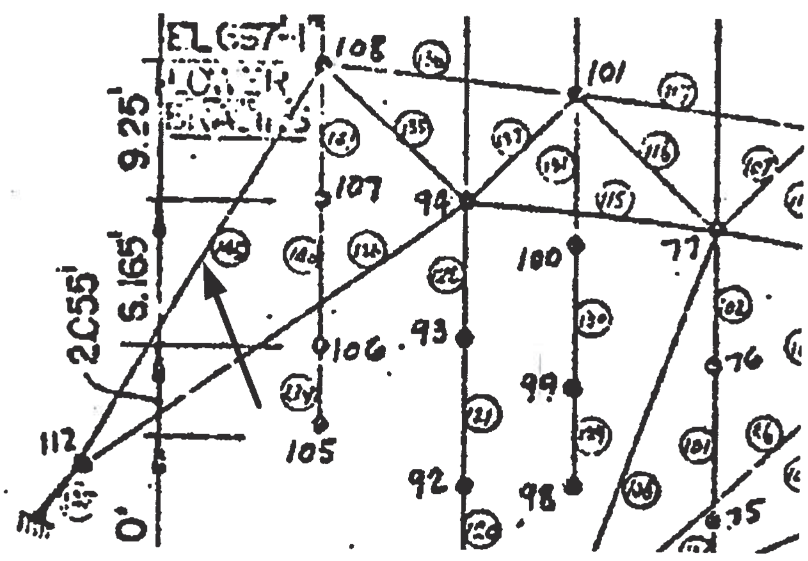


**Figure 7.4.1-1:** Member 145 Location in PIPSYS Model (Ref. 3a, Section 2.1, page 2)

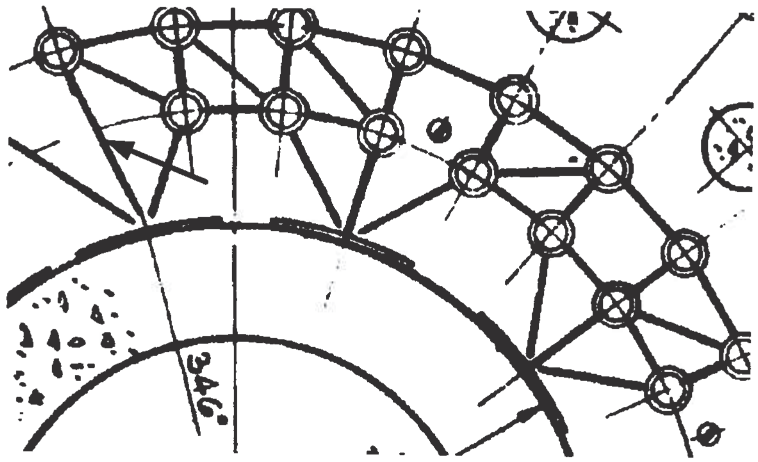



**Figure 7.4.1-2:** Member 145 Location in Installed Configuration (Ref. 2a)

The node-to-node length of this member is determined based on the measurements in Ref. 2a.

$r_1 := 14ft + 11.5in$ $\quad r_2 := (19ft + 9in) + (3ft + 6in) = 23.25 \cdot ft$ Radius to downcomer or pedestal

X- and Y-coordinates of the downcomer/wall embed to which Member 67 attaches:

$$x_{DC} := \begin{pmatrix} -r_1 \cdot \cos(346deg - 270deg) \\ -r_2 \cdot \cos(342deg - 270deg) \end{pmatrix} = \begin{pmatrix} -3.62 \\ -7.18 \end{pmatrix} \cdot ft \qquad y_{DC} := \begin{pmatrix} r_1 \cdot \sin(346deg - 270deg) \\ r_2 \cdot \sin(342deg - 270deg) \end{pmatrix} = \begin{pmatrix} 14.51 \\ 22.11 \end{pmatrix} \cdot ft$$

$$L_{nn} := \sqrt{\left(x_{DC_2} - x_{DC_1}\right)^2 + \left(y_{DC_2} - y_{DC_1}\right)^2} = 8.39 \cdot ft$$ Node-to-node length of Member 67

$$L_{crit} := L_{nn} - \frac{24in}{2} = 7.39 \cdot ft$$ Length to critical section of Member 67, at outer face of downcomer

Calculate seismic SSE moment in brace:

Note that the existing gusset evaluations do not consider dead load or seismic load as they are deemed to be insignificant. Review of all other brace evaluations shows the dead loads are extremely small and will be negligible. However, because there is very little margin in the members, the small but not negligible seismic moments could impact the evaluation and should be included. The seismic moment is calculated following the methodology presented in Section 2.4 of Calc. 187 (Ref. 3a) and used in Section 2.5 of Calc. 187. Per Section 2.4 of Calc. 187, the $M_c$ seismic moment for the inner ring is larger and therefore considered here. This approach distributes a portion of the total seismic moment to the brace based on the stiffness of the brace relative to that of the downcomer. Note that this approach uses the full section (no reduction for corrosion) which is acceptable since the full section is considered for the downcomer, as well.

$M_{c.seis} := 8.071\,kip\cdot ft$ Controlling inner ring seismic SSE moment per Section 2.4 of Calc. 187 (Ref. 3a)

$I_{brace} := 162\,in^4$ Moment of inertia for full brace section per Section 2.4 of Calc. 187 (Ref. 3a)

$I_{down} := 2004.3\,in^4$ Moment of inertia for full downcomer section per Section 2.4 of Calc. 187 (Ref. 3a)

$L_{down} := 23.92\,ft$ Length of downcomer considered in distribution of seismic moment per Section 2.4 of Calc. 187 (Ref. 3a)

$$M_{SEIS.gp} := M_{c.seis}\cdot\left(\frac{I_{brace}}{L_{nn}}\right)\left(\frac{I_{brace}}{L_{nn}} + \frac{I_{down}}{L_{down}}\right)^{-1} = 1.51\cdot kip\cdot ft$$

Seismic in brace gusset plate

Since the thermal moment gradient is known, pro-rate to find the thermal moment components at the face of the downcomer.

$$M_{Th.146.gp} := \left|\text{linterp}\left[\begin{pmatrix}0\\L_{nn}\end{pmatrix}, M_{Th.146.gp}, L_{crit}\right]\right| = 20.34\cdot ft\cdot kip$$

Moment due to thermal load at 146°F, linearly pro-rated to determine moment at face of downcomer

### 7.4.2 Evaluate Load Combination 7-1

$F_{A.Th.212.gp} := IF_{212} \cdot (F_{A.Th.146.gp}) = 40.84 \cdot kip$

$M_{Th.212.gp} := IF_{212} \cdot (M_{Th.146.gp}) = 38.03 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 212°F

Design axial load on gusset section, Load Combination 7-1:

$F_{a.tot.gp.71} := F_{A.Th.212.gp} + F_{A.RSSD.gp} + F_{A.RSSD.DRAG.gp} = 53.74 \cdot kip$

Design moment on gusset section, Load Combination 7-1:

$M_{R.tot.gp.71} := M_{RSSD.DRAG.gp} + M_{SEIS.gp} + M_{Th.212.gp} + M_{RSSD.gp} = 51.45 \cdot ft \cdot kip$

$$IC_{gp.71} := \frac{\frac{F_{a.tot.gp.71}}{A_{gp}} + \frac{M_{R.tot.gp.71}}{Z_{gp}}}{F_{ba.gp}} = 0.45$$

Interaction coefficient for normal stress in gusset plate

$$MF_{gp.71} := \frac{1}{IC_{gp.71}} = 2.21$$

Margin factor for normal stress in gusset plate

### 7.4.3 Evaluate Load Combination 7-2

$$F_{A.Th.190.gp} := IF_{190} \cdot \left(F_{A.Th.146.gp}\right) = 34.51 \cdot kip$$

Axial load and moment due to thermal load, prorated for 190°F

$$M_{Th.190.gp} := IF_{190} \cdot \left(M_{Th.146.gp}\right) = 32.14 \cdot ft \cdot kip$$

SRV loads are reduced to 40% of the full load per Section 6.1.2.1.

Design axial load on gusset section, Load Combination 7-2:

$$F_{a.tot.gp.72} := F_{A.Th.190.gp} + \gamma_{SRV.72} \cdot F_{A.RSSD.gp} + F_{A.chug.lat.gp} \cdots + F_{A.chug.drag.gp} + F_{A.RSSD.DRAG.gp} = 116.21 \cdot kip$$

Design moment on gusset section, Load Combination 7-2:

$$M_{tot.gp.72} := M_{RSSD.DRAG.gp} + M_{SEIS.gp} + M_{Th.190.gp} \cdots + \left(\gamma_{SRV.72} \cdot M_{RSSD.gp} \cdots + M_{chug.lat.gp} + M_{chug.drag.gp}\right) = 78.94 \cdot ft \cdot kip$$

$$IC_{gp.72} := \frac{\dfrac{F_{a.tot.gp.72}}{A_{gp}} + \dfrac{M_{tot.gp.72}}{Z_{gp}}}{F_{ba.gp}} = 0.73$$

Interaction coefficient for normal stress in gusset plate

$$MF_{gp.72} := \frac{1}{IC_{gp.72}} = 1.37$$

Margin factor for normal stress in gusset plate

### 7.4.4 Evaluate Load Combination 7-3

$F_{A.Th.150.gp} := IF_{150} \cdot (F_{A.Th.146.gp}) = 22.99 \cdot kip$

$M_{Th.150.gp} := IF_{150} \cdot (M_{Th.146.gp}) = 21.41 \cdot ft \cdot kip$

Axial load and moment due to thermal load, prorated for 150°F

SRV RSSD loads are reduced by 20% per Section 6.1.2.1.

Design axial load on gusset section, Load Combination 7-3:

$$F_{a.tot.gp.73} := F_{A.Th.150.gp} + \gamma_{RSSD} \cdot F_{A.RSSD.gp} + F_{A.chug.lat.gp} \cdots + F_{A.chug.drag.gp} + F_{A.RSSD.DRAG.gp} = 108.71 \cdot kip$$

Design moment on gusset section, Load Combination 7-3:

$$M_{R.tot.gp.73} := M_{RSSD.DRAG.gp} + M_{SEIS.gp} + M_{Th.150.gp} \cdots + \left(\gamma_{RSSD} \cdot M_{RSSD.gp} \cdots + M_{chug.lat.gp} + M_{chug.drag.gp}\right) = 71.91 \cdot ft \cdot kip$$

$$IC_{gp.73} := \frac{\dfrac{F_{a.tot.gp.73}}{A_{gp}} + \dfrac{M_{R.tot.gp.73}}{Z_{gp}}}{F_{ba.gp}} = 0.67$$

Interaction coefficient for normal stress in gusset plate

$$MF_{gp.73} := \frac{1}{IC_{gp.73}} = 1.50$$

Margin factor for normal stress in gusset plate

# 8.0 RESULTS & CONCLUSIONS

## 8.1 RESULTS

Results are tabulated in the sections that follow.

### 8.1.1 Lower Downcomer Bracing, Inner Ring

$$IC := \begin{pmatrix} IC_{126.ir.LC71} \\ IC_{126.ir.LC72} \\ IC_{126.ir.LC73} \\ IC_{75.ir.LC71} \\ IC_{75.ir.LC72} \\ IC_{75.ir.LC73} \\ IC_{86.ir.LC71} \\ IC_{86.ir.LC72} \\ IC_{86.ir.LC73} \\ IC_{7.ir.LC71} \\ IC_{7.ir.LC72} \\ IC_{7.ir.LC73} \\ IC_{57.ir.LC71} \\ IC_{57.ir.LC72} \\ IC_{57.ir.LC73} \\ IC_{47.ir.LC71} \\ IC_{47.ir.LC72} \\ IC_{47.ir.LC73} \end{pmatrix} = \begin{pmatrix} 0.80 \\ 0.97 \\ 0.81 \\ 0.70 \\ 0.90 \\ 0.80 \\ 0.80 \\ 0.99 \\ 0.73 \\ 0.20 \\ 0.42 \\ 0.46 \\ 0.37 \\ 0.66 \\ 0.68 \\ 0.28 \\ 0.61 \\ 0.60 \end{pmatrix}$$

$$MF := \begin{pmatrix} MF_{126.ir.LC71} \\ MF_{126.ir.LC72} \\ MF_{126.ir.LC73} \\ MF_{75.ir.LC71} \\ MF_{75.ir.LC72} \\ MF_{75.ir.LC73} \\ MF_{86.ir.LC71} \\ MF_{86.ir.LC72} \\ MF_{86.ir.LC73} \\ MF_{7.ir.LC71} \\ MF_{7.ir.LC72} \\ MF_{7.ir.LC73} \\ MF_{57.ir.LC71} \\ MF_{57.ir.LC72} \\ MF_{57.ir.LC73} \\ MF_{47.ir.LC71} \\ MF_{47.ir.LC72} \\ MF_{47.ir.LC73} \end{pmatrix} = \begin{pmatrix} 1.25 \\ 1.03 \\ 1.24 \\ 1.43 \\ 1.11 \\ 1.25 \\ 1.26 \\ 1.01 \\ 1.38 \\ 5.09 \\ 2.36 \\ 2.19 \\ 2.70 \\ 1.51 \\ 1.48 \\ 3.63 \\ 1.63 \\ 1.68 \end{pmatrix}$$

| Table 8.1.1-1: Summary of Results for Lower Downcomer Bracing, Inner Ring | | |
|---|---|---|
| Member/Node and Load Combination | Interaction Coefficient | Margin Factor |
| 126/94, LC 7-1 (212°F Temperature, SBO) | 0.80 | 1.25 |
| 126/94, LC 7-2 (190°F Temperature, IBA) | 0.97 | 1.03 |
| 126/94, LC 7-3 (150°F Temperature, IBA/SBA) | 0.81 | 1.24 |
| 75/49, LC 7-1 (212°F Temperature, SBO) | 0.70 | 1.43 |
| 75/49, LC 7-2 (190°F Temperature, IBA) | 0.90 | 1.11 |
| 75/49, LC 7-3 (150°F Temperature, IBA/SBA) | 0.80 | 1.25 |
| 86/63, LC 7-1 (212°F Temperature, SBO) | 0.80 | 1.26 |
| 86/63, LC 7-2 (190°F Temperature, IBA) | 0.99 | 1.01 |
| 86/63, LC 7-3 (150°F Temperature, IBA/SBA) | 0.73 | 1.38 |
| 7/11, LC 7-1 (212°F Temperature, SBO) | 0.20 | 5.09 |
| 7/11, LC 7-2 (190°F Temperature, IBA) | 0.42 | 2.36 |
| 7/11, LC 7-3 (150°F Temperature, IBA/SBA) | 0.46 | 2.19 |
| 57/49, LC 7-1 (212°F Temperature, SBO) | 0.37 | 2.70 |
| 57/49, LC 7-2 (190°F Temperature, IBA) | 0.66 | 1.51 |
| 57/49, LC 7-3 (150°F Temperature, IBA/SBA) | 0.68 | 1.48 |
| 47/35, LC 7-1 (212°F Temperature, SBO) | 0.28 | 3.63 |
| 47/35, LC 7-2 (190°F Temperature, IBA) | 0.61 | 1.63 |
| 47/35, LC 7-3 (150°F Temperature, IBA/SBA) | 0.60 | 1.68 |

### 8.1.2 Lower Downcomer Bracing, Outer Ring

$$IC := \begin{pmatrix} IC_{126.or.LC71} \\ IC_{126.or.LC72} \\ IC_{126.or.LC73} \\ IC_{41.or.LC71} \\ IC_{41.or.LC72} \\ IC_{41.or.LC73} \\ IC_{101.or.LC71} \\ IC_{101.or.LC72} \\ IC_{101.or.LC73} \\ IC_{104.or.LC71} \\ IC_{104.or.LC72} \\ IC_{104.or.LC73} \\ IC_{40.or.LC71} \\ IC_{40.or.LC72} \\ IC_{40.or.LC73} \\ IC_{67.or.LC71} \\ IC_{67.or.LC72} \\ IC_{67.or.LC73} \end{pmatrix} = \begin{pmatrix} 0.69 \\ 0.75 \\ 0.60 \\ 0.72 \\ 0.83 \\ 0.65 \\ 0.27 \\ 0.52 \\ 0.53 \\ 0.26 \\ 0.42 \\ 0.39 \\ 0.34 \\ 0.53 \\ 0.53 \\ 0.39 \\ 0.50 \\ 0.37 \end{pmatrix}$$

$$MF := \begin{pmatrix} MF_{126.or.LC71} \\ MF_{126.or.LC72} \\ MF_{126.or.LC73} \\ MF_{41.or.LC71} \\ MF_{41.or.LC72} \\ MF_{41.or.LC73} \\ MF_{101.or.LC71} \\ MF_{101.or.LC72} \\ MF_{101.or.LC73} \\ MF_{104.or.LC71} \\ MF_{104.or.LC72} \\ MF_{104.or.LC73} \\ MF_{40.or.LC71} \\ MF_{40.or.LC72} \\ MF_{40.or.LC73} \\ MF_{67.or.LC71} \\ MF_{67.or.LC72} \\ MF_{67.or.LC73} \end{pmatrix} = \begin{pmatrix} 1.45 \\ 1.33 \\ 1.66 \\ 1.40 \\ 1.20 \\ 1.54 \\ 3.65 \\ 1.93 \\ 1.87 \\ 3.92 \\ 2.41 \\ 2.58 \\ 2.91 \\ 1.87 \\ 1.89 \\ 2.59 \\ 1.99 \\ 2.70 \end{pmatrix}$$

**Table 8.1.2-1: Summary of Results for Lower Downcomer Bracing, Outer Ring**

| Member/Node and Load Combination | Interaction Coefficient | Margin Factor |
|---|---|---|
| 126/100, LC 7-1 (212°F Temperature, SBO) | 0.69 | 1.45 |
| 126/100, LC 7-2 (190°F Temperature, IBA) | 0.75 | 1.33 |
| 126/100, LC 7-3 (150°F Temperature, IBA/SBA) | 0.60 | 1.66 |
| 41/31, LC 7-1 (212°F Temperature, SBO) | 0.72 | 1.40 |
| 41/31, LC 7-2 (190°F Temperature, IBA) | 0.83 | 1.20 |
| 41/31, LC 7-3 (150°F Temperature, IBA/SBA) | 0.65 | 1.54 |
| 101/73, LC 7-1 (212°F Temperature, SBO) | 0.27 | 3.65 |
| 101/73, LC 7-2 (190°F Temperature, IBA) | 0.52 | 1.93 |
| 101/73, LC 7-3 (150°F Temperature, IBA/SBA) | 0.53 | 1.87 |
| 104/100, LC 7-1 (212°F Temperature, SBO) | 0.26 | 3.92 |
| 104/100, LC 7-2 (190°F Temperature, IBA) | 0.42 | 2.41 |
| 104/100, LC 7-3 (150°F Temperature, IBA/SBA) | 0.39 | 2.58 |
| 40/22, LC 7-1 (212°F Temperature, SBO) | 0.34 | 2.91 |
| 40/22, LC 7-2 (190°F Temperature, IBA) | 0.53 | 1.87 |
| 40/22, LC 7-3 (150°F Temperature, IBA/SBA) | 0.53 | 1.89 |
| 67/51, LC 7-1 (212°F Temperature, SBO) | 0.39 | 2.59 |
| 67/51, LC 7-2 (190°F Temperature, IBA) | 0.50 | 1.99 |
| 67/51, LC 7-3 (150°F Temperature, IBA/SBA) | 0.37 | 2.70 |

### *8.1.3 Upper Downcomer Bracing*

$IC_{UB.212} = 0.92$ $MF_{UB.212} = 1.08$ IC and margin factor for Upper Bracing, LC 7-1, IBA case, conservatively using 212°F temperature instead of 190°F

### *8.1.4 Lower Downcomer Bracing Gusset Plate Section*

$IC_{gp.71} = 0.45$ $MF_{gp.71} = 2.21$ IC and margin factor for Lower Bracing Gusset Plate Section, LC 7-1, SBO case with 212°F accident temperature

$IC_{gp.72} = 0.73$ $MF_{gp.72} = 1.37$ IC and margin factor for Lower Bracing Gusset Plate Section, LC 7-2, IBA case with 190°F accident temperature

$IC_{gp.73} = 0.67$ $MF_{gp.73} = 1.50$ IC and margin factor for Lower Bracing Gusset Plate Section, LC 7-3, IBA/SBA case with 150°F accident temperature

## 8.2 CONCLUSIONS

The purpose of this minor revision is to provide a bounding evaluation for the upper and lower downcomer brace members and lower downcomer brace gusset plate section used at some connections to the downcomers. The refined analysis considering the correct bounding loads and using the elastic section modulus determined the stresses exceed the DB allowables for the lower downcomer braces and the gusset plate section. Therefore, a LAR is prepared via Licensing Action LI-21-0215 to allow for the use of plastic section modulus for these. The upper downcomer bracing members are evaluated using elastic section properties, consistent with the current licensing basis.

As shown herein, the critical downcomer brace members and the gusset plate section are acceptable for the design loading.