January 11, 2019

Docket No. 52-048

U.S. Nuclear Regulatory Commission
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Rockville, MD 20852-2738

SUBJECT: NuScale Power, LLC Supplemental Response to NRC Request for Additional Information No. 131 (eRAI No. 8970) on the NuScale Design Certification Application

REFERENCES:
1. U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 131 (eRAI No. 8970)," dated August 05, 2017
2. NuScale Power, LLC Response to NRC "Request for Additional Information No. 131 (eRAI No.8970)," dated January 31, 2018

The purpose of this letter is to provide the NuScale Power, LLC (NuScale) supplemental response to the referenced NRC Request for Additional Information (RAI).

The Enclosure to this letter contains NuScale's supplemental response to the following RAI Question from NRC eRAI No. 8970:

- 03.08.04-10

This letter and the enclosed response make no new regulatory commitments and no revisions to any existing regulatory commitments.

If you have any questions on this response, please contact Marty Bryan at 541-452-7172 or at mbryan@nuscalepower.com.

Sincerely,

Zackary W. Rad
Director, Regulatory Affairs
NuScale Power, LLC

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Enclosure 1: NuScale Supplemental Response to NRC Request for Additional Information eRAI No. 8970

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NUSCALE
Power for all humankind

Response to Request for Additional Information
Docket No. 52-048

eRAI No.: 8970
Date of RAI Issue: 08/05/2017

NRC Question No.: 03.08.04-10

10 CFR 50, Appendix A, GDC 1, 2, and 4, provide requirements to be met by SSC important to safety. In accordance with these requirements, DSRS Section 3.8.4 provides review guidance pertaining to the design of seismic Category I structures, other than the containment.

DSRS Section 3.8.4 references AISC N690-1994 including Supplement 2 (2004) as being acceptable to the staff for establishing the load and load combinations, design and analysis procedures, and structural acceptance criteria, for seismic Category I Steel Structures. FSAR Sections 3.8.4.2.1, 3.8.4.3, and 3.8.4.5, indicate the use of AISC N690-2012 for the design of seismic Category I structures. Provide specific reasons for using AISC N690-2012 in place of AISC N690-1994 including Supplement 2 (2004).

NuScale Response:

<u>Question</u>

The NRC provided supplemental questions to eRAI 8970 Question 03.08.04-10 as follows:

In its response the applicant described the use of ANSI/AISC N690-12 for determining the design loads for the NPM steel supports.

The applicant also stated the strength increase factors from ANSI/AISC N690-12 and the additional codes used in the analysis and design of such NPM steel supports.

The staff notes that the response focuses on the determination of loads for the NPM supports, however it lacks details with respect to the determination of the strength of the NPM supports.

Further, based on the RAI response and FSAR information (including updated information provided in response to RAI 8975, Question 3.8.4-71) the staff was not able to confirm the D/C ratio for the bolts connecting the passive support ring to the embedded bearing plate at the bottom of the NPM support.

Therefore the staff request the applicant to clarify which provisions and or information (e.g. material properties) from N690-12 and additional codes referenced in the response were used in the determination of the strength of the NPM steel supports.

Also, The NRC Staff commented on the use of ANSI/ASCE 8 for stainless steel members, assemblies and connections as per N690-12 during a public meeting on May 29, 2018.

Response

Service history of existing structures, development of research in statistics, probabilistic methods, and structural reliability have progressively led to newer codes. Code development is a transparent and rigorous process that includes a balance of all relevant stakeholders, including government, citizens/public interests, and building industry representatives, without undue influence from any one particular stakeholder. NuScale utilizes, when applicable, the latest engineering design codes, standards, and specifications for design. This is considered good engineering practice, since using the latest revisions of codes and standards takes advantage of the latest test data and analysis of materials and design procedures to create a more predictable and cost-effective solution.

ANSI/AISC N690-12 is used in the design of two safety-related, Seismic Category (SC) I NuScale Power Module (NPM) steel supports. The NPM is supported at the bottom and at the lug locations (located approximately halfway up the NPM). The bottom skirt support comprises four passive plates that resist horizontal loads from the NPM produced by the safe shutdown earthquake (SSE). The lug supports are also passive supports designed to resist the horizontal loads from the NPM produced by the SSE. The reactor flange tool (RFT) assembly embed plate is also an SC-I structure. Its design is currently being revised, yet the fundamental principles detailed in this response are also applicable.

The NPM passive support plates serve the function of restraining the horizontal movement of the NPM at the basemat/embed plate interface during an SSE event. FSAR markups attached to this response provide the new design details. The NPM lug supports are steel brackets constructed from steel plate welded to embed plates on the operating bay and pool walls. The embed plates on both sides of the bay walls are anchored together with through bolts. Steel brackets on both sides of the NPM shear lugs restrain seismic movement in the East-West and North-South directions approximately 45’ above the basemat.

In the sections below, justification is provided for the use of the AISC N690-2012 code in lieu of the 1994 revision. These sections provide reasons that the designs of the structures mentioned above are equally robust if either ANSI/AISC N690-1994 or 2012 codes are used, in spite of subtle differences between the two codes. In general, any subsequent revision to a code is substantiated by new knowledge, with which the revisions are reviewed and approved by code committees, industry experts, and academia.

NPM Lug Support Bracket Design

Lug support bracket design is primarily based on ACI 349-06 and only the shear strength of shear lugs is based on AISC N690.

The governing load combination for the design of NPM supports at basemat and shear lug elevations using ANSI/AISC N690-12 is NB2-15.

ANSI/AISC N690-12 (NB2-15) $D + L + C + R_o + T_o + E_s$

The equivalent load combination in ANSI/AISC N690-1994 is load combination 8, Table Q1.5.7.1.

ANSI/AISC N690-1994 (8) $D + L + R_o + T_o + E_{ss}$

It is apparent that load combination NB2-15 envelops/is equivalent to load combination 8. On the capacity side, for load combination 8 (ANSI/AISC N690-1994), the allowable stress limits are increased by a factor 1.6, but the stress limit coefficient in shear shall not exceed 1.4 in members and bolts (Note g in Table Q1.5.7.1). For load combination NB2-15 (ANSI/AISC N690-2012), the allowable stress limits are increased by a factor 1.6. However, this increase shall be limited to 1.5 for members or fasteners in axial tension or shear (Note 8 in Section NB2 6d).

A quick summary of the codes and sections used for design of the lug support brackets is given below:

- SAP2000 model developed and analyzed to obtain design forces and moments

- Shear lugs' yield and ultimate strength given by ASTM A572 Grade 50
- Through bolt material is ASTM A193 Grade B7
- Bumper plate material is Stainless Steel Type 630 - H1150
- Through bolt checks performed IAW ACI 349-06, Appendix D
- Through bolts and shear lug capacity from ACI-349, RD.11
    - Through bolt tension D/C ratio: 0.51
    - Shear lug moment D/C ratio: 0.61
    - Shear lug shear D/C ratio: 0.19
    - Maximum stress from bumper base plate D/C ratio: 0.11
- Moment capacity and shear capacity IAW AISC 360-10 with enhancement factor for seismic load from AISC N690, NB2 6.3
- Punching shear check IAW ACI 349-06, Section 11.12.2.1
    - Punching shear in NPM support D/C ratio: 0.26
    - Punching shear in pool wall D/C ratio: 0.20
    - Concrete bearing stress D/C ratio: 0.40

NPM Skirt Support Design

The NPM passive support plates are designed to restrain horizontal NPM movement during a seismic event. The four passive support plates are attached to the embed plate using threaded bolts/pins of 3 ½" diameter. The bolts/pins transfer the shear reaction forces of the NPM from the passive support plates to the embed plate that is anchored to the basemat through #18 reinforcing bars welded to the embed plate. A guide plate assembly is welded to each passive plate to help position the NPM in place. The bolts/pins are designed using ANSI/AISC-N690-2012, while the embed plate anchorage design is based on ACI 349-06. Embed plate, passive plates, and guide plates are made of ASTM A240 Type S32205 with a yield strength of 65 ksi and ultimate strength of 91.7 ksi at a design temperature of 300 degrees Fahrenheit. The bolts and pins are made of ASTM A564, Type 17400 with heat treatment condition of H1150 and a yield and tensile strength of 105 and 135 ksi, respectively, at 300 degrees Fahrenheit. #18 bars used for embed plate anchorage are ASTM A706 Grade 60.

The shear bolts/pins are designed for shear/tension using Table J3.2 in the ANSI/AISC 2010 Specification for Structural Steel Buildings. The nominal shear strength in bearing-type connections, $F_{nv,}$ is taken as $0.450F_u$, with a factor of safety Ω=2.00. For load combination NB2-15 (ANSI/AISC-N690-2012), Section 6d (8) permits the allowable strength to be increased by 1.5 for members or fasteners in axial tension or shear, therefore,

$$\frac{R_n}{\Omega} = \frac{1.5 \times R_n}{2} = 0.75R_n$$ (The increase factor was used only for bolts and anchorage welds.)

The design/capacity ratios were calculated for different failure modes and are summarized below:

- The bolts/pins meet the design requirements for shear with a D/C ratio of 0.63
- The passive plates meet the design requirements for block shear with a D/C ratio of 0.47
- The passive plate meets the design requirement for bearing with a D/C ratio of 0.33
- The embed plate anchorage meets the shear strength design requirements with a D/C ratio of 0.66
- The embed plate bearing strength against concrete meets the bearing strength design requirements with D/C ratio of 0.68.

A thorough comparison of the code editions are presented for the case of allowable shear stress on fasteners, as it is one of the critical failure modes for these supports.

ANSI/AISC N690-1994 Table Q1.5.2.1 and ANSI/AISC-1989 Table J3.2 show that the allowable shear stress on fasteners in bearing-type connections, when threads are not excluded from shear planes, is 0.17 F_u. The 0.17 factor for allowable shear stress (F_v) is obtained by using the following factors, F_v = 0.625 x 0.8 x 0.8/2.35 = 0.17F_u. The factor 0.17 accounts for: the effect of a shear/tension ratio of 0.625, a reduction due to the effect of the reduced area of the threaded portion of the fastener when the threads are not excluded from the shear plane of 0.80, a reduction factor of 0.8 when the length of the connection is less than 50 in., and a safety factor of 2.35 used for the allowable shear. Based on the above factors, the nominal shear strength is equal to: F_{nv} = 0.625 x 0.80 x 0.80 x F_u = 0.4F_u.

ANSI/AISC N690-2012 uses the ANSI/AISC 2010 Specification for Structural Steel Buildings. The nominal shear strength in bearing-type connection, F_{nv}, in Table J3.2, when threads are not excluded from shear planes is 0.450F_u. The factor 0.45 accounts for: the effect of a shear/tension ratio of 0.625, a reduction due to the effect of the reduced area of the threaded portion of the fastener when the threads are not excluded from the shear plane of 0.80, and an initial reduction factor of 0.90 imposed on connections with lengths up to and including 38 in.

This specification does not limit the length, but requires that the initial 0.90 factor be replaced by 0.75 when determining bolt shear strength for connections longer than 38 in by multiplying the tabulated values by 0.75/0.9 = 0.833. A summary of the above discussion is shown in Table 1 below.

Table 1: Summary of Nominal and Allowable Shear Strength.

Thread Location Connection Length	ANSI/AISC N690-1994 Nominal and Allowable Shear Strength F_{nv}	ANSI/AISC N690-2012 Nominal and Allowable Shear Strength F_{nv}
Threads in shear plane Connection length ≤ 38”	0.625 x 0.8 x 0.80 x F_u = 0.4 F_u Allowable = $\frac{0.4F_u}{2.35}=0.17F_u$	0.625 x 0.8 x 0.90 x F_u = 0.4 F_u Allowable = $\frac{0.45F_u}{2.0}=0.225F_u$
Threads in shear plane Connection length >38” & ≤ 50”	0.625 x 0.8 x 0.80 x F_u = 0.4 F_u Allowable = $\frac{0.4F_u}{2.35}=0.17F_u$	0.625 x 0.8 x 0.90 x0.833 x F_u = 0.375 F_u Allowable = $\frac{0.375F_u}{2.0}=0.1875F_u$

In consideration of the ANSI/AISC N690-2012 update for fasteners, a final report was submitted to the Research Council on Structural Connections in 2008 titled “Evaluation of the Current Resistance Factors for High-Strength Bolts”. In it, the authors based their conclusions on 1553 bolts tested, and provided the following design recommendation: “Based on a reliability index of 4.0 and a live-to-dead load ratio of 3.0, it is recommended to have a resistance factor equal to 0.90 for tension and to 0.85 for shear (both with the threads excluded and not excluded from the shear plane)”. A resistance factor of 0.85 for shear in LRFD with live-to-dead load ratio of 3.0 corresponds to an ASD safety factor of 1.5/0.85 = 1.765. Based on the significant amount of test data and the ASD safety factors in ANSI/AISC-2005 and ANSI/AISC-2010, the use of a safety factor of 2.35 in ANSI/AISC N690-1994 does not imply that the structure is more robust and that a design using the most recent code is somehow less conservative. The use of the ASD safety factor of 2.0 and the LRFD resistance factor of 0.75 for shear in recent codes (2005, 2010), whether the threads are included or excluded from the shear planes, will not affect the structural integrity of the structure.

Further, even without the recent advances in material testing and structural reliability, the commentary on the RCSC Specification, 1985 edition, states that it was shown that the factor of safety against shear failure ranged from 3.3 for short joints to approximately 2.0 for joints with an overall length in excess of 50 inches. It is noted with interest to report that the longest (and often the most important) joints had the lowest factor, indicating that a factor of safety of 2.0 has proven satisfactory in service.

The codes are continuously being updated based on acquired new knowledge. For example, within AISC, the allowable shear strength in bolt limit state (ASD), $\frac{F_{nv}}{\Omega}$, has had the following changes (Table 2):

Table 2: Allowable Shear Strength

ASD 1989		ASD 2005		ASD 2010	
A325N	21 ksi	A325N	24 ksi	A325N	27 ksi
A325X	30 ksi	A325X	30 ksi	A325X	34 ksi
A490N	28 ksi	A490N	30 ksi	A490N	34 ksi
A490X	40 ksi	A490X	37.5 ksi	A490X	42 ksi

Similarly, the ASD safety factor of 2.35 for the allowable shear and the LRFD resistance factor of 0.65 or 0.75, depending on the position of the shear plane relative to the bolt threads, in ANSI/AISC-1989 were changed in ANSI/AISC-2005 and ANSI/AISC-2010 to an ASD factor of safety of 2.0 and LRFD resistance factor of 0.75, regardless of the location of shear plane relative to the threads. Those changes were implemented based on knowledge acquired through testing.

While a design using ANSI/AISC N690-2012 may seemingly be less conservative, as safety factors decreased with time, it is a robust design, and just as robust as a design based on ANSI/AISC N690-94.

As to the use of ASCE 8-02 for the design of SC-I structures, the scope of ASCE-8 specifically states that it is limited to structural members shaped from sheet, strip, plate, or flat bar stainless steel. However, according to ANSI/AISC N690-2012, ASCE 8 only applies to the material subset, sheets. Current NuScale SC-I structural designs do not include the use of sheet metal.

Impact on DCA:

FSAR Tier 2, Appendix 3B.2.7.3 and Figures 3B-48 through 3B-50 have been revised as described in the response above and as shown in the markup provided in this response.

The base of the NPM is located at the bottom of the RXB pool at EL. 25'-0". There are up to 12 NPMs located in the RXB pool in their respective bays. The pool floor liner in the NPM bay is made of half-inch thick stainless steel whereas the wall liner is made of quarter-inch stainless steel.

RAI 03.07.02-20

The NPM is vertically supported for the dead load and seismic loads acting downwards at the base, but free to move up vertically for any uplifting forces (such as seismic load acting upwards and buoyant forces due to the water in the reactor pool). The NPM is also laterally restrained against seismic forces at the base.

RAI 03.07.02-20

The details of the NPM base support are shown in Figure 3B-48 through Figure 3B-50. The NPM base support includes the following:

RAI 03.07.02-20, RAI 03.08.04-10S1, RAI 03.08.04-31

- The skirt of the NPM is supported on a donut-shaped, 5 3/4 in. thick embed plate. The embed plate extends beyond the donut shape at four quadrants to support 4 passive plates. In each quadrant, the embed plate has two 8 in. openings to accommodate concrete placement and consolidation. The central opening and the additional 8 openings are to be sealed by welding a stainless steel cover plate after concrete placement. The embed plate is made of stainless steel and is anchored to the basemat concrete using steel reinforcing bars.~~14.5 ft square, 4 in. thick bearing plate embedded in the basemat. This plate is made of austenitic stainless steel that is anchored to the concrete base mat through 36 concrete anchors welded to the bottom of the plate. The liner plate is discontinuous in the area around the NPM. A leaktight boundary is ensured by a seal weld between the liner plate and the embedded plate. Figure 3B-50 shows the details of the 4 in. thick bearing plate.~~ Figure 3B-48, Figure 3B-49 and Figure 3B-50 show the details of the NPM embed plate. The NPM is free to move upward vertically, and the vertical downward NPM load is transferred to the concrete basemat in bearing.

RAI 03.07.02-20, RAI 03.08.04-10S1, RAI 03.08.04-31

- The NPM is laterally restrained by four 4 1/2 in. thick stainless steel passive support plates. Each passive support plate is attached to the embed plate using two groups of six bolt/pin sets at both ends. Each set of bolts/pins is designed for the full seismic load. The passive plates transfer the seismic loads to the embed plate through the two groups of bolts/pins mainly by shear. The guide plate assembly, as shown in Figure 3B-48 is welded to the passive plate. The function of the guide plate assembly is to guide NPM installation to design position. Figure 3B-48 shows the details of passive plates and the guide plate assembly.~~an 8-in.-thick passive support ring made of stainless steel bolted to the underlying bearing plate. At the inside periphery of the passive ring, a beveled edge at the top is provided in order to guide the NPM at initial placement and during its removal and replacement for refueling operation.~~ If the NPM impacts the passive support ~~ring~~plates, the resulting upward vertical and horizontal loads will be resisted by the ~~concrete~~ anchors in tension and shear and concrete in edge bearing. Figure 3B-48 and Figure 3B-49 show the details of the passive support ring.

RAI 03.07.02-10, RAI 03.08.04-31

NuScale Power Module Model:

RAI 03.07.02-10S1

A SASSI building model with a detailed NPM beam model, described in Section 3.7.2, is used to perform dynamic analyses on the RXB and extract results at the NPM to RXB interface locations. The RXB analysis produces local acceleration time histories that are used as input to the NPM seismic analysis discussed in Appendix 3A.

RAI 03.07.02-10S1, RAI 03.08.04-10S1

A separate ANSYS model is used to perform a non-linear dynamic analysis of the NPM. This model only includes the pool water and one NPM (1 or 6). The analysis results are based on the envelope of the six runs shown in Table 3B-53. The static reaction force, including the dead weight and the static buoyancy, is ~~1,090.4~~1,250 kips in the vertical direction. The maximum uplift displacement, due to seismic, of the module from the floor is less than 0.125 inch. The enveloping reaction forces between the ANSYS and SASSI models are provided in Table 3B-28 and used for the design basis in the following subsections.

Envelope Loads:

RAI 03.07.02-10, RAI 03.07.02-20, RAI 03.08.04-10S1, RAI 03.08.04-31

- Vertical downward load, P = ~~3,859~~3,242 kips. This load includes dead load, fluid pressure load, and seismic load. Dead load is the static buoyancy load described above and is equal to ~~1,090.4~~1,250 kips. The fluid pressure load is determined by the product of the ~~baseplate~~NPM skirt ring area (~~14.5' x 14.5'~~4,310 in^2), the fluid density (62.4 pcf), and the normal operating reactor pool depth (69') and is equal to ~~905.3~~129 kips. The enveloping downward seismic load is 1,863 kips.

RAI 03.07.02-20, RAI 03.08.04-10S1

- The vertical displacement is less than 0.125 inch. The passive support ~~ring~~plate is 4.5 inches thick ~~below the bevel~~, therefore, there will always be lateral support from the passive support ring.

RAI 03.07.02-10, RAI 03.07.02-20

- Lateral load:
  - East-West seismic load = 1,144 kips
  - North-South seismic load = 1,103 kips
  - Square Root Sum of Squares horizontal seismic load =

$$\sqrt{(1{,}144^2 + 1{,}103^2)} = 1{,}589 \text{ kips}$$

RAI 03.08.04-10S1

Accounting for 5% load increase for accidental torsion, the SRSS horizontal seismic load is 1669 kips.

RAI 03.07.02-20

It is possible for the support ring and anchors to experience an upward vertical force if the NPM were to strike the support ring during a seismic event. Because this force is of extremely short duration and the contact surface small, only a limited amount of force is transferred to the support ring. A coefficient of friction value between wet steel and steel of 0.2 is multiplied by the square root sum of squares of east-west and north-south seismic loads to determine this force.

RAI 03.07.02-10, RAI 03.07.02-20, RAI 03.08.04-10S1

$$f_{uplift} = 0.2 \times 1{,}669 \text{ kips} = 333.8 \text{ kips}$$

Materials and Material Strength:

- Stainless Steel: The stainless steel used for the liner plate conforms to ASTM A-167 or ASTM A-240 Type 304L and has a 0.2 percent offset yield strength of 25 ksi, and ultimate tensile strength 70 ksi.

RAI 03.07.02-10, RAI 03.07.02-20, RAI 03.08.04-10S1

- ~~Austenitic~~Duplex Stainless: The steel used for the 5 3/4-in.-thick bearing plate that supports the NPMs vertically is ASTM A240~~965~~ Type S32205~~Grade F304~~ with a yield strength of ~~22.4~~65 ksi and ultimate tensile strength of ~~61.8~~91.7 ksi at a design temperature of 300 degrees Fahrenheit.
- Concrete for Basemat: The concrete strength, f'_c is 5000 psi

RAI 03.07.02-20, RAI 03.08.04-10S1

~~A total of 36, 3/4 in. diameter, ASTM F1554, Grade 55 concrete anchors are used to anchor the passive support ring and embedded plate assembly. These anchors have a yield strength of 55 ksi and designations of S1 (weldable) and S4 (Charpy test).~~A total of 88 #18 ASTM A706 Grade 60 steel reinforcing bars are used to anchor the embed plate in the four quadrants. The number of anchors in each quadrant (22) is designed for NPM loads.

RAI 03.07.02-20, RAI 03.08.04-10S1

~~A total of 30, 1.5 in. thread diameter, ASTM A479, Type UNS S21800 bolts fasten the passive support ring to the embedded plate.~~A total of 16 threaded bolts and 32 pins made of material ASTM A564, Type 17400 with heat treatment condition of H1150, with yield strength of 105 ksi and tensile strength at 300 degrees Fahrenheit of 135 ksi, are used to attach the four passive plates to the embed plate.

Load Path:

RAI 03.07.02-20, RAI 03.08.04-10S1

- The vertical load is resisted by the 5 3/4 in. thick donut-shape embed plate supporting the 4 1/2 NPM skirt ring.~~14.5 ft square, 4 in. thick bearing ring plate.~~

RAI 03.07.02-20, RAI 03.08.04-10S1

- The lateral load is resisted by bolts/pins that connect the passive ~~support ring~~plate to the embed~~ded~~ bearing plate. The bolts/pins transfer the lateral load to the ~~bearing~~embed plate, which, in turn, transfers the load, via bearing, to the concrete basemat.

Evaluation:

Vertical Load Bearing Capacity

RAI 03.07.02-10, RAI 03.07.02-20, RAI 03.08.04-10S1, RAI 03.08.04-31

- Area of concrete in bearing, A_{brg}, is 4310 in^2, therefore the bearing pressure (P_V/ A_{brg}) is 0.75~~90~~ ksi
- Allowable bearing pressure = (Φ)(0.85f'c) = 2.76 ksi [Φ = 0.65]

RAI 03.07.02-10, RAI 03.07.02-20, RAI 03.08.04-10S1, RAI 03.08.04-31

- Vertical bearing D/C Ratio: = 0.27~~33~~

RAI 03.07.02-10, RAI 03.07.02-20, RAI 03.08.04-10S1

- The ~~maximum~~ D/C ratio of the anchor bars shear strength is equal to 0.66~~bolts is due to concrete breakout in tension and is equal to 0.74~~.

Lateral Load Resistance

RAI 03.07.02-10, RAI 03.07.02-20, RAI 03.08.04-10S1

- SRSS Lateral Load is ~~1,589~~1,669 kips

RAI 03.07.02-10, RAI 03.07.02-20, RAI 03.08.04-10S1

- The D/C ratio of the bolts/pins in shear and tension is 0.75~~92~~.

RAI 03.07.02-10, RAI 03.07.02-20, RAI 03.08.04-10S1, RAI 03.08.04-31

- The ~~maximum~~ D/C ratio for concrete edge bearing due to lateral load transferred from the bearing plate is 0.68~~83~~.

3B.2.7.4 Nuscale Power Module Lug Restraint

The NPM lug restraint design consists of a stainless steel bumper comprised of 2" thick plates with 2" thick stiffener plates. The bumpers are welded to 2" thick stainless steel liner plates. On the inside of the liner plate there are 3" thick, 5" wide (48" depth) steel shear lugs to transfer the lateral shear loads into the wall. Finally, the two bumpers on either side of the lug on the pool walls are bolted together with through-bolts to withstand tensile loads due to moments from the eccentric lateral shear loads. The design layout for the support system for the NPM lug restraints is shown in Figure 3B-51.

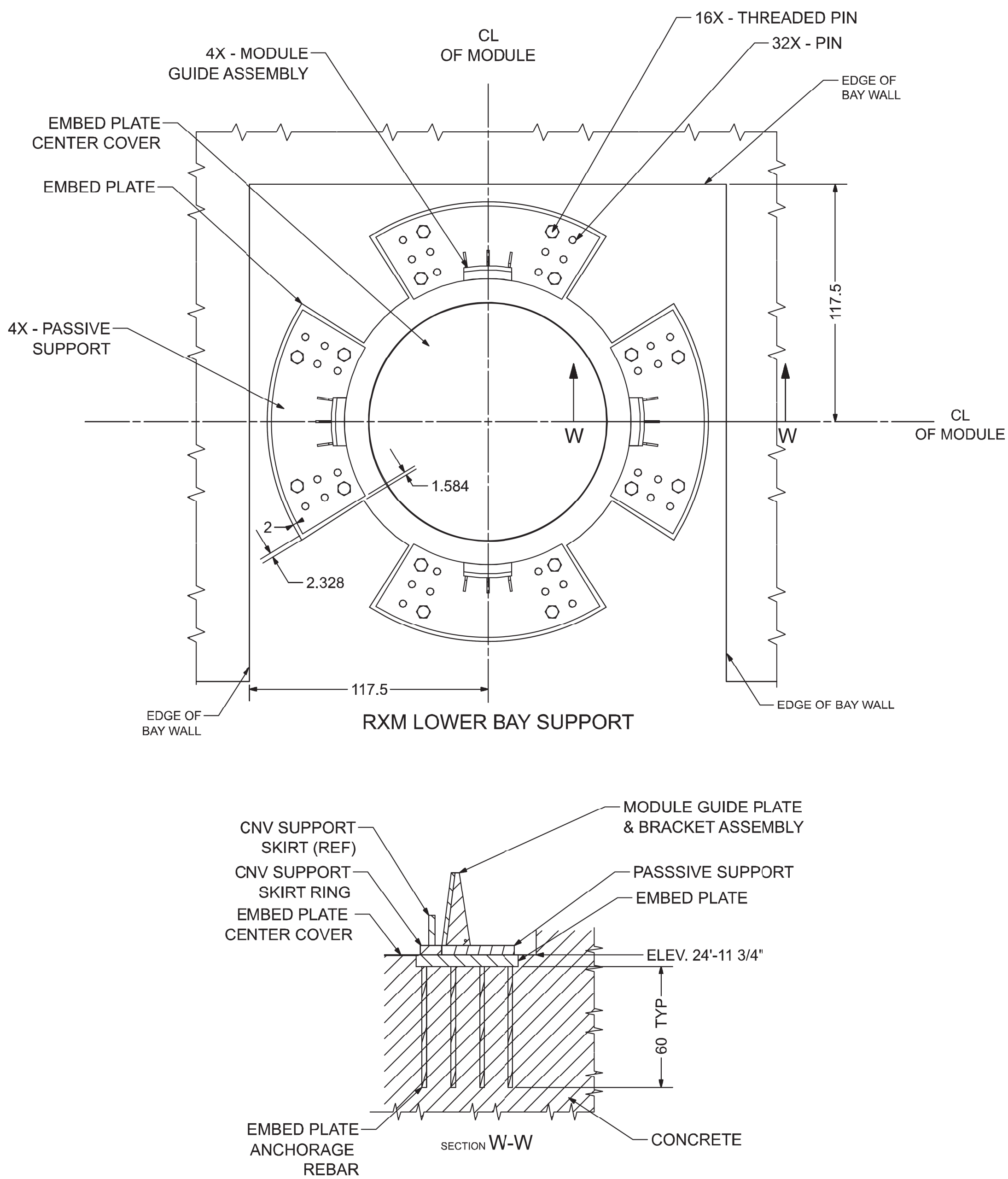
The bumpers are Stainless Steel Type 630 - H1150, with a yield strength of 100.8 ksi, and an ultimate strength of 135 ksi. The shear lugs are carbon steel ASTM A572 GR 50, with a yield strength of 50 ksi, and an ultimate strength of 65 ksi. The through-bolts are ASTM A193 GR B7, with a yield strength of 105 ksi, and an ultimate strength of 125 ksi.

RAI 03.08.04-21S2

A separate SAP2000 model is created for the local analysis of the RXB lug support system. This lug restraint model is a comprehensive, finite-element model of half of a single NPM wing wall. Therefore, 2.5' of the wall thickness, with two lugs on one face of the wall, are included in the model. The load is distributed as point loads to one of the lugs. The wing wall is modeled with solid elements. The liner plate, the stainless steel lug, and the bumper built-up section are modeled with shell

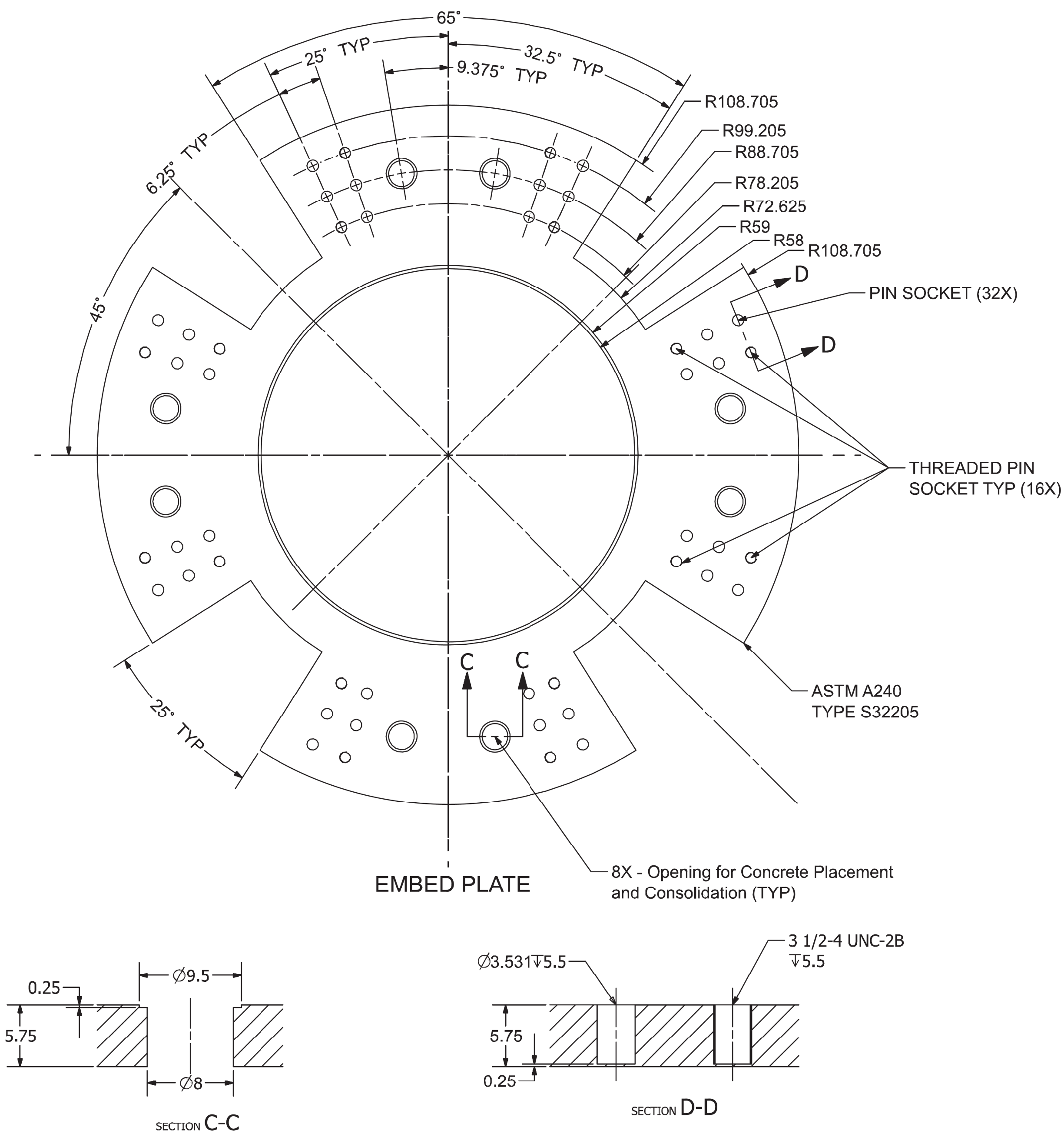
RAI 03.07.02-20, RAI 03.07.02-20S1, RAI 03.08.04-10S1

Figure 3B-48: ~~Elevation View of the NPM~~NuScale Power Module Base Support Assembly at Reactor Building~~RXB~~ Pool Floor



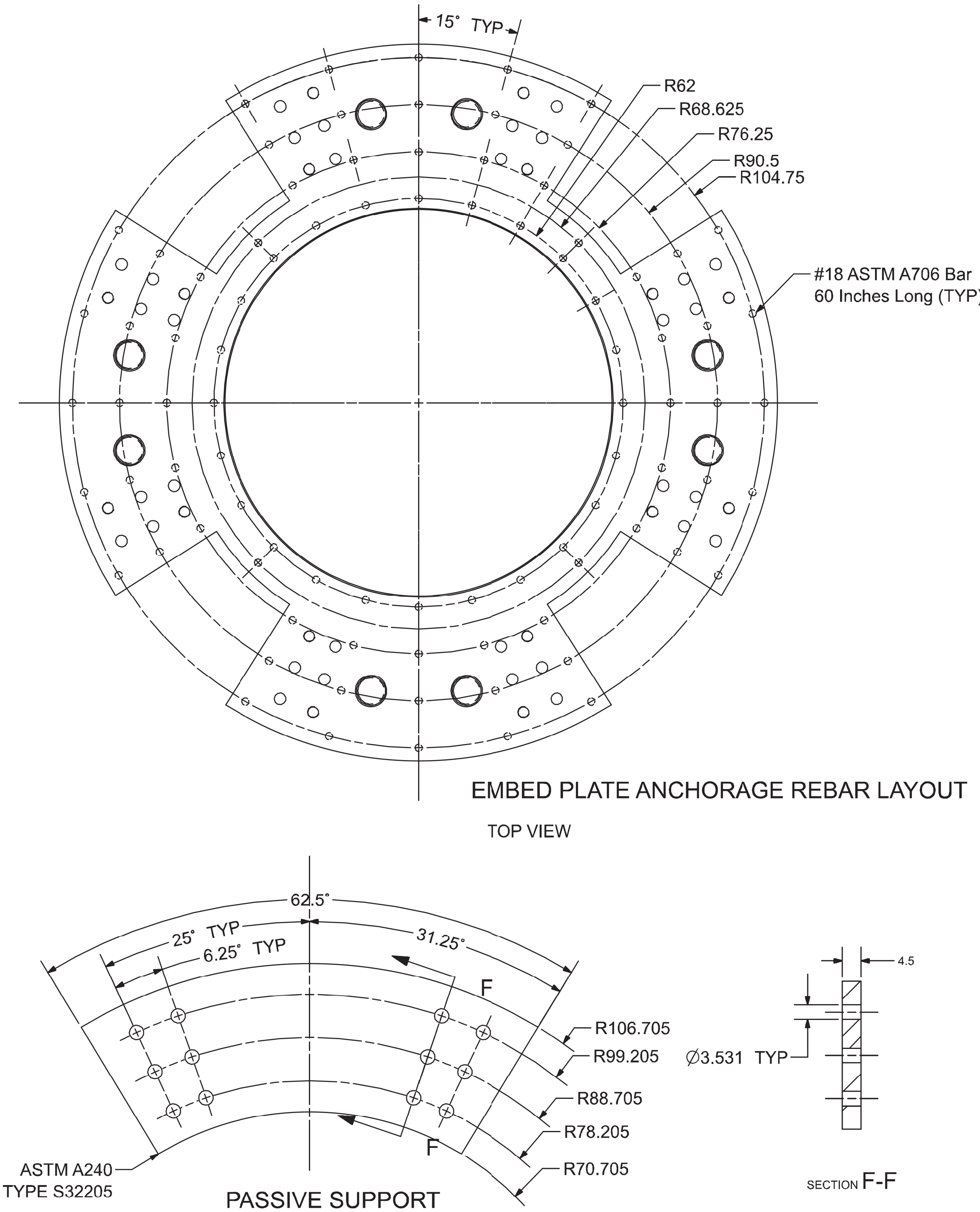
RAI 03.07.02-20, RAI 03.08.04-10S1

Figure 3B-49: Plan View and Cross Sections ~~of NPM Base Support Passive Support Ring~~of NPM Embed Plate



RAI 03.07.02-20, RAI 03.07.02-20S1, RAI 03.08.04-10S1

Figure 3B-50: Plan View of NPM ~~Base Support Bearing~~Embed Plate Anchorage and Passive Plate



direction and 19'-7" deep in the east-west direction, and extends from the pool floor at EL. 25'-0" up to EL. 125'-0". The bottom of the bay is the RXB foundation slab. The walls which make up the bay are 5 feet thick reinforced concrete. The top of the bay is capped with the Bioshield during operation. The bay provides restraints to prevent the NPM from moving laterally. Restraint is provided via a NPM skirt restraint located at EL. 25′-0" and lug restraints located on the three bay walls at EL. 71'-7".

3B.2.7.1 West Wing Wall

The west wing wall is one of the walls at grid line 4. The SAP2000 analysis model elevation view is shown in Figure 3B-42, along with the shell element labels. The west wing walls have the refueling pool on one side and an NPM located on the other. (See Figure 3B-52). Because of this location, it experiences the highest forces of the NPM bay wing walls.

Reinforcement drawings and section details are presented in Figure 3B-43 and Figure 3B-44.

RAI 03.08.04-11

A summary table of the element-based design check results for the wall at Grid Line 4 is presented in Table 3B-22. This summary table shows the maximum D/C ratios within each design check zone. All design check zones have no D/C exceedances. The bounding static, dynamic (seismic), and final design forces and moments are shown in Table 3B-22a and Table 3B-22b. Based on the above results and evaluations, the west wing wall is acceptable.

3B.2.7.2 Pool Wall

The portion of the pool wall that supports the NPMs is part of the wall at grid line B. This is an interior wall of the RXB that is 5 feet thick. The SAP2000 analysis model elevation view is shown in Figure 3B-45, along with the shell element labels.

Reinforcement drawings and section details are presented in Figure 3B-46 and Figure 3B-47.

RAI 03.08.04-11

A summary table of the element-based design check results for the wall at grid line B is presented in Table 3B-23. This summary table shows the maximum D/C ratios within each design check zone and highlights the YZ plane shear exceedance. The bounding static, dynamic (seismic), and final design forces and moments are shown in Table 3B-23a and Table 3B-23b. Table 3B-24 shows the element averaging for that exceedance. Table 3B-25 provides a summary of D/C ratios after averaging.

RAI 03.07.02-20, RAI 03.08.04-10S1, RAI 03.08.04-31

3B.2.7.3 NuScale Power Module Passive Support Plates~~Ring~~ Assembly

RAI 03.07.02-20, RAI 03.08.04-10S1

The base of the NPM is located at the bottom of the RXB pool at EL. 25'-0". There are up to 12 NPMs located in the RXB pool in their respective bays. The pool floor liner in the NPM bay is made of half-inch thick stainless steel, whereas the wall liner is made of quarter-inch stainless steel.

RAI 03.07.02-20

The NPM is vertically supported for the dead load and seismic loads acting downwards at the base, but free to move up vertically for any uplifting forces (such as seismic load acting upwards and buoyant forces due to the water in the reactor pool). The NPM is also laterally restrained against seismic forces at the base.

RAI 03.07.02-20

The details of the NPM base support are shown in Figure 3B-48 through Figure 3B-50. The NPM base support includes the following:

RAI 03.07.02-20, RAI 03.08.04-10S1, RAI 03.08.04-31

- The skirt of the NPM is supported on a donut-shaped, 5 3/4 in. thick embed plate. The embed plate extends beyond the donut shape at four quadrants to support 4 passive plates. In each quadrant, the embed plate has two 8 in. openings to accommodate concrete placement and consolidation. The central opening and the additional 8 openings are to be sealed by welding a stainless steel cover plate after concrete placement. The embed plate is made of stainless steel and is anchored to the basemat concrete using steel reinforcing bars.~~14.5 ft square, 4 in. thick bearing plate embedded in the basemat. This plate is made of austenitic stainless steel that is anchored to the concrete base mat through 36 concrete anchors welded to the bottom of the plate. The liner plate is discontinuous in the area around the NPM. A leaktight boundary is ensured by a seal weld between the liner plate and the embedded plate. Figure 3B-50 shows the details of the 4 in. thick bearing plate.~~ Figure 3B-48, Figure 3B-49 and Figure 3B-50 show the details of the NPM embed plate. The NPM is free to move upward vertically, and the vertical downward NPM load is transferred to the concrete basemat in bearing.

RAI 03.07.02-20, RAI 03.08.04-10S1, RAI 03.08.04-31

- The NPM is laterally restrained by four 4 1/2 in. thick stainless steel passive support plates. Each passive support plate is attached to the embed plate using two groups of six bolt/pin sets at both ends. Each set of bolts/pins is designed for the full seismic load. The passive plates transfer the seismic loads to the embed plate through the two groups of bolts/pins mainly by shear. The guide plate assembly, as shown in Figure 3B-48, is welded to the passive plate. The function of the guide plate assembly is to guide NPM installation to the design position. Figure 3B-48 shows the details of passive plates and the guide plate assembly.~~an 8-in.-thick passive support ring made of stainless steel bolted to the underlying bearing plate. At the inside periphery of the passive ring, a beveled edge at the top is provided in order to guide the NPM at initial placement and during its removal and replacement for refueling operation.~~ If the NPM impacts the passive support ~~ring~~plates, the resulting upward vertical and horizontal loads will be resisted by the ~~concrete~~ anchors in tension and shear and concrete in edge bearing. Figure 3B-48 and Figure 3B-49 show the details of the passive support plate~~ring~~.

RAI 03.07.02-10, RAI 03.08.04-31

NuScale Power Module Model:

RAI 03.07.02-10S1

A SASSI building model with a detailed NPM beam model, described in Section 3.7.2, is used to perform dynamic analyses on the RXB and extract results at the NPM to RXB interface locations. The RXB analysis produces local acceleration time histories that are used as input to the NPM seismic analysis discussed in Appendix 3A.

RAI 03.07.02-10S1, RAI 03.08.04-10S1

A separate ANSYS model is used to perform a non-linear dynamic analysis of the NPM. This model only includes the pool water and one NPM (1 or 6). The analysis results are based on the envelope of the six runs shown in Table 3B-53. The static reaction force, including the dead weight and the static buoyancy, is ~~1,090.4~~1,250 kips in the vertical direction. The maximum uplift displacement, due to seismic, of the module from the floor is less than 0.125 inch. The enveloping reaction forces between the ANSYS and SASSI models are provided in Table 3B-28 and used for the design basis in the following subsections.

Envelope Loads:

RAI 03.07.02-10, RAI 03.07.02-20, RAI 03.08.04-10S1, RAI 03.08.04-31

- Vertical downward load, P = ~~3,859~~3,242 kips. This load includes dead load, fluid pressure load, and seismic load. Dead load is the static buoyancy load described above and is equal to ~~1,090.4~~1,250 kips. The fluid pressure load is determined by the product of the ~~baseplate~~NPM skirt ring area (~~14.5' x 14.5'~~4,310 in^2), the fluid density (62.4 pcf), and the normal operating reactor pool depth (69') and is equal to ~~905.3~~129 kips. The enveloping downward seismic load is 1,863 kips.

RAI 03.07.02-20, RAI 03.08.04-10S1

- The vertical displacement is less than 0.125 inch. The passive support ~~ring~~plate is 4.5 inches thick~~ below the bevel~~, therefore, there will always be lateral support from the passive support plate~~ring~~.

RAI 03.07.02-10, RAI 03.07.02-20

- Lateral load:
  - East-West seismic load = 1,144 kips
  - North-South seismic load = 1,103 kips
  - Square Root Sum of Squares horizontal seismic load =

$$\sqrt{(1{,}144^2 + 1{,}103^2)} = 1{,}589 \text{ kips}$$

RAI 03.08.04-10S1

Considering a 5% load increase to account for accidental torsion, the SRSS horizontal seismic load is 1669 kips.

RAI 03.07.02-20, RAI 03.08.04-10S1

It is possible for the support ~~ring~~plates and anchors to experience an upward vertical force if the NPM were to strike ~~the~~a support ~~ring~~plate during a seismic event. Because this force is of extremely short duration and the contact surface small, only a limited amount of force is transferred to the support plate~~ring~~. A coefficient of friction value between wet steel and steel of 0.2 is multiplied by the square root sum of squares of east-west and north-south seismic loads to determine this force.

RAI 03.07.02-10, RAI 03.07.02-20, RAI 03.08.04-10S1

$$/_{\text{uplift}} = 0.2 \times 1{,}669 \text{ kips} = 333.8 \text{ kips}$$

Materials and Material Strength:

- Stainless Steel: The stainless steel used for the liner plate conforms to ASTM A-167 or ASTM A-240 Type 304L and has a 0.2 percent offset yield strength of 25 ksi, and ultimate tensile strength 70 ksi.

RAI 03.07.02-10, RAI 03.07.02-20, RAI 03.08.04-10S1

- ~~Austenitic~~Duplex Stainless: The steel used for the 5 3/4-in.-thick bearing plate that supports the NPMs vertically is ASTM A240~~965~~ Type S32205~~Grade F304~~ with a yield strength of ~~22.4~~65 ksi and ultimate tensile strength of ~~61.8~~91.7 ksi at a design temperature of 300 degrees Fahrenheit. Passive plates and guide plates are made of the same material type.
- Concrete for Basemat: The concrete strength, f'_c is 5000 psi

RAI 03.07.02-20, RAI 03.08.04-10S1

~~A total of 36, 3/4 in. diameter, ASTM F1554, Grade 55 concrete anchors are used to anchor the passive support ring and embedded plate assembly. These anchors have a yield strength of 55 ksi and designations of S1 (weldable) and S4 (Charpy test).~~A total of 88 #18 ASTM A706 Grade 60 steel reinforcing bars are used to anchor the embed plate in the four quadrants. The number of anchors in each quadrant (22) is designed for NPM loads.

RAI 03.07.02-20, RAI 03.08.04-10S1

~~A total of 30, 1.5 in. thread diameter, ASTM A479, Type UNS S21800 bolts fasten the passive support ring to the embedded plate.~~A total of 16 threaded bolts and 32 pins made of material ASTM A564, Type 17400 with heat treatment condition of H1150, with yield strength of 105 ksi and tensile strength at 300 degrees Fahrenheit of 135 ksi, are used to attach the four passive plates to the embed plate.

Load Path:

RAI 03.07.02-20, RAI 03.08.04-10S1

- The vertical load is resisted by the 5 3/4 in. thick donut-shape embed plate supporting the 4 1/2 in. thick NPM skirt ring.~~14.5 ft square, 4 in. thick bearing ring plate.~~

RAI 03.07.02-20, RAI 03.08.04-10S1

- The lateral load is resisted by bolts/pins that connect the passive ~~support ring~~plate to the embedded bearing plate. The bolts/pins transfer the lateral load to the ~~bearing~~embed plate, which, in turn, transfers the load, via bearing, to the concrete basemat.

Evaluation:

Vertical Load Bearing Capacity

RAI 03.07.02-10, RAI 03.07.02-20, RAI 03.08.04-10S1, RAI 03.08.04-31

- Area of concrete in bearing, A_{brg}, is 4310 in^2, therefore the bearing pressure (P_V/ A_{brg}) is 0.75~~90~~ ksi
- Allowable bearing pressure = (Φ)(0.85f'c) = 2.76 ksi [Φ = 0.65]

RAI 03.07.02-10, RAI 03.07.02-20, RAI 03.08.04-10S1, RAI 03.08.04-31

- Vertical bearing D/C Ratio: = 0.27~~33~~

RAI 03.07.02-10, RAI 03.07.02-20, RAI 03.08.04-10S1

- The ~~maximum~~ D/C ratio of the anchor bar shear strength is equal to 0.66~~bolts is due to concrete breakout in tension and is equal to 0.74~~.

Lateral Load Resistance

RAI 03.07.02-10, RAI 03.07.02-20, RAI 03.08.04-10S1

- SRSS Lateral Load is ~~1,589~~1,669 kips

RAI 03.07.02-10, RAI 03.07.02-20, RAI 03.08.04-10S1

- The D/C ratio of the bolts/pins in shear and tension is 0.75~~92~~.

RAI 03.07.02-10, RAI 03.07.02-20, RAI 03.08.04-10S1, RAI 03.08.04-31

- The ~~maximum~~ D/C ratio for concrete edge bearing due to lateral load transferred from the bearing plate is 0.68~~83~~.

RAI 03.08.04-10S1

- The true capacity of the NPM support plate assembly, where D/C would reach a value of 1.0, occurs for a load of 1669 kips/0.75=2225 kips.

3B.2.7.4 Nuscale Power Module Lug Restraint

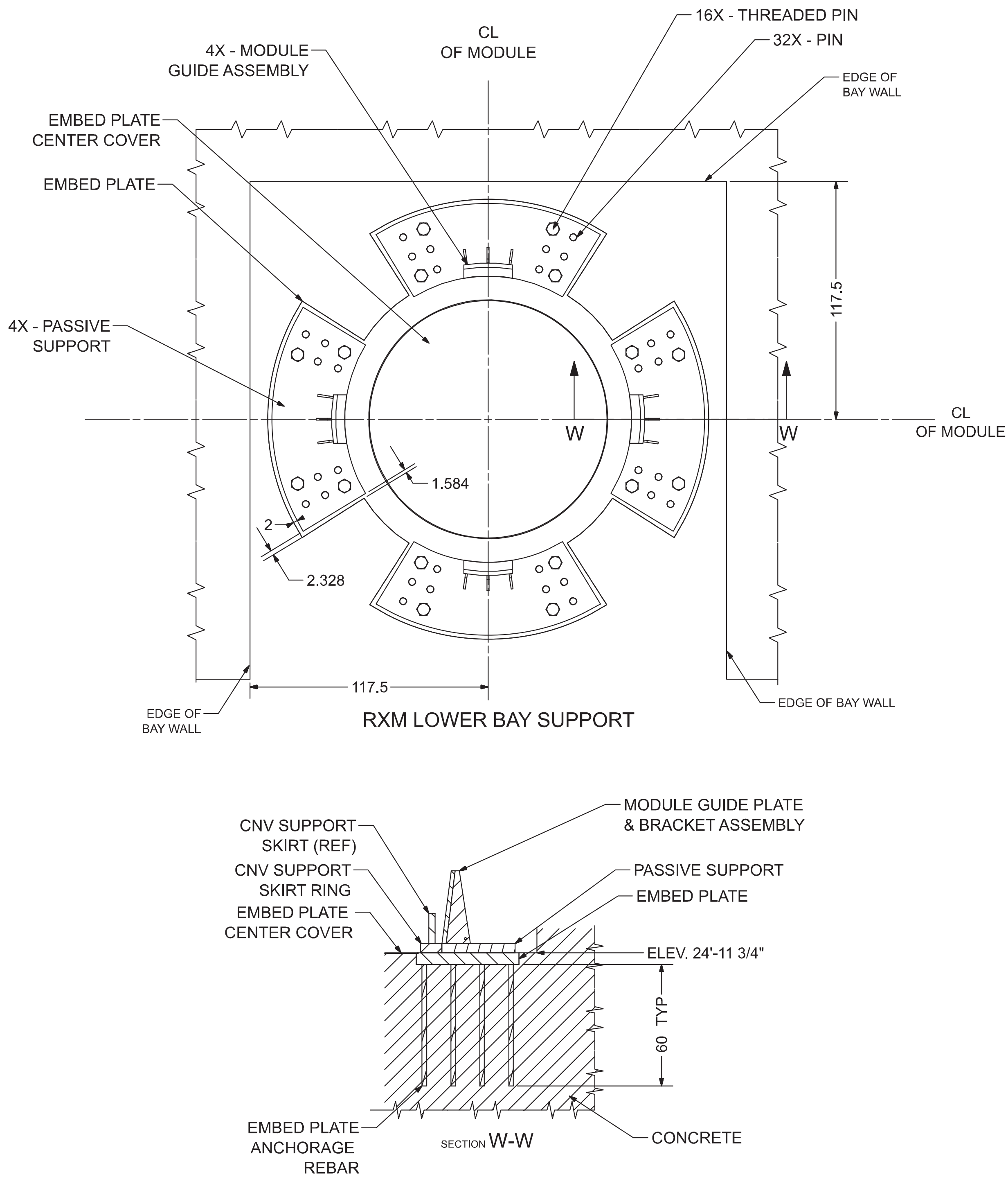
The NPM lug restraint design consists of a stainless steel bumper comprised of 2″ thick plates with 2″ thick stiffener plates. The bumpers are welded to 2″ thick stainless steel liner plates. On the inside of the liner plate there are 3″ thick, 5″ wide (48″ depth) steel shear lugs to transfer the lateral shear loads into the wall. Finally, the two bumpers on either side of the lug on the pool walls are bolted together with through-bolts to withstand tensile loads due to moments from the eccentric lateral shear loads. The design layout for the support system for the NPM lug restraints is shown in Figure 3B-51.

The bumpers are Stainless Steel Type 630 - H1150, with a yield strength of 100.8 ksi, and an ultimate strength of 135 ksi. The shear lugs are carbon steel ASTM A572 GR 50, with a yield strength of 50 ksi, and an ultimate strength of 65 ksi. The through-bolts are ASTM A193 GR B7, with a yield strength of 105 ksi, and an ultimate strength of 125 ksi.

RAI 03.08.04-21S2

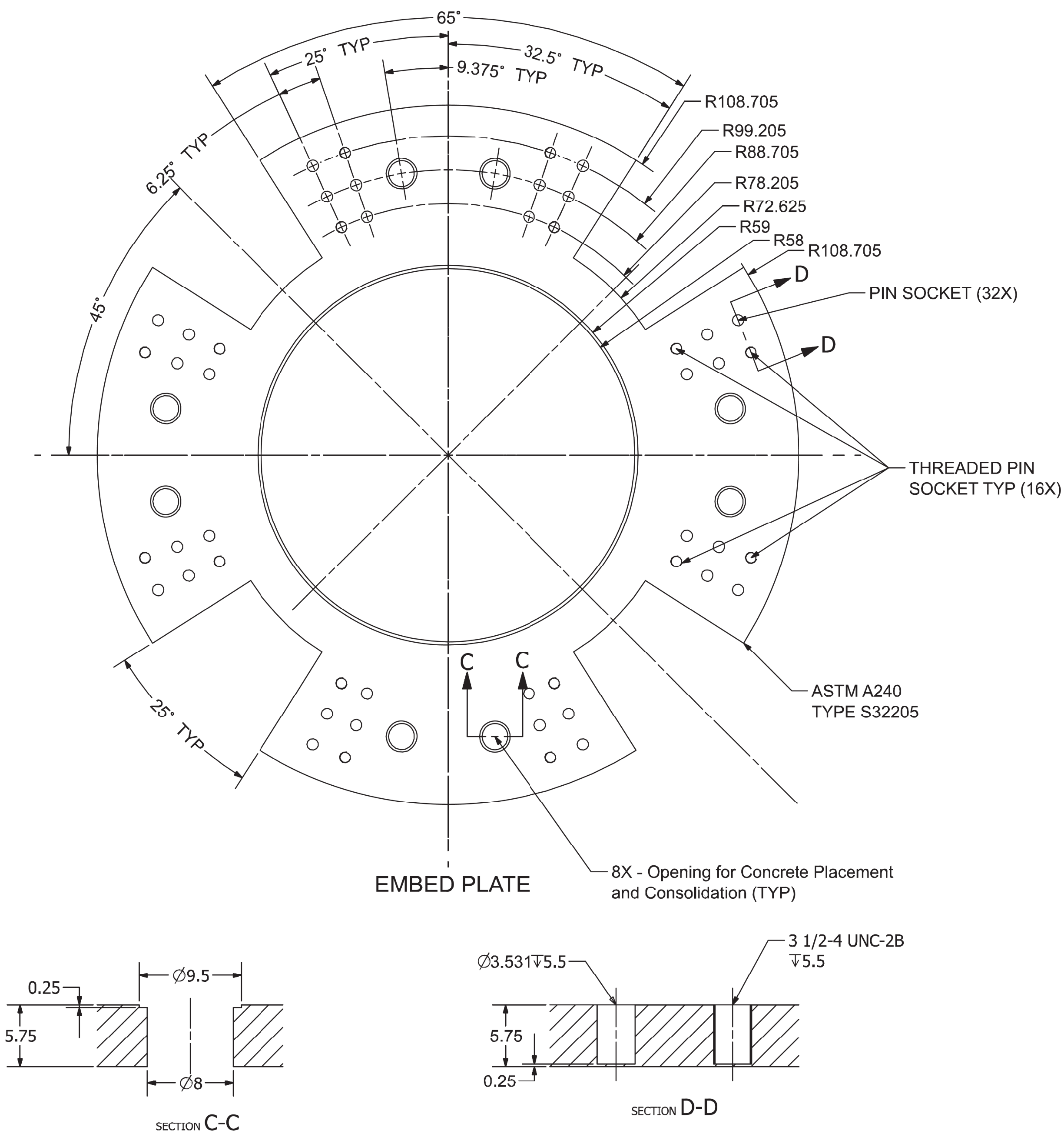
RAI 03.07.02-20, RAI 03.07.02-20S1, RAI 03.08.04-10S1

Figure 3B-48: ~~Elevation View of the NPM~~NuScale Power Module Base Support Assembly at Reactor Building~~RXB~~ Pool Floor



RAI 03.07.02-20, RAI 03.08.04-10S1

Figure 3B-49: Plan View and Cross Sections ~~of NPM Base Support Passive Support Ring~~of NPM Embed Plate



RAI 03.07.02-20, RAI 03.07.02-20S1, RAI 03.08.04-10S1

Figure 3B-50: Plan View of NPM ~~Base Support Bearing~~Embed Plate Anchorage and Passive Plate