INL/MIS-24-78478-Revision-0

ECAR-6584 MARVEL Reactor Support Frame Analysis

September 2023

Brandon L Moon

Changing the World's Energy Future

Idaho National Laboratory

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Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

1. Effective Date	09/26/23	**Professional Engineer's Stamp**
2. Does this ECAR involve a Safety SSC (see def. LWP-10200)?	YES	PROFESSIONAL ENGINEER LICENSED 14896 STATE OF IDAHO LUCAS AVERY ANDREW
3. Safety SSC Determination Document ID	TBD	Luke Andrew
4. SSC ID	TBD	Walsh Engineering Services
5. Project No.	33526	2023.09.21 15:14:14-06'00'
6. Engineering Job (EJ) or Engineering Change (EC) No.	EC 1755	
7. Building	720	
8. Site Area	MFC	

9. Objective / Purpose

The purpose of this document is to provide the structural and seismic analyses for the MARVEL Reactor Support Frame which will comply to ANSI/AISC N690-18, Specification for Safety Related Steel Structures for Nuclear Facilities.

10. If revision, please state the reason and list sections and/or page being affected.

11. Conclusion / Recommendations

All demand-to-capacities, per ANSI/AISC N690-18, Specification for Safety Related Steel Structures for Nuclear Facilities, are less than one (1) and are satisfactory. The Reactor Support Frame will provide sufficient support and spacing for the MARVEL reactor in the event of a seismic event detailed in SAR – 420 and postulated events described herein.

Although temperatures were validated by analysis and incorporated conservatively, temperatures should be validated upon issuance of ECAR-6574 for higher fidelity and accuracy of this analysis.

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APPENDIXES

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Appendix B Seismic Analysis Results Report
Appendix C ANSI - AISC N690-18 Compliance
Appendix D Thermal Analysis
Appendix E Tipping Analysis

1. PROJECT ROLES AND RESPONSIBILITIES

Project Role	Name	Organization	Pages Covered (if applicable)
Performer	Mathew Floyd	Walsh Engineering Services	See DCR 704404
Checker[a]	Luke Andrew	Walsh Engineering Services	See DCR 704404
Independent Reviewer[b]	Ben Coryell	U710	See DCR 704404
CUI Reviewer[c]	Mike Patterson	C120	See DCR 704404
Manager[d]	Brandon Moon	U022	See DCR 704404
Requestor[ef]	Yasir Arafat	C120	See DCR 704404
Nuclear Safety[f]	Doug Gerstner	H374	See DCR 704404
Document Owner[f]	Brandon Moon	U022	See DCR 704404
Reviewer[f]	Carl Bailey	U720	See DCR 704404

Responsibilities:

a. Confirmation of completeness, mathematical accuracy, and correctness of data and appropriateness of assumptions.

b. Concurrence of method or approach. See definition, LWP-10106.

c. Concurrence with the document’s markings in accordance with LWP-11202.

d. Concurrence of procedure compliance. Concurrence with method/approach and conclusion.

e. Authorizes the commencement of work of the engineering deliverable.

f. Concurrence with the document’s assumptions and input information. See definition of Acceptance, LWP-10200.

NOTE: *Delete or mark “N/A” for project roles not engaged. Include ALL personnel and their roles listed above in the DCR system. The list of the roles above is not all inclusive. If needed, the list can be extended or reduced.*

2. SCOPE AND BRIEF DESCRIPTION

Idaho National Laboratory (INL) is developing a small microreactor to produce electrical power utilizing a small nuclear core and Stirling engines for power output under the Microreactor Application Research Validation and Evaluation (MARVEL) program. The MARVEL Reactor will be installed in the Transient Reactor Test (TREAT) Facility. Walsh Engineering Services, PC (WES) has contracted with the INL to support the completion of the final design. There are six main systems in the MARVEL, one of which is the MARVEL Reactor System (MRS). The MRS contains a subsystem – the Reactor Support Frame (RSF) – that supports and orients nearly all the MRS and the RSF will be bolted to the TREAT Facility. The subject of this Engineering Calculations and Analysis Report (ECAR) is the frame weldment (see Figure 1), which is the only item that is contained in the RSF subsystem and will be called herein "RSF".

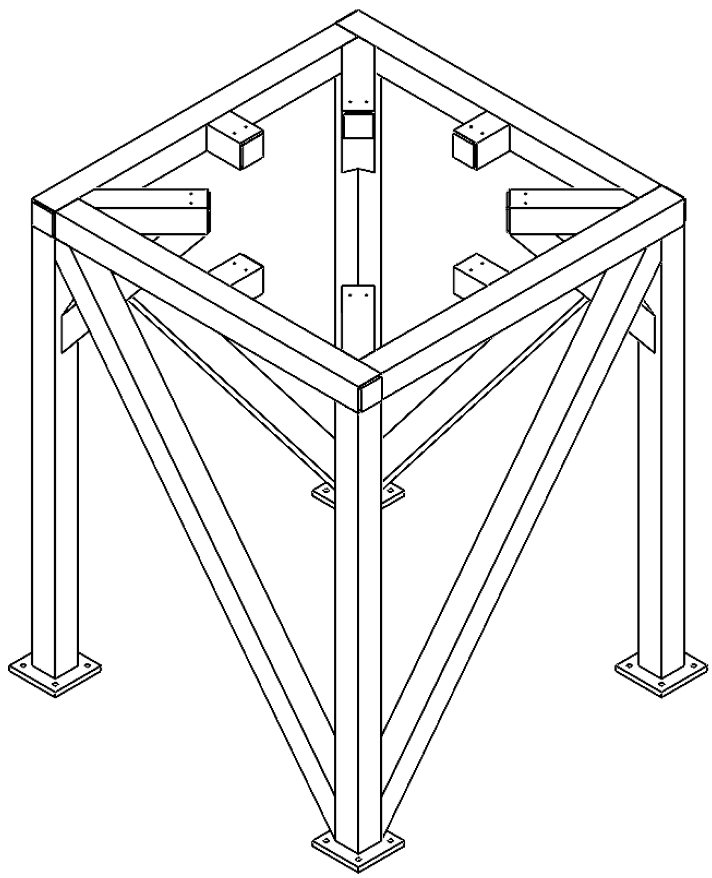


Figure 1: Reactor Support Frame, Drawing 1014726

The RSF has four legs and four mounting plates which are welded to the bottom of the frame. Each mounting plate has four thru holes for mounting to the TREAT Facility mounting pad. There will be insulation bolted onto the RSF to lower the temperatures that the RSF will experience by heat transfer from the Guard Vessel. All load bearing welds are designed as partial joint penetration welds, as detailed in drawing 1014726.

3. DESIGN OR TECHNICAL PARAMETER INPUT AND SOURCES

The following inputs were included in the FEA (Appendix A & B) and limits (Appendix C).

PHYSICAL GEOMETRY

The physical geometry is shown in Figure 2 and in drawing 1014726. The RSF is made from 5" x 5" x 0.375" hollow steel structure (HSS) square tube. The structure is 89 inches tall and 71 inches wide by 71 inches deep. The seating surface for the reactor equipment is shown in Figure 3. For more information, refer to drawing 1014726.

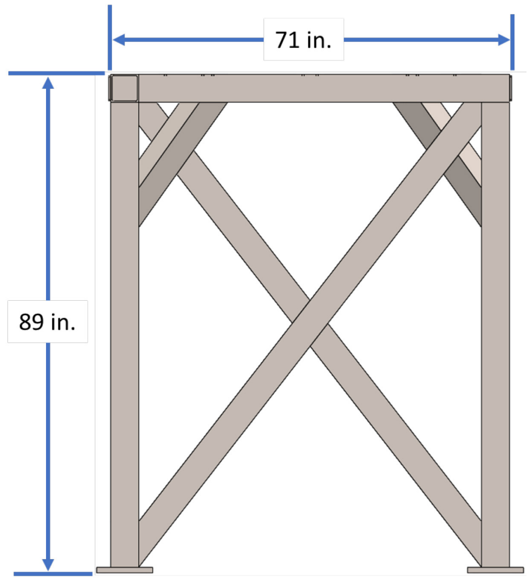


Figure 2: RSF Dimensions (side view)

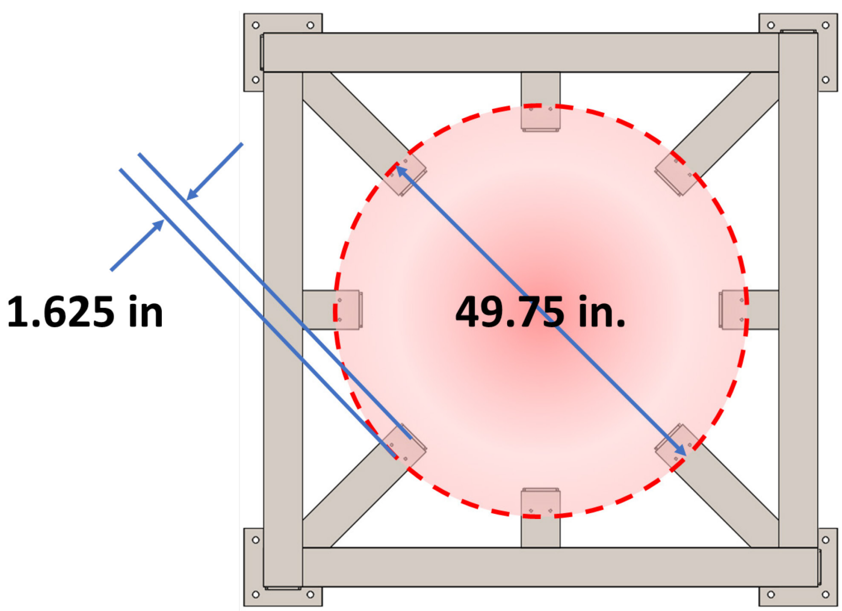


Figure 3: Nominal 1.625-inch Seating Surface of Guard Vessel and PCS onto RSF Beams (top view)

MATERIAL PROPERTIES

As shown in drawing number 1014726, the material selected for the RSF is 316H stainless steel.

TEMPERATURE LOADING

Per Reference 3, the RSF will experience an approximate 200°F (93°C) temperature load on the seating surfaces from the Guard Vessel. The temperature of the RSF floor plates is approximately room temperature (68°F). Additionally, thermal convection was included in this analysis (see Appendix D) with an approximate bulk ambient temperature of 40°C (104°F, which is discussed in detail in Appendix D, section 1).

LOADS APPLIED

As shown in Figure 4, the RSF supports the guard vessel and the primary coolant system. The outer shield seats on the TREAT pit floor and will not be included in this analysis; however, the guard vessel is shown herein for reference.

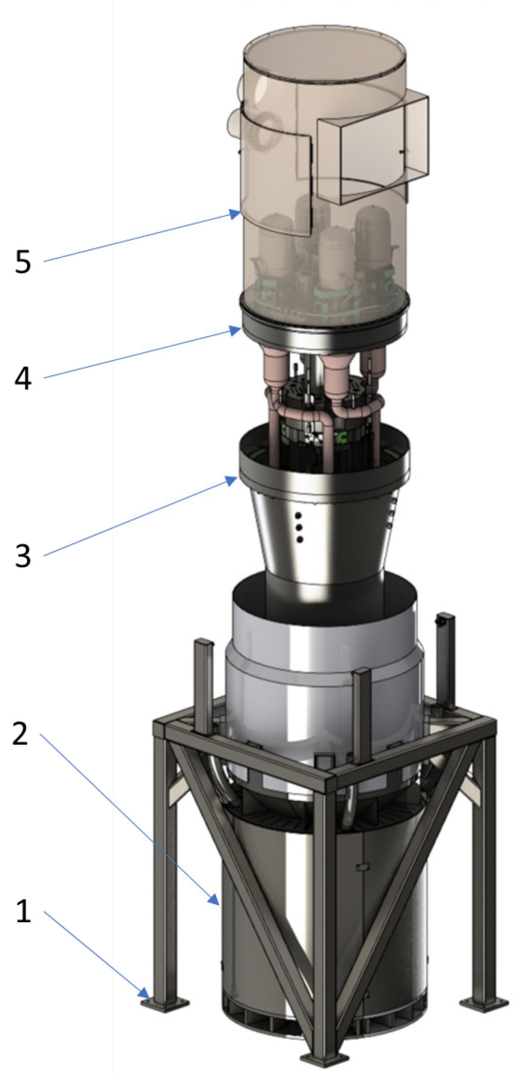


Figure 4: 1. RSF; 2. Outer Shield; 3. Guard Vessel; 4. Primary Coolant System; 5. Upper Confinement (conceptual), Sterling Engines, and other Supporting Equipment

The approximate weight of all the items that are supported by the RSF are shown in Figure 5. The weight of the items supported by the RSF is the dominant load placed on the RSF. However, the loading is multiplied by a seismic event as described in Reference 1. The approximate weight being placed on the RSF is 16000 lbs. as shown in Figure 5. As described in Appendix C, the load was increased by approximately 10% to total 18,000 lbs., for any uncertainty in manufacturing and fabrication. The center of gravity of the items being placed onto the RSF is approximately 11.18" below the seating surface on the top of the RSF as shown in Figure 5.

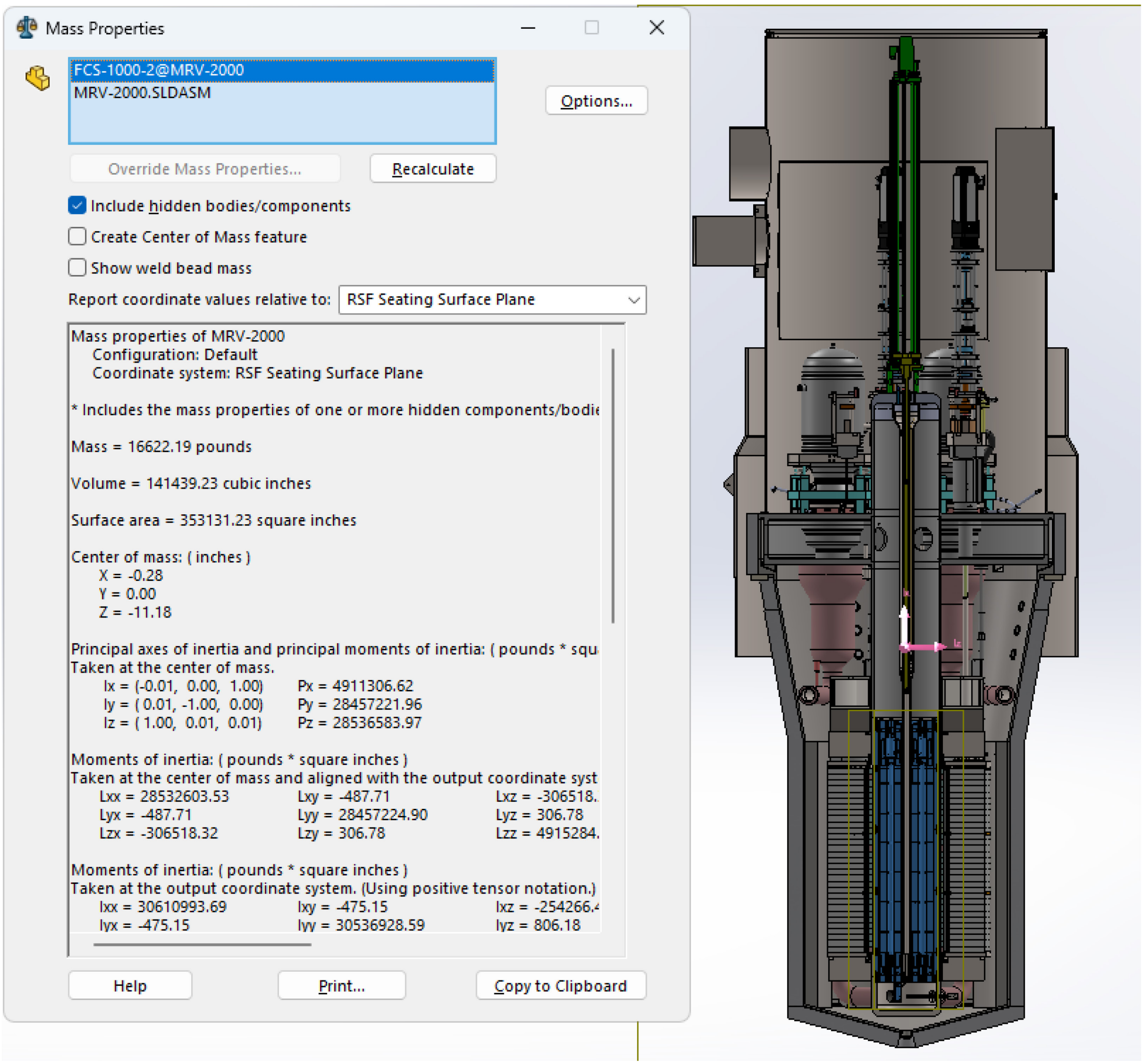


Figure 5: Center of Gravity Location (11.18" away from Guard Vessel seating surface)

4. RESULTS OF LITERATURE SEARCHES AND OTHER BACKGROUND DATA

N/A

5. ASSUMPTIONS

The following assumptions were made:

- Instead of loads being placed in a somewhat distributed manner on each of the 8 supporting members of the RSF, the loading in the FEA model was concentrated to point loads onto the ends of the supporting members, for conservatism.
- Although the max temperature that the RSF experiences is approximately 200°F (93°C, preliminary results based on ECAR-6574 which is not yet issued), the max temperature utilized for allowables for this analysis and Guard Vessel temperature boundary condition applied is 325°F (163°C) as well as applied temperature onto the seating surfaces of the RSF. Upon issuance of ECAR-6574, the thermal boundary conditions shall be validated, and allowables/stresses validated if found above 325°F.
- Recommended NaK (Sodium Potassium Eutectic) coolant starting mass–160.7kg–was approximated with ECAR-6586 which has not yet been issued, see conclusions/recommendations section. The NaK mass and fluid geometry was accounted for and was hidden for clarity in Figure 5 of this ECAR.
- Seismic loads included a 10% additional factor, a conservative weight loading of the fluid, and a “100%-100%-100%” approach to the seismic loading; therefore, the scaling factor which increases loading specifically for fluid damping (per ASCE 4) was inherently included in this analysis.

6. COMPUTER CODE VALIDATION

A. Computer type: Blackbird

B. Operating System and Version: Windows 10 Pro Build 19045.2486

C. Computer program name and revision: SolidWorks 2022 Service Pack 4.0

D. Inputs (may refer to an appendix): See QT-WES-041, Reference 6.

E. Outputs (may refer to an appendix): See QT-WES-041, Reference 6.

F. Evidence of, or reference to, computer program validation: See QT-WES-041, Reference 6.

G. Bases supporting application of the computer program to the specific physical problem: SolidWorks is an engineering-focused computer-aided design software, which includes finite element analysis capabilities intended for analyzing a wide range of problems.

7. DISCUSSION/ANALYSIS

The RSF supports the entire weight of the MARVEL reactor (approximately 16,000 lbs.) and must be able to sustain that weight in all postulated accident scenarios and normal operations.

The FEA for the RSF utilized beam elements to best reflect the geometry of the RSF. The set up and results of the FEA are shown in Appendix A and B for structural and seismic, respectively. The thermal analysis is presented in Appendix D.

Typically, each individual beam and connection joint is analyzed for its strength compared to the controlling code (N690-18 in this case). However, all maximum values determined by FEA were treated as if they were placed on the same beam and connection joint, for conservatism. Therefore, if the maximum valued stress, force, or moment are applied to all beams, welds and connection joints are satisfactory compared to N690-18 then all beams will succeed in compliance to N690-18. See Table 1 for a summary of the maximum value FEA results as well as allowable and demands to capacity from Appendices A, B, and C. Demand-to-capacity is an inverse to the safety factor. As shown in Table 1, all demand-to-capacities are less than one (1) and is therefore acceptable. Additionally, reaction forces are shown in Appendices A and B. The maximum reaction forces are summarized in Table 2.

A tipping analysis was performed and is shown in Appendix E to ensure that in the event of an earthquake (as detailed in Reference 1) that there will be no tipping. There is approximately a demand-to-capacity of 0.26 for tipping in a seismic event.

Table 1: Demand-to-Capacity Summary

Chapter	Demand-to-Capacity Description	Demand (ksi)	Capacity (ksi)	Demand-to-Capacity†	Reference
D	Tension, NLC	1.29	13.94	**0.09**	ANSI/AISC 360-16 Chapter D, Equation D2-1
D	Tension, ELC	1.75		**0.13**	ANSI/AISC 360-16 Chapter D, Equation D2-1
E	Compression, NLC	1.61	9.70	**0.17**	ANSI/AISC 360-16 Chapter E, Equation E3-1
E	Compression, ELC	1.96		**0.20**	ANSI/AISC 360-16 Chapter E, Equation E3-1
F	Flexure, NLC	37.0*	138.9*	**0.27**	ANSI/AISC 360-16 Chapter F, Equation F7-1
F	Flexure, ELC	47.7*		**0.34**	ANSI/AISC 360-16 Chapter F, Equation F7-1
G	Shear, NLC	0.66	8.37	**0.08**	ANSI/AISC 360-16 Chapter G, Section G1
G	Shear, ELC	0.83		**0.10**	ANSI/AISC 360-16 Chapter G, Section G1
H	Combined forces and Torsion, NLC	0.14	8.40	**0.02**	ANSI/AISC 360-16 Chapter H, Equation H3-1
H	Combined forces and Torsion, ELC	0.27		**0.03**	ANSI/AISC 360-16 Chapter H, Equation H3-1
H	Combined forces and Torsion, NLC	0.44†	1.00†	**0.44**	ANSI/AISC 360-16 Chapter H, Equation H3-6
H	Combined forces and Torsion, ELC	0.56†		**0.56**	ANSI/AISC 360-16 Chapter H, Equation H3-6
J	Connections, NLC	20.6	360.3	**0.06**	ANSI/AISC 360-16 Chapter J, Section J2
J	Connections, ELC	30.4		**0.08**	ANSI/AISC 360-16 Chapter J, Section J2
J	Weld strength, NLC	20.6‡	43.7‡	**0.47**	ANSI/AISC 360-16 Chapter J, Equation J8-1
J	Weld strength, ELC	30.4‡		**0.70**	ANSI/AISC 360-16 Chapter J, Equation J8-1
K	HSS to HSS Connections, NLC	1.61	7.53	**0.21**	ANSI/AISC 360-16 Chapter K, Equation K3-7
K	HSS to HSS Connections, ELC	1.94		**0.26**	ANSI/AISC 360-16 Chapter K, Equation K3-7

* Measured in kip-in.
† Unitless.
‡ Measured in kip.

Table 2: Max Resultant Reaction Forces

	Reaction forces					
	Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
ELC	Entire Model	lbf	-8997.12	28367.20	6299.85	**30419.30**
	Reaction Moments					
	Selection set Units	Units	Sum X	Sum Y	Sum Z	Resultant
	Entire Model	lbf-in	19371.00	0.1893	31169.40	**36698.30**
NLC	**Reaction forces**					
	Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
	Entire Model	lbf	0.0001	20600.70	0.0002	**20600.70**
	Reaction Moments					
	Selection set Units	Units	Sum X	Sum Y	Sum Z	Resultant
	Entire Model	lbf-in	17.2823	0.0000	-17.2931	**24.4485**

8. REFERENCES

1. ECAR-6601, Revision 0, "MARVEL Project Seismic Accelerations", April 17th, 2023
2. ANSI/AISC 360-16, Specification for Structural Steel Buildings, July 7th, 2016
3. ECAR- 6574, MARVEL Guard Vessel System FEA and ASME Analysis
4. ANSI/AISC N690-18, Specification for Safety Related Steel Structures for Nuclear Facilities, June 28th, 2018
5. AISC Steel Design Guide 27, Structural Stainless Steel
6. QT-WES-041, SolidWorks Simulation Verification, June 14th, 2023

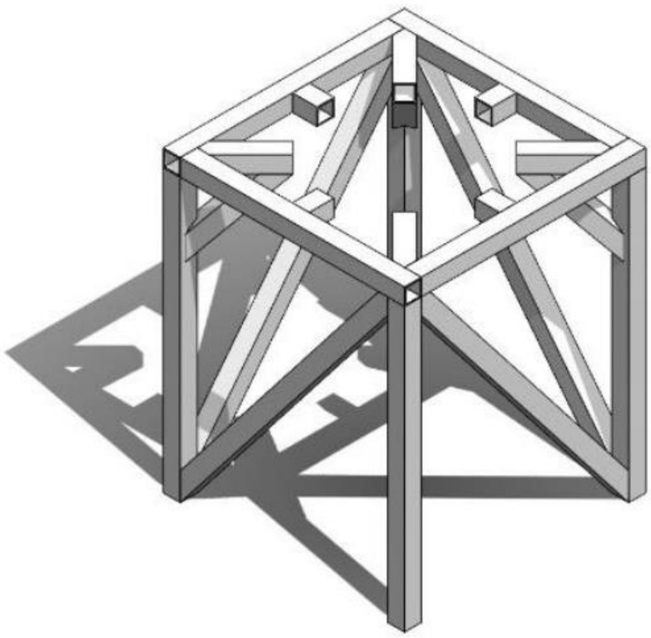
9. APPENDICES

Appendix A: Structural Analysis Results Report
Appendix B: Seismic Analysis Results Report
Appendix C: ANSI - AISC N690-18 Compliance
Appendix D: Thermal Analysis
Appendix E: Tipping Analysis

Appendix A

Structural Analysis Results Report

1935 International Way
Idaho Falls, ID 83402
Phone: 208.524.2286
Fax: Fax: 208-522-4269
https://www.walshengr.com/



Simulation of RSF

Date: Tuesday, September 5, 2023
Designer: Mat Floyd
Study name: NLC
Analysis type: Static

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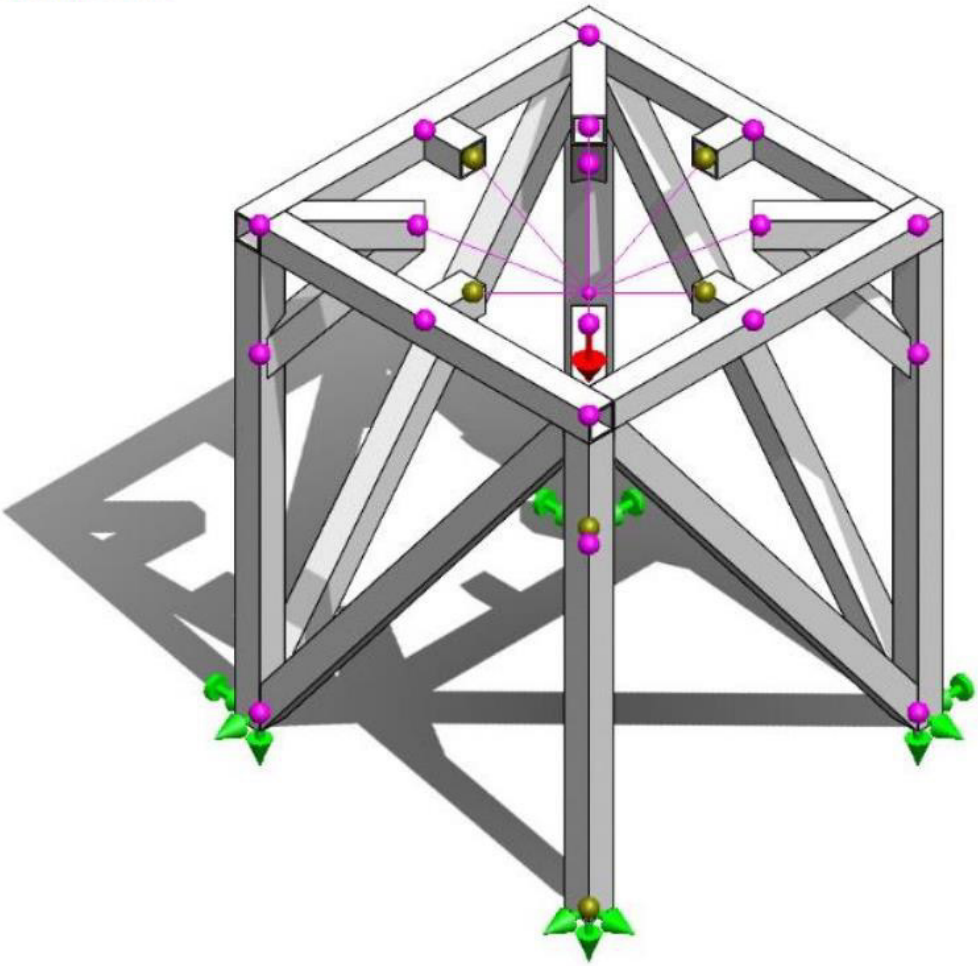
WALSH ENGINEERING SERVICES
1935 International Way
Idaho Falls, ID 83402

Mat Floyd
9/5/2023

Model Information



Model name: RSF
Current Configuration: Default<As Machined>

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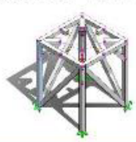
1935 International Way
Idaho Falls, ID 83402

Mat Floyd
9/5/2023

Beam Bodies:			
Document Name and Reference	**Formulation**	**Properties**	**Document Path/Date Modified**
SolidBody 1(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[13]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:460.892mm** **Volume:0.00206286m^3** **Mass Density:8,030kg/m^3** **Mass:16.5647kg** **Weight:162.335N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 2(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[1]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:2,108.2mm** **Volume:0.00943588m^3** **Mass Density:8,030kg/m^3** **Mass:75.7701kg** **Weight:742.547N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 3(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[17])	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:184.15mm** **Volume:0.000824218m^3** **Mass Density:8,030kg/m^3** **Mass:6.61847kg** **Weight:64.861N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 4(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[7]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:1,676.4mm** **Volume:0.00750323m^3** **Mass Density:8,030kg/m^3** **Mass:60.2509kg** **Weight:590.459N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023

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SolidBody 6(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[9]) 	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:460.892mm Volume:0.00206286m^3 Mass Density:8,030kg/m^3 Mass:16.5647kg Weight:162.335N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023
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SolidBody 11(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[2])	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:2,108.2mm Volume:0.00943588m^3 Mass Density:8,030kg/m^3	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023

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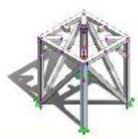
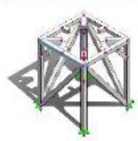
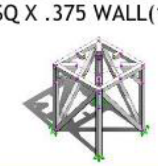
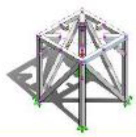
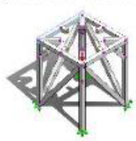
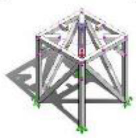
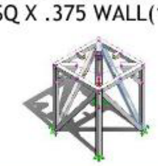
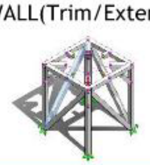
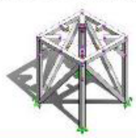
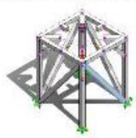
		**Mass:75.7701kg** **Weight:742.547N**	
SolidBody 12(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[5]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:1,676.4mm** **Volume:0.00750323m^3** **Mass Density:8,030kg/m^3** **Mass:60.2509kg** **Weight:590.459N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 13(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[15]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:649.507mm** **Volume:0.00290706m^3** **Mass Density:8,030kg/m^3** **Mass:23.3437kg** **Weight:228.768N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 14(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[16]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:649.507mm** **Volume:0.00290706m^3** **Mass Density:8,030kg/m^3** **Mass:23.3437kg** **Weight:228.768N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 15(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[6])	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:1,676.4mm** **Volume:0.00750323m^3** **Mass Density:8,030kg/m^3** **Mass:60.2509kg** **Weight:590.459N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023

			
SolidBody 16(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[8]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:1,676.4mm Volume:0.00750323m^3 Mass Density:8,030kg/m^3 Mass:60.2509kg Weight:590.459N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 17(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[19])	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:184.15mm Volume:0.000824218m^3 Mass Density:8,030kg/m^3 Mass:6.61847kg Weight:64.861N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 18(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[11]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:649.507mm Volume:0.00290706m^3 Mass Density:8,030kg/m^3 Mass:23.3437kg Weight:228.768N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 19(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[4]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:2,108.2mm Volume:0.00943588m^3 Mass Density:8,030kg/m^3 Mass:75.7701kg Weight:742.547N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023

SolidBody 21(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[14]) 	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:649.507mm Volume:0.00290706m^3 Mass Density:8,030kg/m^3 Mass:23.3437kg Weight:228.768N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023
SolidBody 24(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[18])	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:184.15mm Volume:0.000824218m^3 Mass Density:8,030kg/m^3 Mass:6.61847kg Weight:64.861N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023
SolidBody 57(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[23]) 	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:2,482.8mm Volume:0.0111224m^3 Mass Density:8,030kg/m^3 Mass:89.3125kg Weight:875.262N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023
SolidBody 59(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[21]) 	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:2,482.8mm Volume:0.0111224m^3 Mass Density:8,030kg/m^3 Mass:89.3125kg Weight:875.262N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023
SolidBody 60(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(Trim/Extend2) 	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:2,482.8mm Volume:0.0111224m^3 Mass Density:8,030kg/m^3 Mass:89.3125kg Weight:875.262N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023

SolidBody 61(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[12]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:460.892mm** **Volume:0.00206286m^3** **Mass Density:8,030kg/m^3** **Mass:16.5647kg** **Weight:162.335N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 63(Trim/Extend1) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:2,482.8mm** **Volume:0.0111224m^3** **Mass Density:8,030kg/m^3** **Mass:89.3125kg** **Weight:875.262N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023

Study Properties

Study name	NLC
Analysis type	Static
Mesh type	Beam Mesh
Solver type	Automatic
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Result folder	SOLIDWORKS document (C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23)

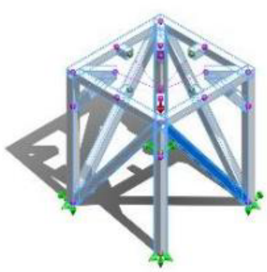
Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

WALSH ENGINEERING SERVICES
1935 International Way
Idaho Falls, ID 83402

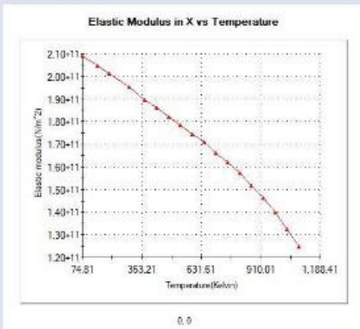
Mat Floyd
9/5/2023

Material Properties

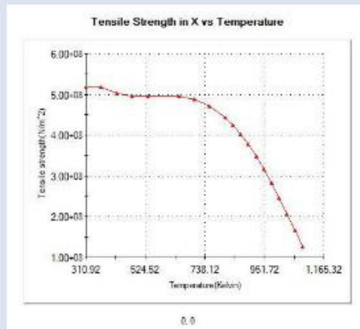
Model Reference	Properties	Components
	Name: SA 240 316H Model type: Linear Elastic Isotropic Default failure criterion: Max von Mises Stress Yield strength: Temp dependent Tensile strength: Temp dependent Elastic modulus: Temp dependent Poisson's ratio: 0.31 Mass density: 8,030 kg/m^3 Thermal expansion coefficient: Temp dependent	SolidBody 1(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[13])(RSF), SolidBody 2(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[1])(RSF), SolidBody 3(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[17])(RSF), SolidBody 4(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[7])(RSF), SolidBody 5(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[3])(RSF), SolidBody 6(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[9])(RSF), SolidBody 8(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[10])(RSF), SolidBody 9(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[20])(RSF), SolidBody 11(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[2])(RSF), SolidBody 12(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[5])(RSF), SolidBody 13(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square)

		TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[15])(RSF), SolidBody 14(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[16])(RSF), SolidBody 15(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[6])(RSF), SolidBody 16(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[8])(RSF), SolidBody 17(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[19])(RSF), SolidBody 18(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[11])(RSF), SolidBody 19(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[4])(RSF), SolidBody 21(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[14])(RSF), SolidBody 24(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[18])(RSF), SolidBody 57(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[23])(RSF), SolidBody 59(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[21])(RSF), SolidBody 60(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(Trim/Extend2)(RSF), SolidBody 61(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[12])(RSF), SolidBody 63(Trim/Extend1)(RSF)

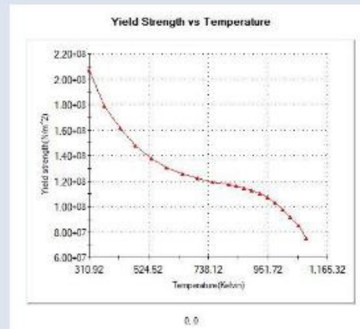
Curve Data:



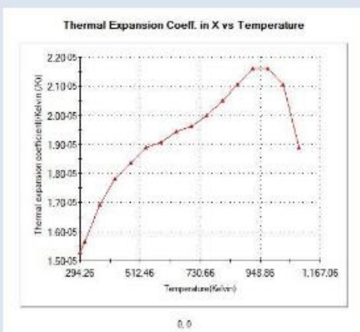
Elastic Modulus in X vs Temperature



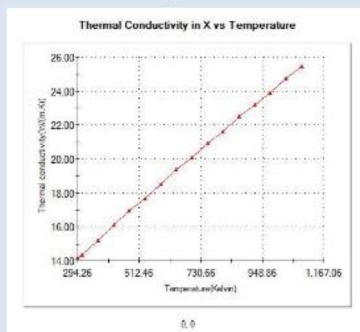
Tensile Strength in X vs Temperature



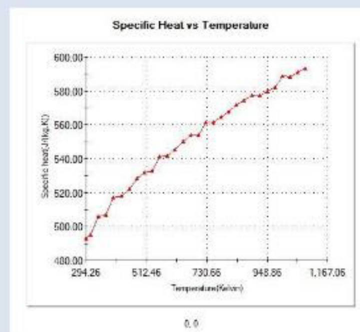
Yield Strength vs Temperature



Thermal Expansion Coeff. in X vs Temperature

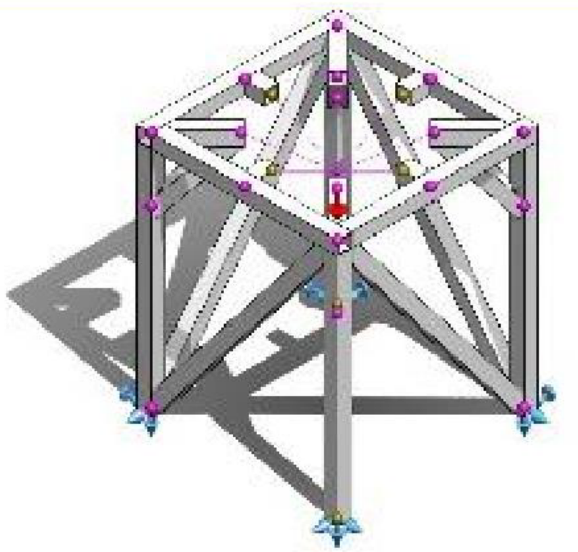


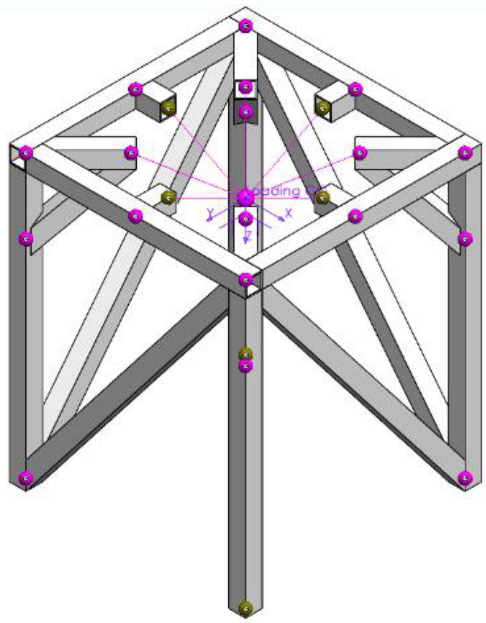
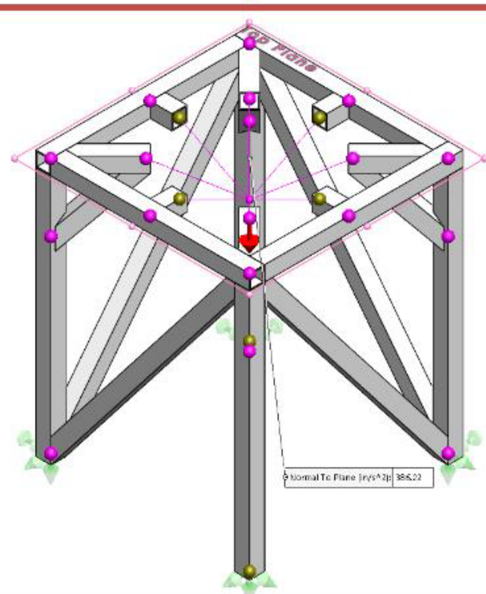
Thermal Conductivity in X vs Temperature



Specific Heat vs Temperature

Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		Entities: 4 Joint(s) Type: Fixed Geometry

Load name	Load Image	Load Details
Remote Load/Mass (Rigid connection)-1		**Connection Type:** Rigid **Coordinate System:** Loading CG **Translational Components:** ---,---,--- **Rotational Components:** ---,---,--- **Reference coordinates:** 0 0 0 in **Remote Mass:** 18000 lb **Moment of Inertia:** 0,0,0,0,0,0 lb.in^2
Gravity-1		**Reference:** Top Plane **Values:** 0 0 -386.22 **Units:** in/s^2

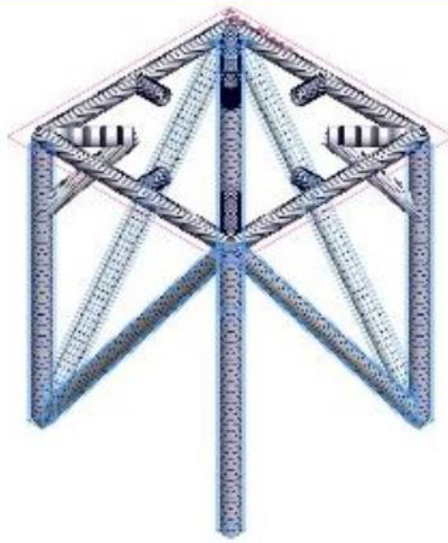
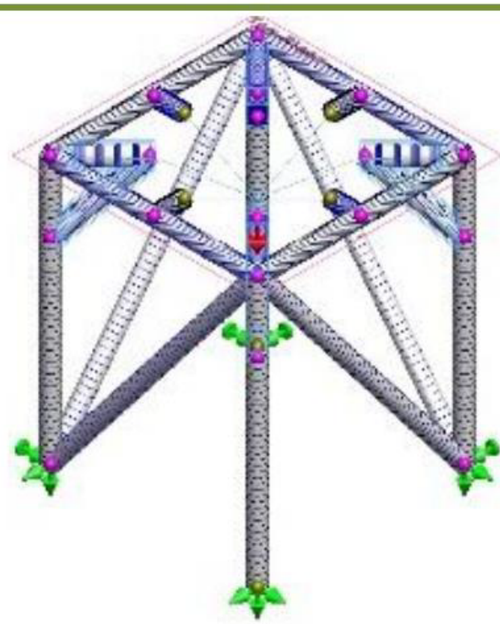
Mesh information

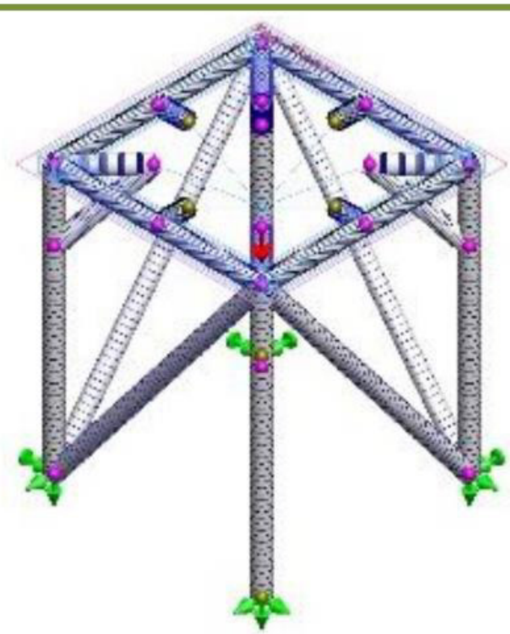
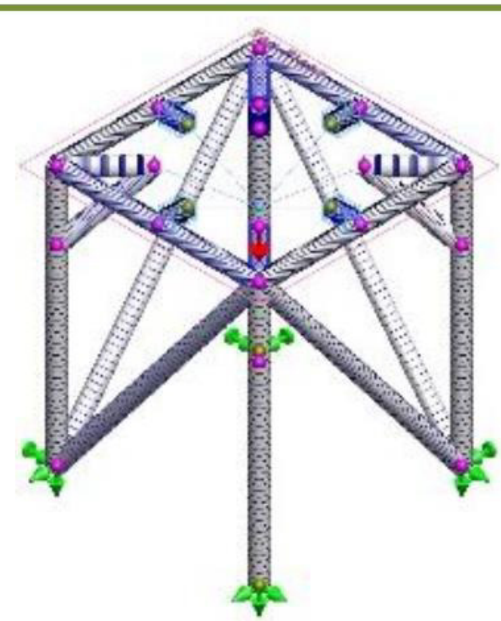
Mesh type	Beam Mesh

Mesh information - Details

Total Nodes	1246
Total Elements	1230
Time to complete mesh(hh;mm;ss):	00:00:02
Computer name:	BLACKBIRD

Mesh Control Information:

Mesh Control Name	Mesh Control Image	Mesh Control Details
Control-1		**Entities:** 8 Beam (s) **Number of Elements:** 50
Control-2		**Entities:** 8 Beam (s) **Number of Elements:** 30

Control-3		Entities: 4 Beam (s) Number of Elements: 100
Control-4		Entities: 4 Beam (s) Number of Elements: 20

Resultant Forces

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-0.000976563	91,636.5	-0.000488281	91,636.5

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	-0.00146484	9.43001e-06	-0.000244141	0.00148508

Free body forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0	0	0	0

Free body moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Beams

Beam Forces

Beam Name	Joints	Axial(N)	Shear1(N)	Shear2(N)	Moment1(N.m)	Moment2(N.m)	Torque(N.m)
Beam-49(Tube (square) TS5X5X0.375(1)[13])	1	-34,498.2	0.000275186	-3,068.87	-95.4428	-9.34513e-05	-5.36464e-05
	2	34,498.2	-0.000275194	2,868.41	-1,592.38	-6.30085e-05	5.36464e-05
Beam-50(Tube (square) TS5X5X0.375(1)[1])	1	720.396	2,845.63	2,845.6	977.722	-977.732	8.13777e-06
	2	-17,681.5	-2,716.51	-2,716.51	-2,338.89	2,338.89	-6.58422e-07
	3	18,239.2	2,716.51	2,716.51	-1,957.44	1,957.44	6.58422e-07
Beam-51(Tube (square) TS5X5X0.375(1)[21])	1	1,447	-1,156.01	-18.8317	-272.028	-158.452	168.522
	2	-1,447	1,156.01	-68.484	265.88	-127.835	-168.522
Beam-52(Tube (square) TS5X5X0.375(1)[7])	1	39,932.5	-582.594	-584.263	80.0876	249.156	-170.454
	2	-38,776.5	-864.403	-75.2881	-338.189	-357.534	-95.4271
	3	38,776.5	864.403	-220.242	277.439	-367.009	95.4271
Beam-53(Tube (square) TS5X5X0.375(1)[3])	1	720.367	-2,845.62	-2,845.65	-977.734	977.724	2.62456e-05
	2	-17,681.5	2,716.51	2,716.51	2,338.89	-2,338.89	-1.23513e-05
	3	18,239.2	-2,716.51	-2,716.51	1,957.44	-1,957.44	1.23513e-05
Beam-54(Tube (square) TS5X5X0.375(1)[9])	1	-49,591.5	870.961	8.46706e-05	2.13453e-05	-769.493	4.71723e-05
	2	49,591.5	-1,071.42	-8.46633e-05	2.67922e-05	217.324	-4.71723e-05
Beam-56(Tube (square) TS5X5X0.375(1)[10])	1	49,591.5	870.938	0.000127083	-1.50519e-05	769.492	4.76953e-05
	2	-49,591.5	-1,071.4	-0.000127098	-5.72058e-05	-217.336	-4.76954e-05
Beam-57(Tube (square) TS5X5X0.375(1)[24])	1	-1,447	-1,156.01	-18.8231	272.03	158.452	168.523
	2	1,447	1,156.01	-68.4927	-265.88	127.835	-168.523
Beam-59(Tube (square) TS5X5X0.375(1)[2])	1	-6,340.13	-3,009.2	3,009.2	-2,166.09	-2,166.09	1.38119e-06
	2	27,759.4	-2,730.37	2,730.4	921.937	921.928	-0.000148246
	3	6,905.45	3,009.2	-3,009.2	-2,658.84	-2,658.84	-1.38119e-06
Beam-60(Tube (square) TS5X5X0.375(1)[5])	1	38,776.5	864.404	-75.2874	338.188	-357.534	95.4257
	2	39,932.5	-582.594	288.736	445.96	239.174	-170.454
	3	-39,932.5	582.594	-584.266	-80.0852	249.156	170.454
Beam-61(Tube (square) TS5X5X0.375(1)[15])	1	18,431	-0.160562	-7,312.18	2,403.35	-0.0525814	9.53567e-05
	2	-18,230.6	0.0952311	7,111.78	3,394.2	-0.0456413	-9.53573e-05

Beam-62(Tube (square) TS5X5X0.375(1)[16])	1	20,342.1	-0.195081	8,869	-2,869.52	-0.0627944	-0.000242211
	2	-20,141.6	0.11641	-8,668.61	-4,179.54	-0.0564479	0.000242212
Beam-63(Tube (square) TS5X5X0.375(1)[6])	1	38,776.5	-864.403	-75.2903	338.189	357.534	-95.427
	2	-39,932.5	-582.593	-584.27	-80.0841	-249.155	-170.454
	3	39,932.5	582.593	288.739	445.962	-239.174	170.454
Beam-64(Tube (square) TS5X5X0.375(1)[8])	1	39,932.5	582.594	-584.26	80.0883	-249.156	170.454
	2	-38,776.5	864.404	-75.2852	-338.188	357.534	95.4258
	3	38,776.5	-864.404	-220.245	277.435	367.009	-95.4258
Beam-65(Tube (square) TS5X5X0.375(1)[23])	1	1,447	1,156.01	-18.8258	-272.031	158.451	-168.521
	2	-1,447	-1,156.01	-68.49	265.881	127.835	168.521
Beam-66(Tube (square) TS5X5X0.375(1)[11])	1	-18,431	-7,312.22	0.000118093	-0.000115331	2,403.37	0.000102938
	2	18,230.6	7,111.83	-0.000118083	0.00021026	3,394.22	-0.000102939
Beam-67(Tube (square) TS5X5X0.375(1)[4])	1	27,759.4	2,730.39	-2,730.36	-921.925	-921.934	-5.60447e-07
	2	-6,340.13	3,009.2	-3,009.2	2,166.09	2,166.09	-4.94952e-06
	3	6,905.45	-3,009.2	3,009.2	2,658.84	2,658.84	4.94952e-06
Beam-69(Tube (square) TS5X5X0.375(1)[14])	1	20,141.6	0.115202	8,668.6	-4,179.53	0.0552154	0.000219421
	2	-20,342	-0.193873	-8,868.99	-2,869.52	0.063056	-0.00021942
Beam-72(Tube (square) TS5X5X0.375(1)[22])	1	-1,447	1,156.01	-18.8166	272.033	-158.452	-168.522
	2	1,447	-1,156.01	-68.4991	-265.881	-127.835	168.522
Beam-81(Tube (square) TS5X5X0.375(1)[23])	1	-21,144.1	-464.429	-410.059	-429.067	301.552	-59.8566
	2	20,386.1	-126.641	410.059	-688.841	158.854	59.8573
Beam-83(Tube (square) TS5X5X0.375(1)[21])	1	20,386.1	410.058	126.645	158.848	688.843	59.8579
	2	0	0	0	0	0	0
Beam-84(Tube (square) TS5X5X0.375(1)[24])	1	20,386.1	410.058	-126.644	-158.849	688.842	-59.8574
	2	0	0	0	0	0	0
Beam-85(Tube (square) TS5X5X0.375(1)[12])	1	34,498.2	0.00167513	-3,068.84	95.4334	0.000741015	-0.00013064
	2	-34,498.2	-0.00167514	2,868.38	1,592.37	0.000211382	0.00013064
Beam-87(Trim/Extend1[1])	1	-21,144.1	464.43	-410.058	-429.067	-301.553	59.859
	2	20,386.1	126.64	410.058	-688.841	-158.855	-59.8597

Beam Stresses

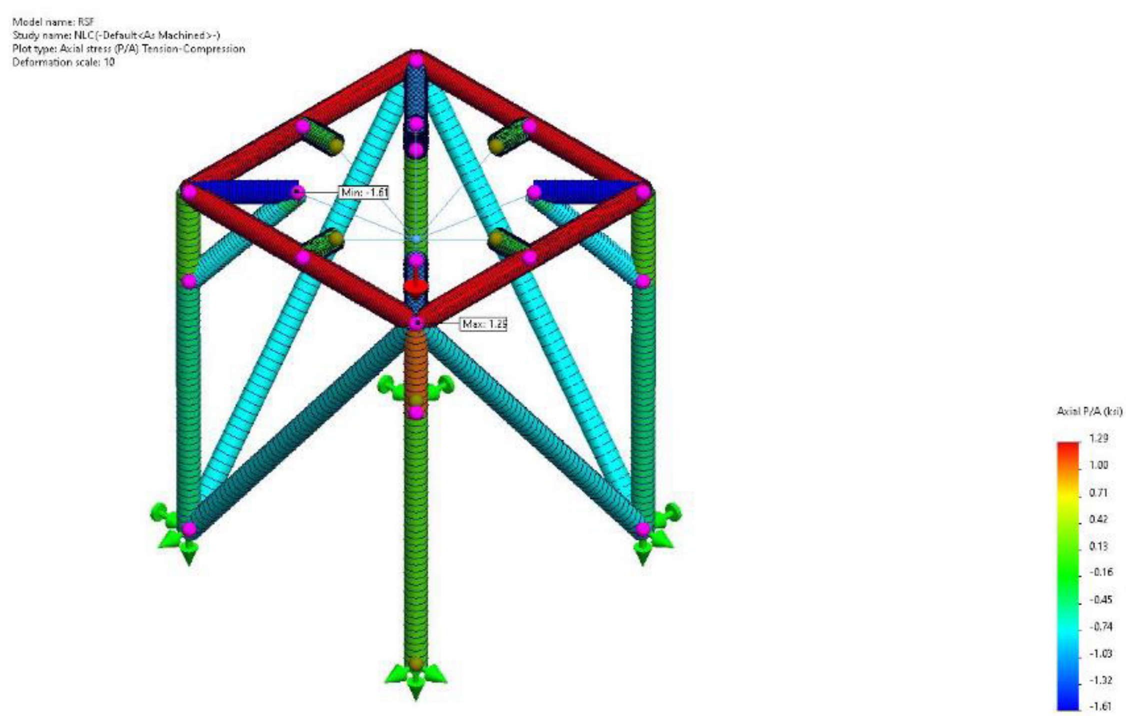
Beam Name	Joints	Axial(N/m^2)	Bending Dir1(N/m^2)	Bending Dir2(N/m^2)	Torsional (N/m^2)	Upper bound axial and bending(N/m^2)
Beam-49(Tube (square) TS5X5X0.375(1)[13])	1	-7.70773e+06	-584,872	0.572668	-0.299737	8.2926e+06

	2	- 7.70773e+06	9.75807e+06	-0.386115	-0.299737	1.74658e+07
Beam-50(Tube (square) TS5X5X0.375(1)[1])	1	160,954	5.99147e+06	5.99153e+06	0.0454679	1.2144e+07
	2	- 3.95048e+06	-1.43327e+07	-1.43327e+07	-0.00367878	3.26159e+07
	3	- 4.07506e+06	1.19952e+07	1.19952e+07	-0.00367879	2.80654e+07
Beam-51(Tube (square) TS5X5X0.375(1)[21])	1	-323,294	1.66699e+06	-970,991	-941,580	2.96127e+06
	2	-323,294	1.62931e+06	783,371	-941,580	2.73597e+06
Beam-52(Tube (square) TS5X5X0.375(1)[7])	1	8.92188e+06	490,776	-1.52682e+06	-952,373	1.09395e+07
	2	8.6636e+06	2.07242e+06	-2.19096e+06	533,177	1.2927e+07
	3	8.6636e+06	1.70014e+06	2.24903e+06	533,177	1.26128e+07
Beam-53(Tube (square) TS5X5X0.375(1)[3])	1	160,947	-5.99154e+06	-5.99148e+06	0.146641	1.2144e+07
	2	- 3.95048e+06	1.43327e+07	1.43327e+07	-0.06901	3.26159e+07
	3	- 4.07506e+06	-1.19952e+07	-1.19952e+07	-0.06901	2.80654e+07
Beam-54(Tube (square) TS5X5X0.375(1)[9])	1	- 1.10799e+07	0.130804	4.71544e+06	0.263594	1.57954e+07
	2	- 1.10799e+07	-0.164183	1.33176e+06	0.263594	1.24117e+07
Beam-56(Tube (square) TS5X5X0.375(1)[10])	1	- 1.10799e+07	0.0922382	4.71544e+06	-0.266517	1.57954e+07
	2	- 1.10799e+07	-0.350557	1.33183e+06	-0.266517	1.24118e+07
Beam-57(Tube (square) TS5X5X0.375(1)[24])	1	-323,294	1.667e+06	-970,991	941,586	2.96128e+06
	2	-323,294	1.62931e+06	783,371	941,586	2.73597e+06
Beam-59(Tube (square) TS5X5X0.375(1)[2])	1	1.41654e+06	1.32738e+07	-1.32738e+07	-0.00771708	2.79641e+07
	2	6.20212e+06	5.64962e+06	-5.64956e+06	-0.828289	1.75013e+07
	3	1.54284e+06	-1.62933e+07	1.62933e+07	-0.00771707	3.41295e+07
Beam-60(Tube (square) TS5X5X0.375(1)[5])	1	8.6636e+06	2.07241e+06	2.19097e+06	533,170	1.2927e+07
	2	8.92188e+06	2.73284e+06	-1.46566e+06	-952,374	1.31204e+07
	3	8.92188e+06	490,761	1.52683e+06	-952,374	1.09395e+07
Beam-61(Tube (square) TS5X5X0.375(1)[15])	1	- 4.11793e+06	-1.47277e+07	-322.218	-0.532844	1.8846e+07
	2	- 4.07316e+06	2.07996e+07	279.689	-0.532848	2.48731e+07
Beam-62(Tube (square) TS5X5X0.375(1)[16])	1	-4.5449e+06	1.75844e+07	-384.804	1.35345	2.21297e+07
	2	- 4.50012e+06	-2.56121e+07	345.912	1.35346	3.01126e+07
Beam-63(Tube (square) TS5X5X0.375(1)[6])	1	8.6636e+06	2.07242e+06	-2.19096e+06	-533,177	1.2927e+07
	2	8.92188e+06	490,755	-1.52682e+06	952,372	1.09395e+07
	3	8.92188e+06	2.73285e+06	1.46565e+06	952,372	1.31204e+07
Beam-64(Tube (square) TS5X5X0.375(1)[8])	1	8.92188e+06	490,780	1.52683e+06	952,375	1.09395e+07
	2	8.6636e+06	2.07241e+06	2.19097e+06	-533,170	1.2927e+07
	3	8.6636e+06	1.70012e+06	-2.24903e+06	-533,170	1.26127e+07
Beam-65(Tube (square) TS5X5X0.375(1)[23])	1	-323,294	1.667e+06	970,989	941,573	2.96128e+06
	2	-323,294	1.62932e+06	-783,370	941,573	2.73598e+06

Beam-66(Tube (square) TS5X5X0.375(1)[11])	1	-4.11793e+06	-0.706744	-1.47278e+07	0.575143	1.88458e+07
	2	-4.07316e+06	-1.28847	2.07997e+07	0.575146	2.48729e+07
Beam-67(Tube (square) TS5X5X0.375(1)[4])	1	6.20212e+06	-5.64954e+06	5.6496e+06	-0.00313137	1.75013e+07
	2	1.41654e+06	-1.32738e+07	1.32738e+07	0.0276543	2.79641e+07
	3	1.54284e+06	1.62933e+07	-1.62933e+07	0.0276543	3.41295e+07
Beam-69(Tube (square) TS5X5X0.375(1)[14])	1	-4.50012e+06	2.56121e+07	338.359	-1.2261	3.01126e+07
	2	-4.54489e+06	-1.75844e+07	-386.406	-1.2261	2.21296e+07
Beam-72(Tube (square) TS5X5X0.375(1)[22])	1	-323,293	1.66701e+06	970,990	-941,578	2.9613e+06
	2	-323,293	1.62932e+06	-783,371	-941,578	2.73598e+06
Beam-81(Tube (square) TS5X5X0.375(1)[23])	1	-4.72409e+06	-2.62932e+06	-1.84791e+06	-334,467	9.20132e+06
	2	-4.55474e+06	4.22121e+06	973,452	-334,470	9.7494e+06
Beam-83(Tube (square) TS5X5X0.375(1)[21])	1	-4.55474e+06	-973,422	4.22122e+06	-334,481	9.74938e+06
	2	0	0	0	0	0
Beam-84(Tube (square) TS5X5X0.375(1)[24])	1	-4.55474e+06	973,422	4.22122e+06	334,478	9.74938e+06
	2	0	0	0	0	0
Beam-85(Tube (square) TS5X5X0.375(1)[12])	1	-7.70773e+06	-584,815	4.54093	0.730003	8.29254e+06
	2	-7.70773e+06	9.75801e+06	-1.29535	0.730003	1.74657e+07
Beam-87(Trim/Extend1[1])	1	-4.72409e+06	-2.62932e+06	1.84792e+06	334,449	9.20133e+06
	2	-4.55474e+06	4.22121e+06	-973,462	334,452	9.74941e+06

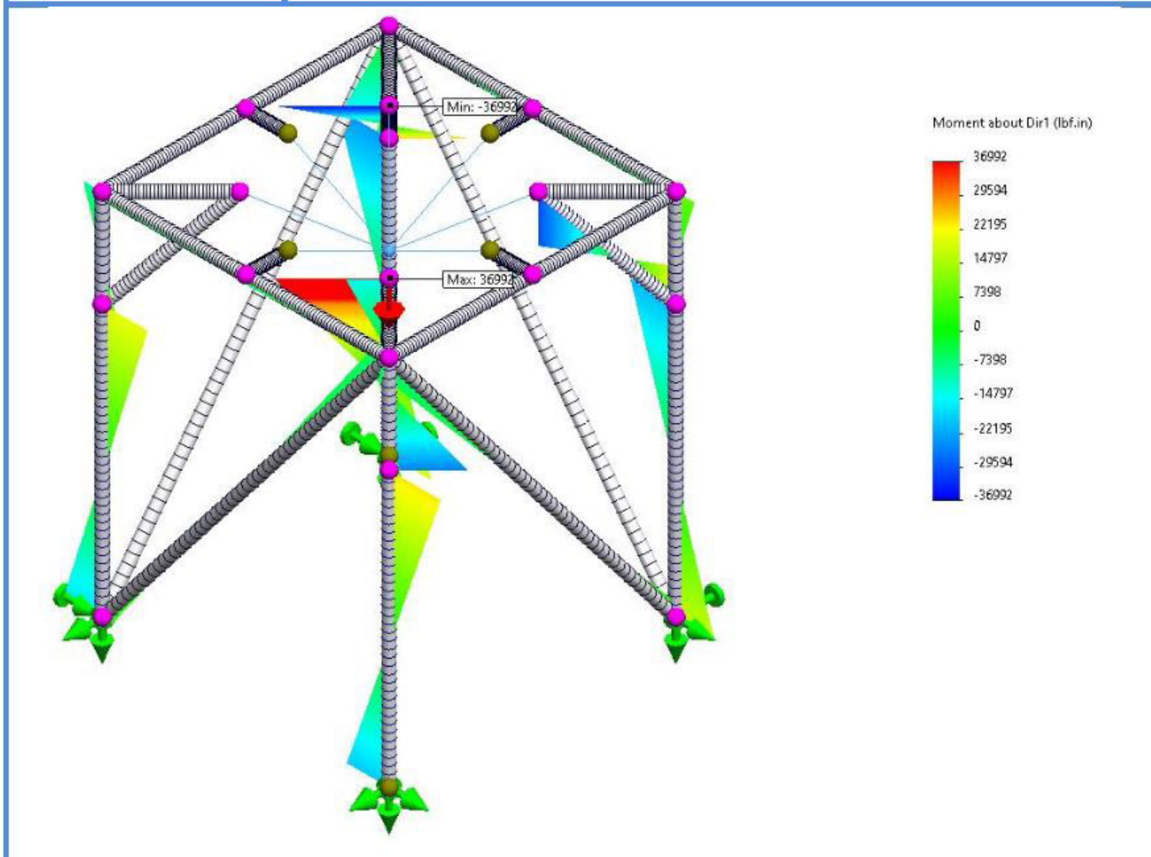
Study Results

Name	Type	Min	Max
Tension-Compression	Axial P/A	-1.61ksi Element: 267	1.29ksi Element: 593



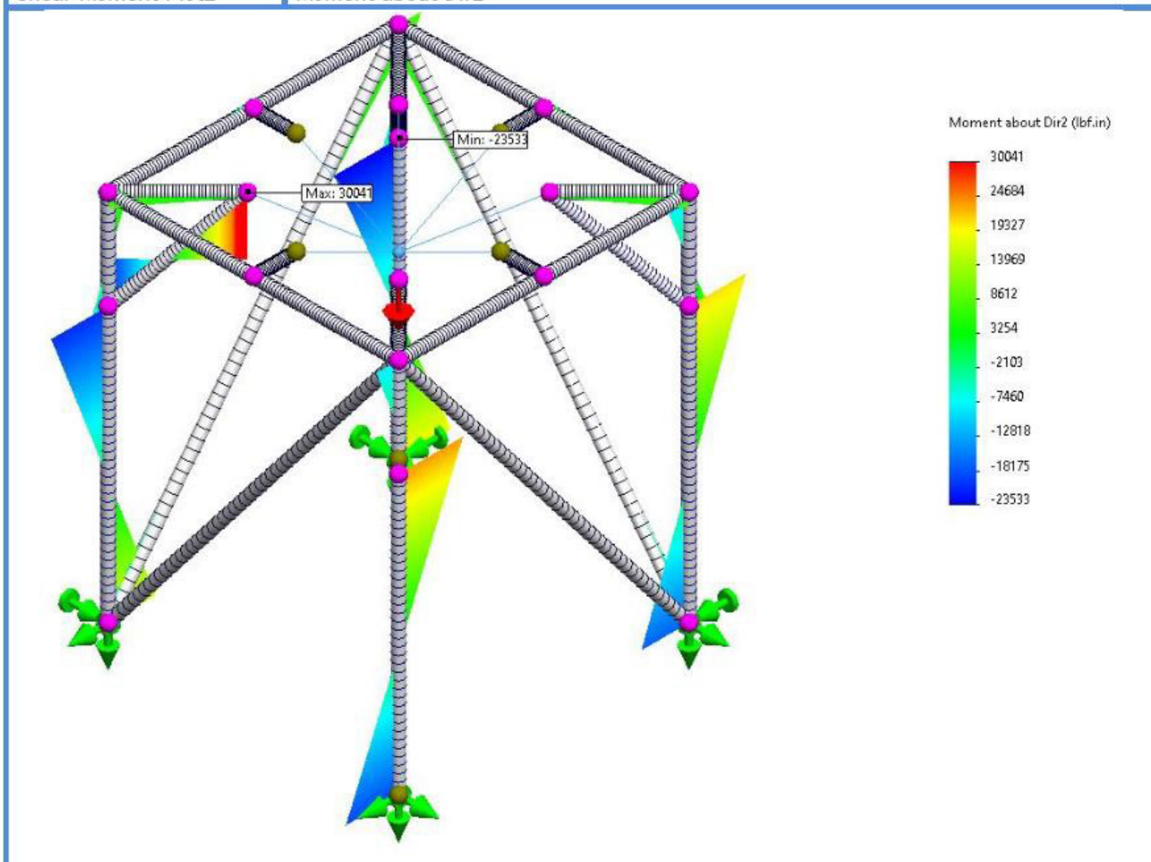
RSF-NLC-Stress-Tension-Compression

Name	Type
Shear-Moment Plot1	Moment about Dir1



RSF-NLC-Shear-Moment Plot-Shear-Moment Plot1

Name	Type
Shear-Moment Plot2	Moment about Dir2



RSF-NLC-Shear-Moment Plot-Shear-Moment Plot2

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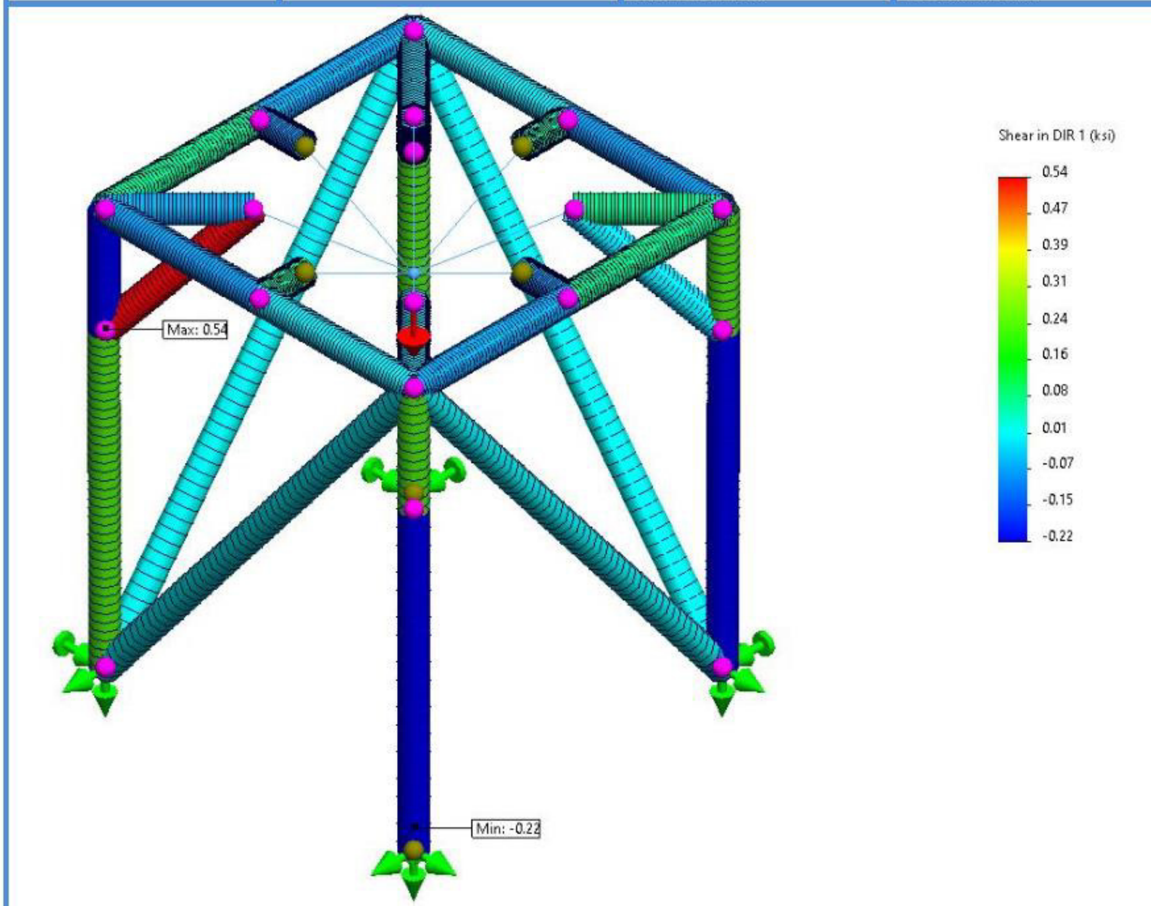
9/5/2023

Name	Type	Min	Max
Shear 1	Shear in DIR 1	-0.22ksi Element: 370	0.54ksi Element: 856



RSF-NLC-Stress-Shear 1

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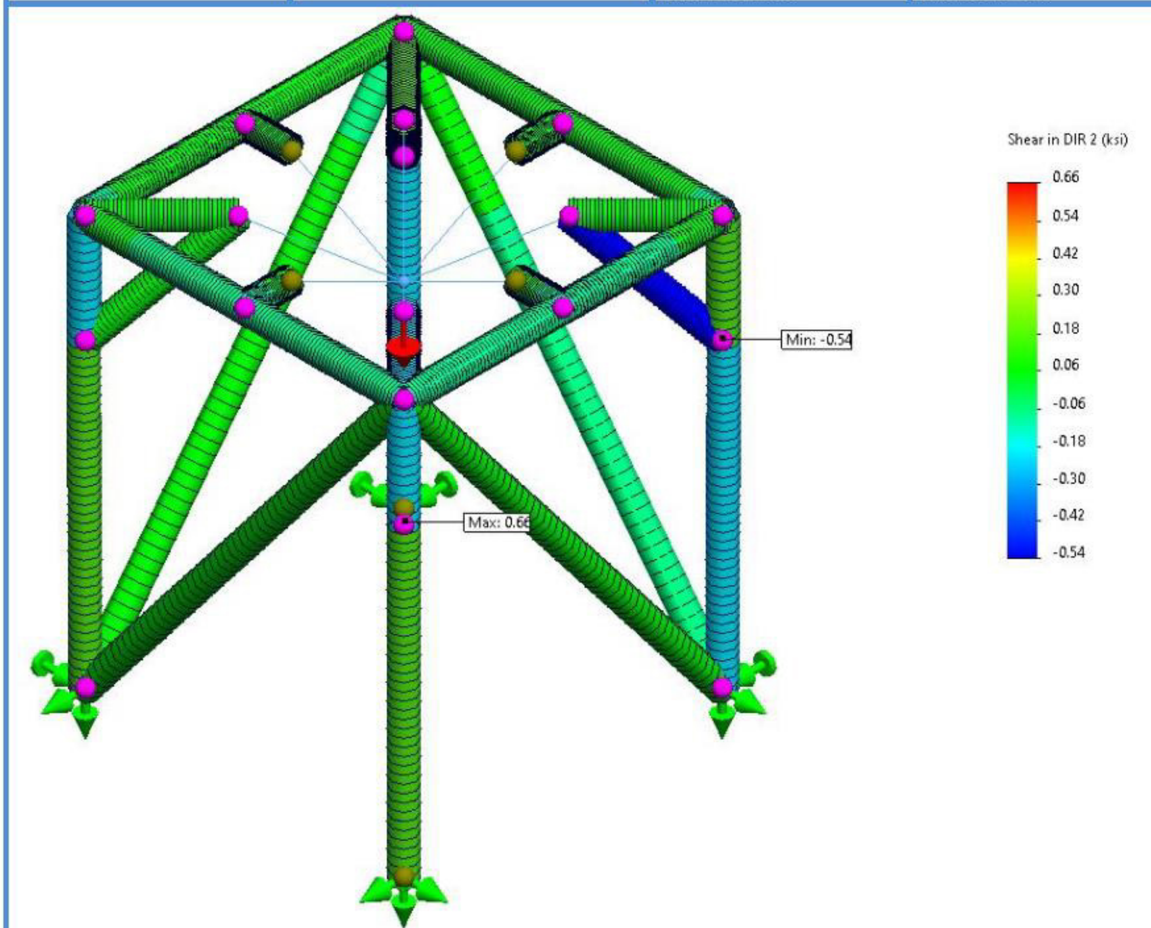
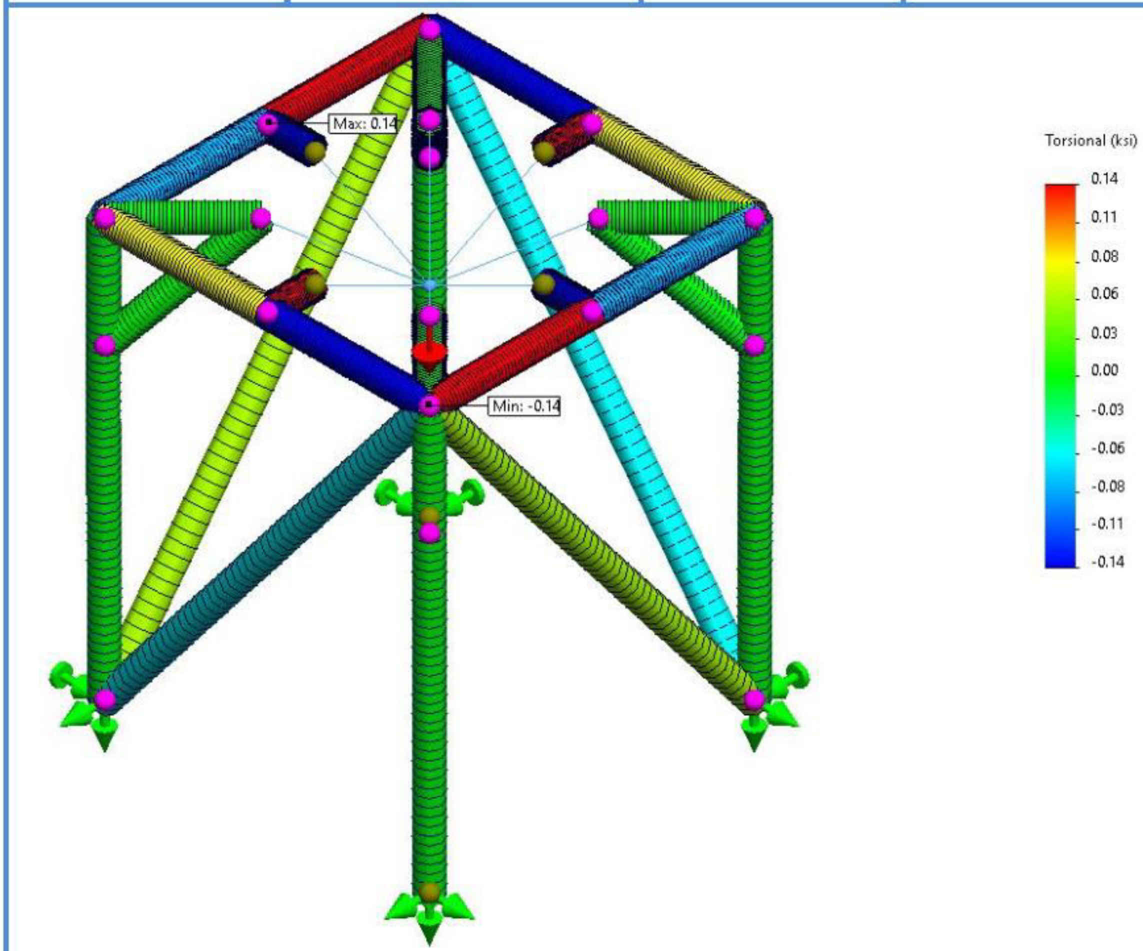
Name	Type	Min	Max
Shear 2	Shear in DIR 2	-0.54ksi Element: 519	0.66ksi Element: 556



RSF-NLC-Stress-Shear 2

Name	Type	Min	Max
Torsional	Torsional	-0.14ksi Element: 419	0.14ksi Element: 743



RSF-NLC-Stress-Torsional

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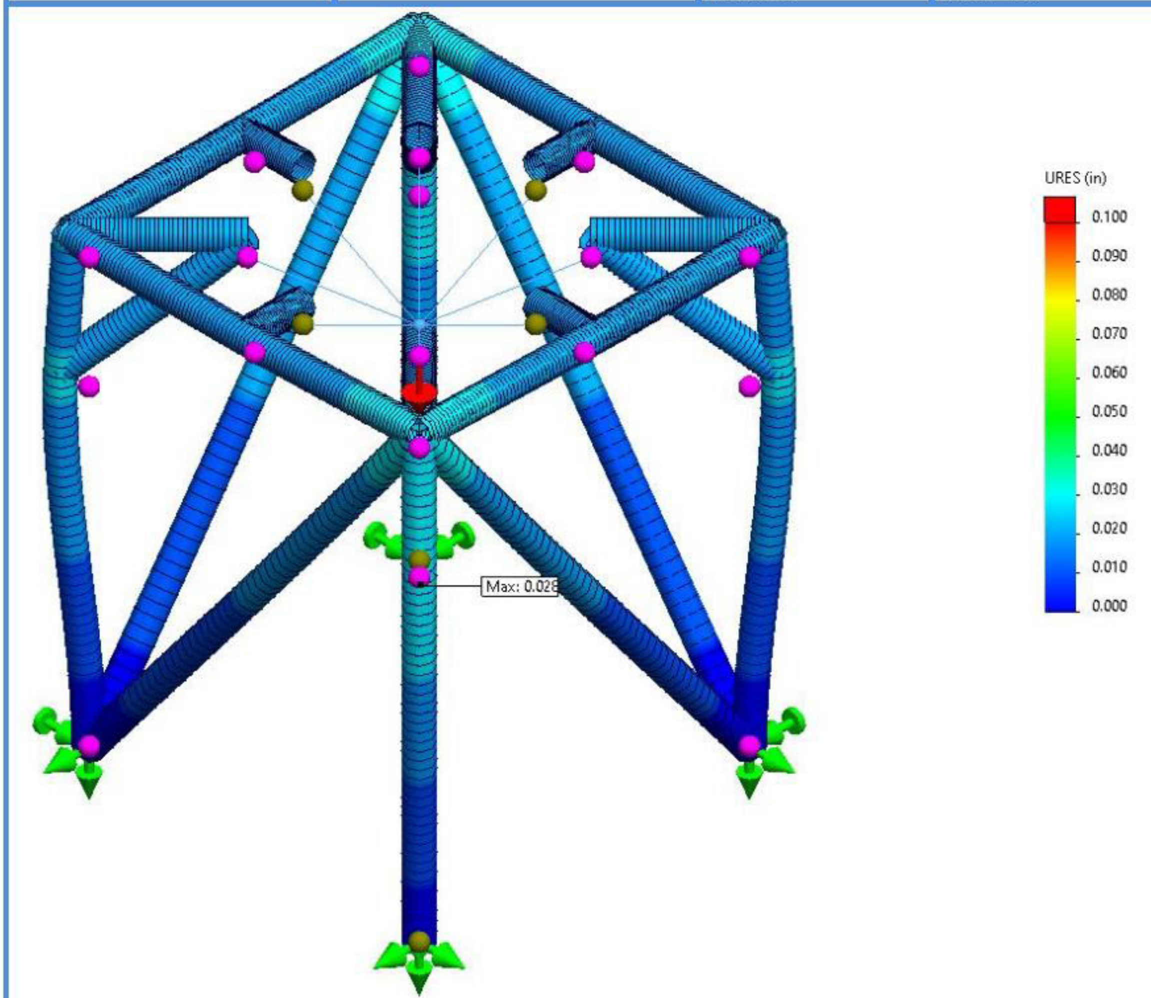
Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000in Node: 39	0.028in Node: 409

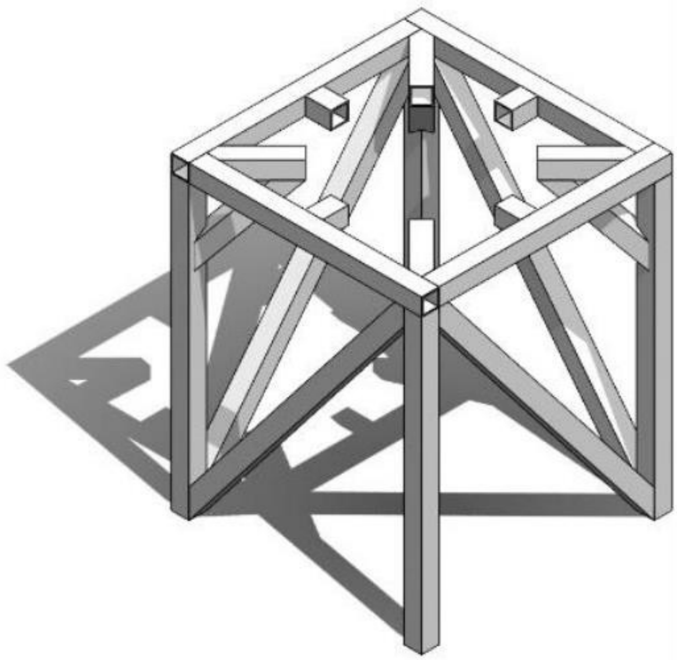


RSF-NLC-Displacement-Displacement1

Appendix B

Seismic Analysis Results Report

1935 International Way
Idaho Falls, ID 83402
Phone: 208.524.2286
Fax: Fax: 208-522-4269
https://www.walshengr.com/



Simulation of RSF

Date: Tuesday, September 5, 2023
Designer: Mat Floyd
Study name: ELC
Analysis type: Static

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Units 9
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Mesh information.................................. 16
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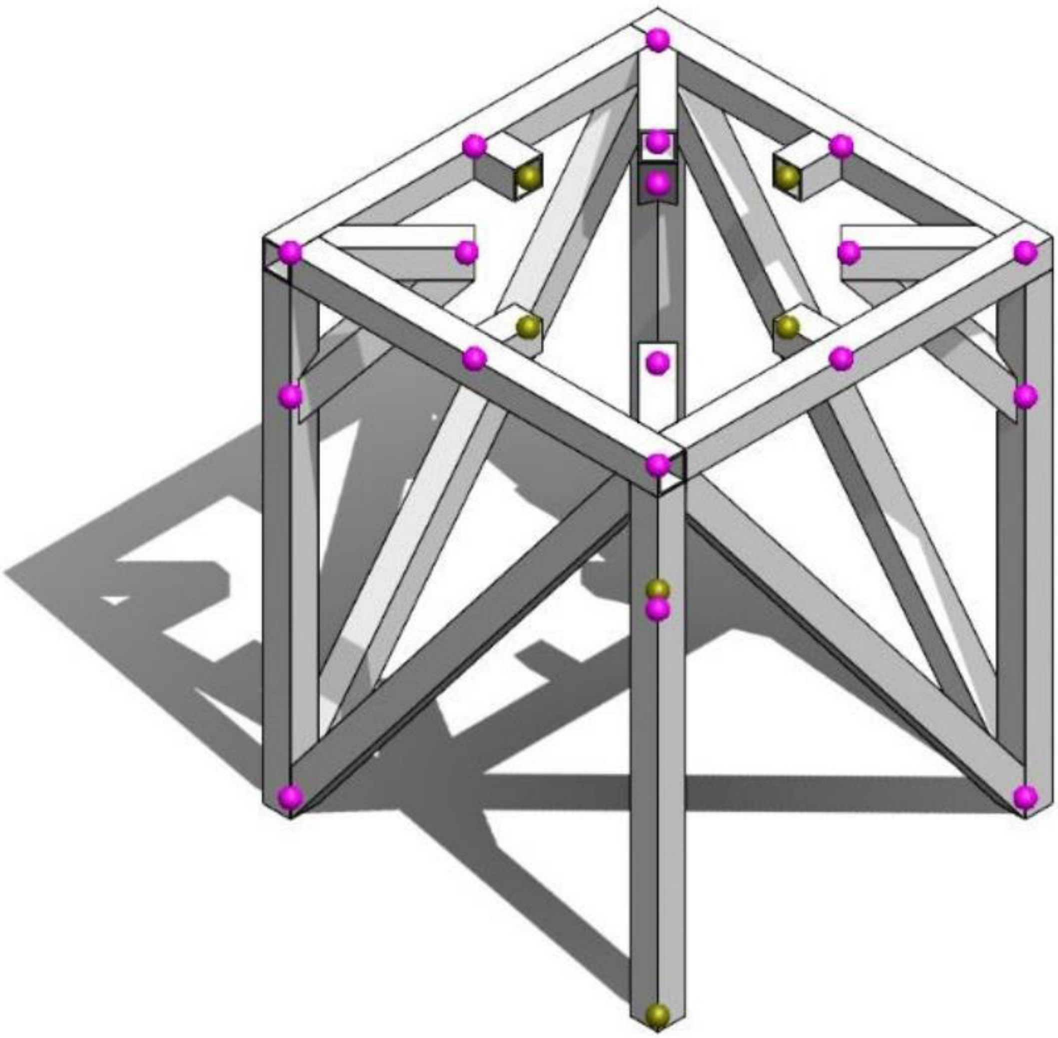
1935 International Way
Idaho Falls, ID 83402

Mat Floyd
9/5/2023

Model Information



Model name: RSF
Current Configuration: Default<As Machined>

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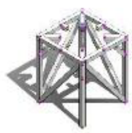
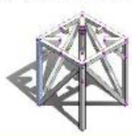
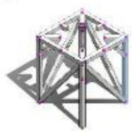
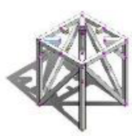
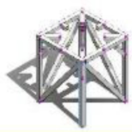
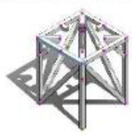
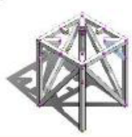
Idaho Falls, ID 83402

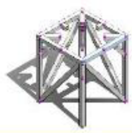
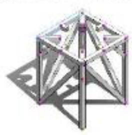
Mat Floyd
9/5/2023

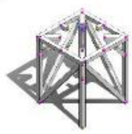
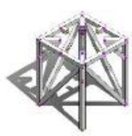
Beam Bodies:

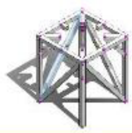
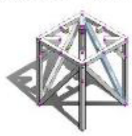
Document Name and Reference	Formulation	Properties	Document Path/Date Modified
SolidBody 1(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[13]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:460.892mm** **Volume:0.00206286m^3** **Mass Density:8,030kg/m^3** **Mass:16.5647kg** **Weight:162.335N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 2(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[1]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:2,108.2mm** **Volume:0.00943588m^3** **Mass Density:8,030kg/m^3** **Mass:75.7701kg** **Weight:742.547N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 3(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[17])	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:184.15mm** **Volume:0.000824218m^3** **Mass Density:8,030kg/m^3** **Mass:6.61847kg** **Weight:64.861N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 4(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[7]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:1,676.4mm** **Volume:0.00750323m^3** **Mass Density:8,030kg/m^3** **Mass:60.2509kg** **Weight:590.459N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023

SolidBody 5(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[3]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:2,108.2mm** **Volume:0.00943588m^3** **Mass Density:8,030kg/m^3** **Mass:75.7701kg** **Weight:742.547N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 6(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[9]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:460.892mm** **Volume:0.00206286m^3** **Mass Density:8,030kg/m^3** **Mass:16.5647kg** **Weight:162.335N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 8(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[10]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:460.892mm** **Volume:0.00206286m^3** **Mass Density:8,030kg/m^3** **Mass:16.5647kg** **Weight:162.335N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 9(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[20])	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:184.15mm** **Volume:0.000824218m^3** **Mass Density:8,030kg/m^3** **Mass:6.61847kg** **Weight:64.861N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 11(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[2])	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:2,108.2mm** **Volume:0.00943588m^3** **Mass Density:8,030kg/m^3**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023

		**Mass:75.7701kg** **Weight:742.547N**	
SolidBody 12(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[5]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:1,676.4mm** **Volume:0.00750323m^3** **Mass Density:8,030kg/m^3** **Mass:60.2509kg** **Weight:590.459N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 13(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[15]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:649.507mm** **Volume:0.00290706m^3** **Mass Density:8,030kg/m^3** **Mass:23.3437kg** **Weight:228.768N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 14(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[16]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:649.507mm** **Volume:0.00290706m^3** **Mass Density:8,030kg/m^3** **Mass:23.3437kg** **Weight:228.768N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 15(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[6])	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:1,676.4mm** **Volume:0.00750323m^3** **Mass Density:8,030kg/m^3** **Mass:60.2509kg** **Weight:590.459N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023

			
SolidBody 16(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[8]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:1,676.4mm Volume:0.00750323m^3 Mass Density:8,030kg/m^3 Mass:60.2509kg Weight:590.459N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 17(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[19])	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:184.15mm Volume:0.000824218m^3 Mass Density:8,030kg/m^3 Mass:6.61847kg Weight:64.861N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 18(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[11]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:649.507mm Volume:0.00290706m^3 Mass Density:8,030kg/m^3 Mass:23.3437kg Weight:228.768N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 19(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[4]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:2,108.2mm Volume:0.00943588m^3 Mass Density:8,030kg/m^3 Mass:75.7701kg Weight:742.547N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023

SolidBody 21(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[14]) 	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:649.507mm Volume:0.00290706m^3 Mass Density:8,030kg/m^3 Mass:23.3437kg Weight:228.768N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023
SolidBody 23(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[12]) 	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:460.892mm Volume:0.00206286m^3 Mass Density:8,030kg/m^3 Mass:16.5647kg Weight:162.335N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023
SolidBody 24(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[18])	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:184.15mm Volume:0.000824218m^3 Mass Density:8,030kg/m^3 Mass:6.61847kg Weight:64.861N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023
SolidBody 42(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[23]) 	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:2,482.8mm Volume:0.0111224m^3 Mass Density:8,030kg/m^3 Mass:89.3125kg Weight:875.262N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023
SolidBody 43(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(Trim/Extend2)	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:2,482.8mm Volume:0.0111224m^3 Mass Density:8,030kg/m^3 Mass:89.3125kg Weight:875.262N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023

			
SolidBody 44(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[21]) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:2,482.8mm** **Volume:0.0111224m^3** **Mass Density:8,030kg/m^3** **Mass:89.3125kg** **Weight:875.262N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023
SolidBody 45(Trim/Extend1) 	Beam - Uniform C/S	**Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall** **Section Area: 0.0044758m^2** **Length:2,482.8mm** **Volume:0.0111224m^3** **Mass Density:8,030kg/m^3** **Mass:89.3125kg** **Weight:875.262N**	**C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT** Sep 5 12:45:02 2023

Study Properties

Study name	ELC
Analysis type	Static
Mesh type	Beam Mesh
Solver type	Automatic
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Result folder	SOLIDWORKS document (C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23)

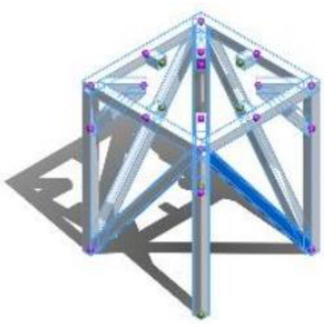
WALSH ENGINEERING SERVICES
1935 International Way
Idaho Falls, ID 83402

Mat Floyd
9/5/2023

Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

Model Reference	Properties	Components
	**Name:** SA 240 316H **Model type:** Linear Elastic Isotropic **Default failure criterion:** Max von Mises Stress **Yield strength:** Temp dependent **Tensile strength:** Temp dependent **Elastic modulus:** Temp dependent **Poisson's ratio:** 0.31 **Mass density:** 8,030 kg/m^3 **Thermal expansion coefficient:** Temp dependent	SolidBody 1(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[13])(RSF), SolidBody 2(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[1])(RSF), SolidBody 3(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[17])(RSF), SolidBody 4(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[7])(RSF), SolidBody 5(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[3])(RSF), SolidBody 6(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[9])(RSF), SolidBody 8(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[10])(RSF), SolidBody 9(Tube square TS5X5X0.375(Tube (square)

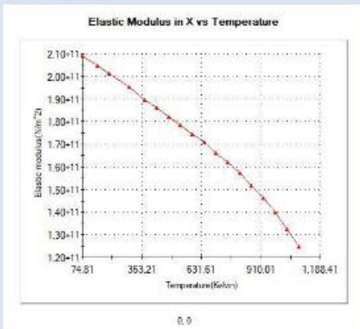
		TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[20])(RSF), SolidBody 11(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[2])(RSF), SolidBody 12(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[5])(RSF), SolidBody 13(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[15])(RSF), SolidBody 14(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[16])(RSF), SolidBody 15(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[6])(RSF), SolidBody 16(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[8])(RSF), SolidBody 17(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[19])(RSF), SolidBody 18(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square)

		TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[11])(RSF), SolidBody 19(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[4])(RSF), SolidBody 21(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[14])(RSF), SolidBody 23(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[12])(RSF), SolidBody 24(Tube square TS5X5X0.375(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[18])(RSF), SolidBody 42(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[23])(RSF), SolidBody 43(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(Trim/Extend2)(RSF), SolidBody 44(Tube (square) TS5X5X0.375(Al tube (square) 5 SQ X .375 WALL(1)[21])(RSF), SolidBody 45(Trim/Extend1)(RSF)

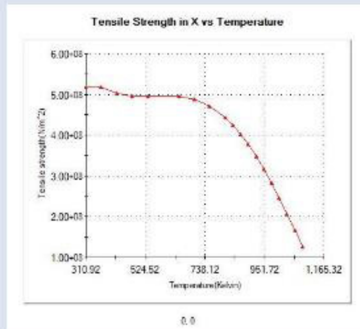
1935 International Way
Idaho Falls, ID 83402

Mat Floyd
9/5/2023

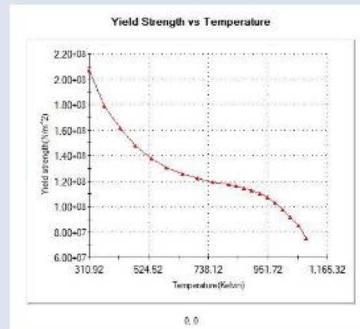
Curve Data:



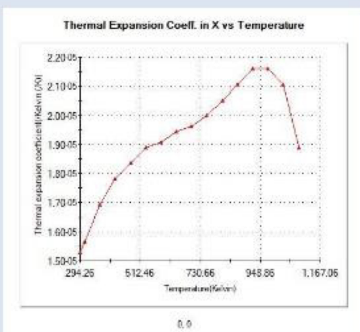
Elastic Modulus in X vs Temperature



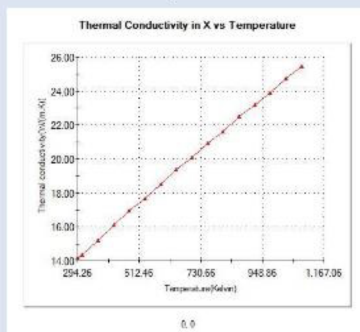
Tensile Strength in X vs Temperature



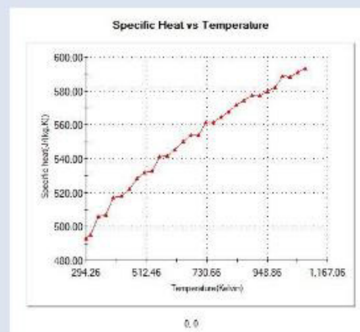
Yield Strength vs Temperature



Thermal Expansion Coeff. in X vs Temperature

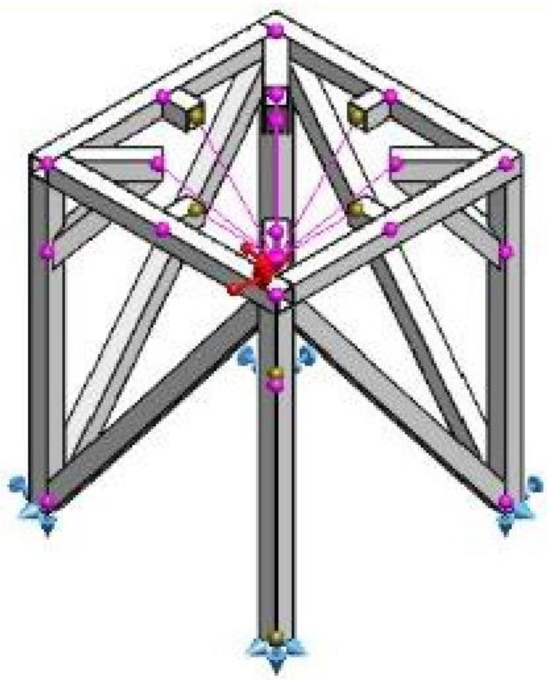


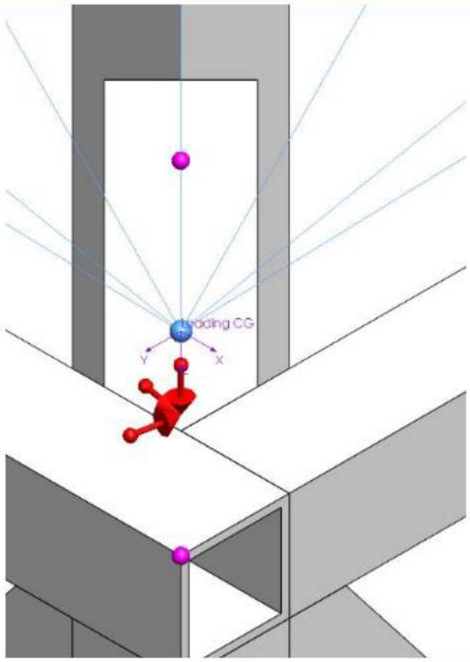
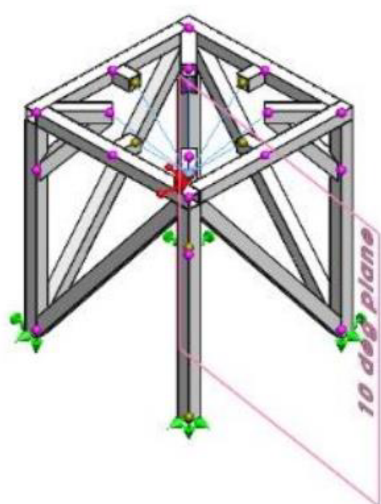
Thermal Conductivity in X vs Temperature



Specific Heat vs Temperature

Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		Entities: 4 Joint(s) Type: Fixed Geometry

<table>
<tr><th>Load name</th><th>Load Image</th><th>Load Details</th></tr>
<tr><td>Remote Load/Mass (Rigid connection)-1</td><td></td><td>Connection Type: Rigid
Coordinate System: Loading CG
Translational Components: ---,---,---
Rotational Components: ---,---,---
Reference coordinates: 0 0 0 in
Remote Mass: 18000 lb
Moment of Inertia: 0,0,0,0,0,0 lb.in^2</td></tr>
<tr><td>Gravity-1</td><td></td><td>Reference: 10 deg plane
Values: 531.826 145.605 -145.605
Units: in/s^2</td></tr>
</table>

Mesh information

Mesh type	Beam Mesh

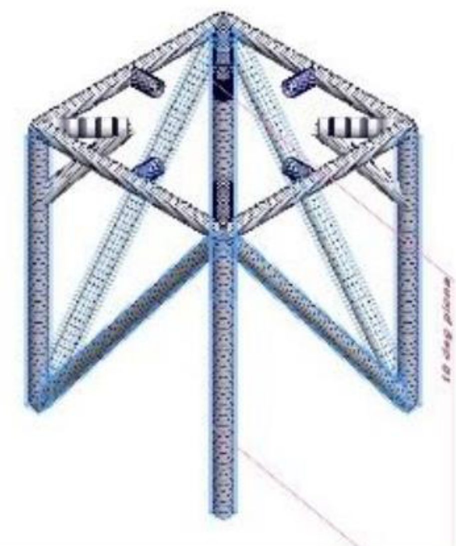
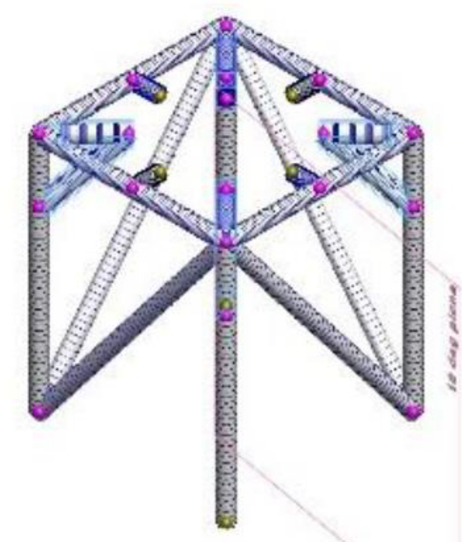
Mesh information - Details

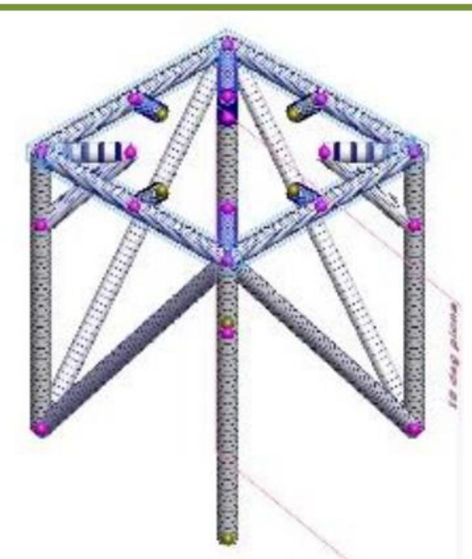
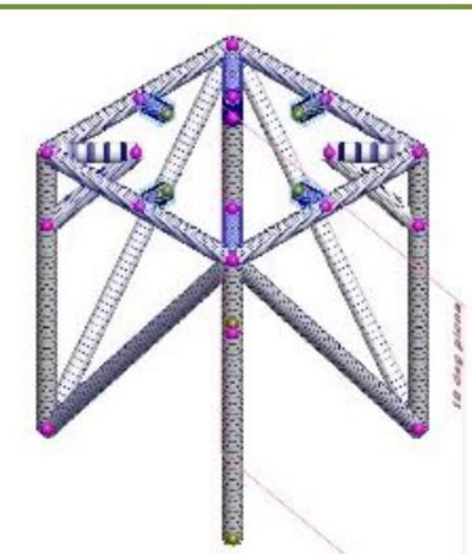
Total Nodes	1164
Total Elements	1148
Time to complete mesh(hh;mm;ss):	00:00:02
Computer name:	BLACKBIRD

1935 International Way
Idaho Falls, ID 83402

Mat Floyd
9/5/2023

Mesh Control Information:

Mesh Control Name	Mesh Control Image	Mesh Control Details
Control-1		Entities: 8 Beam (s) Number of Elements: 50
Control-2		Entities: 8 Beam (s) Number of Elements: 30

Control-3		Entities: 4 Beam (s) Number of Elements: 80
Control-4		Entities: 4 Beam (s) Number of Elements: 20

Resultant Forces

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-40,021.2	126,184	28,023.1	135,312

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	2,186.52	-0.00244522	3,523.8	4,147.05

Free body forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0	0	0	0

Free body moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Beams

Beam Forces

Beam Name	Joints	Axial(N)	Shear1(N)	Shear2(N)	Moment1(N.m)	Moment2(N.m)	Torque(N.m)
Beam-49(Tube (square) TS5X5X0.375(1)[13])	1	-30,290.6	-2,125.53	-6,705.27	-608.956	440.188	104.704
	2	30,309.2	2,020.28	6,429.24	-3,124.85	738.363	-104.704
Beam-50(Tube (square) TS5X5X0.375(1)[1])	1	-6,712.16	1,842.18	1,819.81	621.974	-726.728	3.36431
	2	-29,054.9	-2,834.54	-3,025.27	-2,679.74	2,556.83	-2.65804
	3	29,822.7	2,591.01	2,854.74	-1,970.07	1,733.59	2.65804
Beam-51(Tube (square) TS5X5X0.375(1)[21])	1	1,154.91	2,574.63	2,586.58	-1,179.25	509.038	100.941
	2	-1,116.78	-2,601.33	-2,706.81	523.794	131.876	-100.941
Beam-52(Tube (square) TS5X5X0.375(1)[7])	1	53,959.8	-407.407	-900.563	214.708	124.038	-247.674
	2	-47,884.5	-1,466.65	-405.288	-293.524	-533.272	-84.0693
	3	48,013.6	1,376.55	-1.65732	462.686	-658.313	84.0671
Beam-53(Tube (square) TS5X5X0.375(1)[3])	1	739.134	-3,817.01	-3,839.4	-1,122.88	1,018.12	-3.36392
	2	-21,106.3	3,682.29	3,491.56	3,018.54	-3,141.44	2.65788
	3	21,874.1	-3,925.82	-3,662.09	2,638.43	-2,874.91	-2.65788
Beam-54(Tube (square) TS5X5X0.375(1)[9])	1	-39,529.3	-4,219.97	-64.2181	-9.83887	-228.504	-14.2757
	2	39,634.5	3,943.94	45.6594	-21.3965	2,549.29	14.2757
Beam-56(Tube (square) TS5X5X0.375(1)[10])	1	60,195.2	1,330.29	-64.2151	9.83826	917.265	-14.2757
	2	-60,090	-1,606.32	45.6563	21.3954	-82.4598	14.2757
Beam-57(Tube (square) TS5X5X0.375(1)[24])	1	-1,188.59	3,191.5	2,134.52	1,034.74	-602.932	44.3875
	2	1,161.88	-3,229.63	-2,254.76	-491.234	-192.163	-44.3875
Beam-59(Tube (square) TS5X5X0.375(1)[2])	1	5,069.6	-4,279.79	3,110.08	-2,175.39	-3,108.29	48.0352
	2	20,828	-3,583.48	2,718.85	1,052.21	899.183	41.3435
	3	-4,291.15	4,032.89	-3,282.96	-2,949.89	-3,555.96	-48.0352
Beam-60(Tube (square) TS5X5X0.375(1)[5])	1	30,034.3	276.86	-1,136.39	296.882	-186.983	260.193
	2	26,675.6	-794.638	1,525.31	1,123.24	275.193	-231.039
	3	-26,546.5	704.111	-1,932.26	325.822	352.933	231.041
Beam-61(Tube (square) TS5X5X0.375(1)[15])	1	22,591	100.336	-7,915.98	2,822.82	-14.9566	-23.4193
	2	-22,209.8	-74.1656	7,745.24	3,472.04	85.0986	23.4194
Beam-62(Tube (square) TS5X5X0.375(1)[16])	1	24,360.6	1,036.25	10,776	-3,452.81	61.1707	65.1555
	2	-24,066	-887.526	-10,518.6	-5,106.34	712.076	-65.1563
Beam-63(Tube (square) TS5X5X0.375(1)[6])	1	47,825.2	-1,457.52	-185.881	380.104	520.07	-86.0919
	2	-53,194.8	-539.043	-667.91	-255.838	-168.54	-213.092
	3	53,104.4	410.276	260.964	645.131	-229.319	213.089
Beam-64(Tube (square) TS5X5X0.375(1)[8])	1	27,311.5	572.481	-2,164.9	-366.949	-308.435	265.623
	2	-30,093.6	285.997	-1,355.8	-210.302	200.186	258.171
	3	30,003.2	-415.237	948.854	1,176.18	93.7008	-258.167
Beam-65(Tube (square) TS5X5X0.375(1)[23])	1	1,666.89	5,778.96	371.726	-438.688	957.27	-336.324
	2	-1,693.6	-5,817.09	-491.96	331.742	478.61	336.324
Beam-66(Tube (square) TS5X5X0.375(1)[11])	1	-20,436.6	-10,772.6	-100.51	14.8949	3,155.02	-23.4201
	2	20,265.9	10,391.5	74.2695	-85.1455	5,351.67	23.4203
Beam-67(Tube (square) TS5X5X0.375(1)[4])	1	32,549.6	2,157.57	-3,022.2	-741.485	-894.51	-41.3429
	2	-7,044.38	2,855.41	-4,025.12	2,879.28	1,946.38	-48.0352

	3	7,822.82	-3,102.31	3,852.24	3,435.97	2,829.9	48.0352
Beam-69(Tube (square) TS5X5X0.375(1)[14])	1	23,109.9	887.809	10,919.5	-5,395.68	712.215	-65.1564
	2	-23,367.3	-1,036.73	-11,214	-3,500.65	61.3219	65.1556
Beam-71(Tube (square) TS5X5X0.375(1)[12])	1	35,623.7	-2,125.51	-5,418.64	416.942	-440.18	104.699
	2	-35,605.1	2,020.25	5,142.61	2,585.35	-738.354	-104.699
Beam-72(Tube (square) TS5X5X0.375(1)[22])	1	-1,700.57	5,162.12	-80.3341	294.175	-863.382	-279.771
	2	1,738.71	-5,188.82	-39.8999	-299.182	-418.323	279.771
Beam-78(Tube (square) TS5X5X0.375(1)[23])	1	5,410.3	-932.282	-279.355	-411.344	577.345	-72.3651
	2	-6,195.93	-212.669	573.298	-750.913	403.554	72.3646
Beam-79(Tube (square) TS5X5X0.375(1)[24])	1	2,339.4	585.376	-203.106	-397.927	731.034	-81.9993
	2	-3,202.41	-165.614	-842.577	-473.745	292.628	81.9996
Beam-80(Tube (square) TS5X5X0.375(1)[21])	1	51,632.6	638.724	189.496	143.817	1,182.31	57.0979
	2	-52,934.4	-932.679	293.188	-2.34742	959.674	-57.0994
Beam-81(Trim/Extend1[1])	1	-44,321.7	382.922	-1,046.44	-1,078.41	-101.277	47.4678
	2	43,097.2	199.057	626.645	-1,202.19	-149.449	-47.4661

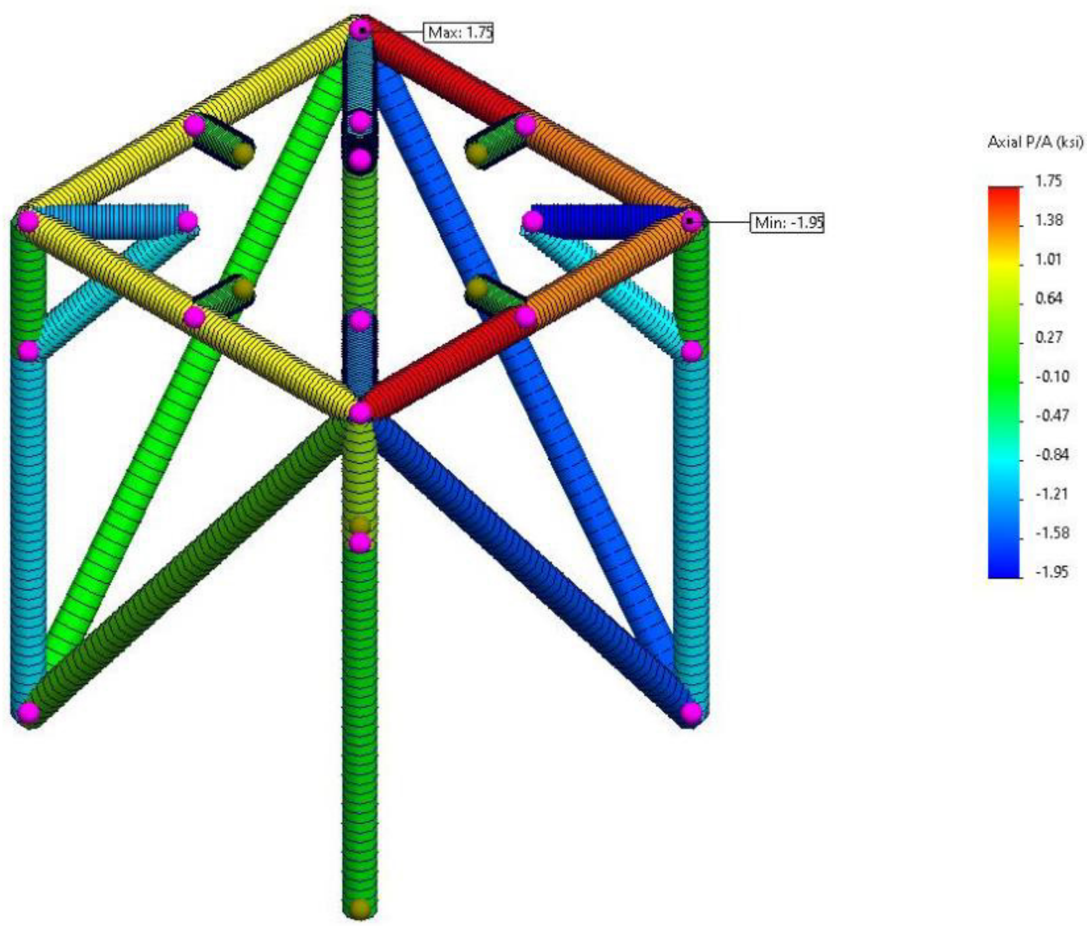
Beam Stresses

Beam Name	Joints	Axial(N/m^2)	Bending Dir1(N/m^2)	Bending Dir2(N/m^2)	Torsional (N/m^2)	Upper bound axial and bending(N/m^2)
Beam-49(Tube (square) TS5X5X0.375(1)[13])	1	-6.76765e+06	-3.73167e+06	-2.69746e+06	585,009	1.31968e+07
	2	-6.7718e+06	1.9149e+07	4.52468e+06	585,009	3.04455e+07
Beam-50(Tube (square) TS5X5X0.375(1)[1])	1	-1.49966e+06	3.81145e+06	4.45338e+06	18,797.3	9.76448e+06
	2	-6.49156e+06	-1.64214e+07	-1.56682e+07	-14,851.2	3.85812e+07
	3	-6.66311e+06	1.20726e+07	1.06234e+07	-14,851.2	2.93591e+07
Beam-51(Tube (square) TS5X5X0.375(1)[21])	1	-258,035	7.22642e+06	3.11938e+06	-563,982	1.06038e+07
	2	-249,515	3.2098e+06	-808,133	-563,982	4.26745e+06
Beam-52(Tube (square) TS5X5X0.375(1)[7])	1	1.20559e+07	1.31573e+06	-760,104	-1.38382e+06	1.41317e+07
	2	1.06985e+07	1.79871e+06	-3.26789e+06	469,718	1.57651e+07
	3	1.07274e+07	2.83534e+06	4.03413e+06	469,706	1.75969e+07
Beam-53(Tube (square) TS5X5X0.375(1)[3])	1	165,140	-6.88098e+06	-6.23902e+06	-18,795.1	1.32851e+07
	2	-4.71565e+06	1.84976e+07	1.92507e+07	14,850.3	4.24639e+07
	3	-4.8872e+06	-1.61683e+07	-1.76174e+07	14,850.3	3.86729e+07
Beam-54(Tube (square) TS5X5X0.375(1)[9])	1	-8.83178e+06	-60,292.5	1.40027e+06	-79,771.2	1.02923e+07
	2	-8.8553e+06	131,118	1.5622e+07	-79,771.2	2.46085e+07
Beam-56(Tube (square) TS5X5X0.375(1)[10])	1	-1.3449e+07	-60,288.7	5.62099e+06	79,771.6	1.91303e+07
	2	-1.34255e+07	131,111	505,313	79,771.6	1.4062e+07
Beam-57(Tube (square) TS5X5X0.375(1)[24])	1	-265,558	6.34086e+06	3.69476e+06	248,005	1.03012e+07
	2	-259,592	3.01028e+06	-1.17758e+06	248,005	4.44745e+06
Beam-59(Tube (square) TS5X5X0.375(1)[2])	1	-1.13267e+06	1.33308e+07	-1.90476e+07	-268,386	3.3511e+07
	2	4.65348e+06	6.44791e+06	-5.51018e+06	230,998	1.66116e+07

	3	-958,745	-1.80769e+07	2.17909e+07	-268,386	4.08265e+07
Beam-60(Tube (square) TS5X5X0.375(1)[5])	1	6.71037e+06	1.81929e+06	1.14583e+06	1.45377e+06	9.67549e+06
	2	5.95996e+06	6.88323e+06	-1.68638e+06	-1.29088e+06	1.45296e+07
	3	5.93112e+06	-1.99663e+06	2.16277e+06	-1.29089e+06	1.00905e+07
Beam-61(Tube (square) TS5X5X0.375(1)[15])	1	- 5.04737e+06	-1.72982e+07	-91,654.1	130,865	2.24372e+07
	2	-4.9622e+06	2.12766e+07	-521,483	130,866	2.67603e+07
Beam-62(Tube (square) TS5X5X0.375(1)[16])	1	- 5.44273e+06	2.11588e+07	374,853	-364,083	2.69764e+07
	2	- 5.37693e+06	-3.12916e+07	-4.36359e+06	-364,088	4.10321e+07
Beam-63(Tube (square) TS5X5X0.375(1)[6])	1	1.06853e+07	2.32927e+06	-3.18698e+06	-481,019	1.62016e+07
	2	1.1885e+07	1.56777e+06	-1.03281e+06	1.1906e+06	1.44856e+07
	3	1.18648e+07	3.95335e+06	1.40527e+06	1.19059e+06	1.72234e+07
Beam-64(Tube (square) TS5X5X0.375(1)[8])	1	6.10204e+06	-2.24866e+06	1.89009e+06	1.48411e+06	1.02408e+07
	2	6.72363e+06	1.28873e+06	1.22674e+06	-1.44247e+06	9.23909e+06
	3	6.70343e+06	7.20764e+06	-574,197	-1.44245e+06	1.44853e+07
Beam-65(Tube (square) TS5X5X0.375(1)[23])	1	-372,424	2.68827e+06	5.86614e+06	1.87914e+06	8.92684e+06
	2	-378,390	2.03291e+06	-2.93292e+06	1.87914e+06	5.34422e+06
Beam-66(Tube (square) TS5X5X0.375(1)[11])	1	- 4.56602e+06	91,275.9	-1.93339e+07	-130,855	2.39912e+07
	2	- 4.52789e+06	521,771	3.2795e+07	-130,855	3.78447e+07
Beam-67(Tube (square) TS5X5X0.375(1)[4])	1	7.27237e+06	-4.54381e+06	5.48155e+06	-230,994	1.72977e+07
	2	1.57388e+06	-1.76442e+07	1.19274e+07	268,386	3.11454e+07
	3	1.74781e+06	2.10556e+07	-1.73416e+07	268,386	4.0145e+07
Beam-69(Tube (square) TS5X5X0.375(1)[14])	1	- 5.16331e+06	3.30646e+07	4.36444e+06	364,088	4.25924e+07
	2	- 5.22082e+06	-2.1452e+07	-375,780	364,083	2.70486e+07
Beam-71(Tube (square) TS5X5X0.375(1)[12])	1	- 7.95918e+06	-2.55502e+06	-2.69742e+06	-585,050	1.32116e+07
	2	- 7.95503e+06	1.5843e+07	4.52462e+06	-585,050	2.83227e+07
Beam-72(Tube (square) TS5X5X0.375(1)[22])	1	-379,949	1.8027e+06	5.29079e+06	-1.56316e+06	7.47344e+06
	2	-388,469	1.83338e+06	-2.56348e+06	-1.56316e+06	4.78533e+06
Beam-78(Tube (square) TS5X5X0.375(1)[23])	1	1.20879e+06	-2.52071e+06	-3.53796e+06	-404,361	7.26747e+06
	2	1.38432e+06	4.60159e+06	2.47297e+06	-404,359	8.45888e+06
Beam-79(Tube (square) TS5X5X0.375(1)[24])	1	-522,678	2.43849e+06	4.47977e+06	458,204	7.44094e+06
	2	-715,496	-2.90311e+06	-1.79322e+06	458,206	5.41182e+06
Beam-80(Tube (square) TS5X5X0.375(1)[21])	1	- 1.15359e+07	-881,311	7.24516e+06	-319,058	1.96624e+07
	2	- 1.18268e+07	-14,385	-5.88087e+06	-319,066	1.77221e+07
Beam-81(Trim/Extend1[1])	1	- 9.90253e+06	-6.60847e+06	620,625	265,215	1.71316e+07
	2	- 9.62895e+06	7.36699e+06	-915,823	265,206	1.79118e+07

Study Results

Name	Type	Min	Max
Tension-Compression	Axial P/A	-1.95ksi Element: 284	1.75ksi Element: 195



RSF-ELC-Stress-Tension-Compression

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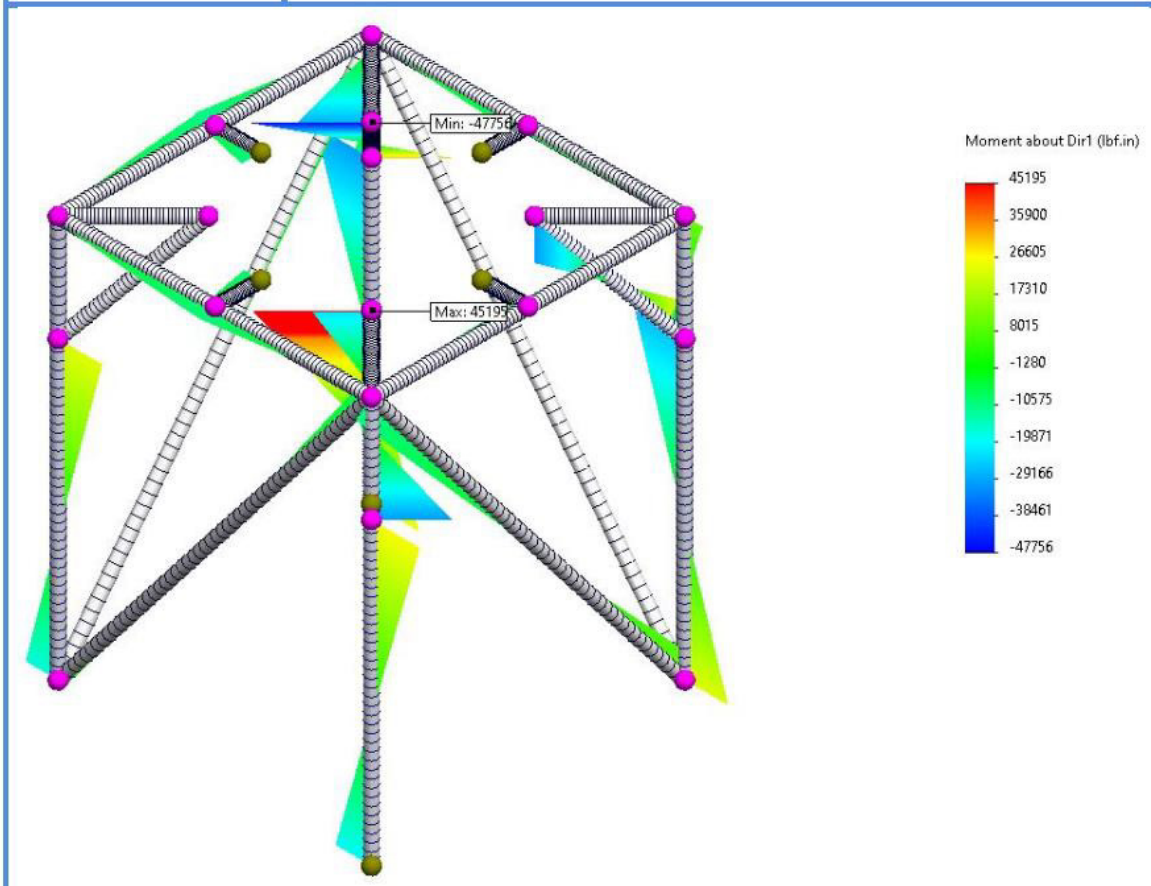
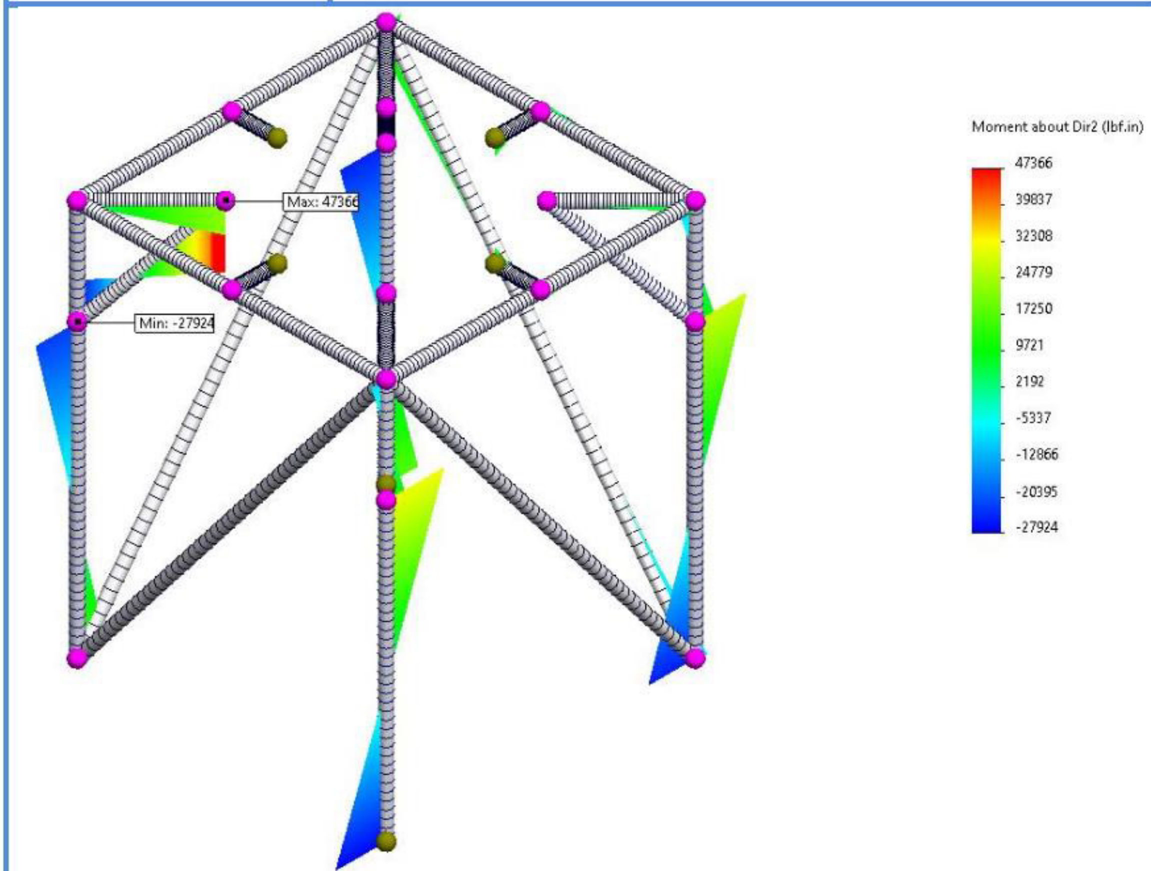
Name	Type
Shear-Moment Plot1	Moment about Dir1



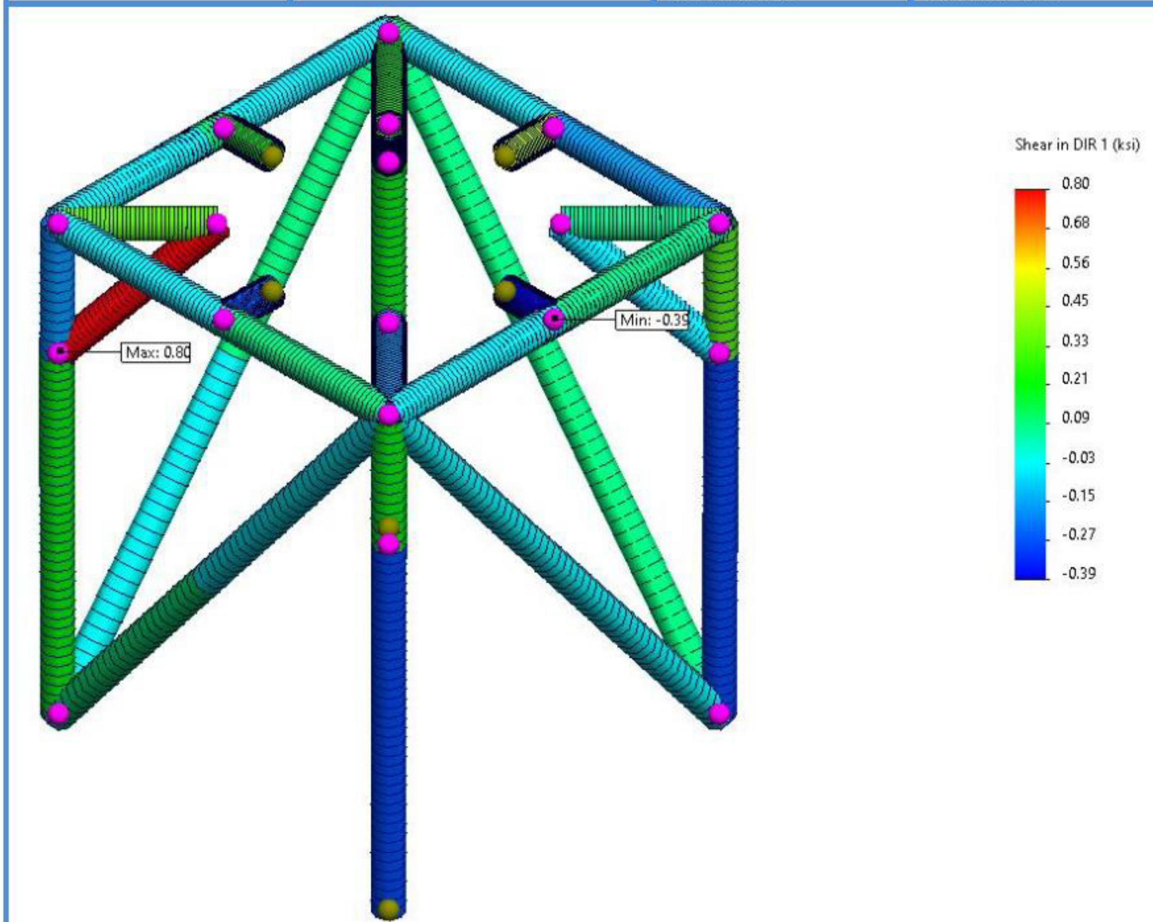
RSF-ELC-Shear-Moment Plot-Shear-Moment Plot1

Name	Type
Shear-Moment Plot2	Moment about Dir2



RSF-ELC-Shear-Moment Plot-Shear-Moment Plot2

Name	Type	Min	Max
Shear 1	Shear in DIR 1	-0.39ksi Element: 902	0.80ksi Element: 776



RSF-ELC-Stress-Shear 1

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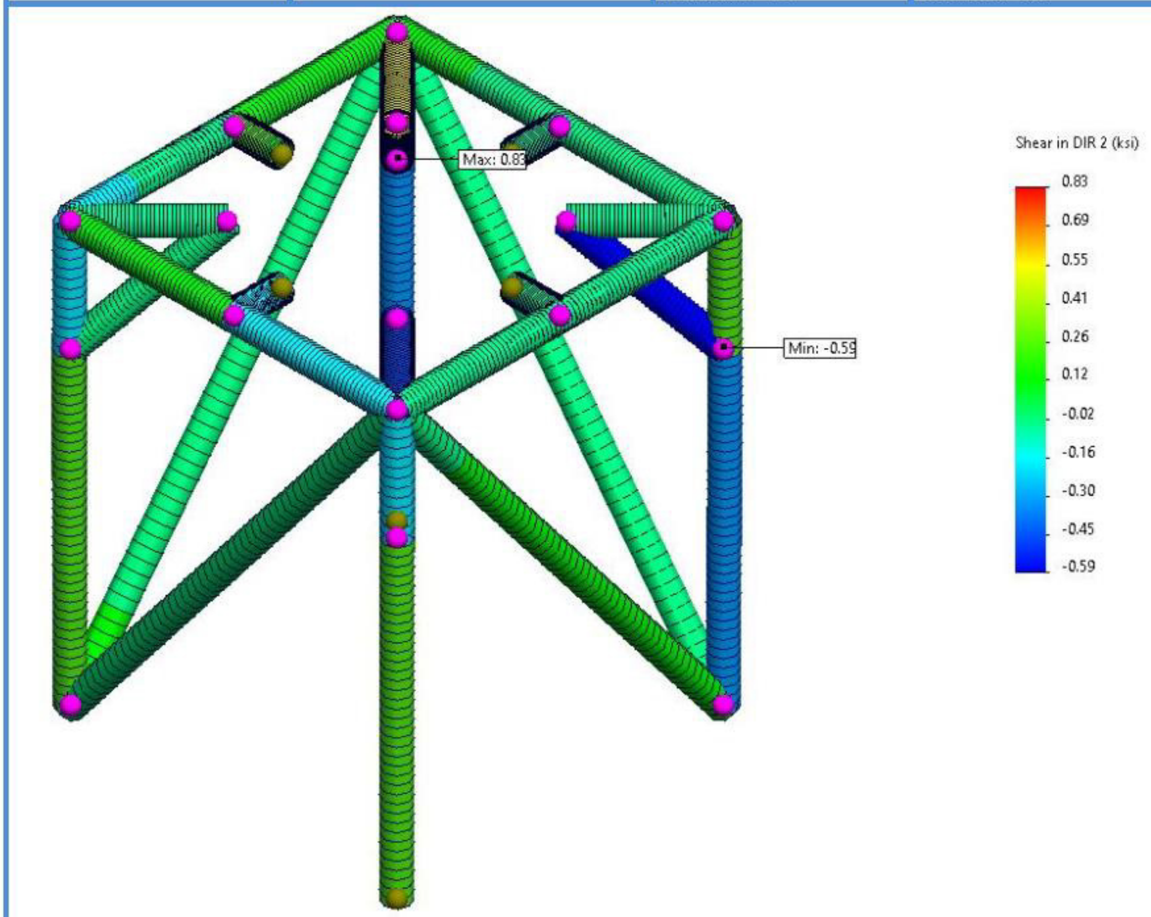
Name	Type	Min	Max
Shear 2	Shear in DIR 2	-0.59ksi Element: 479	0.83ksi Element: 864



RSF-ELC-Stress-Shear 2

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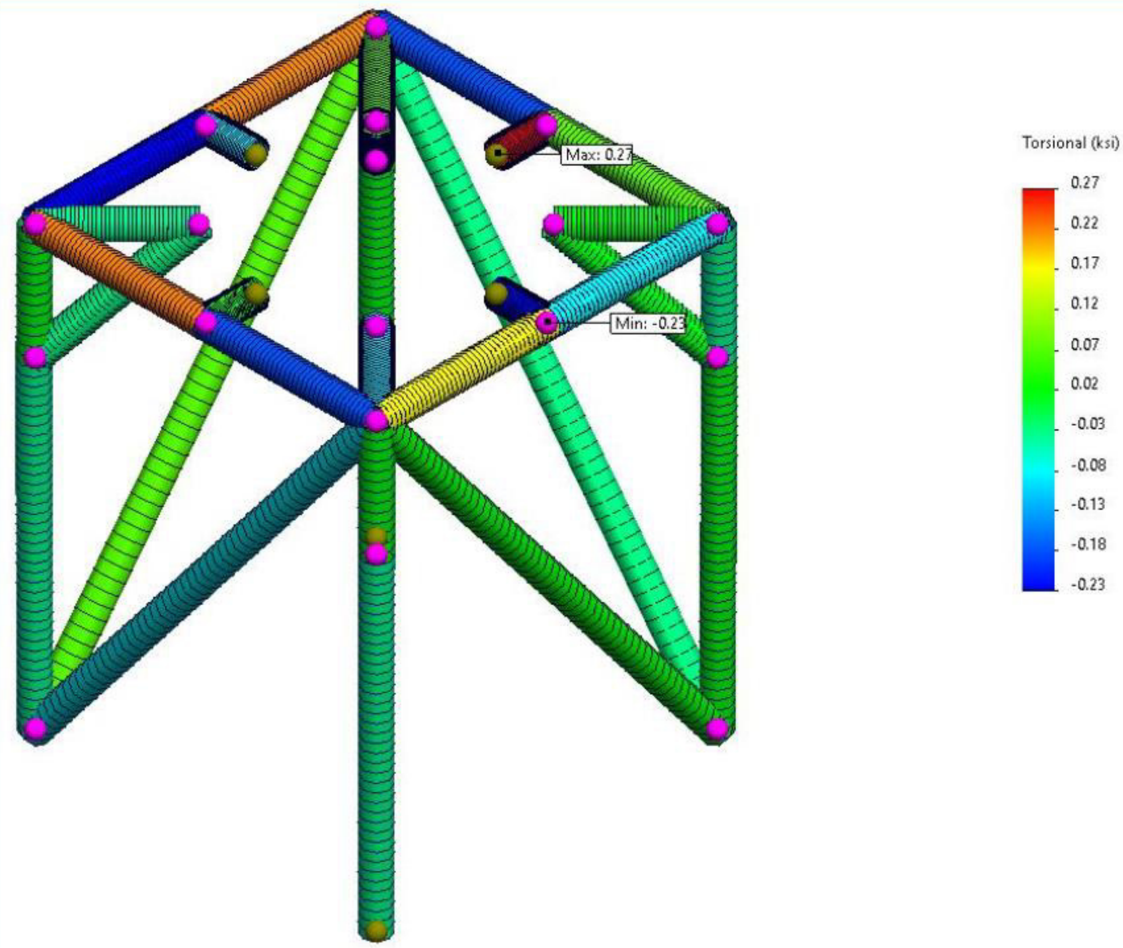
Name	Type	Min	Max
Torsional	Torsional	-0.23ksi Element: 902	0.27ksi Element: 713



RSF-ELC-Stress-Torsional

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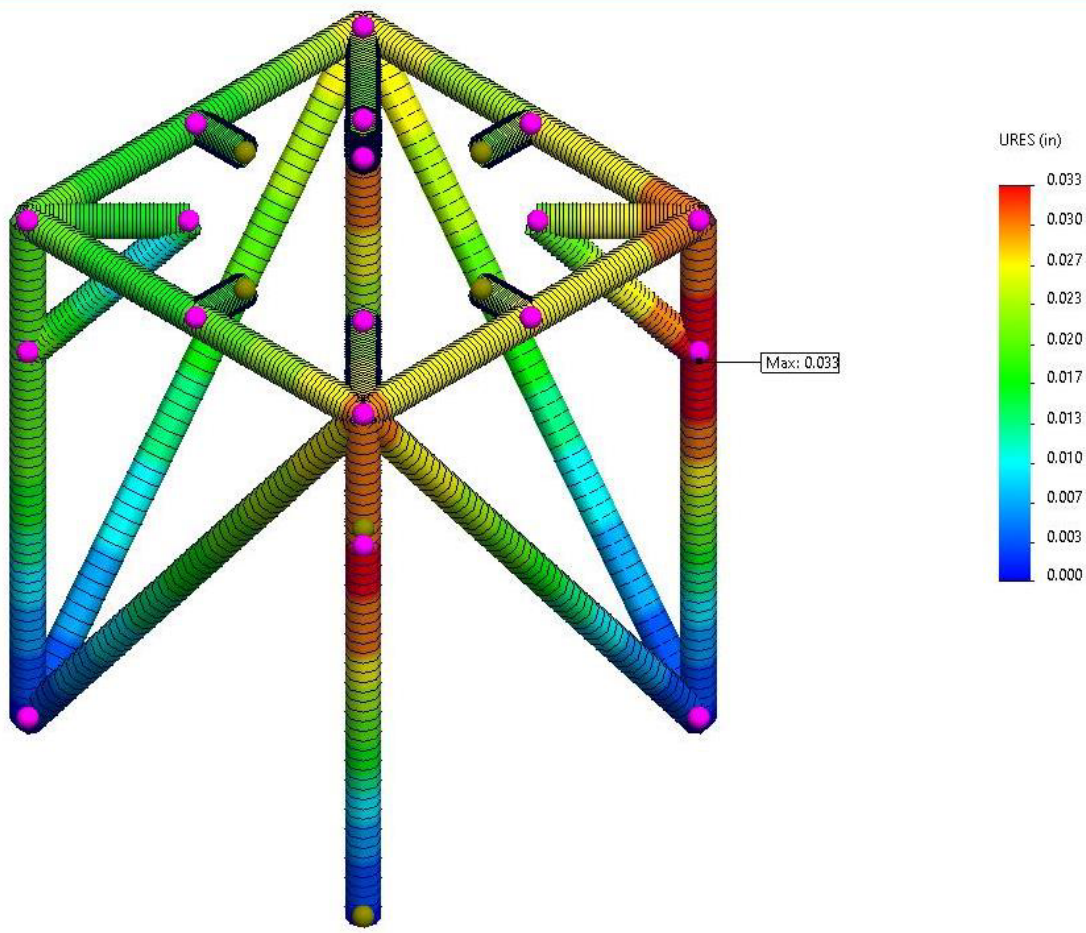
Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000in Node: 39	0.033in Node: 236



RSF-ELC-Displacement-Displacement1

Appendix C

ANSI - AISC N690-18 Compliance

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Appendix C
Stress Allowable Calculations & Compliance

Compliance to ANSI AISC N690-18 contained in this appendix will be organized as follows:

1. Preliminary/Preparatory Calculations and information
2. Chapter ND - Design of Members for Tension
3. Chapter NE - Design of Members for Compression
4. Chapter NF - Design of Members for Flexure
5. Chapter NG - Design of Members for Shear
6. Chapter NH - Design of Members for Combined Forces and Torsion
7. Chapter NJ - Design of Connections
8. Chapter NK - Additional Requirements for HSS and Box-Section Connections

Acronyms:

- HSS - Hollow Structural Section
- RSF - Reactor Support Frame
- FEA - Finite Element Analysis
- ASD - Allowable Strength Design
- TREAT - Transient Reactor Test
- ASCE - American Society of Civil Engineers
- SEI - Structural Engineering Institute
- ASME - American Society of Mechanical Engineers
- ANSI - American National Standards Institute
- AISC - American Institute of Steel Construction
- B&PV - Boiler Pressure Vessel
- NLC - Normal Load Conditions
- ELC - Extreme Load Conditions
- CJP - Complete Joint Penetration

These chapters will utilize the ASD method of comparing the load combinations as shown below with calculated allowables per chapter. Chapter NI Design of Composite Members is not applicable since all members of the RSF are not made of composite members and only HSS beams. FEA was performed to calculate stresses with the given load combinations and results of those analyses are presented in Appendix A & B. Thermal calculations were performed using hand calculations for determining the convection coefficient which then was utilized in the FEA thermal analysis. Both thermal analyses are contained in Appendix D and thermal data are feed into the FEA structural and seismic analyses.

For the purposes of this analysis, Dead/live load and fluid loads were combined into one load. Fluids included in the weight calculation are the primary coolant (NaK) and the secondary coolant (Ga-In-Sn). Weights were derived per Drawing 1014577 (MARVEL Reactor Assembly), 1014726 (RSF), 1014698 (Outer Shield Assembly), 1014705 (upper plenum duct), ECAR-6586 (preliminary results). All FEA calculations utilized a 10% increase to applied loads. For example, the calculated approximate weight of the supported equipment was approximately 16,000 lbs. The load applied to the RSF was then increased by 10% (17600 and further rounded to up 18,000lbs.) for any uncertainty in construction, fabrication, and assembly.

The center of mass was approximated utilizing CAD solid models. Although the max temperature that the RSF experiences is approximately 200 $^{\circ}F$ (preliminary results based on ECAR-6574 which is not yet issued), the max temperature utilized for allowables for this analysis and Guard Vessel temperature boundary condition applied is 325 $^{\circ}F$ as well as applied temperature onto the seating surfaces of the RSF in the FEA structural and seismic analyses. Calculated values for boundary conditions were calculated in first section of Appendix D.

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Appendix C
Stress Allowable Calculations & Compliance

6. Allowable Strength Design (ASD)

The allowable strength, R_n/Ω, of each structural component shall be equal to or greater than the required strength, R_a, determined from the critical combinations of the loads. The most critical structural effects may occur when one or more loads are not acting. The following load combinations shall be investigated:

6a. Normal Load Combinations

$$D+L+R_o+F+H+T_o+C \qquad \text{(NB2-10)}$$
$$D+(L_r \text{ or } S \text{ or } R)+R_o+F+H+T_o+C \qquad \text{(NB2-11)}$$
$$D+F+0.75L+0.75H+0.75(L_r \text{ or } S \text{ or } R)+T_o+C \qquad \text{(NB2-12)}$$

6b. Severe Environmental Load Combinations

$$D+R_o+F+0.6W+0.75(L+H)+C+0.75(L_r \text{ or } S \text{ or } R)+T_o \qquad \text{(NB2-13)}$$
$$D+R_o+F+E_o+0.75(L+H)+C+0.75(L_r \text{ or } S \text{ or } R)+T_o \qquad \text{(NB2-14)}$$

6c. Extreme Environmental and Abnormal Load Combinations

$$D+L+C+R_o+T_o+E_s+F+H \qquad \text{(NB2-15)}$$
$$D+L+R_o+T_o+W_t+F+H \qquad \text{(NB2-16)}$$
$$D+L+C+P_a+R_a+T_a+F+H \qquad \text{(NB2-17)}$$
$$D+L+P_a+R_a+T_a+Y_r+Y_j+Y_m+0.7E_s+F+H \qquad \text{(NB2-18)}$$

From
Chapter NB in N690 pg. 14

Normal load conditions NB2-10 thru NB-12 are identical in this loading scenario. NB2-13 thru NB-18 are identical in this loading scenario when $T_0 = T_a$ and $E_0 = E_S$. This was assumed due to the fact that in the postulated accident scenarios, the reactor will be scrammed and the system will cool down. The reactor has thermal mass that will absorb heat up during a transient scram scenario before it will heat up the RSF.

The following loading was neglected due to the fact that the RSF will be inside the TREAT facility, will not be supporting anything but what is stated in this analysis, and no pipes are near the RSF:

C	Rated capacity of the crane
H	Loads due to weight and pressure of soil, water in soil, or bulk materials
L_r	Roof live load
R	Rain load
R_0	Pipe reactions during normal operating, start-up or shutdown conditions, based on the most critical transient or steady-state condition
S	Snow load as stipulated in Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE/SEI 7) for Risk Category IV facilities
R_a	Pipe and equipment reactions generated by the postulated accident, including R_0
Y_j	Jet impingement load generated by the postulated accident
Y_m	Missile impact load, such as pipe whip generated by or during the postulated accident
Y_r	Loads on the structure generated by the reaction of the broken high-energy pipe during the postulated accident
W_t	Loads generated by the specified design (basis) tornado, including wind pressures, pressure differentials, and tornado borne missiles, as defined in the U.S. Nuclear Regulatory Commission Standard Review Plan 3.3.2 (NUREG-0800) or as specified by the AHJ

Allowables are calculated in accordance with ANSI-AISC N690-18. Because it is built on top of ANSI/AISC 360-16, for many sections ANSI-AISC N690-18 will simply list "no change" and the corresponding section of ANSI/AISC 360-16 will apply. Therefore, all page, section, and table references are to ANSI/AISC 360-16 unless otherwise noted.

The Nuclear Specification is compatible with the AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360), hereafter referred to as the *Specification*. Provisions of the *Specification* are applicable unless stated otherwise. Only those sections that differ from the *Specification* provisions are indicated in the Nuclear Specification.

From
Chapter NA in N690 pg. 1

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Appendix C
Stress Allowable Calculations & Compliance

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1. Preliminary/Preparatory Calculations and Information

Table 2-9. Room Temperature Physical Properties, Annealed Condition

Type	Initial Modulus of Elasticity		Density		Thermal Conductivity at 68 °F (20 °C)		Specific Thermal Capacity at 68 °F (20 °C)	
	ksi	MPa	lb/ft³	kg/m³	BTU/(hr-ft-°F)	W/(m-K)	BTU/(lb-°F)	J/(kg-K)
S30400 S30403	28,000	193,000	490	7900	8.7	15	0.12	500
S31600 S31603	28,000	193,000	500	8000				
S32101 S32304 S32205	29,000	200,000	485	7800				
S17400	28,500	197,000	485	7800	9.2	16		

Note:
The data are taken from EN 10088, *Stainless Steels—Part 1: List of Stainless Steels* (CEN, 2005d) apart from the values for the initial modulus of elasticity which are taken from *Boiler and Pressure Vessel Code, Section II: Materials—Part D: Properties (Customary)* (ASME, 2010), with the value for the austenitic stainless steels rounded down to 28,000 ksi (193,000 MPa).
Poisson's ratio can be taken as 0.3 and the shear modulus of elasticity, G, as 0.385E.

From
AISC Design Guide 27
Section 2.3.3

$E_i := 28000\ ksi$ Initial Modulus of Elasticity, 316H, from Table 2-9

(1) If strength Grade 1 is specified, then the mechanical properties shall be in accordance with the appropriate specification, either Specification A240/A240M, A276/A276M, or Specification A479/A479M.

from
ASTM 1069, section 5.1.1.1.(1)

While ASTM A276/A276M does not have a specification for 316H, ASTM A240/A240M-22a & A479/A479M does (shown below). Tensile and yield strength match with ASTM A240/A240M-22a & A479/A479M .

A240/A240M – 22a

TABLE 2 *Continued*

UNS Designation	Type[A]	Tensile Strength, min		Yield Strength,[B] min		Elongation in 2 in. or 50 mm, min, %	Hardness, max[C]		Cold Bend[D]
		ksi	MPa	ksi	MPa		Brinell, HBW	Rockwell	
S30940	309Cb[F]	75	515	30	205	40	217	95 HRBW	not required
S30941	309HCb[F]	75	515	30	205	40	217	95 HRBW	not required
S31008	310S	75	515	30	205	40	217	95 HRBW	not required
S31009	310H[F]	75	515	30	205	40	217	95 HRBW	not required
S31040	310Cb[F]	75	515	30	205	40	217	95 HRBW	not required
S31041	310HCb[F]	75	515	30	205	40	217	95 HRBW	not required
S31050	310 MoLN[F]								
	t ≤ 0.25 in.	84	580	39	270	25	217	95 HRBW	not required
	t > 0.25 in.	78	540	37	255	25	217	95 HRBW	not required
S31060	. . .	87	600	41	280	40	217	95 HRBW	not required
S31254									
Sheet and Strip		100	690	45	310	35	223	96 HRBW	not required
Plate		95	655	45	310	35	223	96 HRBW	not required
S31266	. . .	109	750	61	420	35	. . .	. . .	not required
S31277	. . .	112	770	52	360	40	. . .	. . .	not required
S31600	316	75	515	30	205	40	217	95 HRBW	not required
S31603	316L	70	485	25	170	40	217	95 HRBW	not required
S31609	316H	75	515	30	205	40	217	95 HRBW	not required

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Appendix C
Stress Allowable Calculations & Compliance

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A479/A479M – 20

TABLE 2 Mechanical Property Requirements

UNS Designation	Type	Condition	Tensile Strength, min, ksi [MPa]	Yield Strength,[A] min, ksi [MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min, %[B,C]	Brinell Hardness, max
Austenitic Grades							
N08020	Alloy 20	stabilized-annealed	80 [550]	35 [240]	30[D]	50	
	Up to 2 in. [50.8 mm], incl	strain-hardened	90 [620]	60 [415]	15	40	
N08367	. . .	annealed	95 [655]	45 [310]	30	. . .	241
N08800	800	annealed	75 [515]	30 [205]	30	. . .	192
N08810	800H	annealed	65 [450]	25 [170]	30	. . .	192
N08811	. . .	annealed	65 [450]	25 [170]	30	. . .	192
N08700	. . .	annealed	80 [550]	35 [240]	30	50	. . .
N08904	904L	annealed	71 [490]	31 [220]	35	. . .	. . .
N08925	. . .	annealed	87 [600]	43 [295]	40	. . .	217
N08926	. . .	annealed	94 [650]	43 [295]	35	. . .	256
S20161	. . .	annealed	125 [860]	50 [345]	40	40	311
S20910	XM-19	annealed	100 [690]	55 [380]	35	55	293
	Up to 2 in. [50.8 mm], incl	hot-rolled	135 [930]	105 [725]	20	50	. . .
	Over 2 to 3 in. [50.8 to 76.2 mm], incl	hot-rolled	115 [795]	75 [515]	25	50	. . .
	Over 3 to 8 in. [76.2 to 203.2 mm], incl	hot-rolled	100 [690]	60 [415]	30	50	. . .
	Up to 1½ in. [38.1 mm], incl	strain-hardened	145 [1000]	125 [860]	12	40	. . .
	Over 1½ to 2¼ in. [38.1 to 57.2 mm], incl	strain-hardened	120 [825]	105 [725]	15	45	. . .
S21600, S21603	XM-17, XM-18	annealed	90 [620]	50 [345]	40	50	212
S21800	. . .	annealed	95 [655]	50 [345]	35	55	241
S21904	XM-11	annealed	90 [620]	50 [345]	45	60	. . .
S24000	XM-29	annealed	100 [690]	55 [380]	30	50	. . .
S30200, S30400, S30409, S30453, S30880, S30908, S30909, S30940, S31008, S31009, S31040, S31600, S31609, S31635, S31640, S31653, S31700, S32100, S32109, S34700, S34709, S34800, S34809 , S30403, S31603	302, 304, 304H, 304LN, ER308,[E] 309S, 309H, 309Cb, 310S, 310H, 310Cb, 316, 316H, 316Ti, 316Cb, 316LN, 317, 321, 321H, 347, 347H, 348, 348H	annealed	75 [515][F]	30 [205]	30	40	. . .

From
AISC Design Guide 27 pg. 55

Table 10-3. Reduction Factors for Type S31600/S31603 Stainless Steel			
Steel Temperature, T °F (°C)	$k_E(T) = E(T)/E$	$k_y(T) = F_y(T)/F_y$	$k_u(T) = F_u(T)/F_u$
68 (20)	1.00	1.00	1.00
200 (93)	0.96	0.87	0.88
400 (204)	0.92	0.72	0.80
600 (316)	0.87	0.66	0.78
750 (399)	0.84	0.62	0.77
800 (427)	0.83	0.61	0.76
1000 (538)	0.78	0.58	0.71
1200 (649)	0.74	0.53	0.59
1400 (760)	0.66	0.45	0.41
1600 (871)	0.50	0.27	0.23
1800 (982)	0.24	0.15	0.12
2000 (1090)	0.11	0.07	0.07

$k_{x\_T} := \begin{bmatrix} 200 \\ 400 \end{bmatrix}$ Temperature range

$k_{E\_y} := \begin{bmatrix} 0.96 \\ 0.92 \end{bmatrix}$ Modulus of Elasticity

$k_{y\_y} := \begin{bmatrix} 0.87 \\ 0.72 \end{bmatrix}$ Yield Strength

$k_{u\_y} := \begin{bmatrix} 0.88 \\ 0.80 \end{bmatrix}$ Ultimate Tensile Strength

$F_{i\_y} := 30\ ksi$ Initial Yield Strength, 316H, from Table 2 of ASTM A240/A240M-22a & A479/A479M

$F_{i\_u} := 75\ ksi$ Initial Ultimate Tensile Strength, 316H, from Table 2 of ASTM A240/A240M-22a & A479/A479M

$k_{modulus} := \text{linterp}\left(k_{x\_T}, k_{E\_y}, 325\right) = 0.935$

$k_{yield} := \text{linterp}\left(k_{x\_T}, k_{y\_y}, 325\right) = 0.776$

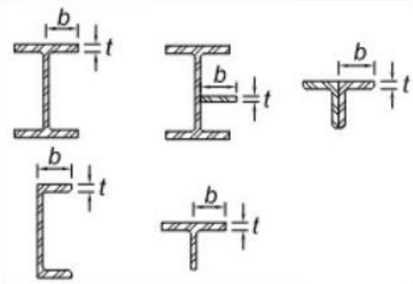
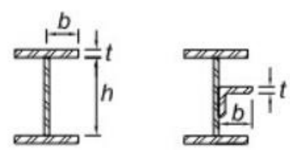
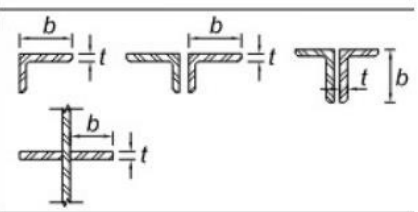
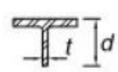
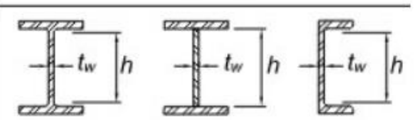
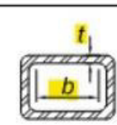
$k_{ultimate} := \text{linterp}\left(k_{x\_T}, k_{u\_y}, 325\right) = 0.83$

$E := E_i \cdot \text{linterp}\left(k_{x\_T}, k_{E\_y}, 325\right) = 26180\ ksi$

$F_y := F_{i\_y} \cdot \text{linterp}\left(k_{x\_T}, k_{y\_y}, 325\right) = 23.3\ ksi$

$F_u := F_{i\_u} \cdot \text{linterp}\left(k_{x\_T}, k_{u\_y}, 325\right) = 62.3\ ksi$

TABLE B4.1a
Width-to-Thickness Ratios: Compression Elements Members Subject to Axial Compression

	Case	Description of Element	Width-to-Thickness Ratio	Limiting Width-to-Thickness Ratio λ_r (nonslender/slender)	Examples
Unstiffened Elements	1	Flanges of rolled I-shaped sections, plates projecting from rolled I-shaped sections, outstanding legs of pairs of angles connected with continuous contact, flanges of channels, and flanges of tees	b/t	$0.56\sqrt{\frac{E}{F_y}}$	
	2	Flanges of built-up I-shaped sections and plates or angle legs projecting from built-up I-shaped sections	b/t	[a] $0.64\sqrt{\frac{k_c E}{F_y}}$	
	3	Legs of single angles, legs of double angles with separators, and all other unstiffened elements	b/t	$0.45\sqrt{\frac{E}{F_y}}$	
	4	Stems of tees	d/t	$0.75\sqrt{\frac{E}{F_y}}$	
	5	Webs of doubly symmetric rolled and built-up I-shaped sections and channels	h/t_w	$1.49\sqrt{\frac{E}{F_y}}$	
	6	Walls of rectangular HSS	b/t	$1.40\sqrt{\frac{E}{F_y}}$	

from pg. 16.17

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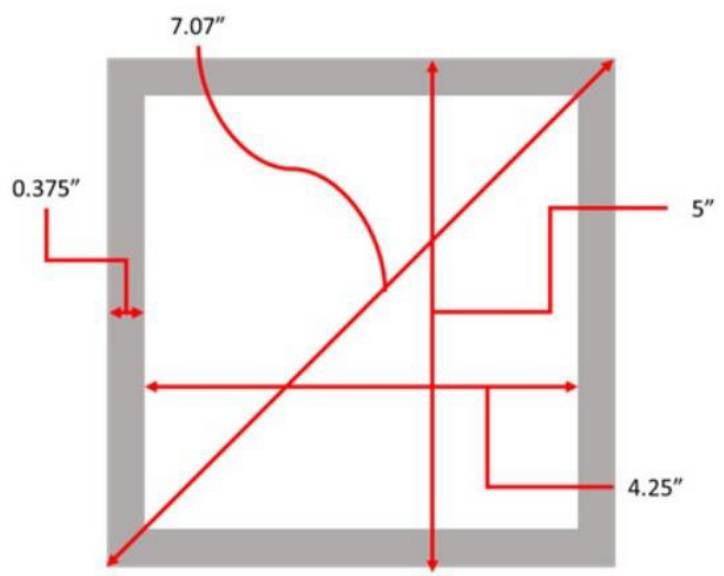
TABLE B4.1b (continued) Width-to-Thickness Ratios: Compression Elements Members Subject to Flexure

	Case	Description of Element	Width-to-Thickness Ratio	Limiting Width-to-Thickness Ratio λ_p (compact/noncompact)	λ_r (noncompact/slender)	Examples
Stiffened Elements	15	Webs of doubly symmetric I-shaped sections and channels	h/t_w	$3.76\sqrt{\frac{E}{F_y}}$	$5.70\sqrt{\frac{E}{F_y}}$	t_w, h
	16	Webs of singly symmetric I-shaped sections	h_c/t_w	$\frac{\frac{h_c}{h_p}\sqrt{\frac{E}{F_y}}}{\left(0.54\frac{M_p}{M_y}-0.09\right)^2} \le \lambda_r$ [c]	$5.70\sqrt{\frac{E}{F_y}}$	$\frac{h_c}{2}$, $\frac{h_p}{2}$, ENA, PNA
	17	Flanges of rectangular HSS	b/t	$1.12\sqrt{\frac{E}{F_y}}$	$1.40\sqrt{\frac{E}{F_y}}$	b, t
	18	Flange cover plates and diaphragm plates between lines of fasteners or welds	b/t	$1.12\sqrt{\frac{E}{F_y}}$	$1.40\sqrt{\frac{E}{F_y}}$	b, t

from
pg. 16.18



HSS 5x5

$b_1 := 3.5\ in$ Inner width of 5x5 HSS, less the corners

2. Design Wall Thickness for HSS

The design wall thickness, t, shall be used in calculations involving the wall thickness of hollow structural sections (HSS). The design wall thickness, t, shall be taken equal to the nominal thickness for box sections and HSS produced according to ASTM A1065/A1065M or ASTM A1085/A1085M. For HSS produced according to other standards approved for use under this Specification, the design wall thickness, t, shall be taken equal to 0.93 times the nominal wall thickness.

from:
pg. 16.1-20

$t := 0.375 \cdot 0.93\ in$ Thickness of 5x5 HSS, reduced by 0.93, will be produced from ASTM A1069 HSS

$d := 5\ in$ Outer thickness of HSS, 5x5

$\lambda_{r\_allow\_1} := 1.4 \cdot \sqrt{\frac{E}{F_y}} = 46.9$ limiting width-to-thickness ratio, Compression Elements Members Subject to Axial Compression, per table B4.1a-b

$\lambda_{r\_allow\_2} := 1.12 \cdot \sqrt{\frac{E}{F_y}} = 37.6$ limiting width-to-thickness ratio, Compression Elements Members Subject to Flexure, per table B4.1a-b

$\lambda_r := \frac{b_1}{t} = 10.0$ Width-to-thickness ratio less than limiting width-to-thickness ratio, therefore all beams analyzed in this analysis are considered not slender and is "compact", per table B4.1a-b and section B4.1 paragraph 2.

$A_1 := (d - t \cdot 2)^2 = 18.5\ in^2$ Inner hollow cross-sectional area of square HSS, 5x5 sharp corners

$A_2 := (5\ in)^2 = 25.0\ in^2$ Outer cross-sectional area of square HSS, 5x5, including hollow area with sharp corners

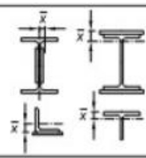
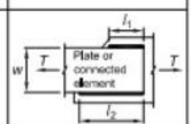
$A_g := A_2 - A_1 = 6.488\ in^2$ Gross area of HSS members, total cross-sectional area

$A_{0.375\_hole} := 0.375\ in \cdot t = 0.131\ in^2$ 0.375" threaded hole cutout on 8 members, see drawing 1014726, item 10

$A_n := A_g - 2 \cdot A_{0.375\_hole} = 6.227\ in^2$ Net area, from pg. 16.1-20, with two 0.375" threaded holes cutout on 8 members

2. Chapter ND - Design of Members for Tension

TABLE D3.1
Shear Lag Factors for Connections to Tension Members

Case	Description of Element		Shear Lag Factor, U	Example
1	All tension members where the tension load is transmitted directly to each of the cross-sectional elements by fasteners or welds (except as in Cases 4, 5 and 6).		$U = 1.0$	–
2	All tension members, except HSS, where the tension load is transmitted to some but not all of the cross-sectional elements by fasteners or by longitudinal welds in combination with transverse welds. Alternatively, Case 7 is permitted for W, M, S and HP shapes. (For angles, Case 8 is permitted to be used.)		$U = 1 - \frac{\bar{x}}{l}$	
3	All tension members where the tension load is transmitted only by transverse welds to some but not all of the cross-sectional elements.		$U = 1.0$ and A_n = area of the directly connected elements	–
4[a]	Plates, angles, channels with welds at heels, tees, and W-shapes with connected elements, where the tension load is transmitted by longitudinal welds only. See Case 2 for definition of $\bar{x}$.		$U = \frac{3l^2}{3l^2 + w^2}\left(1 - \frac{\bar{x}}{l}\right)$	
5	Round HSS with a single concentric gusset plate through slots in the HSS.		$l \geq 1.3D$, $U = 1.0$ $D \leq l < 1.3D$, $U = 1 - \frac{\bar{x}}{l}$ $\bar{x} = \frac{D}{\pi}$	
6	Rectangular HSS.	with a single concentric gusset plate	$l \geq H$, $U = 1 - \frac{\bar{x}}{l}$ $\bar{x} = \frac{B^2 + 2BH}{4(B+H)}$	
		with two side gusset plates	$l \geq H$, $U = 1 - \frac{\bar{x}}{l}$ $\bar{x} = \frac{B^2}{4(B+H)}$	
7	W-, M-, S- or HP-shapes, or tees cut from these shapes. (If U is calculated per Case 2, the larger value is permitted to be used.)	with flange connected with three or more fasteners per line in the direction of loading	$b_f \geq \frac{2}{3}d$, $U = 0.90$ $b_f < \frac{2}{3}d$, $U = 0.85$	–
		with web connected with four or more fasteners per line in the direction of loading	$U = 0.70$	–
8	Single and double angles. (If U is calculated per Case 2, the larger value is permitted to be used.)	with four or more fasteners per line in the direction of loading	$U = 0.80$	–
		with three fasteners per line in the direction of loading (with fewer than three fasteners per line in the direction of loading, use Case 2)	$U = 0.60$	–

B – overall width of rectangular HSS member, measured 90° to the plane of the connection, in. (mm); D – outside diameter of round HSS, in. (mm); H = overall height of rectangular HSS member, measured in the plane of the connection, in. (mm); d = depth of section, in. (mm); for tees, d = depth of the section from which the tee was cut, in. (mm); l = length of connection, in. (mm); w = width of plate, in. (mm); $\bar{x}$ = eccentricity of connection, in. (mm).

[a] $l = \frac{l_1 + l_2}{2}$, where l_1 and l_2 shall not be less than 4 times the weld size.

from:
pg. 16.1-30

$\Omega_{t\_n} := 1.67$	Safety Factor for tensile yielding in gross section, section D2
$\Omega_{t\_u} := 2$	Safety Factor for tensile rupture in net section, section D2
$U_C := 1.0$	Shear Lag Factor, Table D3.1
$A_e := A_n \cdot U_C = 6.227\ in^2$	Effective net area, equation D3-1
$P_n := F_y \cdot A_g = 151.1\ kip$	Critical force in tensile yielding, equation D2-1, smaller therefore it is selected
$P_u := F_u \cdot A_e = 387.6\ kip$	Critical force in tensile rupture, equation D2-2, larger therefore not selected

$$R_n := \frac{\frac{P_n}{A_g}}{\Omega_{t\_n}} = 13.94\ ksi$$

Allowable Tensile Stress, ASD, derived from equation D2-1 to use stresses instead of forces

$$R_{a\_T\_NLC} := 1.29\ ksi$$

FEA Calculated Tensile Stress, see FEA results in Appendix A with NLC

$$R_{a\_T\_ELC} := 1.75\ ksi$$

FEA Calculated Tensile Stress, see FEA results in Appendix B with ELC

$$DC_{D\_NLC} := \frac{R_{a\_T\_NLC}}{R_n} = 0.09$$

Demand to capacity Tensile Stress with NLC, <1, satisfactory

$$DC_{D\_ELC} := \frac{R_{a\_T\_ELC}}{R_n} = 0.13$$

Demand to capacity Tensile Stress with ELC, <1, satisfactory

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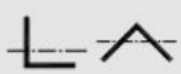
3. Chapter NE - Design of Members for Compression

TABLE USER NOTE E1.1
Selection Table for the Application of Chapter E Sections

Cross Section	Without Slender Elements		With Slender Elements	
	Sections in Chapter E	Limit States	Sections in Chapter E	Limit States
	E3 E4	FB TB	E7	LB FB TB
	E3 E4	FB FTB	E7	LB FB FTB
	E3	FB	E7	LB FB
	E3	FB	E7	LB FB
	E3 E4	FB FTB	E7	LB FB FTB
	E6 E3 E4	FB FTB	E6 E7	LB FB FTB
	E5		E5	
	E3	FB	N/A	N/A
Unsymmetrical shapes other than single angles	E4	FTB	E7	LB FTB

FB = flexural buckling, TB = torsional buckling, FTB = flexural-torsional buckling, LB = local buckling, N/A = not applicable

from:
pg. 16.1-34

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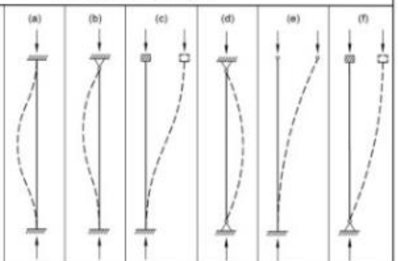
As shown in Section 1 of this appendix, the RSF does not have any slender members

$\Omega_c := 1.67$ Factor of Safety for compression (ASD), from section E1

TABLE C-A-7.1
Approximate Values of Effective Length Factor, *K*

	(a)	(b)	(c)	(d)	(e)	(f)
Buckled shape of column is shown by dashed line						
Theoretical *K* value	0.5	0.7	1.0	1.0	2.0	2.0
Recommended design value when ideal conditions are approximated	0.65	0.80	1.2	1.0	2.1	2.0
End condition code	Rotation fixed and translation fixed; Rotation free and translation fixed; Rotation fixed and translation free; Rotation free and translation free					

from
pg. 16.1-570

$K := 2.1$ Effective Length Factor, Assume worst case (e) for conservatism, from above table C-A-7.1

Moments of Inertia, Section Moduli, and Radii of Gyration

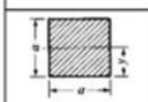
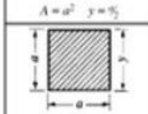
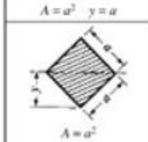
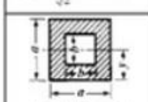
Section A = area y = distance from axis to extreme fiber	Moment of Inertia I	Section Modulus $Z = \frac{I}{y}$	Radius of Gyration $k = \sqrt{\frac{I}{A}}$
Square and Rectangular Sections			
 $A = a^2 \quad y = a/2$	$\frac{a^4}{12}$	$\frac{a^3}{6}$	$\frac{a}{\sqrt{12}} = 0.289a$
 $A = a^2 \quad y = a$	$\frac{a^4}{3}$	$\frac{a^3}{3}$	$\frac{a}{\sqrt{3}} = 0.577a$
 $A = a^2$ $y = \frac{a}{\sqrt{2}} = 0.707a$	$\frac{a^4}{12}$	$\frac{a^3}{6\sqrt{2}} = 0.118a^3$	$\frac{a}{\sqrt{12}} = 0.289a$
 $A = a^2 - b^2 \quad y = a/2$	$\frac{a^4 - b^4}{12}$	$\frac{a^4 - b^4}{6a}$	$\sqrt{\frac{a^2 + b^2}{12}} = 0.289\sqrt{a^2 + b^2}$

Table from Machinery's Handbook, 27th edition, pg. 238

$a_2 := 5\ in$ $b_2 := a_2 - 2 \cdot 0.375\ in$ 5" x 5" x 0.375" HSS

$r := 0.289\ \sqrt{a_2^{\ 2} + b_2^{\ 2}} = 1.896\ in$ Radius of Gyration, See above table from Machinery's Handbook

$L := 88\ in$ Worst case length of compressive member with the RSF, per drawing 1014726, item 12

E2. EFFECTIVE LENGTH

The effective length, L_c, for calculation of member slenderness, L_c/r, shall be determined in accordance with Chapter C or Appendix 7,

where
K = effective length factor
$L_c = KL$ = effective length of member, in. (mm)
L = laterally unbraced length of the member, in. (mm)
r = radius of gyration, in. (mm)

User Note: For members designed on the basis of compression, the effective slenderness ratio, L_c/r, preferably should not exceed 200.

from section E2
pg. 16.1-35

$L_c := K \cdot L = 184.8\ in$ — Effective Length

$F_e := \dfrac{\pi^2 \cdot E}{\left(\dfrac{L_c}{r}\right)^2} = 27.2\ ksi$ — Elastic bucking stress, equation E3-4

$\dfrac{L_c}{r} = 97.4$ — Less than 200, acceptable, per user note above in section E2

$4.71 \cdot \sqrt{\dfrac{E}{F_y}} = 157.923$ — Since $\dfrac{L_c}{r}$ is less than this value use E3-2 to determine F_{cr}, pg. 16.1-35

$F_{cr} := \left(0.658^{\frac{F_y}{F_e}}\right) \cdot F_y = 16.3\ ksi$ — Critical compressive stress, equation E3-2

$R_{n\_C} := \dfrac{F_{cr}}{\Omega_c} = 9.7\ ksi$ — Allowable compressive strength, equation E3-1

$R_{a\_C\_NLC} := 1.61\ ksi$ — FEA Calculated Compressive Stress, see FEA results in Appendix A with NLC

$R_{a\_C\_ELC} := 1.95\ ksi$ — FEA Calculated Compressive Stress, see FEA results in Appendix B with ELC

$DC_{C\_NLC} := \dfrac{R_{a\_C\_NLC}}{R_{n\_C}} = 0.17$ — Demand to capacity, Compressive Stress with NLC, <1 satisfactory

$DC_{C\_ELC} := \dfrac{R_{a\_C\_ELC}}{R_{n\_C}} = 0.20$ — Demand to capacity, Compressive Stress with ELC, <1 satisfactory

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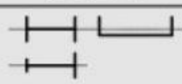
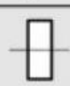
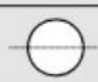
4. Chapter NF - Design of Members for Flexure

$\Omega_b := 1.67$ Factor of Safety, pg. 16.1-46

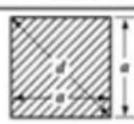
TABLE USER NOTE F1.1
Selection Table for the Application of Chapter F Sections

Section in Chapter F	Cross Section	Flange Slenderness	Web Slenderness	Limit States
F2		C	C	Y, LTB
F3		NC, S	C	LTB, FLB
F4		C, NC, S	C, NC	CFY, LTB, FLB, TFY
F5		C, NC, S	S	CFY, LTB, FLB, TFY
F6		C, NC, S	N/A	Y, FLB
F7		C, NC, S	C, NC, S	Y, FLB, WLB, LTB
F8		N/A	N/A	Y, LB
F9		C, NC, S	N/A	Y, LTB, FLB, WLB
F10		N/A	N/A	Y, LTB, LLB
F11		N/A	N/A	Y, LTB
F12	Unsymmetrical shapes, other than single angles	N/A	N/A	All limit states

Y = yielding, CFY = compression flange yielding, LTB = lateral-torsional buckling, FLB = flange local buckling, WLB = web local buckling, TFY = tension flange yielding, LLB = leg local buckling, LB = local buckling, C = compact, NC = noncompact, S = slender, N/A = not applicable

from pg. 16.1-45

Polar Moment of Inertia and Polar Section Modulus

Section	Polar Moment of Inertia, J	Polar Section Modulus, Z_p
	$\frac{a^4}{6} = 0.1667a^4$	$0.208a^3 = 0.074d^3$

From Machinery's Handbook 27th edition, pg. 249

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Moments of Inertia, Section Moduli, and Radii of Gyration

Section A = area y = distance from axis to extreme fiber	Moment of Inertia I	Section Modulus $Z = \frac{I}{y}$	Radius of Gyration $k = \sqrt{\frac{I}{A}}$
Square and Rectangular Sections			
$A = a^2$ $y = a/2$	$\frac{a^4}{12}$	$\frac{a^3}{6}$	$\frac{a}{\sqrt{12}} = 0.289a$
$A = a^2$ $y = a$	$\frac{a^4}{3}$	$\frac{a^3}{3}$	$\frac{a}{\sqrt{3}} = 0.577a$
$A = a^2$ $y = \frac{a}{\sqrt{2}} = 0.707a$	$\frac{a^4}{12}$	$\frac{a^3}{6\sqrt{2}} = 0.118a^3$	$\frac{a}{\sqrt{12}} = 0.289a$
$A = a^2 - b^2$ $y = a/2$	$\frac{a^4 - b^4}{12}$	$\frac{a^4 - b^4}{6a}$	$\sqrt{\frac{a^2 + b^2}{12}} = 0.289\sqrt{a^2 + b^2}$

From Machinery's Handbook
27th edition, pg. 238

$Z := \frac{a_2^{\ 4} - b_2^{\ 4}}{6\ a_2} = 10\ in^3$ Polar Section Modulus, Plastic section modulus equals Polar section modulus, equation from Machinery's Handbook, see table above

$M_p := F_y \cdot Z = 231.9\ kip \cdot in$ Plastic bending moment , equation F7-1

$M_{n\_F} := \frac{M_p}{\Omega_b} = 138.9\ kip \cdot in$ Allowable flexural strength, derived from equation F7-1

$r_y := r$ Radius of gyration about y-axis, $r_y = r$, square HSS, as calculated herein, page 12

$J := \frac{a_2^{\ 4}}{6} - \frac{b_2^{\ 4}}{6} = 49.8\ in^4$ Torsional Constant, aka Polar Moment of Inertia, from page 14 table herein, Torsional constant of solid 5x5 minus the hollow portions.

$L_p := 0.13 \cdot E \cdot r_y \cdot \frac{\sqrt{J \cdot A_g}}{M_p} = 500.3\ in$ Limiting laterally unbraced length for the limit state of yielding, equation F2-5

$L_b := 71\ in$ Length between braced points, worst case for RSF, see drawing 1014726, item

Per section F2.2(a), Since $L_b \le L_p$ lateral-torsional buckling does not apply.

$M_{a\_F\_NLC} := 37.0\ kip \cdot in$ FEA Calculated Moment, see FEA results in Appendix A with NLC

$M_{a\_F\_ELC} := 47.8\ kip \cdot in$ FEA Calculated Moment, see FEA results in Appendix B with NLC

$DC_{F\_NLC} := \frac{M_{a\_F\_NLC}}{M_{n\_F}} = 0.27$ Demand to capacity, Flexure with NLC, <1 satisfactory

$DC_{F\_ELC} := \frac{M_{a\_F\_ELC}}{M_{n\_F}} = 0.34$ Demand to capacity, Flexure with ELC, <1 satisfactory

5. Chapter NG - Design of Members for Shear

$\Omega_v := 1.67$ Factor of Safety with ASD for shear, section G1, pg. 16.1-70

$h := 3.5\ in$ Clear distance between flanges less the fillet at each flange, per section G4, pg. 16.1-74

$A_w := 2 \cdot h \cdot t = 2.4\ in^2$ Web area, per section G4, pg. 16.1-74

$k_v := 5$ Web plate shear buckling coefficient, per section G4, pg. 16.1-74

$1.10 \cdot \sqrt{\frac{k_v \cdot E}{F_y}} = 82.5$ Equation G2-9, directed from equation G4-1

$\frac{h}{t} = 10.04$

Since $\frac{h}{t} \leq 1.10 \cdot \sqrt{\frac{k_v \cdot E}{F_y}}$ is true, C_{v2} = 1.0, per equation G2-9

$C_{v2} := 1.0$

$V_n := 0.6 \cdot F_y \cdot A_w \cdot C_{v2} = 34.1\ kip$ Nominal shear strength, equation G4-1

$V_{n\_v} := \frac{\left(\frac{V_n}{A_w}\right)}{\Omega_v} = 8.37\ ksi$ Design Shear Strength, per section G1

$V_{a\_v\_NLC} := 0.66\ ksi$ FEA Calculated Shear Stress, see FEA results in Appendix A with NLC

$V_{a\_v\_ELC} := 0.83\ ksi$ FEA Calculated Shear Stress, see FEA results in Appendix B with ELC

$DC_{v\_NLC} := \frac{V_{a\_v\_NLC}}{V_{n\_v}} = 0.08$ Demand to capacity, Flexure with NLC, <1 satisfactory

$DC_{v\_ELC} := \frac{V_{a\_v\_ELC}}{V_{n\_v}} = 0.10$ Demand to capacity, Flexure with ELC, <1 satisfactory

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6. Chapter NH - Design of Members for Combined Forces and Torsion

$\Omega_T := 1.67$ Factor of Safety for Torsion, section H3

$\frac{h}{t} = 10.036$

$2.45 \cdot \sqrt{\frac{E}{F_y}} = 82.147$

Since $\frac{h}{t} \le 2.45 \cdot \sqrt{\frac{E}{F_y}}$ is true, use equation H3-3

$F_{cr\_H3} := 0.6 \cdot F_y = 14.0\ ksi$ Critical stress, equation H3-3

$T_n := \frac{F_{cr\_H3}}{\Omega_T} = 8.4\ ksi$ Allowable Torsional Strength, section H3

$T_{r\_NLC} := 0.14\ ksi$ FEA Calculated Torsional Shear Stress, see FEA results in Appendix A with NLC

$T_{r\_ELC} := 0.27\ ksi$ FEA Calculated Torsional Shear Stress, see FEA results in Appendix B with ELC

$DC_{T\_NLC} := \frac{T_{r\_NLC}}{T_n} = 0.02$ Demand to capacity, Flexure with NLC, <1 satisfactory

$DC_{T\_ELC} := \frac{T_{r\_ELC}}{T_n} = 0.03$ Demand to capacity, Flexure with ELC, <1 satisfactory, < 20%, but it will be considered regardless in combined forces analysis as shown below, per H3-6

$M_{r1} := M_{a\_F\_NLC} = 37\ kip \cdot in$ Required flexural strength, see FEA results in Appendix A, with NLC

$M_{r2} := M_{a\_F\_ELC} = 47.8\ kip \cdot in$ Required flexural strength, see FEA results in Appendix B, with ELC

$M_c := M_{n\_F} = 138.9\ kip \cdot in$ Allowable flexural strength, as calculated herein

$P_{r1} := \max\left(R_{a\_T\_NLC}, R_{a\_C\_NLC}\right) = 1.61\ ksi$ Required maximum axial/compressive strength, see FEA results in Appendix A, with NLC, as calculated herein

$P_{r2} := \max\left(R_{a\_T\_ELC}, R_{a\_C\_ELC}\right) = 1.95\ ksi$ Required maximum axial/compressive strength, see FEA results in Appendix B, with ELC, as calculated herein

$P_c := R_{n\_C} = 9.75\ ksi$ Allowable tensile or compressive strength, determined in accordance with Chapter D or E, choosing the lesser of the two (compressive), as calculated herein

$V_{r1} := V_{a\_v\_NLC} = 0.66\ ksi$ Required shear strength, see FEA results in Appendix A, with NLC

$V_{r2} := V_{a\_v\_ELC} = 0.83\ ksi$ Required shear strength, see FEA results in Appendix B, with ELC

$V_c := V_{n\_v} = 8.37\ ksi$ Allowable shear strength, as calculated herein

$T_{r1} := T_{r\_NLC} = 0.14\ ksi$ Required torsional strength, see FEA results in Appendix A, with NLC

$T_{r2} := T_{r\_ELC} = 0.27\ ksi$ Required torsional strength, see FEA results in Appendix B, with ELC

$T_c := T_n = 8.37\ ksi$ Allowable torsional strength, as calculated herein

2. HSS Subject to Combined Torsion, Shear, Flexure and Axial Force

When the required torsional strength, T_r, is less than or equal to 20% of the available torsional strength, T_c, the interaction of torsion, shear, flexure and/or axial force for HSS may be determined by Section H1 and the torsional effects may be neglected. When T_r exceeds 20% of T_c, the interaction of torsion, shear, flexure and/or axial force shall be limited, at the point of consideration, by

$$\left(\frac{P_r}{P_c} + \frac{M_r}{M_c}\right) + \left(\frac{V_r}{V_c} + \frac{T_r}{T_c}\right)^2 \leq 1.0 \qquad \text{(H3-6)}$$

from Section H3, pg. 16.1-83

$$DC_{H\_comb\_NLD} := \left(\frac{P_{r1}}{P_c} + \frac{M_{r1}}{M_c}\right) + \left(\frac{V_{r1}}{V_c} + \frac{T_{r1}}{T_c}\right)^2 = 0.44$$

Combined Demand to capacity, NLD, Less than 1, acceptable, equation H3-6, including torsion

$$DC_{H\_comb\_ELD} := \left(\frac{P_{r2}}{P_c} + \frac{M_{r2}}{M_c}\right) + \left(\frac{V_{r2}}{V_c} + \frac{T_{r2}}{T_c}\right)^2 = 0.56$$

Combined Demand to capacity, ELD, Less than 1, acceptable, equation H3-6, including torsion

Chapter NI - Design of Composite Members is N/A due to this structure only being made of only HSS and not HSS and concrete composite beams/supports or other combinations.

7. Chapter NJ - Design of Connections

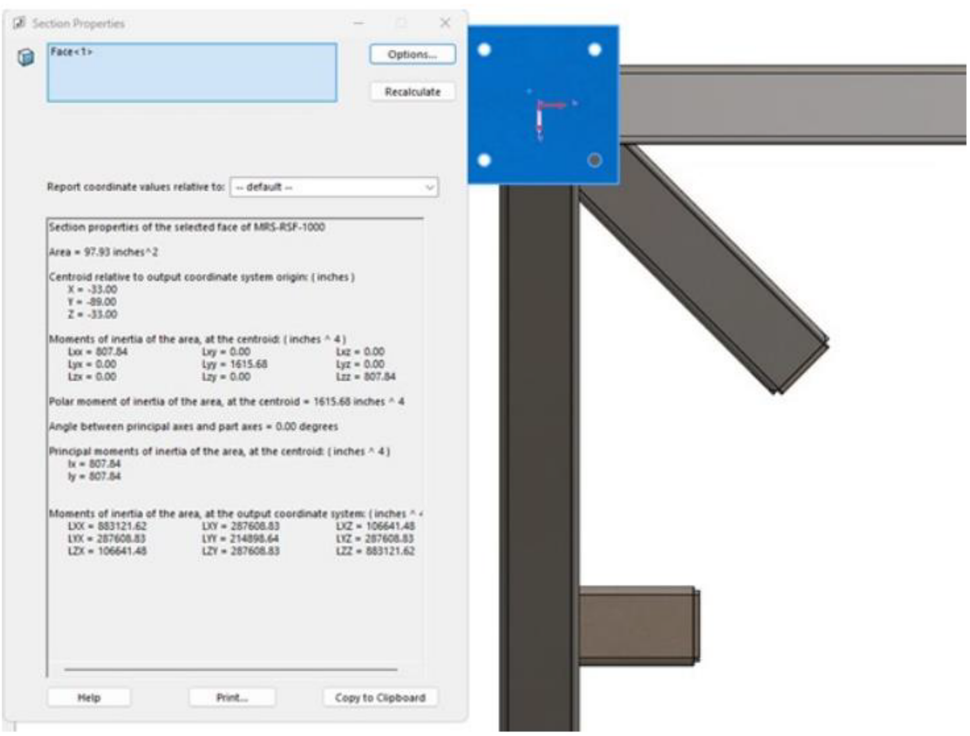
There is no bolts sharing loads with welds. Bolts that will be taking a load are on the mounting plates at the bottom of the RSF. Additionally, bolts will be utilized to mount the insulation pads near the bearing surfaces of the top of the frame. Insulation mounting bolts will be not take any load.

TABLE J2.5
Available Strength of Welded Joints, ksi (MPa)

Load Type and Direction Relative to Weld Axis	Pertinent Metal	ϕ and Ω	Nominal Stress (F_{nBM} or F_{nw}), ksi (MPa)	Effective Area (A_{BM} or A_{we}), in.[2] (mm[2])	Required Filler Metal Strength Level[a][b]
COMPLETE-JOINT-PENETRATION GROOVE WELDS					
Tension—Normal to weld axis	Strength of the joint is controlled by the base metal.				Matching filler metal shall be used. For T- and corner-joints with backing left in place, notch tough filler metal is required. See Section J2.6.
Compression—Normal to weld axis	Strength of the joint is controlled by the base metal.				Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.
Tension or compression—Parallel to weld axis	Tension or compression in parts joined parallel to a weld is permitted to be neglected in design of welds joining the parts.				Filler metal with a strength level equal to or less than matching filler metal is permitted.
Shear	Strength of the joint is controlled by the base metal.				Matching filler metal shall be used.[c]

from
pg. 16.1-123

Although the RSF will be mounted onto at steel/stainless steel plate which will then be mounted to the concrete, it will be analyzed as if it is mounted directly to the concrete.



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Appendix C
Stress Allowable Calculations & Compliance

$\Omega_{cb} := 2.31$ Factor of Safety, bearing strength for column bases, Section J8

$f'_c := 2500\ psi$ Compressive strength of concrete for residential concrete, expected higher at TREAT

$A_{1\_J} := 97.93\ in^2 \cdot 4 = 391.7\ in^2$ area of steel concentrically bearing on a concrete support, see section properties calculation from Solidworks below.

$P_p := 0.85 \cdot f'_c \cdot A_{1\_J} = 832.4\ kip$ Nominal bearing strength, Section J8

$$P_{c\_J} := \frac{P_p}{\Omega_{cb}} = 360.3\ kip$$ Allowable bearing strength, Section J8

$P_{a\_NLC} := 91636.5\ N = 20.6\ kip$ FEA calculated resultant force, NLC, see appendix A under resultant forces

$P_{a\_ELC} := 135312\ N = 30.4\ kip$ FEA calculated resultant force, ELC, see appendix B under resultant forces

$$DC_{c\_NLC} := \frac{P_{a\_NLC}}{P_{c\_J}} = 0.06$$ Demand to capacity bearing strength, <1 acceptable

$$DC_{c\_ELC} := \frac{P_{a\_ELC}}{P_{c\_J}} = 0.08$$ Demand to capacity bearing strength, <1 acceptable

	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL/ SPECIFICATION OR VENDOR NAME	ITEM NO.
	AR		WELD FILLER METAL	ER16-8-2 ASME SFA5.9	14
					13
	4		LEG	TUBING, 5X5X3/8 WALL 316H SST ASTM A1069	12
	4		GUARD VESSEL SUPPORT 2	TUBING, 5X5X3/8 WALL 316H SST ASTM A1069	11
	4		GUARD VESSEL SUPPORT 1	TUBING, 5X5X3/8 WALL 316H SST ASTM A1069	10
	4		UPPER BRACE	TUBING, 5X5X3/8 WALL 316H SST ASTM A1069	9
	4		TOP FRAME	TUBING, 5X5X3/8 WALL 316H SST ASTM A1069	8
					7
	12	-6	END CAP	PLATE, .375 THK 316H SST ASTM A240	6
	4	-5	CROSS BRACE	TUBING, 5X5X3/8 WALL 316H SST ASTM A1069	5
	4	-4	FLOOR PLATE	PLATE, 1.0 THK 316H SST ASTM A240	4
					3
					2
		-1	REACTOR SUPPORT FRAME		1
	-1				

PARTS LIST

DIMENSIONING AND SYMBOLOGY PER ASME Y14.5M AND STD-1011 UNLESS OTHERWISE SPECIFIED SURFACE ROUGHNESS DIMENSIONS AND TOLERANCES ARE IN INCHES

REQUESTER: Y. ARAFAT
RESP ENGR: L. ANDREW
DESIGN: M. FLOYD
DRAWN: T. FUNDERBURG
PROJECT NO: 33526
SPCL CODE: NA
FOR REVIEW/APPROVAL SIGNATURES SEE DCR NO: 704073
EFFECTIVE DATE:

INL Idaho National Laboratory

MARVEL
REACTOR STRUCTURE

REACTOR SUPPORT FRAME
WELDMENT

SIZE: D | CAGE CODE: 01MF3 | INDEX CODE NUMBER: AREA 800, TYPE 0785, CL 46, ORIG 920 | DWG NO: 1014726 | REV: 000A

SCALE: 1/10 AND NOTED | SHEET 1 OF 3

Weld Material for RSF

from
Drawing 1014726

Table 1 (Continued)
Chemical Composition Requirements[a]

AWS Classification[d]	UNS Number[e]	C	Cr	Ni	Mo	Mn	Si[f]	P	S	N	Cu	Other Elements: Element	Other Elements: Amount
ER409	S40900	0.08	10.5–13.5	0.6	0.50	0.8	0.8	0.03	0.03	—	0.75	Ti	10 × C min/1.5 max
ER409Nb	S40940	0.08	10.5–13.5	0.6	0.50	0.8	1.0	0.04	0.03	—	0.75	Nb[g]	10 × C min/0.75 max
ER410	S41080	0.12	11.5–13.5	0.6	0.75	0.6	0.5	0.03	0.03	—	0.75	—	—
ER410NiMo	S41086	0.06	11.0–12.5	4.0–5.0	0.4–0.7	0.6	0.5	0.03	0.03	—	0.75	—	—
ER420	S42080	0.25–0.40	12.0–14.0	0.6	0.75	0.6	0.5	0.03	0.03	—	0.75	—	—
ER430	S43080	0.10	15.5–17.0	0.6	0.75	0.6	0.5	0.03	0.03	—	0.75	—	—
ER439	S43035	0.04	17.0–19.0	0.6	0.5	0.8	0.8	0.03	0.03	—	0.75	Ti	10 × C min./1.1 max.
ER446LMo	S44687	0.015	25.0–27.5	h	0.75–1.50	0.4	0.4	0.02	0.02	0.015	h	—	—
ER630	S17480	0.05	16.00–16.75	4.5–5.0	0.75	0.25–0.75	0.75	0.03	0.03	—	3.25–4.00	Nb[g]	0.15–0.30
ER19-10H	S30480	0.04–0.08	18.5–20.0	9.0–11.0	0.25	1.0–2.0	0.30–0.65	0.03	0.03	—	0.75	Nb[g]	0.05
												Ti	0.05
ER16-8-2	S16880	0.10	14.5–16.5	7.5–9.5	1.0–2.0	1.0–2.0	0.30–0.65	0.03	0.03		0.75	—	—

from
ASME BPVC Section II, Part C
pg. 279

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TABLE J2.5
Available Strength of Welded Joints, ksi (MPa)

Load Type and Direction Relative to Weld Axis	Pertinent Metal	ϕ and Ω	Nominal Stress (F_{nBM} or F_{nw}), ksi (MPa)	Effective Area (A_{BM} or A_{we}), in.^{2} (mm^2)	Required Filler Metal Strength Level[a][b]
COMPLETE-JOINT-PENETRATION GROOVE WELDS					
Tension—Normal to weld axis	Strength of the joint is controlled by the base metal.				Matching filler metal shall be used. For T- and corner-joints with backing left in place, notch tough filler metal is required. See Section J2.6.
Compression—Normal to weld axis	Strength of the joint is controlled by the base metal.				Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.
Tension or compression—Parallel to weld axis	Tension or compression in parts joined parallel to a weld is permitted to be neglected in design of welds joining the parts.				Filler metal with a strength level equal to or less than matching filler metal is permitted.
Shear	Strength of the joint is controlled by the base metal.				Matching filler metal shall be used.[c]
PARTIAL-JOINT-PENETRATION GROOVE WELDS INCLUDING FLARE V-GROOVE AND FLARE BEVEL GROOVE WELDS					
Tension—Normal to weld axis	Base	$\phi = 0.75$ $\Omega = 2.00$	F_u	See J4	Filler metal with a strength level equal to or less than matching filler metal is permitted.
	Weld	$\phi = 0.80$ $\Omega = 1.88$	$0.60F_{EXX}$	See J2.1a	
Compression—Column to base plate and column splices designed per Section J1.4(a)	Compressive stress is permitted to be neglected in design of welds joining the parts.				
Compression—Connections of members designed to bear other than columns as described in Section J1.4(b)	Base	$\phi = 0.90$ $\Omega = 1.67$	F_y	See J4	
	Weld	$\phi = 0.80$ $\Omega = 1.88$	$0.60F_{EXX}$	See J2.1a	
Compression—Connections not finished-to-bear	Base	$\phi = 0.90$ $\Omega = 1.67$	F_y	See J4	
	Weld	$\phi = 0.80$ $\Omega = 1.88$	$0.90F_{EXX}$	See J2.1a	
Tension or compression—Parallel to weld axis	Tension or compression in parts joined parallel to a weld is permitted to be neglected in design of welds joining the parts.				
Shear	Base	Governed by J4			
	Weld	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{EXX}$	See J2.1a	

from
Section J2
pgs. 16.1-123 through 16.1-124

TABLE J2.5 (continued)
Available Strength of Welded Joints, ksi (MPa)

Load Type and Direction Relative to Weld Axis	Pertinent Metal	ϕ and Ω	Nominal Stress (F_{nBM} or F_{nw}), ksi (MPa)	Effective Area (A_{BM} or A_{we}), in.^{2} (mm^2)	Required Filler Metal Strength Level[a][b]
FILLET WELDS INCLUDING FILLETS IN HOLES AND SLOTS AND SKEWED T-JOINTS					
Shear	Base	Governed by J4			Filler metal with a strength level equal to or less than matching filler metal is permitted.
	Weld	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{EXX}$[d]	See J2.2a	
Tension or compression—Parallel to weld axis	Tension or compression in parts joined parallel to a weld is permitted to be neglected in design of welds joining the parts.				
PLUG AND SLOT WELDS					
Shear—Parallel to faying surface on the effective area	Base	Governed by J4			Filler metal with a strength level equal to or less than matching filler metal is permitted.
	Weld	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{EXX}$	See J2.3a	

[a] For matching weld metal, see AWS D1.1/D1.1M clause 3.3.
[b] Filler metal with a strength level one strength level greater than matching is permitted.
[c] Filler metals with a strength level less than matching are permitted to be used for groove welds between the webs and flanges of built-up sections transferring shear loads, or in applications where high restraint is a concern. In these applications, the weld joint shall be detailed and the weld shall be designed using the thickness of the material as the effective throat, where $\phi = 0.80$, $\Omega = 1.88$ and $0.60F_{EXX}$ is the nominal strength.
[d] The provisions of Section J2.4(b) are also applicable.

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Table A.3
All-Weld-Metal Mechanical Property Requirements from AWS A5.4/A5.4M:2006

AWS Classification	Tensile Strength, min. ksi	Tensile Strength, min. MPa	Elongation, min. percent	Heat Treatment
E209-XX	100	690	15	none
E219-XX	90	620	15	none
E240-XX	100	690	15	none
E307-XX	85	590	30	none
E308-XX	80	550	35	none
E308H-XX	80	550	35	none
E308L-XX	75	520	35	none
E308Mo-XX	80	550	35	none
E308LMo-XX	75	520	35	none
E309-XX	80	550	30	none
E309H-xx	80	550	30	none
E309L-XX	75	520	30	none
E309Nb-XX	80	550	30	none
E309Mo-XX	80	550	30	none
E309LMo-XX	75	520	30	none
E310-XX	80	550	30	none
E310H-XX	90	620	10	none
E310Mo-XX	80	550	30	none
E312-XX	95	660	22	none
E316-XX	75	520	30	none
E316H-XX	75	520	30	none
E316L-XX	70	490	30	none
E316LMn-XX	80	550	20	none
E317-XX	80	550	30	none
E317L-XX	75	520	30	none
E318-XX	80	550	25	none
E320-XX	80	550	30	none
E320LR-XX	75	520	30	none
E330-XX	75	520	25	none
E330H-XX	90	620	10	none
E347-XX	75	520	30	none
E349-XX	100	690	25	none
E383-XX	75	520	30	none
E385-XX	75	520	30	none
E409Nb-XX	65	450	20	a
E410-XX	75	520	20	b
E410NiMo-XX	110	760	15	c
E430-XX	65	450	20	a
E630-XX	135	930	7	d
E16-8-2-XX	80	550	35	none
E2209-XX	100	690	20	none
ER2307-XX[e]	*100*	*690*	*20*	*none*
E2553-XX	110	760	15	none
E2594-XX	110	760	15	none
E33-31-XX	105	720	25	none

[a] Heat to 1400 °F to 1450 °F [760 °C to 790 °C], hold for two hours (–0, +15 minutes), furnace cool at a rate not exceeding 100 °F [55 °C] per hour to 1100 °F [595 °C] and air cool to ambient.
[b] Heat to 1350 °F to 1400 °F [730 °C to 760 °C], hold for one hour (–0, +15 minutes), furnace cool at a rate not to exceed 200 °F [110 °C] per hour to 600 °F [315 °C] and air cool to ambient.
[c] Heat to 1100 °F to 1150 °F [595 °C to 620 °C], hold for one hour (–0, +15 minutes), and air cool to ambient.
[d] Heat to 1875 °F to 1925 °F [1025 °C to 1050 °C], hold for one hour (–0, +15 minutes), and air cool to ambient, and then precipitation harden at 1135 °F to 1165 °F [610 °C to 630 °C], hold for four hours (–0, +15 minutes), and air cool to ambient.
[e] Not found in AWS A5.4/A5.4M:2006, but expected to be added to the next revision of AWS A5.4/A5.4M.

from
AWS A5.9/A5.9M:2012,
pg. 26

A2. Classification System

A2.1 The chemical composition of the filler metal is identified by a series of numbers and, in some cases, chemical symbols, the letters L, H, and LR, or both. Chemical symbols are used to designate modifications of basic alloy types, for example, ER308Mo. The letter "H" denotes carbon content restricted to the upper part of the range that is specified for the standard grade of the specific filler metal. The letter "L" denotes carbon content in the lower part of the range that is specified for the corresponding standard grade of filler metal. The letters "LR" denote low residuals (see A8.31).

A2.1.1 The first two designators may be "ER" for solid wires that may be used as electrodes or rods; or they may be "EC" for composite cored or stranded wires; or they may be "EQ" for strip electrodes.

A2.1.2 The three- or four-digit number, such as 308 in ER308, designates the nominal chemical composition of the filler metal.

from
AWS A5.9, pg. 11

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$\Omega_{weld} := 2.00$ — Worst case Factor of Safety, welded joints, Table J2.5, pg. 16.1-123

$A_{BM} := A_e = 6.227\ in^2$ — Cross-sectional area of base material, pg. 16.1-122

$l_{weld} := 5 \cdot 4\ in = 20\ in$ — Length of weld, all-around welds on Drawing 1014726

$E_{throat} := \frac{3}{16}\ in$ — Minimum effective throat of groove welds, Table J2.1, Table J3.1, and Table J2.3, pg. 16.1-117 through 16.1-118

$A_{we} := l_{weld} \cdot E_{throat} = 3.75\ in^2$ — Effective area of the weld, pg. 16.1-122

$\max\left(P_{r1}, V_{r1}, T_{r1}\right) \cdot A_{BM} = 10\ kip$

$\max\left(P_{r1}, V_{r1}, T_{r1}\right) \cdot A_{we} = 6\ kip$

Maximum nominal stress of base metal, FEA calculated NLC see Appendix A and in this appendix pg. 77, 81, 84, and 85, pg. 16.1-122, weld material is limiting

$R_{w1} := \max\left(P_{r1}, V_{r1}, T_{r1}\right) = 1.61\ ksi$ — Compressive stress is most limiting, NLC

$\max\left(P_{r2}, V_{r2}, T_{r2}\right) \cdot A_{BM} = 12.1\ kip$

$\max\left(P_{r2}, V_{r2}, T_{r2}\right) \cdot A_{we} = 7.3\ kip$

Maximum nominal stress of base metal, FEA calculated ELC see Appendix B and in this appendix pg. 77, 81, 84, and 85, pg. 16.1-122, weld material is limiting

$R_{w2} := \max\left(P_{r2}, V_{r2}, T_{r2}\right) = 1.95\ ksi$ — Shear stress is most limiting, ELC

$F_u = 62.25\ ksi$ — Ultimate tensile strength, reduced as shown herein see page 4 of this appendix

$F_y = 23.3\ ksi$ — Yield strength, reduced as shown herein see page 4 of this appendix

$F_{E16.8.2} := 80\ ksi \cdot k_{yield}$ — Weld material ultimate tensile strength, reduced for temperature, see page 4 of this appendix, F_{EXX} is from Table A-3

$S_{weld} := min\left(F_u, F_y, F_{E16.8.2} \cdot 0.6\right) = 23.3\ ksi$ — Yield strength (ksi) of base material is most limiting

$F_{weld} := S_{weld} \cdot A_{we} = 87.3\ kip$ — Available strength of welds in kips

$P_{a\_weld} := \frac{F_{weld}}{\Omega_{weld}} = 43.7\ kip$ — Allowable weld strength

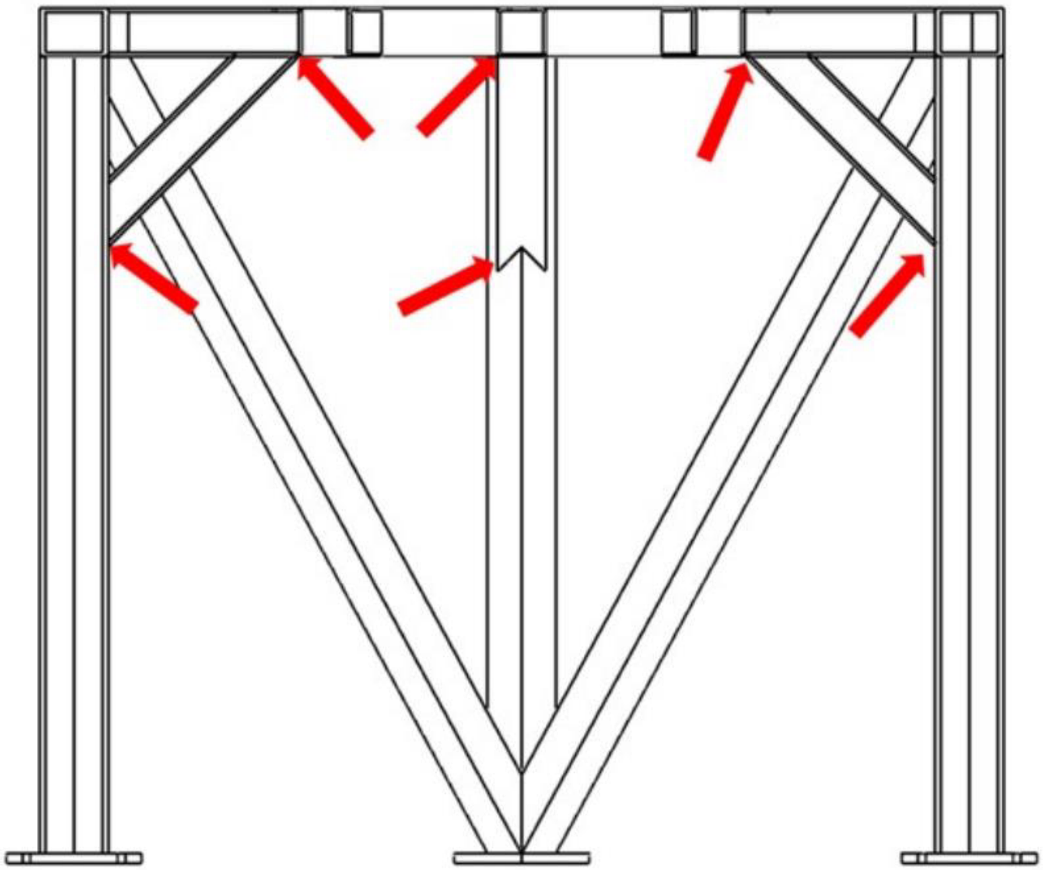
$R_{w1\_kip} := \max\left(R_{w1} \cdot A_{BM}, P_{a\_NLC}\right) = 20.6\ kip$ — Required Weld Strength, NLC

$R_{w2\_kip} := \max\left(R_{w2} \cdot A_{BM}, P_{a\_ELC}\right) = 30.4\ kip$ — Required Weld Strength, ELC

$DC_{weld\_NLC} := \frac{R_{w1\_kip}}{P_{a\_weld}} = 0.47$ — Demand to capacity, weld strength NLC, less than 1, acceptable

$DC_{weld\_ELC} := \frac{R_{w2\_kip}}{P_{a\_weld}} = 0.70$ — Demand to capacity, weld strength ELC, less than 1, acceptable

8. Chapter NK - Additional Requirements for HSS and Box-Section Connections



$t_b := t = 0.349\ in$ Design thickness for 5x5 HHS

$F_{yb} := F_y = 23.3\ ksi$ Yield strength of 5x5 HHS's

$B := 6.01\ in$ 5x5 HHS diagonal width

$B_b := 5\ in$ 5x5 HHS branch width

$B_e := \left(\frac{10 \cdot t}{B}\right)\left(\frac{F_y \cdot t}{F_{yb} \cdot t_b}\right) \cdot B_b = 2.9\ in$ Effective width of elements perpendicular to longitudinal axis, equation K1-1, less than B_b and therefore acceptable

$\frac{B}{t} = 17.2$ Since $\frac{B}{t} \geq 15$, equation K3-9 is N/A, See Section K-1, pg. 16.1-150

Equation K3-8 and limit state for shear of chord side walls in the gap region are N/A, since the chord and branch are square. Equations K3-7 thru K3-13 are N/A because there are no overlapping nor gapped K-connections in the RSF, see pg. 16.1-155 through 156

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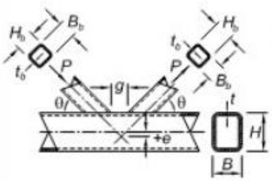
TABLE K3.2
Available Strengths of Rectangular HSS-to-HSS Truss Connections

Connection Type	Connection Available Axial Strength
Gapped K-Connections 	Limit State: Chord Wall Plastification, for all β $P_n \sin\theta = F_y t^2 (9.8 \beta_{eff} \gamma^{0.5}) Q_f$ (K3-7) $\phi = 0.90$ (LRFD) $\Omega = 1.67$ (ASD)
	Limit State: Shear Yielding (punching), when $B_b < B - 2t$ This limit state need not be checked for square branches. $P_n \sin\theta = 0.6 F_y t B (2\eta + \beta + \beta_{eop})$ (K3-8) $\phi = 0.95$ (LRFD) $\Omega = 1.58$ (ASD)
	Limit State: Shear of Chord Side Walls in the Gap Region Determine $P_n \sin\theta$ in accordance with Section G4. This limit state need not be checked for square chords.
	Limit State: Local Yielding of Branch/Branches due to Uneven Load Distribution This limit state need not be checked for square branches or where $B/t \geq 15$. $P_n = F_{yb} t_b (2H_b + B_b + B_e - 4t_b)$ (K3-9) $\phi = 0.95$ (LRFD) $\Omega = 1.58$ (ASD)

from
pg. 16.1-155

$\Omega_{K3\_7} := 1.67$ Factor of Safety for chapter K, per Table K3.2

$F_c := F_y \cdot 0.6 = 14.0\ ksi$ Available Stress in main member, pg. 16.1-150

$H := 5\ in$ $\quad H_b := H = 5\ in$ Height of HSS Chord

$$\beta_{eff} := \frac{\left(\left(B_b + H_b\right) + \left(B_b + H_b\right)\right)}{4 \cdot B} = 0.83$$

Effective width ratio, 5x5 square to 5x5 square, Table K3.2A, Additional Limits for Gapped K-Connections, pg. 16.1-157, $\beta_{eff} \geq 0.35$, acceptable

$S := Z = 9.958\ in^3$ Section Modulus, calculated herein

$P_{ro1} := P_{r1}$ Required axial strength in the cord at the joint, on the side of the joint with lower compression stress, assuming all members have worst case required axial loading, NLC

$P_{ro2} := P_{r2}$ Required axial strength in the cord at the joint, on the side of the joint with lower compression stress, assuming all members have worst case required axial loading, ELC

$M_{ro1} := M_{a\_F\_NLC} = 37\ kip \cdot in$ FEA Calculated Moment, see FEA results in Appendix A with Normal Load Combinations (NLC)

$M_{ro2} := M_{a\_F\_ELC} = 47.8\ kip \cdot in$ FEA Calculated Moment, see FEA results in Appendix B with Extreme Load Combinations (NLC)

$$U_1 := \left| \frac{P_{ro1}}{F_c} + \frac{M_{ro1}}{F_c \cdot S} \right| = 0.381$$

Utilization Ratio, equation K2-4 from Table K3.1, A_e is used and already divided in P_{ro}, NLC

$$U_2 := \left| \frac{P_{ro1}}{F_c} + \frac{M_{ro2}}{F_c \cdot S} \right| = 0.459$$

Utilization Ratio, equation K2-4 from Table K3.1, A_e is used and already divided in P_{ro}, ELC

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Appendix C
Stress Allowable Calculations & Compliance

$\beta := 1$ Width ratio, 5x5 square to 5x5 square

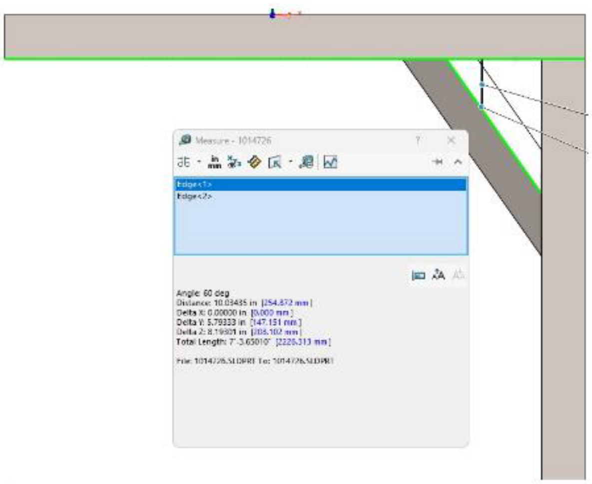
$Q_{f\_T\_Y1} := 1.3 - 0.4 \cdot \frac{U_1}{\beta} = 1.148$ Chord Stress Interaction Parameter for T-, Y- and cross connections, equation K3-14

$Q_{f\_T\_Y2} := 1.3 - 0.4 \cdot \frac{U_2}{\beta} = 1.116$ Chord Stress Interaction Parameter for T-, Y- and cross connections, equation K3-14

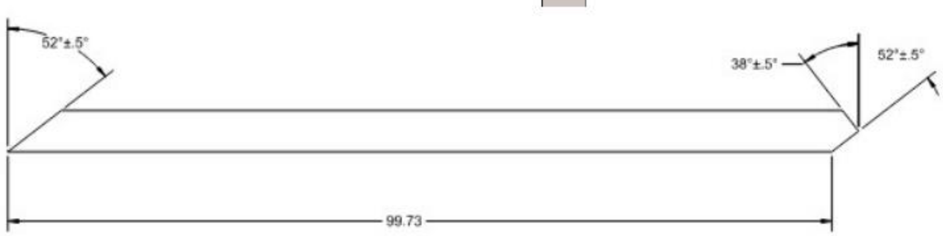
$Q_{f\_K1} := 1.3 - 0.4 \cdot \frac{U_1}{\beta_{eff}} = 1.117$ Chord Stress Interaction Parameter for K-connections, equation K3-15

$Q_{f\_K2} := 1.3 - 0.4 \cdot \frac{U_2}{\beta_{eff}} = 1.079$ Chord Stress Interaction Parameter for K-connections, equation K3-15

$Q_f := 1$ Chord Stress Interaction Parameter, tension, pg. 16.1-144, selected worst case (see Table K3.2 for chord in tension) for inputting into allowable K3-7



θ_c from Solidworks RSF model



θ_1 & θ_2 from 1014726, item 5

$\theta_c := 60°$ Upper Brace, Drawing 1014726, Item 9, angle derived from SolidWorks model

$\theta_1 := 38°$ Cross Brace, Drawing 1014726, Item 5, Angle 1

$\theta_2 := 52°$ Cross Brace, Drawing 1014726, Item 5, Angle 2

$\sin(\theta_c) = 0.866$ $\sin(\theta_1) = 0.616$ $\sin(\theta_2) = 0.788$ Worst case angle is θ_c

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Appendix C
Stress Allowable Calculations & Compliance

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TABLE K3.2A
Limits of Applicability of Table K3.2

Joint eccentricity:	$-0.55 \le e/H \le 0.25$ for K-connections
Chord wall slenderness:	B/t and $H/t \le 35$ for gapped K-connections and T-, Y-and cross-connections
Branch wall slenderness:	$B/t \le 30$ for overlapped K-connections
	$H/t \le 35$ for overlapped K-connections
	B_b/t_b and $H_b/t_b \le 35$ for tension branch
	$\le 1.25\sqrt{\frac{E}{F_{yb}}}$ for compression branch of gapped K-, T-, Y- and cross-connections
	≤ 35 for compression branch of gapped K-, T-, Y- and cross-connections
	$\le 1.1\sqrt{\frac{E}{F_{yb}}}$ for compression branch of overlapped K-connections
Width ratio:	B_b/B and $H_b/B \ge 0.25$ for T-, Y- cross- and overlapped K-connections
Aspect ratio:	$0.5 \le H_b/B_b \le 2.0$ and $0.5 \le H/B \le 2.0$
Overlap:	$25\% \le O_v \le 100\%$ for overlapped K-connections
Branch width ratio:	$B_{bi}/B_{bj} \ge 0.75$ for overlapped K-connections, where subscript i refers to the overlapping branch and subscript j refers to the overlapped branch
Branch thickness ratio:	$t_{bi}/t_{bj} \le 1.0$ for overlapped K-connections, where subscript i refers to the overlapping branch and subscript j refers to the overlapped branch
Material strength:	F_y and $F_{yb} \le 52$ ksi (360 MPa)
Ductility:	F_y/F_u and $F_{yb}/F_{ub} \le 0.8$ Note: ASTM A500 Grade C is acceptable.
End distance:	$l_{end} \ge B\sqrt{1-\beta}$ for T- and Y-connections
Additional Limits for Gapped K-Connections	
Width ratio:	$\frac{B_b}{B}$ and $\frac{H_b}{B} \ge 0.1 + \frac{\gamma}{50}$
	$\beta_{eff} \ge 0.35$
Gap ratio:	$\zeta = g/B \ge 0.5(1-\beta_{eff})$
Gap:	$g \ge t_{b\,compression\,branch} + t_{b\,tension\,branch}$
Branch size:	smaller $B_b \ge 0.63$ (larger B_b), if both branches are square

from
pg. 16.1-157

$\gamma := \frac{B}{2 \cdot t} = 8.616$ Chord slenderness ratio, pg. 16.1-157

$\frac{B_b}{B} = 0.832$ Width ratio, $\frac{B_b}{B} \ge 0.25$, acceptable

$l_{end} := \begin{bmatrix} 2.50 \\ 2.21 \\ 0.80 \end{bmatrix}$ Distance from the near side of the connecting branch or plate to end of chord, Section K1.1, pg. 16.1-150, values derived from Solidworks for T and K connections

$B \cdot \sqrt{1-\beta} = 0.000\ in$ Limits of Applicability of Table K3.2, $l_{end} \ge B \cdot \sqrt{1-\beta}$, acceptable

$\frac{F_y}{F_u} = 0.374$ Ductility ratio, Table K3.2, $\frac{F_y}{F_u} \le 0.8$, acceptable

$\frac{B}{t} = 17.233$ $\frac{B}{t} \le 35$, acceptable, from Table K3.2A

$\frac{H}{t} = 14.337$ $\frac{H}{t} \le 35$, acceptable, from Table K3.2A

$\frac{H_b}{t_b} = 14.337$ $\frac{H_b}{t_b} \le 35$, acceptable, from Table K3.2A, for tension and compression branches

$\frac{B_b}{t_b} = 14.337$ $\frac{B_b}{t_b} \le 35$, acceptable, from Table K3.2A

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$$P_{n\_K3\_7\_a} := \frac{F_y \cdot t^2 \left(9.8 \cdot \beta_{eff} \cdot \gamma^{0.5}\right) \cdot Q_f}{\sin\left(\theta_c\right)} = 78.3\ kip$$

Allowable axial strength for K joint, chord wall plastification, equation K3-7 in kips

$$P_{n\_K3\_7} := \frac{P_{n\_K3\_7\_a}}{A_e \cdot \Omega_{K3\_7}} = 7.53\ ksi$$

Allowable axial strength for K joint, chord wall plastification, equation K3-7 in ksi

$$DC_{K\_c\_NLC} := \frac{R_{a\_C\_NLC}}{P_{n\_K3\_7}} = 0.21$$

Demand to capacity, K joint axial strength, NLC, < 1, acceptable

$$DC_{K\_c\_ELC} := \frac{R_{a\_C\_ELC}}{P_{n\_K3\_7}} = 0.26$$

Demand to capacity, K joint axial strength, ELC, < 1, acceptable

Appendix D

Thermal Analysis

Contents:

1. Convection Coefficient Calculations
2. Finite Element Analysis Thermal Report

Convection Coefficient Calculations

Convective Coefficient calculated as equivalent to vertical plate, since majority of RSF faces are vertical.

$T_{hot} := 325\ °F = 436\ K$ Conservative hottest temperature expected in RSF is approximately 200F and 325F was selected as design temperature for conservatism, ECAR-6574, Reference 4

$T_{cold} := 65\ °C = 338\ K$ Minimum RSF temperature, 65°C to prevent overheating concrete, per FOR-684 4.15.1

$T_{plate} := \frac{T_{hot} + T_{cold}}{2} = 387.0\ K$ Average "vertical plate" temperature assumed mean of hot and cold temperatures

$T_{\infty} := 40\ °C = 313.2\ K$ Air temperature, 40°C air temperature requirement from FOR-684, "Fundamental and Operations Requirements Transient Reactor Test (TREAT) Facility micro-Reactor Experiment Cell (TREXc)", Rev. C, Idaho National Laboratory, section 4.2.2 ". Micro Reacto Area Maximum Operating Temperature: The average internal air temperature of the micro reactor area shall be maintained at or below 40°C (104°F) during reactor operation."

Physical properties of Air at 1atm pressure and 40°C. From Çengal and Cimbala, pg. 930.

$\rho := 1.127\ \frac{kg}{m^3}$ $k_{air} := 0.02662\ \frac{W}{m \cdot K}$ $c_p := 1007\ \frac{J}{kg \cdot K}$ $v := 1.702 \cdot 10^{-5}\ \frac{m^2}{s}$

Equations from Incropera, DeWitt, Bergman, and Lavine, "Fundamentals of Heat and Mass Transfer," Sixth Edition, John Wiley and Sons Inc.:

$\alpha := \frac{k_{air}}{\rho \cdot c_p} = \left(2.35 \cdot 10^{-5}\right)\ \frac{m^2}{s}$ Thermal Diffusivity equation pg. 68

$L_{plate} := 88 \cdot in$ "Vertical plate length" estimated as height of support frame

$Pr := \frac{v}{\alpha} = 0.73$ Prandtl Number

$\beta := \frac{1}{T_{\infty}} = 0.003\ \frac{1}{K}$ Equation 9.9, pg. 564

$Gr := \frac{g \cdot \beta \cdot \left(T_{plate} - T_{\infty}\right)\ L_{plate}^{\ 3}}{v \cdot \alpha} = 6.47 \cdot 10^{10}$ Equation 9.12, pg. 565

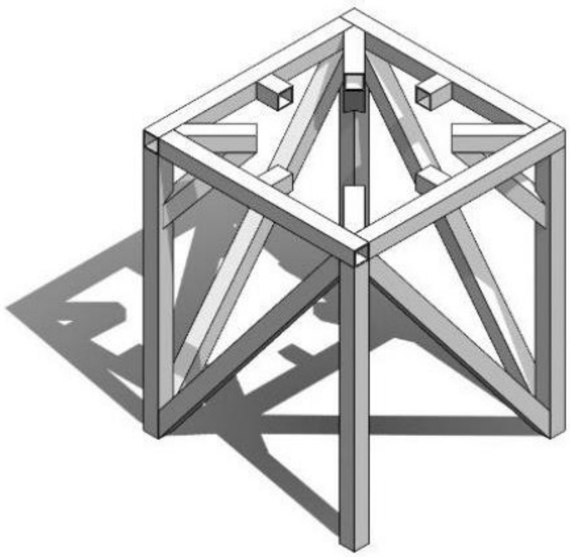
$Ra := Gr \cdot Pr = 4.697 \cdot 10^{10}$ Equation 9.25, pg. 571 Ra>10^9, use Equation 9.26 for Nusselt number

$$Nu := \left(0.825 + \frac{0.387\ Ra^{\frac{1}{6}}}{\left(1 + \left(\frac{0.492}{Pr}\right)^{\frac{9}{16}}\right)^{\frac{8}{27}}}\right)^2 = 413.9$$ Equation 9.26, pg. 571

$h_c := Nu \cdot \frac{k_{air}}{L_{plate}} = 4.93\ \frac{W}{m^2\ K}$ Air heat transfer coefficient

Finite Element Analysis Thermal Report

1935 International Way
Idaho Falls, ID 83402
Phone: 208.524.2286
Fax: Fax: 208-522-4269
https://www.walshengr.com/



Simulation of RSF

Date: Tuesday, September 5, 2023
Designer: Mat Floyd
Study name: Thermal 1
Analysis type: Thermal(Steady state)

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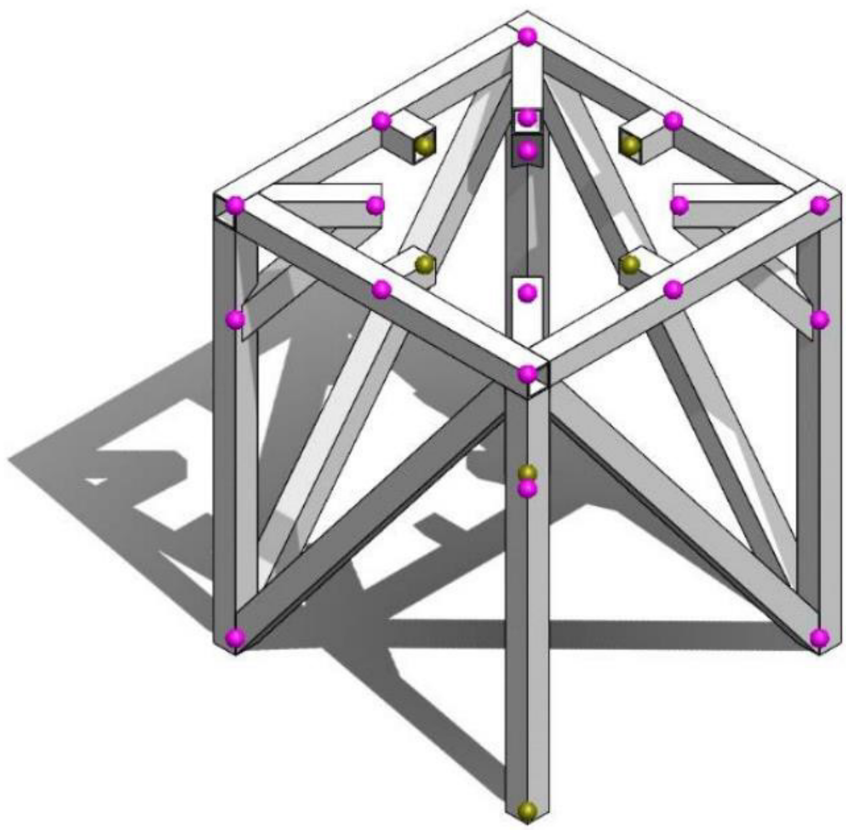
1935 International Way
Idaho Falls, ID 83402

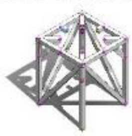
Mat Floyd
9/5/2023

Model Information



Model name: RSF
Current Configuration: Default<As Machined>

Beam Bodies:

Document Name and Reference	Formulation	Properties	Document Path/Date Modified
SolidBody 12(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Tube (square) TS5X5X0.375(1)[17]) 	Beam – Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:184.15mm Volume:0.000824218m^3 Mass Density:8,030kg/m^3 Mass:6.61847kg Weight:64.861N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023
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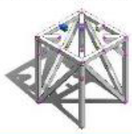
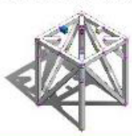
SolidBody 25(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[14]) 	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:649.507mm Volume:0.00290706m^3 Mass Density:8,030kg/m^3 Mass:23.3437kg Weight:228.768N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023
SolidBody 27(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[16]) 	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:649.507mm Volume:0.00290706m^3 Mass Density:8,030kg/m^3 Mass:23.3437kg Weight:228.768N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023
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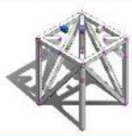
SolidBody 24(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[13]) 	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:460.892mm Volume:0.00206286m^3 Mass Density:8,030kg/m^3 Mass:16.5647kg Weight:162.335N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023
SolidBody 3(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[8]) 	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:1,676.4mm Volume:0.00750323m^3 Mass Density:8,030kg/m^3 Mass:60.2509kg Weight:590.459N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023
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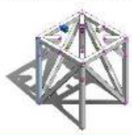
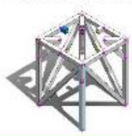
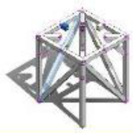
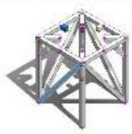
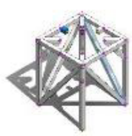
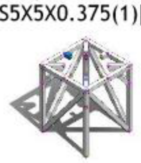
SolidBody 22(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[7])	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:1,676.4mm Volume:0.00750323m^3 Mass Density:8,030kg/m^3	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023

		Mass:60.2509kg Weight:590.459N	
SolidBody 6(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[1]) 	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:2,108.2mm Volume:0.00943588m^3 Mass Density:8,030kg/m^3 Mass:75.7701kg Weight:742.547N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023
SolidBody 16(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[2]) 	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:2,108.2mm Volume:0.00943588m^3 Mass Density:8,030kg/m^3 Mass:75.7701kg Weight:742.547N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023
SolidBody 18(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[3]) 	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:2,108.2mm Volume:0.00943588m^3 Mass Density:8,030kg/m^3 Mass:75.7701kg Weight:742.547N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023
SolidBody 29(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[4]) 	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:2,108.2mm Volume:0.00943588m^3 Mass Density:8,030kg/m^3 Mass:75.7701kg Weight:742.547N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023
SolidBody 57(Tube (square) TS5X5X0.375(Trim/Extend2)	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:2,482.8mm Volume:0.0111224m^3 Mass Density:8,030kg/m^3	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023

		Mass:89.3125kg Weight:875.262N	
SolidBody 58(Tube (square) TS5X5X0.375(1)[23]) 	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:2,482.8mm Volume:0.0111224m^3 Mass Density:8,030kg/m^3 Mass:89.3125kg Weight:875.262N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023
SolidBody 60(Tube (square) TS5X5X0.375(1)[21]) 	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:2,482.8mm Volume:0.0111224m^3 Mass Density:8,030kg/m^3 Mass:89.3125kg Weight:875.262N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023
SolidBody 61(Tube (square) TS5X5X0.375(1)[12]) 	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:460.892mm Volume:0.00206286m^3 Mass Density:8,030kg/m^3 Mass:16.5647kg Weight:162.335N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023
SolidBody 63(Trim/Extend1) 	Beam - Uniform C/S	Section Standard-ansi inch/Al Tube (square)/5 SQ x .375 Wall Section Area: 0.0044758m^2 Length:2,482.8mm Volume:0.0111224m^3 Mass Density:8,030kg/m^3 Mass:89.3125kg Weight:875.262N	C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23\RSF.SLDPRT Sep 5 12:45:02 2023

Study Properties

Study name	Thermal 1
Analysis type	Thermal(Steady state)
Mesh type	Beam Mesh
Solver type	FFEPlus
Solution type	Steady state
Contact resistance defined?	No
Result folder	SOLIDWORKS document (C:\Users\mat.floyd\Documents\PDMVault\MARVEL\Reactor Design\Analysis Models\Reactor Stand\8-14-23)

Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

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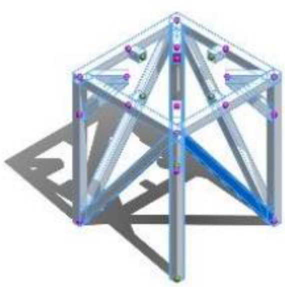
Material Properties

Model Reference	Properties	Components
	**Name:** SA 240 316H **Model type:** Linear Elastic Isotropic **Default failure criterion:** Max von Mises Stress **Thermal conductivity:** Temp dependent **Specific heat:** Temp dependent **Mass density:** 8,030 kg/m^3	SolidBody 3(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[8])(weldment_4), SolidBody 4(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[9])(weldment_4), SolidBody 5(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[5])(weldment_4), SolidBody 6(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[1])(weldment_4), SolidBody 11(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[6])(weldment_4), SolidBody 12(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Tube (square) TS5X5X0.375(1)[17])(weldment_4), SolidBody 16(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[2])(weldment_4), SolidBody 17(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[10])(weldment_4), SolidBody 18(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[3])(weldment_4), SolidBody 19(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Tube (square) TS5X5X0.375(1)[18])(weldment_4), SolidBody 21(Tube (square) TS5X5X0.375(Tube (square)

		TS6X6X0.375(Tube (square) TS5X5X0.375(1)[11])(weldment_4), SolidBody 22(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[7])(weldment_4), SolidBody 24(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[13])(weldment_4), SolidBody 25(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[14])(weldment_4), SolidBody 26(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Tube (square) TS5X5X0.375(1)[19])(weldment_4), SolidBody 27(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[16])(weldment_4), SolidBody 29(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[4])(weldment_4), SolidBody 30(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(1)[15])(weldment_4), SolidBody 31(Tube (square) TS5X5X0.375(Tube (square) TS6X6X0.375(Tube (square) TS5X5X0.375(Tube (square) TS5X5X0.375(1)[20])(weldment_4), SolidBody 57(Tube (square) TS5X5X0.375(Trim/Extend2)(weldment_4), SolidBody 58(Tube (square) TS5X5X0.375(1)[23])(weldment_4), SolidBody 60(Tube (square) TS5X5X0.375(1)[21])(weldment_4), SolidBody 61(Tube (square) TS5X5X0.375(1)[12])(weldment_4), SolidBody 63(Trim/Extend1)(weldment_4)

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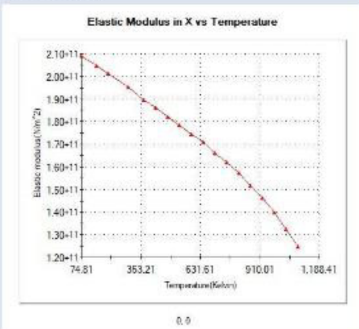
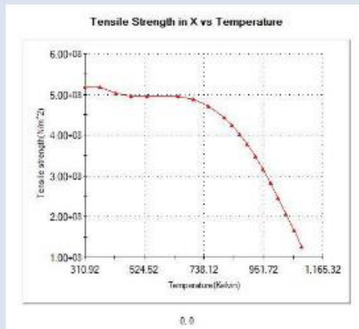
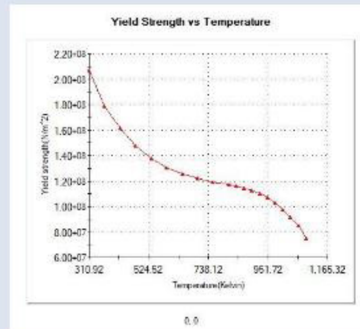
Curve Data:



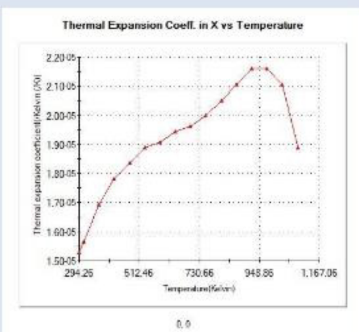
Elastic Modulus in X vs Temperature



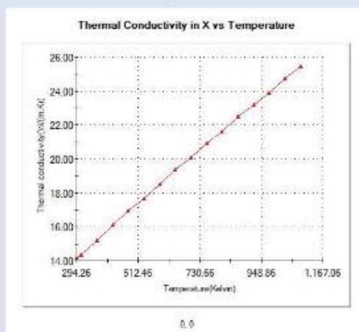
Tensile Strength in X vs Temperature



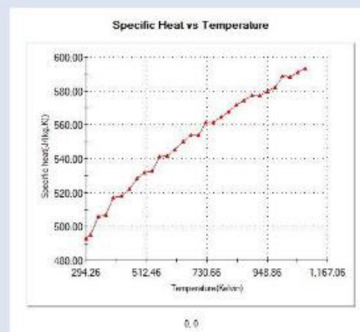
Yield Strength vs Temperature



Thermal Expansion Coeff. in X vs Temperature



Thermal Conductivity in X vs Temperature



Specific Heat vs Temperature

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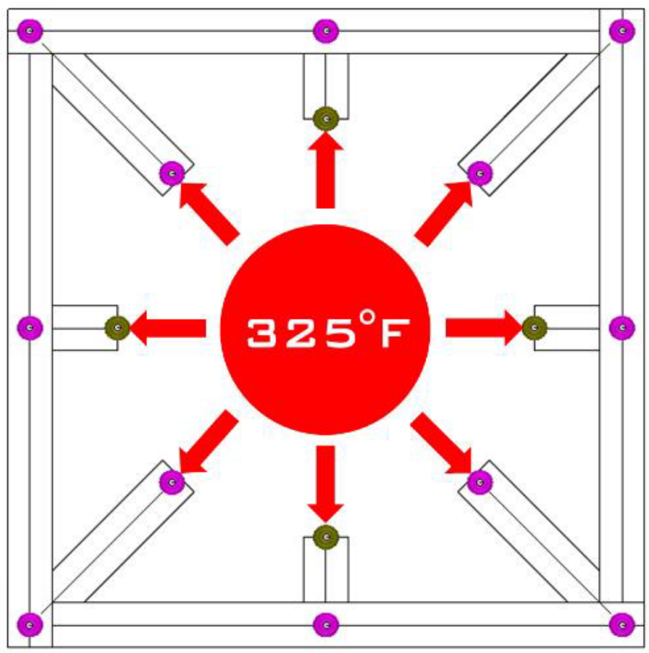
Thermal Loads

Load name	Load Image	Load Details
Temperature-1		**Entities:** 8 Joint(s) **Temperature:** 325 Fahrenheit

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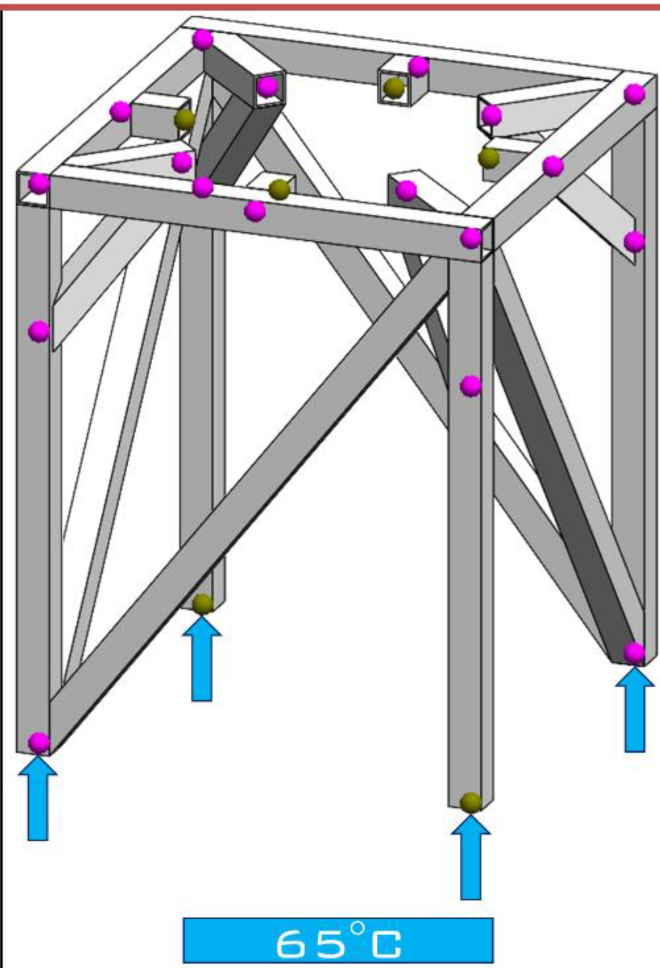
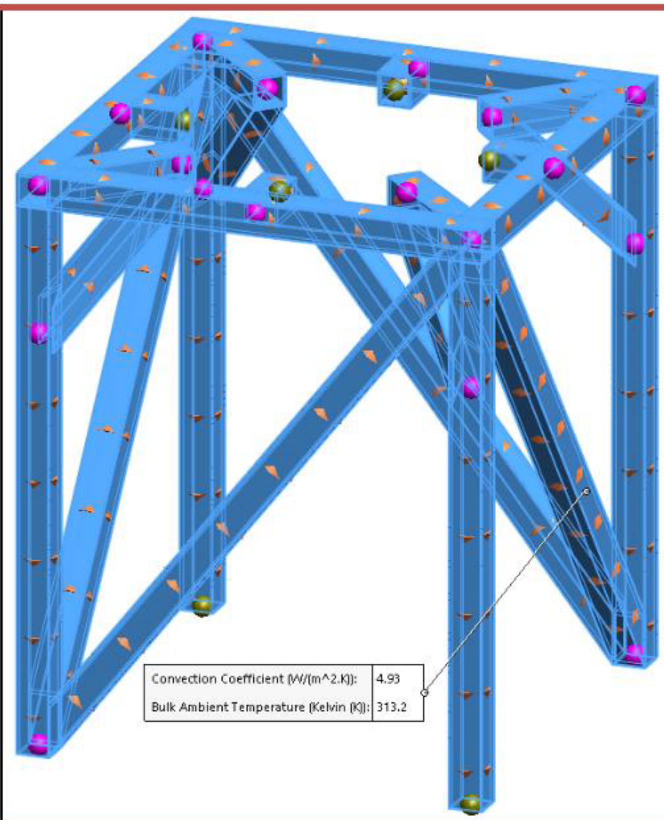
Temperature-2		Entities: 4 Joint(s) Temperature: 65 Celsius

Convection-1		**Entities:** 24 Beam (s) **Convection Coefficient:** 4.93 W/(m^2.K) **Time variation:** Off **Temperature variation:** Off **Bulk Ambient Temperature :** 313.2 Kelvin **Time variation:** Off

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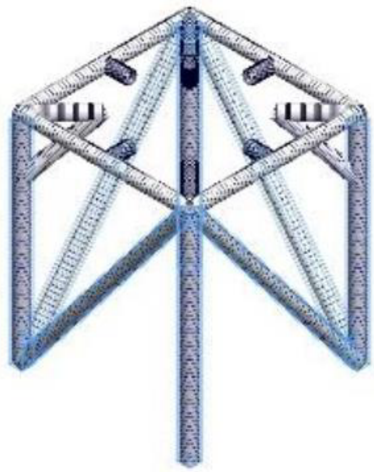
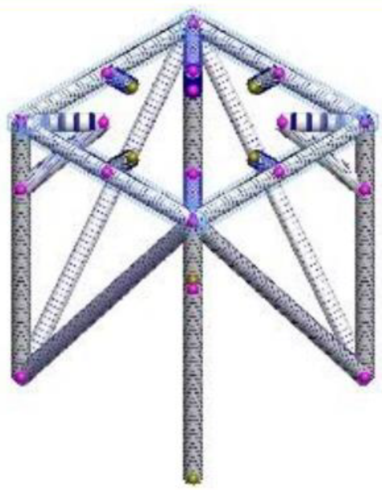
Mesh information

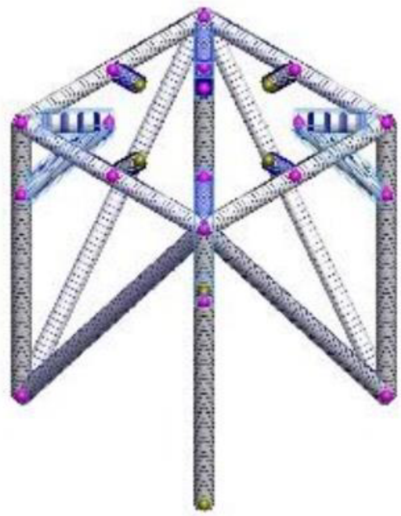
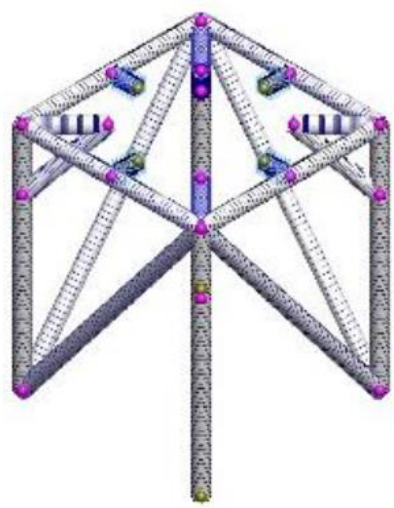
Mesh type	Beam Mesh

Mesh information - Details

Total Nodes	1088
Total Elements	1072
Time to complete mesh(hh;mm;ss):	00:00:01
Computer name:	BLACKBIRD

Mesh Control Information:

Mesh Control Name	Mesh Control Image	Mesh Control Details
Control-1		**Entities:** 8 Beam (s) **Number of Elements:** 55
Control-2		**Entities:** 4 Beam (s) **Number of Elements:** 50

Control-3		Entities: 8 Beam (s) Number of Elements: 30
Control-4		Entities: 4 Beam (s) Number of Elements: 20

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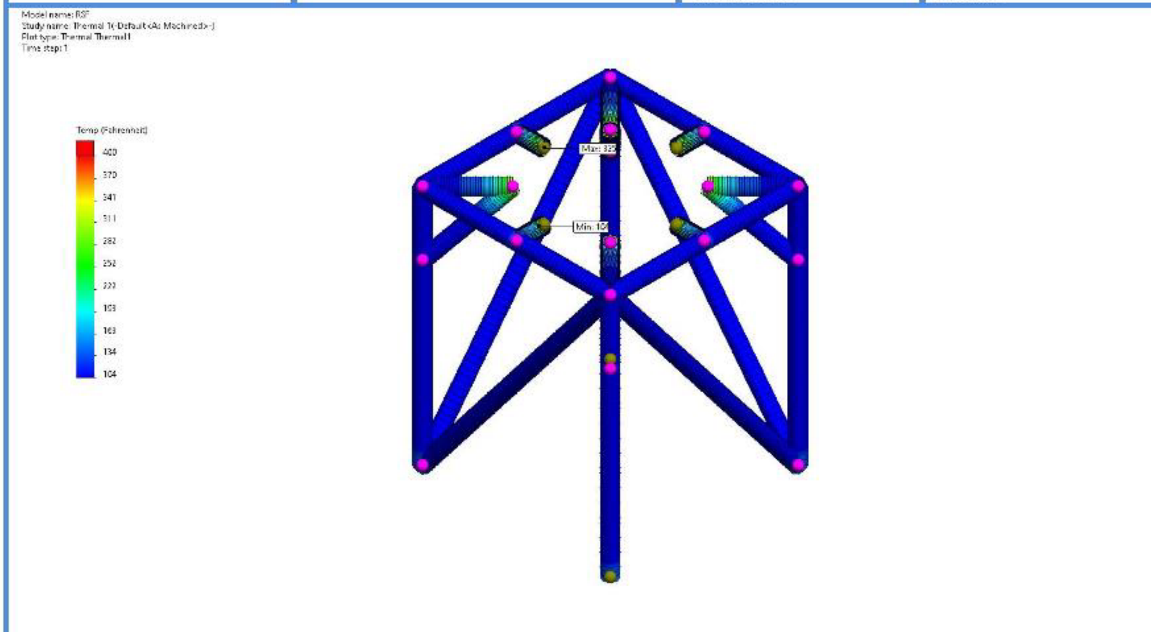
Study Results

Name	Type	Min	Max
Thermal1	TEMP: Temperature	104°F Node: 815	325°F Node: 1



RSF-Thermal 1-Thermal-Thermal1

Appendix E

Tipping Analysis

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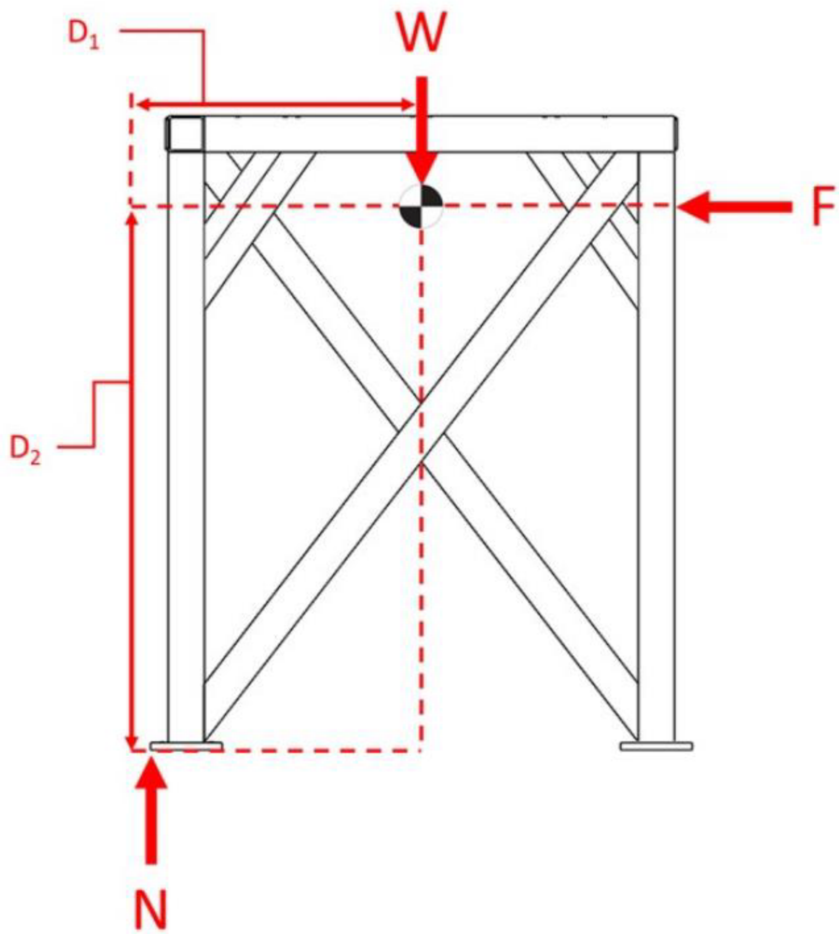
Tipping Analysis

The purpose of this analysis is to determine the force that will initiate tipping of the Reactor Support Frame (RSF).



$\Sigma M_N = 0$

-W•D1 + F•D2 = 0

Solving for Force to tip:
F=W•D1/D2

$W := (16625 + 2500)\ lbf$ Weight of the equipment placed onto the RSF plus the weight of the RSF per Solidworks Computer Aided Design (CAD).

$D_1 := (89 - 11.18)\ in = 77.8\ in$ Horizontal location of CG per Solidworks CAD.

$D_2 := 38\ in$ Vertical location of CG per Solidworks CAD.

$F := \frac{W \cdot D_1}{D_2} = 39166\ lbf$ Force required to start tipping the RSF.

$F_{seismic} := \sqrt{(W \cdot .377)^2 + (W \cdot .377)^2} = 10197\ lbf$ Per seismic inputs per ECAR-6601, loading onto the RSF, less than force required to tip, acceptable. Additionally, the RSF will be bolted down with 4 bolts per floor plate.

$\frac{F_{seismic}}{F} = 0.26$ Demand to capacity for tipping, less than 1, acceptable.