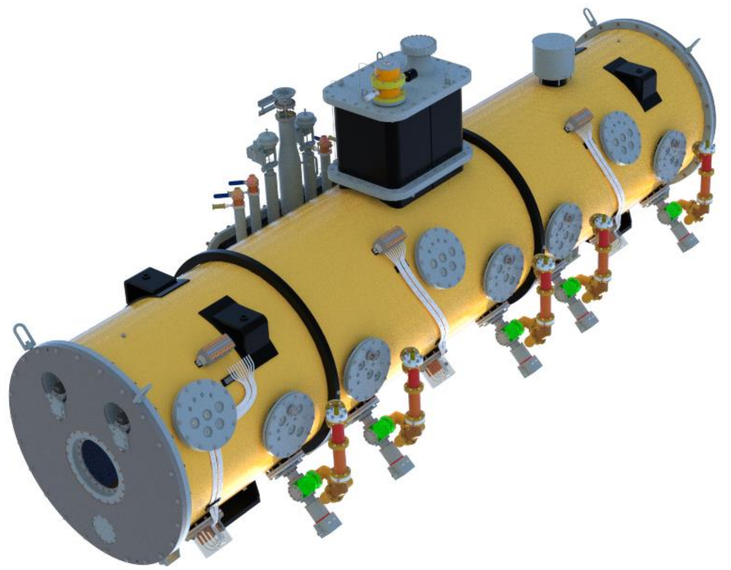

Single Spoke Resonator (SSR) cryomodules assembly tooling and procedure for PIP-II

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The following report is the result of the internship at FNAL
(Batavia, Jul-Sept 2023)
in the
PIP-II Project Group
September 29, 2023

Abstract

This report is a resume of the activities in which I was involved during my internship at Fermilab Particle Physics and Accelerator Laboratory in Batavia. The project at whom my work is connected is the PIP-II (Proton Improvement Plan – II), in particular I worked on the SSR cryomodules. The main task of my training program was to write an Engineering Note concerning the design of the lifting holders for the SSR1 and SSR2 string assembly. In the meanwhile, I was also commissioned to design some additional components that will take part actively in the project as well. During the initial phase I was lightly trained about the project and its general design, then I was supervised on my specific tasks. I want to thank primarily Jacopo Bernardini that was my supervisor, he attempted to create a favorable workplace, suggesting, listening and meeting all the requests, without his help achieving the result would have been greatly harder. Donato Passerelli and Mattia prise deserve a special thanks too for being always available for support and source of motivation. I had also the chance to share my work during the "Weekly Students Meetings" dealing with other bright engineers and students such as Colin Narug and Caleb Denton. I want also to express my gratitude to Simone Donati, Giorgio Bellettini and Emanuela Barzi that make this unique experience possible organizing this program for decades.

Table of Contents

1. Introduction

PIP II is the new Proton Improvement Plan undergoing at Fermilab National Laboratory. It features a new brand 800-MeV accelerator that will replace the old Linear Accelerator updating the core technology to superconductivity. PIP-II will enable the most intense high-energy neutrino beam for the laboratory's flagship project, the Long Baseline Neutrino Facility and Deep Underground Neutrino Experiment. PIP-II is the first U.S. accelerator project that will have significant contributions from international partners, with Italy surely being one of the main contributors. The most important components of the new Linac are the cryomodules (Figure 1). The accelerator will be made of five types of cryomodules, but this work will focus mainly on the Single Spoke Resonator (SSR) ones.

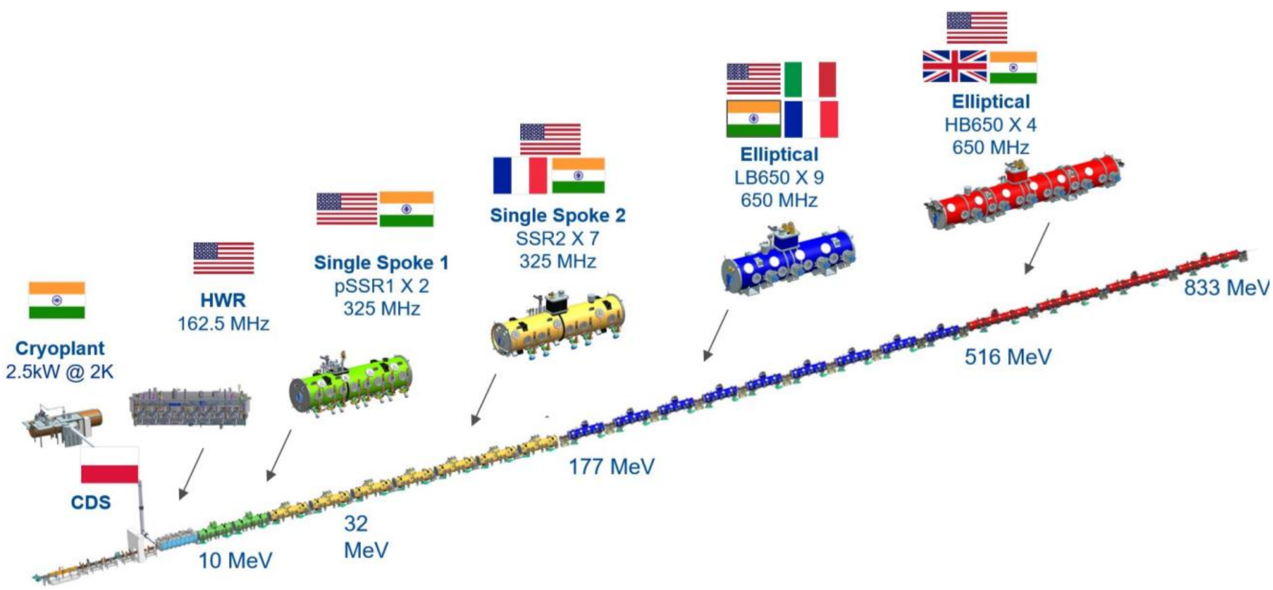


***Figure 1**: Linac overview*

The main components of a SSR cryomodule are depicted in Figure 2. Everything is designed with the aim of keeping the beam-line assembly at cryogenic temperatures to get the superconductive properties needed for accelerating of ions. The strongback is the element that will have to support the weight of the string and is designed to operate at room temperature to avoid misalignments during cooldown, unlike resonant cavities and solenoids that will be kept at 2K.

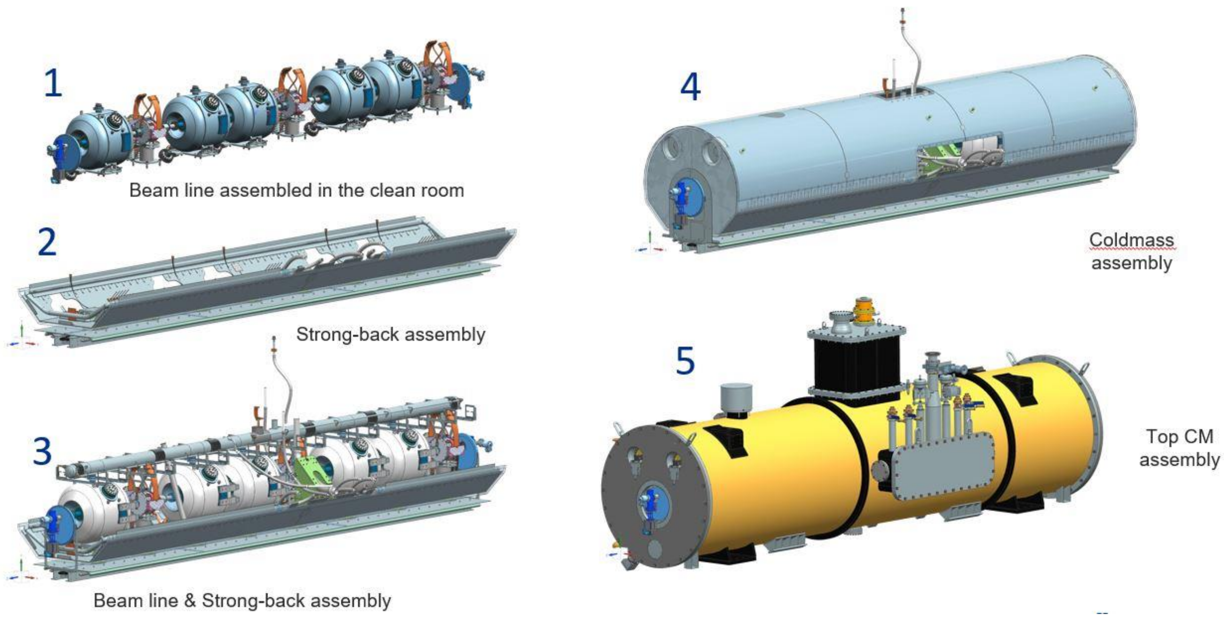
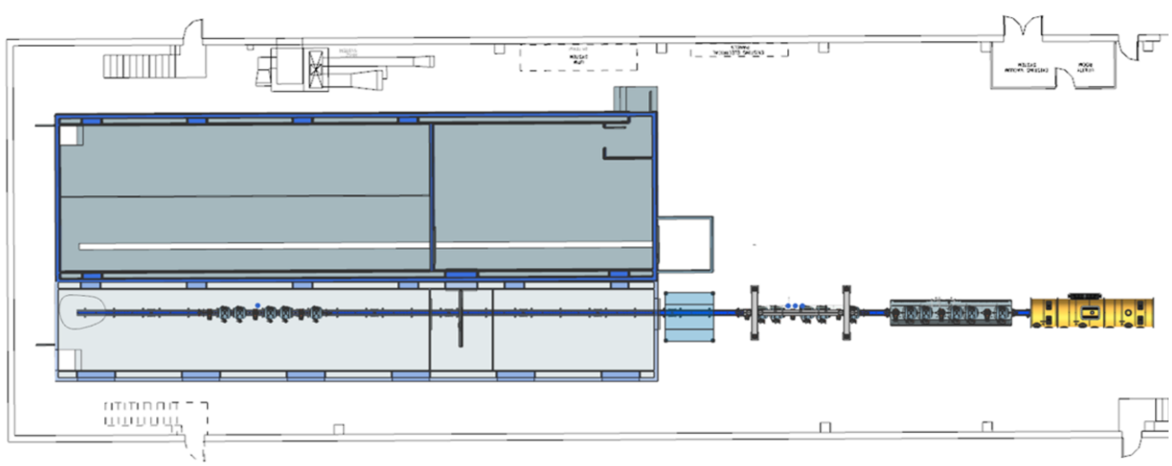


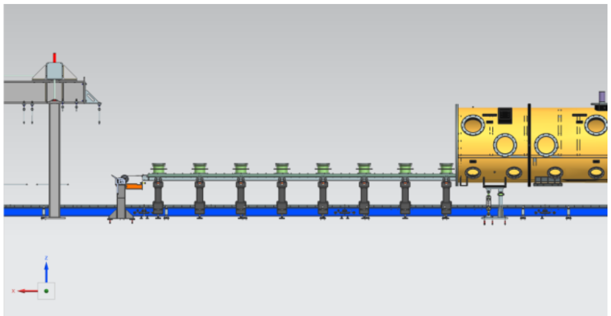
Figure 2: Cryomodule description

1.1 Assembling Procedure

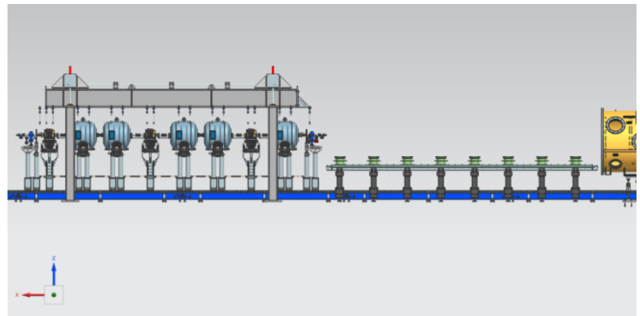
The main phases of the assembling procedure for an SSR cryomodule are shown in Figure 3.



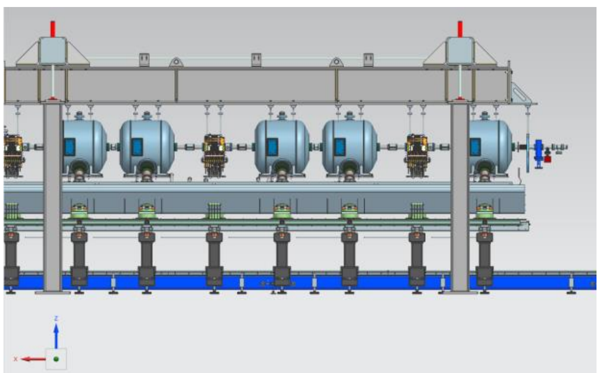
(a) Cavities and solenoids are assembled in the MP9 at Fermilab to form the string.



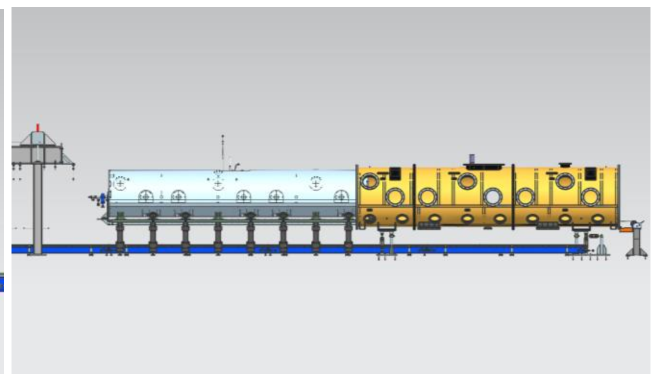
(b) Strongback extraction



(c) String fixing to lifting tooling



(d) String lifting



(e) coldmass assembling and insertion

***Figure 3**: Assembly phases*

The lifting holders used to fix the string to the tooling shown in phases *c* and *d* have been the objects of the analysis and the evaluation of the adequacy conducted during the two months.

2. Engineering Note

The Engineering Note, with all the calculations, evaluating the design of the lifting holders is reported in the Appendix.

3. Additional tasks

Besides the main goal of writing the Engineering Note, a couple of additional tasks were assigned to me.

3.1 Locking System

The newest approach of the PIP-II project is to use a robot arm (Figure 4 a) to substitute manual cleanroom assembling with automated one. The robot is meant to be put in place using a positioning cart (Figure 4 b) and the design of a locking system was needed.

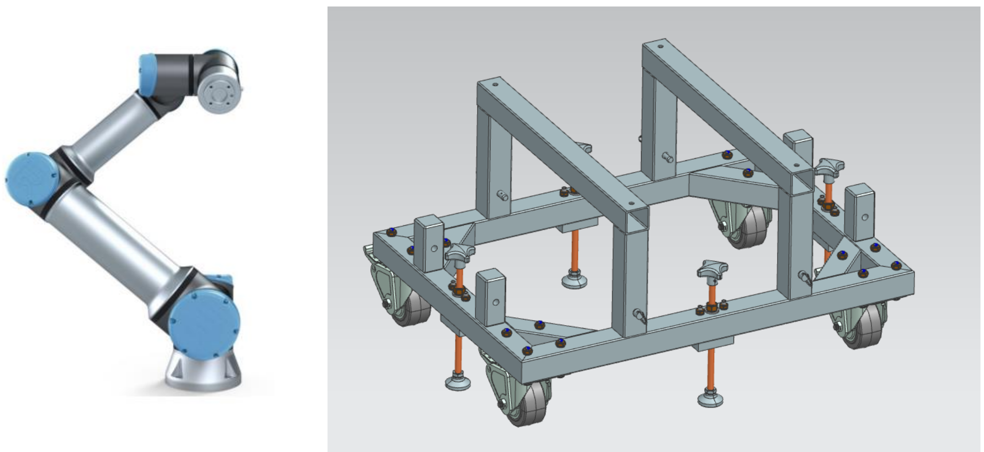


***Figure 4**: (a) robot arm; (b) positioning cart*

The design was quite complex since the requirements to be met were to create a connection with at least two points with the most rigid component of the cleanroom to make the system as stiff as possible. It was chosen to connect the cart directly to the main rail of the cleanroom despite the difficulty to reach it and the little clearance available since the rail is the stiffest component (Figure 5, Figure 6).

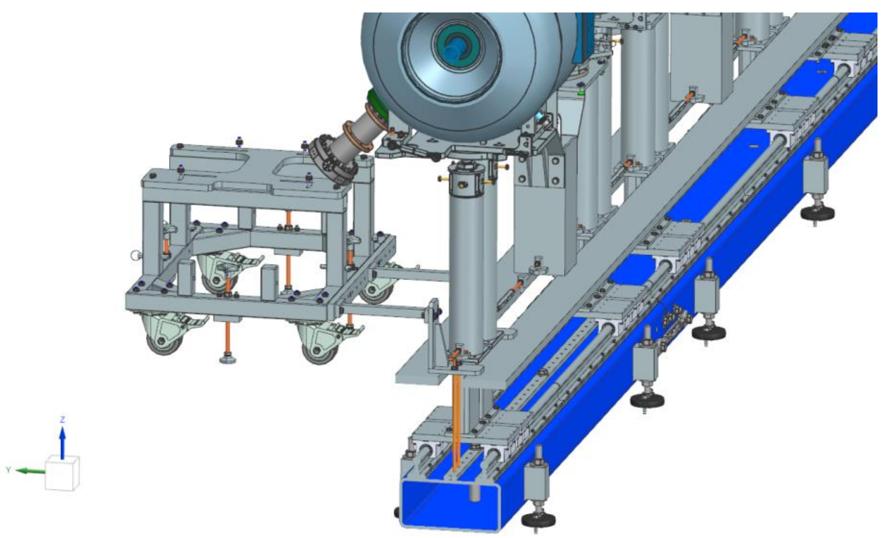


***Figure 5**: locking system*

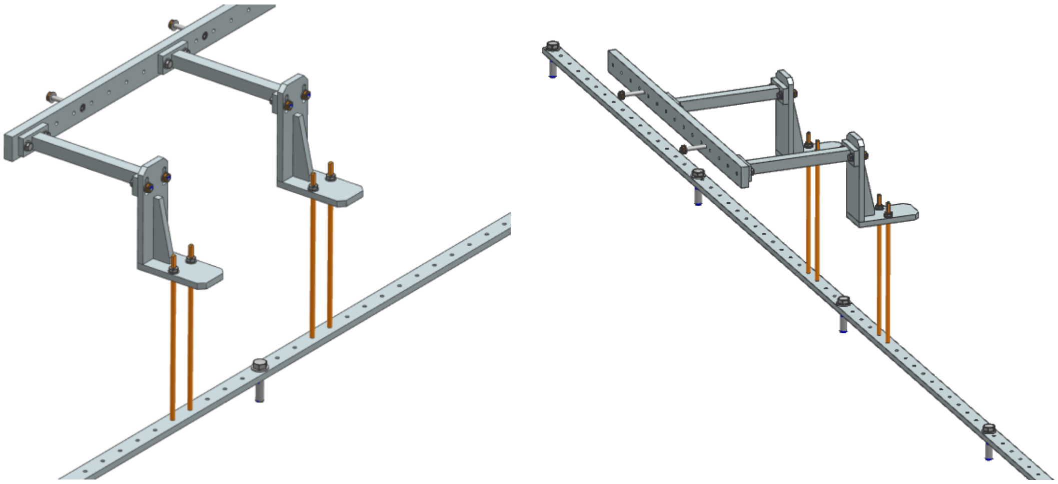


Figure 6: locking system

The key components of this design are the drilled plate and the long threaded rods. They will connect the fixing brackets to the main rail, granting numerous positionings.

3.1.1 Quick-Release Solution

During the design came up the necessity to implement fast assembling components to the locking system to sped up the positioning process. Some of them looked more promising than others, such as the Quick-Release One-Touch Fasteners form (IMAO, s.d.) (Figure 7).

Figure 7: One-Touch Quarter-Turn Fastener

The use of this solution could reduce substantially the time spent by operators in the cleanroom, but maximum clamping force and cleanroom environment compatibility needs to be tested before implementing it.

3.2 Solenoid Test Stand

Before assembling the solenoids with cavities to form the string, they are tested into the Test Stand vessel (Figure 8), where the magnetic field is measured. Inside the vacuum vessel operational conditions are reached and then the solenoid is turned on.

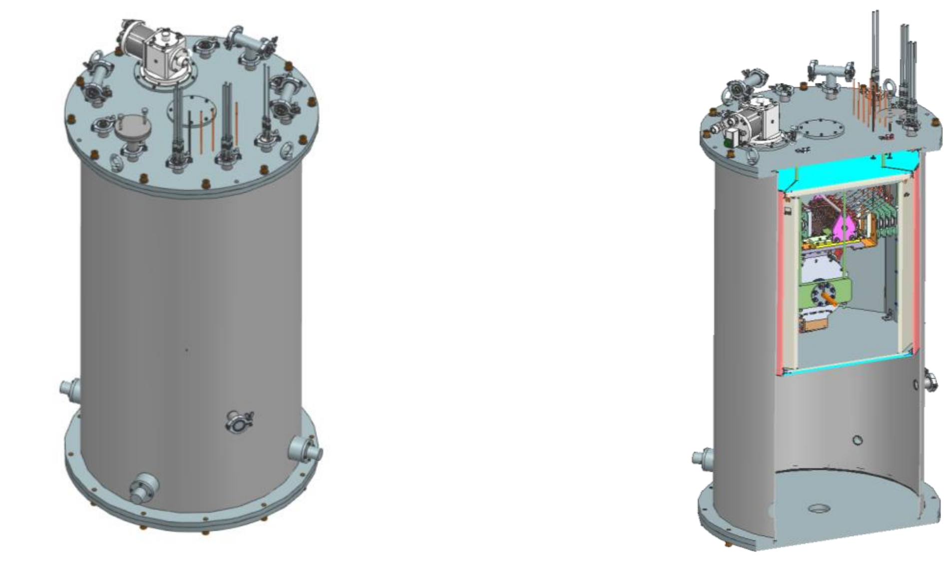


Figure 8: *Solenoid Test Stand vessel (a) and section (b)*

3.2.1 Probe Stage

It was needed to design a stage for a Gaussmeter (Figure 9) that will measure the magnetic field also outside of the vessel in a repeatable way. The requirements were to be able to position the probe along a 90° angular span and between 0 and 15 cm from the outer surface of the vessel radially.

Figure 9: *Gaussmeter*

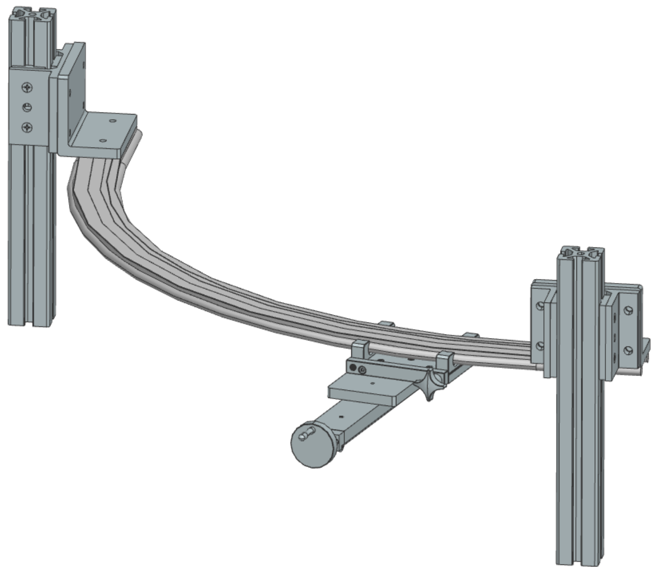


Figure 10: *Preliminary stage design*

4. Conclusions and further developments

The adequacy of the lifting holders was evaluated and the preliminary design of the locking system and of the probe stage were almost completed. The next steps will be to release the Engineering Note, after passing the reviewing process, to investigate thoroughly the feasibility of the quick-release fasteners and to validate the design with specific calculations.

5. Appendix

Fermi National Accelerator Laboratory

PIP-II SSR1 and SSR2 Cryomodules

Lifter Holders of SSRs Cryomodules Cavity String Assembly

Author: Giusti Matteo

Document Number: ED rev. –

Document Approval		Date Approved
Originator	M. Giusti	As in TC
Checker		As in TC
Approver		As in TC

Revision History		
Author	Revision Date	Description of Change

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Table of Contents

1 Introduction

This document addresses the analysis of a lifting tooling that is to be used to lift the cold mass string assembly of SSR2 and SSR1 cryomodules. The lifting operation will be a part of the installation procedure of the cold mass string assembly into the cryostat. The lifting fixture (Figure 1, Figure 2) will be used in conjunction with a Lifting Tooling Assembly (Fermilab drawing – F10088592). The lifter holders consist of ten units of Cavity Holder, six units of Solenoid Holders and two units of End Flange Holder for SSR2 (Figure 3, Figure 4) and sixteen units of Cavity Holder, eight units of Solenoid Holders and two units of End Flange Holder (for SSR1 (Figure 5, Figure 6). The maximum load the fixture will support is 2270 lbs for SSR2 and 3470 lbs for SSR1. The total weight of the holders for SSR2 is 717 lbs and for SSR1 is 857 lbs. The units will be analyzed both analytically and through a finite element simulation. The criterion used to evaluate the design are the rules specified by FESHM 10110: “Below-The-Hook Lifting Devices”; ASME B30.20, for “Below-The-Hook Lifting Devices”, ASCE 7-16 “Minimum Design Loads and Associated Criteria for Buildings and Other Structures” and by ASME BTH-1 “Design of Below-The-Hook Lifting Devices”.

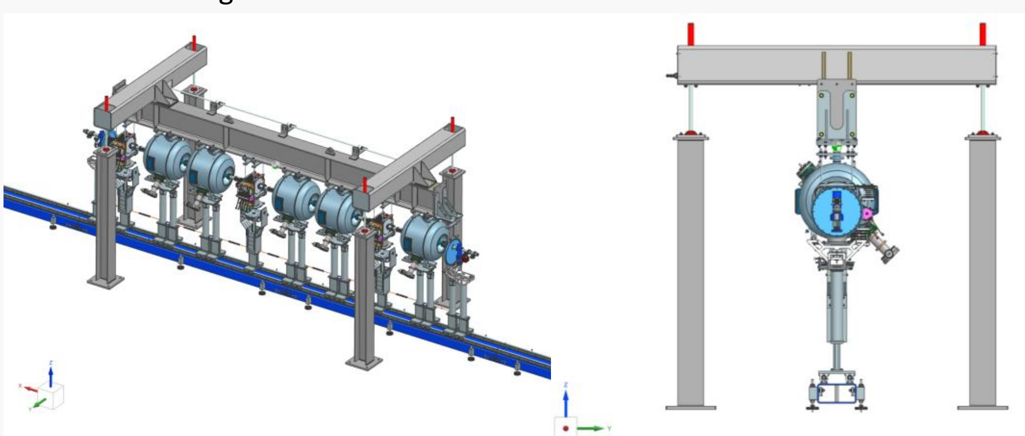


Figure 1 Lifter Holders of String Assembly and Lifting Tooling Assembly (SSR2)

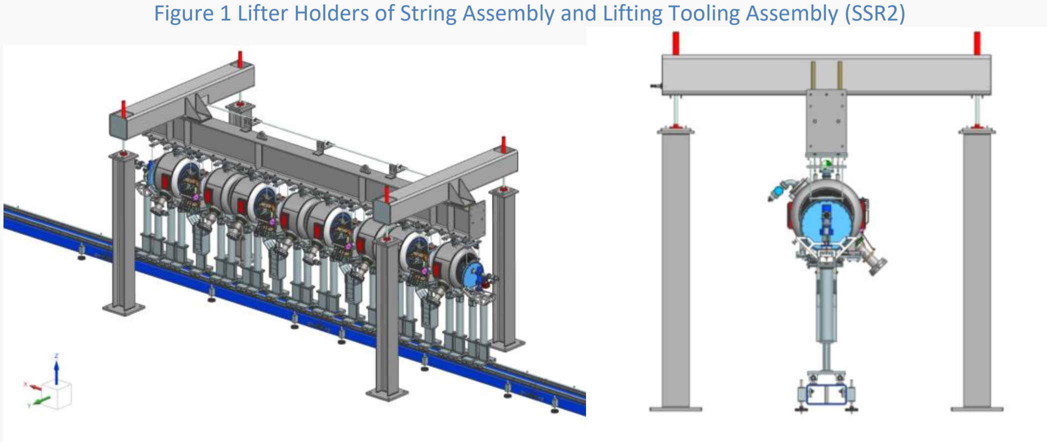


Figure 2 Lifter Holders of String Assembly and Lifting Tooling Assembly (SSR1)

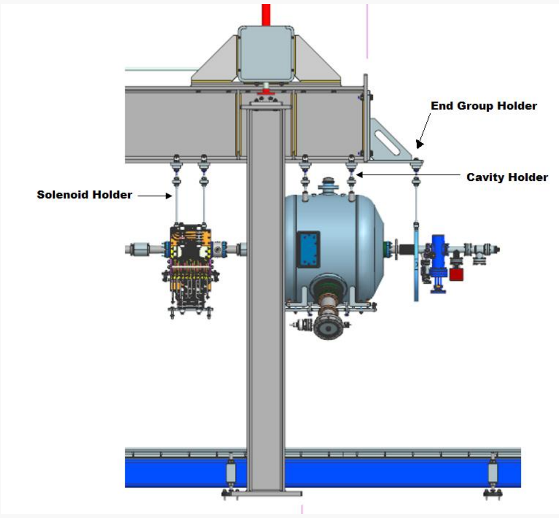


Figure 3 Lifter Holders of String Assembly (SSR2)

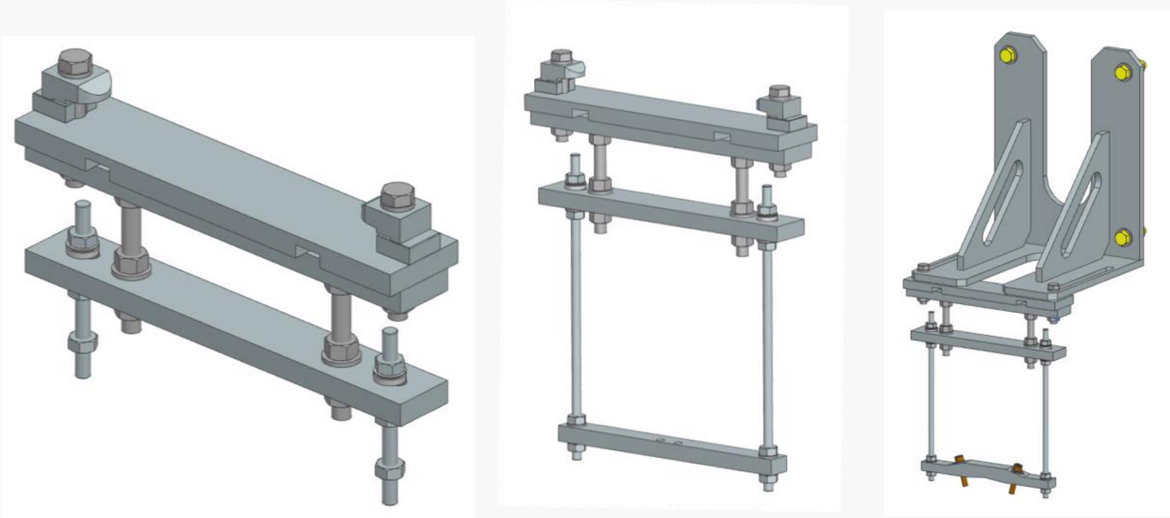


Figure 4 Cavity Holder (left), Solenoid Holder (middle), End Flange Holder (right) (SSR2)

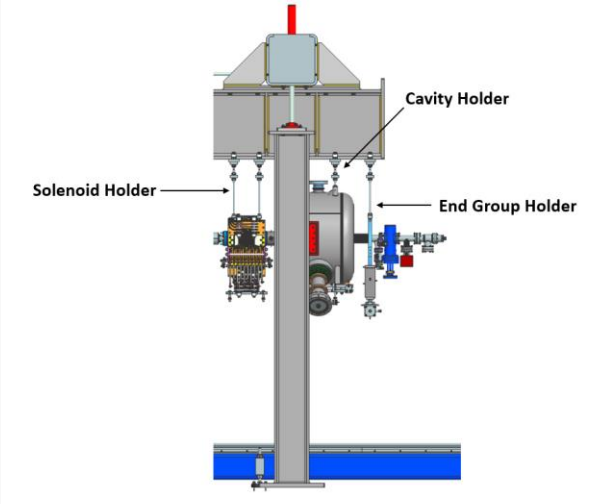


Figure 5 Lifter Holders of String Assembly (SSR1)

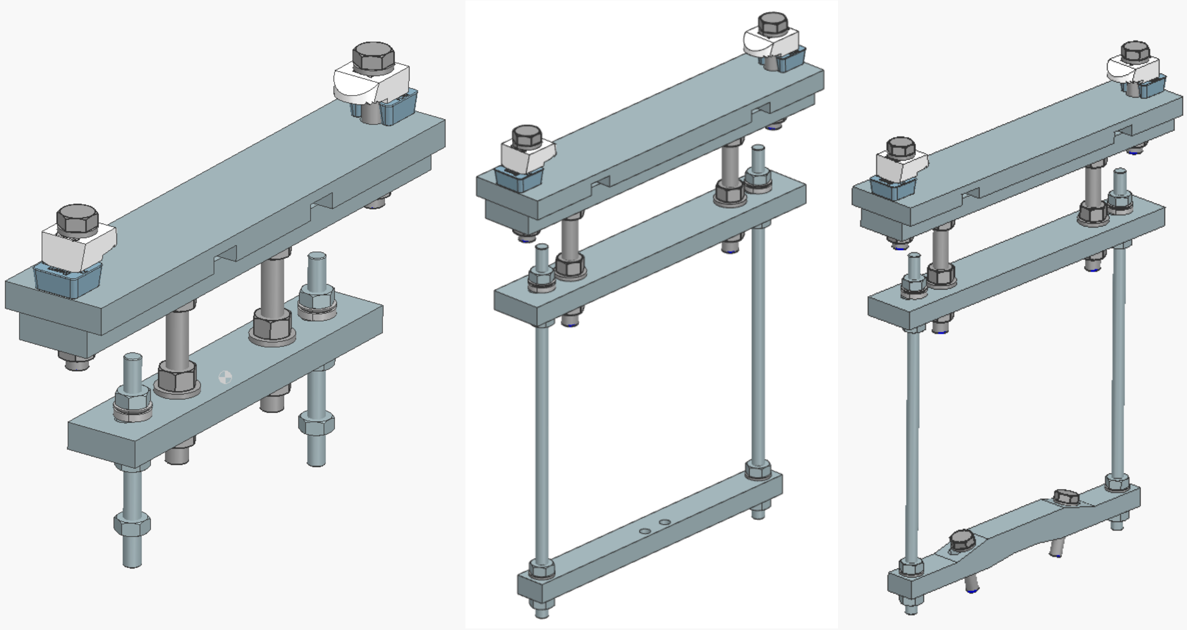


Figure 6 Cavity Holder (left), Solenoid Holder (middle), End Flange Holder (right) (SSR1)

2 Geometry and Load Path

The lifter holders consist of sets of 304SS plates, 18-8SS M10 threaded studs and nuts, 18-8SS 1/2-13 bolts, G8S 5/8-11 bolts and 6061-T6 plates. The load is the weight of string assembly 2270 lbs. Moreover, a force F_p is applied in the horizontal plane to simulate an incidental lateral load. In accordance with ASCE 7-16 chapter 13.3, the value of F_p is calculated with equation (13.3-1):

$$F_p = \frac{0.4 a_p S_{DS} W_p}{\left(\frac{R_p}{I_p}\right)} \left(1 + 2\frac{z}{h}\right) \quad (13.3\text{-}1)$$

Where:

F_p = seismic design force.
$S_{DS} = 0.144 =$ spectral acceleration, short period.
$a_p = 1 =$ component amplification factor (Laboratory equipment).
$I_p = 1 =$ component Importance Factor.
W_p = component operating weight.
$R_p = 2.5 =$ component response modification factor (Laboratory equipment).
$\frac{z}{h} = 1$
$z =$ height in structure of point of attachment of component with respect to the base. For items at or below the base, z shall be taken as 0. The value of z=h need not exceed 1.0
$h =$ average roof height of structure with respect to the base.

So $F_p = 0.07W_p$, conservatively the horizontal load will be taken as a 10% of the weight.

Each component of string assembly is connected through bellows therefore one can consider each load independent. The Cavity Holder pair will carry the weight of resonant cavity, coupler, tuner, support structure subassembly which is 335 lbs (152 kg) for SSR2 and 320 lbs (145 kg) for SSR1. The Solenoid Holder pair will carry the weight of solenoid assembly and support structure subassembly 160 lbs (73.6 kg). The End Flange Holder will carry the weight of end group 55 lbs (24.8 kg). The Cavity Holders the Solenoid Holders and the SSR1 End Flange Holders are attached to the Lifting Tooling beam assembly using BB1G12 beam clamps by LNA Solution. The End Flange Holder pair of SSR2 is instead attached to Lifting Tooling beam assembly using a Flange Support (Fermilab drawing - F10206901) and a set of four Grade 8 Steel 5/8-11 bolts.

Item	Material	Analysis Temperature	Minimum Yield Strength (psi)	Ultimate Tensile Strength (psi)
Support plates	304 Stainless Steel	Room	30,000	70,000
Threaded studs, Nuts and Bolts	18-8 Stainless Steel		25,000	65,000
Flange support	6061-T6 Aluminum		35,000	42,000
Flange Bolts	Grade 8 Steel		92,000	150,000

Table 1 Material Properties (ASME BPVC.II.D, 2023)

The initial alignment will be performed with beam clamps not fully tightened, once the load gets final alignment the beam clamps will be tightened to specified torque.

3 General requirements

The Lifter holders of Cavity String Assembly was designed according to the criteria of ASME BTH-1, paragraph 1-4.3 and ASME B30.20, chapter 20-1. The rate load, load geometry, Design Category and Service Class were taken into consideration to determine forces and stresses value affecting components and connections. Materials used for fabrication of mechanical components are identified by industry-wide specifications that are required by ASME BTH-1, paragraph 1-4.5. ASME B30.20 states that “mechanical lifting devices shall be designed to ASME BTH-1 Design Category B (static strength criteria) and the proper Service

Class (fatigue life criteria) selected for its number of load cycles, unless a qualified person representing the owner, purchaser, or user of the lifting device determines and can demonstrate that ASME BTH-1 Design Category A is appropriate". It further states in section 20-1.2.2 that "design Category A shall only be designated when the magnitude and variation of the loads applied to the lifter are predictable and do not exceed the rated capacity, where the loading and environmental conditions are accurately defined, service is not severe, and the anticipated number of load cycles does not exceed Service Class 0."

The design category depends on the care of use, possible uncertainty in lifted load, etc. Based on purpose of tooling and previous experience of using similar supporting the fixture is designed in accordance with Design Category A, according to paragraph 2-2.1, ASME BTH-1. Service Class of the fixture was determined from Table 2-3-1, ASME BTH-1. Lifting fixture with load cycle range up to 20,000 is qualified as a device of Service Class 0. This device is expected to be used a finite number of times and undergo a few dozen cycles. Mechanical drawings for the lifting fixture are included in the Appendix. The Design factor, or "Safety Factor" N_d for the lifting fixture (Design Category A) shall not be less than 2.00 for limit states of yielding, and 2.40 for limit states of fracture and for connection design according ASME BHT-1, paragraph 3-1.3. The fixture will not be analyzed in buckling due to the lack of compressive forces. Additionally, according to paragraph 3-1.4, ASME BTH-1, lifting fixture subjected to fewer than 20,000 cycles (Service Class 0) do not need to be analyzed for fatigue.

The SSR2 components will be analyzed firstly, then the SSR1 components will be discussed.

4 SSR2

4.1 Finite Element Method

4.1.1 The Cavity Holder stress analysis

The Cavity Holder pair will carry the weight of resonant cavity, coupler, tuner, support structure subassembly 335 lbs (152 kg). Each Cavity Holder will carry the load 152/2=76 kg, using safety factor for mass calculation 1.25 each Cavity Holder will carry 76*1.25=95 kg. The force with components of 950 N in the z direction and 95 N in x and y directions (Figure 7) will be applied in addition to the gravitational load. Fixed support will be used as boundary condition for beam clamps, compression only support for the cavity strip and cylindrical supports for bolts (connection between holder and cavity support structure).

The maximum total deformation 0.028 mm occurs at the cavity bar (Figure 8). The maximum combined stress of 52 MPa (7540 psi) occurs at the edge of contact between washer and cavity bar. This is obviously a stress concertation due to singularity (Figure 9). But even with those artificial conditions minimum safety factor is 3.7 which is higher than 2.0 (Figure 10).

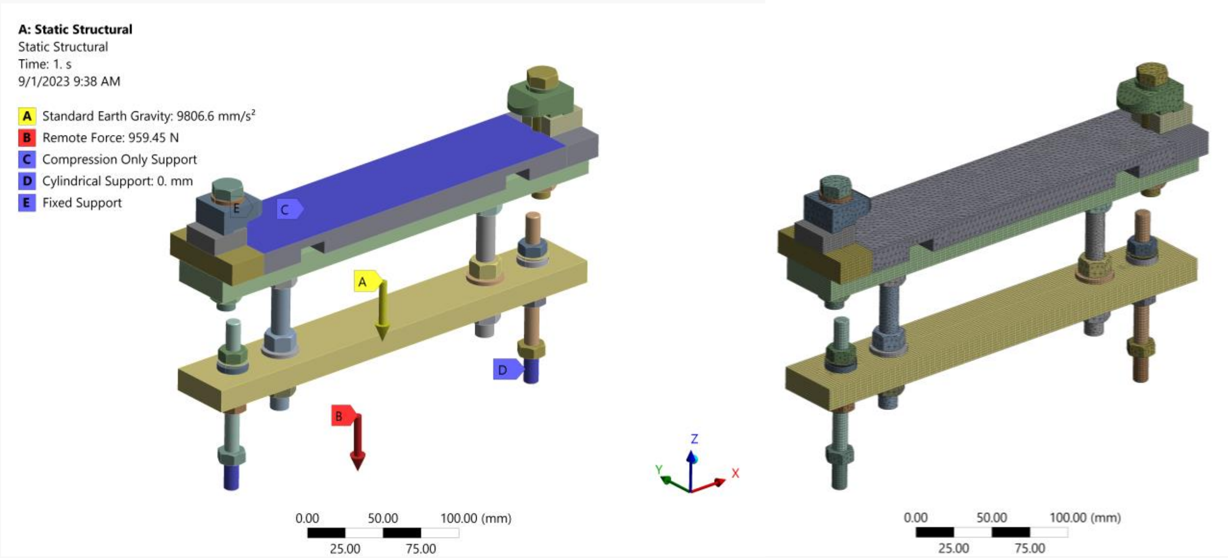


Figure 7 Cavity Holder FEA Boundary Conditions and Mesh

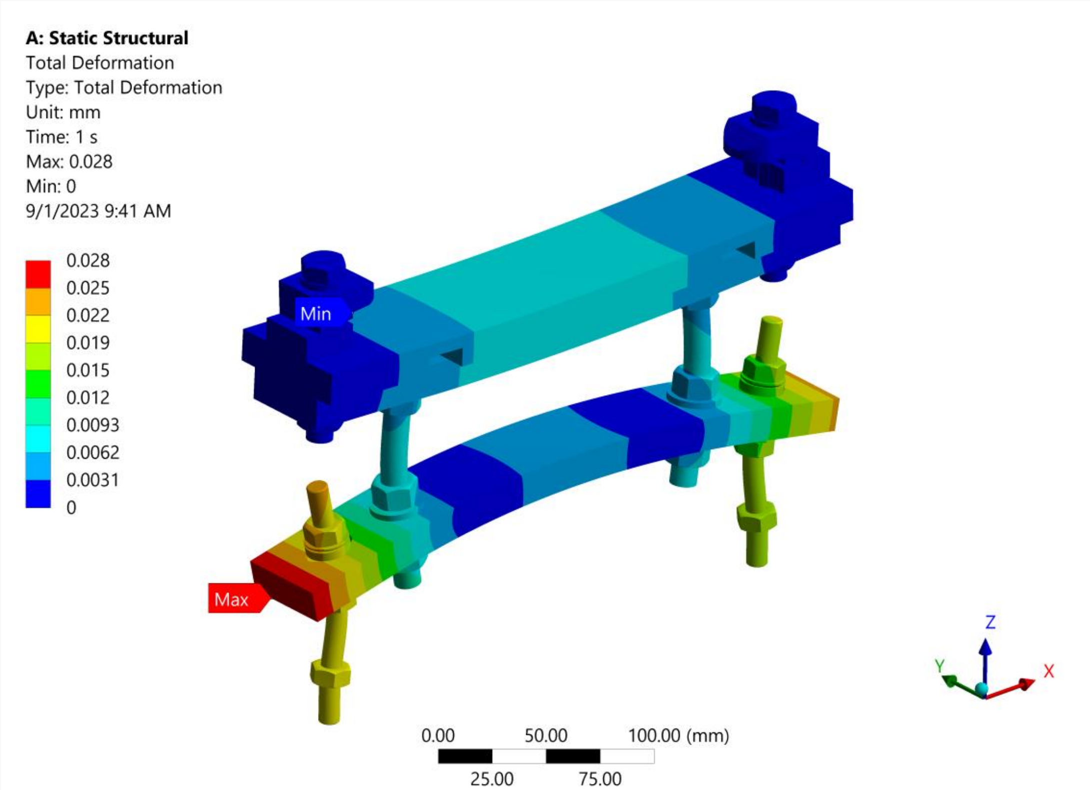


Figure 8 Cavity Holder FEA Total Deformation

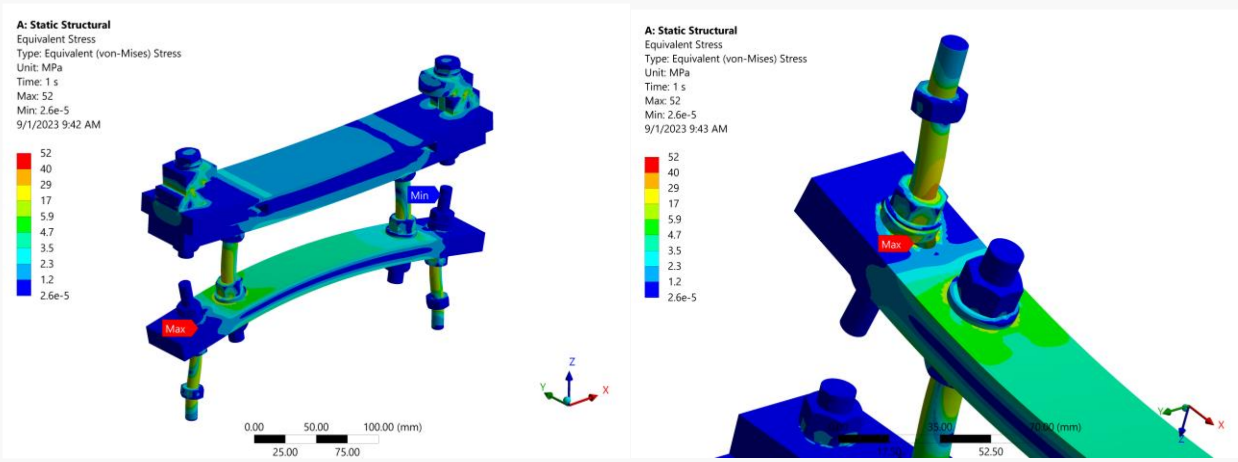


Figure 9 Cavity Holder FEA Equivalent Stress

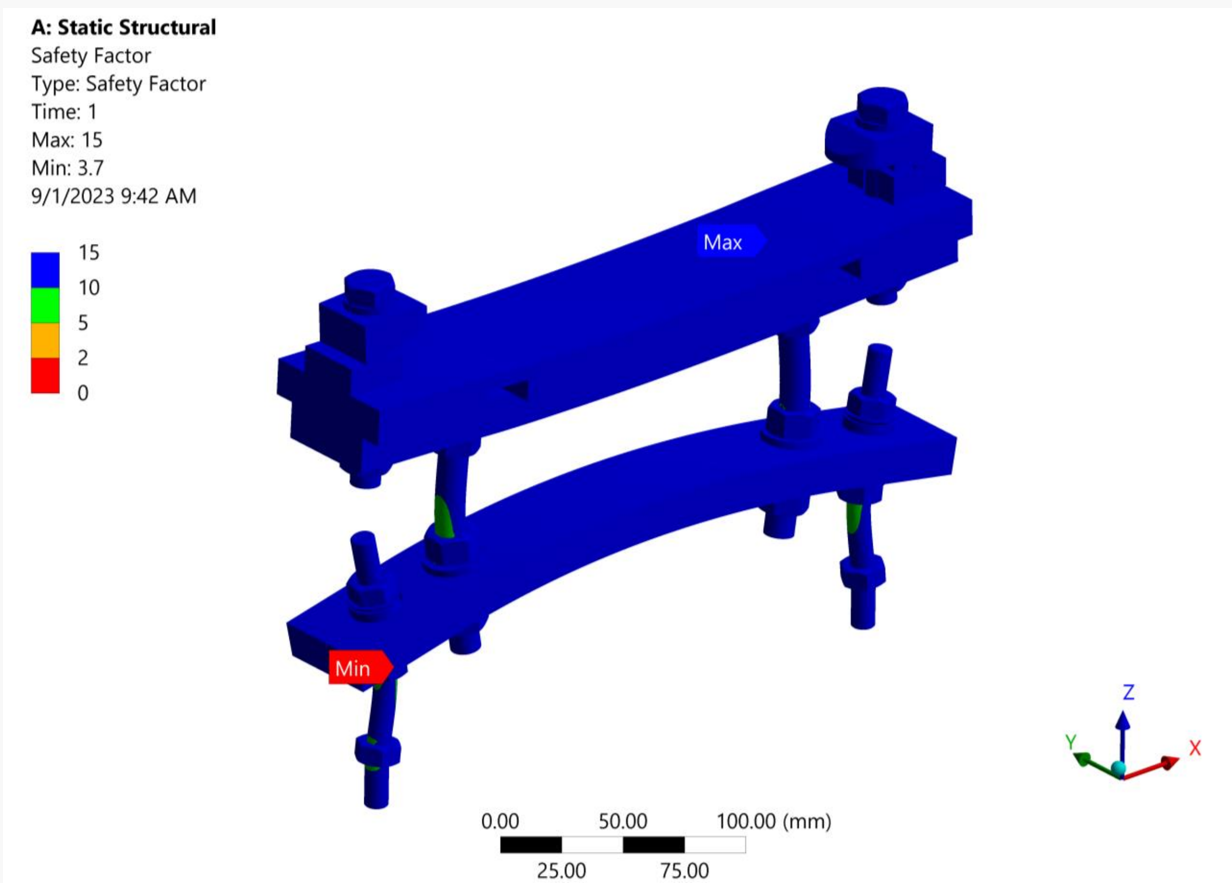
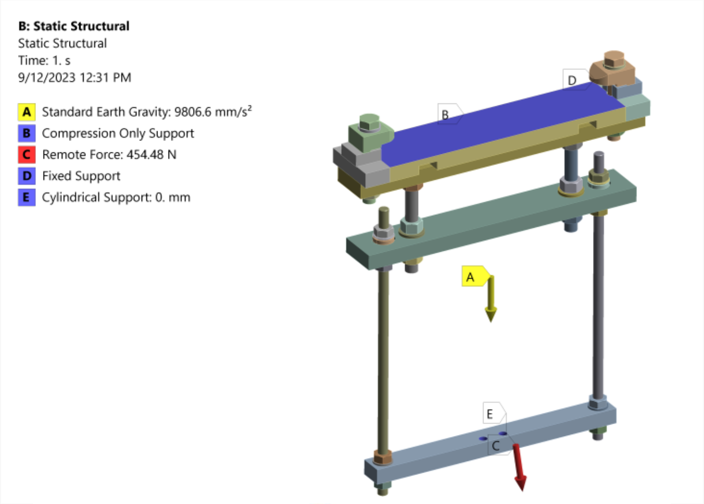


Figure 10 Cavity Holder FEA Safety Factor

4.1.2 The Solenoid Holder stress analysis

The Solenoid Holder pair will carry the weight of solenoid assembly, support structure subassembly 160 lbs (73.6 kg). Each Solenoid Holder will carry the load 73.6/2=36.8 kg, using safety factor for mass calculation 1.25 each Solenoid Holder will carry 36.8*1.25=46 kg. The force with components of 450 N in the z direction and 45 N in x and y directions (Figure 11) will be applied in addition to the gravitational load. Fixed support will be used as boundary condition for beam clamps, compression only support for the solenoid strip and cylindrical supports for holes in the bar (connection between holder and solenoid support structure).

The maximum total deformation 0.065 mm occurs at the solenoid bar (Figure 12). The maximum combined stress of 60 MPa (8700 psi) occurs at the solenoid bar connection hole (Figure 13). This is obviously a stress concertation due to singularity (Figure 14). But even with those artificial conditions minimum safety factor is 3.4, which is higher than 2.0 (Figure 15).



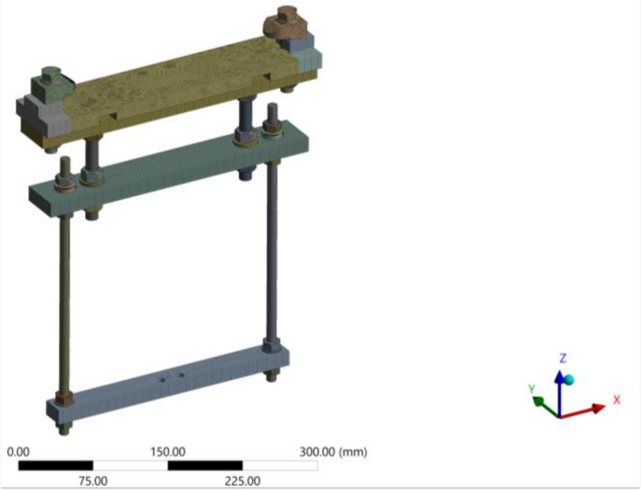


Figure 11 Solenoid Holder FEA Boundary Conditions and Mesh

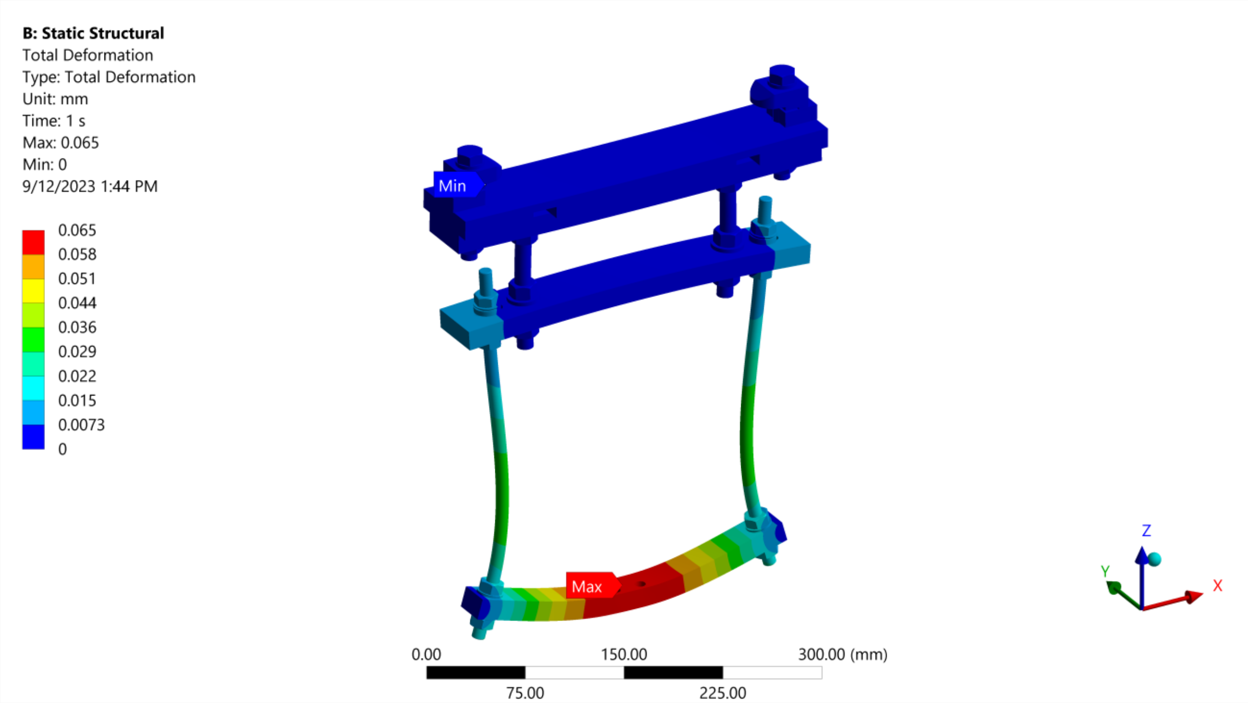


Figure 12 Solenoid Holder FEA Total Deformation

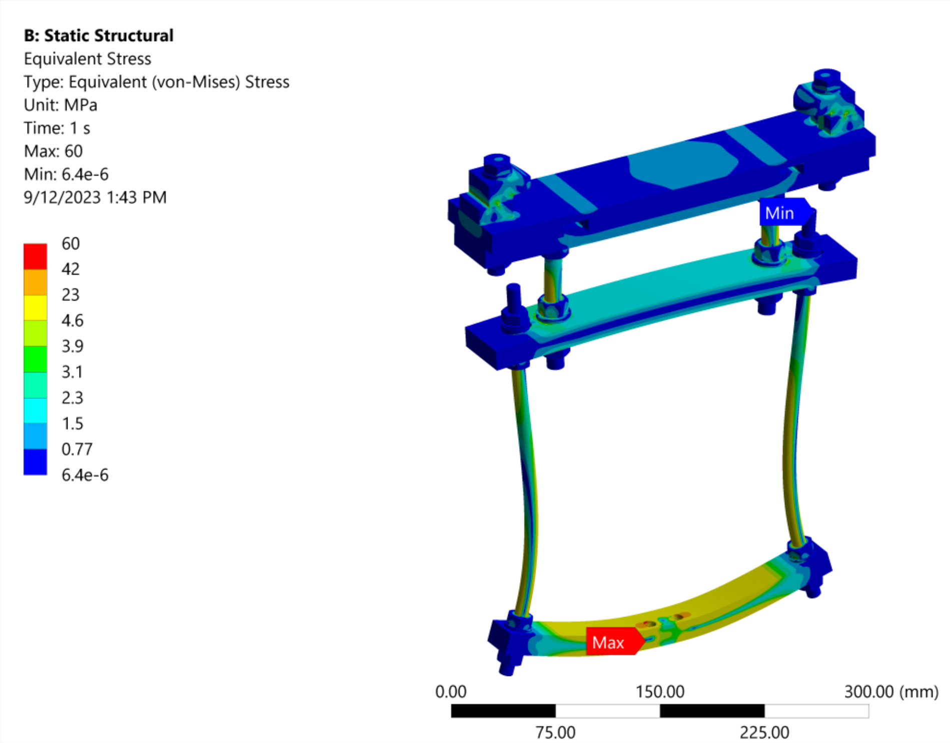


Figure 13 Solenoid Holder FEA Equivalent Stress

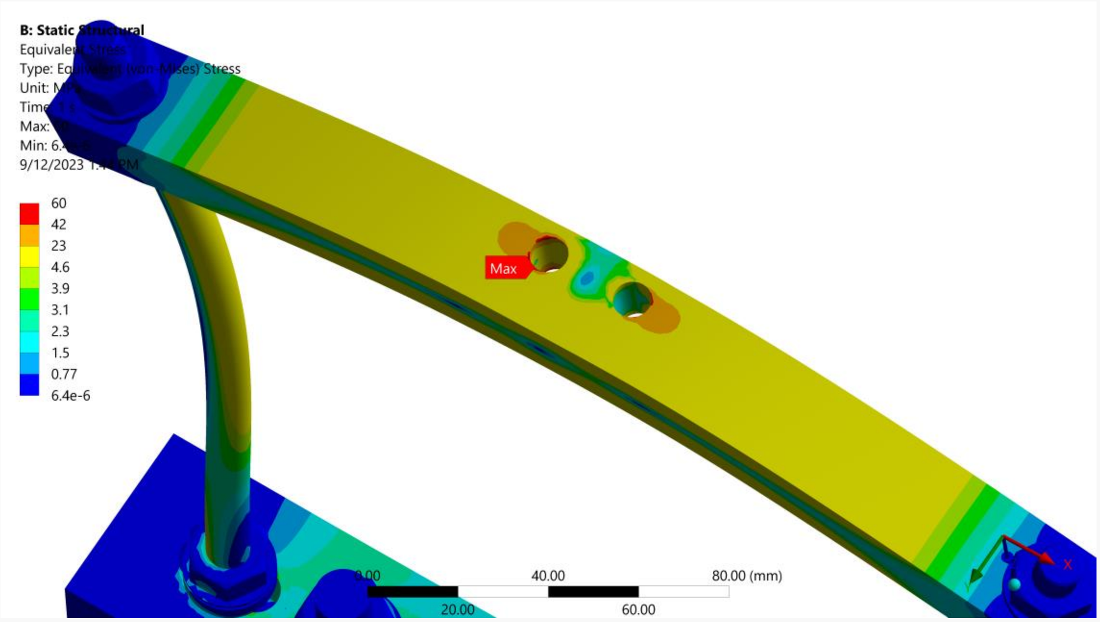


Figure 14 Solenoid Holder FEA Equivalent Stress

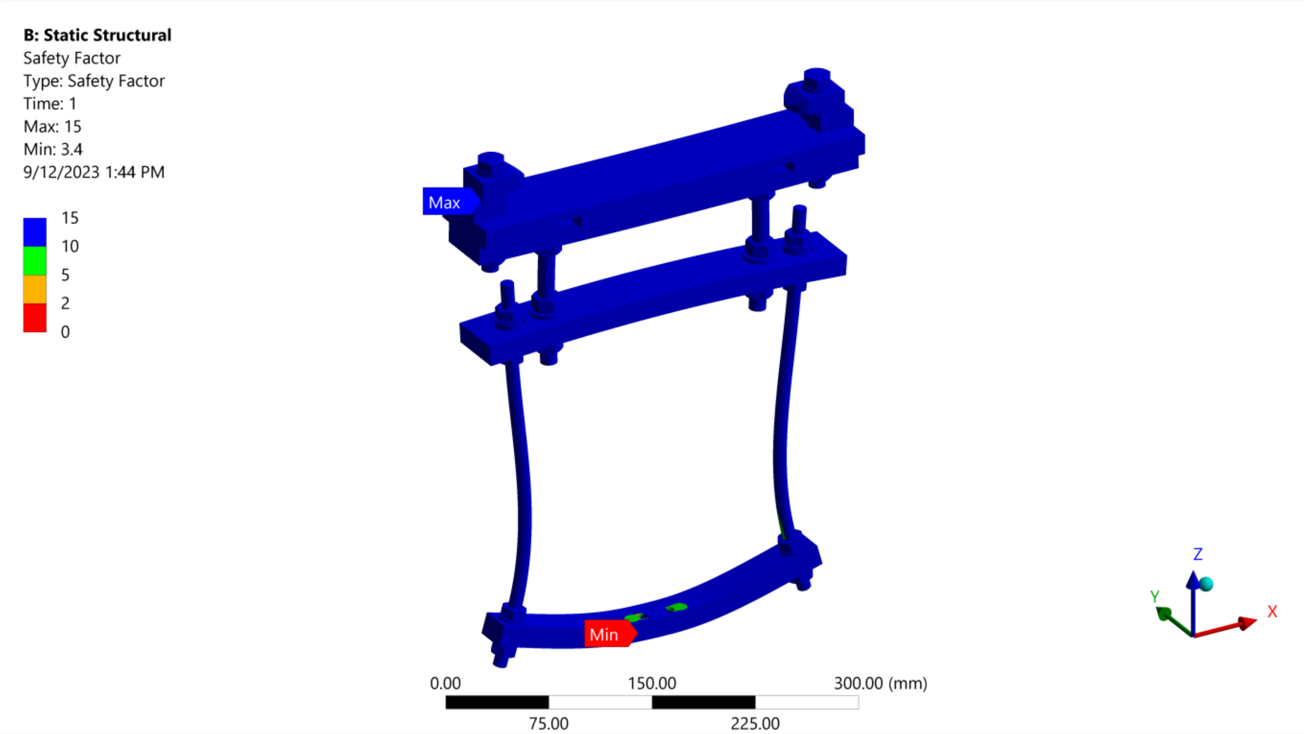


Figure 15 Solenoid Holder FEA Safety Factor

4.1.3 The End Flange Holder stress analysis

The End Flange Holder will carry the weight of end group 55lbs (24.8kg). Using safety factor for mass calculation 1.25 each Solenoid Holder will carry 24.8*1.25=31kg. The force with components of 304N in the z direction and 30.4N in x and y directions (Figure 16, Figure 17) will be applied in addition to the gravitational load. Fixed support will be used as boundary condition for beam bolts, compression only support for the welded flange, displacement allowed for bolts only in z direction.

The maximum total deformation 0.12 mm occurs at the middle plate (Figure 18). The maximum combined stress of 22 MPa (3190 psi) occurs at fixing bolt (Figure 19).

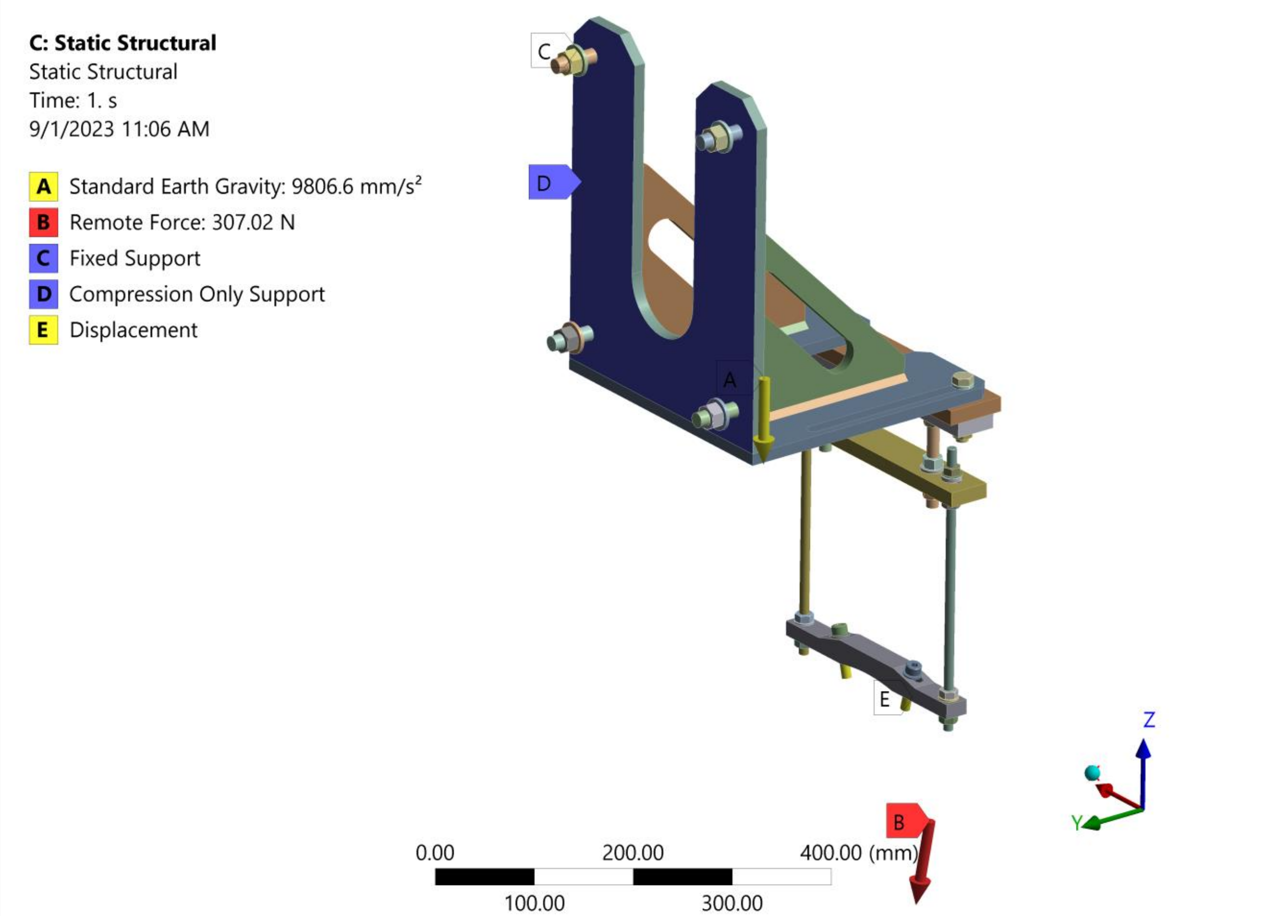


Figure 16 End Flange Holder FEA Boundary Conditions

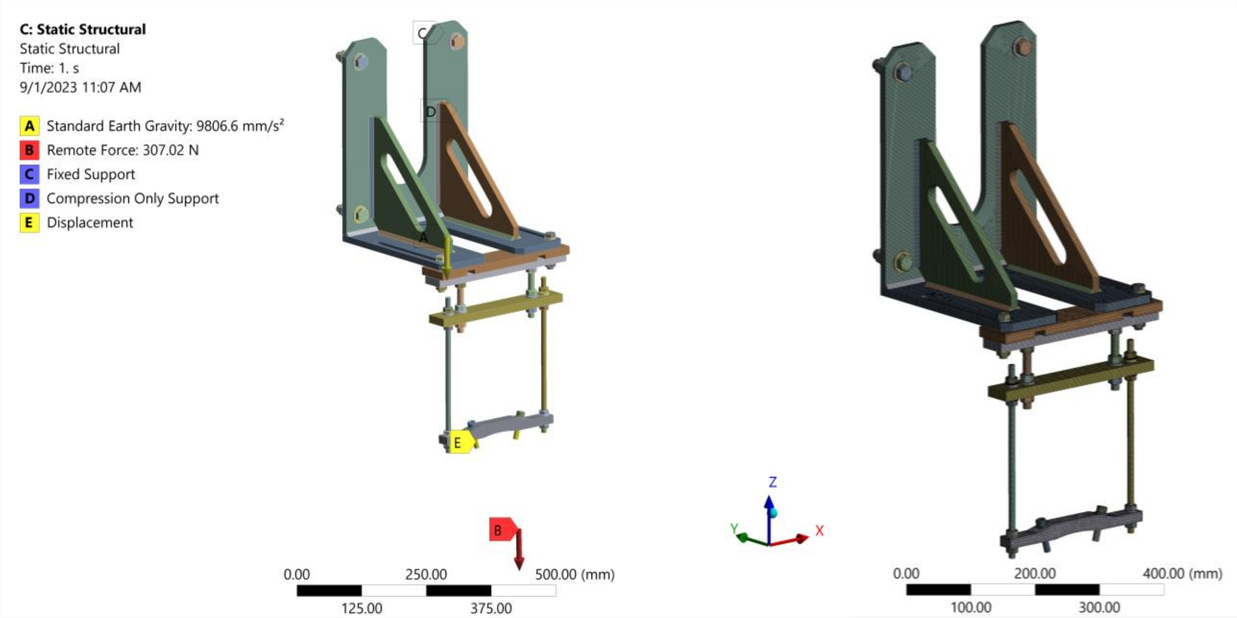


Figure 17 End Flange Holder FEA Boundary Conditions and Mesh

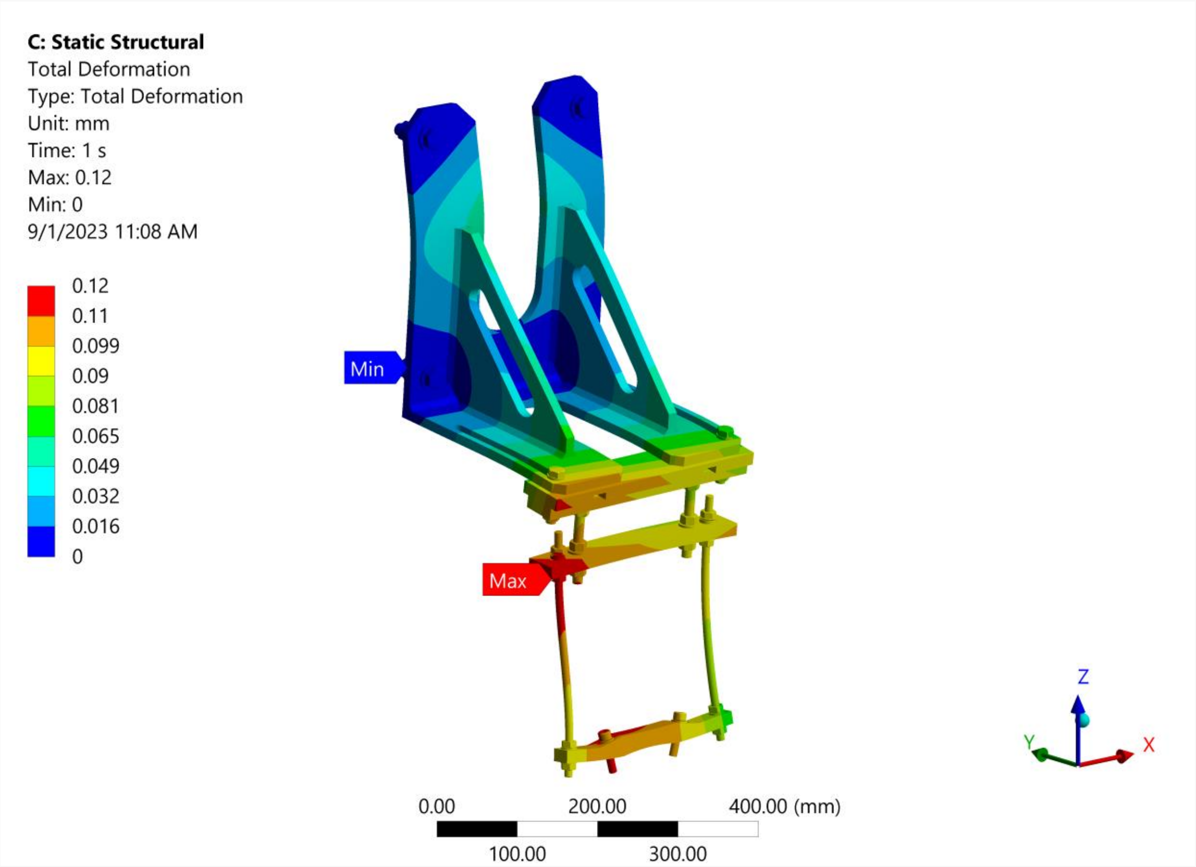


Figure 18End Flange Holder FEA Total Deformation

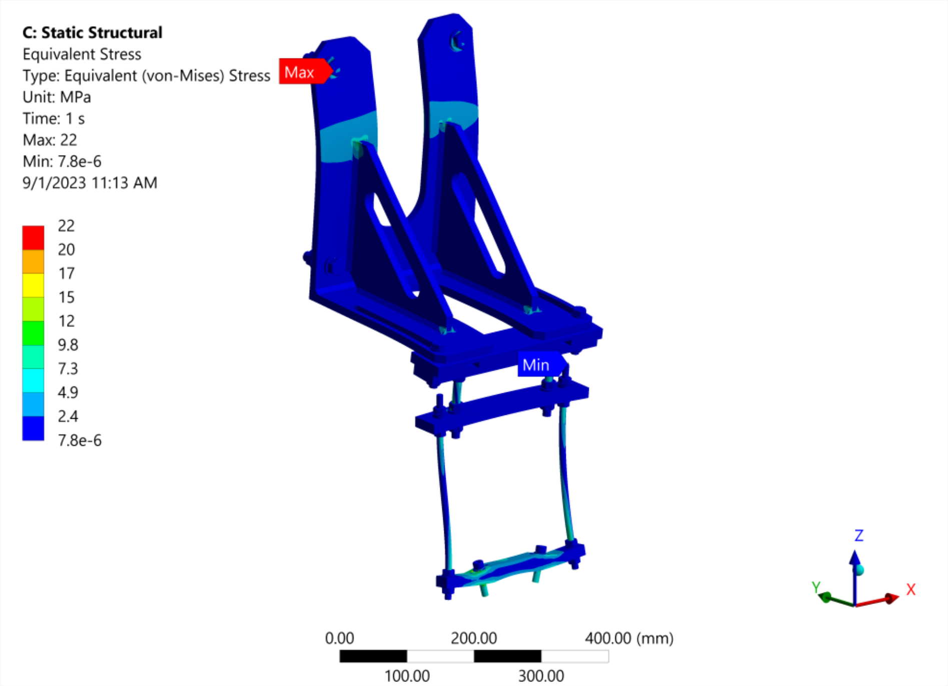


Figure 19 End Flange Holder FEA Equivalent Stress

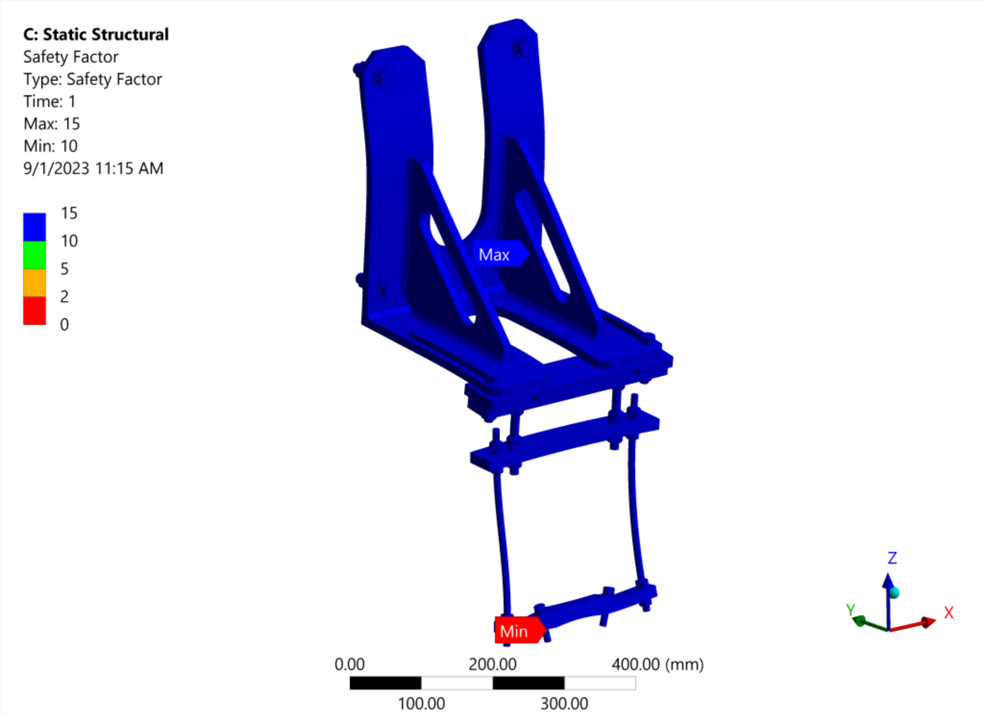


Figure 20 End Flange Holder FEA Safety Factor

4.2 Tension Members

4.2.1 Threaded Stud, M10, 18-8 SS

Section 3.2.1 of ASME BTH-1 states that the allowable tensile stress F_t shall not exceed the value given by equation 3-1 on the gross area, nor the value given by equation 3-2 on the effective net tensile area.

The most loaded studs of all the holders will be the Cavity Holder ones.

The Cavity Holder pair will carry the weight of resonant cavity, coupler, tuner, support structure subassembly 335 lbs (152 kg). Each Cavity Holder will carry the load 152/2=76 kg, using safety factor for mass calculation 1.25 each Cavity Holder will carry 76*1.25=95 kg. The cavity holder consists of two studs, so each stud will carry 95/2=47.5 kg. The force L=475 N (105 lbs).

$$F_t = \frac{F_y}{N_d} \quad (3\text{-}1)$$

$$F_t = \frac{F_u}{1.2N_d} \quad (3\text{-}2)$$

where:

F_u = specified minimum ultimate tensile strength.

F_y = specified minimum yield stress.

N_d = design factor for limit states of yielding or buckling (equal to 2.0 for tension members).

D = outer diameter of threaded stud = 3/8 in

n = number of threads per inch = 16

The critical areas for the treaded stud tension and shear stress calculation are:

A_g = gross area = $\pi(0.5 * D)^2 = \pi(0.5 * 3/8)^2 = 0.110\ in^2$

A_t = effective net tensile area $= \frac{\pi}{4}\left(D - \frac{0.9743}{n}\right)^2 = \frac{\pi}{4}\left(0.375 - \frac{0.9743}{16}\right)^2 = 0.0775\ in^2$

The tensile stress on each rod is as follows:

$$F_{t_{gross}} = \frac{105\ lbs}{0.110\ in^2} = 955\ psi$$

$$F_t = \frac{105\ lbs}{0.0775\ in^2} = 1355\ psi$$

$$F_{t_{gross}}(allowed) = \frac{F_y}{N_d} = \frac{25000\ psi}{2} = 12500\ psi$$

$$F_t(allowed) = \frac{F_u}{1.2 * N_d} = \frac{65000\ psi}{1.2 * 2} = 27080\ psi$$

The tensile stress F_t=1355 psi is not exceeding the value given by equation 3-1 F_t(allowed) = 12500 psi on the gross area, nor the value given by equation 3-2 F_t(allowed) = 27080 psi on the effective net tensile area.

$$\text{Minimum Safety Factor } = \frac{12500}{955} = 13$$

4.2.2 Beam Clamp Bolt, 1/2-13, 18-8 SS

The most loaded bolt is shown on Figure 21.

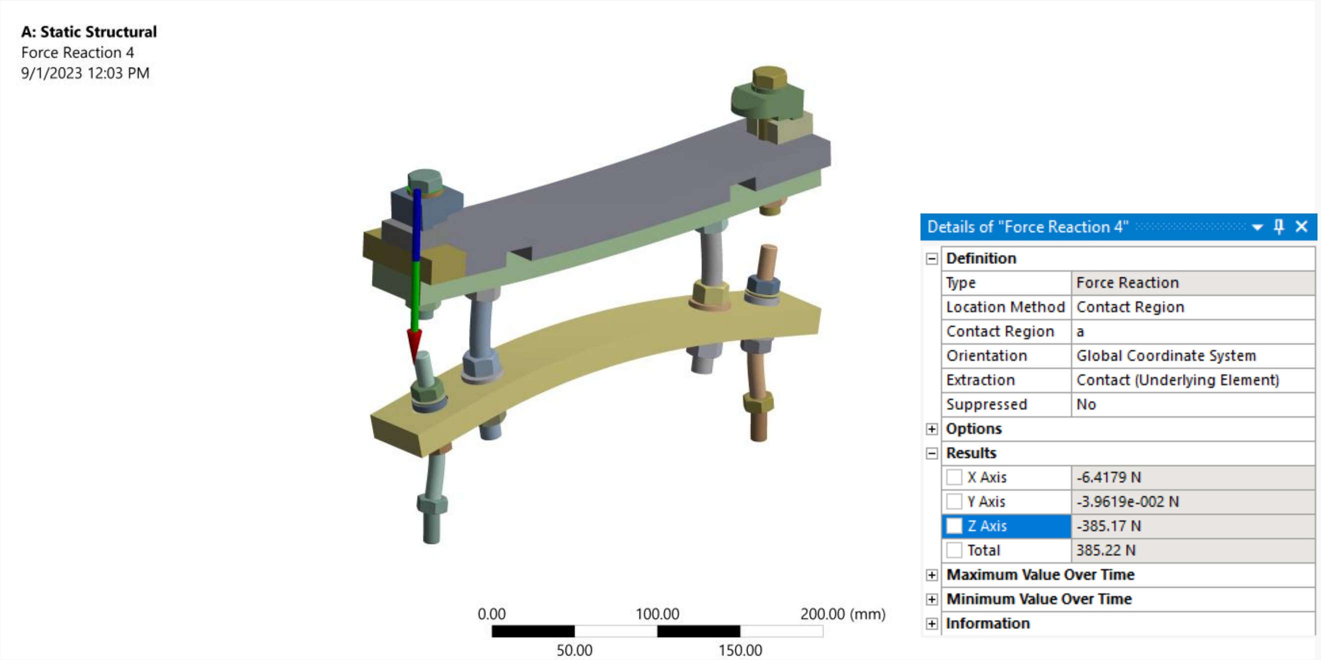


Figure 21 The Most Loaded Beam Clamp bolt

The maximum tension force in the bolt is 385 N (87 lbs).
The tensile stress on each rod is as follows:

$$F_{t_{gross}} = \frac{87\ lbs}{0.196\ in^2} = 440\ psi$$

$$F_t = \frac{87\ lbs}{0.142\ in^2} = 610\ psi$$

$$F_{t_{gross}}(allowed) = \frac{F_y}{N_d} = \frac{25000\ psi}{2} = 12500\ psi$$

$$F_t(allowed) = \frac{F_u}{1.2 * N_d} = \frac{65000\ psi}{1.2 * 2} = 27080\ psi$$

The tensile stress F_t=610 psi is not exceeding the value given by equation 3-1 F_t(allowed) = 12500 psi on the gross area, nor the value given by equation 3-2 F_t(allowed) = 27080 psi on the effective net tensile area.

$$\text{Minimum Safety Factor } = \frac{12500}{440} = 28$$

4.3 Flexural Members

4.3.1 Threaded Stud, M10, 18-8 SS

Section 3.2.3 of ASME BTH-1 states that the allowable bending stress F_b shall not exceed the value given by equation 3-25, for solid round bars.
The most loaded component of the Cavity Holder is shown on Figure 22.

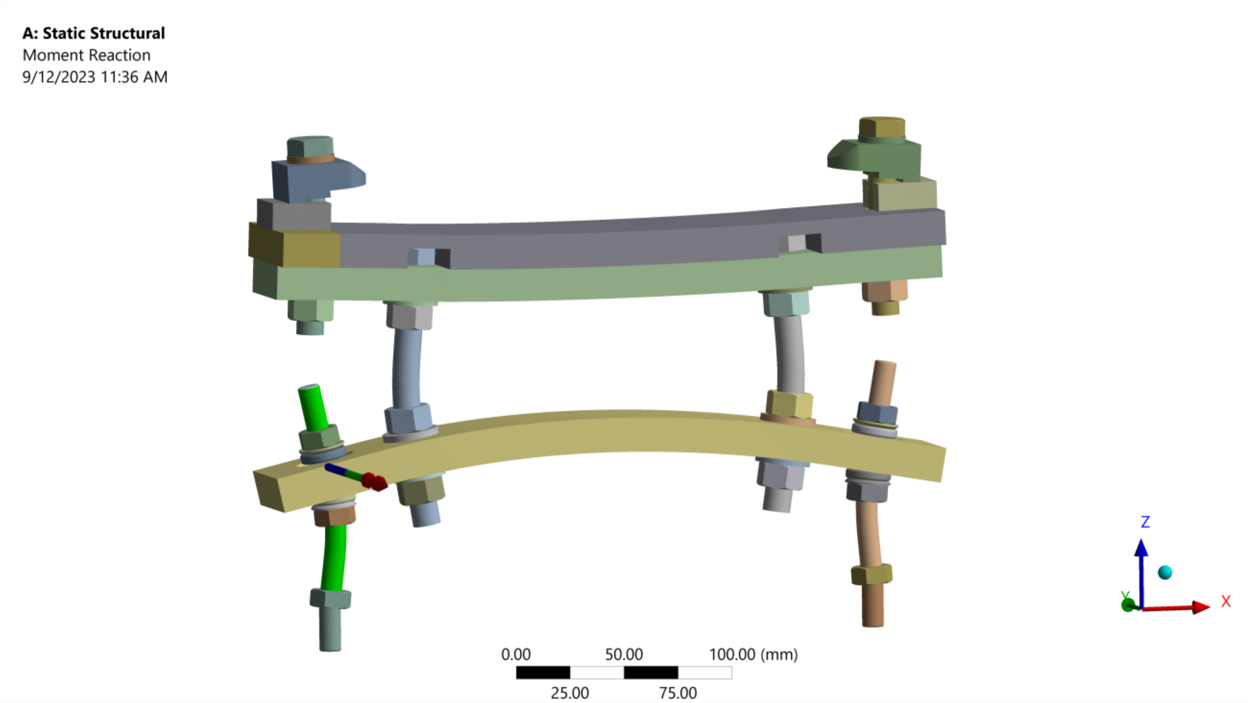


Figure 22 The Most Loaded Stud

The value of the bending torque is 3796 Nmm.

$$F_b = \frac{1.25 F_y}{N_d} \quad (3\text{-}25)$$

$I = 0.00118\ in^4$

The calculated bending stress is as follow:

$$F_b = \frac{M}{I} R = 5608\ psi$$

$$F_b(allowed) = \frac{1.25F_y}{N_d} = \frac{1.25 * 25000}{2} = 15625\ psi$$

Safety factor $= \frac{15625}{5608} = 2.8$

4.3.2 Solenoid Bar, SS304

Section 3.2.3 of ASME BTH-1 states that the allowable bending stress F_b shall not exceed the value given by equation 3-20, for solid rectangular bars that satisfy the relation 3-19.
The most loaded plate is shown in figure 23.

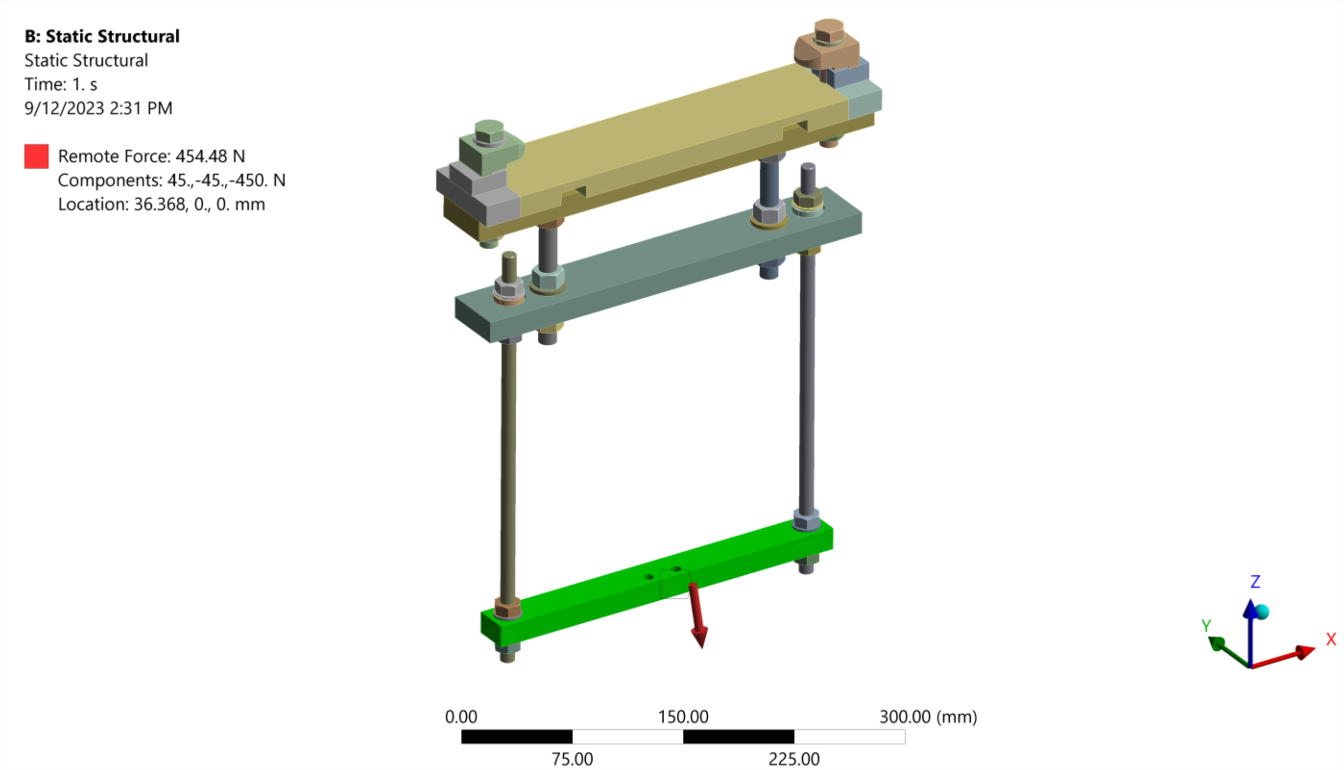


Figure 23 The Most Loaded Stud

$$\frac{L_b d}{t^2} \leq \frac{0.08E}{F_y} \quad (3\text{-}19)$$

$$F_b = \frac{1.25F_y}{N_d} \quad (3\text{-}20)$$

Where:

$L_b = 240\ mm =$ the greater of the maximum distance between supports or the distance between the two points of applied load that are farthest apart.

$d = 25.4\ mm =$ depth of bar.

$t = 15.875\ mm =$ thickness of bar.

Since $\frac{L_b d}{t^2} = 24.2$ and $\frac{0.08E}{F_y} = 77.3$, equation 3-19 is satisfied.

The calculated bending stress is:

$$F_b = \frac{P * a}{I}\frac{t}{2} = 3282\ psi$$

Where:

$P = \frac{450}{2} = 225\ N$

$d = 1\ in =$ depth of bar.

$t = \frac{5}{8}\ in =$ thickness of bar.

$I = 0.02034\ in^4$

$$F_b(allowed) = \frac{1.25F_y}{N_d} = \frac{1.25 * 30000}{2} = 18750\ psi$$

Safety factor $= \frac{18750}{3282} = 5.7$

4.4 Connections

4.4.1 Threaded Stud, M10, 18-8 SS

Section 3-3.2 of ASME BTH-1 states that the allowable tensile stress, Ft, of the bolt shall not exceed the value given by equation (3-40).

The most loaded studs of all the holders will be the Cavity Holder ones.

The Cavity Holder pair will carry the weight of resonant cavity, coupler, tuner, support structure subassembly 335 lbs (152 kg). Each Cavity Holder will carry the load 152/2=76 kg, using safety factor for mass calculation 1.25 each Cavity Holder will carry 76*1.25=95 kg. The cavity holder consists of two studs, so each stud will carry 95/2=47.5 kg. The force L=475 N (105 lbs).

$$F_t = \frac{F_u}{1.2N_d} \tag{3-40}$$

where:

F_u = specified minimum ultimate tensile strength.

F_y = specified minimum yield stress.

N_d = design factor for limit states of yielding or buckling (2.4 for connections).

D = outer diameter of threaded stud = 3/8 in

n = number of threads per inch = 16

The critical areas for the treaded stud tension and shear stress calculation are:

A_g = gross area = $\pi(0.5 * D)^2 = \pi(0.5 * 3/8)^2 = 0.110\ in^2$

A_t = effective net tensile area $= \frac{\pi}{4}\left(D - \frac{0.9743}{n}\right)^2 = \frac{\pi}{4}\left(0.375 - \frac{0.9743}{16}\right)^2 = 0.0775\ in^2$

The tensile stress on each rod is as follows:

$$F_t = \frac{105\ lbs}{0.0775\ in^2} = 1355\ psi$$

$$F_t(allowed) = \frac{F_u}{1.2 * N_d} = \frac{65000\ psi}{1.2 * 2.4} = 22570\ psi$$

Safety Factor $= \frac{22570}{1355} = 16.7$

4.4.2 Beam Clamp Bolt, 1/2-13, 18-8 SS

The most loaded bolt is shown on Figure 24.

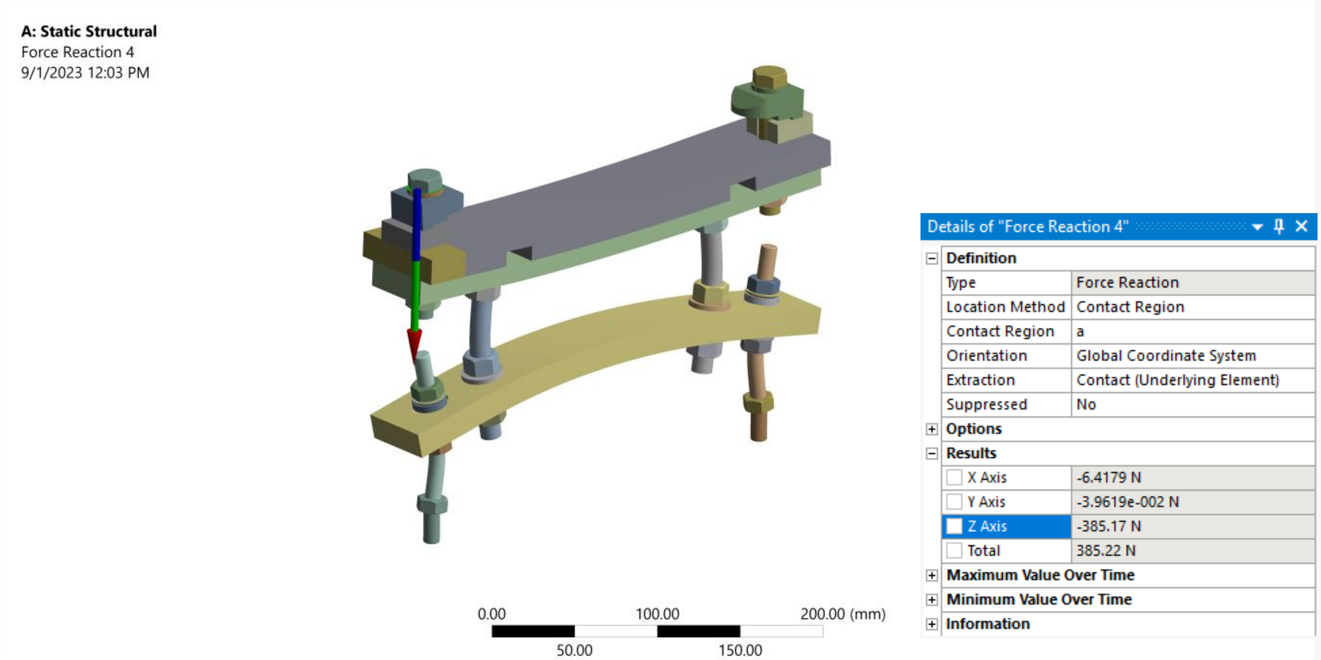


Figure 24 The Most Loaded Beam Clamp bolt

The maximum tension force in the bolt is 385 N (87 lbs).
At Table 3 one can see the tensile Safe Working Load (SWL) 1293 lbf (5752 N) with a given torque
51 ft*lbs (69N*m) specified by manufacturer. SWL is the maximum safe force that a piece of lifting equipment, lifting device or accessory can exert to lift, suspend, or lower, a given mass without fear of breaking. The safety factor $\frac{1293}{87} = 15$, which is greater than 2.4.
The tensile stress on each rod is as follows:

$$F_t = \frac{87\ lbs}{0.142\ in^2} = 610\ psi$$

$$F_t(allowed) = \frac{F_u}{1.2 * N_d} = \frac{65000\ psi}{1.2 * 2.4} = 22570\ psi$$

Minimum Safety Factor $= \frac{22570}{610} = 37$

4.4.3 End Flange Support Bolt 5/8-11, G8S

The most loaded bolt of the End Flange Holder is shown on Figure 25.

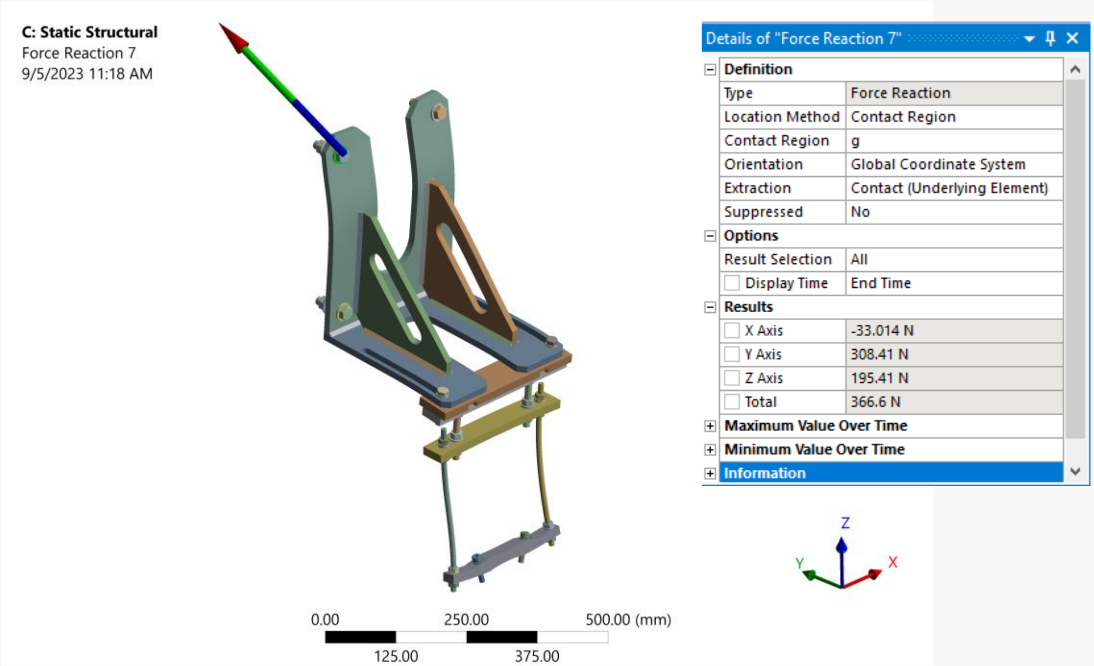


Figure 25 The Most Loaded End Flange Holder Bolt

The maximum tension force in the bolt is 310 N (70 lbs) and the maximum shear force is $\sqrt{33^2 + 195^2} = 198$ N (44.5 lbs).

Section 3-3.2 of ASME BTH-1 states that the allowable shear stress, F_v, of a bolted connection design shall not exceed the value given by equation 3-41.

$$F_v = \frac{0.62F_u}{1.2N_d} \tag{3-41}$$

Section 3-3.2 of ASME BTH-1 states that the allowable tensile stress, F_t', for a bolt subjected to combined tension and shear stresses is:

$$F_t' = \sqrt{F_t^2 - 2.60f_v^2} \tag{3-42}$$

where:

$F_t = \frac{F_u}{1.2N_d} = \frac{150000\,psi}{1.2 * 2.4} = 52080\,psi$

f_v = actual shear stress.

F_u = specified minimum ultimate tensile strength.

N_d = design factor for limit states of yielding or buckling (equal to 2.4).

D = outer diameter of threaded stud = 5/8 in

n = number of threads per inch = 11

d_1 = minimum pitch diameter of thread = 0.5668 in

L_e = length of thread engagement = 0.5469 in

The critical areas for the treaded stud tension and shear stress calculation are:

A_g = gross area = $\pi(0.5 * D)^2 = \pi(0.5 * 5/8)^2 = 0.307\ in^2$

A_t = effective net tensile area = $\frac{\pi}{4}\left(D - \frac{0.9743}{n}\right)^2 = \frac{\pi}{4}\left(0.625 - \frac{0.9743}{11}\right)^2 = 0.226\ in^2$

A_s= thread shear area = $\pi d_1 \left(\frac{L_e}{2}\right) = \pi 0.5668 \left(\frac{0.5469}{2}\right) = 0.487\ in^2$

The thread shear stress on each bolt is as follows:

$$F_v = \frac{44.5\ lbs}{0.487\ in^2} = 91 \text{ psi}$$

$$F_v(allowed) = \frac{0.62F_u}{1.2N_d} = \frac{0.62 * 150000\ psi}{1.2 * 2.4} = 32290\ psi$$

Shear Safety Factor $= \frac{32290}{91} = 355$

The tensile stress on each rod is as follows:

$$F_t' = \frac{70\ lbs}{0.226\ in^2} = 310 \text{ psi}$$

$$F_t'(allowed) = \sqrt{52080^2 - 2.60 * 91^2} \approx 52080 \text{ psi}$$

Tensile Safety Factor $= \frac{52080}{310} = 170$

4.4.4 Welded Connection

Section 3-3.4 of ASME BTH-1 states that the allowable stress, Fv, of fillet welds shall not exceed the value given by equation (3-55).

The most loaded weld is shown on Figure 26.

$$F_v = \frac{0.60E_{xx}}{1.2N_d} \quad (3\text{-}55)$$

Where:

$E_{xx} = 42000\ psi =$ nominal tensile strength of the weld metal

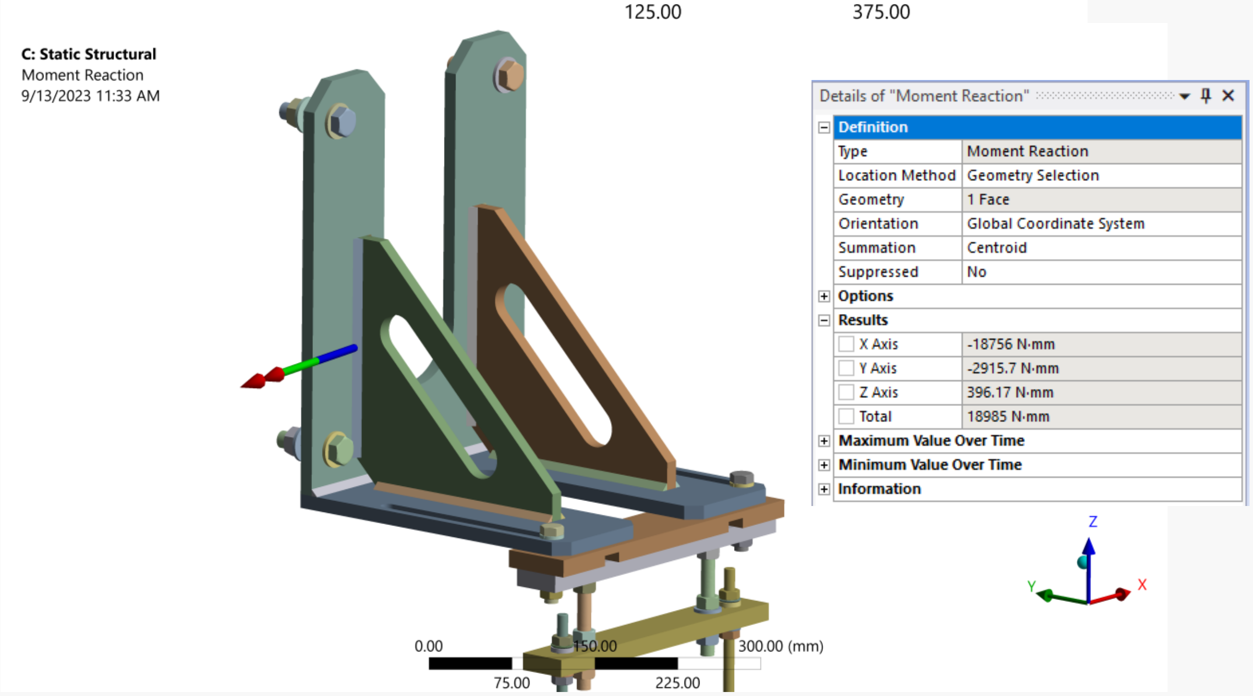


Figure 26 The Most Loaded weld

The stress on the weld is as follows:

$$F_v = \sqrt{\sigma_\perp^2 + \tau_\parallel^2 + \tau_\perp^2} = 228.6\, psi$$

Where:

$$l = 8\ in$$

$$t = \frac{1}{4} * \frac{\sqrt{2}}{2} = 0.177\ in$$

$$A = l * t = 1.41\ in^2$$

$$I_x = \frac{l^3 t}{12} = 7.54\ in^4$$

$$I_z = \frac{t^3 l}{12} = 3.68 * 10^{-3}\ in^4$$

$$I_y = I_x + I_z \approx I_x$$

$$\sigma_\perp = \frac{F_y}{A} + \frac{M_x}{I_x}\frac{l}{2} + \frac{M_z}{I_z}\frac{t}{2} = \frac{68}{1.41} + \frac{166}{7.54}\frac{8}{2} + \frac{3.5}{3.68*10^{-3}}\frac{0.177}{2} = 220.5\, psi$$

$$\tau_\parallel = \frac{F_z}{A} + \frac{M_y}{I_y}\frac{t}{2} = \frac{76.7}{1.41} + \frac{25.8}{7.54}\frac{0.177}{2} = 54.7\, psi$$

$$\tau_\perp = \frac{F_x}{A} + \frac{M_y}{I_y}\frac{l}{2} = \frac{16.1}{1.41} + \frac{25.8}{7.54}\frac{8}{2} = 25.1\, psi$$

$$F_v(allowed) = \frac{0.60 E_{xx}}{1.2 N_d} = 8750\, psi$$

Safety factor$= \frac{8750}{228.6} = 38$

5 SSR1

Since the loads and the holders for the solenoid and the end flange of SSR1 are the same as the ones of SSR2 only the Cavity Holder will be analyzed.

5.1 Finite Element Method

5.1.1 The Cavity Holder stress analysis

The Cavity Holder pair will carry the weight of resonant cavity, coupler, tuner, support structure subassembly 320 lbs (145 kg). Each Cavity Holder will carry the load 145/2=72.5 kg, using safety factor for mass calculation 1.25 each Cavity Holder will carry 72.5*1.25=90.6 kg. The force with components of 900 N in the z direction and 90 N in x and y directions (Figure 27) will be applied in addition to the gravitational load. Fixed support will be used as boundary condition for beam clamps, compression only support for the cavity strip and cylindrical supports for bolts (connection between holder and cavity support structure).

The maximum total deformation 0.036 mm occurs at the cavity bar (Figure 28). The maximum combined stress of 77 MPa (11170 psi) occurs at the edge of contact between washer and cavity bar (Figure 29). This is obviously a stress concertation due to singularity (Figure 30). But even with those artificial conditions minimum safety factor is 2.7 which is higher than 2.0 (Figure 30).

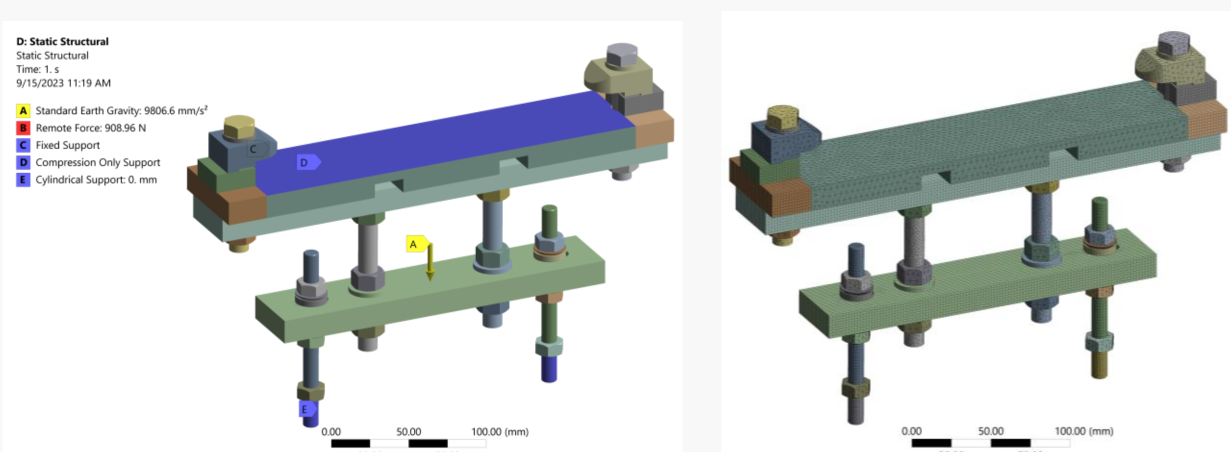


Figure 27 Cavity Holder FEA Boundary Conditions and Mesh

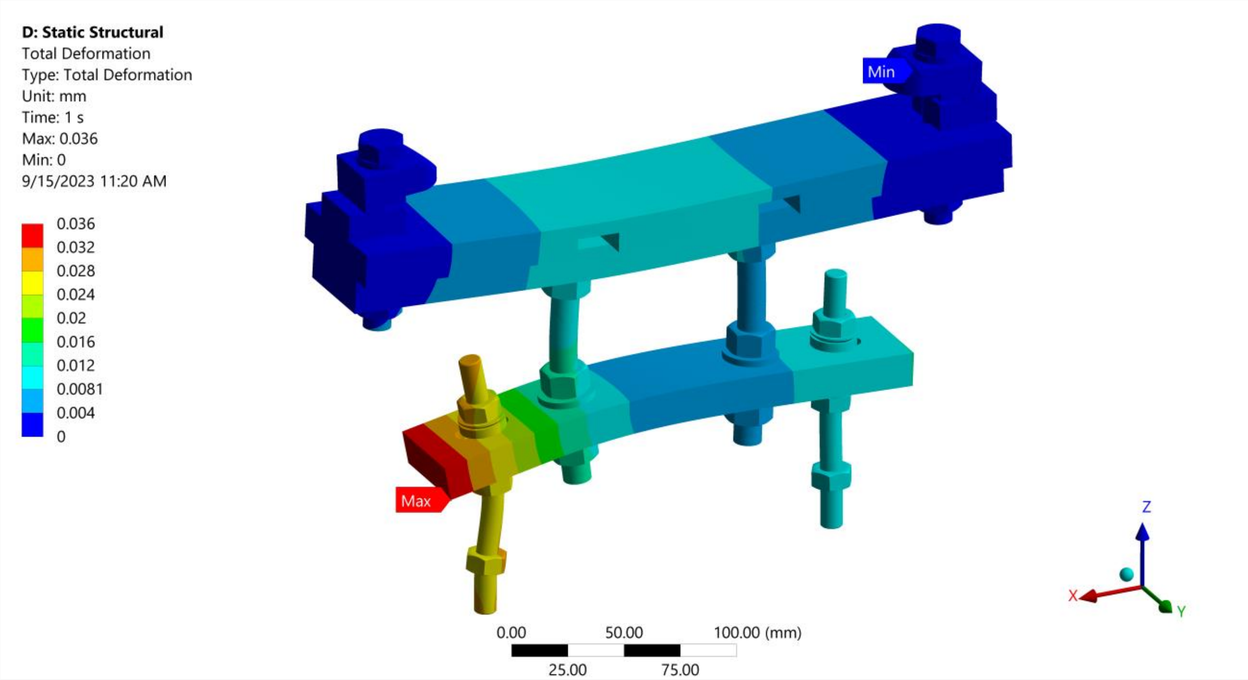


Figure 28 Cavity Holder FEA Total Deformation

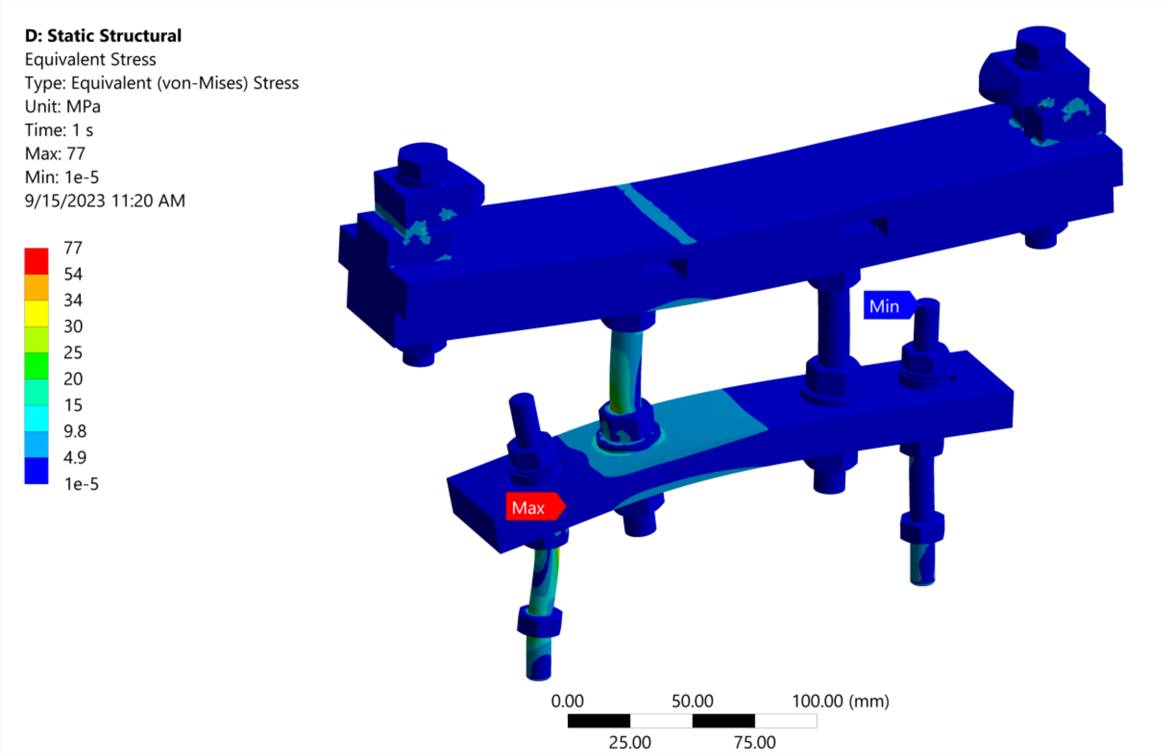


Figure 29 Cavity Holder FEA Equivalent Stress

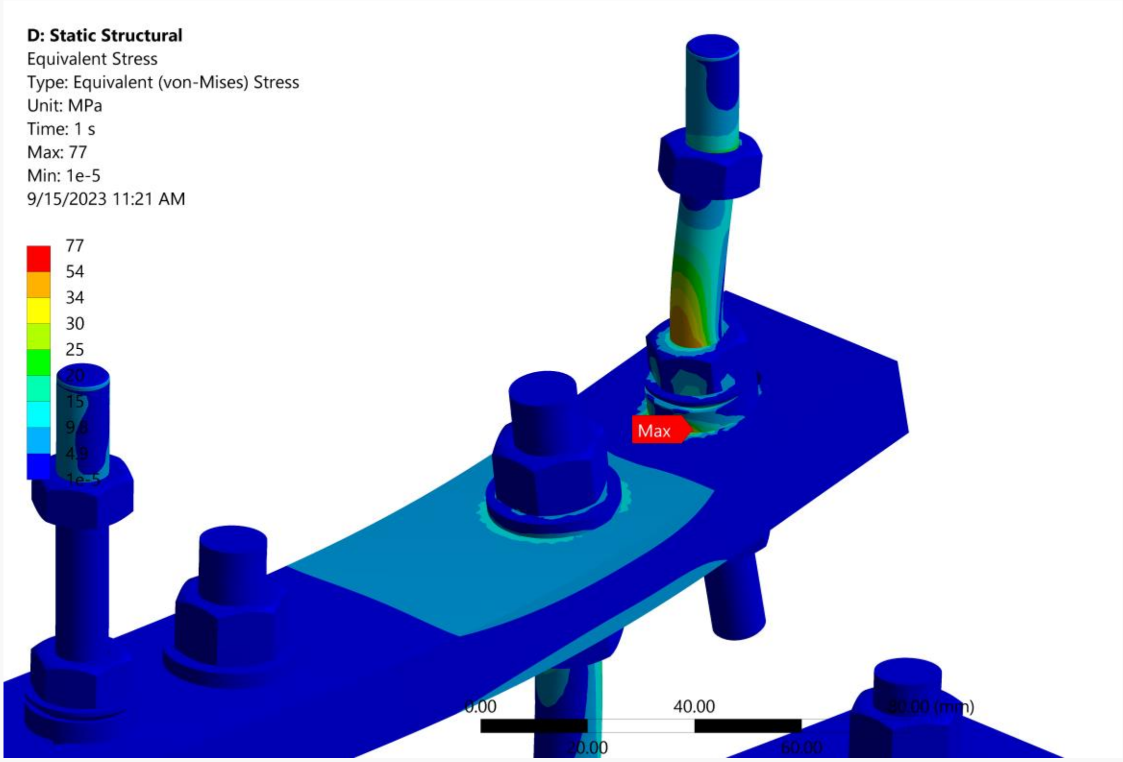


Figure 30 Cavity Holder FEA Equivalent Stress

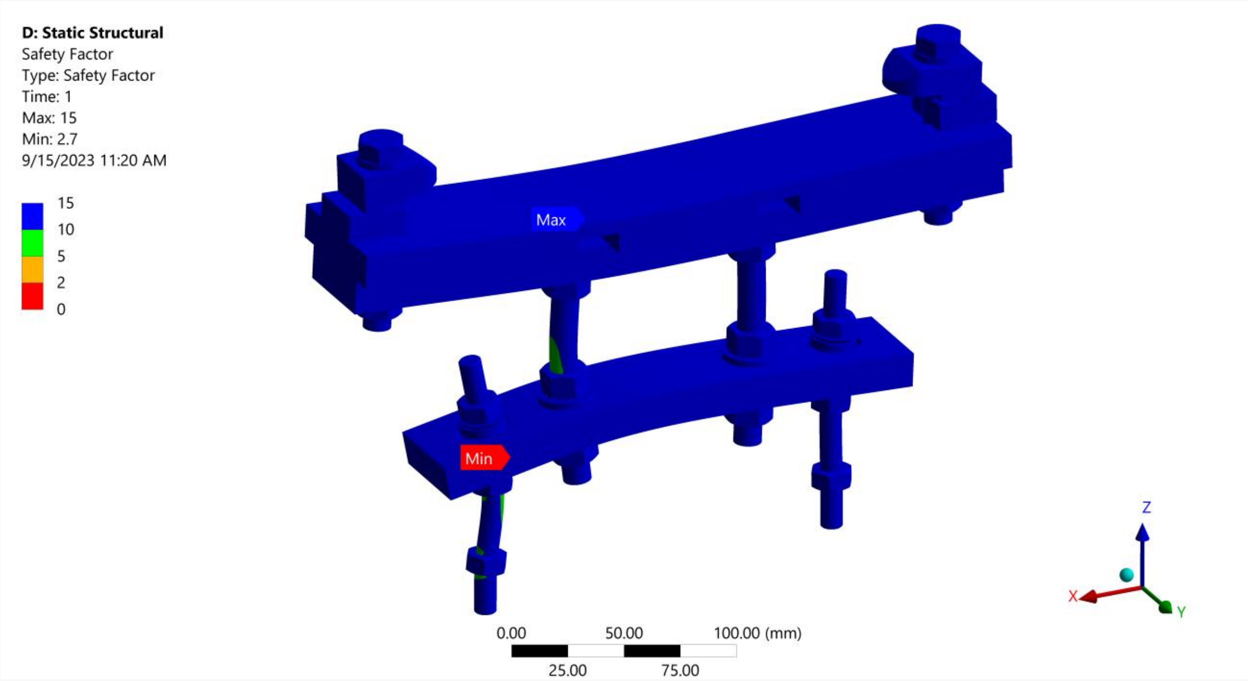


Figure 31 Cavity Holder FEA Safety Factor

5.2 Tension Members

5.2.1 Threaded Stud, M10, 18-8 SS

Section 3.2.1 of ASME BTH-1 states that the allowable tensile stress F_t shall not exceed the value given by equation 3-1 on the gross area, nor the value given by equation 3-2 on the effective net tensile area.
The most loaded stud is shown on figure 32.

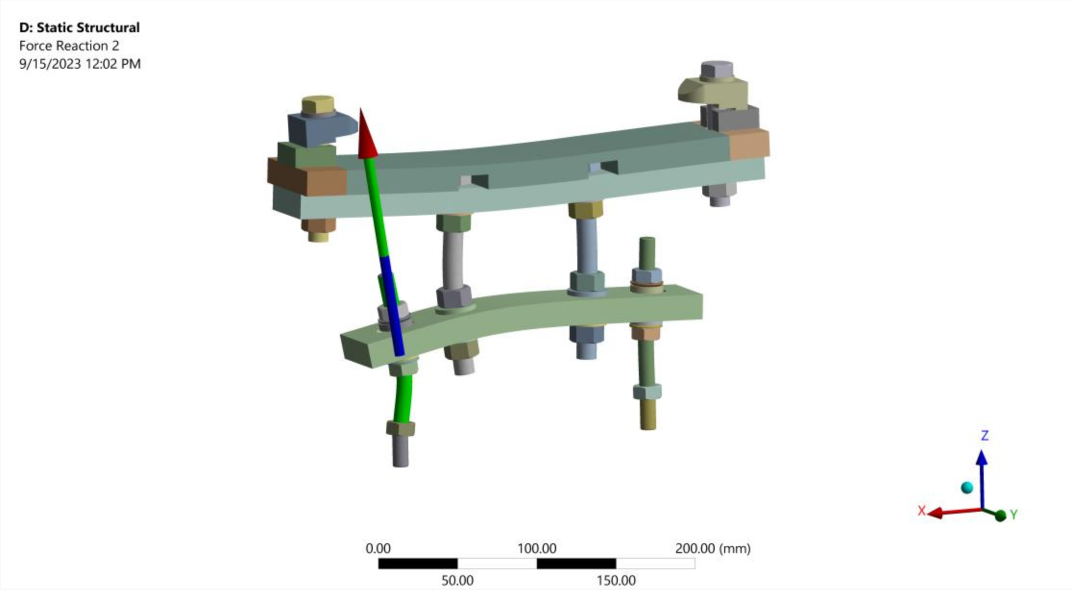


Figure 22 The Most Loaded Stud

The force L=814 N (183 lbs).

$$F_t = \frac{F_y}{N_d} \quad (3\text{-}1)$$

$$F_t = \frac{F_u}{1.2N_d} \quad (3\text{-}2)$$

where:
F_u = specified minimum ultimate tensile strength.
F_y = specified minimum yield stress.
N_d = design factor for limit states of yielding or buckling (equal to 2.0 for tension members).
D = outer diameter of threaded stud = 3/8 in
n = number of threads per inch = 16
The critical areas for the treaded stud tension and shear stress calculation are:
A_g = gross area = $\pi(0.5 * D)^2 = \pi(0.5 * 3/8)^2 = 0.110\ in^2$
A_t = effective net tensile area $= \frac{\pi}{4}\left(D - \frac{0.9743}{n}\right)^2 = \frac{\pi}{4}\left(0.375 - \frac{0.9743}{16}\right)^2 = 0.0775\ in^2$

The tensile stress on each rod is as follows:

$$F_{t_{gross}} = \frac{183\ lbs}{0.110\ in^2} = 1664\ psi$$

$$F_t = \frac{183\ lbs}{0.0775\ in^2} = 2360\ psi$$

$$F_{t_{gross}}(allowed) = \frac{F_y}{N_d} = \frac{25000\ psi}{2} = 12500\ psi$$

$$F_t(allowed) = \frac{F_u}{1.2 * N_d} = \frac{65000\ psi}{1.2 * 2} = 27080\ psi$$

The tensile stress F_t=2360 psi is not exceeding the value given by equation 3-1 F_t(allowed) = 12500 psi on the gross area, nor the value given by equation 3-2 F_t(allowed) = 27080 psi on the effective net tensile area.

Minimum Safety Factor $= \frac{12500}{955} = 7.5$

5.3 Flexural Members

5.3.1 Threaded Stud, M10, 18-8 SS

Section 3.2.3 of ASME BTH-1 states that the allowable bending stress F_b shall not exceed the value given by equation 3-25, for solid round bars.
The most loaded component is shown on Figure 33.

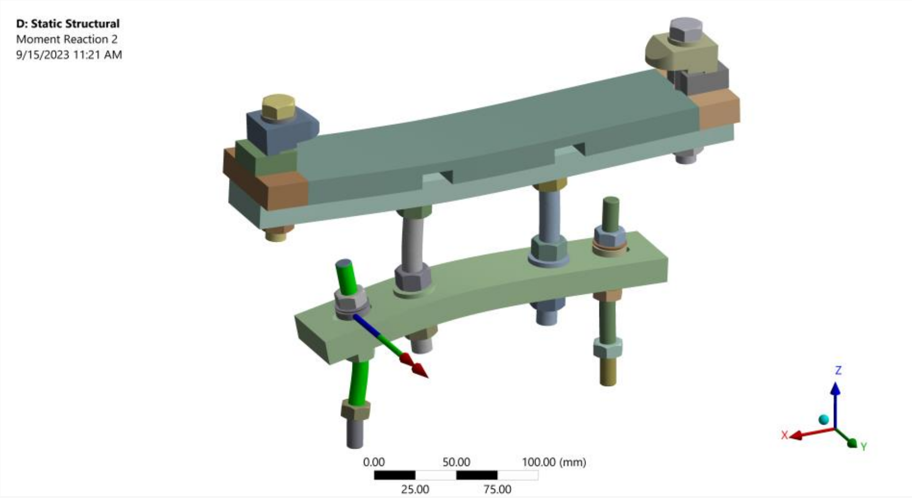


Figure 22 The Most Loaded Stud

The value of the bending torque is 5580 Nmm.

$$F_b = \frac{1.25F_y}{N_d} \tag{3-25}$$

$I = 0.00118\ in^4$

The calculated bending stress is as follow:

$$F_b = \frac{M}{I}R = 8244\ psi$$

$$F_b(allowed) = \frac{1.25F_y}{N_d} = \frac{1.25 * 25000}{2} = 15625\ psi$$

The bending stress $F_b = 8244\ psi$ is not exceeding the value given by equation 3-25

$F_b(\text{allowed}) = 15625\text{ psi.}$

Safety factor $= \frac{15625}{8244} = 1.9$

5.4 Connections

5.4.1 Threaded Stud, M10, 18-8 SS

Section 3-3.2 of ASME BTH-1 states that the allowable tensile stress, Ft, of the bolt shall not exceed the value given by equation (3-40).
The force L=814 N (183 lbs).

$$F_t = \frac{F_u}{1.2N_d} \tag{3-40}$$

where:
F_u = specified minimum ultimate tensile strength.
F_y = specified minimum yield stress.
N_d = design factor for limit states of yielding or buckling (2.4 for connections).
D = outer diameter of threaded stud = 3/8 in
n = number of threads per inch = 16
The critical areas for the treaded stud tension and shear stress calculation are:
A_g = gross area = $\pi(0.5 * D)^2 = \pi(0.5 * 3/8)^2 = 0.110\ in^2$
A_t = effective net tensile area $= \frac{\pi}{4}\left(D - \frac{0.9743}{n}\right)^2 = \frac{\pi}{4}\left(0.375 - \frac{0.9743}{16}\right)^2 = 0.0775\ in^2$
The tensile stress on each rod is as follows:

$$F_t = \frac{183\ lbs}{0.0775\ in^2} = 2360\ psi$$

$$F_t(allowed) = \frac{F_u}{1.2 * N_d} = \frac{65000\ psi}{1.2 * 2.4} = 22570\ psi$$

Safety Factor $= \frac{22570}{2360} = 9.6$

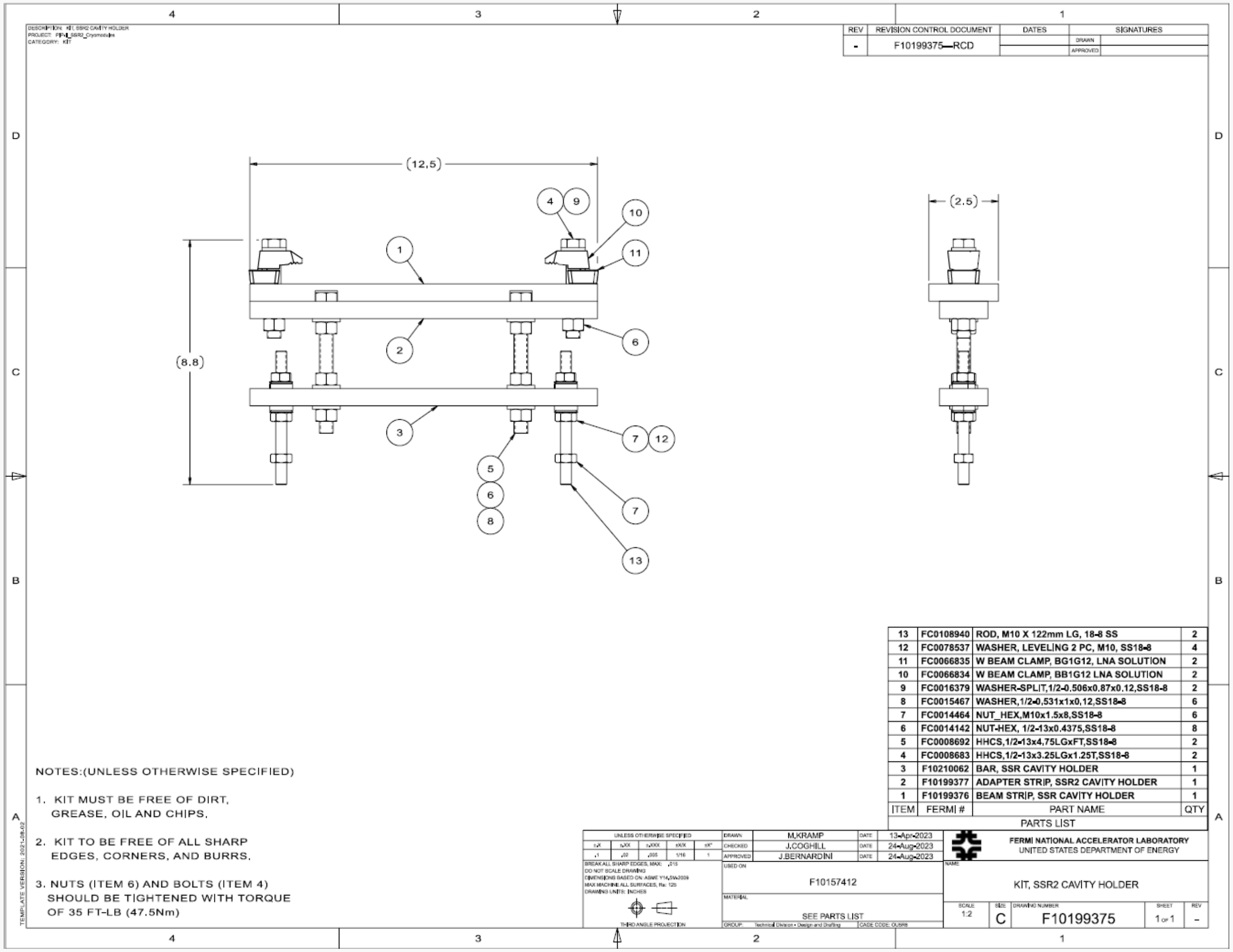
6 Summary

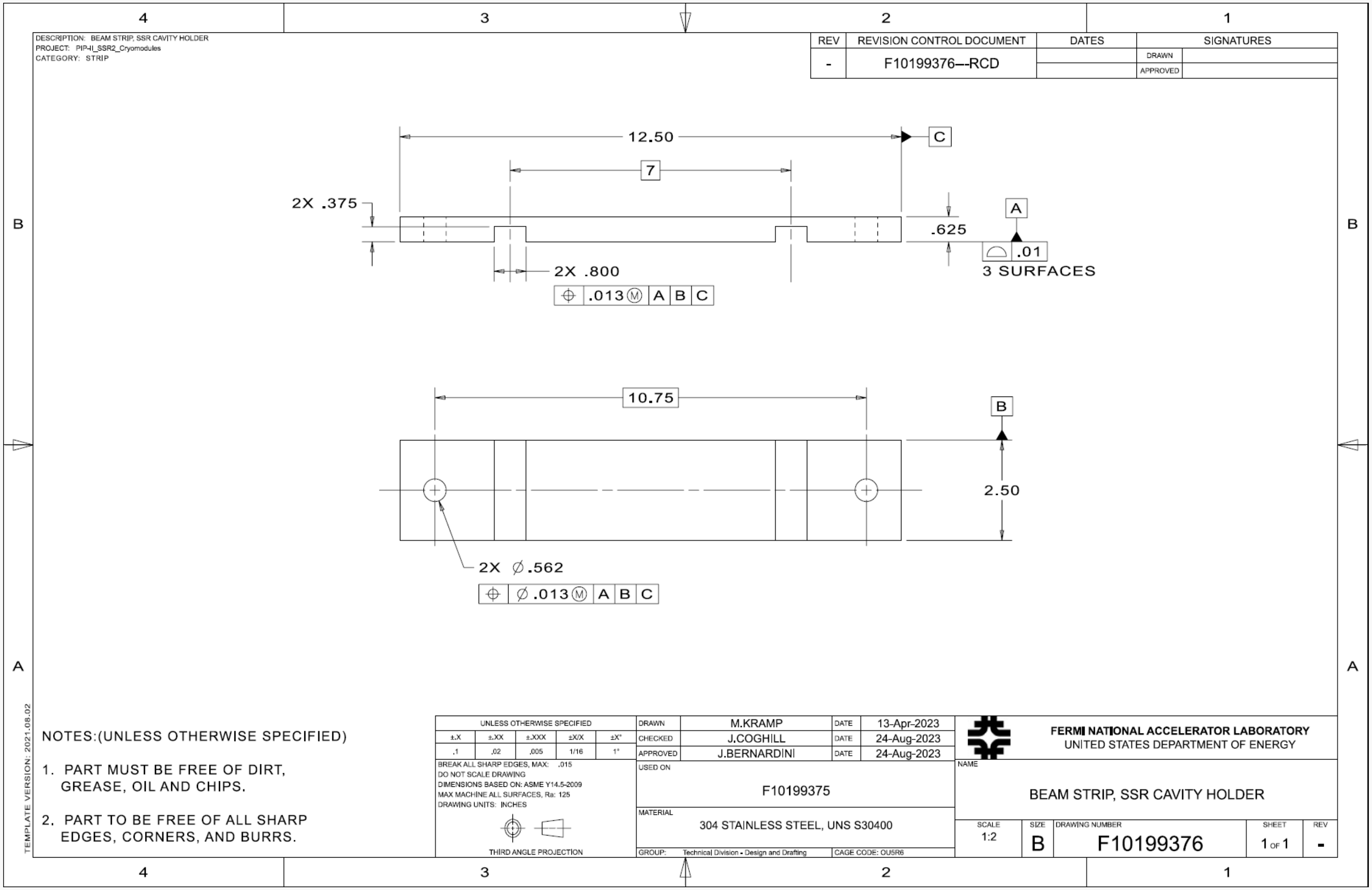
The results of calculation are summarized at Table 2. The resultant stresses due to the design loads are below the requirements of the maximum allowable stress limits identified in ASME BTH-1 and ASME B30.20.

	Part	MIN Safety Factor
SSR2	Cavity Holder (FEA)	3.7
	Solenoid Holder (FEA)	3.4
	End Flange Holder (FEA)	10
	Threaded Stud, M10, 18-8 SS (tension)	13
	Beam Clamp Bolt, 1/2-13, 18-8 SS (tension)	28
	Threaded Stud, M10, 18-8 SS (flexion)	2.8
	Solenoid Bar, SS304 (flexion)	5.7
	Threaded Stud, M10, 18-8 SS (connection)	16.7
	Beam Clamp Bolt, 1/2-13, 18-8 SS (connection)	37
	End Flange Support Bolt 5/8-11, G8S (tensile)	170
	End Flange Support Bolt 5/8-11, G8S (shear)	355
	Welds	38
SSR1	Cavity Holder (FEA)	2.7
	Threaded Stud, M10, 18-8 SS (tension)	7.5
	Threaded Stud, M10, 18-8 SS (flexion)	1.9
	Threaded Stud, M10, 18-8 SS (connection)	9.6

Table 2 MIN Safety Factor

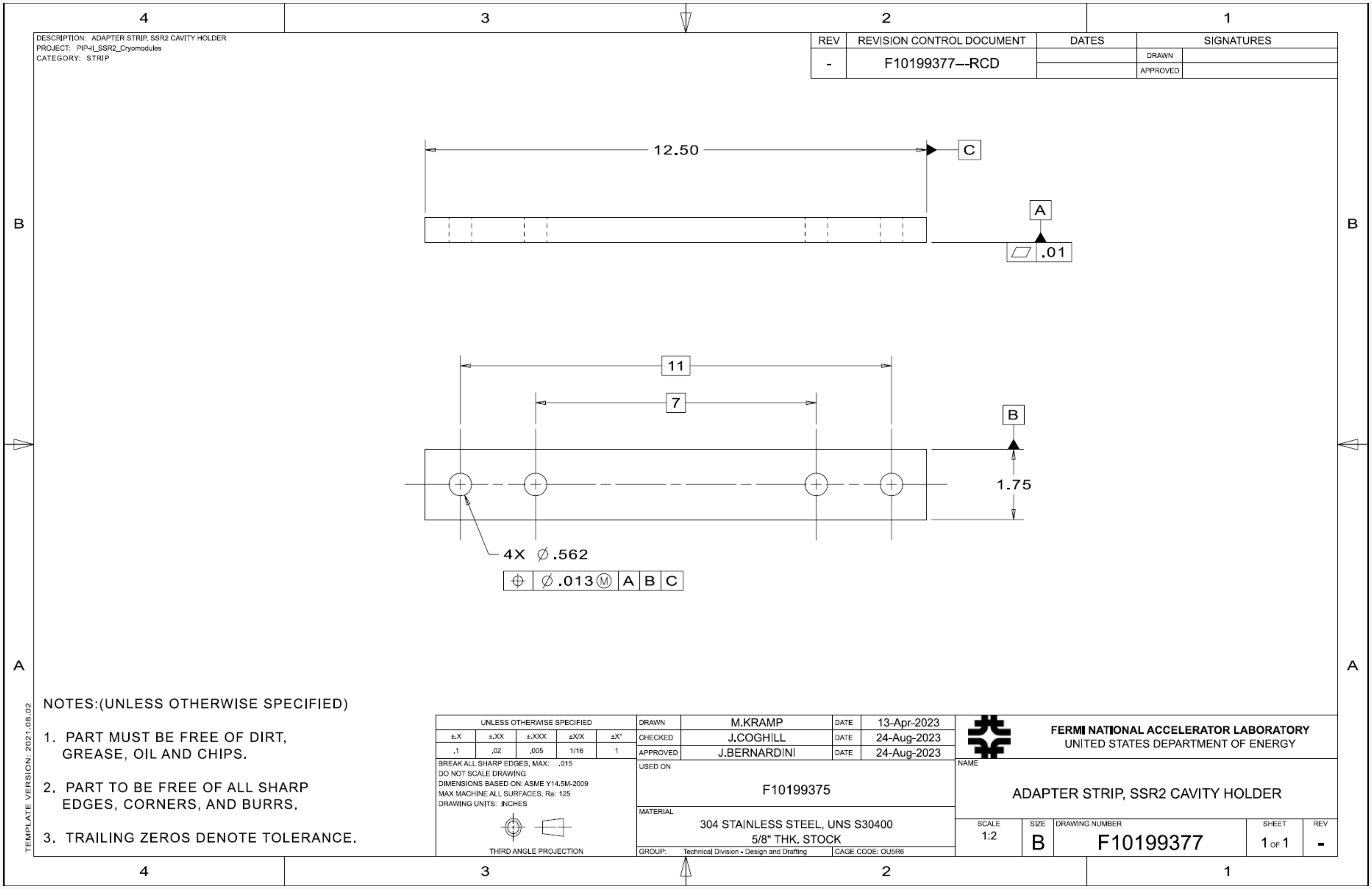
7 Appendix

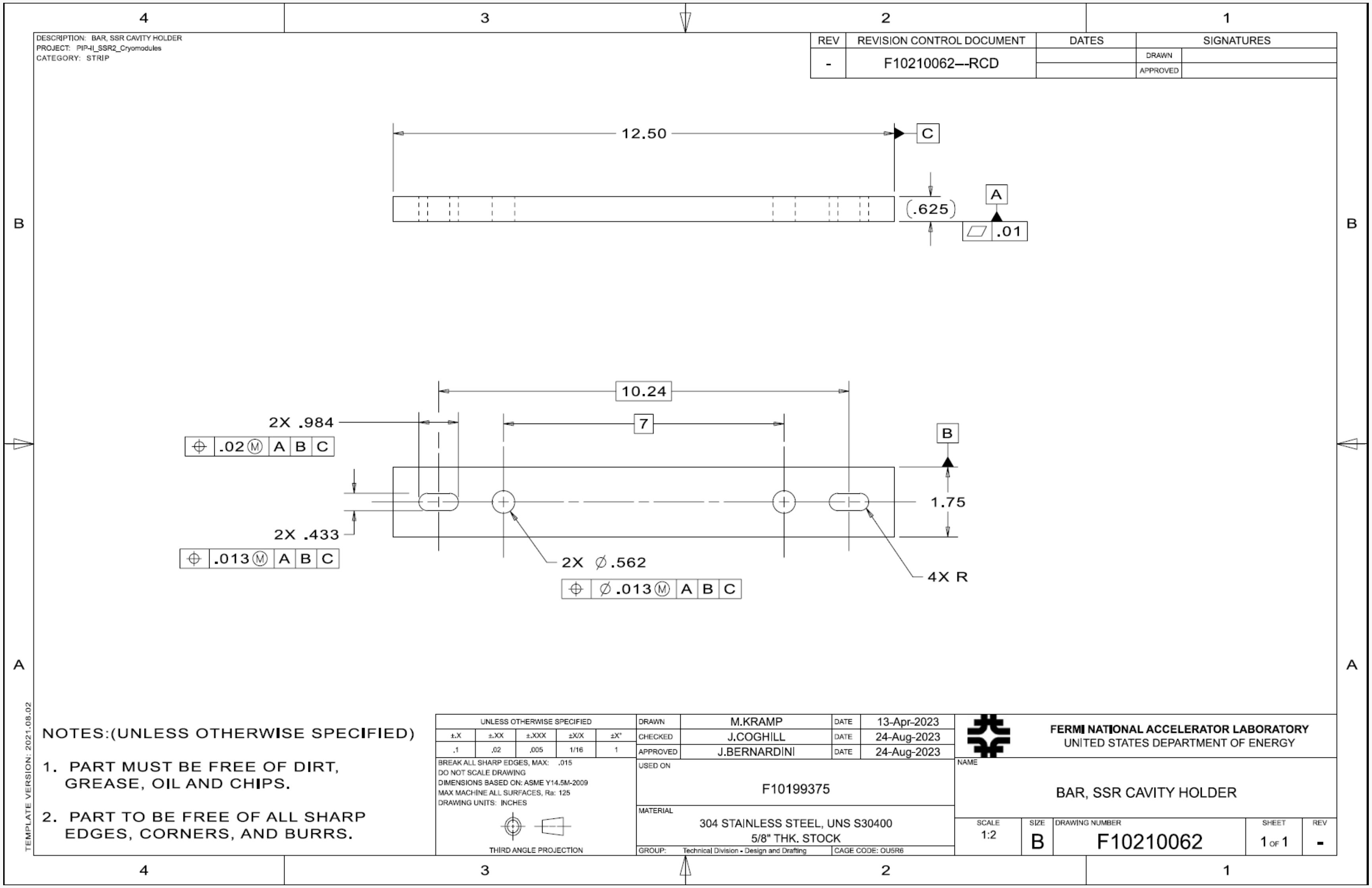

REV
REVISION CONTROL DOCUMENT
DATES
SIGNATURES
F10199375—RCD
(12.5)
(2.5)
(8.8)
NOTES:(UNLESS OTHERWISE SPECIFIED)
1. KIT MUST BE FREE OF DIRT, GREASE, OIL AND CHIPS.
2. KIT TO BE FREE OF ALL SHARP EDGES, CORNERS, AND BURRS.
3. NUTS (ITEM 6) AND BOLTS (ITEM 4) SHOULD BE TIGHTENED WITH TORQUE OF 35 FT-LB (47.5Nm)
13 FC0108940 ROD, M10 X 122mm LG, 18-8 SS 2
12 FC0078537 WASHER, LEVELING 2 PC, M10, SS18-8 4
11 FC0066835 W BEAM CLAMP, BG1G12, LNA SOLUTION 2
10 FC0066834 W BEAM CLAMP, BB1G12 LNA SOLUTION 2
9 FC0016379 WASHER-SPLIT,1/2-0.506x0.87x0.12,SS18-8 2
8 FC0015467 WASHER,1/2-0,531x1x0,12,SS18-8 6
7 FC0014464 NUT_HEX,M10x1.5x8,SS18-8 6
6 FC0014142 NUT-HEX, 1/2-13x0.4375,SS18-8 8
5 FC0008692 HHCS,1/2-13x4,75LGxFT,SS18-8 2
4 FC0008683 HHCS,1/2-13x3.25LGx1.25T,SS18-8 2
3 F10210062 BAR, SSR CAVITY HOLDER 1
2 F10199377 ADAPTER STRIP, SSR2 CAVITY HOLDER 1
1 F10199376 BEAM STRIP, SSR CAVITY HOLDER 1
ITEM FERMI # PART NAME QTY
PARTS LIST
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES, MAX: .015
DO NOT SCALE DRAWING
DIMENSIONS BASED ON: ASME Y14.5M-2009
MAX MACHINE ALL SURFACES, Ra: 125
DRAWING UNITS: INCHES
THIRD ANGLE PROJECTION
DRAWN M.KRAMP DATE 13-Apr-2023
CHECKED J.COGHILL DATE 24-Aug-2023
APPROVED J.BERNARDINI DATE 24-Aug-2023
USED ON F10157412
MATERIAL SEE PARTS LIST
GROUP: Technical Division • Design and Drafting
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
KIT, SSR2 CAVITY HOLDER
SCALE 1:2
SIZE C
DRAWING NUMBER F10199375
SHEET 1 OF 1
REV -



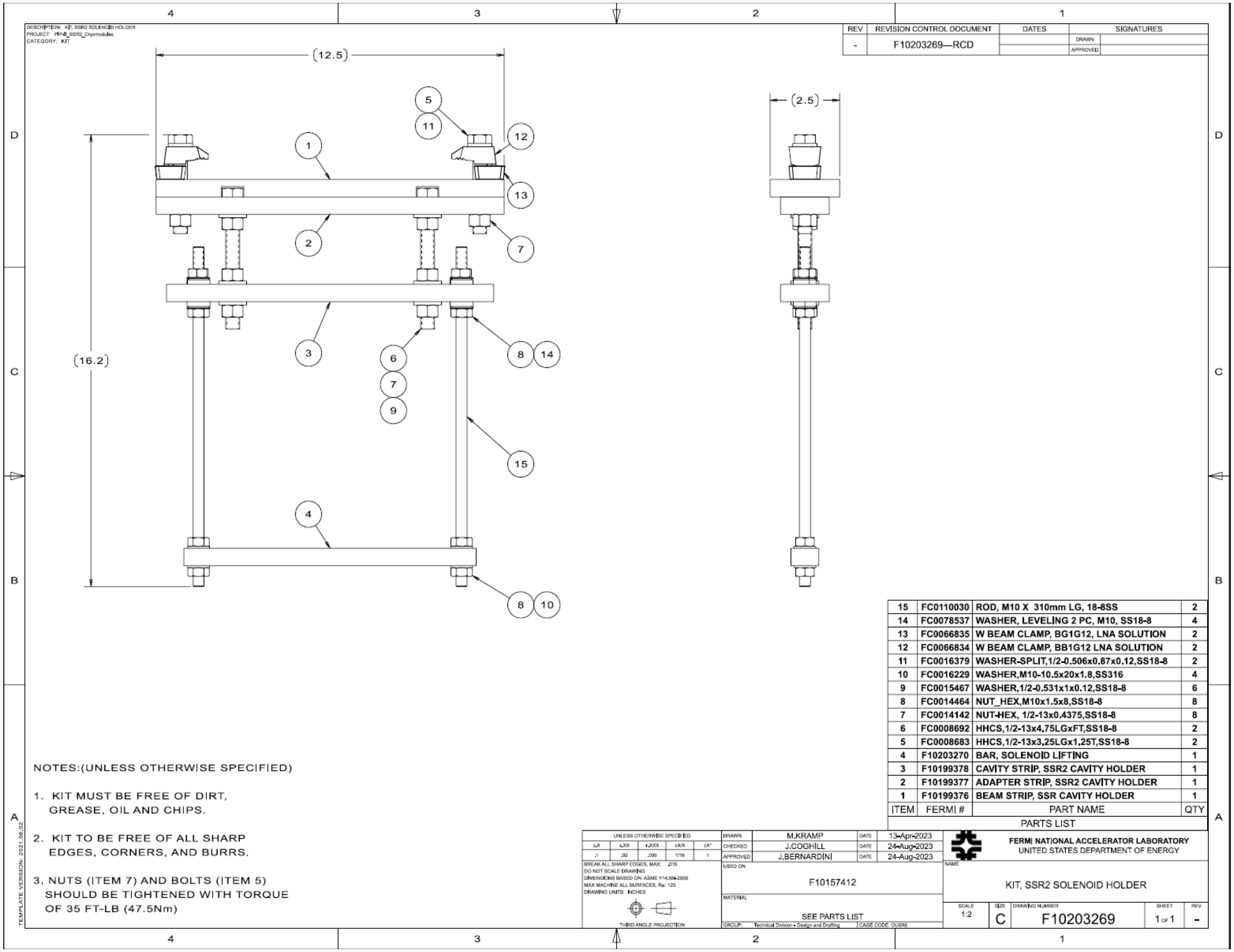
DESCRIPTION: BEAM STRIP, SSR CAVITY HOLDER
PROJECT: PIP-II_SSR2_Cryomodules
CATEGORY: STRIP
REV
REVISION CONTROL DOCUMENT
DATES
SIGNATURES
-
F10199376--RCD
DRAWN
APPROVED
12.50
C
7
2X .375
A
.625
.01
3 SURFACES
2X .800
.013 M A B C
10.75
B
2.50
2X ∅.562
∅.013 M A B C
NOTES:(UNLESS OTHERWISE SPECIFIED)
1. PART MUST BE FREE OF DIRT, GREASE, OIL AND CHIPS.
2. PART TO BE FREE OF ALL SHARP EDGES, CORNERS, AND BURRS.
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES, MAX: .015
DO NOT SCALE DRAWING
DIMENSIONS BASED ON: ASME Y14.5-2009
MAX MACHINE ALL SURFACES, Ra: 125
DRAWING UNITS: INCHES
THIRD ANGLE PROJECTION
DRAWN M.KRAMP DATE 13-Apr-2023
CHECKED J.COGHILL DATE 24-Aug-2023
APPROVED J.BERNARDINI DATE 24-Aug-2023
USED ON F10199375
MATERIAL 304 STAINLESS STEEL, UNS S30400
GROUP: Technical Division - Design and Drafting
CAGE CODE: OU5R6
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
NAME BEAM STRIP, SSR CAVITY HOLDER
SCALE 1:2
SIZE B
DRAWING NUMBER F10199376
SHEET 1 OF 1
REV -
TEMPLATE VERSION: 2021.08.02

PIP-II	Engineering Note	
	Document Title:	Lifter Holders of SSR2 Cryomodule Cavity String Assembly
	Document Number:	ED rev. -

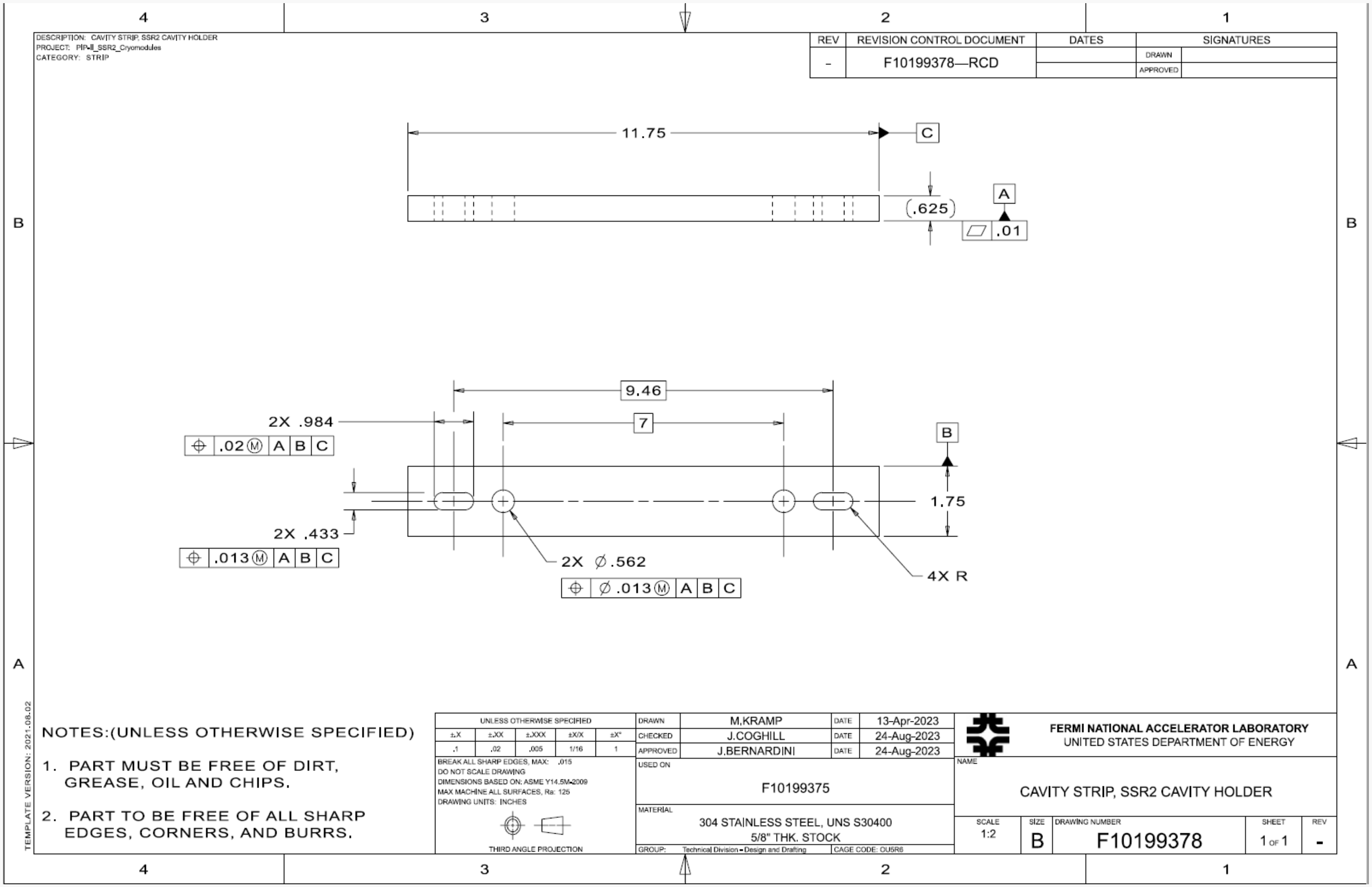




DESCRIPTION: BAR, SSR CAVITY HOLDER
PROJECT: PIP-II_SSR2_Cryomodules
CATEGORY: STRIP
REV | REVISION CONTROL DOCUMENT | DATES | SIGNATURES
- | F10210062--RCD
DRAWN
APPROVED
12.50
C
A
.625
.01
10.24
7
2X .984
.02 M A B C
B
1.75
2X .433
.013 M A B C
2X ∅.562
∅.013 M A B C
4X R
NOTES:(UNLESS OTHERWISE SPECIFIED)
1. PART MUST BE FREE OF DIRT, GREASE, OIL AND CHIPS.
2. PART TO BE FREE OF ALL SHARP EDGES, CORNERS, AND BURRS.
UNLESS OTHERWISE SPECIFIED
±.X ±.XX ±.XXX ±X/X ±X°
.1 .02 .005 1/16 1
BREAK ALL SHARP EDGES, MAX: .015
DO NOT SCALE DRAWING
DIMENSIONS BASED ON: ASME Y14.5M-2009
MAX MACHINE ALL SURFACES, Ra: 125
DRAWING UNITS: INCHES
THIRD ANGLE PROJECTION
DRAWN M.KRAMP DATE 13-Apr-2023
CHECKED J.COGHILL DATE 24-Aug-2023
APPROVED J.BERNARDINI DATE 24-Aug-2023
USED ON F10199375
MATERIAL 304 STAINLESS STEEL, UNS S30400 5/8" THK. STOCK
GROUP: Technical Division • Design and Drafting
CAGE CODE: 0U5R6
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
NAME BAR, SSR CAVITY HOLDER
SCALE 1:2
SIZE B
DRAWING NUMBER F10210062
SHEET 1 OF 1
REV -
TEMPLATE VERSION: 2021.08.02

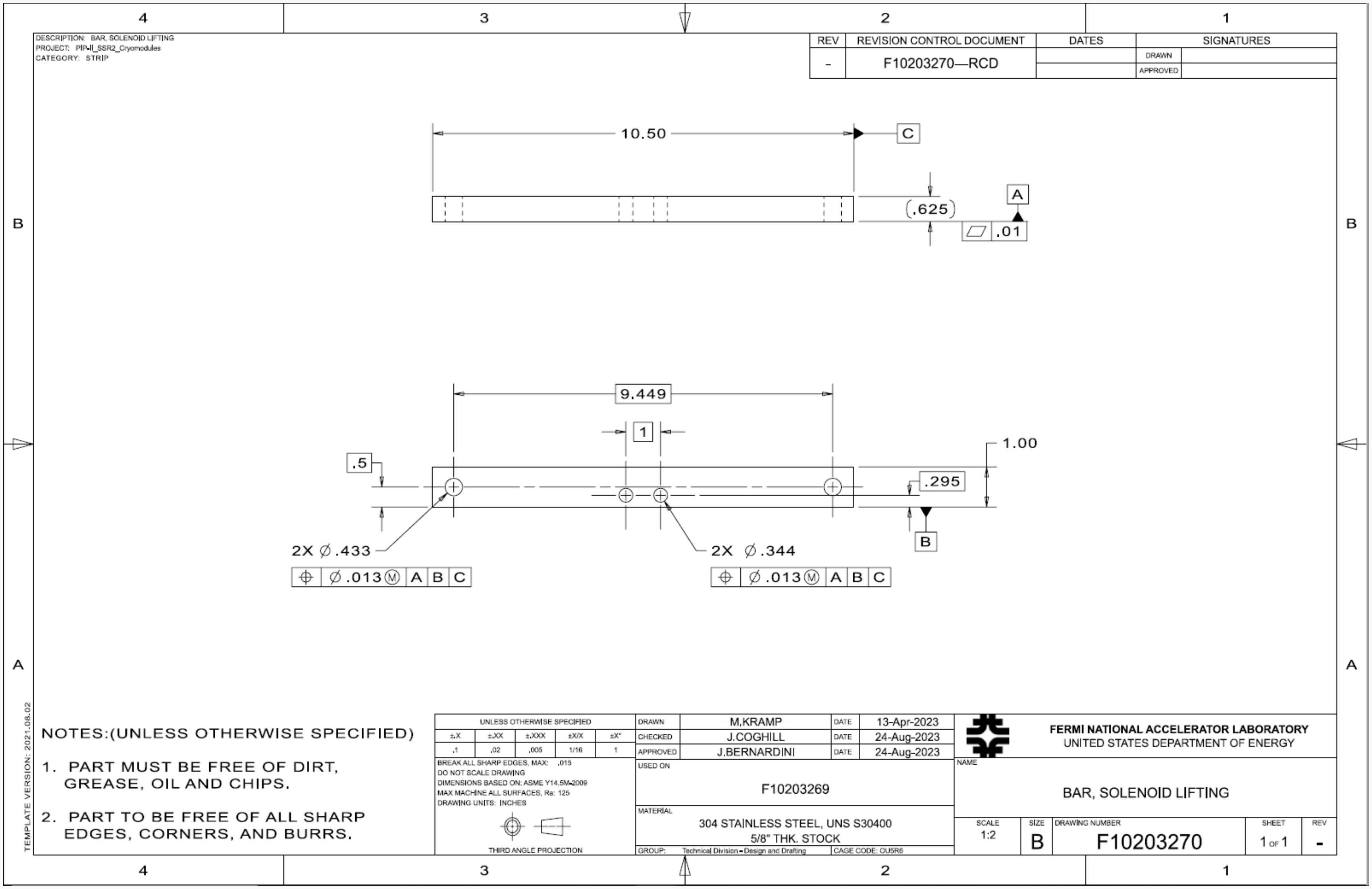


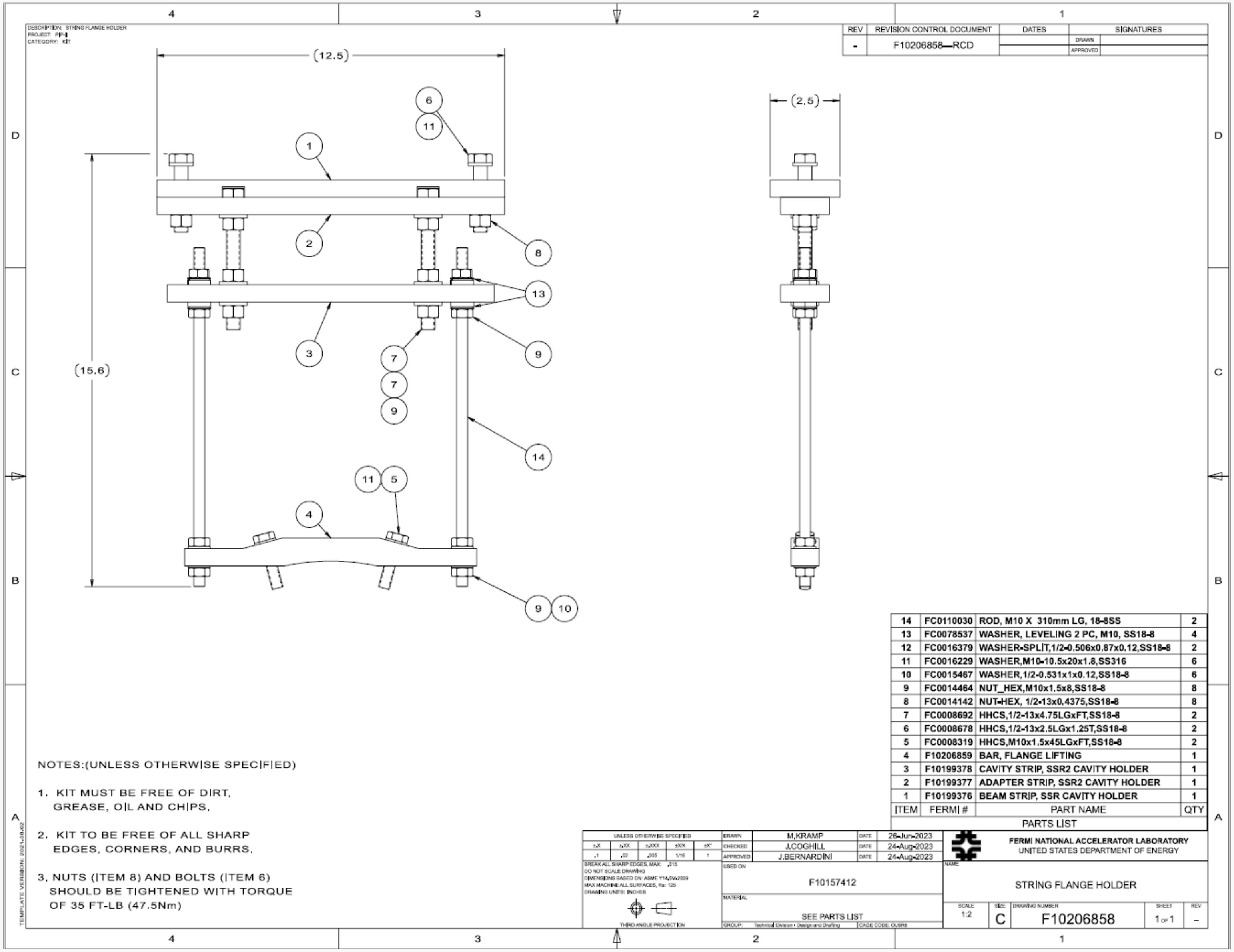
DESCRIPTION: KIT, SSR2 SOLENOID HOLDER
PROJECT: PIP-II_SSR2_Cryomodules
CATEGORY: KIT
REV
REVISION CONTROL DOCUMENT
DATES
SIGNATURES
-
F10203269—RCD
DRAWN
APPROVED
(12.5)
(2.5)
(16.2)
NOTES:(UNLESS OTHERWISE SPECIFIED)
1. KIT MUST BE FREE OF DIRT, GREASE, OIL AND CHIPS.
2. KIT TO BE FREE OF ALL SHARP EDGES, CORNERS, AND BURRS.
3. NUTS (ITEM 7) AND BOLTS (ITEM 5) SHOULD BE TIGHTENED WITH TORQUE OF 35 FT-LB (47.5Nm)
15 FC0110030 ROD, M10 X 310mm LG, 18-8SS 2
14 FC0078537 WASHER, LEVELING 2 PC, M10, SS18-8 4
13 FC0066835 W BEAM CLAMP, BG1G12, LNA SOLUTION 2
12 FC0066834 W BEAM CLAMP, BB1G12 LNA SOLUTION 2
11 FC0016379 WASHER-SPLIT,1/2-0.506x0.87x0.12,SS18-8 2
10 FC0016229 WASHER,M10-10.5x20x1.8,SS316 4
9 FC0015467 WASHER,1/2-0.531x1x0.12,SS18-8 6
8 FC0014464 NUT_HEX,M10x1.5x8,SS18-8 8
7 FC0014142 NUT-HEX, 1/2-13x0.4375,SS18-8 8
6 FC0008692 HHCS,1/2-13x4,75LGxFT,SS18-8 2
5 FC0008683 HHCS,1/2-13x3,25LGx1,25T,SS18-8 2
4 F10203270 BAR, SOLENOID LIFTING 1
3 F10199378 CAVITY STRIP, SSR2 CAVITY HOLDER 1
2 F10199377 ADAPTER STRIP, SSR2 CAVITY HOLDER 1
1 F10199376 BEAM STRIP, SSR CAVITY HOLDER 1
ITEM FERMI # PART NAME QTY
PARTS LIST
DRAWN M.KRAMP DATE 13-Apr-2023
CHECKED J.COGHILL DATE 24-Aug-2023
APPROVED J.BERNARDINI DATE 24-Aug-2023
USED ON F10157412
MATERIAL SEE PARTS LIST
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
KIT, SSR2 SOLENOID HOLDER
SCALE 1:2
SIZE C
DRAWING NUMBER F10203269
SHEET 1 OF 1
REV -
THIRD ANGLE PROJECTION



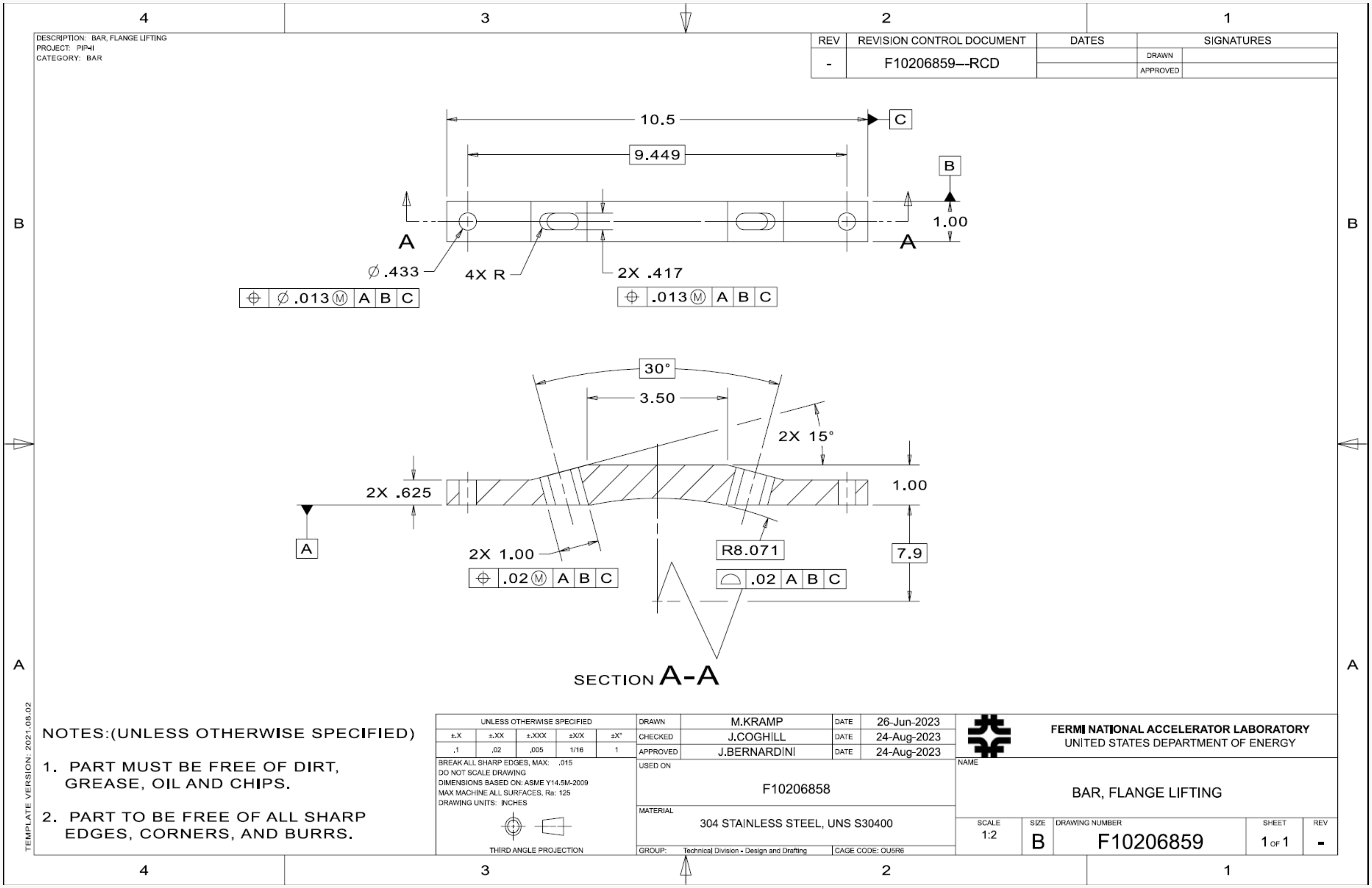
DESCRIPTION: CAVITY STRIP, SSR2 CAVITY HOLDER
PROJECT: PIP-II_SSR2_Cryomodules
CATEGORY: STRIP
REV
REVISION CONTROL DOCUMENT
DATES
SIGNATURES
-
F10199378—RCD
DRAWN
APPROVED
11.75
C
(.625)
A
.01
9.46
7
2X .984
.02 Ⓜ A B C
B
1.75
2X .433
.013 Ⓜ A B C
2X ∅.562
∅.013 Ⓜ A B C
4X R
NOTES:(UNLESS OTHERWISE SPECIFIED)
1. PART MUST BE FREE OF DIRT, GREASE, OIL AND CHIPS.
2. PART TO BE FREE OF ALL SHARP EDGES, CORNERS, AND BURRS.
UNLESS OTHERWISE SPECIFIED
±.X ±.XX ±.XXX ±X/X ±X°
.1 .02 .005 1/16 1
BREAK ALL SHARP EDGES, MAX: .015
DO NOT SCALE DRAWING
DIMENSIONS BASED ON: ASME Y14.5M-2009
MAX MACHINE ALL SURFACES, Ra: 125
DRAWING UNITS: INCHES
THIRD ANGLE PROJECTION
DRAWN M.KRAMP DATE 13-Apr-2023
CHECKED J.COGHILL DATE 24-Aug-2023
APPROVED J.BERNARDINI DATE 24-Aug-2023
USED ON
F10199375
MATERIAL
304 STAINLESS STEEL, UNS S30400
5/8" THK. STOCK
GROUP: Technical Division - Design and Drafting
CAGE CODE: 0U5R6
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
NAME
CAVITY STRIP, SSR2 CAVITY HOLDER
SCALE 1:2
SIZE B
DRAWING NUMBER F10199378
SHEET 1 OF 1
REV -
TEMPLATE VERSION: 2021.08.02

PIP-II	Engineering Note	
	Document Title:	Lifter Holders of SSR2 Cryomodule Cavity String Assembly
	Document Number:	ED rev. -

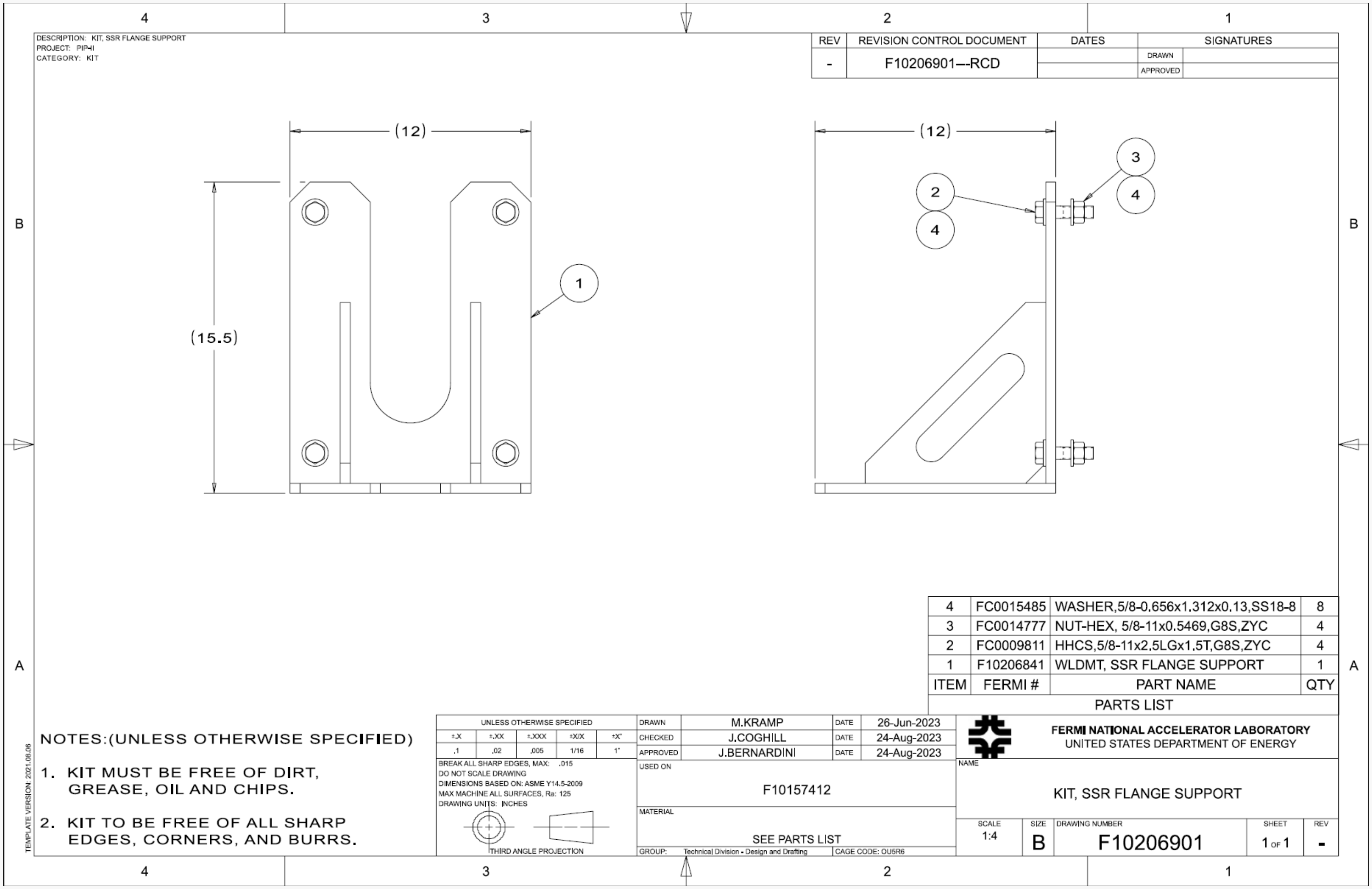




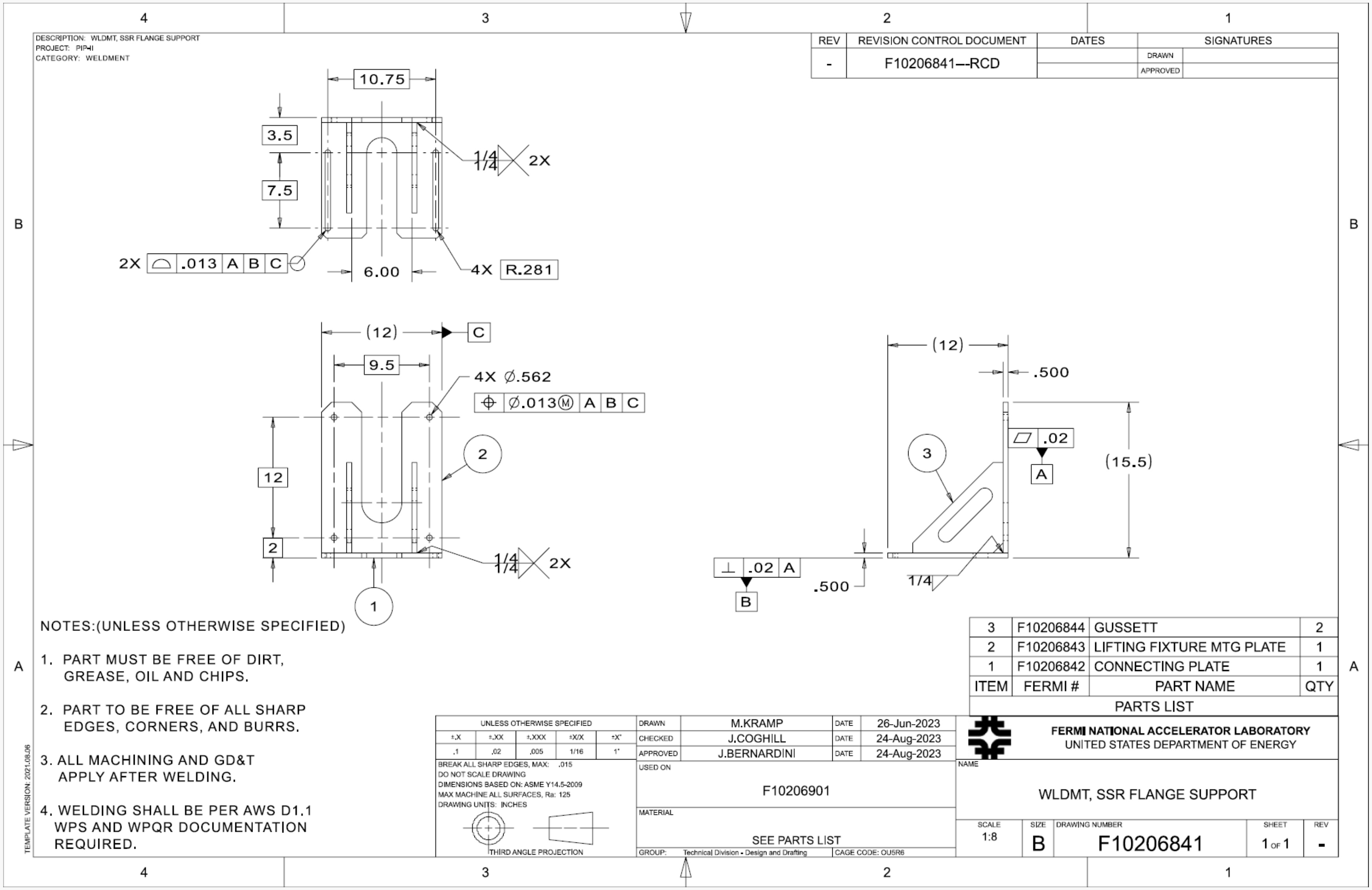
DESCRIPTION: STRING FLANGE HOLDER
PROJECT: PIP-II
CATEGORY: KIT
REV
REVISION CONTROL DOCUMENT
DATES
SIGNATURES
-
F10206858—RCD
DRAWN
APPROVED
(12.5)
(15.6)
(2.5)
1
2
3
4
5
6
7
8
9
10
11
13
14
NOTES:(UNLESS OTHERWISE SPECIFIED)
1. KIT MUST BE FREE OF DIRT, GREASE, OIL AND CHIPS.
2. KIT TO BE FREE OF ALL SHARP EDGES, CORNERS, AND BURRS.
3. NUTS (ITEM 8) AND BOLTS (ITEM 6) SHOULD BE TIGHTENED WITH TORQUE OF 35 FT-LB (47.5Nm)
14 | FC0110030 | ROD, M10 X 310mm LG, 18-8SS | 2
13 | FC0078537 | WASHER, LEVELING 2 PC, M10, SS18-8 | 4
12 | FC0016379 | WASHER-SPLIT,1/2-0,506x0,87x0,12,SS18-8 | 2
11 | FC0016229 | WASHER,M10-10.5x20x1.8,SS316 | 6
10 | FC0015467 | WASHER,1/2-0.531x1x0.12,SS18-8 | 6
9 | FC0014464 | NUT_HEX,M10x1.5x8,SS18-8 | 8
8 | FC0014142 | NUT-HEX, 1/2-13x0,4375,SS18-8 | 8
7 | FC0008692 | HHCS,1/2-13x4.75LGxFT,SS18-8 | 2
6 | FC0008678 | HHCS,1/2-13x2.5LGx1.25T,SS18-8 | 2
5 | FC0008319 | HHCS,M10x1,5x45LGxFT,SS18-8 | 2
4 | F10206859 | BAR, FLANGE LIFTING | 1
3 | F10199378 | CAVITY STRIP, SSR2 CAVITY HOLDER | 1
2 | F10199377 | ADAPTER STRIP, SSR2 CAVITY HOLDER | 1
1 | F10199376 | BEAM STRIP, SSR CAVITY HOLDER | 1
ITEM | FERMI # | PART NAME | QTY
PARTS LIST
UNLESS OTHERWISE SPECIFIED
±.X ±.XX ±.XXX ±X/X ±X°
.1 .02 .005 1/16 1
BREAK ALL SHARP EDGES, MAX: .015
DO NOT SCALE DRAWING
DIMENSIONS BASED ON: ASME Y14.5M-2009
MAX MACHINE ALL SURFACES, Ra: 125
DRAWING UNITS: INCHES
THIRD ANGLE PROJECTION
DRAWN M.KRAMP DATE 26-Jun-2023
CHECKED J.COGHILL DATE 24-Aug-2023
APPROVED J.BERNARDINI DATE 24-Aug-2023
USED ON
F10157412
MATERIAL
SEE PARTS LIST
GROUP: Technical Division • Design and Drafting
CAGE CODE: 0U8R6
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
NAME
STRING FLANGE HOLDER
SCALE 1:2
SIZE C
DRAWING NUMBER F10206858
SHEET 1 OF 1
REV -



DESCRIPTION: BAR, FLANGE LIFTING
PROJECT: PIP-II
CATEGORY: BAR
REV
REVISION CONTROL DOCUMENT
DATES
SIGNATURES
-
F10206859---RCD
DRAWN
APPROVED
10.5
9.449
C
B
1.00
A
A
∅.433
4X R
2X .417
∅.013 Ⓜ A B C
.013 Ⓜ A B C
30°
3.50
2X 15°
2X .625
1.00
A
2X 1.00
.02 Ⓜ A B C
R8.071
.02 A B C
7.9
SECTION A-A
NOTES:(UNLESS OTHERWISE SPECIFIED)
1. PART MUST BE FREE OF DIRT, GREASE, OIL AND CHIPS.
2. PART TO BE FREE OF ALL SHARP EDGES, CORNERS, AND BURRS.
UNLESS OTHERWISE SPECIFIED
±.X ±.XX ±.XXX ±X/X ±X°
.1 .02 .005 1/16 1
BREAK ALL SHARP EDGES, MAX: .015
DO NOT SCALE DRAWING
DIMENSIONS BASED ON: ASME Y14.5M-2009
MAX MACHINE ALL SURFACES, Ra: 125
DRAWING UNITS: INCHES
THIRD ANGLE PROJECTION
DRAWN M.KRAMP DATE 26-Jun-2023
CHECKED J.COGHILL DATE 24-Aug-2023
APPROVED J.BERNARDINI DATE 24-Aug-2023
USED ON
F10206858
MATERIAL
304 STAINLESS STEEL, UNS S30400
GROUP: Technical Division - Design and Drafting
CAGE CODE: OU5R6
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
NAME
BAR, FLANGE LIFTING
SCALE 1:2
SIZE B
DRAWING NUMBER F10206859
SHEET 1 OF 1
REV -
TEMPLATE VERSION: 2021.08.02

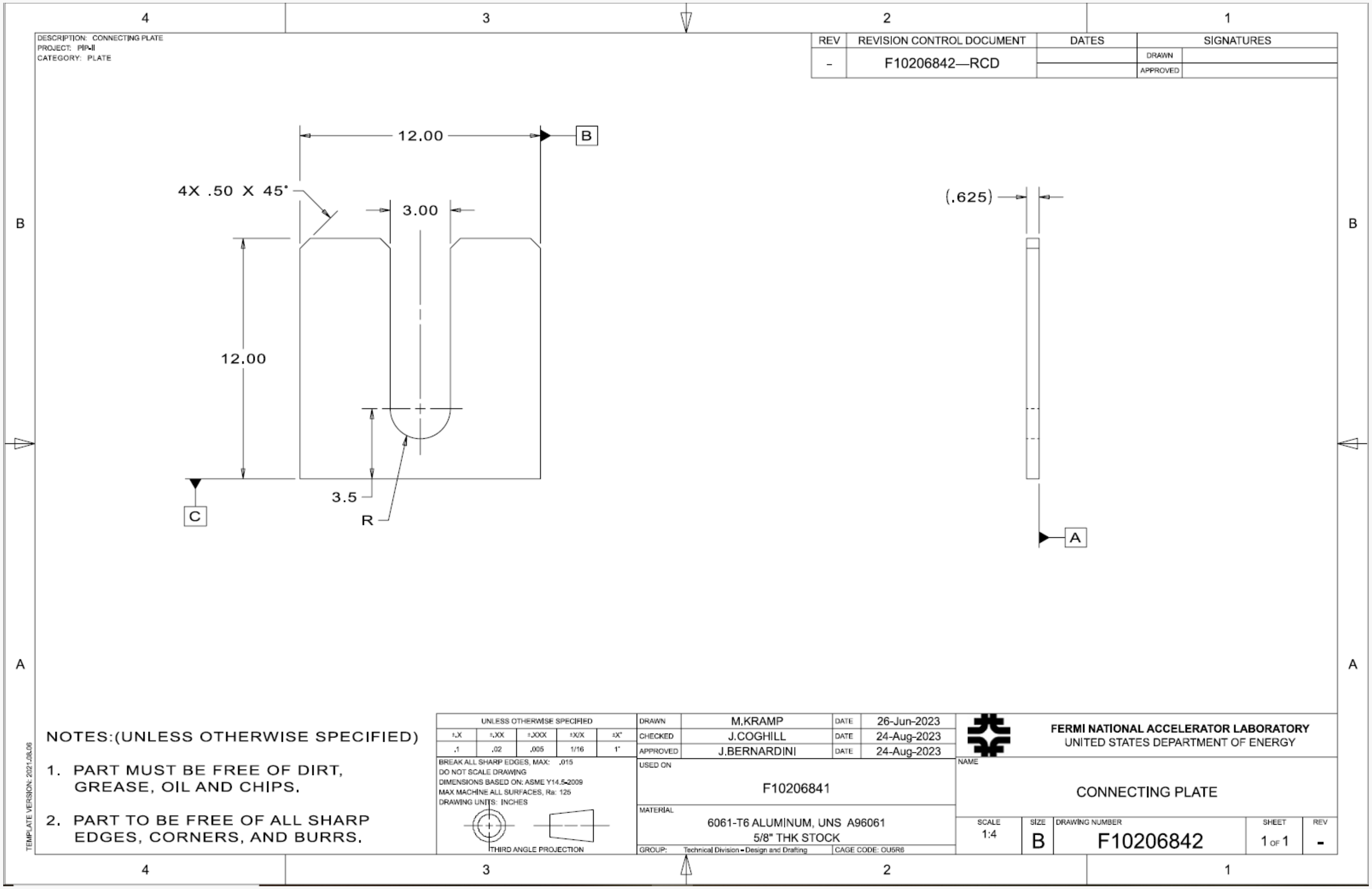


DESCRIPTION: KIT, SSR FLANGE SUPPORT
PROJECT: PIP-II
CATEGORY: KIT
REV
REVISION CONTROL DOCUMENT
DATES
SIGNATURES
-
F10206901---RCD
DRAWN
APPROVED
(12)
(15.5)
1
2
3
4
4 FC0015485 WASHER,5/8-0.656x1.312x0.13,SS18-8 8
3 FC0014777 NUT-HEX, 5/8-11x0.5469,G8S,ZYC 4
2 FC0009811 HHCS,5/8-11x2.5LGx1.5T,G8S,ZYC 4
1 F10206841 WLDMT, SSR FLANGE SUPPORT 1
ITEM FERMI # PART NAME QTY
PARTS LIST
NOTES:(UNLESS OTHERWISE SPECIFIED)
1. KIT MUST BE FREE OF DIRT, GREASE, OIL AND CHIPS.
2. KIT TO BE FREE OF ALL SHARP EDGES, CORNERS, AND BURRS.
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES, MAX: .015
DO NOT SCALE DRAWING
DIMENSIONS BASED ON: ASME Y14.5-2009
MAX MACHINE ALL SURFACES, Ra: 125
DRAWING UNITS: INCHES
THIRD ANGLE PROJECTION
DRAWN M.KRAMP DATE 26-Jun-2023
CHECKED J.COGHILL DATE 24-Aug-2023
APPROVED J.BERNARDINI DATE 24-Aug-2023
USED ON F10157412
MATERIAL SEE PARTS LIST
GROUP: Technical Division - Design and Drafting
CAGE CODE: OU5R6
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
NAME KIT, SSR FLANGE SUPPORT
SCALE 1:4
SIZE B
DRAWING NUMBER F10206901
SHEET 1 OF 1
REV -
TEMPLATE VERSION: 2021.08.06

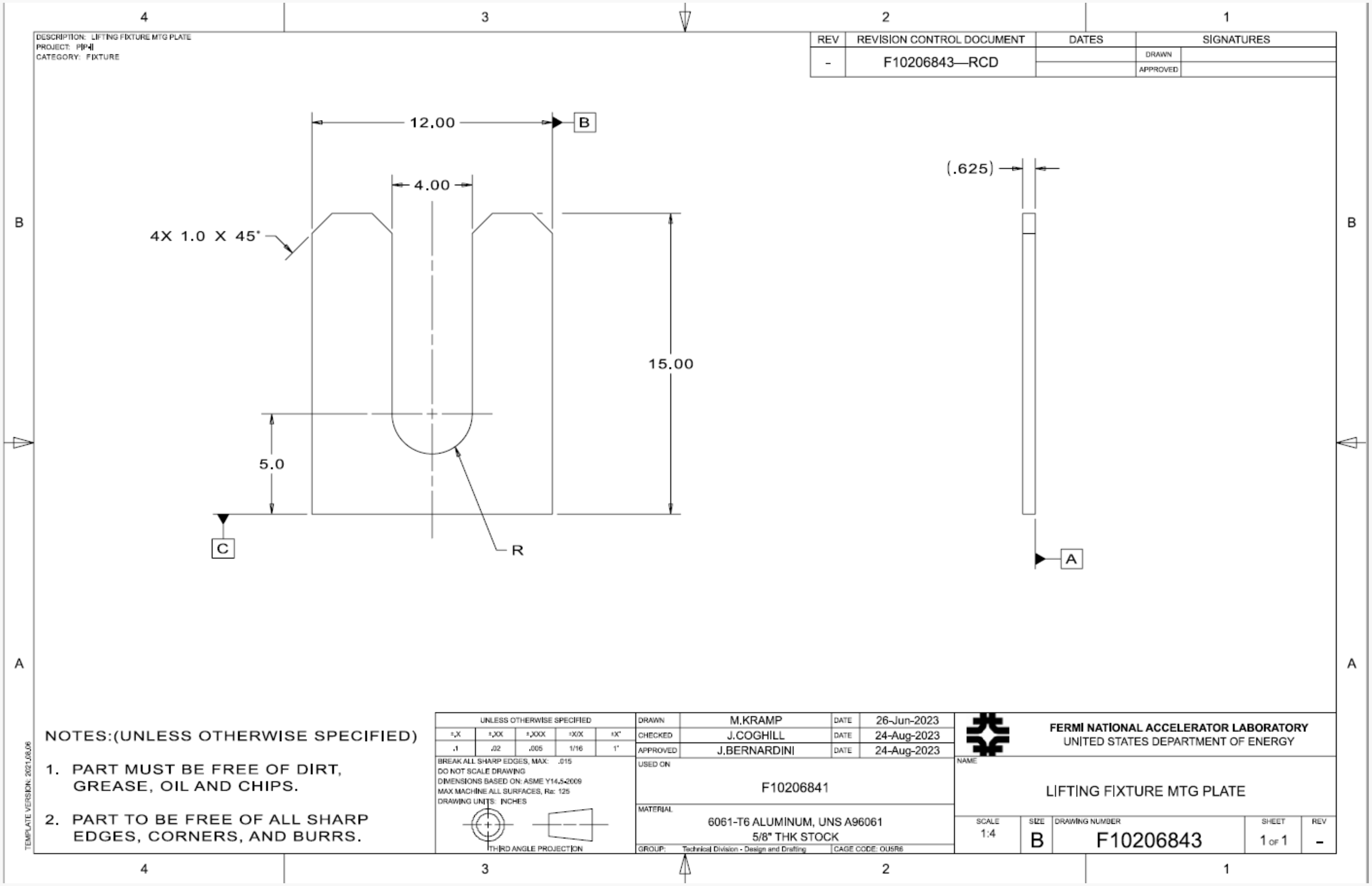


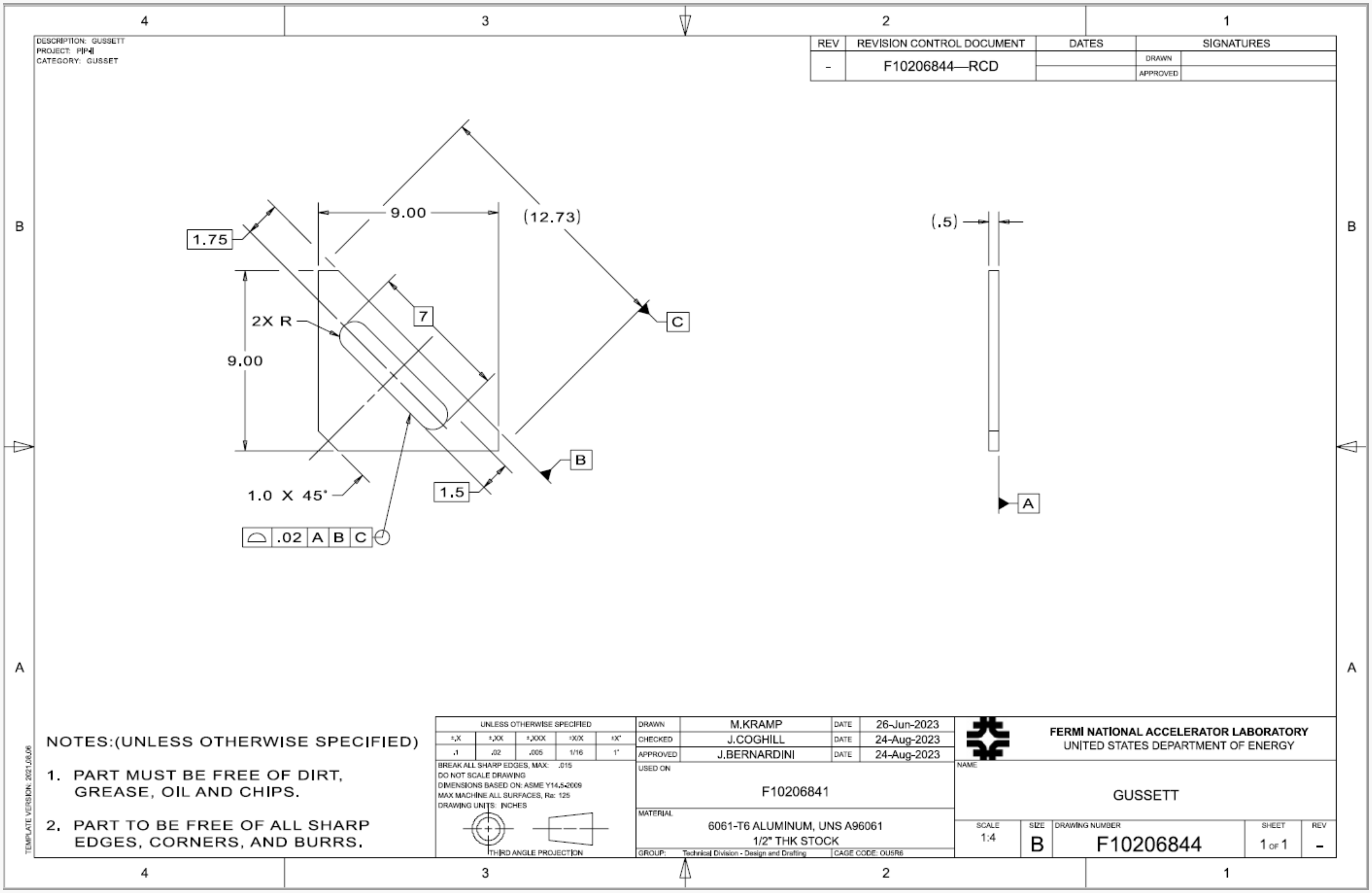
DESCRIPTION: WLDMT, SSR FLANGE SUPPORT
PROJECT: PIP-II
CATEGORY: WELDMENT
REV
REVISION CONTROL DOCUMENT
DATES
SIGNATURES
-
F10206841--RCD
DRAWN
APPROVED
10.75
3.5
7.5
1/4
2X
.013 A B C
6.00
4X R.281
(12)
C
9.5
4X ∅.562
∅.013Ⓜ A B C
12
2
1/4
2X
.500
.02
A
(15.5)
.02 A
B
.500
1/4
NOTES:(UNLESS OTHERWISE SPECIFIED)
1. PART MUST BE FREE OF DIRT, GREASE, OIL AND CHIPS.
2. PART TO BE FREE OF ALL SHARP EDGES, CORNERS, AND BURRS.
3. ALL MACHINING AND GD&T APPLY AFTER WELDING.
4. WELDING SHALL BE PER AWS D1.1 WPS AND WPQR DOCUMENTATION REQUIRED.
3 F10206844 GUSSETT 2
2 F10206843 LIFTING FIXTURE MTG PLATE 1
1 F10206842 CONNECTING PLATE 1
ITEM FERMI # PART NAME QTY
PARTS LIST
UNLESS OTHERWISE SPECIFIED
±.X ±.XX ±.XXX ±X/X ±X°
.1 .02 .005 1/16 1°
BREAK ALL SHARP EDGES, MAX: .015
DO NOT SCALE DRAWING
DIMENSIONS BASED ON: ASME Y14.5-2009
MAX MACHINE ALL SURFACES, Ra: 125
DRAWING UNITS: INCHES
THIRD ANGLE PROJECTION
DRAWN M.KRAMP DATE 26-Jun-2023
CHECKED J.COGHILL DATE 24-Aug-2023
APPROVED J.BERNARDINI DATE 24-Aug-2023
USED ON
F10206901
MATERIAL
SEE PARTS LIST
GROUP: Technical Division - Design and Drafting
CAGE CODE: OU5R6
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
NAME
WLDMT, SSR FLANGE SUPPORT
SCALE 1:8
SIZE B
DRAWING NUMBER F10206841
SHEET 1 OF 1
REV -
TEMPLATE VERSION: 2021.08.06

PIP-II	Engineering Note	
	Document Title:	Lifter Holders of SSR2 Cryomodule Cavity String Assembly
	Document Number:	ED rev. -



PIP-II	Engineering Note	
	Document Title:	Lifter Holders of SSR2 Cryomodule Cavity String Assembly
	Document Number:	ED rev. -





DESCRIPTION: GUSSETT
PROJECT: PIP-II
CATEGORY: GUSSET
REV
REVISION CONTROL DOCUMENT
DATES
SIGNATURES
-
F10206844—RCD
DRAWN
APPROVED
9.00
(12.73)
1.75
7
2X R
9.00
C
B
1.0 X 45°
1.5
.02 A B C
(.5)
A
NOTES:(UNLESS OTHERWISE SPECIFIED)
1. PART MUST BE FREE OF DIRT, GREASE, OIL AND CHIPS.
2. PART TO BE FREE OF ALL SHARP EDGES, CORNERS, AND BURRS.
UNLESS OTHERWISE SPECIFIED
BREAK ALL SHARP EDGES, MAX: .015
DO NOT SCALE DRAWING
DIMENSIONS BASED ON: ASME Y14.5-2009
MAX MACHINE ALL SURFACES, Ra: 125
DRAWING UNITS: INCHES
THIRD ANGLE PROJECTION
DRAWN M.KRAMP DATE 26-Jun-2023
CHECKED J.COGHILL DATE 24-Aug-2023
APPROVED J.BERNARDINI DATE 24-Aug-2023
USED ON
F10206841
MATERIAL
6061-T6 ALUMINUM, UNS A96061
1/2" THK STOCK
GROUP: Technical Division - Design and Drafting
CAGE CODE: 0U5R6
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
NAME
GUSSETT
SCALE 1:4
SIZE B
DRAWING NUMBER F10206844
SHEET 1 OF 1
REV -

https://www.lnasolutions.com/products/beamclamp-type-ba-bb-flange-clamp/

BeamClamp Type BA + BB Flange Clamp

Tail Length	Product Code	Product Code	A Bolt Dia	B	C	D1	D2	E	Width	Torque (ft lb)	Tensile SWL (lbs) (per bolt)	Friction SWL (lbs) (per 4 bolts)
Short	BA1G10	BB1G10	3/8	1/2	13/16	1/4	7/16	1/8	1	14	562	X
	BA1G12	BB1G12	1/2	5/8	1	5/16	1/2	3/16	1-1/8	51	1,293	292
	BA1G16	BB1G16	5/8	11/16	1-1/4	3/8	11/16	1/4	1-7/16	109	2,219	877
	BA1G20	BB1G20	3/4	13/16	1-3/8	7/16	13/16	5/16	1-3/4	210	3,703	2,473
	BA1G24	BB1G24	1	1	1-15/16	1/2	1	3/8	2-1/8	355	4,743	4,047

Table 3 Beam Clamp Measurements and Specification

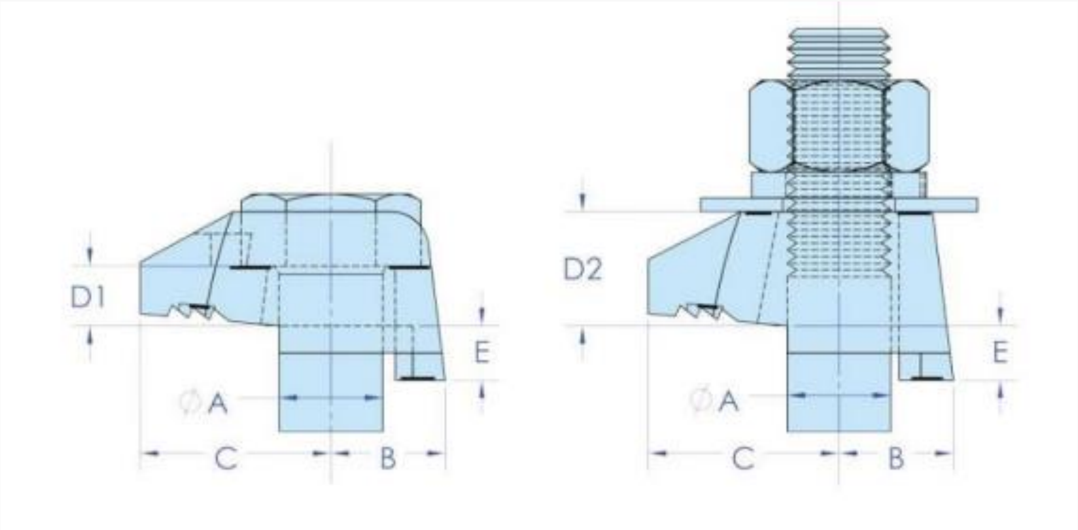


Figure 18 Beam Clamp