Fermilab

Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

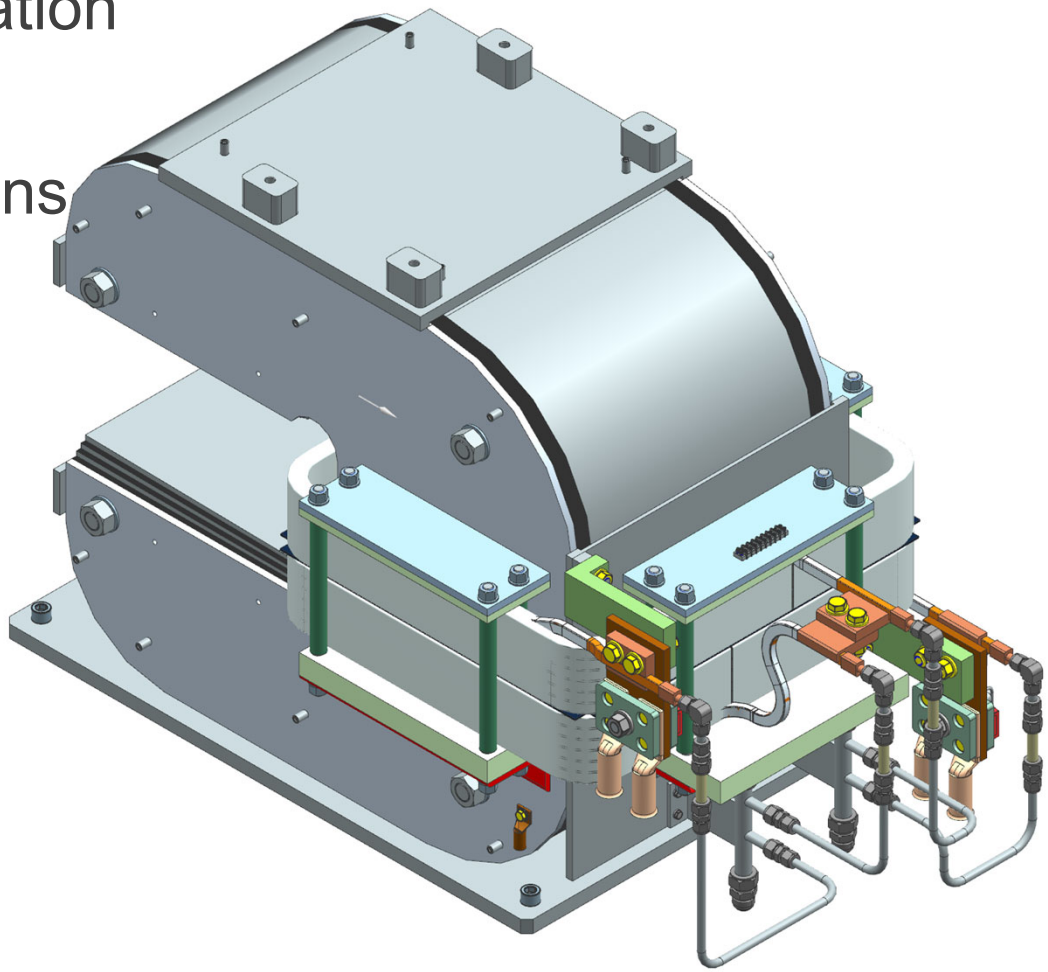
STS Pulsed Dipole Engineering Design Review
Mechanical Design

Sergey Cheban, PhD

04-16-24

OUTLINE

- Mechanical Design
- Compliance with Specification
- Tooling & Handling
- Previous Recommendations
- Summary



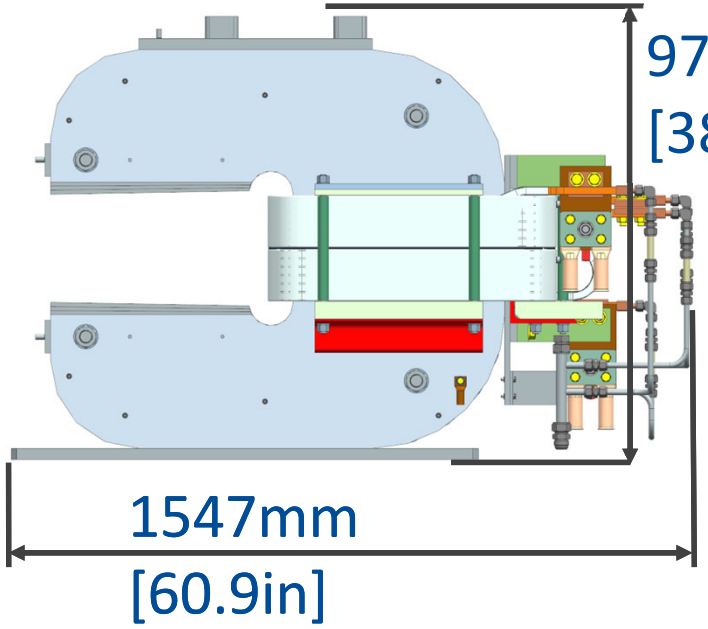
COMPLIANCE WITH SPECIFICATION

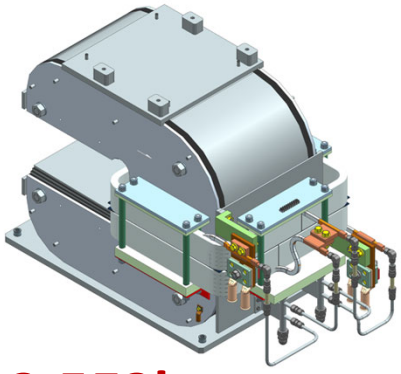
DOCUMENT NUMBER - REV	DISCIPLINE	TYPE
S02040000-SRD10000 - 1	Systems Requirement Document	Document
LEGACY DOCUMENT NUMBER	PUBLISHED ON / REVISION / STATUS	
	02/09/2024 / 1 / Published	

Table 1	Extraction Magnet Common Requirements	
ID	Slide#	Requirement
S02.04-R002	8	Max current density
S02.04-R004	9	Max temperature rise
S02.04-R005	9	Water flow velocity
S02.04-R006	9	Water pressure differential
S02.04-R007	10	Magnet temperature switch
S02.04-R008	10	Magnet temperature switch
S02.04-R009	10	Temperature switch trip point
S02.04-R010	11	Magnet water manifold
S02.04-R012	6	Magnet assembly design
S02.04-R014	13	External fiducials
S02.04-R015	9	Hydrostatic (water) test pressure
S02.04-R016	8	Insulation damage or breakdown
S02.04-R018	12	Terminal blocks or flags
S02.04-R020	14	Magnet support
S02.04-R021	13	Core shall be grounded
S02.04-R023	14	Interface for supporting the vacuum chamber
S02.04-R024	8, 15	Coil from a single length of conductor.
S02.04-R025	8, 15	Specification for Radiation Resistant Fiberglass/Epoxy
S02.04-R026	12	Magnet electrical mating surfaces
S02.04-R027	11	Magnet assembly wetted parts
S02.04-R028	11	Water connection ports
S02.04-R029	11	Water hoses
S02.04-R063	5	Transport loads.
S02.04-R064	5	WB-40 (or smaller) truck.
S02.04-R068	16	Lifting features

Table 2	Pulsed Dipole Requirements	
ID	Slide#	Requirement
S02.04-R041	5	Envelope size
S02.04-R042	7	Magnet core aperture
S02.04-R043	6	Restrained to prevent coil motion
S02.04-R048	12	Radiation Safety Hold

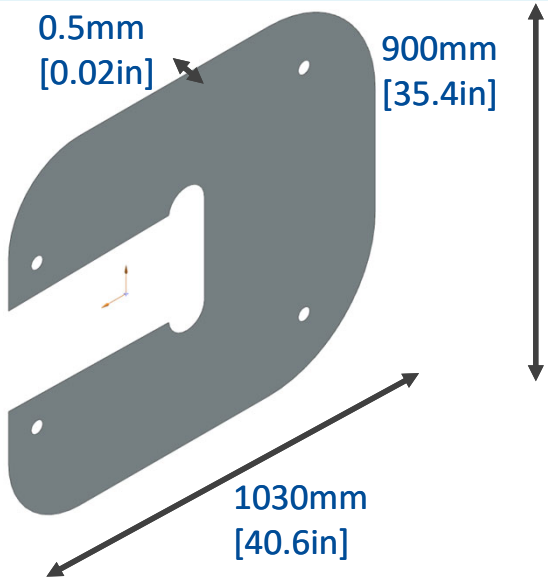
PULSED DIPOLE MAGNET ASSEMBLY, ORNL STS



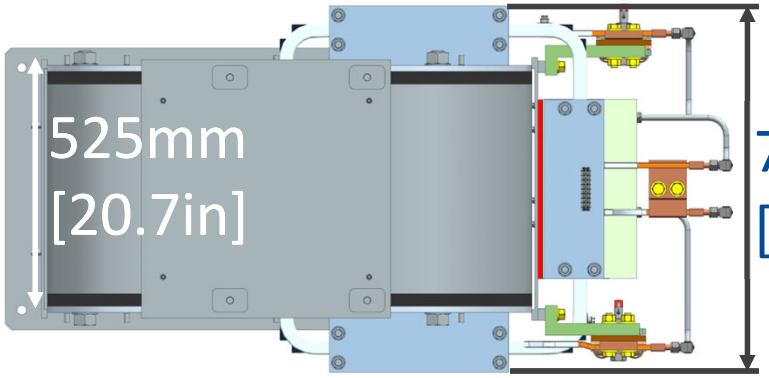


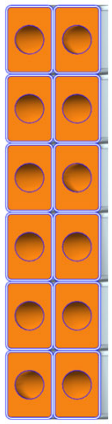
M~3.5E3kg
[7.7E3lb]

M=2.8E3kg [6.3E3lb] M15
M=90kg [200lb] COPPER

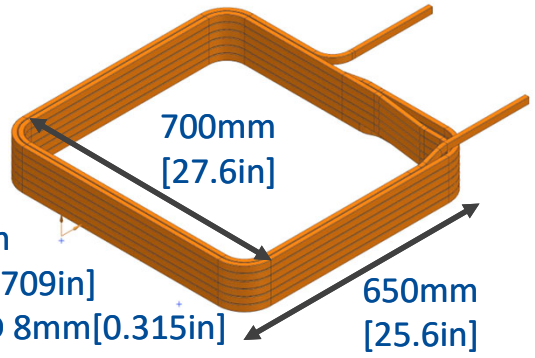


M=2.8kg [6.3lb] ASTM A677 NON-ORIENTED ELECTRICAL STEEL, M-15





6x2 turns



12x18mm
[0.472x0.709in]
Cooling D 8mm[0.315in]

M=45kg [100lb] OXYGEN FREE COPPER

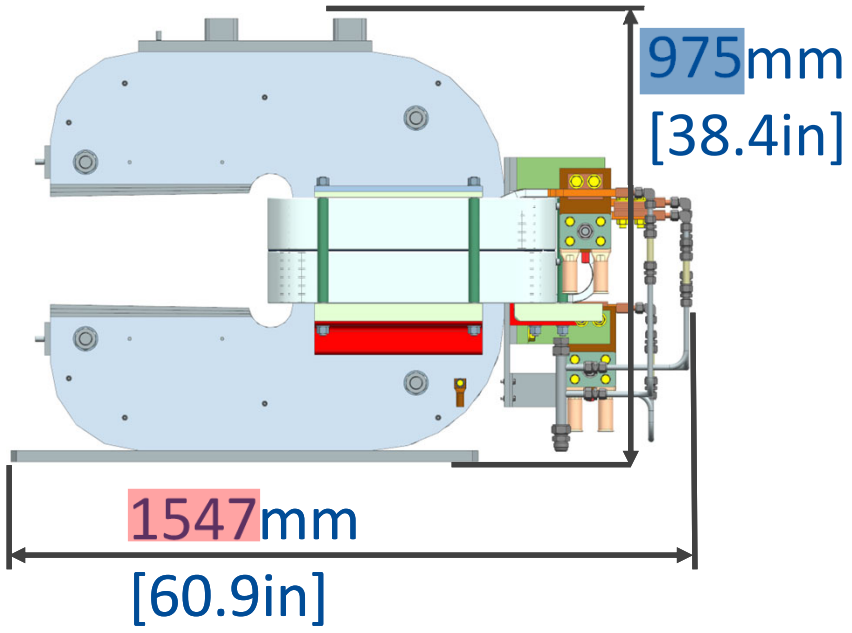
COIL x 2

Fermilab

PULSED DIPOLE MAGNET ASSEMBLY

Table 2 Pulsed Dipole Requirements

ID	Requirement	Traceability
S02.04-R041	The Pulsed Dipole magnet assembly shall fit into a volume such that X ≤ 1.55, Y ≤ 1.00, Z ≤ 0.80 meters. Discussion: To avoid having to move any magnets in the RTBT. X is width, Y is height, and Z is along beam axis.	S02-R007
S02.04-R063	Extraction magnet assembly packaging shall be designed to protect the magnet from damage due to transport loads.	Design requirement
S02.04-R064	Extraction magnet assemblies shall be transportable in a WB-40 (or smaller) truck. Discussion: The STS access road design basis is a WB-40 truck.	Design requirement



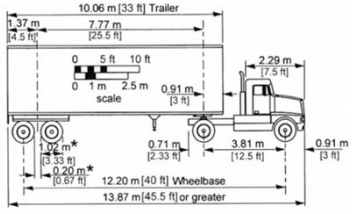
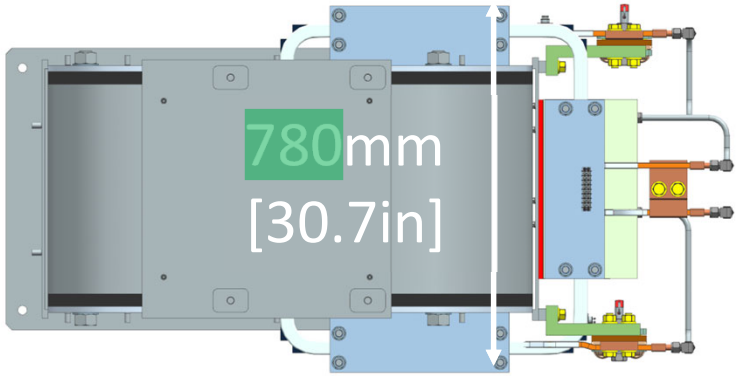


Figure 6. Dimensions of intermediate semitrailer (WB-12 [WB-40]) design vehicle in current Green Book (1).

M~3.5E3kg
[7.7E3lb]

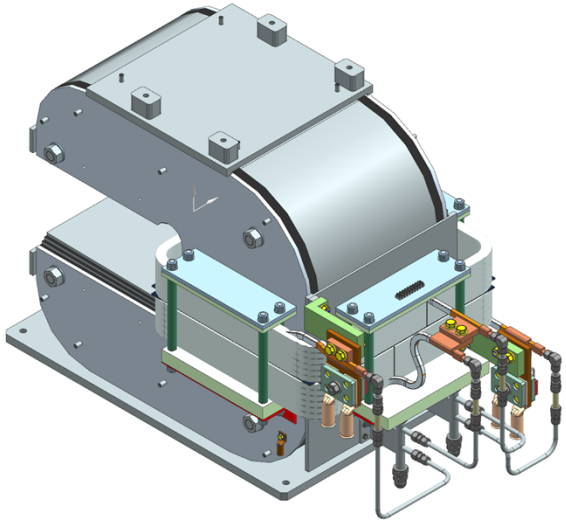


PUP TRAILER

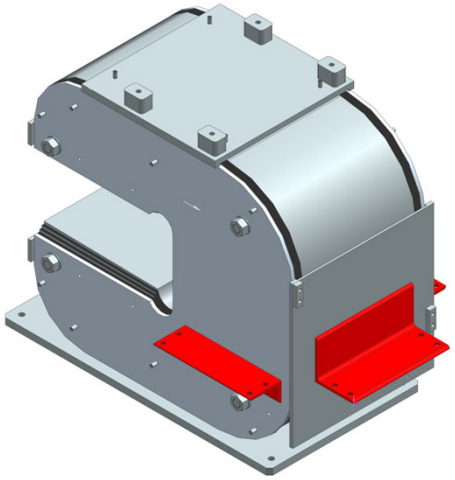
TYPICAL CARGO MAXIMUMS	
Cargo Width	98” - 100”
Cargo Height	95”
Cargo Weight	22,000 lbs
Pallet Count	14

MAGNET ASSEMBLY

S02.04-R012	The extraction magnet assembly design should consist of subassemblies if required for: a) Installation or replacement of magnet coils b) Installation or replacement of magnet vacuum chamber **Discussion:** This requirement has two objectives: to facilitate initial installation and alignment of the magnet, and to allow for in situ repair/replacement of the magnet coils or vacuum chamber while minimizing the need for realignment of the magnet.	S02-R004 S02-R006



F10203414--;1-PULSED DIPOLE MAGNET ASSEMBLY, ORNL STS

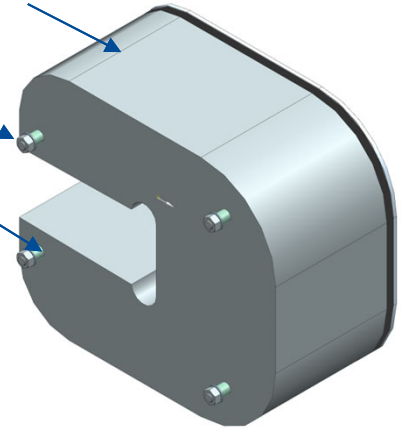


F10182790--;1-CORE ASSEMBLY, PULSED DIPOLE MAGNET, ORNL STS

F10182786--;1-LAMINATION, PULSED DIPOLE MAGNET, ORNL STS

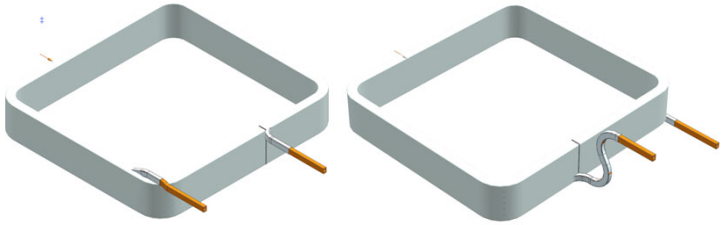
FC0072983-A;1-THREADED ROD; M30x3.5MLG; CLASS 12.9 HIGH STRENGTH STEEL

FC0116357--;1-TUBE, 1.5"OD, 1.25"ID X 48"LG, G-10



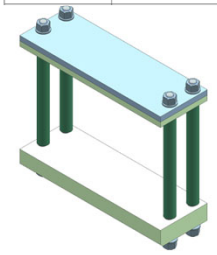
F10196517--;1-END PLATE, RH, CORE ASSEMBLY, PULSED DIPOLE MAGNET, ORNL STS

S02.04-R043	The Pulsed Dipole magnet coil shall be restrained to prevent coil motion during ramping. **Discussion:** Intent is to minimize opportunity for coils to develop a short.	S02-R004

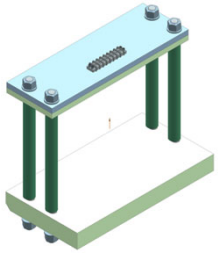


F10182796--;1-COIL ASSEMBLY, UPPER, PULSED DIPOLE MAGNET, ORNL STS

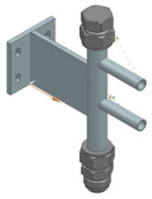
F10182797--;1-COIL ASSEMBLY, LOWER, PULSED DIPOLE MAGNET, ORNL STS



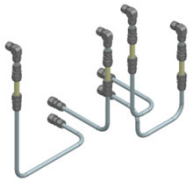
F10187024--;1-ASSEMBLY, SIDE COIL SUPPORT, PULSED DIPOLE MAGNET, ORNL STS



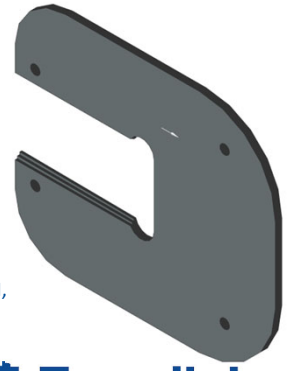
F10189029--;1-ASSEMBLY, LEAD SIDE COIL SUPPORT, PULSED DIPOLE MAGNET, ORNL STS



F10189375--;1-MANIFOLD WELDMENT, PULSED DIPOLE MAGNET, ORNL STS



F10189375--;1-MANIFOLD WELDMENT, PULSED DIPOLE MAGNET, ORNL STS



F10183600--;1-END PACK, RH, CORE ASSEMBLY, PULSED DIPOLE MAGNET, ORNL STS

CORE ASSEMBLY

Table 2 Pulsed Dipole Requirements

S02.04-R042	The Pulsed Dipole magnet core shall have a vertical aperture ≥ 24.73 cm (9.74 in) and a horizontal aperture ≥ 42.5 cm (16.7 in) and ≤ 50 cm (19.7 in). **Discussion:** The vertical aperture must accommodate a vacuum chamber with a max OD of 241.3 + 3 mm of clearance on the radius = 247.3 mm. The preferred method of installing the vacuum chamber is sliding it in from the side. The horizontal aperture must accommodate that same chamber offset by 28 mm toward the coil. Each coil, with insulation, will be 30mm x 118mm. The gap between the core and the surface of the insulation will be 30mm.	S02-R006 S02-R007 S02-R009

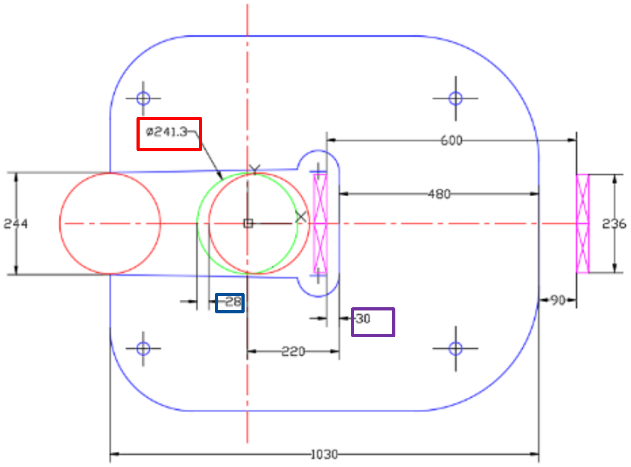


Fig. 5. Beampipe in the center (green), shifted 28 mm to the coil and at the pole edge (red).

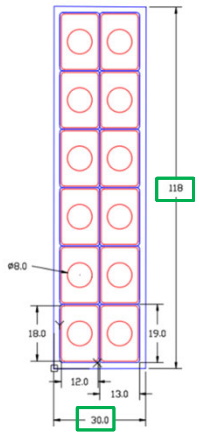


Fig. 4. Coil dimensions. Conductor 12 x 18 mm, hole dia. 8 mm, 12 turns, 2 coils.

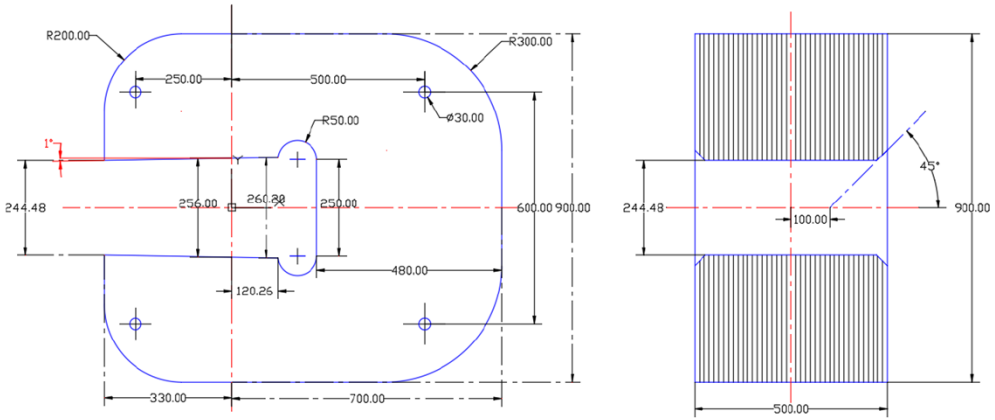


Fig. 2. Magnet core dimensions.

COIL

- Two identical coils (rotated 180). Leads are different
- Turn electrical insulation 0.5mm. Coil ground insulation 2mm

S02.04-R002	Water-cooled extraction magnet coils should be designed for a current density < 450 Amps/cm^2. The current density shall not exceed 1000 Amps/cm^2. **Discussion:** *Design Criteria Ring Magnet Systems* [1] recommends a current density < 450 amps/cm^2 to reduce the resistive energy loss in the coils and keep the voltage drop across the magnets as low as possible. This will reduce the possibility of turn-to-turn shorts occurring in the coil should the insulation be damaged by radiation. The low current density will also reduce the resistive heat loss in the magnet system.	S02-R004

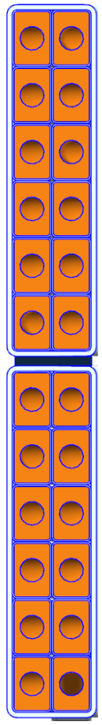
I [A]	S [mm^2]	I/S [A/m^2]	I/S [A/cm^2]
660	1.65E-04	4.00E+06	400
1606	1.65E-04	9.73E+06	973

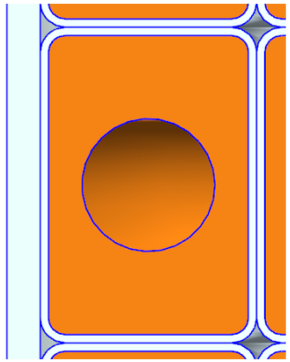
S02.04-R024	Each extraction magnet coil shall be made from a single length of conductor. **Discussion:** This is to avoid splices inside the coil.	S02-R004
S02.04-R025	The water-cooled extraction magnet coils shall meet the requirements of *Specification for Radiation Resistant Fiberglass/Epoxy Insulated Magnet Coils* [4]. Discussion: This includes silver plating, hydrostatic test to 300 psi, turn-to-turn insulation test.	S02-R004

4. 105030100-TS0001-R0, *Specification for Radiation Resistant Fiberglass/Epoxy Insulated Magnet Coils*

S02.04-R016	Unless otherwise stated, the assembled extraction magnet shall withstand 1000 V DC for one minute between the coil leads and the magnet core without evidence of insulation damage or breakdown, or leakage current > 5 µA.	S02-R004

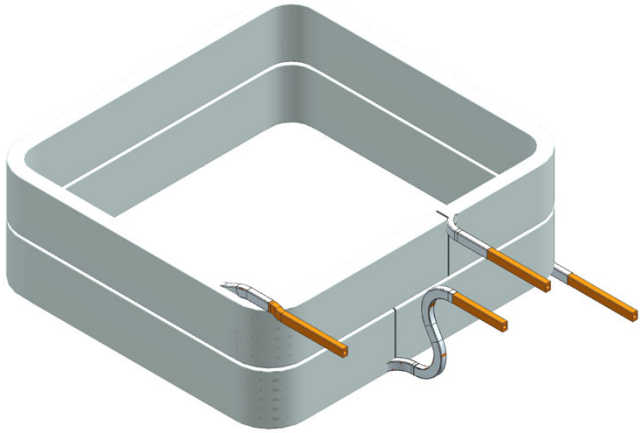
6x2 turns



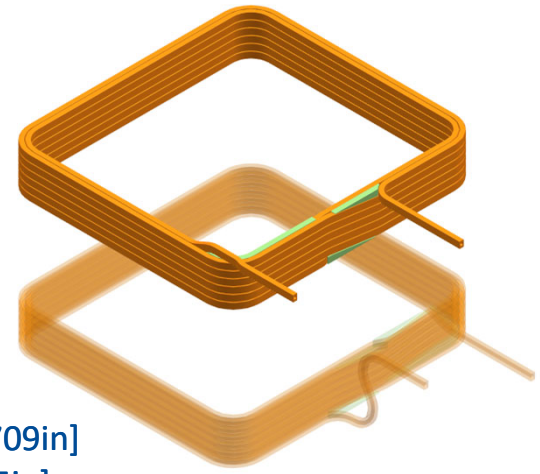


12x18mm [0.472x0.709in]
Cooling D 8mm[0.315in]

F10182796--;1-COIL ASSEMBLY, UPPER, PULSED DIPOLE MAGNET, ORNL STS



F10182797--;1-COIL ASSEMBLY, LOWER, PULSED DIPOLE MAGNET, ORNL STS



COOLING PARAMETRS

Table 1 Extraction Magnet Common Requirements

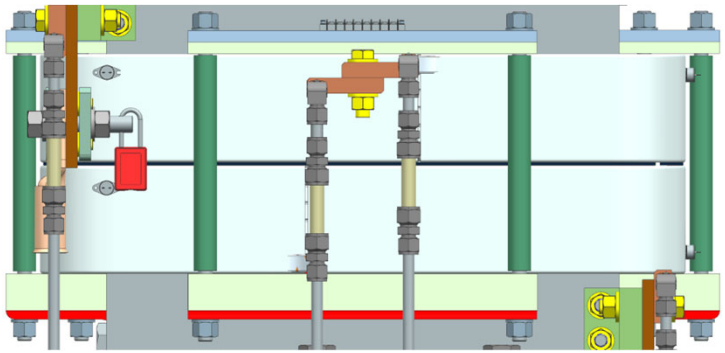
ID	Requirement	Traceability
S02.04-R004	Water-cooled extraction magnet coils should be designed to have a temperature rise < 20° C (36° F) at the maximum power supply current with an inlet water temperature between 29.4° C (85° F) and 35.0° C (95° F). Discussion: Desired maximum temperature rise is 11-14° C (20-25° F)	Design Requirement
S02.04-R005	Water-cooled extraction magnet coils should be designed for a water flow velocity < 2 m/s (6.56 ft/s). The water flow velocity shall not exceed 2.4 m/s (8 ft/s). Discussion: From Review of Cooling Water Chemistry at ORNL/SNS [2], "High local water velocities (> 2m/s) … would cause accelerated dissolution of the oxide layer, possibly causing local material loss and increased copper transport. Also need to ensure that the water flow is moderately turbulent (2000 ≤ Re ≤ 100000)."	S02-R004
S02.04-R006	The cooling water pressure differential across the extraction magnets shall not exceed 60 psi (414 kPa) to meet requirement S02.04-R004. Discussion: This is to support a Cooling Water System design pressure ≤ 150 psi. The desired pressure differential is between 30 and 50 psi.	Design Requirement
S02.04-R015	For water-cooled extraction magnets, the assembled magnet shall withstand 300 psig (2068 kPa) hydrostatic (water) test pressure for one hour without evidence of external leakage or internal pressure drop other than that resulting from a change in water temperature. Discussion: 300 psi is 2 x the max targeted water pressure in the SNS water system.	S02-R006

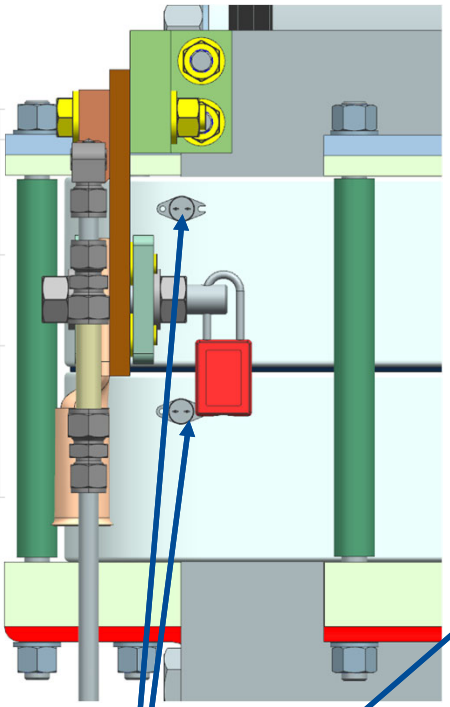
Parameter	Unit	Value
Average power losses	kW	3.371
Conductor dimensions (hole diameter)	mm	12 x 18 (8)
Water pressure drop (20 psi)	MPa	0.138
Total water flow	l/s	0.138
Water velocity	m/s	1.375
Water temperature rise at 2 water circuits	°C	6

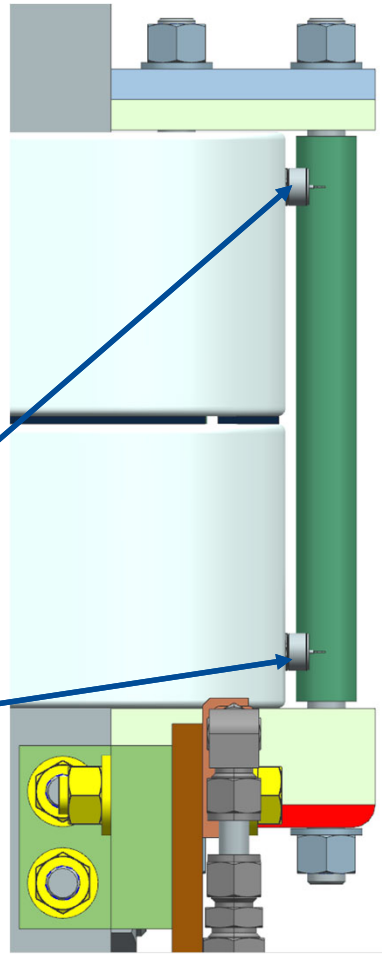
TEMPERATURE SWITCH

Table 1 Extraction Magnet Common Requirements

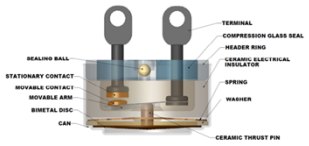
ID	Requirement	Traceability
S02.04-R007	Each extraction magnet temperature switch shall be hardwired to the magnet power supply to turn off the supply if the temperature limit is exceeded.	S02-R004 S02-R006
S02.04-R008	Water-cooled extraction magnet coils shall have at least one temperature switch per water flow path. The switch shall be mounted on the insulated coil near the cooling water outlet end of the coil.	S02-R004 S02-R006
S02.04-R009	The temperature switch required in S02.04-R008 shall have a specified 170° ± 5° F (76.7° ± 2.8° C) trip point. The switch contacts shall be electrically isolated from the coil. The reset temperature shall be specified to be 150 ± 5° F (65.6° ± 2.8° C). Discussion: The preferred switch is Sensata 4344.	S02-R004 S02-R006





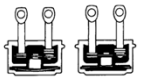


Typical Cross Section View



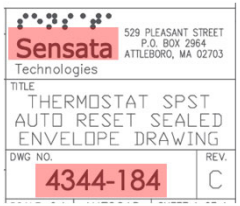
[FC0075125-SWITCH, THERMAL, SINGLE POLE SEALED]

Operation



When heated, the internal stresses of the bi-metal cause the disc to reverse its curvature with a snap-action at a fixed, preset temperature and operate the electrical contacts.

A decrease in the ambient temperature below the reset temperature of the disc relieves the internal stresses in the disc. The disc returns to its normal curvature and the contacts assume their normal operating position.



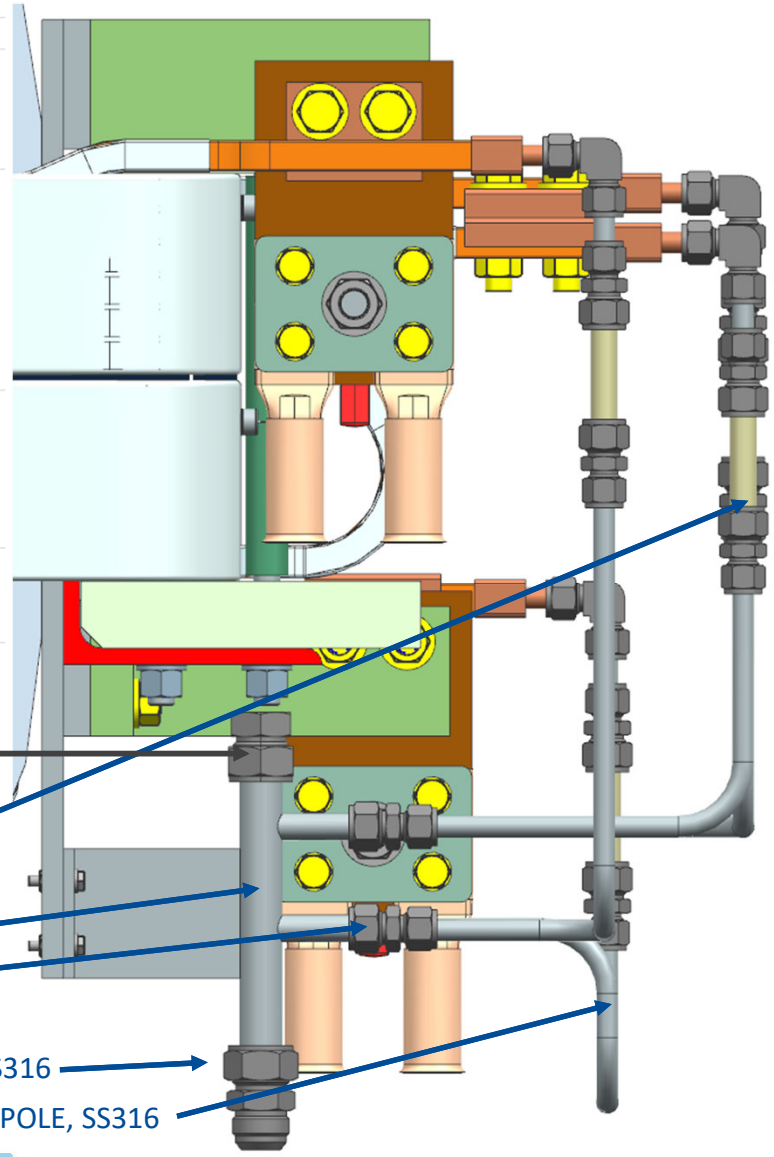
PDR: The temperature switched should be mounted on the coils, not the leads. If water cooling fails, the coil bulk will heat faster than the lead.

Fermilab

MANIFOLD ASSEMBLY

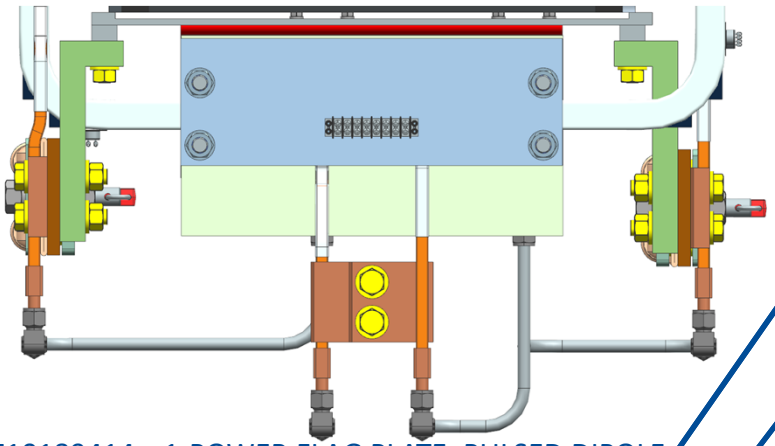
ID	Requirement	Traceability
S02.04-R010	All extraction magnet water manifold components shall be electrically grounded to the magnet core.	S02-R009
S02.04-R027	The extraction magnet assembly wetted parts shall be OFHC copper, stainless steel, ceramic, or approved hose material. Discussion: No aluminum or brass is allowed. OFHC copper and stainless steel are preferred. See Characterization of Particulate Material from Two Filters Associated with the SNS Cooling System [5], and Review of Cooling Water Chemistry at ORNL/SNS [2] for water quality discussions.	S02-R004
S02.04-R028	Extraction magnet water connection ports shall be compatible with female 37° flair JIC (SAE J514/ISO 8434-2) hose fittings, 1 – 1/16 - 12 thread size. Discussion: Intent is to be compatible with Parker p/n 10656-12-12C hose fitting.	S02-R008
S02.04-R029	Extraction magnet water hoses shall be routed a minimum of 6" (15.2 cm) away from the magnet aperture. Discussion: Intent is to minimize radiation damage to hoses.	S02-R004

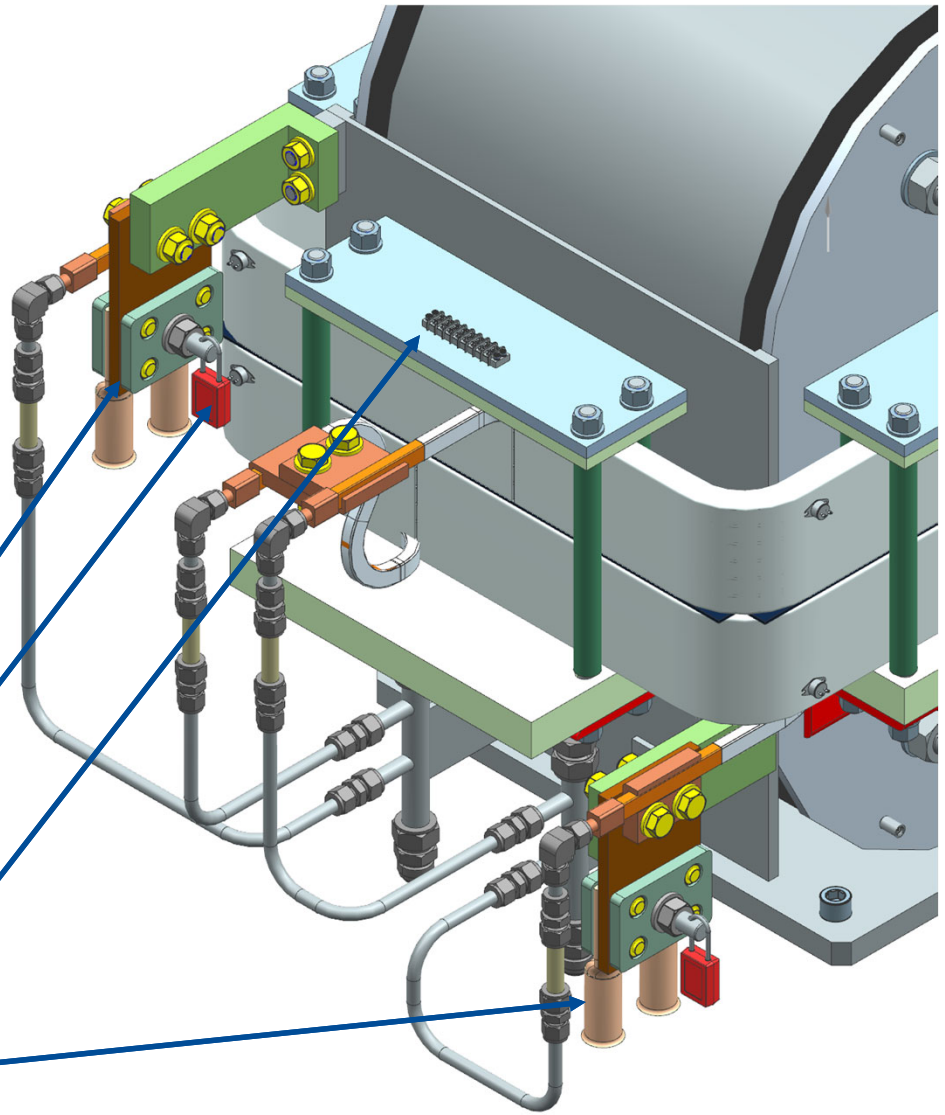
PDR: A concern is the proximity to each other of cooling tubes that have a potential difference between them. Recommend moving the PEEK insulating breaks to close to the electrical flags.



POWER FLAG ASSEMBLY

ID	Requirement	Traceability
S02.04-R018	The extraction magnet assembly shall be designed with terminal blocks or flags to mate with cable termination lugs. Discussion: Intent is to conform to SNS standard connections.	S02-R008
S02.04-R026	Extraction magnet electrical mating surfaces shall be plated with 0.0003" (7.6 µm) silver in accordance with ASTM B700-20. Discussion: To provide a corrosion-resistant joint. Barrel plating appears to be the most cost-effective method, so that should be considered in the design and procurement strategy.	S02-R004
S02.04-R048	The Pulsed Dipole magnet assembly shall provide a Radiation Safety Hold (RS Hold) interface. Discussion: Details TBD. The RS hold will impact the bussing connection to the magnet. This requirement addresses an interface defined in Interface Sheet for ICS PPS and Accelerator Pulsed Dipole Magnets [9].	S02-R009





F10189414--;1-POWER FLAG PLATE, PULSED DIPOLE MAGNET, ORNL STS

FC0105359-LOCKOUT PADLOCK, EXTRA CLEARANCE

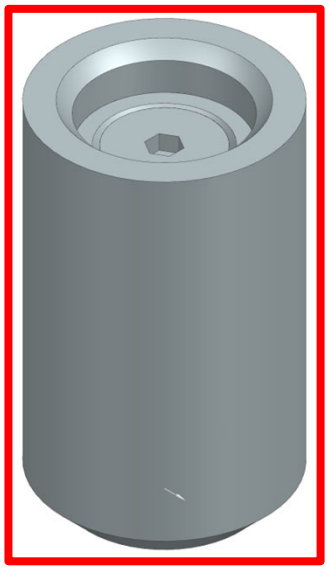
FC0108568-TERMINAL BLOCK, 8 CIRCUIT, 300V AC/DC, 20A, 22-12 AWG

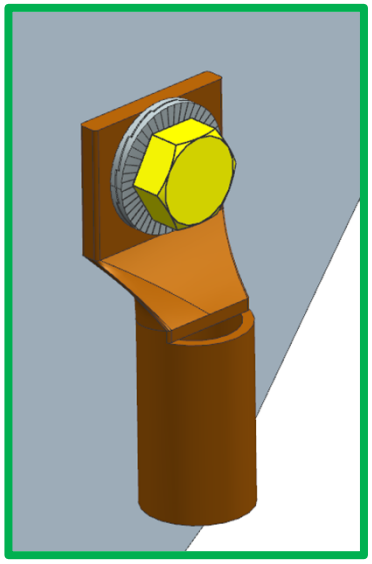
FC0094169-COMPRESSION LUG 2 HOLE, FLARED LONG BARREL

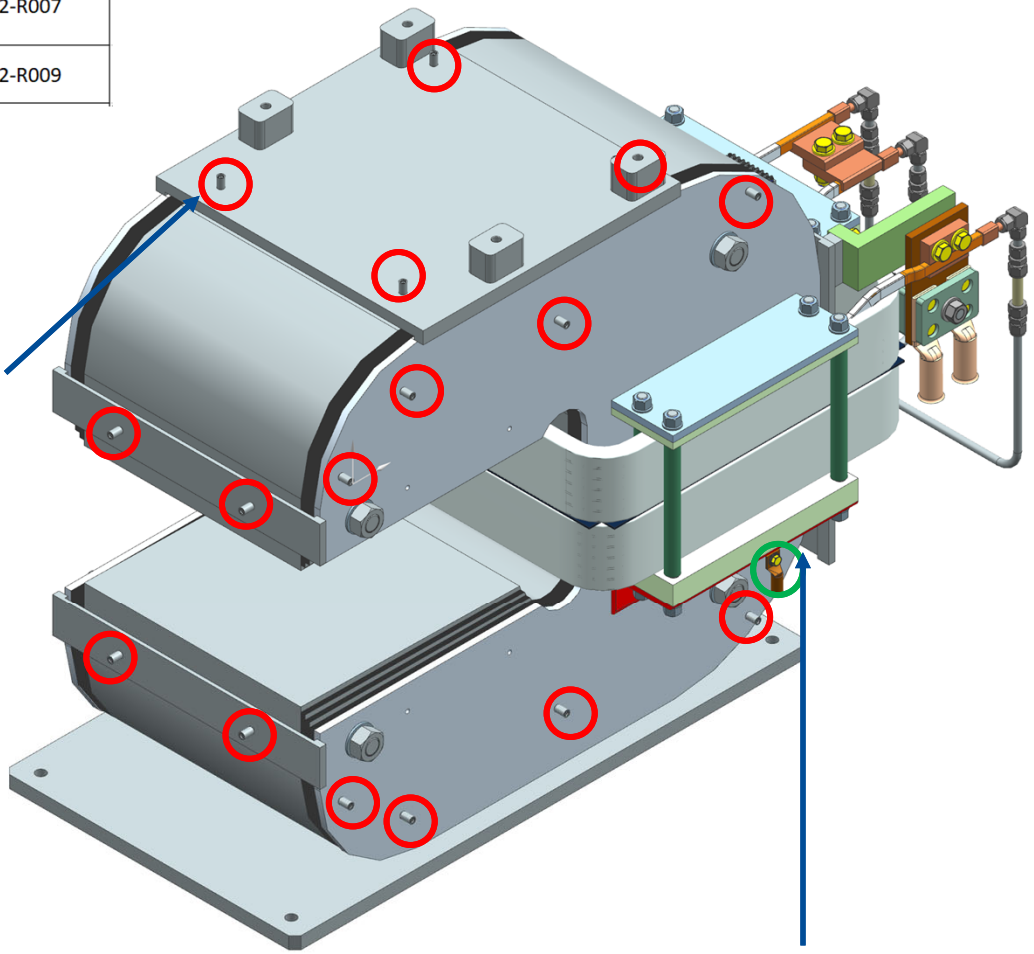
FIDUCIALS

ID	Requirement	Traceability
S02.04-R014	The extraction magnet assembly shall have external fiducials capable of supporting magnet alignment to 100-micron in x/y and 1-mrad yaw, pitch, and roll. Discussion: This requirement is relative to the SNS Coordinate System	S02-R003 S02-R007
S02.04-R021	The extraction magnet core shall be grounded to the tunnel ground system.	S02-R009

FC0116360--;1-FIDUCIAL MONUMENT 0.5"ODx.838"LG, WELD ON 17-4SS

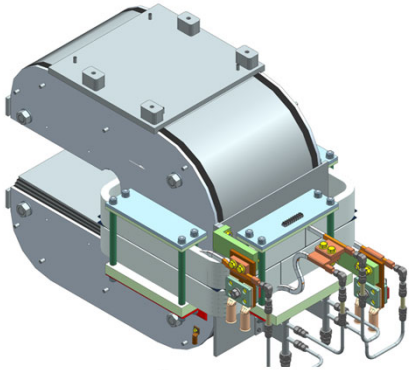


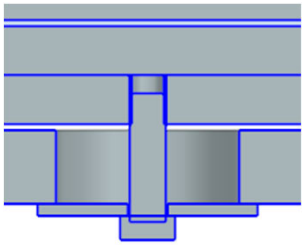


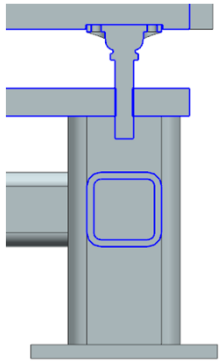


FC0120528--;1-COPPER LUG, 1 HOLE, STD BARREL, .71"OD, 2.5"LG

STAND INTERFACE

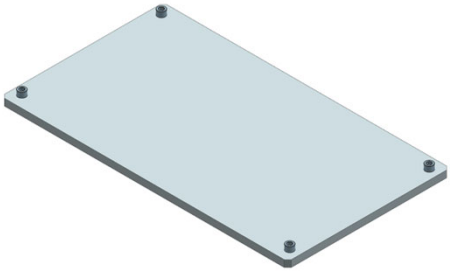




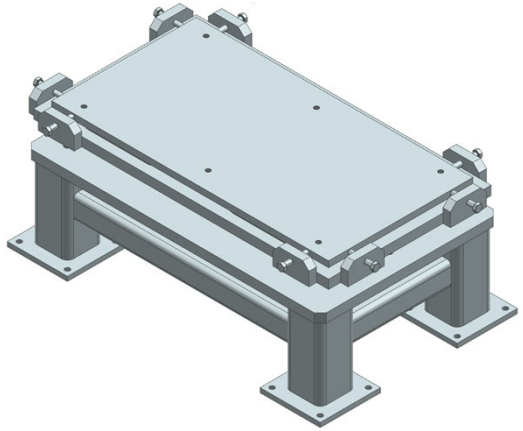


ID	Requirement	Traceability
S02.04-R020	The extraction magnet assembly shall be designed such that the magnet (mechanical) central axis can be placed coincident with the beam path (at a 1.045 m nominal beam height) mounted on a support that meets requirements S02.11-R002 and S02.11-R011. Discussion: This is intended to ensure that there is enough clearance between the magnet and the floor for a support stand with some vertical adjustment. The nominal beam height was derived from the elevations on the Burns and McDonnell RTST Stub drawings. Floor elevation 1076', Beam line elevation 1079.43'. The RTBT beam height is listed in [3] as "approximately 41 inches above the floor". The SNS Parameters List [11] lists the beam-floor distance for the RTBT as 0.996 to 1.0414 m.	S02-R003 S02-R007
S02.04-R023	Each extraction magnet assembly shall provide an interface for supporting the vacuum chamber, if required.	Design Requirement

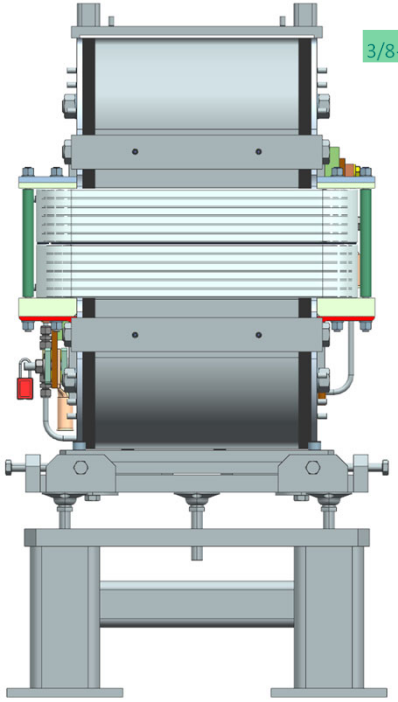
993.6+50.8=1044.4mm

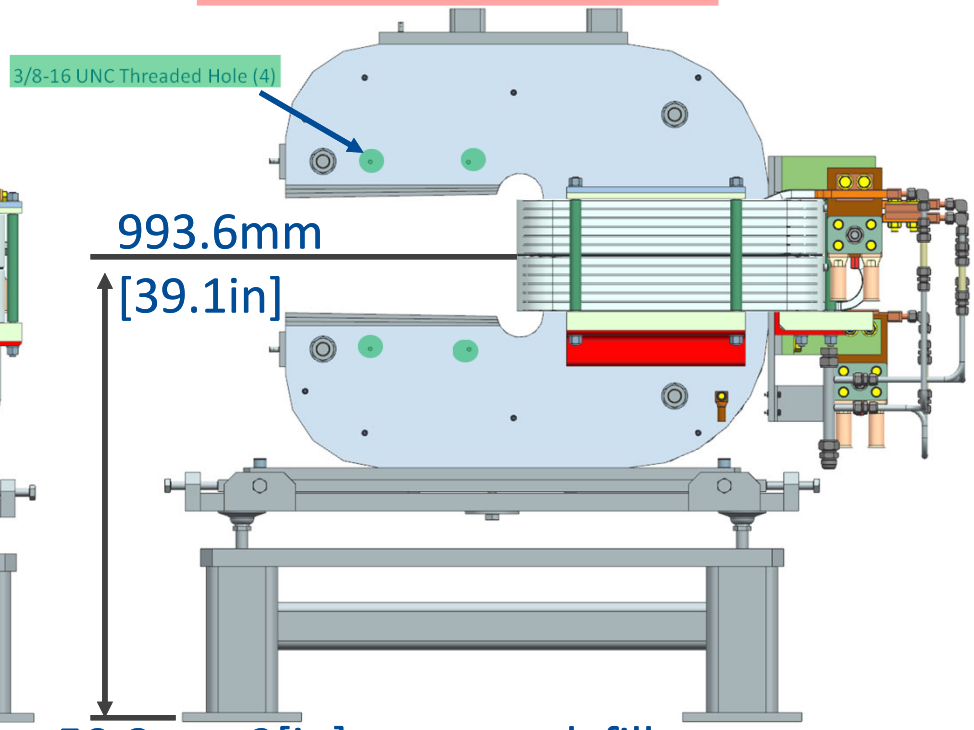


F10189003--;1-PLATE, BOTTOM CORE SUPPORT, PULSED DIPOLE MAGNET, ORNL STS



FC0099587-STAND, ORNL PULSED DIPOLE -FROM ORNL

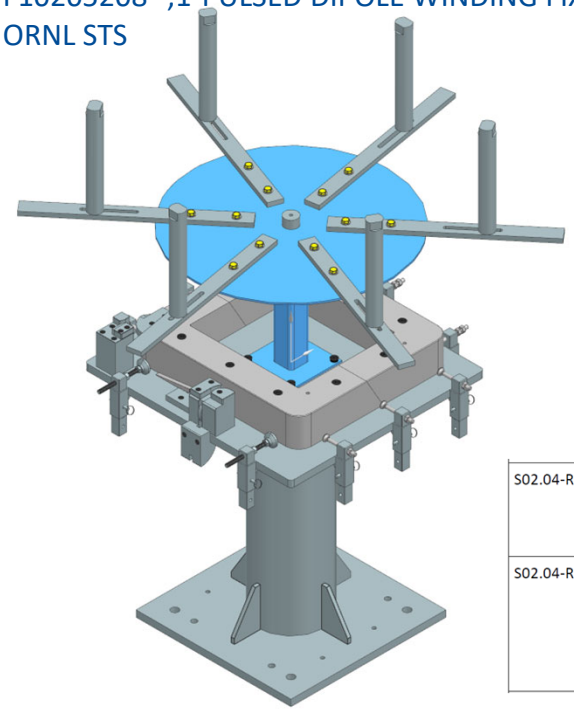


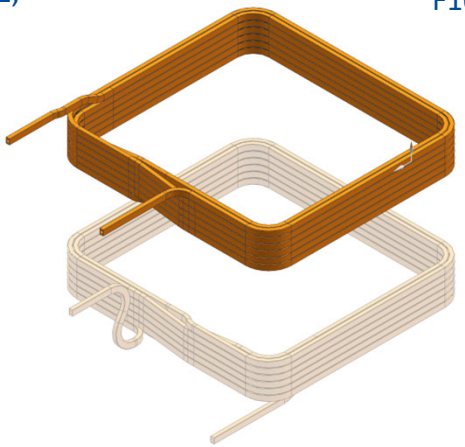


Fermilab

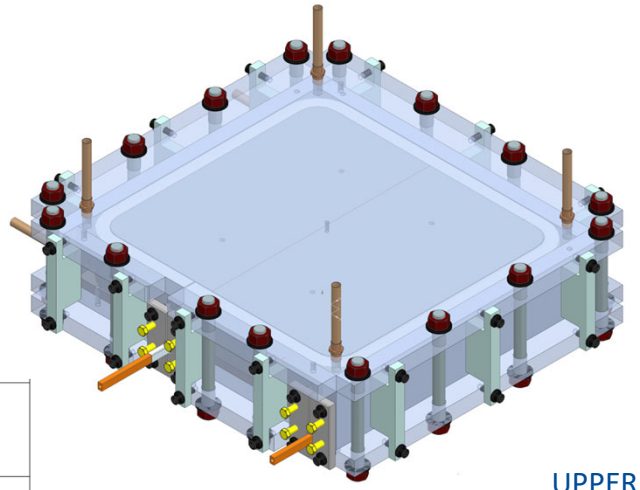
WINDING AND CURING FIXTURES

F10205208--;1-PULSED DIPOLE WINDING FIXTURE, ORNL STS

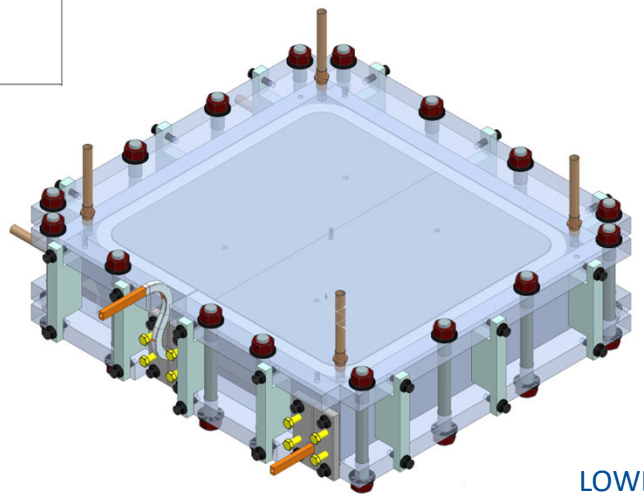




F10204164--;1-PULSED DIPOLE CURING FIXTURE, ORNL STS



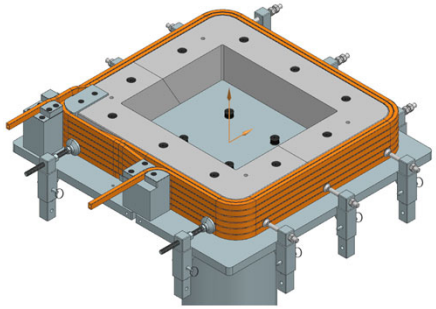
UPPER



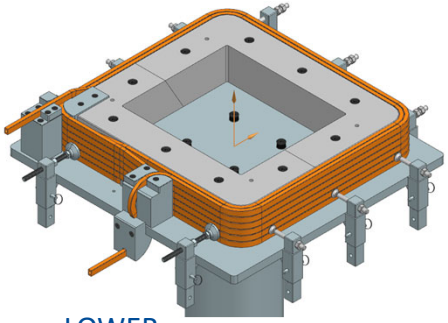
LOWER

S02.04-R024	Each extraction magnet coil shall be made from a single length of conductor. **Discussion:** This is to avoid splices inside the coil.	S02-R004
S02.04-R025	The water-cooled extraction magnet coils shall meet the requirements of *Specification for Radiation Resistant Fiberglass/Epoxy Insulated Magnet Coils* [4]. Discussion: This includes silver plating, hydrostatic test to 300 psi, turn-to-turn insulation test.	S02-R004

FC0104639--;1-COIL, PULSED DIPOLE MAGNET, ORNL STS



UPPER

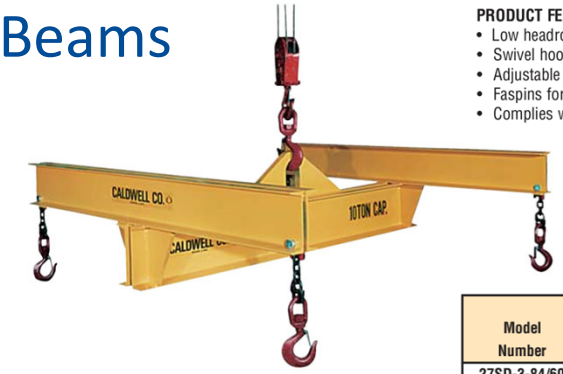


LOWER

Fermilab

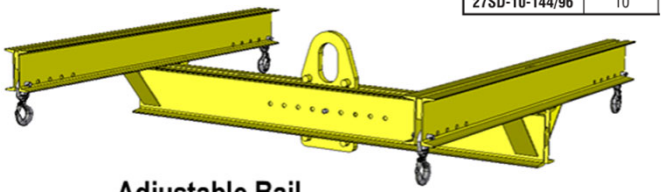
LIFTING TOOLING

Model 27F - Four Point Lifting Beams

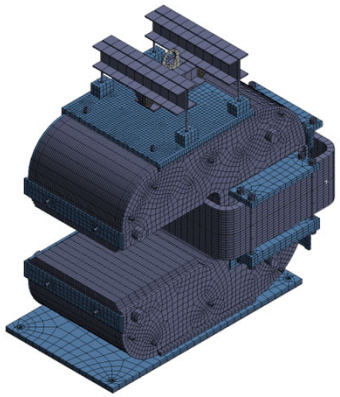


PRODUCT FEATURES:
- Low headroom design.
- Swivel hooks with latches standard.
- Adjustable spreads on 1' increments.
- Faspins for easy crossarm adjustment.
- Complies with ASME standards.

Model Number	Capacity (tons)
27SD-3-84/60	3
27SD-5-120/96	5
27SD-10-144/96	10



Adjustable Bail



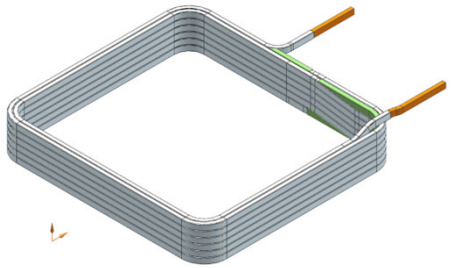
M~3.5E3kg [7.7E3lb]

S02.04-R068	Magnet assembly lifting features shall comply with the design requirements in *ASME BTH-1-2020* [7].	S02-R009

Bushman Model FR / Serial #43230-2 (TLF1148)

The Bushman Flip-Rite® material handling system allows safe raising, lowering, leveling and rotating of large, bulky or oddly shaped loads weighing up to 100 tons. Each Flip-Rite® unit is custom-engineered to your application and is designed in accordance with ASME codes B30.20 and BTH-1. Quality-built throughout, the Flip-Rite® will provide years of safe and efficient service. Flip-Rite® is built in three models:

M=45kg [100lb] OXYGEN FREE COPPER

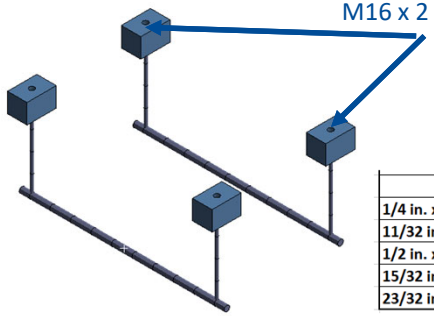


The standard Flip-Rite® is the Model FR. It has a fixed center lifting bail that attaches to a crane hook or two end bails that attach to twin hooks on one crane or to separate hooks from two cranes. One drum or multiple drums can accommodate flipping straps spaced close together or far apart.

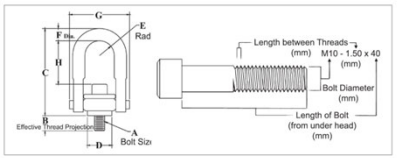
PDR
(Fixturing will be required for the coil installation)

Fermilab

WOODEN MOCKUP



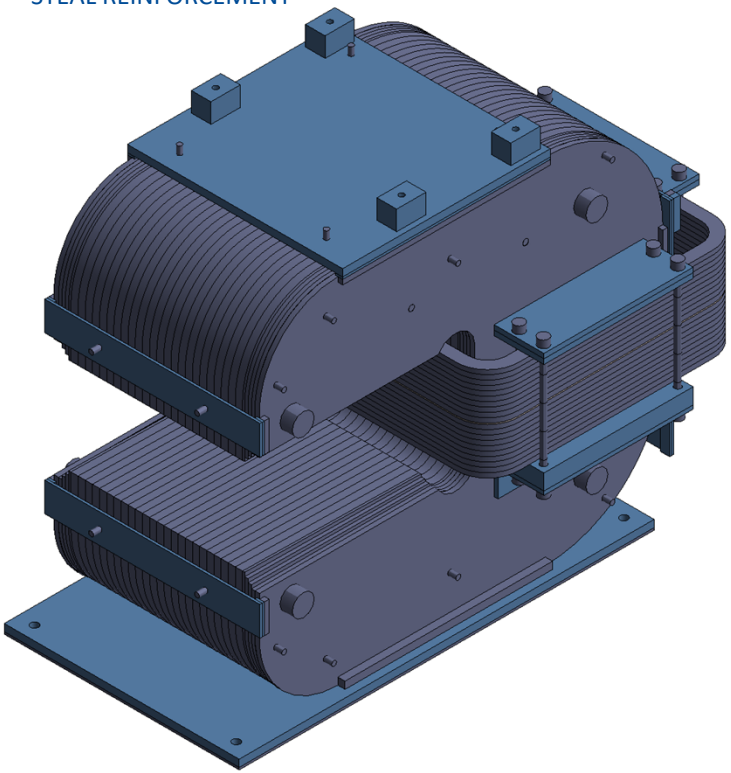
	full sheet
1/4 in. x 4 ft. x 8 ft. PureBond Birch Plywood	1
11/32 in. or 3/8 in. x 4 ft. x 8 ft. BC Sanded Pine Plywood	3
1/2 in. x 4 ft. x 8 ft. PureBond Birch Plywood	2
15/32 in. x 4 ft. x 8 ft. BC Sanded Pine Plywood	9
23/32 in. x 4 ft. x 8 ft. BC Sanded Pine Plywood	12

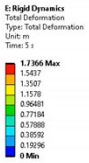


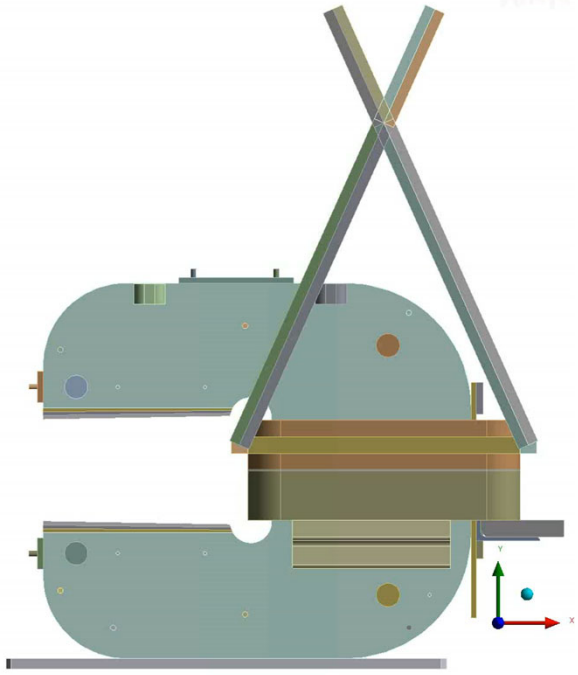
HR-125M Metric Threads

Frame Size No.	HR-125M Stock No.	Working Load Limit (kg)		Torque in (Nm)*	Dimensions (mm)								Weight Each (kg)
		At a 5:1 Design Factor †	At a 4:1 Design Factor †		(A) Bolt Size ‡	(B)Effective Thread Projection Length	C	D	Radius E	Diameter F	G	H	
1	1016602	400	500	10	M8X1.25X40	16.9	69.9	24.6	11.8	8.5	47.5	29.9	.17
1	1016613	450	550	16	M10X1.50X40	16.9	69.9	24.6	11.8	8.5	47.5	28.1	.18
2	1016624	1050	1300	38	M12X1.75X50	16.9	123	49.8	22.3	17.5	85.1	60.4	1.05
2	1016635	1900	2400	81	M16X2.00X60	26.9	123	49.8	22.3	17.5	85.1	56.3	1.11

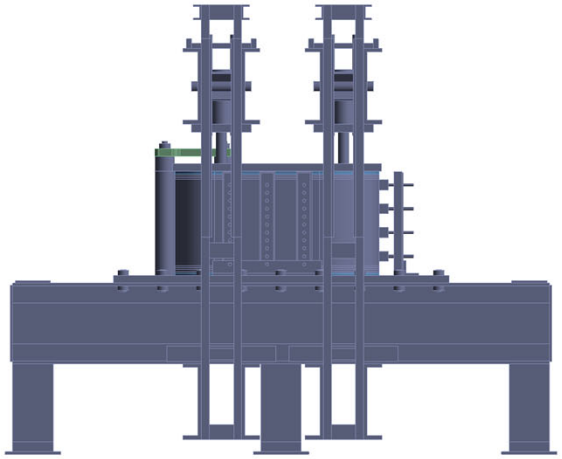
STEAL REINFORCEMENT

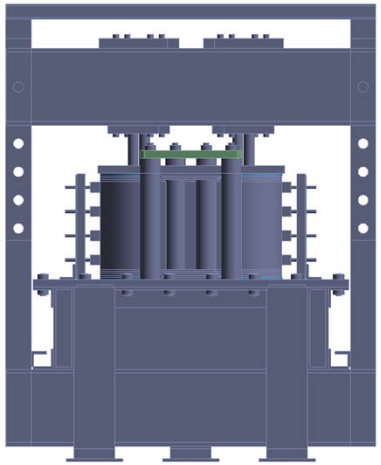


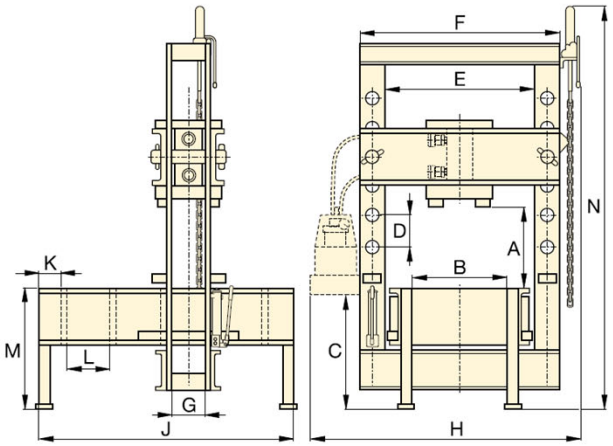


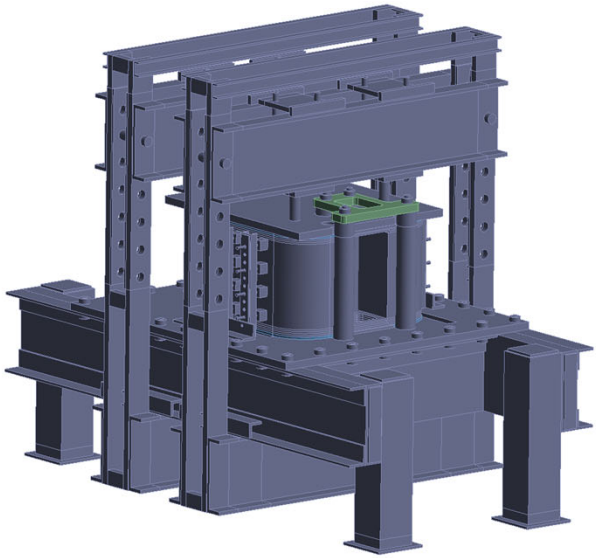


STACKING TOOLING









Press Capacity ton (kN)	Vertical Daylight A (mm) min.	Vertical Daylight A (mm) max.	Maximum Bed Width E (mm)	Electric Pump Model Number	Page
50 (498)	131	922	813	ZE4410SE	92
100 (933)	320	1208	886	ZE5410SW	92
200 (1995)	376	1138	1222	ZE4420SW	92

Press Model Number	Double-Acting Cylinder Stroke (mm)	Model Number	Page	Speed (mm/sec) Rapid Advance	Pressing
IPR-5075	334	RR-5013	32	20,8	1,9
IPR-10075	333	RR-10013	32	14,5	2,1
IPR-20075	330	RR-20013	32	5,2	0,5

PDR

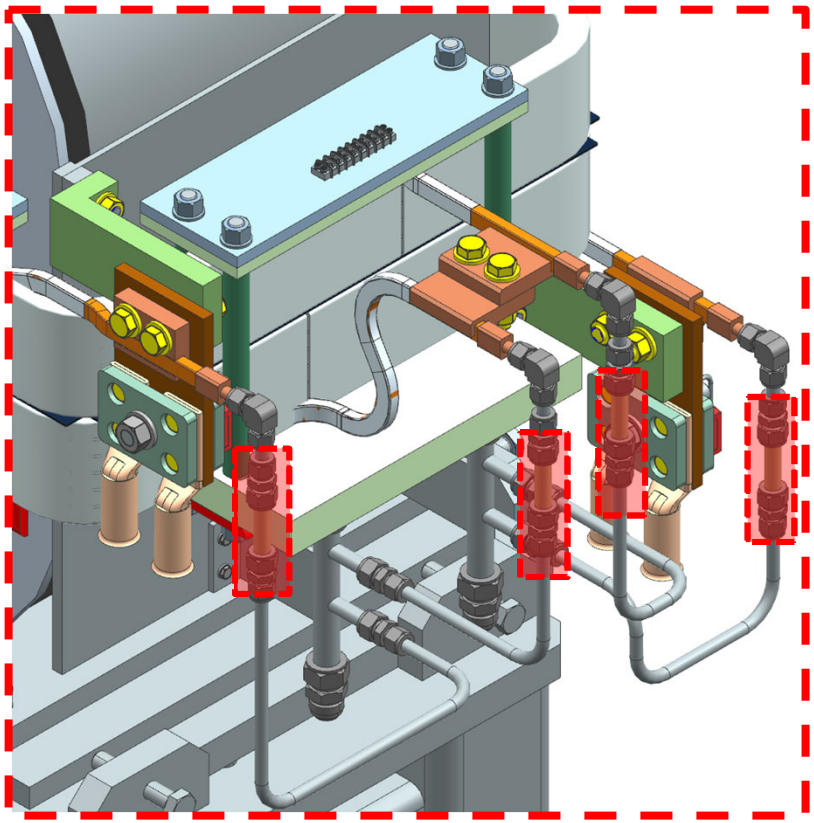
(It is planned to use a fixture for stacking the laminations)

PREVIOUS RECOMMENDATIONS

PDR recommendation	Slide #
A concern is the proximity to each other of cooling tubes that have a potential difference between them. Recommend moving the PEEK insulating breaks to close to the electrical flags.	20
The temperature switches will be attached by glue, no drilling and tapping into the conductor is planned.	21
The coil clamp provides 200 kN of clamping force with the bolts at 75% of their maximum torque. Recommend verifying magnetic forces on the coils.	23
Recommend thinking about using a compliant material between the coils.	22
The CAD model shows there is sufficient clearance between the core and the coil to allow assembly.	+
The coil lead routing leads to 23.75 turns instead of the design 24 and creates a loop. Recommend moving the power leads as close together as possible.	Other Talk
It is planned to use a fixture for stacking the laminations.	18
Recommend thinking about carrying out a vibration analysis for the magnet on its stand.	26
There is a risk the bottom plate will deform during welding	+
Recommend laser cutting the laminations rather than punching. Die will be expensive for the small number of magnets needed.	+
The temperature switched should be mounted on the coils, not the leads. If water cooling fails, the coil bulk will heat faster than the lead.	21
Think about whether a spacer is needed between the coil and the core. Friction provides 100 kN horizontal clamping force.	23
The L-shaped G10 supports for the power flags could be vulnerable to cracking, be careful with the fiber orientation.	24
The expectation is that the cooling tubes will be bent in advance and cut to size on the factory floor. This will be easier after the PEEK tubes have been moved.	20
Fixturing will be required for the coil installation.	16
If horizontal clamping is required for the coil, an opportunity could be to use wedges between the existing 4 G10 rods.	23
Recommend checking the deformation that occurs during lifting.	25

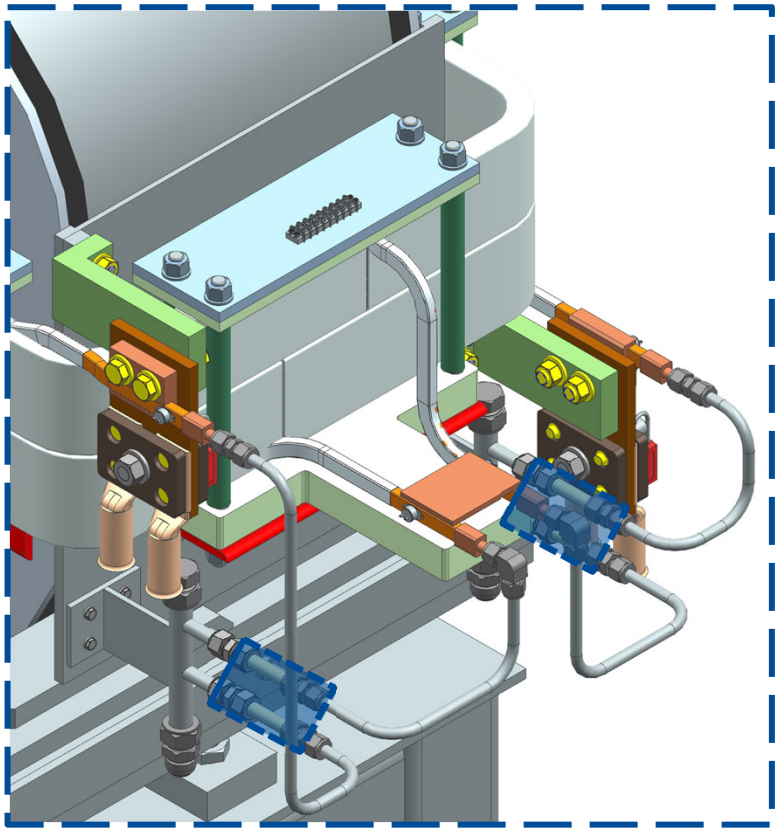
PREVIOUS RECOMMENDATIONS

- A concern is the proximity to each other of cooling tubes that have a potential difference between them. Recommend moving the PEEK insulating breaks to close to the electrical flags.
- The expectation is that the cooling tubes will be bent in advance and cut to size on the factory floor. This will be easier after the PEEK tubes have been moved.



Current

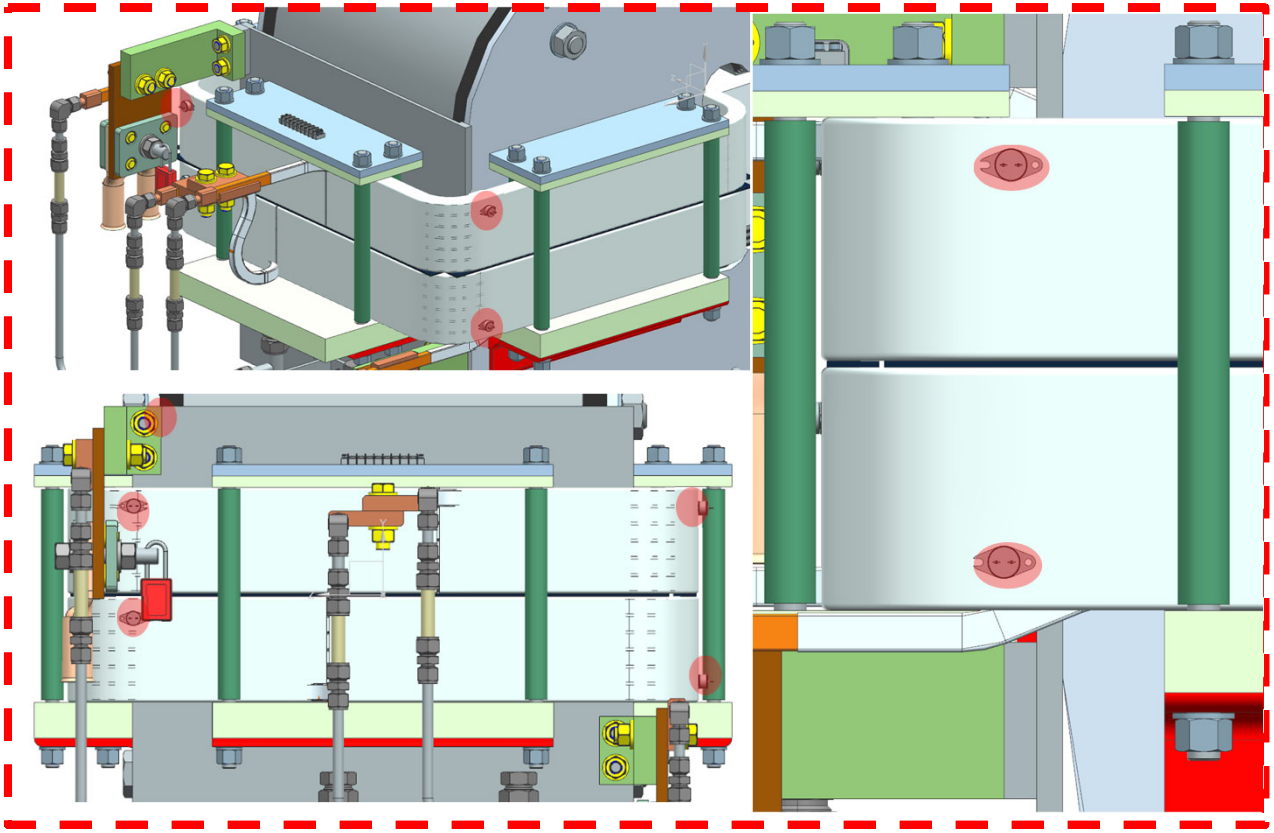
F10196280-TUBE 1 F10196282-TUBE 3
F10196281-TUBE 2 F10196285-TUBE 4



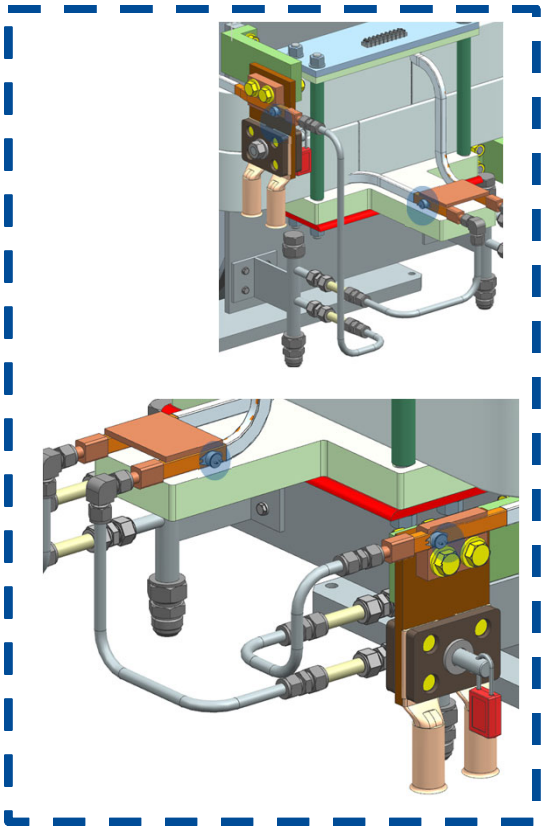
Previous

PREVIOUS RECOMMENDATIONS

- The temperature switches will be attached by glue, no drilling and tapping into the conductor is planned.
- The temperature switched should be mounted on the coils, not the leads. If water cooling fails, the coil bulk will heat faster than the lead.



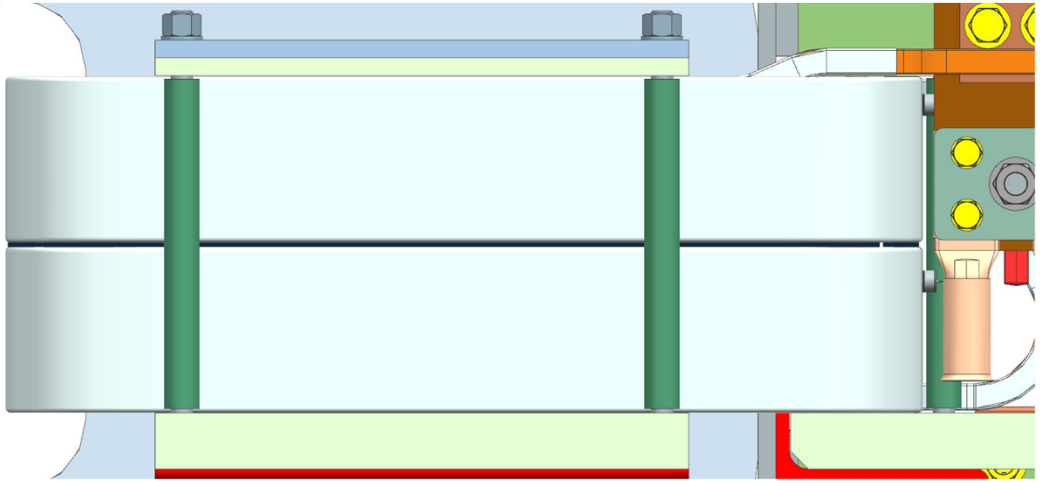
Current

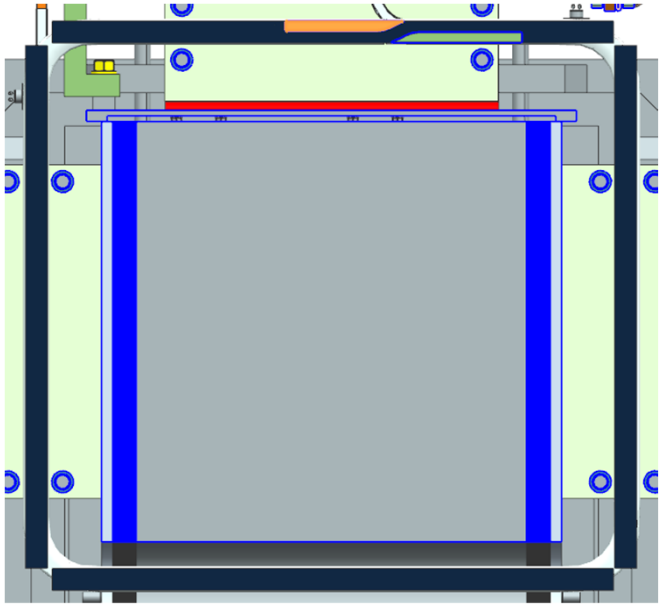


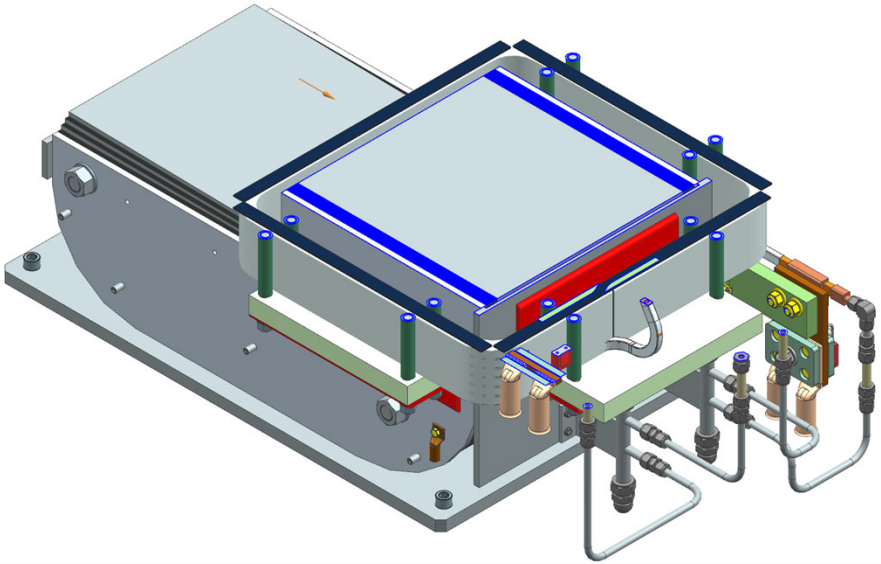
Previous

PREVIOUS RECOMMENDATIONS

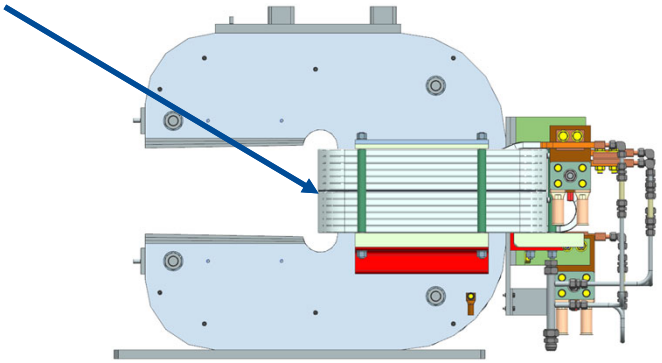
- Recommend thinking about using a compliant material between the coils.







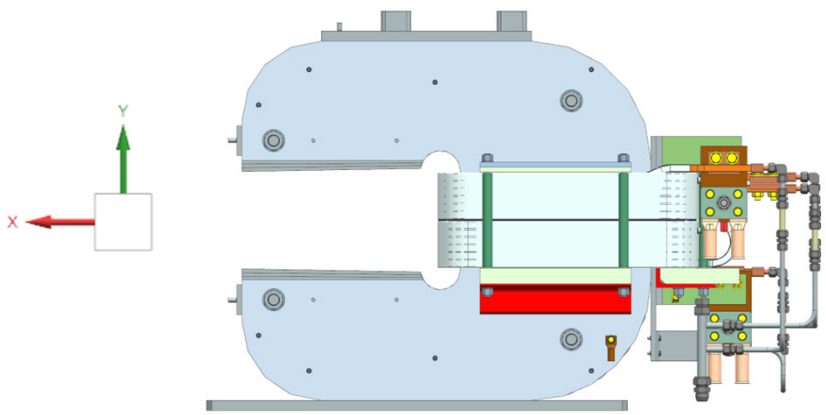
FC0109296--;1-1" x 1/8" X 10' NEOPRENE STRIP WITH ADHESIVE

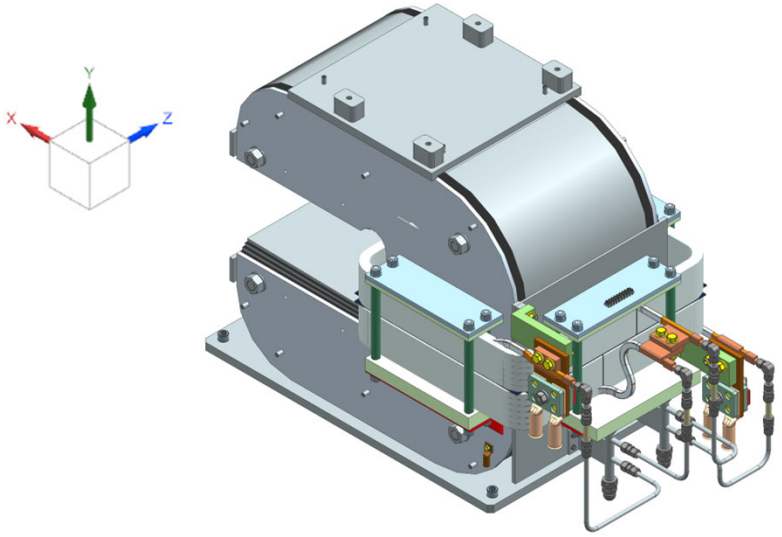


Fermilab

PREVIOUS RECOMMENDATIONS

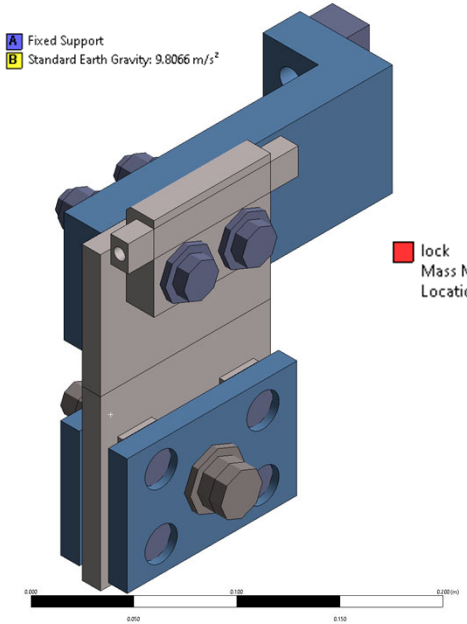
- The coil clamp provides 200 kN of clamping force with the bolts at 75% of their maximum torque. Recommend verifying magnetic forces on the coils.
- Think about whether a spacer is needed between the coil and the core. Friction provides 100 kN horizontal clamping force.
- If horizontal clamping is required for the coil, an opportunity could be to use wedges between the existing 4 G10 rods.
- Magnetic forces Fx=-1.4kN; Fy=7.8kN; Fz=0.2kN. The friction will be enough to withstand magnetic forces.

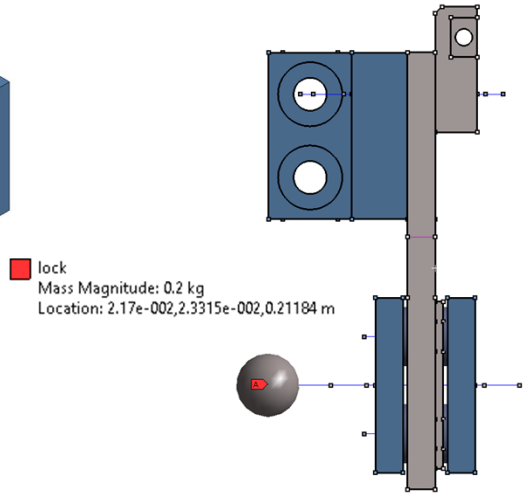


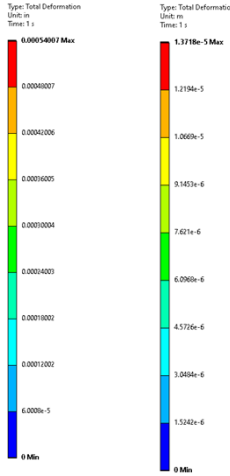


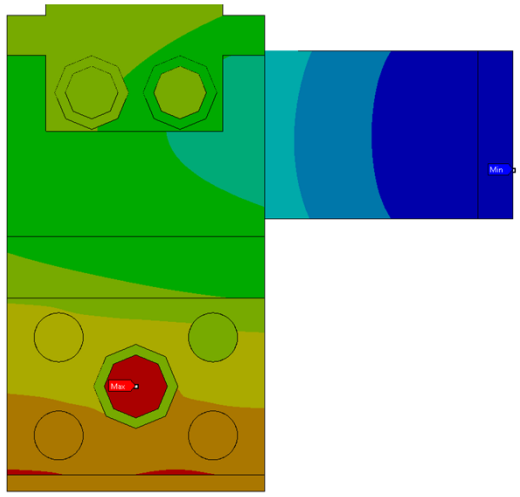
L-SHAPED G10

- The L-shaped G10 supports for the power flags could be vulnerable to cracking, be careful with the fiber orientation.

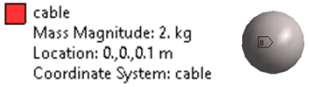


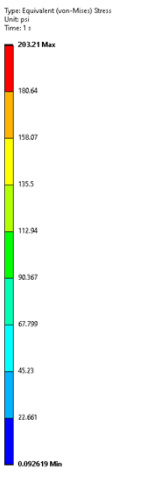


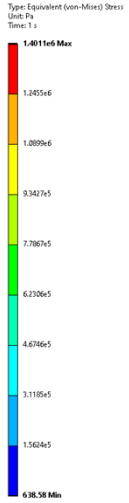


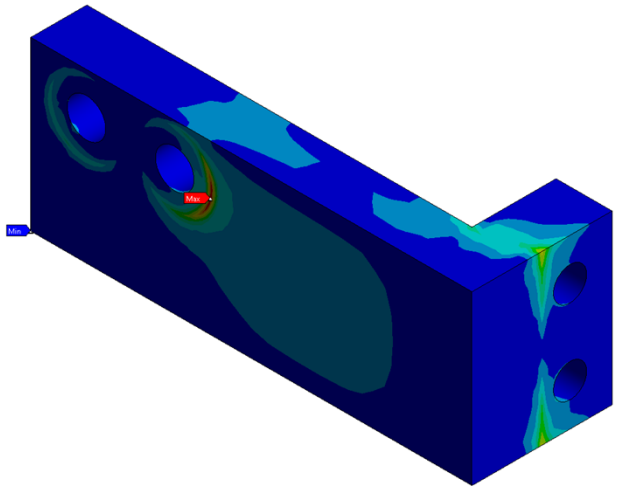


Mechanical Properties	Metric	English
Hardness, Rockwell M	110	110
Tensile Strength at Break	262 MPa	38000 psi
	310 MPa	45000 psi
Flexural Strength	448 MPa	65000 psi
	517 MPa	75000 psi
Flexural Modulus	16.5 GPa	2400 ksi
	18.6 GPa	2700 ksi
Compressive Strength	448 MPa	65000 psi



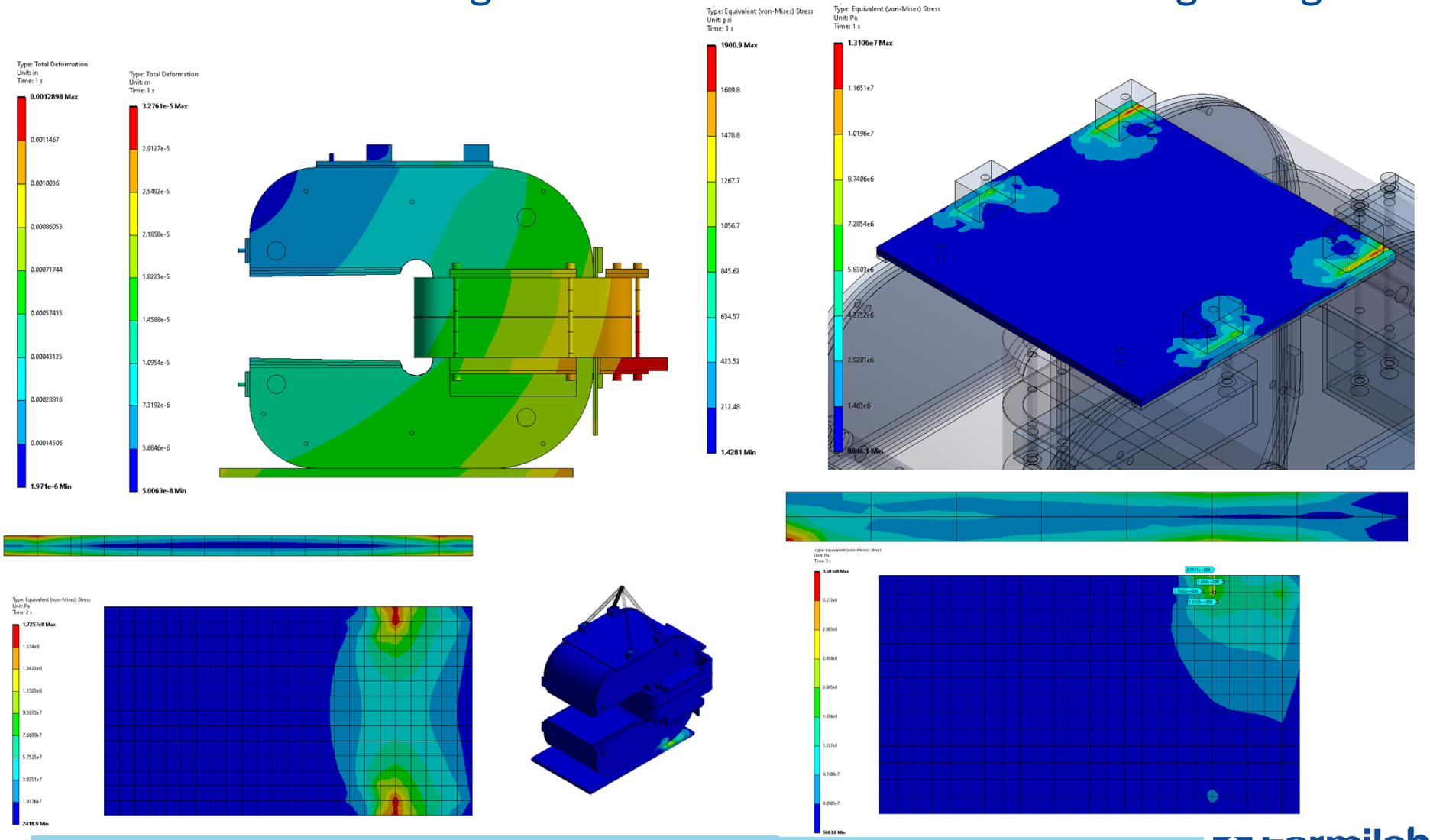






LIFTING DEFORMATION

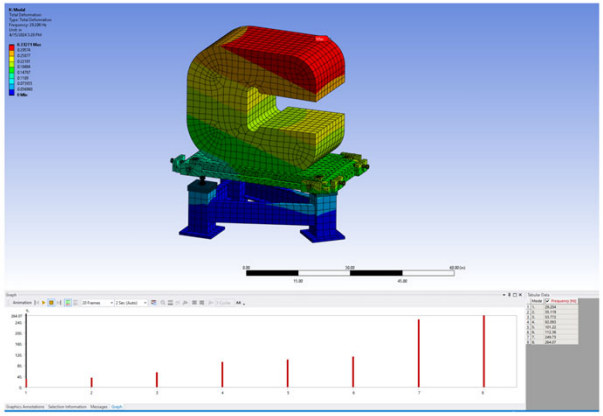
- Recommend checking the deformation that occurs during lifting.



MODAL ANALYSIS

Tabular Data

	Mode	Frequency [Hz]
1	1.	29.204
2	2.	35.119
3	3.	53.772
4	4.	92.093
5	5.	101.22
6	6.	112.36
7	7.	249.73
8	8.	264.07



OAK RIDGE National Laboratory

Rotation X
168.35

Participation Factor

Effective Mass

Cumulative Effective Mass Fraction

Ratio of Effective Mass to Total Mass

OAK RIDGE National Laboratory

Structural and Seismic Analysis

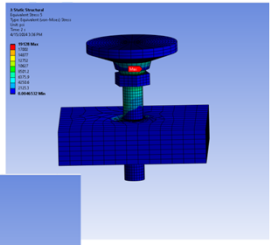
- Stand designed to ASCE 7-16 Ch. 13 Nonstructural components
- Only dead load and seismic loads are applicable
- Load combination cases (basic and seismic) for strength design
  - 1.4*D
  - 1.2*D + E_v + E_H + ~~L~~ + ~~0.2*S~~
    - Seismic applied in 2 horizontal directions
    - E_H = .20G
    - E_V = .08G
- Ch 13 suggested allowable of .9F_y

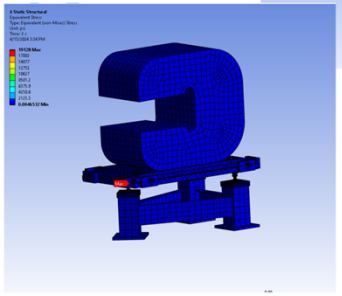
OAK RIDGE National Laboratory

S02.11-R004

Structural Analysis

- Results
  - Results as expected
  - Leveler is area of concern
    - FoS of ~5
- Stresses low on remaining stand





OAK RIDGE National Laboratory

Fermilab

SUMMARY

- Magnet drawings 100% (Released)
- The coast estimated completed
- The schedule ready for prototyping