Fermilab

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25D50 Pulsed Dipole PDR Mechanical Design

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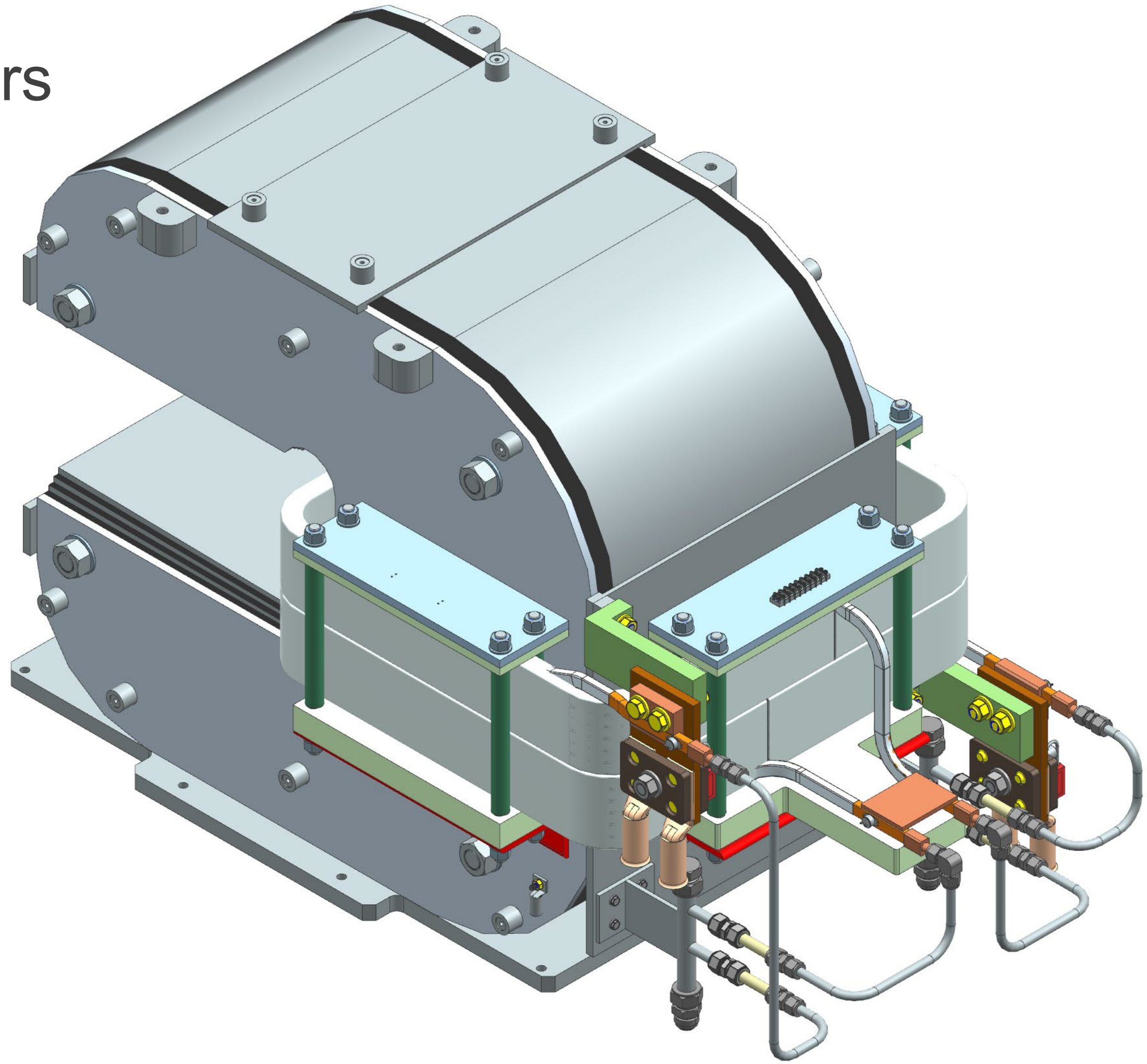
03-06-23

Outline

- Engineering Parameters
- Design Description
- Assembly methods
- Stand Interface
- Summary



Engineering Parameters (Mechanical Design)

S02020300-SRD10000 S02.02.03 RTST Systems L4 Extraction Magnet Requirements

Table 1 Extraction Magnet Common Requirements

Requirement
Magnet System

- S02.02.03-R002 slide#9
- S02.02.03-R004 slide#10
- S02.02.03-R005 slide#10
- S02.02.03-R006 slide#10
- S02.02.03-R007 slide#11

Magnet Assembly

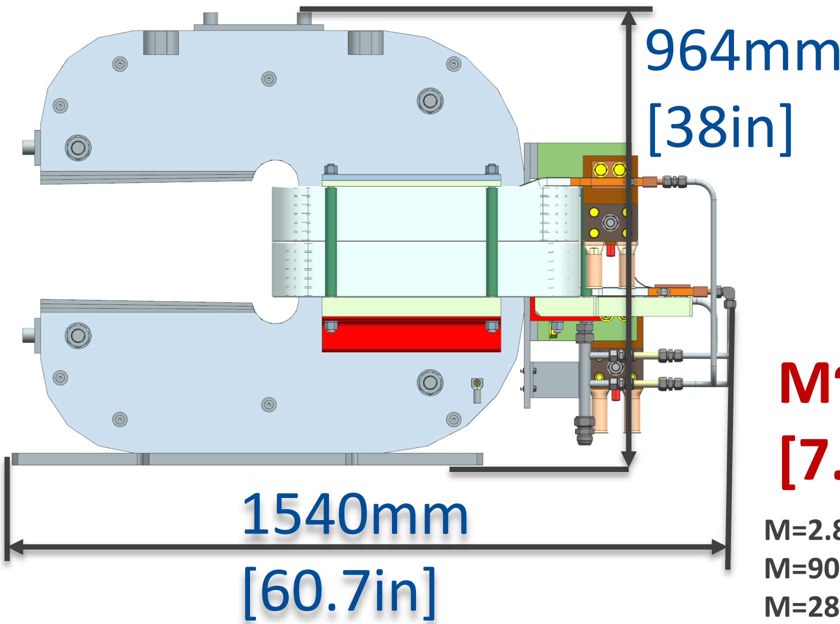
- S02.02.03-R008 slide#11
- S02.02.03-R009 slide#11
- S02.02.03-R010 slide#12
- S02.02.03-R011 slide#5
- S02.02.03-R012 slide#6
- S02.02.03-R014 slide#14
- S02.02.03-R015 slide#10
- S02.02.03-R016 slide#9
- S02.02.03-R018 slide#14
- S02.02.03-R021 slide#15
- S02.02.03-R024 slide#9
- S02.02.03-R025 slide#9
- S02.02.03-R026 slide#14
- S02.02.03-R027 slide#12
- S02.02.03-R028 slide#12
- S02.02.03-R029 slide#12

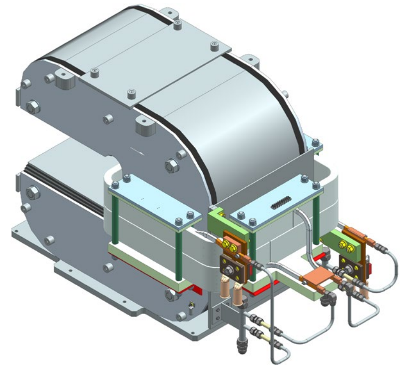
Table 2 Pulsed Dipole Requirements

Requirement
Pulsed Dipole System
Pulsed Dipole Magnet Assembly

- S02.02.03-R041 slide#5
- S02.02.03-R042 slide#7
- S02.02.03-R043 slide#6

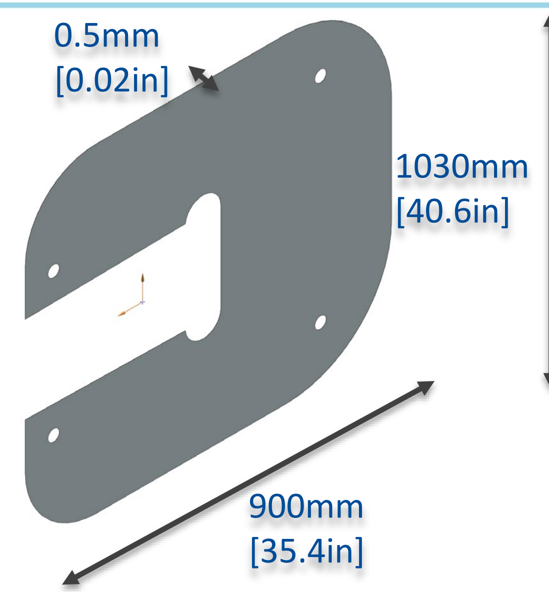
PULSED DIPOLE MAGNET ASSEMBLY, ORNL STS



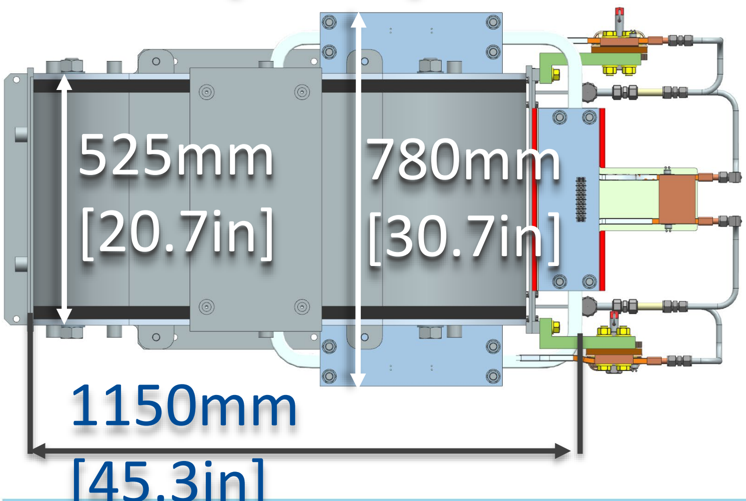


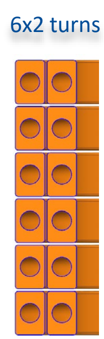
M~3.5E3kg [7.7E3lb]

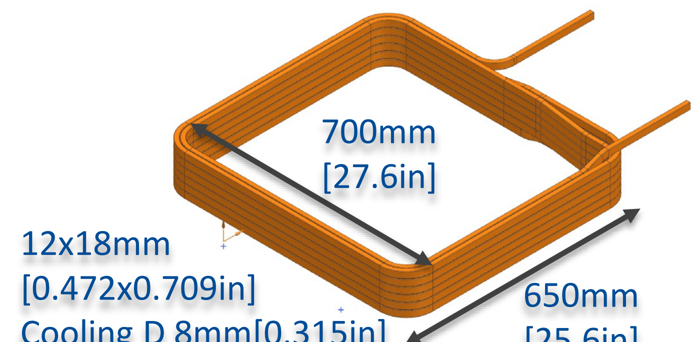
M=2.8E3kg [6.3E3lb] M15
M=90kg [200lb] COPPER
M=280kg [610lb] SS304



M=2.8E3kg [6lb] ASTM A677 NON-ORIENTED ELECTRICAL STEEL, M-15







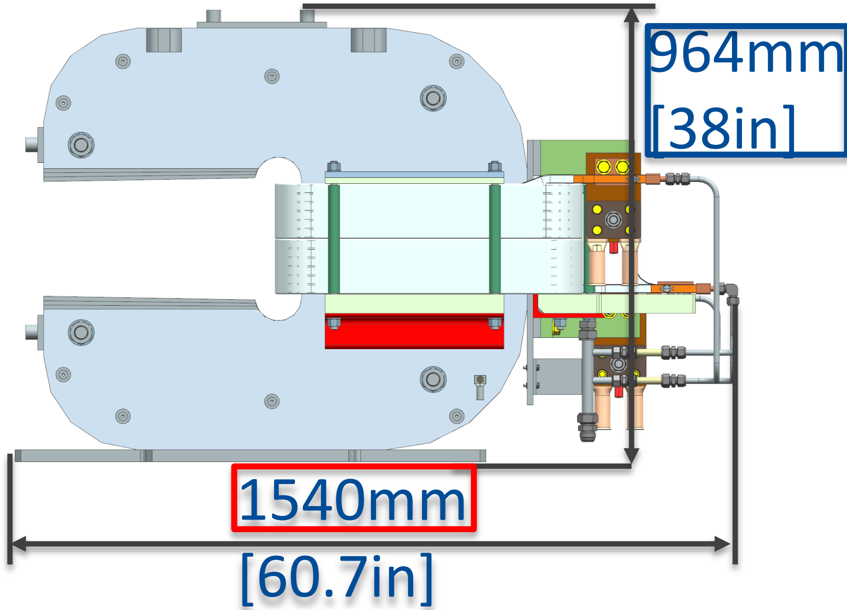
M=45kg [1.2E3lb] OXYGEN FREE COPPER

COIL x 2

PULSED DIPOLE MAGNET ASSEMBLY

Table 1 Extraction Magnet Common Requirements

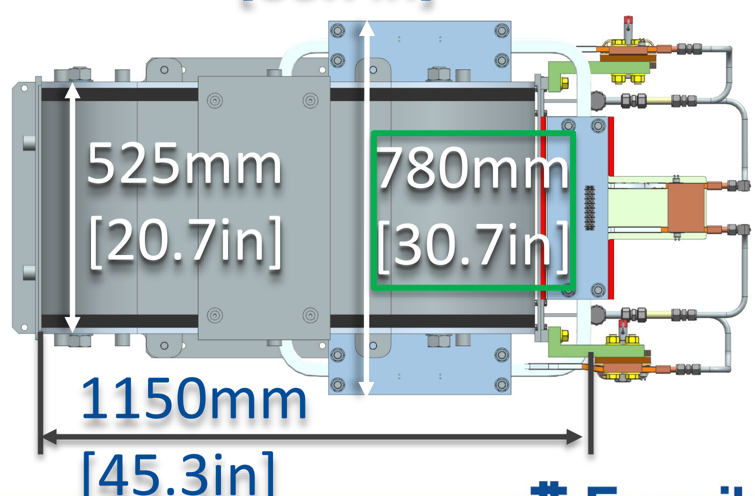
ID	Requirement	Traceability [1], [12], [13], [14]
	Magnet Assembly	
S02.02.03-R011	For extraction magnets located in the RTBT tunnel, any piece that will be lifted with the RTBT tunnel overhead crane for installation or maintenance should weigh no more than 12.5 tons (11,340 kg) but shall weigh no more than 25 tons (22,680 kg). **Discussion:** There are two 12.5 ton cranes on a single rail in the RTBT that can be used together if necessary.	Design requirement



M~3.5E3kg
[7.7E3lb]

Table 2 Pulsed Dipole Requirements

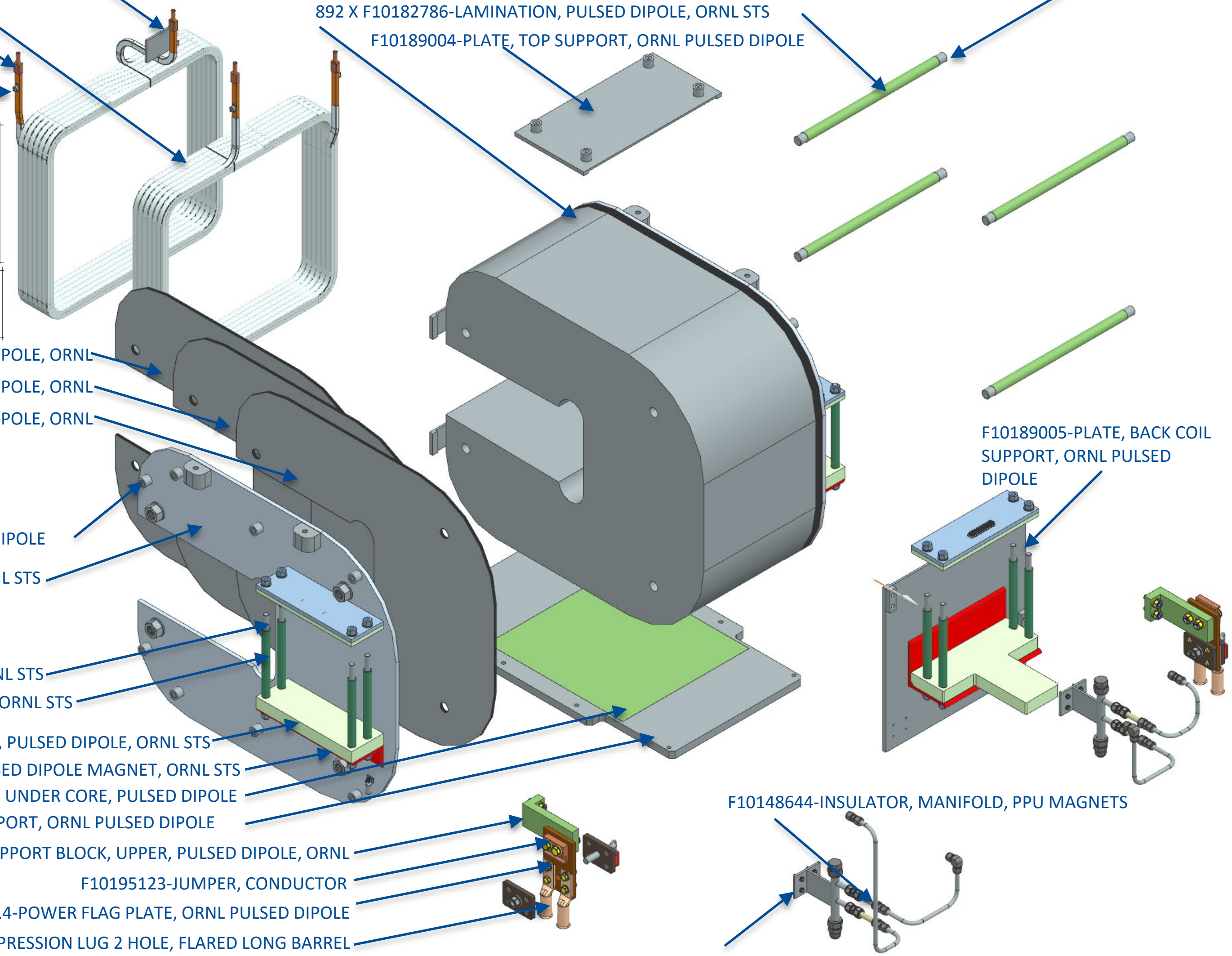
ID	Requirement	Traceability [1], [12], [13], [14]
	Pulsed Dipole Magnet Assembly	
S02.02.03-R041	The Pulsed Dipole magnet assembly shall fit into a volume such that X ≤ 1.20, Y ≤ 1.00, Z ≤ 0.70 meters **Discussion:** To avoid having to move any magnets in the RTBT. X is width, Y is height, and Z is along beam axis.	S02-R007



MAGNET ASSEMBLY

S02.02.03-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.

S02.02.03-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.



CORE ASSEMBLY

Table 2 Pulsed Dipole Requirements

ID	Requirement	Traceability [1], [12], [13], [14]
	Pulsed Dipole Magnet Assembly	
S02.02.03-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.	S02.02.02-R004 S02.02.02-R007 S02.02.02-R008 S02.02.02-R009

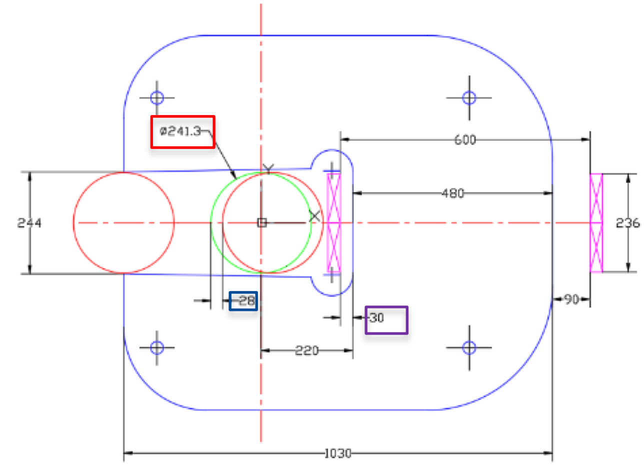


Fig. 5. Beampipe in the center (green), shifted 28 mm to the coil and at the pole edge (red).

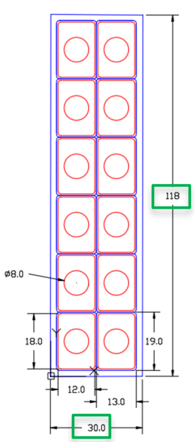


Fig. 4. Coil dimensions. Conductor 12 x 18 mm, hole dia. 8 mm, 12 turns, 2 coils.

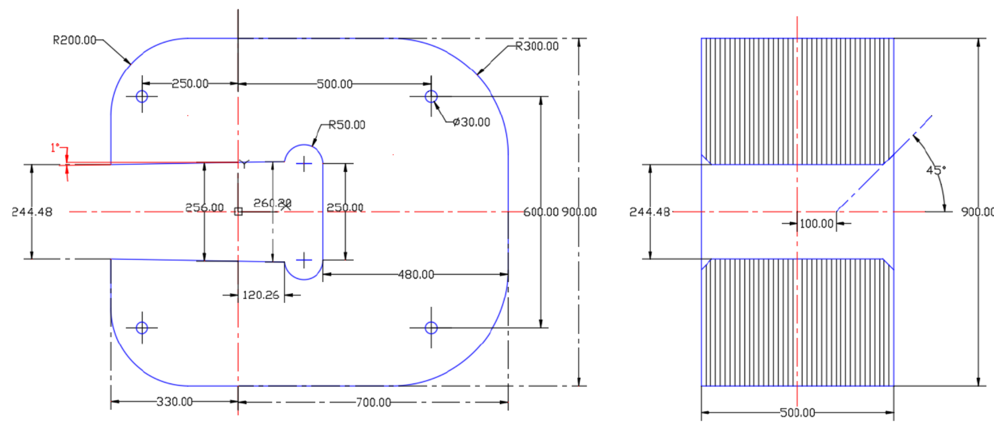


Fig. 2. Magnet core dimensions.

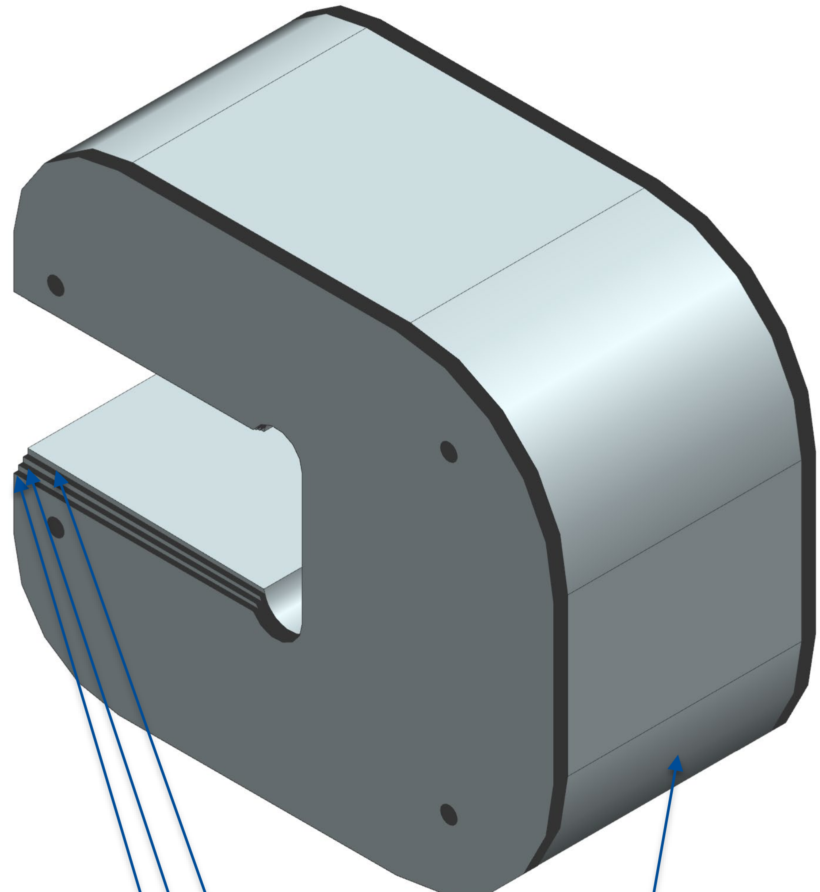
CORE ASSEMBLY

- Lamination material AK M15, C-5 electrical insulation 0.5 mm thickness

Thickness Corresponding to Electrical Steel
Standard Gauge Numbers (ESSG No.)

ESSG No.	Inches	Millimeters
29	0.014	0.36
26	0.0185	0.47
24	0.025	0.64

- The lamination will be produced using a two stage die to insure critical dimensions tolerances. The end lamination final dimensions will be achieved by secondary operation.



Requirements

- Material should conform specification (TBD)
- Lamination before stamping must be handled carefully so as not to cause damage by bending, denting scratching
- The edge burr shall not exceed max value (TBD)
- Variation between parts shall not exceed (TBD)
- Piece parts shall be flat within (TBD)

COIL

- Coils wound and potted at Fermilab
- Two identical coils (rotated 180). Leads are different
- Turn electrical insulation 0.5mm. Coil ground insulation 2mm

ID	Requirement	Traceability [1], [12], [13], [14]
	Magnet System	
S02.02.03-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* [2] 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

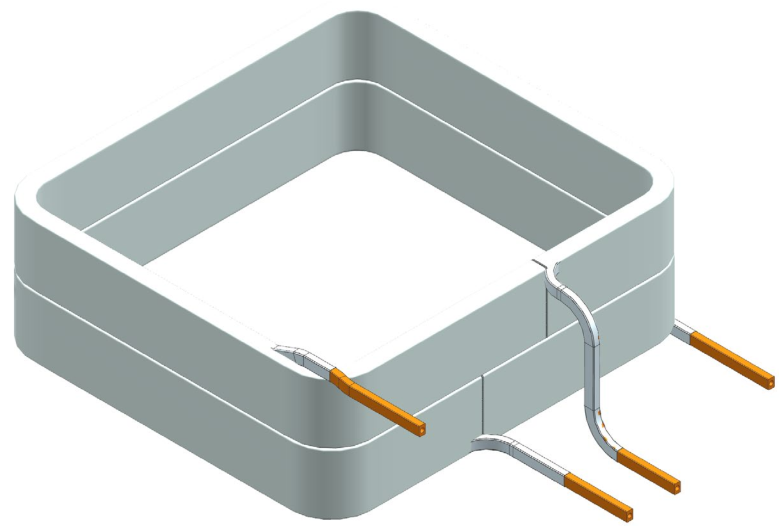
I [A]	S [mm^2]	I/S [A/m^2]	I/S [A/cm^2]
660	1.65E-04	4.00E+06	400
1606	1.65E-04	9.73E+06	973

S02.02.03-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
S02.02.03-R025	The water-cooled extraction magnet coils shall meet the requirements of Specification for Radiation Resistant Fiberglass/Epoxy Insulated Magnet Coils [5]. **Discussion:** This includes silver plating, hydrostatic test to 300 psi, turn-to-turn insulation test.	S02-R004

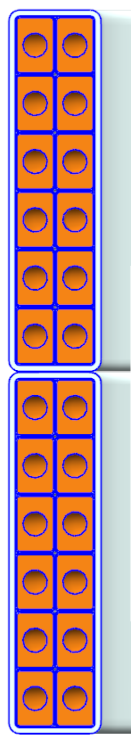
5. 105030100-TS0001-R0, *Specification for Radiation Resistant Fiberglass/Epoxy Insulated Magnet Coils*

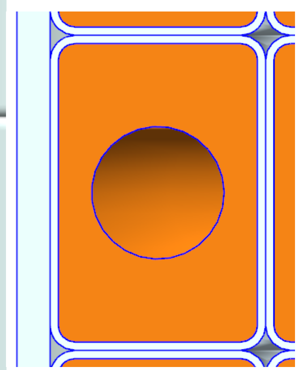
S02.02.03-R016	Unless otherwise stated, the assembled extraction magnet shall withstand 1000 V DC for one minute between the coil leads and the magnet core without evidence of insulation damage or breakdown, or leakage current > 5 µA.	S02-R004

F10182796-COIL ASSEMBLY, UPPER, PULSED DIPOLE, ORNL STS

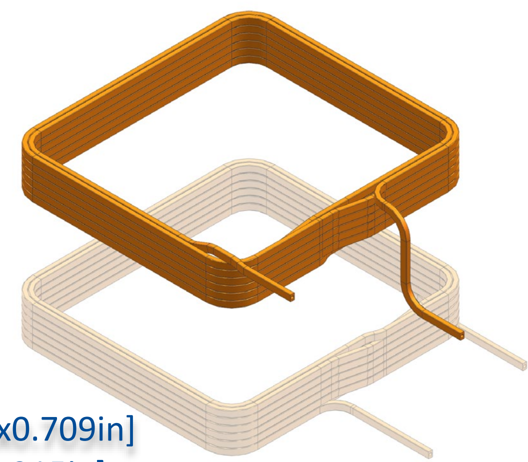


6x2 turns





F10182797-COIL ASSEMBLY, LOWER, PULSED DIPOLE, ORNL STS



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

COOLING PARAMETRS

Table 1 Extraction Magnet Common Requirements

ID	Requirement	Traceability [1], [12], [13], [14]
	Magnet System	
S02.02.03-R004	Water-cooled extraction magnet coils shall 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
S02.02.03-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* [3], "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 ≤ R_e ≤ 100000)."	S02-R004
S02.02.03-R006	The cooling water pressure differential across the extraction magnets shall not exceed 60 psi (414 kPa) to meet requirement S02.02.03-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
S02.02.03-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

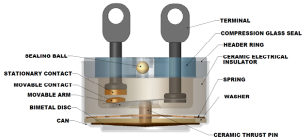
Parameter	Unit	Value
Average power losses	kW	3.371
Conductor dimensions (hole diameter)	mm	12 x 18 (8)
Water pressure drop (20 psi)	MPa	0.138
Total water flow	l/s	0.138
Water velocity	m/s	1.375
Water temperature rise at 2 water circuits	°C	6

MANIFOLD ASSEMBLY

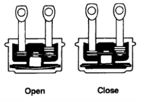
Table 1 Extraction Magnet Common Requirements

ID	Requirement	Traceability [1], [12], [13], [14]
	Magnet System	
S02.02.03-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. **Discussion:** There needs to be an indication of what caused the power supply to shut off. See AS1-2 in PHA [1].	S02-R009 PHA
	Magnet Assembly	
S02.02.03-R008	Water-cooled extraction magnet coils shall have at least one temperature switch per water flow path. The switch shall be mounted directly on the coil conductor near the cooling water outlet end of the coil. **Discussion:** The purpose of the switch is to detect coil heating that could result in a fire. See AS1-2 in PHA [1].	S02-R009 PHA
S02.02.03-R009	The temperature switch required in S02.02.03-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-R009 PHA

Typical Cross Section View



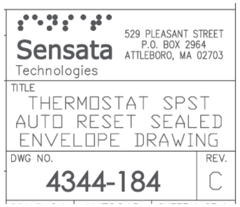
Operation

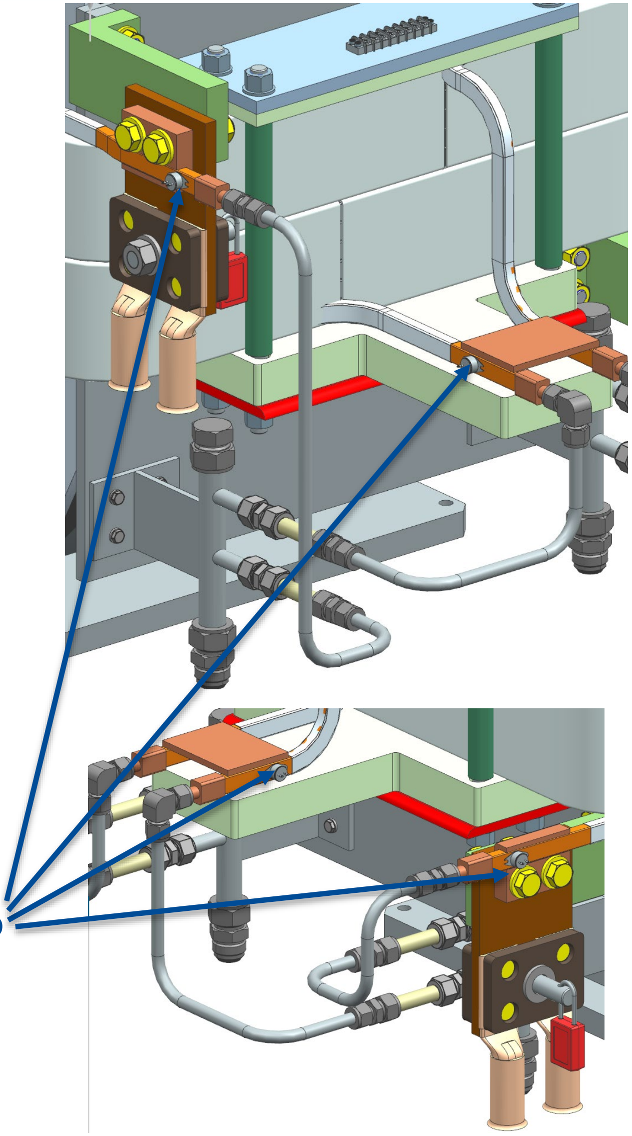


When heated, the internal stresses of the bi-metal cause the disc to reverse its curvature with a snap-action at a fixed, preset temperature and operate the electrical contacts.

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.

FC0075125-SWITCH, THERMAL, SINGLE POLE SEALED





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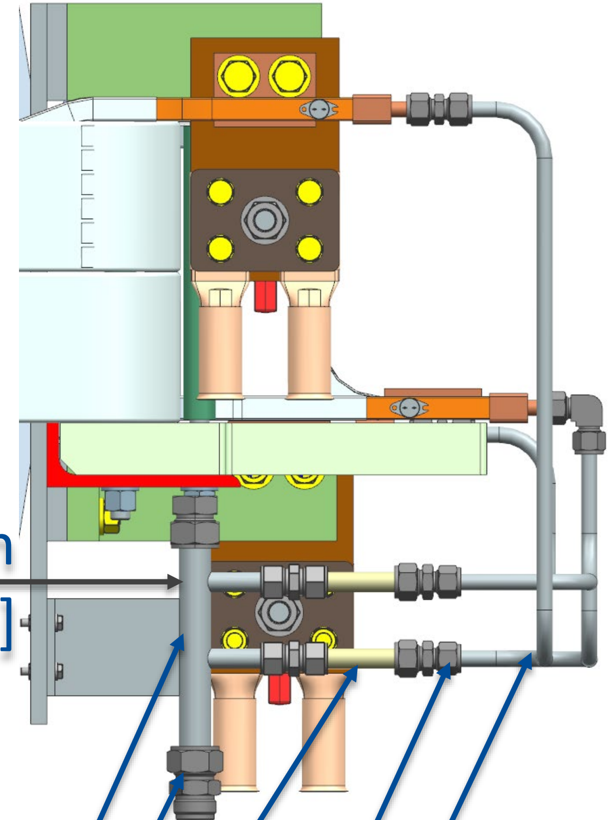
MANIFOLD ASSEMBLY

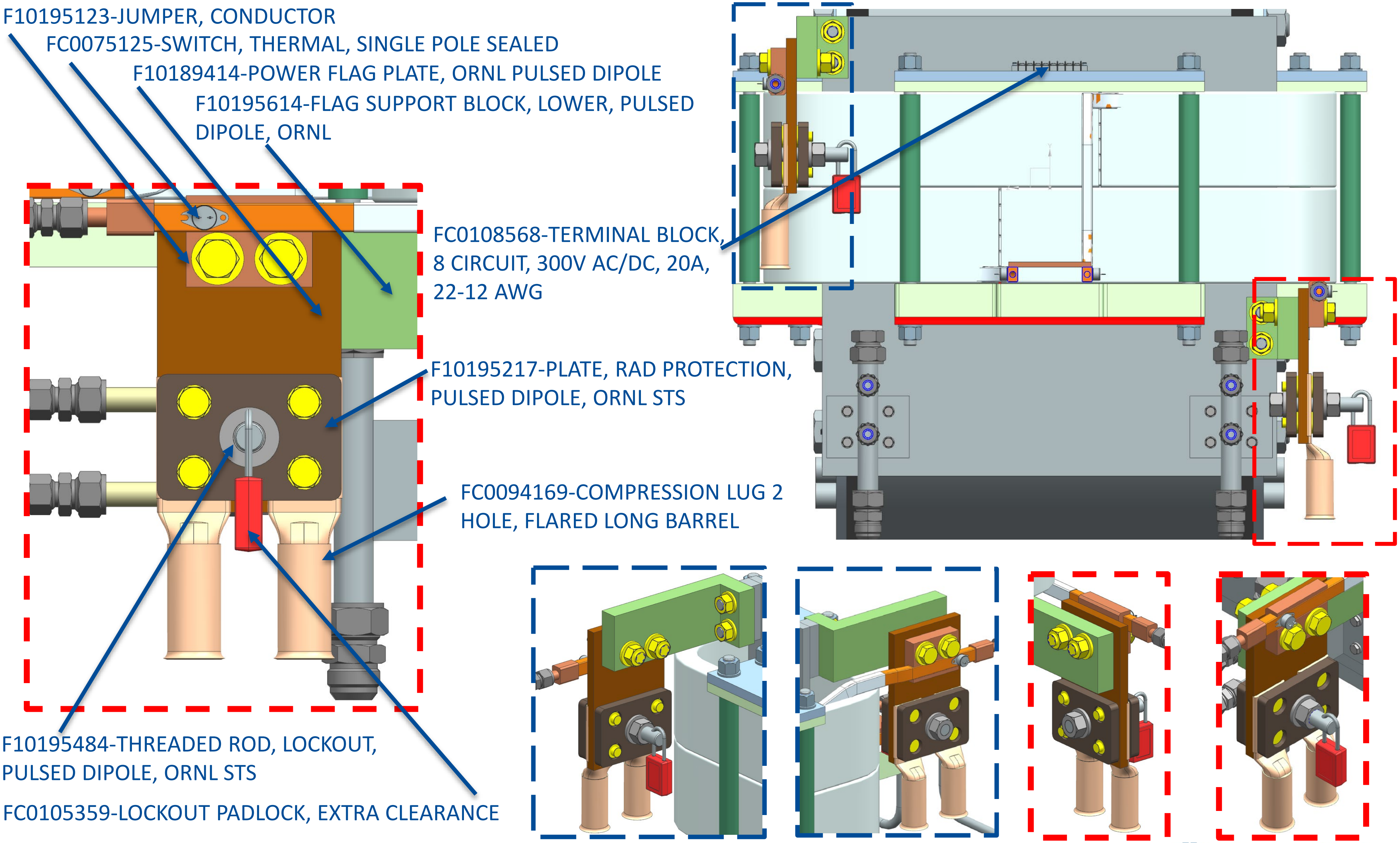
Table 1 Extraction Magnet Common Requirements

ID	Requirement	Traceability [1], [12], [13], [14]
	Magnet Assembly	
S02.02.03-R010	All extraction magnet water manifold components shall be electrically grounded to the magnet core.	SBMS
S02.02.03-R027	The extraction magnet 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 [6], and Review of Cooling Water Chemistry at ORNL/SNS [3] for water quality discussions.	S02-R004
S02.02.03-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.	Design Requirement
S02.02.03-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



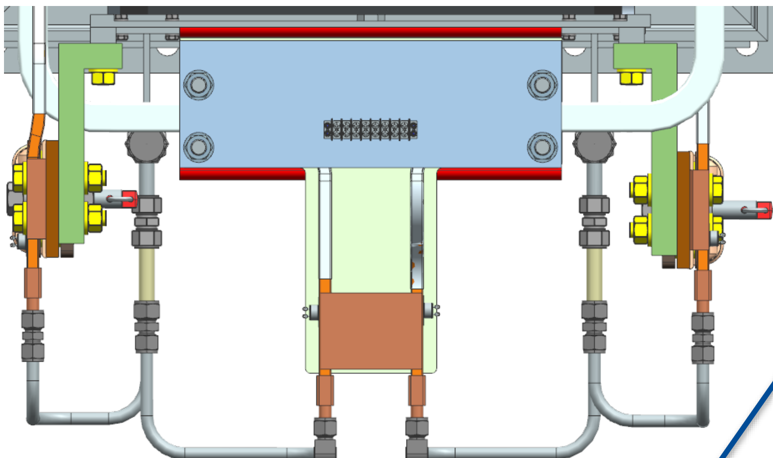
F10189376-MANIFOLD BODY, LEFT, ORNL PULSED DIPOLE, SS316
FC0075589-UNION, 1" TUBE OD X 1" AN TUBE FLARE, SS316
F10148644-INSULATOR, MANIFOLD, PPU MAGNETS, PEEK, GLASS FIBER FILLED
FC0075588-UNION, 1/2" OD TUBE, SS316
F10196280-TUBE 1, ORNL PULSED DIPOLE, SS316

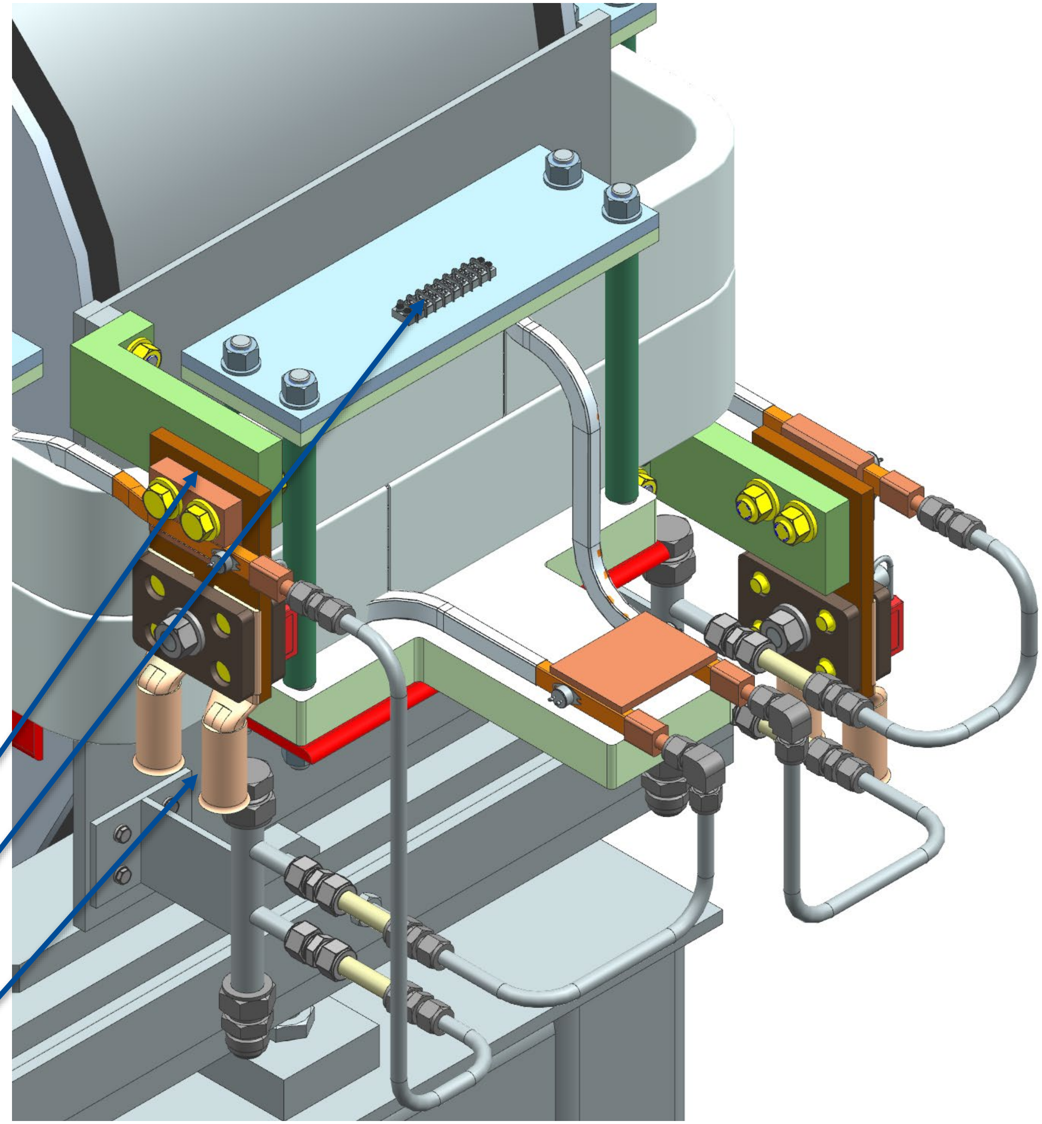
POWER FLAG ASSEMBLY



POWER FLAG ASSEMBLY

ID	Requirement	Traceability [1], [12], [13], [14]
	Magnet Assembly	
S02.02.03-R018	The extraction magnet shall be designed with terminal blocks or flags to mate with cable termination lugs. **Discussion:** Intent is to conform to SNS standard connections.	Design Requirement
S02.02.03-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





F10189414-POWER FLAG PLATE, ORNL PULSED DIPOLE

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

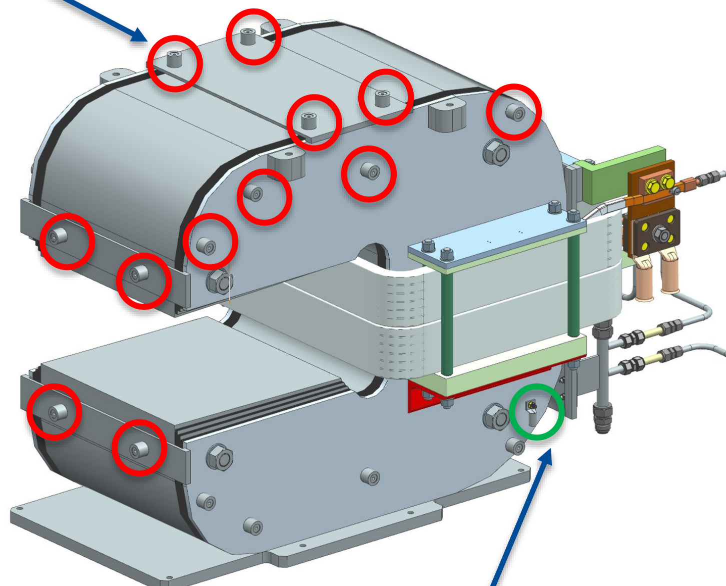
FC0094169-COMPRESSION LUG 2 HOLE, FLARED LONG BARREL

FIDUCIALS

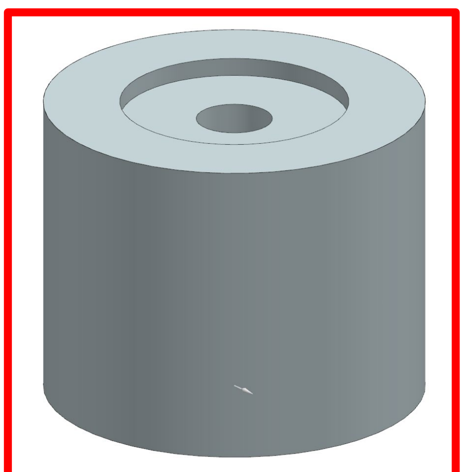
Table 1 Extraction Magnet Common Requirements

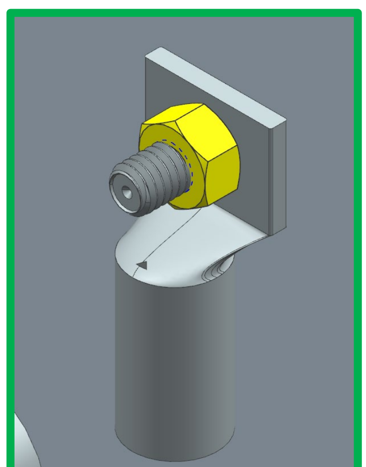
ID	Requirement	Traceability [1], [12], [13], [14]
	Magnet Assembly	
S02.02.03-R014	The extraction magnet shall have external fiducials capable of supporting magnet alignment to 100-micron in x/y and 1-mrad yaw, pitch, and roll. **Discussion:** This requirement is relative to the SNS Coordinate System where the Z axis is along the beam line. The location of fiducials on the magnet is important – details TBD. The positioning along the beam axis is not as critical – within ~ 1 cm.	S02.02.01-R009 S02.02.02-R007
S02.02.03-R021	The extraction magnet core shall be grounded to the tunnel ground system.	SBMS

F10189358-MOUNT BLOCK, FIDUCIAL, ORNL PULSED DIPOLE



FC0107837-COMPRESSION LUG, .64"OD, 1 HOLE





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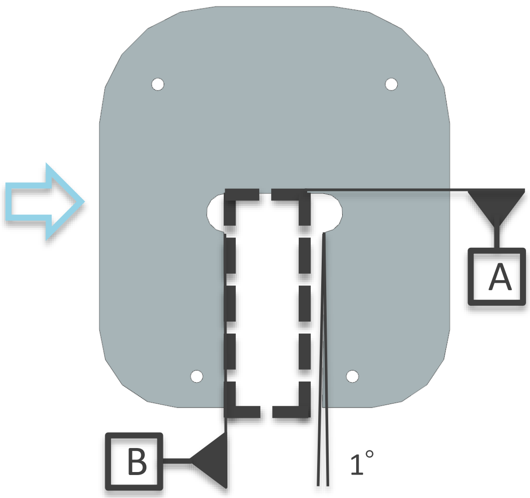
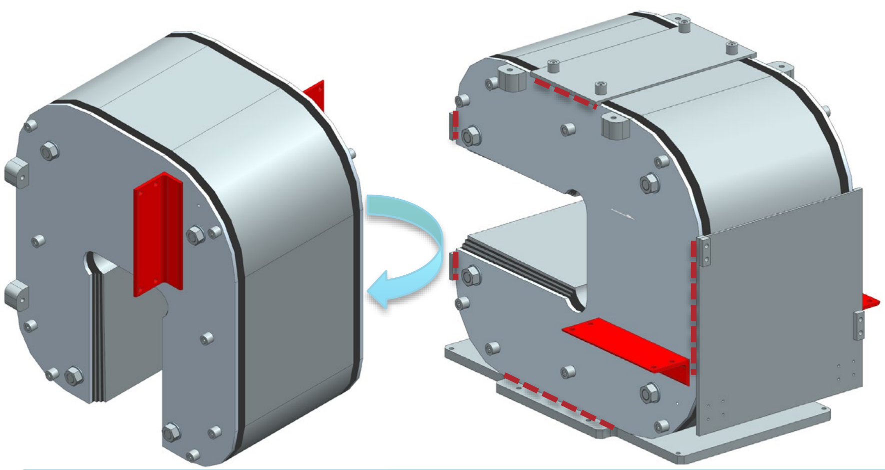
ASSEMBLY METHODS

- Laminations produced outside
- Coils wound and potted at Fermilab

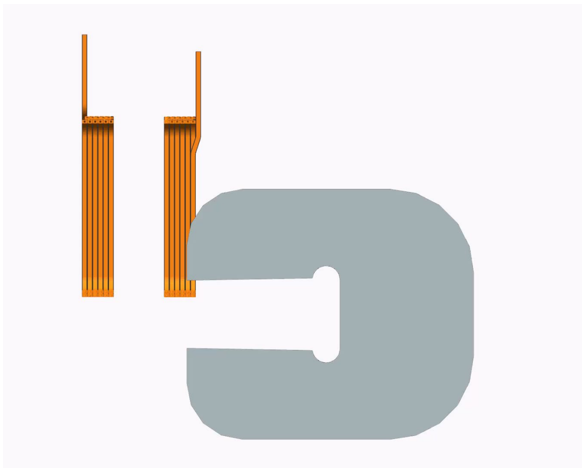
1. Staking



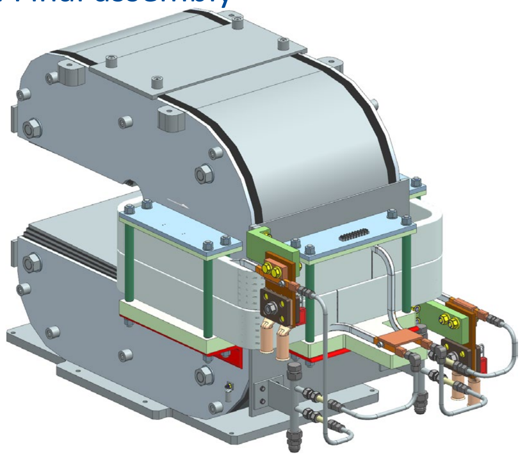
2. Welding



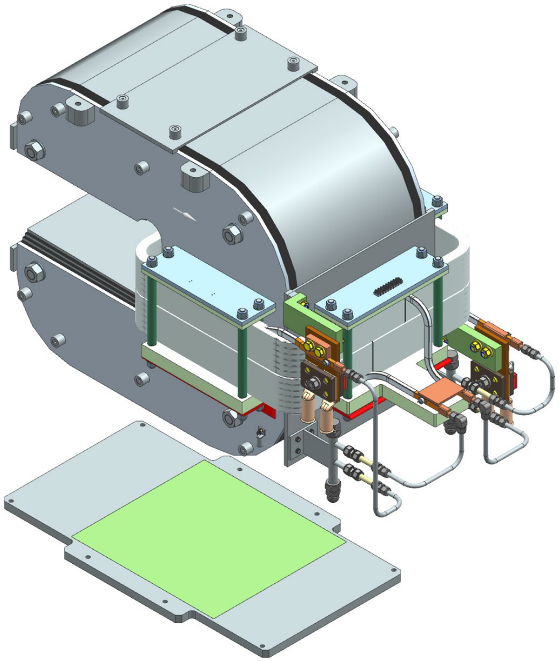
3. Coil installation



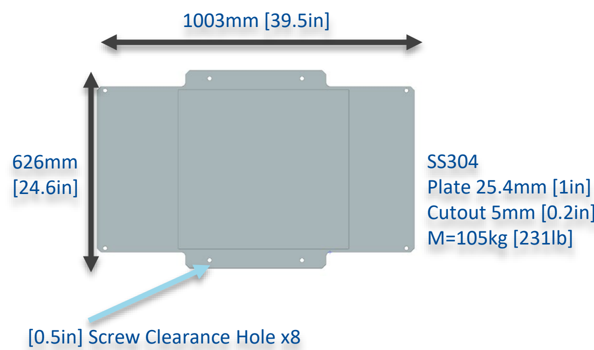
4. Final assembly



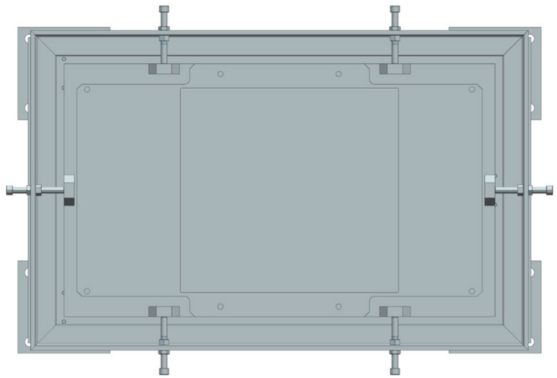
STAND INTERFACE

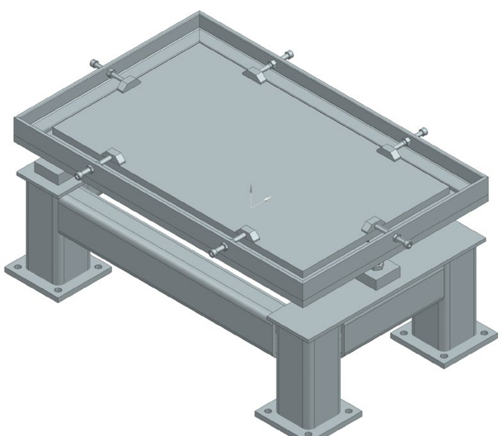


F10189003-PLATE, BOTTOM SUPPORT, ORNL PULSED DIPOLE

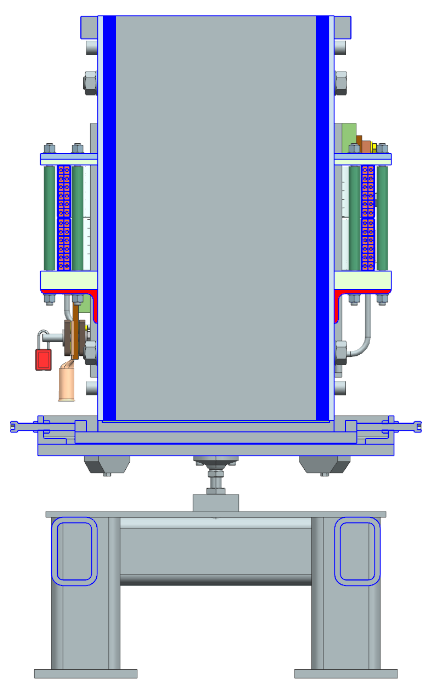


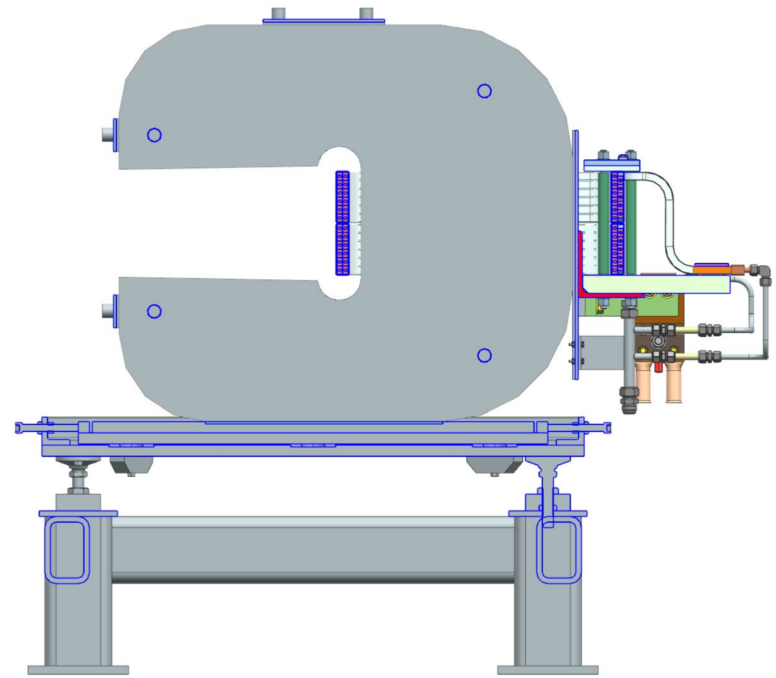
FC0099587-STAND, ORNL PULSED DIPOLE -FROM ORNL





FC0099587-STAND, ORNL PULSED DIPOLE -FROM ORNL





Fermilab

SUMMARY

- 3D CAD model (99% complete)
- Materials and manufactured process were identified
- Current design within engineering parameters
- Assembly
  a. Core steel manufactured by outside vendors
  b. Coils wound and potted at Fermilab.
  c. Final assembly, QA and testing at Fermilab
- We are at design point where the magnet cost can be estimated with high confidence