



# 21Q40 Narrow Quadrupole PDR

## Compliance with Specification

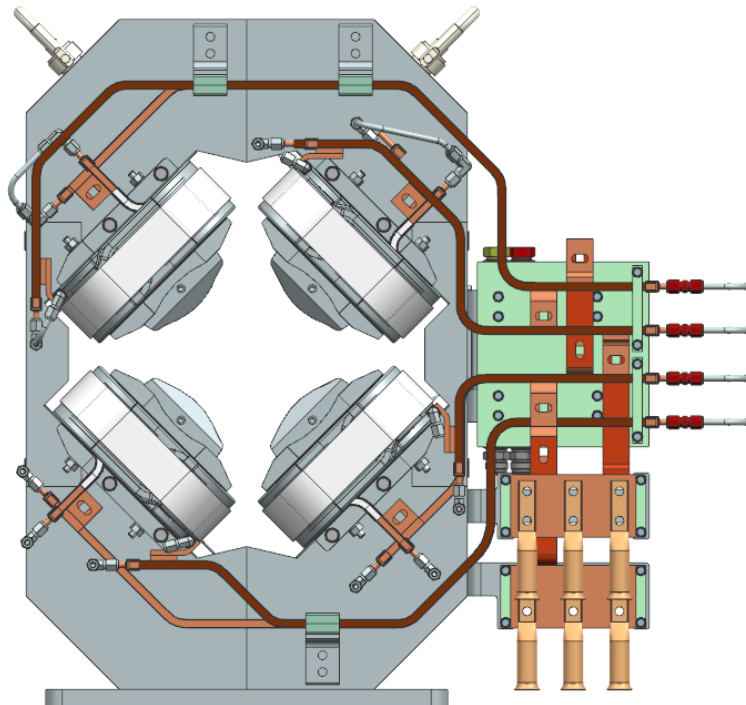
Vitaly Chernenok

16 April 2024

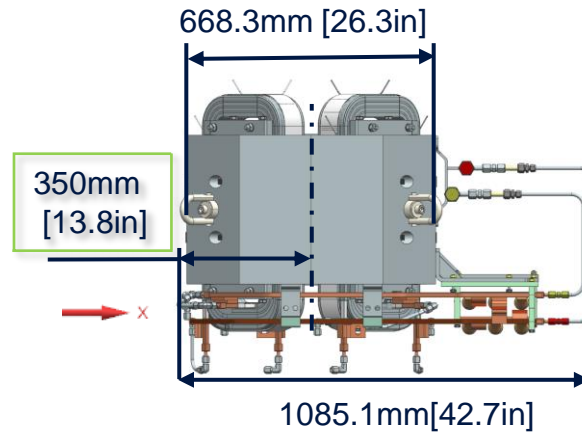
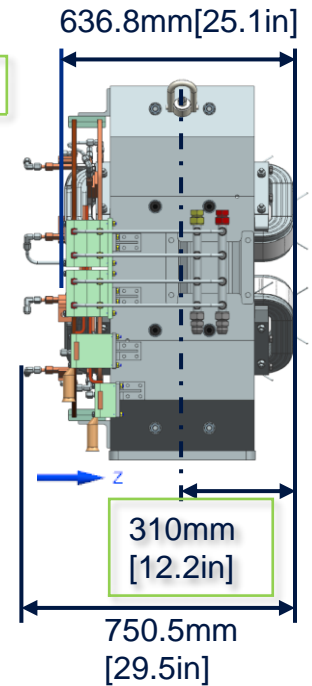
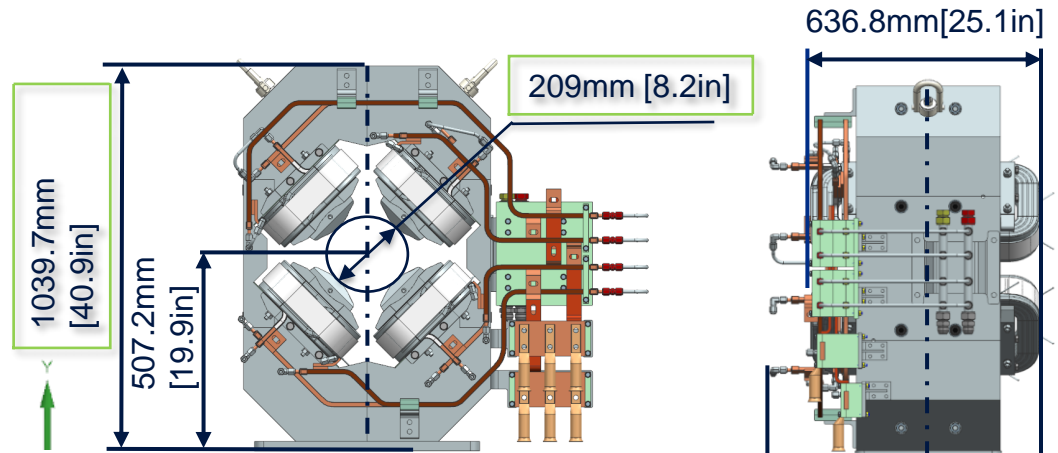
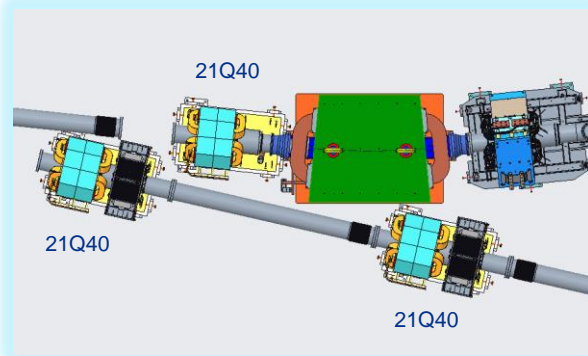
# Outline

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- Geometric dimensions
- Parameter list for cooling system
- Temperature switch
- Grounding and fiducials
- Power flags
- Summary



# Overall dimensions



ID	Requirements	Traceability [13]
S02.04-R061	The Narrow 21Q40 Quadrupole magnet assembly shall have an aperture $\geq 20.9$ cm (8.2 in) diameter.	S02-R006 S02-R009
S02.04-R062	The Narrow 21Q40 Quadrupoles magnet assembly shall fit into a volume such that $X \leq 0.70$ , $Y \leq 1.10$ , $Z \leq 0.64$ meters  Discussion: To avoid interference between the RTST and the RTBT magnets. X is width, Y is height, and Z is along beam axis	S02-R003 S02-R007 S02-R006

# Parameter list for cooling system

ID	Requirement	Traceability [13]
S02.04-R002	Water-cooled extraction magnet coils should be designed for a current density < 450 Amps/cm <sup>2</sup> . The current density shall not exceed 1000 Amps/cm <sup>2</sup> .	S02-R004
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-R024	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
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



6.35mm [0.25in]

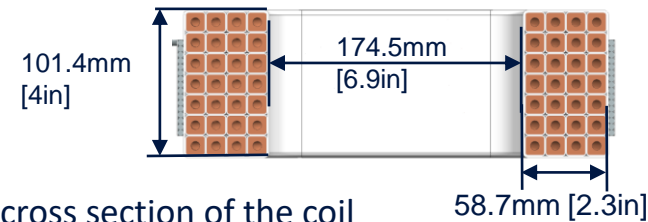


Conductor cross-sectional  
127.7 mm<sup>2</sup> [0.198 Sq.inch]

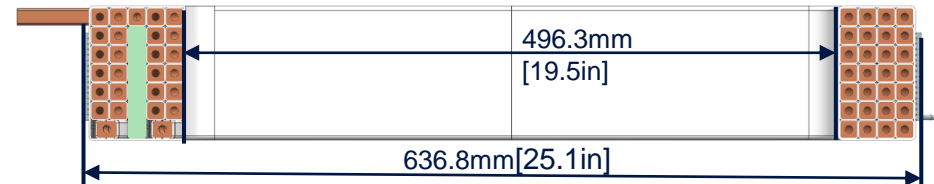
## Electrical power (one coil)

Parameters	Value	Units
Current	978	A
Power losses	5.562	kW
Electrical resistance	0.006	Ohm
Current density	765	Amps/cm <sup>2</sup>
Voltage drop	5.87	Volt

## Front cross section of the coil



## Side cross section of the coil



# Parameter list for cooling system

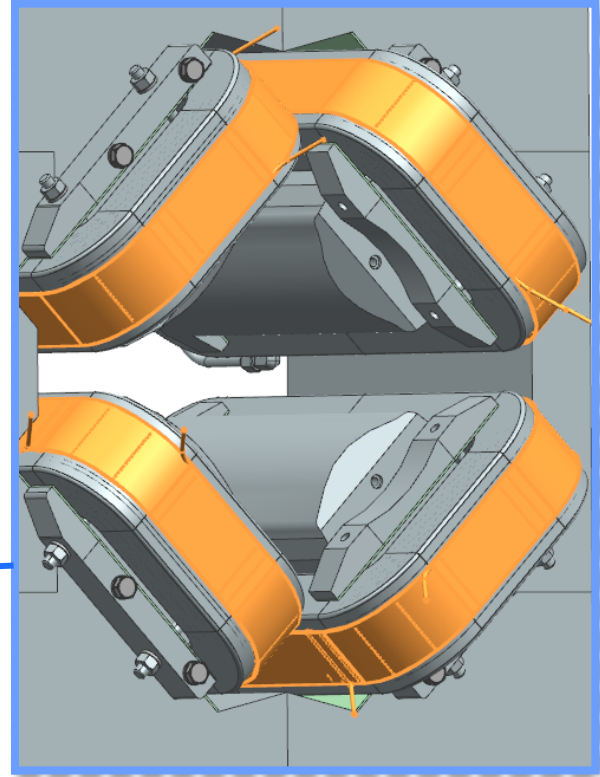
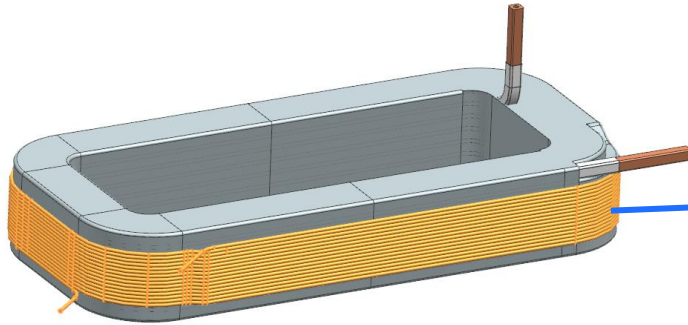
ID	Requirement	Traceability [13]
S02.04-R004	Water-cooled extraction magnet coils should be designed to have a temperature rise <b>&lt; 20° C (36° F)</b> at the maximum power supply current with an inlet water temperature between 29.4° C (85° F) and 35.0° C (95° F). Discussion: Desired maximum temperature 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 <b>&lt; 2 m/s (6.56 ft/s)</b> . 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 <b>60 psi (414 kPa)</b> 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 psi (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

## Cooling system

Parameters	Value	Units
Parallel branch	4	Quantity
Number of turns in one parallel branch	28	Quantity
Copper conductor	0.25x0.25 12.7x12.7	In mm
Diameter of the hole in the conductor	0.25 6.35	In mm
Conductor cross-sectional	0.198 127.7	Sq.inch mm <sup>2</sup>
Nominal input temperature	30 86	° C ° F
Water pressure drop	<b>58</b> 405.3	psi kPa
Total water flow	0.054	l/s
Water velocity	<b>1.71</b>	m/s
Overheating	<b>77.9612</b> 24.534	° F ° C

# Trim coils

ID	Requirement	Traceability [13]
S02.04-R057	<p>The Narrow 21Q40 Quadrupole magnet assembly shall have a trim coil wound on each main coil with an integrated quadrupole field of 0.0284 T.</p> <p>Discussion: The Narrow Quad trim coil will have the same field as the existing 21Q40 trim [1].</p>	S02-R007

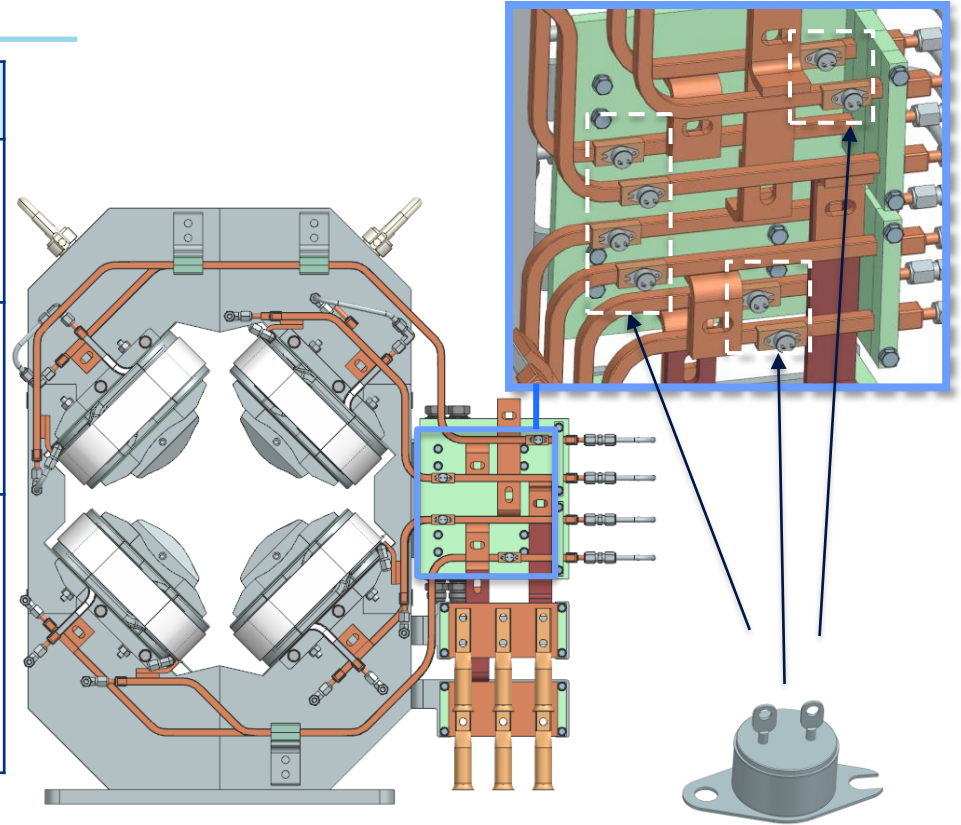


- Trim coils are installed in all main coils

# Temperature switch

ID	Requirement	Traceability [13]
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 $170^{\circ} \pm 5^{\circ} \text{ F}$ ( $76.7^{\circ} \pm 2.8^{\circ} \text{ C}$ ) trip point. The switch contacts shall be electrically isolated from the coil. The reset temperature shall be specified to be $150 \pm 5^{\circ} \text{ F}$ ( $65.6^{\circ} \pm 2.8^{\circ} \text{ C}$ ).  Discussion: The preferred switch is Sensata 4344.	S02-R004 S02-R006

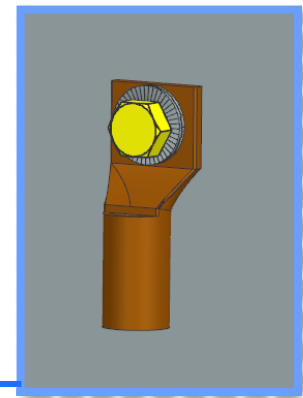
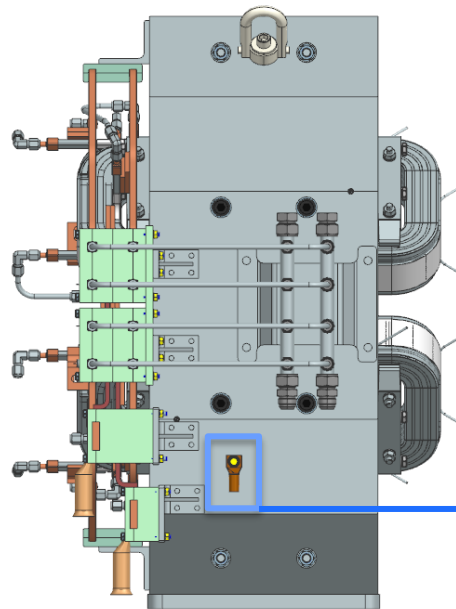
The Sensata 4344-184 is a KLIXON® Commercial Hermetic 1/2" Thermostat manufactured by Sensata Technologies  
Trip point -  $170^{\circ} \pm 5^{\circ} \text{ F}$  ( $76.7^{\circ} \pm 2.8^{\circ} \text{ C}$ ).



FC0075125-SWITCH, THERMAL, SINGLE POLE SEALED

# Grounding and fiducials

ID	Requirement	Traceability [13]
S02.04-R010	All extraction magnet water manifold components shall be electrically grounded to the magnet core.	S02-R009
S02.04-R021	The extraction magnet core shall be grounded to the tunnel ground system.	S02-R009
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 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-R003 S02-R007



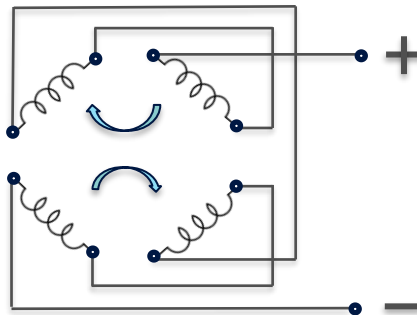
COPPER LUG1 HOLE, STD BARREL

Currently, locations for fiducials were not determined.

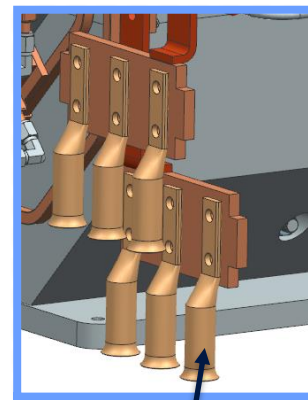


# Power flags

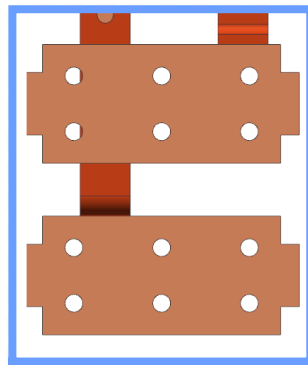
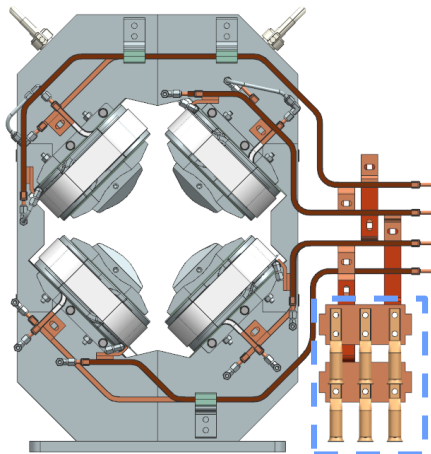
ID	Requirement	Traceability [13]
S02.04-R018	<p>The extraction magnet assembly shall be designed with terminal blocks or flags to mate with cable termination lugs.</p> <p>Discussion: Intent is to conform to SNS standard connections.</p>	Design Requirement



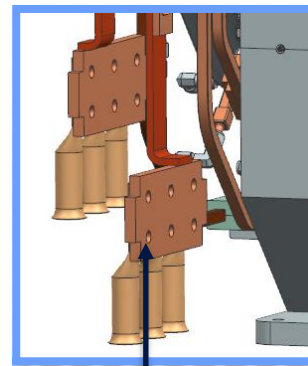
▪ Electrical diagram



COMPRESSION LUG, 2 HOLES, LSSF500-12-6



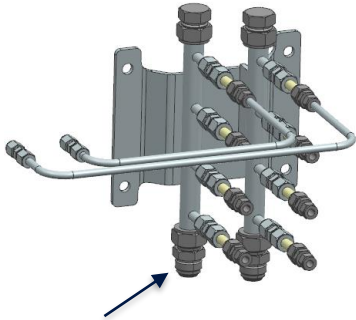
- Thickness busbars 12.7 mm
- Contact area 18588 mm<sup>2</sup>
- Bolted connection for M12



POWER FLAG, NARROW QUAD, ORNL STS

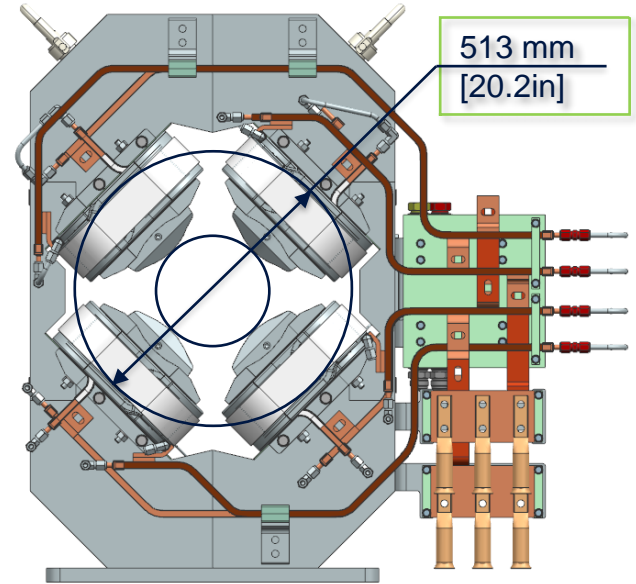
# Manifolds assembly

ID	Requirement	Traceability [13]
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.	Design Requirement
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



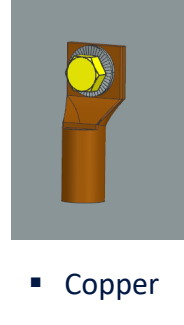
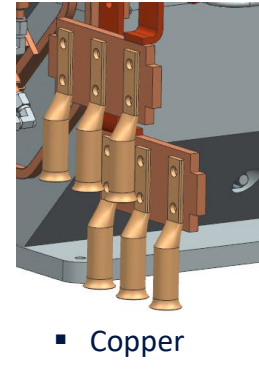
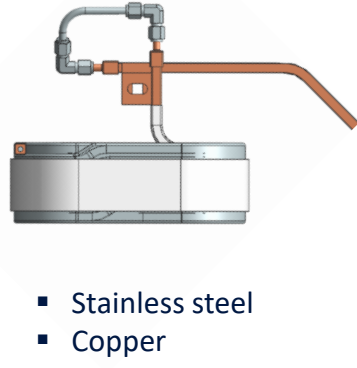
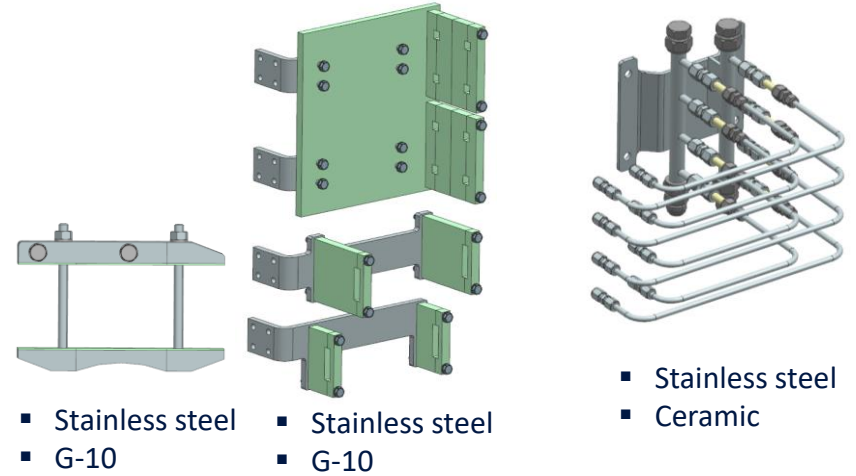
UNION, 1" TUBE OD X 1" AN TUBE FLARE, SS316

- Compatible with female 37° flair JIC (SAE J514/ISO 8434-2)



# Materials

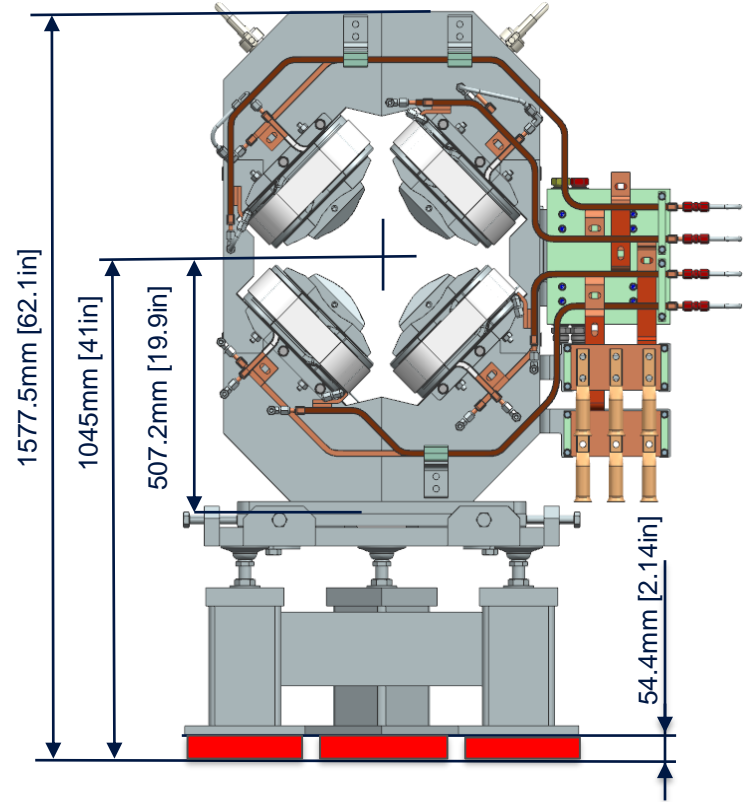
ID	Requirement	Traceability [13]
S02.04 -R027	<p>The extraction magnet assembly wetted parts shall be OFHC copper, stainless steel, ceramic, or approved hose material.</p> <p>Discussion: No aluminum or brass is allowed. OFHC copper and stainless steel are preferred. See Characterization of Particulate 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.</p>	S02-R004



# Stand interface

ID	Requirement	Traceability [13]
S02.04-R020	<p>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.</p> <p>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"..</p>	S02-R003 S02-R007

 - MOUNTING ELEMENTS [54.4mm or 2.14in]



# Summary

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- The Narrow quadrupole design was reviewed to ensure compliance with the specification.
- The water-cooling parameters in the chapter overheating are agreed upon.
- The fiducial system has not been developed but will be added shortly.
- The presented design corresponds to the required technical characteristics.