Action Lists and Responses for Last Review on Engineering Design of the MICE Coupling Magnet Cryostat

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Topic		Review Findings/Comments/Recommendations	Responses	Responsible person	Annotation
Cryostat design	Interface issues between CC cryostat and RF module	Does the mechanical design provide appropriate space for the required MLI? The Coupling Coil cryostat has very stringent space restriction that place very strong constraints on the cold mass assembly, the 70K shield and the magnet's robustness with respect to assembly errors and added heat load. The tightest area is near the coupler cut-outs and this is potentially a problem area.	Since the extremely tight space inside the CC cryostat is in RF coupler region, which is difficult for MLI and assembly as well as being a potential problem area for added heat load. 1). LBNL will make RFCC module slightly longer and keep the RF coupler dimensions, which gives 20mm more space at each side in RF coupler region for MLI of the coupling coil, and will make assembly easier and less risky. 2). The bottom RF vacuum port opening was changed to 3.125" diameter by LBNL to give more clearance locally. 3). The design for the related parts on the CC vacuum vessel was updated accordingly to provide more room for inside parts and MLI. 4). The side plates of thermal shields were modified as a whole body then without any indents on them.	CAO,Yun/Allan Demello	See the details of 3D model
		The gussets have changed position because the angle of the support towers for the cold mass has been changed to the design value 10.03 degree from about 7 degree. This in general does't present a problem to the interface with the vacuum vessel of the RFCC,but must be taken into consideration in the final fabrication drawings.	1). The angles of the gussets have been changed to make room for inserting the RF cavity tuner actuators and avoid interference with the RFCC module support stand mounting bracket 2). 4 of the lower LBNL gussets (2 on each side of coupling coil) was angled in by 10°by LBNL to avoid interference with the support stand.		
		The lower access openings on either side of the new cryostat design interfere with the RFCC support structure.	The lower access openings were shortened to avoid the interference with the RFCC support frame.The current size is 540 mm in length, 430 mm in width, and 16 mm in thickness.		
		The 2.75 inch diameter auxiliary port on the top of the RFCC vacuum vessel interferes with the bracing added to the cryostat utility tower front and rear plate.	The 2.75 inch diameter auxiliary port on the top of the RFCC vacuum vessel interfering with the bracing added to the cryostat utility tower front and rear plate was moved to the other places by LBNL.		
		The lower cold mass support towers on either side of the new cryostat design interfere with the RFCC support structure.	SINAP designed a thinner spherical washer for the load cell to be installed at the warm end of the cold mass support, and then shortened the cold mass support towers where they interfere with the support stand. The cuurent size for the tower cover sleeve is 110 mm in length and 130 mm in outer diameter.		
	Flange connection and seals	The two large rectangular tower flanges should be welded with a weld prep capable of multiple weld/grind operations. O-rings should not be used in these areas. The covers on the sides of the tower should be flanged with O-rings.	The two large rectangular tower flanges on upper turret part as well as two lower access openings on lower vessel were all changed to be welded with a weld prep capable of multiple weld/grind operations at least 5 times. And the welding design was confirmed by the manufacturer (QiHuan). The covers on the sides of the upper turret were designed to be flanged with O-rings.	CAO,Yun	See the details of 3D model
	Access ports for repairs or maintenance	Does the mechanical design allow for repairs? Are there sufficient access ports in the vacuum can?	There are several demountable access ports designed respectively on the upper turret and lower parts of the CC vacuum vessel as well as on the neck shield inside,which may be easily disassembled for maintenance and repairs of inner local parts. The two large rectangular tower flanges and two lower access openings can be disassembled by cutting-away welds, and then to inspect and fix inner parts.		

	FEA analyses	Does the cryostat design support all expected loads? Redo the ANSYS simulations for the case with correct boundary conditions between the cover plate and vessel. Assess the stress at the top tower, cover plate joints and cold-mass support. Verify the cryostat meets the pressure vessel code.	The FE simulation was performed for the updated design of the CC vaccum vessel with more practical boundary conditions for two large rectangular tower flanges, and the stress and deformation on the vaccum vessel under different load cases of cold mass supports were studied. The necessary calculations were done for the cryostat to verify it meets the pressure vessel code.	WANG,Li	See the details in PPT "Calculations and FEA simulations for MICE/Muool Coupling Magnet Cryostat Design".
	Vacuum System	Appropriateness of the planned vacuum pumping system and vacuum instrumentation.	A DIN100 port wass designed for the vacuum pumping out port to connect the pumping system comprising a mechanical pump and a molecular pump, and provision was made for vacuum instrumentation including Pirani gauge(s),Cold and/or Hot cathode gauge(s), and Residual Gas Analyzer. Additional auxiliary ports were provided as well.	CAO,Yun	See the details of 3D model
	Shielding issues (Is the thermal shield design/cooling adequate?)	The shield design is quite complicated and great care will be required in both finalizing its design and in the execution of its parts fabrication and assembly. There are quite a number of individual components to the shield.	The shield design has been simplified due to more room given by lengthened space between RF couplers. Both side shields were designed as a whole body without any indents.	CAO,Yun	See the details of 3D model
		Improvement of the thermal contact at all the joints in the thermal shield is very important. Any thermal joints on the shield should be made with metal fasteners, if possible, in order to maximize the clamping load (i.e. stainless fittings with Belleville washers). For joints that need to be electrically insulated, a sleeve arrangement will be needed.	Modifications have been made according to the recommendations. The indium sheet will be applied bwtween contact surfaces of any themal joints for good contact, and the metal fasteners were adopted for all the thermal joints.		
		The 4 K cold mass support clevises must be shielded. If possible, the shield should be extended around the lower part of the cold mass supports to the cold mass support intercepts. There must be absolutely no shine from 300 K to the cold mass along the cold mass supports.	The local shields to between cold ends and inerceptions of the cold mass supports will be added and made on-site. SINAP will provide the manufacturer with specification for the shields to be added along with the design drawings.		
		Increasing the thickness of the curved section of the shield from 4 mm to 6 mm will reduce the temperature drop from the cold mass support intercepts to the copper that the first stages of the coolers are attached and will reduce the heat load to 4K. Consider increasing the shield thickness.	Simualtion and analyses were carried out to study the effect of increasing the shield thickness on the temperature drop along the shield and heat load to 4.2K. The results show that there is little effect of increasing the outer cylindrical shield thickness on the temperature drop along the shield, however, increasing the thickness of side shields will lower down the temperature on the shield. Considering the tight space on the inner side of the cryostat along the radial direction, the inner cylindrical shield thickness will keep 4mm, and the side shields' thickness increases from 4mm to 6mm.	WANG,Li/CAO,Yun	See the details in PPT "Calculations and FEA simulations for MICE/Muool Coupling Magnet Cryostat Design".
		Soldering of the joint interfaces of the shield is probably the best solution in order to maximize heat conduction. We request that the team look into this possibility.	Possibility of soldering of the joint interfaces of the shield was explored by discussion with the manufacturer.	CAO,Yun/QiHuan	TBD

Cryogenic cooling and Shielding Issues	Cooling issues	Re-evaluate the heat leak of the cryo-cooler's SS sleeves.	Because of the complexity of helium fluid flow inside the SS sleeves, the temperature distribution along the sleeve walls is non-linear and varied with running temperatures at first-stage and second-stage cold heads and temperature distributions along the cryocooler regenerators, it will take time to simulate the fluid flow inside the sleeves using specialized software (e.g. FLUENT) provided that the temperature distributions along the cryocooler regenerators are known. Therefore, SINAP assumed linear temperature distribution along the SS sleeves' walls and simply estimated the heat leak through them. We may compare the calculated values with the data from the tests done at Wang NMR for the cryo-coolers for the spectrometer solenoids if provided.	LBNL, WANG,Li	
		Heat from the current leads appropriatedly intercepted?	1） The connection between the cold end of copper lead and the warm end of the HTS lead was modified a little bit. The cold end of copper lead and the warm end of the HTS lead were attched to their cooling plate on opposite sides in order to avoid the heat leak from the copper lead directly imposed on the HTS lead. 2) For connection between the leads' cooling plates and the copper plate attached to the 1st-stage cold head of the cryocooler, the SS or brass bolt with a G-10 sleeve is to be employed. 3) The temperature on the leads' cooling plates were simulated.	SUN,Sen/WANG,Li	See the details of 3D model and Calculations
		Some issues regarding heat interception around the cold mass supports remain. Heat from the cold mass supports appropriatedly intercepted?	The copper strips to be used for heat interception of the cold mass supports were designed and added. They will be made on-site, and SINAP will provide the manufacturer with specification for the copper strips.	CAO,Yun/WANG,Li	See the details of 3D model and Calculations
		Does the design provide sufficiently low heat load to the cold mass to allow stable operation with 3 cryo-coolers?	The design is optimized in mechanical structure to minimal the heat load to the cold mass. The estimations of heat loads were updated accordingly.	WANG,Li	See the details of calculations
		Make sure the design can separate two phase He and condense the LHe efficiently at the top reservoir and cold-head region. Consider increasing the surface area of the LHe condensers. This will improve efficiency.	The configuration of the recondenser has been modified in order to enhance the heat exchange, and the heat transfer area is increased from 42000 mm^2 to 56477 mm^2 (1.35times).	SUN,Sen	See the details of 3D model
		Attempt to verify by simulation that a gas-plug (vapour-lock) will not be formed.	The simulation is carried out by Fermilab. According to suggestions from cryogenic experts, one cooling piping on the opposite side of the precooling tube, nested into the cover plate of the coil cold mass, will be used to transport the Lhe helium directly from the top He reservoir to the bottom one in order to avoid a gas-plug.	Fermilab	
	Cooling piping	The piping in the cryostat cooling circuits should use thin-wall pipes in order to assure the required flexibility and to allow for the release of the stresses introduced during the welding.	The thickness of the SS piping to be used for the cooling circuit is 1mm, and that of the Al piping is 4 mm.	SUN,Sen	
	Current Leads	1) The cold ends of current leads should be fixed in space, and stress relieved. 2) Provide the stress relief for the cold ends of HTS current leads. Protect them from possible deformations caused by cooling down, shipping, and operation.	The clamping bracket was designed to fix the cold ends of HTS leads in space but allows for stress releasing. And the non-metal clamps were designed for the copper leads to fix them in space as well.		

Mechanical Structure and Assembly	Transportation	Consider using stopping bolts to fix the cold mass inside the cryostat during shipping. These bolts may help during final magnet assembly to simplify the cold mass centering. In any event, the method presented at the review for securing the cold mass during shipment is not workable and a new technique must be developed.	A new configuration for stopping bolt was developed.	CAO,Yun	See the details of 3D model
	Cold mass support	1) Add strain gages to the cold-mass supports to monitor the support load during assembly, cooling down, and operation. 2) The procedure for the cold mass final assembly was not fully developed. The large number of cold mass supports must be unequally upper bolts must compensate for the weight and simultaneously loaded in order to provide a stable coil center position. Utilizing bolt torque control may not be sufficient to maintain the center position. In addition, there may be some cold mass support creep with time. Strain sensors could help to resolve this issue.	The load cell was adopted for measuring and monitoring the support load during assembly and will be installed at warm end of the cold mass support, cooling down, and operation.		
	Assembly procedure	Is there sufficient detail in the assembly procedure plan so that it can be transferred to the vendor and/or will it be the responsibility of the vendor to develop the plan? Are there assembly steps that could be problematic at the vendor site?	SINAP MICE Team discussed with the manufacturer (QiHuan/BJ) before the review and make agreement upon the preliminary fabrication and assembly plan. QiHuan will be responsible for developing the detailed practical fabrication and assembly procedures accordingly, and get approval by LBNL and HIT before taking action.	CAO,Yun/SUN,Sen	
	Alignment	How will the cold-mass reference position be transferred to external survey markers?	The approach to transfer the cold-mass reference position to external survey markers was considered and proposed.	CAO,Yun/SUN,Sen	
Coupling Coil Instrument ation		1) Is the instrumentation plan sufficient in order to debug unexpected problems during cool down? 2) Number of temperature sensors and their location–are there sufficient temperature sensors to determine if there are local “hot” spots? 3) Is the sensor choice appropriate? 4) How are the sensors mounted and heat sunk. How are the leads to the sensors heat sunk? 5) Is the instrumentation for LHe level sensing appropriate?	1) For measurement at the range of 40K-300K, the Platinum resistor temperature sensors (PT111 model) are chosen. There are 22 in total including 3 redundancy at key points, and 3 feedthroughs with 32 pins each are to be applied; 2) For measurement at the range of 3.5K-300K, the Lakeshore CERNOX RTD temperature sensors (CX-1010 model) with the CU (4-wire) package are chosen. There are 18 in total including 3 for redundancy at key points, and 3 feedthroughs with 32 pins each are to be applied; 3) There will be two level meters, one is for the top He vessel, and the other is for cooling tubing nested in cover plate. One 10 pins feedthrough is to be used. 4) The locations of the temperature sensors are mainly determined based on the simulation results for the temperatures of coil cold mass and the thermal shields. 5) The mounting of the sensors and thermal anchor of the leads to the sensors will strictly follow the instruction provided by the vendor.	WANG,Li/ICST	See the PFD for the CC design