MUON CRYOSYSTEM DESIGN NOTE 31

SUBSYSTEM: [ ] CCM [X] CVM [ ] Cryoplant

TITLE: **FOREIGN TRIP REPORT**

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The following report highlights details of the author's trip to the European Organization for Nuclear Research (CERN). The period of travel was from 28 April to 17 May 1986. CERN is located just west of Geneva, Switzerland.

The primary purpose of the trip was to observe the recommissioning of the Vertex Spectrometer Magnet (VSM), a large force-cooled superconducting magnet. This magnet is similar to a CERN built magnet presently on loan to and being installed by Fermilab in the New Muon Laboratory for experiment E665. The magnet at Fermilab (referred to as the CERN Vertex Magnet or CVM) is schedule to be recommissioned in August of this year.

Since the conceptual drawings for the two magnets were never revised, no prints exist of the two systems in their present state. Hence, the secondary purpose for the trip to CERN was to study how the VSM system was assembled and draw the necessary conclusions for the assembly of the CVM system.

This report contains a brief description of the cooldown operation of the VSM. It also describes a quench that occurred during an attempt to reach full current. Results of preliminary investigations concerning the reason for the quench are presented. Finally, a brief description of information obtained to aid in assembling the magnet is supplied.

The cost of the trip was $2034.56 and was borne by Fermilab.

Report

The Vertex Spectrometer Magnet (VSM) at CERN and the CERN Vertex Magnet (CVM) at Fermilab are almost identical forced-cooled, superconducting magnets. Both originated from the same design, a design conceived at CERN under the guidance of Mario Morpurgo in the mid 1970's. Both magnets have been operated successfully at CERN for a number of years. An agreement between CERN and Fermilab resulted in the CVM, after its last run at CERN in 1983, being disassembled and shipped to Fermilab for use in experiment E665. Due to a fortunate quirk in scheduling, the VSM was to be cooled and energized a few months prior to the CVM. This allowed Fermilab an excellent opportunity to obtain first hand knowledge concerning procedures and performances of these magnets during these critical operations. It is primarily for this reason that I traveled to CERN.

I arrived at CERN on the 29th of April, 4 days after cooldown had started. At the time of my arrival the average temperature of the coils was approximately 200 K. I obtained a copy of the data log for the entire cooldown and energizing operations. This copy contains all relevant information I missed for this period of cooldown.

Cooldown proceeds in two stages. Initially, cool helium gas is supplied to the magnet coils and the auxiliary pump dewar by a Sulzer refrigerator. The system cools at a rate of 1.5 K/h with the maximum allowable temperature rise over the entire system during this stage of cooldown being 40 K. The second stage of cooldown starts when the coils approach liquid helium temperature and the auxiliary pump dewar is filled with liquid. A positive displacement pump in the dewar is started at low RPM and liquid helium is forced into the coils. Due to vaporization of helium the dewar pressure rises quickly and the pump must be stopped occasionally to allow the pressure build up to dissipate. When the coils are full both helium pumps are activated and when steady state is reached the coils can be energized.

In addition to the data recorded in the CERN log, I maintained a data log consisting of recordings of various system parameters that I considered important (vacuum values, pump speeds, flowrates, etc). Although the data recorded in my log was obtained at irregular intervals, the data was obtained much more frequently than for the CERN log. Additionally, I kept detailed notes which include precise descriptions of operating procedures and system behavior.

Cooldown proceeded with little delay. The problems encountered were minor and of the type you would expect to see after disassembling and reassembling a major system. The problems consisted primarily of wiring troubles (i.e. crossed wires and disconnected plugs).

Once the coils are cold, energizing the magnet is to proceed in stages. Initially, 20 amps of current is put through the coils and the interlocks tested to verify that they indeed discharge the magnet when tripped. My notes include the set values of thee interlocks. Once the interlocks are verified the magnet is charged to 1000 A at a rate of 2 A/sec. All systems are then monitored for a short period of time. If no problems are encountered the current in the magnet is increased to 2000 A without discharging the magnet. If no problems are encountered the current is again increased in 1000 A increments until full field is reached at 5000 A. A departure from this procedure occurred when it was found that the voltage taps on the current leads were disconnected. After connecting the leads a decision was made to charge to full current, 5000 A. As the current approached its full field value, the magnet quenched. This was a significant event since neither the VSM nor the CVM have ever quenched.

The quench started in the lower part of the lower coil and slowly propagated through the lower coil and then through the upper coil. The three temperature sensors installed at the inlet, middle and outlet of a double pancake in the lower coil indicated a final range of temperatures between 33 and 44 K. The heat load vaporized all the liquid helium in the coils and in the pump dewar, approximately 900 liters. All safety systems performed properly and the pressure in the system reached 2.8 bar abs, far below the maximum allowable working pressure (MAWP) of 4.5 bar abs.

I was not present when the quench occurred. Indeed, the only person present when the quench occurred was the operations engineer. It is his observations that I have cited. Further observations resulting from discussions with the operations engineer and from data automatically recorded in the control room during the quench are included in my notes.

In the aftermath of the quench the magnet was immediately recooled. Once the magnet was cold it was charged to 1000 A. The magnet was then discharged through the dump resistor to verify that the safety switch was functioning. This was done because the temperatures recorded in the coils led one to suspect that the magnet might have absorbed all of its own energy. The switch functioned properly and it was later found that the temperature circuitry was recording a value higher than the actual temperature.

A few theories were advanced as to what caused the quench. The iron of the VSM had recently been modified to include an annular collar on top of the magnet. This modification resulted in a predicted increase in the axial field from 1.5 to 1.7 Tesla which could result in somewhat larger forces on the magnet's conductor than had previously been experienced. If a portion of the conductor became unseated during the recent move, the reseating it would experience under the greater load could lead to the start of a quench. It would be impossible to verify this theory since once reseated, the conductor would not unseat again.

Another theory stems from the fact that the vacuum for the lower coil is poorer than that for the upper coil. This is a result of an oversite in the original design which led to a situation where the diffusion pump on the upper coil can easily communicate with its vacuum space while the pump on the lower coil is unable to communicate with its respective space. The subsequent heat load on the conductor resulting from the poor vacuum around the lower coil would cause excessive vapor build-up at high points in the coil. When a vapor pocket breaks loose, the poor heat transfer it would cause when it passes a hot spot at a conductor joint (pancake to pancake or pancake to current lead) could led to the start of a quench. This theory led to a check of the voltage drops over the joints in the magnet. This check revealed that the quality of most of the joints had deteriorated with time. The worst joint by far was found to be in the upper coil. This joint dropped 1.18 mv at 4000 A which resulted in a heat load of 4.72 watts to the liquid helium. This joint was four times worse than any found in the lower coil. A check of the wiring verified that the upper and lower coil quench detection circuits were not reversed and hence the quench did start in the lower coil.

The consequence of the fact that the conductor joints have deteriorated is that the magnet could not reliably supply the full magnetic field required by the experimenters. A decision was therefore made to warm the magnet, open its vacuum vessels and repair the joints, a two month operation. I left Europe the day after the decision was made.

The secondary reason for my trip to CERN was to gather all the information possible concerning the assembly of the magnet. The existing drawings of the magnet are the original conceptual drawings. These drawings were never updated to "as built status" nor were any other modifications added to the prints. A large portion of my time was therefore spent taking pictures and documentating how various subsystems of the magnet were assembled. Flowcharts were made of the

1. compressed air system used to actuate the various control valves in the vacuum, vent, and current lead systems,

2. magnet vacuum system, and

3. pump dewar vacuum system.

The pump dewar static pressure protection system was updated on the VSM and not on the CVM. However, another CERN magnet uses the same basic system as that of the CVM. Flowcharts were made of both of these systems. Additionally, electrical schematics were made for all the wiring from the various pump dewar systems to their respective control chassis. This includes

1. the current lead protection system and

2. the cryostat vent system.

Other information obtained includes how to set up the automatic pumping procedure for the magnet's vacuum system. Also obtained was a good understanding of the magnet's interlock system. This includes the various settings of the interlocks.

A number of meetings were held with Mario Morpurgo, Michel Marquet and Armand Cyvoct, the three gentlemen most responsible for the original design and construction of the CVM and the VSM. The primary purpose of these meetings was to gain an understanding of their original design decisions and an understanding of the problems they encountered when originally commissioning the magnet.

This concludes the brief summary of my various activities while at CERN. With the information acquired, I believe that I can competently finish the assembly of the CVM and successfully commission the magnet.

Recommendations

I would like to recommend that an official request be made to CERN to allow two of their personnel to come to Fermilab to aid us in energizing the CVM. Their assistance would:

1. Reduce to a minimum the time spent rectifying the minor problems that are sure to arise during commissioning.

2. Provide expert guidance that could prevent major problems from occurring.

I would suggest that the names of the following two people accompany this request for assistance:

1. Mr. Armand Cyvoct - Mr. Cyvoct is the electrical engineer that designed the electronics of the CVM and participated in all phases of the magnet's original commissioning. He has an excellent understanding of the interfacing of the cryogenics with the electrical portions of the systems, and hence understands the subtle indications of problems that may be missed by our less experienced personnel.

2. Mr. Dominic Legrand - Mr. Legrand is an electronic technician who has worked with the two Vertex magnets for a number of years. He has been deeply involved in moving both magnet and hence knows each system intimately.

Both men have an excellent command of the English language and would have no trouble interfacing with our personnel.

Appendix A - Itinerary

28-29 April 86	Traveled from Chicago to CERN near Geneva, Switzerland via Frankfurt, Germany.
29 April - 2 May 86	CERN and environs.
3-4 May 86	Weekend
5-9 May 86	CERN and environs.
10-11 May 86	Weekend
12-16 May 86	CERN and environs.
17 May 86	Traveled from CERN to Chicago via Frankfurt, Germany.

Appendix B - Personnel Contacted

Horst Wenninger - Head of the Experimental Facilities (EF) Division

Mr. Wenninger extended the invitation to Fermilab to send a person to CERN to witness the recommissioning of the VSM. Hence, he was my sponsor. Mr. Wenninger and I discussed the possibility of CERN lending Fermilab two people to aid us during the initial energizing of the CVM.

Mario Morpurgo - Head of the Superconducting Magnet Group in the EF Division

Mr. Morpurgo headed the development and design group that produced the VSM and the CVM. The following topics were discussed.

1. Design features and possible modifications to the liquid helium pumps.
2. Problems that could arise if the CVM's current lead system is modified.
3. Problems CERN had when the CVM's intercepts were cooled with liquid nitrogen and not helium gas.
4. Theories concerning the reasons for the VSM quenching.

Gunter Winkler - Head of Superconducting Magnet Operations in the Magnet Group of the EF Division

Mr. Winkler was my host during my stay at CERN. He arranged and participated in all discussions. All topics mentioned in this report were discussed and at times clarified with him. He was the operations engineer present when the magnet quenched and I interviewed him extensively concerning this matter.

Armand Cyvoct - Electrical Engineer

Mr. Cyvoct was the design engineer for the CVM's electrical systems. The following topics were discussed with Mr. Cyvoct.

1. The theory and history of the quench detection circuits of the VSM and CVM.
2. The relationship between the magnet's charging rate and the quality of helium flow exiting the magnet.
3. The possibility of his coming to Fermilab to aid us in commissioning the CVM.
4. Theories concerning the VSM quenching.

Michel Marquet - Mechanical Engineer

Mr. Marquet did the original design work for a number of the mechanical systems of the VSM and CVM. Our discussion concerned the design and testing of the insulators used in the magnet to isolate the coils from the refrigerant piping.

Appendix C - Literature Acquired

1. Alcatel Technical Manual API 120.
2. Alcatel Technical Manual ACF 122.
3. Alcatel Technical Manual API 122.
4. Alcatel Technical Manual ACF 111.
5. Alcatel Technical Manual ACF 101.
6. Alcatel Technical Manual ATH301.
7. CERN drawing #8139-0380-1 - Helium Refrigerator/Liquefier - 1979.
8. Le Sulf BT (a friction reducing treatment) in French.
9. Isolateurs Dipole Standard - Technical note concerning assembly and testing of the insulators used in the CVM.
10. CERN drawing #TA-7401.4 - Assembly drawing for the insulators.
11. CERN drawing #SU-SPS-VB1 - Quench detection circuit for the Vertex Magnets.
12. Instructions for the SAUTER Type DFQ Pressurestat.
13. CERN drawing #18-023-1 Synoptique Aimant.
14. CERN drawing #18-021-1 Synoptique Boite Friode.
15. CERN drawing #18-022-1 Synoptique Compresseur.
16. CERN drawing #11-001 Helium Refrigerator/Liquefier.
17. Copies of the log book and data sheets for the period of time covering the cooldown and energizing of the VSM.
18. Copy of the AMG catalog for type SAD and type SAF actuators.
19. A complete set of electrical schematics for the Vertex Magnets.