Physics Department Minor Incidents Log

Incident No.	2003-07	**Date:**	7/31/03
Reportable:	Yes	**Date of Incident:**	6/27/03
Status:	ES&H Committee Final Report	**Latest Update:**	9/23/03
Groups Involved:	LEGS		
Lead Investigator:	Andrew Sandorfi and Craig Thorn		

Description:

Background

A superconducting magnet, cryostat, helium dewar, liquid helium transfer line, and associated magnet power supplies and controls manufactured by Cryomagnetics, Inc. were purchased by the University of South Carolina, ultimately for use in the Laser Electron Gamma Source (LEGS) facility at BNL. Physicists from the University of South Carolina (USC) and James Madison University (JMU) share the lead role in the LEGS-Spin-Collaboration for supplying this apparatus and bringing it on line. A steel magnet yoke designed to house this magnet was delivered to BNL in June 2001, and the testing of the magnet in the Physics High-Bay area was added to the LEGS Experimental Safety Review (ESR) document at that time. However, manufacturing problems delayed the delivery of the superconducting coil until November 2002, approximately 1 1/2 years later. At this time the funding agency (National Science Foundation) was pressuring USC to pay for the magnet and close the account. Shortly after delivery, a representative of the manufacturer was scheduled to come to BNL to perform the acceptance tests. Prior to these tests a static magnetic field hazard assessment was completed and appended to the LEGS ESR. The manufacturer's representative and two physicists, one from JMU and the other from USC, then assembled the magnet and performed the acceptance tests in December of 2002. During the course of these tests, the manufacturer's representative installed an electrical heating tape on the magnet cryostat recovery port to prevent seals from freezing. This was the procedure that had been adopted at the factory.

In March 2003, the same USC and JMU physicists returned with two JMU students to operate the magnet and measure liquid helium consumption rates. While the device meets its primary technical specifications, it consumes far more liquid helium than originally anticipated, with the result that its operation is more labor intensive. The USC and JMU physicists requested to come again in June and July with three students, two of these students having participated in the March measurements, to further define the helium consumption and to make measurements of the magnetic field. Their intention was to overlap with the students about 40% of the time. They were told that the BNL/LEGS staff were already over-subscribed to other activities and could provide only minimal help and supervision of the students. They argued that this was sufficient since the manufacturer had already demonstrated operation at BNL; they had gleaned all relevant operating knowledge from the manufacturer and would make sure the students, two of whom already had some experience in operating the magnet, were adequately trained before they left for any period. The BNL LEGS group agreed to this arrangement.

The Incident

The incident reported here occurred during the third period of operation when the USC and JMU physicists were not present. Their students had read the LEGS ESR document and had taken General Employee, Cryogenic Safety, Compressed Gas, Static Magnetic Field and Rad Worker-1 training courses, along with other National Synchrotron Light Source (NSLS) specific training. Before the incident the students, together with the USC and JMU physicists who were present for two of the four weeks of June, had been operating the magnet system for about three weeks in the Physics High-Bay area. On June 27th liquid helium was being transferred from a commercial 250 liter dewar, through a vacuum insulated metal transfer line into a cryostat containing the superconducting magnet mounted in the large steel yoke. This operation was similar to other helium transfers, which were performed about twice per day and requires two people, except that this time it was believed that the helium line inside the magnet cryostat was plugged with frozen air. For this reason, LEGS group members with the most cryogenic experience were present to advise in the operation. Two undergraduate students from JMU were performing the actual transfer. One was standing on a portable stair, inserting the helium transfer tube into the 250 liter dewar to extract warm

boil-off helium. At the same time, the other student was inserting the other end of the transfer line into the superconducting magnet cryostat to blow the warm helium onto the air plug. Both students were wearing gloves intended for protection against cryogenic burns. The students were wearing safety glasses but not face shields. The group technician had entered the area to watch the operation. As he watched, he observed the transfer tube unexpectedly slide deeper into the 250 liter dewar, which could defeat the purpose of the operation by transferring cold helium. To prevent this he reached up to tighten the seal on the transfer tube at the top of the dewar. He immediately received a shock, which he described as passing from the tip of his right finger, touching the nut on the seal, to just below the knuckle on that finger, which was presumably touching the body of the dewar. After the incident, the technician said he felt ill, and was taken to the clinic by a member of the group. The clinic reported that the examinations, including an EKG, were negative. The technician felt recovered in a few hours and was back at work that afternoon. At the time of the transfer the heater on the 250-liter dewar was connected, although in the off position, and an electrical heating tape on the magnet cryostat recovery port was energized through a Variac to 90 volts. The superconducting magnet was not energized.

Subsequent Investigation

After the incident, the resistance between the magnet yoke (5.5 tons of steel resting on a stone floor) and building ground (an electrical conduit) was measured to be greater than 20 mega ohms. As a test, the electrical leakage from wet heater tape, soaked in a salt-water solution, was also measured. The resistance measured between a probe immersed in the solution and one prong of the electrical connector (not in the solution) was about 1 mega ohm. In this condition, which with a salt solution represents a worse case scenario, energizing a wet heating tape to 90 V would produce a leakage current of only 90 microamperes. This suggests that the shock experienced by the technician was probably due to the cumulative charge buildup from the wet heating tape onto the magnet, which was not properly grounded. The 250-liter supply dewar was grounded through the connection to its heater and the metal transfer tube was likely insulated from the dewar by the O-ring. The leakage current and grounding situations could not be directly verified because the setup was partially broken down following the incident. The students did not experience any electrical discharge, presumably because the cryogenic gloves they were wearing were insulating. After the accident, one of the students did mention that he had received a shock on an earlier occasion. A senior person was not present at that time and, unfortunately, the student did not communicate this fact to the LEGS staff. It may be that the shock he received was not as intense due to a smaller level of static charge build up at that time. At any rate, he regarded it as not worth mentioning at the time.

Direct Cause: **Procedure Problem - Defective or Inadequate Procedure**

The procedure for melting ice formations was to use a heater tape not rated for use in wet environments. The manufacturer's representative used this method when the magnet was initially set up and demonstrated to meet the technical specifications. The collaborators and the students subsequently used this method. This procedure is not included in the manual containing the procedures for cooling down the magnet. Additionally, the Principal Investigator had not presented this cool down procedure or operations procedures to the Experimental Safety Committee or the Cryogenic Safety Committee for their review.

Contributing Causes: **Design Problem - Inadequate or Defective Design**

The magnet was considered to be properly grounded by virtue of it being on the floor; however, the piece of granite on which it was sitting was bonded to the floor with epoxy, electrically isolating it from the concrete floor and providing no path to ground. Neither the manufacturer's representative nor the Group had checked that the magnet was properly grounded. Had the magnet been properly grounded it is probable that the current leaking from the heater tape would have discharged to ground.

Contributing Causes: **Management Problem - Inadequate Administrative Control**

The ES&H Coordinator observed the magnet in the Building 510 high bay area during a routine inspection of the area in May 2003, although at the time it was not in operation. Other Departmental Safety Personnel were made aware of its presence and it was recalled that there had been an Experimental Safety Review (ESR) for the magnet but the details were not remembered. No one checked the details of the ESR to see if the level of review was adequate.

The superconducting solenoid magnet was first mentioned in the 2001 ESR, in which it was described as "is being built," and "will be operated" The ES&H Committee and the Experiment Review Coordinator (ERC) correctly interpreted this as a future

acquisition and installation and neither inquired into the details or the operation of the system at that time. Subsequently, in 2002 and again in 2003 the ESR described the magnet with exactly the same words. The 2002 ESR expired on May 15, 2003 and no update was submitted until the ERC notified the Principal Investigator (June 16, 2003) that all work had to stop until an update was submitted and approved. The Deputy group leader responded on June 20th with the old form, which except for the date and some personnel changes was identical to the document from the previous year. The ERC subsequently informed the Deputy group leader that in keeping with Department policy the ESR would be re-reviewed this year and a new form had to be completed. This was received on June 23rd. At this time no authorization to continue working pending the upcoming review was issued, although there was confusion on this point between the ERC and LEGS. A few days before the incident, the authorization to operate the magnet was first brought into question. The ERC knew that the magnet was discussed on the previous year's approved ESR. Unfortunately, the ERC did not go to the ESR to confirm that the actual operation of the magnet was described, knowing that there would be a full review soon, probably within the next week or two.

ESR Policy Contributing Factors reported by the Physics Department Experiment Review Coordinator:

The ESRC has the authority to give quick approval to continuing experiments or projects that have no changes from the previous approved ESR, but requires a full re-review after three years. This leads to efficient use of the ES&H Committee's time to deal with new ESRs and other ES&H issues. This apparently led to some misunderstandings:

PIs were confused about whether they were allowed to make an update or were subject to a re-review. The notification message (an email message that the ESR is about to expire) was changed (before the incident) after the LEGS Deputy group leader misunderstood what was being asked for. This was not the first such misunderstanding. This problem has been rectified by revising the email message.

The LEGS PI believed that submission of an ESR form was all that was required for approval. Following this incident, an email that stressed that submission was not approval was sent to PIs whose ESRs were due to expire. The response indicated that the LEGS PI was not the only one with this impression.

From general comments and questions not related to this incident, it appears that PIs need to be reminded that the accuracy and completeness of the ESR is their responsibility. In this case, it appears the PI did not make a reasonable attempt to ensure that the document reflected the actual work being performed.

Allowing continuing approval has probably contributed to the trend of ESRs to have exactly the same wording as prior years, even when a full re-review is called for. In many cases this is justified due to the static nature of some projects.

Root Cause: **Management Problem - Inadequate Administrative Control**

The Group Leader and the Principal Investigator (PI) who were responsible for the project were fully aware of the policies and procedures that would normally have been followed for any experiment. They were fully cognizant of having a proper Experimental Safety Review (ESR), a review by the Laboratory's Cryogenic Safety Committee, and the need to provide proper oversight to undergraduate students who are performing work for them. Nevertheless, they failed to live up to their responsibilities.

The Group Leader did not have the resources (manpower) to adequately provide oversight for this project in addition to the other research. In spite of this, he agreed to have the collaborators come to BNL and work on the project. He delegated the responsibility to the PI, who informed him that he could not provide the proper oversight due to his workload except in a limited fashion.

Other factors which contributed to the administrative failure include:

1. The division of responsibility between the collaborators and the BNL PI.

The University of South Carolina (USC) ordered the magnet system in 1999 for delivery in 2000. The manufacturer, Cryomagnetics Inc., experienced technical difficulties resulting in the delay of delivery until November 2002. Throughout this period interactions with the manufacturer were handled through USC. By the time the magnet was finally delivered it was tacitly assumed that USC was in control of all issues related to the magnet.

2. Assignment within the Group for various aspects of the project.

A group member, who had shepherded several previous Cryogenic Safety Committee (CRC) reviews, had advised the USC collaborators on technical issues that arose from their interactions with the manufacturer. However, he has major responsibilities with other systems and was not asked either by the Group Leader or the Deputy group leader to deal with the CSC review of the Cryomagnetics system.

The Deputy group leader had not participated in any of the previous CSC reviews and, while cognizant of their need, was unfamiliar with the process and assumed the group member who usually handled the reviews would do whatever had to be done.

3. Maintenance of the Experimental Safety Review process for the project.

Group leadership and the Department Experimental Review Coordinator and Experimental Safety Review Committee were in the process of updating the ESR for this project. However, new equipment (magnet) and new procedures (cryogenic testing of the magnet) were already in place without being described in the existing ESR and without having been reviewed at the time of the incident.

Corrective Actions:

1. Send out a draft Lessons Learned Communication to appropriate Laboratory Personnel to inform them of the hazards encountered in this incident in order to prevent the occurrence of a similar incident on site. This communication will address the grounding issues and the use of heater tapes on wet surfaces.
   Target Completion Date July 15, 2003 Completion Date July 15, 2003

2. Finalize the Lessons Learned Communication and distribute to Personnel via the Laboratory Standards Based Management System.
   Target Completion Date 11/7/03 Completion Date

3. Hold follow-up meetings (after the all-hands meeting discussed in action #10 below) with Group Leaders and with Group Safety Coordinators to discuss the incident and enlist their help in improving safety awareness.
   Target Completion Date August 31, 2003 Completion Date September 18, 2003

4. The ESR Coordinator prepared a report on the weaknesses of the Department's ESR policy and recommended actions (#3, #9, and #10 listed in this report) to the Department Chair, ES&H Committee, and the ESR Committee.
   Target Completion Date July 17, 2003 Completion Date July 17, 2003

5. Prior to further operation of the magnet, the LEGS Group will prepare a new ESR for review by the Physics Department’s ES&H Committee.
   Target Completion Date 11/7/03 Completion Date

6. Prior to further operation of the magnet, the LEGS Group will obtain a review by the Laboratory’s Cryogenic Safety Committee and act on the review’s recommendations.
   Target Completion Date 11/7/03 Completion Date

7. Prior to further operation of the magnet, the magnet will be properly bonded to ground with a cable capable of carrying the full magnet current.
   Target Completion Date 11/7/03 Completion Date

8. A cryogenic design review of the magnet with BNL cryogenic experts will be held in order to resolve some of the cryogenic problems associated with the excessive use of liquid helium. In particular, if heater tapes are to be used, they will be capable of operating safely in a wet environment.
   Target Completion Date 11/7/03 Completion Date

9. Revise the e-mail sent from the ESRC to PI's to provide specific guidance concerning ESR Update Procedures when ESRs are about to expire.
Target Completion Date 7/17/03 Completion Date 7/17/03

10. Physics Department Personnel will be given a summary of this incident by the Department Chair at an all-hands meeting along with a presentation to re-emphasize the importance of Integrated Safety Management principles. In addition, inform all personnel at the Department's All-Hands Meeting that submission of the ESR does not constitute approval, it is the PIs responsibility to fill out the ESR completely and accurately, and that more PIs will be asked to give a presentation of their ESRs to the ES&H Committee. The following topics will also be discussed:
- PIs responsibilities and accountabilities concerning ESRs
- Abnormal conditions must be immediately reported to supervision
- The scene of an incident should not be disturbed, other than to put it into a safe condition, pending an incident investigation
- Required Cryogenic safety reviews
- Staff responsibilities concerning visitors and guest at BNL including impact on ESRs
Target Completion Date August 22, 2003 Completion Date August 22, 2003

Lessons Learned:

1. 1. A complete review of all systems should be conducted prior to any operations, even if the manufacturer's representative has carried out installation.

   2. All electrical equipment connected to line voltage must be bonded to ground. It cannot be assumed that even very heavy equipment sitting on stone is adequately connected to ground.

   3. Heat tapes used in cryogenic applications in order to prevent icing must be capable of functioning in wet environments even when it is not anticipated that ice will build up.

   4. Abnormal conditions must be immediately reported to supervision. This point will be addressed in the all hands meeting and subsequent meetings (see corrective actions 3 and 10 above).

   5. The scene of an incident should not be disturbed, other than to put it into a safe condition, pending an incident investigation.

The above incident has been investigated and requires no further action.

_____ _____
S. Aronson, Department Chair Date

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S. M. Shapiro, ES&H Committee Chair Date