Experiment Safety Assessment Document for the Forward Angle Phase of the G^0 experiment.

November 13, 2003

Contents

1 Introduction and Scope

New experimental apparatus will be installed in Hall C at Jefferson Lab in order to carry out the forward angle measurements of the G^0 experiment. This equipment is not part of the set of standard Hall C equipment. The new equipment items are : two beam line girders containing beam diagnostic instruments, a super-conducting toroidal magnet (SMS) and accompanying power supply, a cryogenic hydrogen target, and eight large scintillator arrays arranged on a Ferris Wheel support structure. The magnet and the detector support are located on platforms, and these platforms can be translated on and off the beam line with rails installed on the floor of Hall C (see figure 1).

Due to the complexity of the super-conducting magnet (SMS) and the cryogenic target, separate Operational Safety Procedures (OSP) documents have been written. The safety concerns for these equipment items has been addressed and reviewed separately. The primary safety concerns are summarized in this document, and references to other safety documentation given. The safety of the Ferris Wheel and the rail system is described in this document. We do not attempt to describe the function or operation of the various subsystems in this document. That information will be found in the various "Operations Manuals".

2 The Super-conducting Magnet System (SMS)

This large super-conducting magnet was specifically designed and constructed for the G^0 experiment. The magnet consist of 8 super-conducting coils arranged symmetrically on a circle to produce a toroidal field. The coils, as well as massive lead collimators, lie inside of an evacuated stainless steel cylinder cryostat approximately 4 m in diameter and 2 m long. The purpose of the magnet is to bend the recoil protons from forward angle e-p elastic scattering in the cryogenic hydrogen target, so that they intersect the plastic scintillation detectors placed on the Ferris Wheel support, external to the cryostat. The upstream and downstream ends of the cylindrical cryostat are covered by aluminum end-caps. The upstream end-cap supports the hydrogen cryotarget system. The downstream end cap has eight 0.020" titanium windows (each with an area of 0.51 m^2) by which the scattered particles can exit the vacuum.

The SMS is supported on rails that permit it to be translated perpendic-

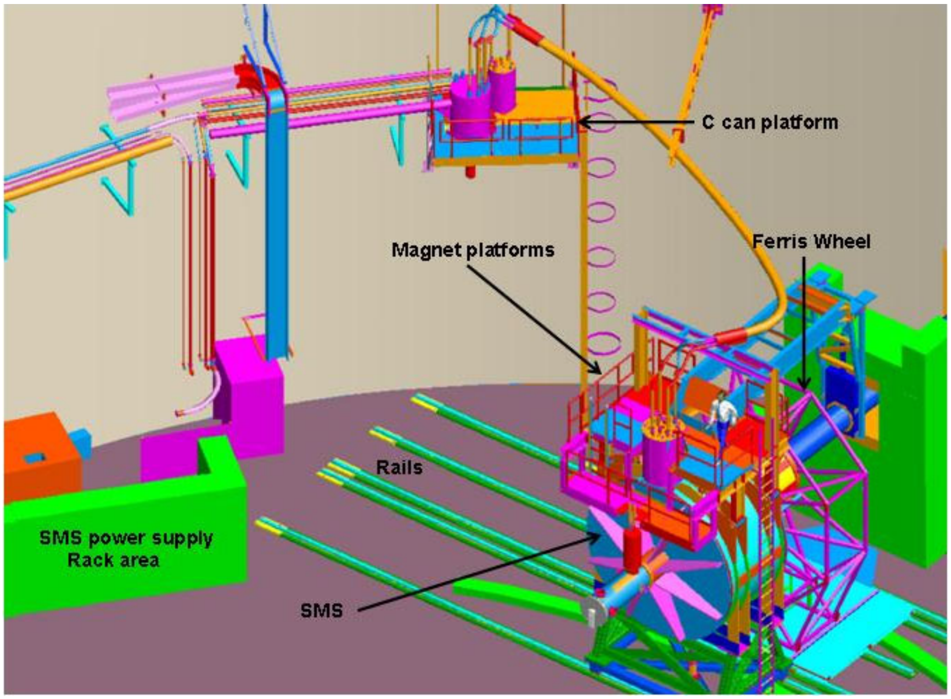

Figure 1: *The G^0 apparatus is depicted as it will be installed in Hall C. The super-conducting magnet (SMS) and the Ferris Wheel are mounted on rails. A He dewar located on the C can platform, delivers cryogens to the magnet through a flexible pipe (orange line from the C can to the top of the SMS). In the left side of the picture, one can see the SMS power supply and the rack area dedicated to the G^0 experiment.*

ular to the Hall C beam line. When running the experiment the magnet will sit directly on the beam line near the beam dump end of Hall C as shown in the figure 1. When not in use the magnet is translated on the rails to the beam left side, as far as can be achieved within the Hall.

The power supply to provide the 5000 Amperes required for the normal operating field is installed near the wall on the left side of Hall C. Shielding blocks have been stacked around the supply and controls to reduce radiation damage to the electronic components. Water cooled cables in a cable tray carry the current to the magnet.

As noted in the figure caption cryogens for the SMS are provided from the C can station mounted high on the left wall of Hall C via flexible hoses and an overhead boom system.

There are a variety of safety hazards associated with the operation of the G^0 SMS. The OSP for the SMS describes in detail the operations and the Hazard Analysis and Mitigation for this device [1]. In the following subsections, the hazards associated with the SMS are discussed. The likelihood and the consequences of each hazard [2], and controls for mitigating the hazard are discussed. This section is largely a summary of the hazards analysis contained in the OSP [1]. The personnel responsible for operating the SMS are listed in Appendix A.1.

2.1 Vacuum System Hazards

The principle hazard associated with the evacuation of the G^0 SMS vacuum vessel and target service module arises from the possible failure of one of the exit windows. A secondary hazard is the possibility of damage to the target cell should the magnet vacuum be released while the cell is evacuated.

2.1.1 Exit Window Hazards

Two scenarios can be envisaged for vacuum window failure.

a) A sudden complete failure of an entire window. It should be emphasized that the consequences of catastrophic failure are severe. There would be major property damage and the possibility of serious to fatal injury. Given design calculations [3], the results of destructive testing [4], and approximately one year of safe operation of the G^0 exit windows under vacuum, a spontaneous catastrophic failure of a window is very unlikely to occur. Though, a catastrophic failure caused by impact of a large heavy object, can only occur if the windows are exposed that is if the the detector support system (the Ferris Wheel) is pulled away from the SMS. The height of the windows above the hall floor implies that objects heavy enough to rupture an entire window would be suspended from the crane or elevated using a man-lift. The hazard controls specified below reduce this risk.

b) A puncture of a window. The risk of injury due to window puncture is very low. Equipment damage would also be minimal. Experience during the destructive testing of the windows showed that the 0.020-inch titanium window material is extremely tough. Never-the-less, with sufficient momentum, it is possible for a sharp object to make a hole in a window under vacuum. Tests showed that such a hole does not propagate to generate scenario a) described above. Instead the vacuum is simply lost at a rate compatible with the conductance through the hole. When the SMS and the Ferris Wheel are mated, the only way a sharp object can hit the windows is if it is droped by someone working on the SMS upper platforms (see figure 3). Protective plates will be installed on the platforms to reduce this risk. When the Ferris Wheel is pulled away, however, a puncture is more likely to happen. The hazard controls specified below reduce this risk.

Both of these scenarios will be mitigated to a low risk level, by a ”vacuum keep-out zone” region within 2 m down-stream of any point on the face of the down-stream end-cap of the SMS (see Figure 2). This volume does not include the SMS upper platform. Whenever the SMS and Ferris Wheel are separated by a distance greater than 0.25 m from the nominal running distance for a period greater than 10 minutes, the access to the vacuum keep-out zone shall be roped off. Only authorized personnel (see Appendix A.1) shall work in this region. Crane and man-lift operations, unless carried out by this authorized personnel, shall be excluded from a volume extending vertically from the roped-off region to a height of 2 m above the top of the vacuum vessel. In addition, when the “keep-out zone” is in place, 3/8” thick lexan window cover sheets will be mounted to studs in the window frames. Although the titanium windows are tough enough to constitute their own protection, this is similar to what is done for the standard pivot Hall C scattering chamber.

2.1.2 Target Cell Implosion Hazard

To prevent damage to the cryotarget, it is imperative that the SMS and target service module be evacuated before pumping on the target loop. The

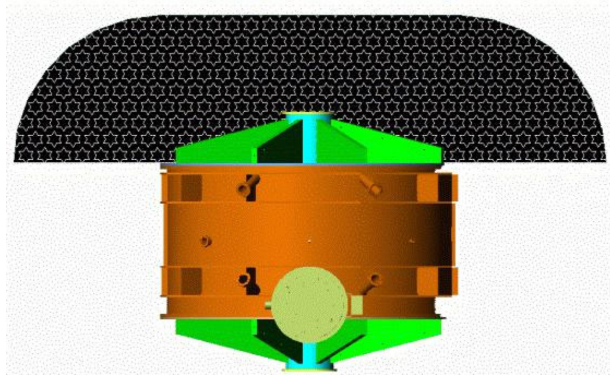

Figure 2: *This plan view of the SMS shows the "vacuum keep-out zone region (stars). The target service module, mounted on the upstream flange, and the magnet platform are not shown in this picture.*

target cell is very thin and will implode if the pressure outside it exceeds the pressure inside. While there is no danger of personnel injury (the target is completely enclosed by the SMS), the property loss, not to mention the labor required to replace the cell, would involve costs in time and money. In order to mitigate this risk, two controls are implemented: 1) The engineering control of interlocking target pneumatic valve PV21 with vacuum as indicated by the SMS vessel cold cathode gauge to prevent pumping on the target loop unless the vessel is evacuated. 2) In addition, any venting of the G^0 SMS vacuum vessel must be approved in writing (or by e-mail) by the target person on-call.

2.2 Hazards Associated with the Cryogenic Cooling Circuits

In addition to the normal hazards inherent to cryogenic materials (e.g. the dangers of "burns" and oxygen concentration near cold surfaces) the following hazards associated with the cryogens in the magnet plumbing have been identified.

a) Over-pressurization of cryogen plumbing. The most likely cause of this event is a sudden loss of the insulating vacuum (LOV). A worst case scenario ([7] and[8]) ignoring mechanical relief or the normal exhaust lines, concludes that both nitrogen and helium reservoirs and piping are quite capable of withstanding these pressures . While the calculations indicate that the system is theoretically safe, there are conditions under which the assumptions of the analysis would be violated; e.g., a faulty pipe material, a poor weld, or blockage of the relief path might become blocked by foreign or frozen material. Such failures were deemed “very unlikely to occur”. If the failure is internal to the cryostat, it could result in over-pressurization of the vacuum vessel. If the failure occurs outside the magnet, cold cryogens and possibly fragments ejected at high speed could be released. The relief of a burst disk entails similar consequences. This could result in personnel injury. The greatest risk comes from the possibility of injury due to burst disk fragments. As it as been estimated that, given sufficient time, a burst disk might rupture.

The risk is reduced through the following controls 1) Burst disks are located at a height and orientation such that all fragments are blown upward above anyone working in the vicinity. 2) If this is impossible, a protective screen has been installed. 3) There are warning signs near the burst disks. 4) Personnel working on the SMS platform, near the burst disks and other external plumbing, will be limited during cool-down to those who are aware of the hazard, i.e., those on the list in Appendix A.1 5) Burst disks will be inspected regularly to ensure that no foreign material can block their operation.

b) Over-pressurization of the vacuum vessel caused by leak in cryogen plumbing. As said before, this is very unlikely to occur. However, should such an event occur a combination of the three relief ports and the strength of the vacuum vessel and target service module will mitigate this hazard.

2.3 Hazards Associated with the Electrical Circuit

The charging circuit for the SMS provides, at full power, 5000 A at about 13.5 V to the 0.53 H inductive load of the magnet and leads. At full power the SMS stores 6.6 MJ of energy. The voltage drop, due to resistive losses in the water cooled leads implies a power dissipation of 67.5 kW. The hazards associated with the electrical circuit arise from this large stored energy and power dissipation.

2.3.1 Magnet Quench Hazard

If, for some reason the SMS super-conducting coils quench, resistive heating will cause the normal zone of the conductor to propagate through the superconductor. Without adequate detection and protection systems, the excess heat released in the normal conductor would destroy the coils, and cause an immediate boil-off of the cryogens causing the LHe and LN2 circuits to be pressurized. Eventually the conductor would fail resulting in high voltages being induced, due to the stored magnetic energy, which would cause further damage to the magnet and possibly electrical shock and burn injuries to those standing nearby.

The strategy for mitigating this quench hazard is to turn off the supply of current to the magnet and safely dump the stored energy before heating of the conductor has reached destructive levels. The estimated time available to react to a quench is on the order of seconds [11]. We rely, therefore, on automatic systems for detection of the quench and fast shut-down of the magnet. As described [1], the method for detecting a quench is to sense the relatively large resistive voltage drop which accompanies local heating of the conductor. This is accomplished by two parallel and independent quench detection systems. The quench detection settings and the dump resistor are designed so that the energy can be dumped with a time constant of 10.6 seconds. In that case the maximum temperature of a hot spot in the coil is expected to reach only 70 K, and the maximum discharge voltage required to dump the magnet stored energy would be 250 V, one-tenth of the insulation test voltage.

The redundancy associated with two quench detection systems greatly reduces the likelihood of simultaneous failure. To further reduce the odds, both systems will be regularly checked by initiating a fast dump at low current.

2.3.2 Hazards from Exposed High-current Contacts

If metal tools accidentally come into contact with exposed leads on the SMS or the power supply and short them out, the likely outcome will be vaporization of the metal tool and an arc flash which could cause severe burns. During the time of a quench (even if the quench detection system is operating correctly), terminal voltages can reach voltage (>50 V) and energies (>0.5 J) conditions which can result in electrocution [12].

Two controls are used to reduce the likelihood and severity of this hazard. First, the power supply is equipped with a ground-fault detector. Any current which leaves the power supply must return. A short from a lead to ground results in the ground fault interlock being opened which leads to a fast-dump and power-supply shut-down. The second control is administrative in nature. The areas inside and on top of the supply where there are exposed high-current leads will be protected by a barrier, which prevents any contact. The power supply will be locked in the off state whenever the magnet platform must be accessed. When the power supply is operated and connected to the magnet, no personnel will be permitted on the magnet platform. JLab rules also require that there be a red beacon to indicate that the SMS is powered.

2.3.3 Hazards of Static Magnetic Field

Because G^0 has a toroidal field configuration, magnetic fields external to the cryostat are not large. Contours of constant magnetic field for the G^0 magnet, when powered at the full operating current of 5000 A, are displayed in Figure 3. Potentially fatal medical outcomes may result from exposure to magnetic fields in people who have ferromagnetic objects in their bodies. A magnetic flux density exceeding 5 Gauss across the torso region of the body may interfere with the operation of bioelectronic devices. At fields above 10 Gauss, magnetic storage media, credit cards and analog watches may be permanently damaged. Fields can also extend out a significant distance with sufficient strength to attract loose ferrous (magnetic) objects. Such common items include but are not limited to iron/steel cuttings, bolts, screwdrivers, most tools, and some survey equipment. These items can ”take flight” in unexpected and potentially dangerous directions.

To mitigate these various hazards during the operation of the G^0 magnet, work areas in which the magnetic field exceeds 5 Gauss will be roped off and posted according to JLab requirements [12]. A red beacon or a “magnet on light”located near the magnet will operate whenever the magnet is powered. These administrative controls are sufficient to drop the risk to ”very unlikely”. Note that there is no accessible region for which the field exceeds 600 Gauss, which by JLab rules would require additional measures.

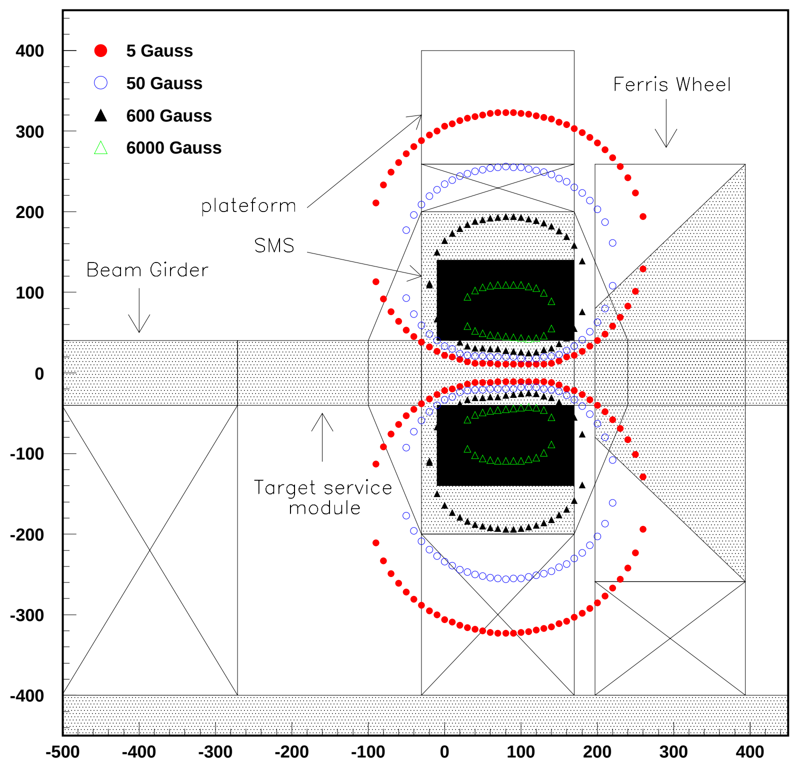

Figure 3: *Representative contours of constant magnetic field for the G^0 magnet when powered at the full operating current of 5000 A. Gray boxes represent regions where no personnel access is possible. The unit of length in the figure is centimeters.*

2.3.4 Vapor Cooled Leads Loss of Coolant

Cold helium boil-off gas is used to cool the conductors, which interconnect the water- cooled warm buss to the super-conducting buss. Loss of coolant automatically triggers a slow dump. The personnel safety hazard associated with this is discussed above.

2.4 Hazards Associated with the Low Conductivity Water Circuit

2.4.1 Loss of LCW Flow With Power

The power dissipated in both leads of the water-cooled warm buss is about 67 kW at full power. If LCW flow were to stop, the water would boil in about 2 minutes. Steam pressure would eventually rupture the cooling line, potentially breaking the electrical circuit and causing the magnet to dump its 6.6 MJ of stored energy. Because the connection to the energy dump resistor might be broken, energy could be dumped through another path, possibly causing additional damage or even electrical shock. An interruption to the cooling of the power supply would also have serious consequences. The SCRs, diode, and transformers are all water-cooled. The consequences of loss of LCW flow are severe. Water flow is dependent on many factors beyond the control of the experiment or even the Hall.

To mitigate the hazards associated with loss of LCW, return water flow is measured independently on the four parallel water flow circuits. A drop in water flow in any of the circuits below a pre-set threshold causes the control system to open an interlock. The time available to deal with a water flow interruption is less than the slow-dump time of 900 s. Therefore, if the water flow interlock opens, a fast dump is initiated. Return water temperature in each of the parallel lines is also monitored. If a pre-set temperature threshold is reached, an alarm is signaled by the control system. Slow reductions in LCW flow can be monitored and acted upon by magnet on-call person before there are serious consequences. These controls eliminate the chance of significant damage or injury due to an interruption in LCW flow.

2.4.2 Loss of LCW Flow Without Power

When the magnet is cold and no power is being supplied to the magnet, the magnet-ends of the leads can become frosted. If, further, the LCW flow is interrupted, ice could form in the water-cooled cable. This could damage the cable, or possibly block flow when the LCW is restored. The chief consequence of this would be loss of time and the cost of repair of the cable, but no personnel hazard. Various sensors and alarms are used to reduce the risk.

2.5 Hazards Associated with the Control System

The control system and its PLC platform perform many of the checks and controls that enable the G^0 SMS to operate safely and reliably. However incorrect adjustment of the control system parameters, or improperly operating hardware can have just the opposite effect. Discussed below are the primary hazards and inherent risks associated with the operation of the control system.

2.5.1 Radiation Damage to the Control System

The failure of control electronics due to radiation damage and, in particular the PLC of the control system, would disable many of the hazard controls discussed above. If such a failure goes unnoticed, the magnet is vulnerable to many serious failure scenarios. To reduce the risk of radiation damage, the PLC and other control electronics (including the power supply) are located upstream of the G^0 target (see figure 1) and are shielded from line-of-sight radiation emanating from either the G^0 or the Moller target by approximately one meter of steel. In addition, the PLC CPU, the ethernet communications module and the computer that read the temperature monitors are surrounded by 4 inches of lead (in all sides). As a check on the continued operation of the PLC, the ladder logic is required to reset a hardware timer relay once per program cycle (every 23 ms). If the timer is not reset within 1 s, a "heart-beat" interlock is opened which initiates a fast dump. Additional parameters read out by the PLC will be monitored continuously as a backup to the "heart-beat" interlock. The random nature of radiation damage implies that it is possible for only a few bits of data to be altered while the PLC program continues to run. Therefore, during normal operation of the experiment, the PLC program will be manually reloaded on a regular basis, whether or not there are any indications of radiation damage. These controls, should minimize the likelihood of a hazard associated with radiation damage to the PLC.

2.5.2 Error in Control System Operation During Cool-down

As it relates to the cryogen circuit, the control system functions mainly as a monitor of temperature and vacuum. However, because a slow reduction of the inlet gas temperature is necessary during the Cool-down I phase, it is managed by a control system PID loop. It is possible that failure of temperature sensors or the "mixing valve" actuator control, or inappropriate adjustment of the PID loop parameters could result in 80 K helium being supplied in large quantities to the G^0 magnet while it is still near 300 K. If this continues for a long enough period (greater than 2 hours), the temperature of parts of the magnet could change rapidly enough to cause damage through differential thermal contraction and thermal shock. This could result in leaks in the cryogen plumbing or faults in the coil internal and external electrical connections. The most straight forward way to reduce the risk is to ensure that an operator is present during critical phases of the cool-down. In order to ensure that operators have the proper level of experience and understanding of the hazards involved in the cool-down, only personnel whose names appear in Appendix A.1 will be allowed to serve as operators or to interact with the control system.

2.6 Fall Hazard

On top of the SMS there is an aluminum platform to permit servicing of the of the various electrical leads, controls, electrical components and cryolines. This platform is approximately 6 m above the floor, and creates a potential fall hazard. This hazard is mitigated by a railing which completely surrounds the platform. Access to the platform is provided by a vertical ladder which is enclosed, making a fall virtually impossible. If it is necessary to work on other elevated parts of the SMS this will have to be done with the use of a man-lift in accordance with Jefferson Lab standard operating procedures.

3 The Cryogenic Target

The cryogenic target used during the G^0 experiment is a cell 20 cm long containing liquid H2 (for the forward angle) at a pressure of 1.7 atm. The total amount of hydrogen contained into the G^0 target system is equivalent to 21,000 STP liters, the target system is a Class 1 installation as defined by the JLab Environmental Safety and Health Document [16]. Mixtures of hydrogen and air are explosive over a wide range of hydrogen concentrations, so care must be exercised in handling the hydrogen safely during normal operation, and a safe vent path provided in the event of cell rupture or accidentally boil-off. The hazards associated with the target have been assessed in the design document [17] and reviewed by a JLab appointed committee, ([18] and [19]).

The hazards which have been considered and their mitigation are briefly described in the following:

3.1 Explosion

This prevention is twofold. First, procedures are used to purge the target before the introduction of hydrogen, thereby preventing an explosive mixture of hydrogen and air. Second, electrical sources capable of igniting a mixture in regions where hydrogen and air might mix (gas panel, cryotarget or vacuum vessel) in the event of an accident or failure to observe the standard operating procedures are minimized. A complete list of those devices is given in [17]. Also calibrated flammable gas detectors are installed above (H2 gas is lighter than air) the target and the gas panel, and are interlocked to the Fast Shut Down System under fault conditions.

3.2 Pressure relief

A change in phase of the hydrogen from liquid to gas can lead to a dramatic increase in the pressure inside the target cell. In the case of a controlled (slow) boil-off of the target, the hydrogen is relieved into a large storage tank outside of Hall C. In the case of a catastrophic vacuum failure in which the target very rapidly boils off due to heating by room temperature air, relief valves begin opening should the pressure in the gas lines exceed 25 psig. In that case the gas is vented directly into the atmosphere outside the Hall. In a worst case scenario (the venting system cannot respond quickly enough), the pressure builds up in the target cell itself. Calculations of such a catastrophic process predict that the cryoloop pressure will reach a maximum pressure of 29 psia. The assembled cryoloop has been successfully tested for rupture to 85 psid. A test of this rapid boil-off scenario have been performed in June 02 [20] in order to test the relief system in the case of a sudden loss of vacuum. This test is known as neon test from the gas filling the target test at that time. The target system pass successfully the test. In the unlikely event of a target cell rupture (without vacuum lost), the H2 contained in the cell will expand inside the vacuum vessel of the super-conducting magnet. Should this happen, the pressure rise due to the hydrogen inside the G^0 magnet cryostat will not exceed 0.26 atm. Since the G^0 magnet has been pressure tested to 1.2 atms, no hydrogen gas should escape and mix with the air of Hall C. Special vents line will be used to vent the Hydrogen outside of Hall C.

3.3 Hydrogen vent into Nitrogen lines

In case of the venting of the cryogenic target (voluntary : purge and pump and warming up, or involuntary : over-pressure event) , hydrogen is released in the atmosphere behind and above the ESR building through nitrogen vent lines (used for the super-conducting magnets). It is assumed that the positive flow of the nitrogen from the five Hall C superconducting magnets nitrogen reservoirs to the outside, forces the hydrogen to evacuate from the hall in an inerted environment. In the extremely unlikely situation of a complete loss of nitrogen in all the reservoirs, the vented hydrogen could build up in the lines and/or reservoirs and become an explosive mixture of hydrogen and oxygen. In order to assure that this positive flow exists (that is the nitrogen reservoirs are full), the following restrictions to the target operations applies :

- Before any pump and purge of the target hydrogen lines , it must be checked that at least one of the five nitrogen reservoirs of Hall C is filled (condition N5OR). The condition N5OR is monitored through EPICS variables.
- If during target operation, the condition N5OR is not satisfied (for more than 5 mn), a formal warm-up procedure of the target should be started. The condition N5OR is monitored by the G^0 target operators.

3.4 Oxygen Deficiency Hazard

The volume of Hall C is approximately 24000m^3 and the volume of hydrogen in the target and storage tank is 21 m^3 at STP, so there is no oxygen deficiency hazard associated with the operation of the G^0 target in the experimental hall.

3.5 Control system and operators

A control system has been developed and documented ([21] and [22]) describing the safe use of the target system. The basic controls will consist of a personal computer running a graphical interface connected to a VME/VXI crate and associated instrument hardware. The primary purpose of the controls system is to monitor the state of the target and the gas handling system. The main function of the control system concerning safety are: 1) monitor target parameters; i.e., temperatures, pressures, and fan and valve settings, 2) sound alarms, if parameters are outside proper operating procedure, 3) trip beam interlocks and sound alarms, if target parameters are in a dangerous condition, 4) record the target status at regular intervals to log files, 5) monitor beam current and maintain a constant heat load on the target using internal heaters in the target loop that can be set manually or by software feedback method, 6) allow and monitor the target motion. The entire control system is powered by an uninterruptable power supply (UPS) to mitigate short power outages.

Whenever coolant is flowing to the G^0 target, a responsible person (defined as a "target operator") will be on duty in the counting house and a local expert (defined as a "black belt") on call. Target operators interact with the graphical interface of the controls, whereas the "black belts" are permitted to operate other controls such as the valve systems which by design are not under computer control, i.e. manual or automatic (pressure activated) valves. Also a system of "lock and tag" have been installed on critical valves, allowing only "black belt" to manipulate those valves. A list of local expert is given in Appendix A.2. In order to become eligible to act as target operator, one must be trained by one of the target experts.

Finally, it is important to be able to disable the electron beam in the case of dangerous or undesirable conditions of the hydrogen target. As part of the monitoring and controls system, a series of (hardware and software) conditions will be required to be satisfied (see [17]) to have the electron beam on target. Particular conditions which will cause a Fast Shut Down (FSD) of the electron beam are the activation of the target motion or the detection of hydrogen gas by the Hall C monitors. In this same document the general behavior of the target system under various types of failures is described. Specific instructions for the target operator are provided for each of those circumstances.

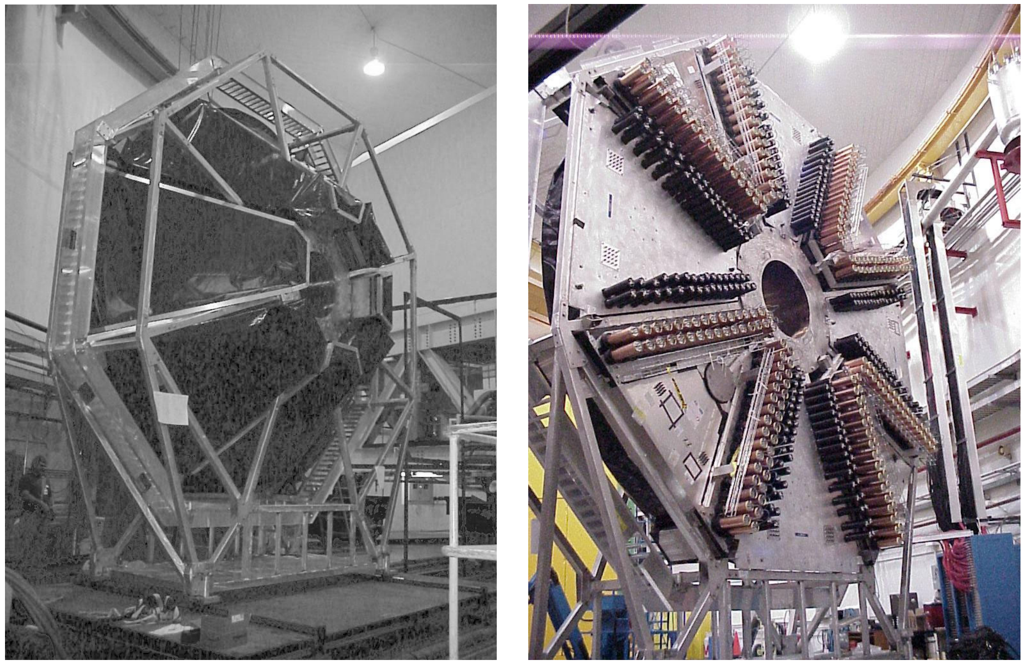

Figure 4: *The Detector package seen from upstream on the left and down stream on the right. The Al Ferris Wheel structure contains 8 detector octants.*

4 The Ferris Wheel and the detector package

The detector system (see figure 4) consists of eight scintillator arrays (each called an octant) arranged around the beam line axis. The eight octants are supported by an Al structure called the Ferris Wheel. It is 7 m above the floor at its highest point with a symmetry axis (the beam line) 4 m from floor. Each octant is attached to the Ferris Wheel by means of three bolts on the downstream face of the structure.

An octant is a black box containing sixteen pair of scintillators with lucite light guides. They are light tight, but not air tight, although no air circulation is provided. Each octant has a triangular back plate and is roughly 2 m by 2 m by 3 m long. The octant consist of Al plates on four sides, with a black plastic cover on the remaining fifth side. No access is possible inside the black box without destroying the integrity of the light tight box. Each octant is equipped with 64 photo-multipliers tubes (PMT) mounted on the downstream face. The octants are of two kinds, as half of them have been designed and built by French collaborators and the other half by the North American ones.

4.1 High voltage

The voltages for the 512 PMT bases are supplied by 8 CAEN SY505 high voltage mainframes whose slots are filled with CAEN 405 cards. These can supply up to 3kV at 3 mA. This voltage represents a potential hazard to personnel, as well as a potential source of ignition. In order to reduce the ignition hazard (as well as to protect the PMTs), the maximum output power is limited to the necessary value. The maximum output voltages were set by adjusting screws on the back of the CAEN cards to 2300 V. The maximum output current is limited by software setting to 1.8μA for the cards connected to the NA PMTs and 0.8μA for the French PMTs. The cables and their connectors are shielded and meet all existing safety standards. The HV supplies are located on the second floor of the counting house in the G^0 electronics cage.

4.2 Low voltage power supply for French PMT

The French PMTs are equipped with built-in amplifiers which are powered by a $\pm$12 V power supply delivering up to 10 A. The power supply box is located in the G^0 rack area (see figure 1). Output voltage and currents measurements are displayed on the front panel of the box. The cables and their connectors are shielded and meet all existing safety standards.

4.3 Flammable material: plastic scintillators and light guides

Flammable materials present on the Ferris Wheel are plastic scintillators (Bicron BC408) and lucite light-guides. The black plastic covers of the octants are flame retardant. The total weight of flammable plastic material enclosed in the eight octants is approximately 600 kg. If exposed to a direct flame, the plastic material would eventually melt and lose structural integrity. It should be noted that in that case the plastic cover of the octant would have failed and the flammable material would be directly in the Hall C enclosure. A VESDA fire safety system is installed on the G^0 ferris wheel. In accordance with the other VESDA systems in Hall C, an audible alarm will sound when the smoke detector is at 60% of full scale and the AC and DC power will be interlocked to turn off at 90% of full scale. The procedure for responding to the fire alarms is the usual procedure for Hall C.

4.4 Gain Monitoring System

A flash lamp[1] will be used to monitor the gain of the PMTs during the course of the experiment; this system is referred to as the Gain Monitoring System (GMS). There are no safety issues related to the use of this flash lamp.

4.5 Fall hazard

Maintenance operations on the detectors can present a potential fall hazard as the detectors are located on the Ferris Wheel. The most probable operation is an intervention on the PMTs located on the back of the ferris Wheel (see figure 4). The replacement of a phototube is relatively easy, and a limited number of the phototubes can be simply accessed from the ferris wheel platform. In the case where a PMT is too high above the platform, or in the case of a major intervention (e.g., the loss of many tubes at one time), a JLG or the scaffolding that was erected for initial installation of the tubes must be used to access the PMTs. In such cases JLab policies for the use of such devices will be followed.

5 The rail system

Both the magnet and the Ferris Wheel are mounted on platforms. These platforms are mounted on rails that allow them to be slid parallel to the beam line (see figure 4). Those rails are roughly 3 m long and are attached to the platforms. The platforms themselves are mounted on rails perpendicular to the beam line (see figure 1). These latter rails are roughly 15 m long, and allow the whole system to be slid in or out of the beam line. Both sets of rails will be equipped with end stops to insure that the platforms cannot be pushed off of the rails. An articulated tray, installed between the

[1] During the G^0 1rst engineering run, a UV laser was used. This laser has been dismantled and replaced by a flash lamp.

perpendicular rails, contains the HV and signal cables running from the G^0 patch panel area to the Ferris Wheel.

Two states have been identified :

- Static mode: the magnet and the Ferris Wheel are in position. Locks will insure that they cannot be moved at a sub-millimeter level.

- Dynamic mode: the magnet and the Ferris Wheel are slid perpendicular to the beam line. Moving the G^0 magnet and detector support into and out of the beam line is a major modification of the installation. The procedure should be directed by the Hall C work coordinator (W. Kellner) who will insure the safety of the operation.

A G^0 Safety Sensitive Apparatus Experts

On the following pages, phone numbers with four digits only are JLab extensions.

A.1 SMS Experts.

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Steve Williamson	217-333-7422	584-5484	williamson@uiuc.edu
Damon Spayde	5192		spayde@jlab.org
Kaz Nakahara			nakahara@jlab.org
Doug Beck	217-244-7944		dhbeck@uiuc.edu
Andy Kenyon	217-333-1503		kenyon@uiuc.edu
	Jefferson Lab		
William Vulcan (Pwr Supply and LCW)	6271	584-6271	vulcan@jlab.org
Steve Wood(controls)	7367	584-7367	saw@jlab.org
Walter Kellner (cryo and vacuum)	5512	584-5512	kellner@jlab.org
Paul Brindza (cryo and magnets)	7588	584-7588	brindza@jlab.org

A.2 Target Experts.

NAME	PHONE	PAGER	EMAIL
		Caltech	
Silviu Covrig	7237	584-5501	covrig@jlab.org
Bob McKeown	626-395-4316		bmck@krl.caltech.edu
Bob Carr	626-395-4583		carr@krl.caltech.edu
		University of Maryland	
Betsy Beise	7604		beise@jlab.org
		Jefferson Lab	
Greg Smith	5405	584-5405	smithg@jlab.org
Mike Seely	5036	584-5036	seely@jlab.org
David Meekins	5434	584-5434	meekins@jlab.org

B Oncall Experts

This section is divided in two part. In the first sub-section, pager numbers that constitute the first point of contact in case of questions/emergency are listed as well as the name of the persons who will bear the pagers at the beginning of the experiment. In the second sub-section, the list of G^0 personnel sorted by area of expertise is given. Each of those persons is eligible to carry the pager for the given area of expertise.

On the following pages, phone numbers with four digits only are JLab extensions.

Those two lists are also available on the net at :
http://g0web.jlab.org/manual/Phone_Pager_list.html

B.1 Pager numbers

Sub system	**PAGER**	**CELL**	**NAME**
RUN COORDINATOR	584-5560	876-1791	
ANALYSIS	584-5682		J. Liu
BEAMLINE	584-5560		M. Pitt
DAQ	584-7194		P. King
FR DETECTORS	584-5681		S. Kox
NA DETECTORS	584-7735		J. Roche
FR ELECTRONICS	584-5474		L. Bimbot
NA ELECTRONICS			B. Quinn
MAGNET	584-5484	876-1338	S. Williamson
	584-5574	876-1338	D. Spayde
TARGET	584-5501	810-7695	S. Covrig
CRYOGENICS	584-5512		W. Kellner
	5822, this number calls guard gate, guards will call cryo expert on call		

B.2 G^0 expert supplementary list

NAME	PHONE	PAGER	EMAIL
		BEAMLINE	
Gary Rutledge	7436	584-7346	rutledge@jlab.org
Junho Yun	5023		jyun@jlab.org
		TARGET	
Silviu Covrig	7237	584-5501	covrig@jlab.org
Greg Smith	5405	584-5405	smithg@jlab.org
Bob McKeown	626-395-4316		bmck@krl.caltech.edu
Bob Carr	626-395-4583		carr@krl.caltech.edu
		MAGNET	
Steve Williamson	217-333-7422	584-5484	williamson@uiuc.edu
Damon Spayde	5192	584-5574	spayde@jlab.org
Kaz Nakahara	5192		nakahara@jlab.org
Doug Beck	217-244-7944		dhbeck@uiuc.edu
Steve Wood(controls)	7367	584-7367	saw@jlab.org
		NA DETECTORS	
Julie Roche	7735	584-7735	jroche@jlab.org
Herbert Breuer	301-405-6108		breuer@enp.umd.edu
		GMS	
David McKee	7492		dmckee@jlab.org
Stephen Pate	505-646-2135		pate@nmsu.edu
		FR DETECTORS	
Jean Sebastien Real	6928		real@in2p3.fr
Serge Kox	6928		kox@in2p3.fr
		NA ELECTRONICS	
Angela Biselli			biselli@jlab.org
Joachim Kuhn			kuhnj@jlab.org
Brian Quinn	412-268-3523		quinn@ernest.phys.cmu.edu
		FR ELECTRONICS	
Dominique Marchand			marchand@ipno.in2p3.fr
Christophe Furget			furget@isn.in2p3.fr
		DAQ	
Paul King	7194	584-7194	pking@jlab.org
Steve Wood	7367	584-7367	saw@jlab.org
		ANALYSIS	
Jianglai Liu	7604		jianglai@jlab.org
Klaus Grimm	6931		grimm@isn.in2p3.fr
Julie Roche	7735	584-7735	jroche@jlab.org
Paul King	7194	584-7194	pking@jlab.org
Benoit Guillon			guillon@jlab.org
Damon Spayde	5192	584-5574	spayde@jlab.org
Kaz Nakahara	5192		nakahara@jlab.org

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