Temporary Operational Safety Procedure (TOSP)

Division serial number _____

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Title: **Evacuation of the G0 SMS Vacuum Vessel and Target Service Module**	
Location: **Hall C**	
Risk classification (See EH&S Manual Chapter 3210.)	Without mitigation measures: **3**
	With specified measures implemented: **1**
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Version 2, 4/23/02

Evacuation of the G0 SMS Vacuum Vessel and Target Service Module

Purpose:
This TOSP is written to define the conditions for safe operation during the initial evacuation and leak checking of the combined assembly of the G0 Superconducting Magnet System (SMS) vacuum vessel and the target service module in Hall C at Jefferson Lab (JLab), and the period until the combined assembly is mated to the Ferris Wheel. The JLab beamline is not attached to the SMS/target vacuum system during these procedures. The scope of this document does not include operations which will follow the initial evacuation including target testing, cryoline pressure testing, magnet cool-down, the powering of the magnet.

Description:
Both the G0 SMS and the G0 target have been evacuated previously, the target in its test vessel at JLab and the SMS at the University of Illinois. Following the installation of the combined assembly of the SMS and target in Hall C, the system as a whole must be evacuated and leak checked. The goals of this operation are 1) to reduce the pressure to 10^{-6} torr, 2) to leak-check seals on all penetrations of the vacuum volume and all welds and to repair any leaks if possible, and 3) to verify that the leak rate is less than $1x10^{-9}$ atm.-cc/sec or if that is not the case, then to measure the leak rate. There are no safety hazards in this procedure additional to those of the separate target and SMS systems. However, after the initial evacuation the complete assembly will stay under vacuum, with associated large vacuum vessel hazards.

The vacuum vessel consists of the following volumes:

- The main stainless steel cylindrical shell, of length 2 meters and inside diameter 3.8 m, which contains the magnet cold mass. The volume of the main vessel, excluding the volume of the cold mass, is estimated to be 16.73 m^3.
- Aluminum end caps covering the ends of the shell, each penetrated by a beam-line pipe of length 0.72 m and inside diameter 0.60 m. The total volume of the pipes is 0.40 m^3.
- The magnet cryobox containing liquid nitrogen and helium reservoirs. The total volume of the 0.90 m diameter, 1.29 m long, cryobox volume, including the volume of the "transition box" which connects the cryobox to the main vessel, and excluding the volumes of the helium and nitrogen reservoirs, is 0.82 m^3.
- The target service module, which is mounted on the up-stream end-cap beam-line flange and which contains the target and its positioning mechanism. This cylindrical volume of length 1.66 m and inside diameter 0.60 m has a volume of 0.46 m^3.

The total volume to be evacuated is estimated to be 18.20 m^3.

Eight trapezoidal holes, each of area 0.51 m^2 on the down-stream end-cap are covered with 0.020 inch thick titanium. During the G0 experiment, these so-called "exit windows" provide a path of low energy loss and multiple scattering for particles emanating from the target toward the detectors.

The vacuum vessel will be evacuated, first by a Roots Blower pump connected to the "shear-pin" port on the bottom of the main vessel and then by two 1000 l/s turbo pumps mounted on the down-stream end-cap beam-line flange and on the 4-way cross on the top of the target service

module. Leak-checking will then be performed using a helium leak detector. An attempt will be made to repair all vacuum leaks that are discovered. This may require back-filling the vacuum vessel with dry nitrogen and re-evacuation. It may be necessary to repeat this cycle a number of times. Finally the leak rate will be measured using the procedure described in Appendix A. Upon completion of leak-checking, the vessel will remain under vacuum in preparation for target testing (which will be carried out under the auspices of a separate TOSP). While under vacuum, and before the Ferris Wheel is mated to the SMS, the titanium windows are accessible to personnel. The vacuum hazards associated with this configuration is what this TOSP is meant to cover. After the ferris wheel and the SMS are mated, the windows are inaccessible. Sometime in late June or July, 2002, we expect the Ferris Wheel to be mated to the SMS.

Authority and Responsibility:
The authority for evacuating the SMS vacuum vessel and the target service module is carried by the G0 SMS and target subsystem managers, Steven Williamson and Robert McKeown respectively, as defined in the G0 Management plan (G0 Internal Report G0-98-019). The responsibility for safely carrying out the procedures associated with the initial evacuation has been delegated and restricted to the following personnel: Andy Kenyon, Steve Williamson, Damon Spade, Paul Hood, Sam Hicks, Walter Kellner, Dave Meekins, and Greg Smith. Only these people are allowed to participate in the operation of the vacuum and leak checking equipment attached to the G0 SMS vacuum vessel and target service module. The area around the SMS will be roped off to prevent access of other personnel. After the initial evacuation the SMS-target assembly will remain in an evacuated state. The area around the SMS will remain roped off during the period until the system is mated to the Ferris Wheel. Access to this area will be restricted to those who have read this TOSP, and whose names are added to Appendix B.

Analysis of the Hazards:
The hazards associated with the evacuation of the G0 SMS vacuum vessel and target service module arise from the possible failure of one of the exit windows. Two scenarios can be envisaged:

1. **A sudden complete failure of an entire window.** Given design calculations (see attached G0 Internal Report G0-99-038), the results of destructive testing (see attached G0 Internal Report G0-99-058), and approximately one year of safe operation of the G0 exit windows under vacuum, the likelihood of spontaneous catastrophic failure of a window is estimated to be very unlikely to occur, i.e. Likelihood Code A according to EH&S Manual §3210. Catastrophic failure caused by impact of a large heavy object is somewhat more likely (Likelihood Code B), unless hazard controls are implemented. 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. Hazard controls which cause heavy objects to be maintained at a safe distance from the window should reduce the likelihood of catastrophic failure to Likelihood Code-A level.

   The consequences of catastrophic failure are severe. There would be major property damage and the possibility of serious to fatal injury. Thus, a Consequence Level of IV is assigned to

this occurrence. The Risk Code, according to Table 3 of EH&S Manual §3210, is therefore 3 without hazard controls and 1 if hazard controls are implemented.

2. **A puncture of a window.** 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 1 described above. Instead the vacuum is simply lost at a rate compatible with the conductance through the hole. Such an event is estimated to be "likely to happen given sufficient time", Likelihood Code C, unless hazard controls are implemented, in which case a Likelihood Code of B would be more appropriate. The risk of injury due to window puncture is very low. Equipment damage would also be minimal. The greatest cost would be associated with window replacement. A Risk Code of 2 is assigned to this event, according to Table 3 of EH&S Manual §3210, without hazard controls. If hazard controls are implemented the Risk Code falls to 1.

Hazards Controls:
Both of the above scenarios should be mitigated to Risk Code 1 level if the following administrative procedure is followed. A region, "the vacuum keep-out zone", within 2 m down-stream of any point on the face of the down-stream end-cap of the magnet shall be roped off (see Figure 1). Only authorized personnel whose names appear in Appendix B shall be permitted to work in this region. Crane and man-lift operations, unless carried out by authorized personnel whose names appear in Appendix B, 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. This volume shall not include the SMS upper platform.

Although we believe that the hazard controls stated above are sufficient to reduce the risk to Risk Code 1, and the thickness of the titanium windows is large enough that they are to a large degree their own window protection, we will take the additional step of installing window covers. These will consist of 3/8" thick lexan sheets mounted to studs in the window frames in a manner similar to what is done for the standard pivot Hall C scattering chamber. These window covers will be put in place prior to the initial evacuation of the system, and will remain in place throughout the procedures covered by this TOSP. During leak checking it might be necessary to temporarily remove one window cover at a time to leak check the windows, however, they will be replaced as soon as possible during this activity.

This control will reduce the risk to Risk Code 1 because the likelihood of a failure event is reduced:

- Large objects capable of causing catastrophic window failure will be unable to approach a window. The likelihood of a catastrophic failure is thus reduced to "Very unlikely to occur" (Likelihood Code A).
- The potential number of people who might perform work near the windows will be reduced to a small group who are aware of the hazard. With fewer people working near the window, the likelihood of a puncture failure drops from "Likely to happen given sufficient time" (Likelihood Code C) to "possible only over a long period of time" (Likelihood Code B).

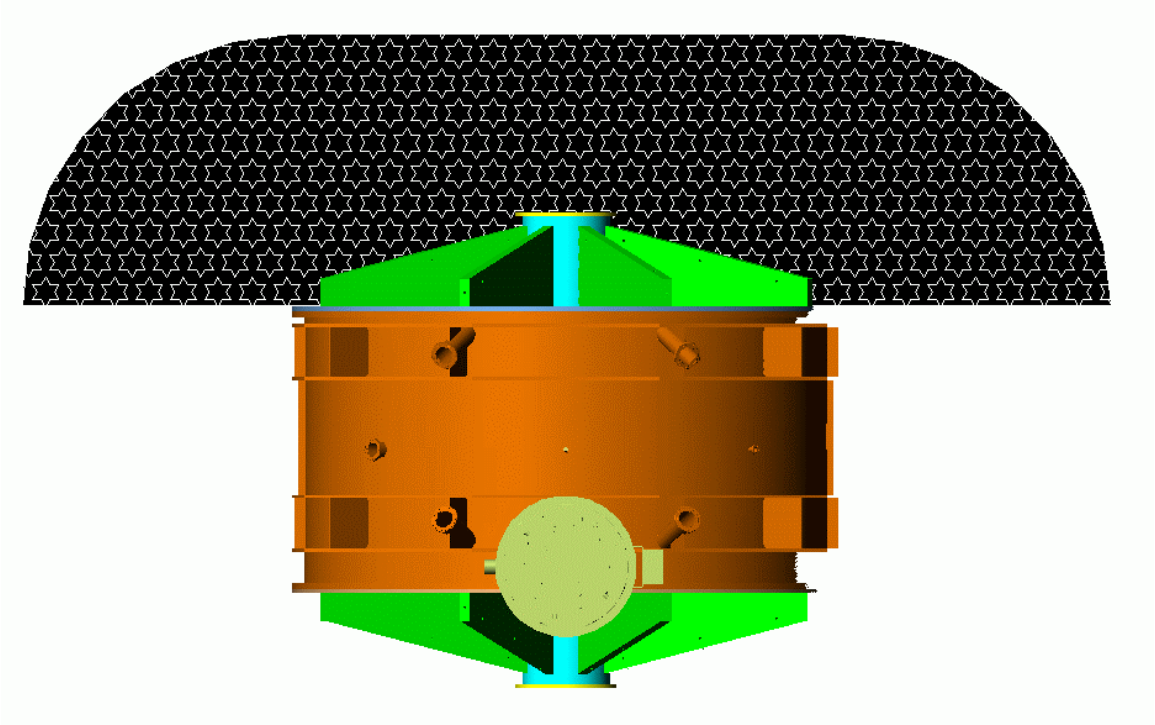

Figure 1. This plan view of the SMS shows the "vacuum keep-out zone" region (stars). The target service module, mounted on the upstream flange, and the magnet platform are not shown in this picture.

Note that once the Ferris Wheel and SMS are mated, this vacuum keep-out zone is automatically maintained since the Ferris Wheel physically prevents access to points inside this keep-out zone.

Operating Guidelines:
See above.

Training guidelines:
The authorization to enter the vacuum keep-out zone shall be recorded in Appendix B on the copy of this TOSP in an envelope near the vacuum keep-out zone boundary. Names may only be added to the list with the approval of Steven Williamson, Robert McKeown, or Greg Smith.

Unusual Emergency Procedures:
None.

Instrument Calibration Requirements:
None.

Appendix A
Leak Rate Measurement Procedure

Calibration of Helium Mass Spec leak detectors.
The sensitivity to detect leaks at $1x10^{-9}$ atm.-cc/sec shall be demonstrated prior to start of testing and after completion of testing by the following method.

1. A standard "traceable" Helium leak shall be mounted on a convenient flange on the G0 SMS vacuum vessel near the top of the vessel or on the G0 SMS cryo-box. One of the CVI ports would be acceptable.
2. The helium mass spectrometer leak detector shall be installed on the G0 SMS along with all pumps required for pressure equilibrium during the calibration and leak testing.
3. This configuration shall not be altered without re-calibration during the leak testing.
4. A chart recorder shall be installed to log the time response of the helium signal from the leak detector for the duration of the calibration and leak detecting.
5. A baseline trace of at least one hour duration shall be recorded to verify constant pressure and helium background level.
6. The standard leak shall be opened and left open until the helium signal reaches equilibrium. This shall be evidenced by a rise in the signal on the chart recorder and flatness at the new level for at least 10 minutes after a "knee" is observed in the response curve.
7. The actual sensitivity is to be calculated by dividing the standard leak by the actual leak detector response (i.e. Detection sensitivity = Standard Leak Rate / (helium signal with leak open – helium signal before leak is opened))

Vessel Final Leak Test
1. The SMS vacuum must be restored to a level that permits full leak detection sensitivity.
2. Perform a standard helium leak test of the vessel exterior welds and all penetrations with a suitable leak detector connected to the vessel vacuum. The success criterion is no detectable leakage at a minimum sensitivity of $1.0x10^{-9}$ atm.-cc/sec.

Appendix B
Record of Authorized Personnel for Access to the Vacuum Keep-out Zone

I have read and understood the attached Temporary Operational Safety Procedure. Names may not be added without approval of Steven Williamson, Robert McKeown, or Greg Smith as indicated by initials appearing in the Approval below.

Greg Smith _____ _____ _____
Signature Date Approval

Doug Beck _____ _____ _____
Signature Date Approval

Andy Kenyon _____ _____ _____
Signature Date Approval

Damon Spayde _____ _____ _____
Signature Date Approval

Steven Williamson _____ _____ _____
Signature Date Approval

Silviu Corvig _____ _____ _____
Signature Date Approval

Retief Neveling _____ _____ _____
Signature Date Approval

Mike Seely _____ _____ _____
Signature Date Approval

Walter Kellner _____ _____ _____
Signature Date Approval

Sam Hicks _____ _____ _____
Signature Date Approval

Steve Hickson _____ _____ _____
Signature Date Approval

Paul Hood _____ _____ _____
Signature Date Approval

Mike Lawing _____ _____ _____
Signature Date Approval

Greg Sammons _____ _____ _____
Signature Date Approval

Record of Authorized Personnel for Access to the Vacuum Keep-out Zone (Continued)

I have read and understood the attached Temporary Operational Safety Procedure. Names may not be added without approval of Steven Williamson, Robert McKeown, or Greg Smith as indicated by initials appearing in the Approval below.

	Signature	Date	Approval
Paul Brindza			
Dave Meekins			
Bob McKeown			
Bob Carr			

Print Name	Signature	Date	Approval

Record of Authorized Personnel for Access to the Vacuum Keep-out Zone (Continued)

I have read and understood the attached Temporary Operational Safety Procedure. Names may not be added without approval of Steven Williamson, Robert McKeown, or Greg Smith as indicated by initials appearing in the Approval below.

Print Name	Signature	Date	Approval

Appendix C
List of Attachments

1. Design Report on a Proposed Titanium Vacuum Window for the G0 Spectrometer (G0 Internal Report G0-99-038) - *L. Bartoszek, Bartoszek Engineering, January 12 1999*

2. Vacuum Window Testing (G0 Internal Report G0-99-058) - *L. Bartoszek, Bartoszek Engineering, December 13, 1999*