JLAB-TN-07-066

Dana M. Arenius

Final ODH Risk Assessment, CMTF
June 8, 2002

Introduction.

This assessment addresses the risk of oxygen deficiency hazard for the Cryomodule Test Facility (Cryomodule Test Cave) within Building 58. The assessment is conducted according to the requirements of Appendix 6500-T3, "ODH Risk Assessment". Two general categories of ODH hazards are identified in the facility. These are sources of nitrogen and helium gas which can dilute the normal oxygen content with health effects as outlined in Appendix 6500-T3.

The following sections covers the modeling scope and methodology for the cryogen dispersion release, a description of the work space, operational modes which affect the risk factors, the risk assess assessment, failure rates of the components, the resultant Area Classification, and self-rescue-atmosphere respirators.

Model for Cryogen Dispersion Release

The Model for Cryogen Dispersion Release is based on a fully operational cryogenic distribution junction box, supply can, and a system connected full size (1600L capacity) cryomodule at 2K under test. An occasional 500L nitrogen dewar is to be rolled in for vacuum break purposes. A ½ inch GN2 supply line with 80 PISG supply pressure with no flow restriction other than line pressure drop is also located in the room along with a warm gaeous helium supply header. Primary/secondary vessel vacuum relief valves and primary/secondary cryomodule process relief valves are vented into the CMTF room for the model. Unlike the JLAB accelerator tunnel, there is no guard vacuum piping system which extends outside of the CMTF for cryomodule primary relief nor is there sufficient 2K return line volume which tends to absorb a possible cryomodule liquid vaporization inventory. Two occupied floor levels are used in the model. The upper floor level has a steep stair for egress. Also, egress from the lower first floor room with the main lift door closed would have to come in close proximity to a cryomodule end can relief which is the major helium inventory venting point.

Recent helium spill tests within the JLAB accelerator tunnel has shown that rising helium gas interacts with the surrounding air, mixing with it as it rises. Once combined with air, the helium does not readily separate out of the air/helium mixture thus is not reversible. It will retain the same helium to air percentages as long as it does not further interact with additional sources of air (dilution) or higher concentrations of helium (enrichment, which is unlikely). Since the helium/air gas "mixture is lighter than air, the mixture rises. If natural convection ventilation is provided, both oxygen and helium are purged from the contained area and the helium will displace more of the confined space in a vertical downward direction.

The model for a helium release rate is based on the worst release cases listed under the Operational Modes below. Failure rate estimates (P_i) are based on previous JLAB cryomodule probability and JLAB listed equipment rates under EH+S Section 6500. Fatality Factors (F_i) are derived from Figure 3, of the EH+S Appendix 6500-T3. The sum of the failure product of the F_i and P_i for each of the operational modes determined the area classification in accordance with table 6 of Section 6500 of the EH+S manual. The classification was adjusted if the normal calculation placed the event in the upper range of the classification and factors, such as ease of escape, were apparent.

Description of Work Space: (see figure 1)

The enclosed space measures 18' wide, 57 feet long and 19 feet in height for a total of 19,500 ft^3. The space is divided into two floors at elevations at grade and 10'. The upper level is comprised of a solid platform (18'W x 41.5' L) with opening to the first floor of 18' W x 2.5' L on the west end and 18' X 13' on the east end. The upper platform forms a complete seal between the first and second floor levels along the room north and south floor edges.

A single steep stair connects the first and second floor at the south east corner of the platform for egress from the second floor. A 16 Ft^2 cross area (4'x4') exhaust fan opening is located in the northwest corner of the ceiling. The opening is fitted with a 42" diameter, 5 hp, approx 10K cfm electric exhaust fan. The fan shutters are gravity close and normally only open when the fan is in operation. A cover plate with side openings between the ceiling opening and fan inlet allows for the same cross section area as the ceiling opening.(~16.8 ft^2).

Three 10" diameter wall vent tubes are located 15" down from top of ceiling along the south upper platform wall. The vent tubes exit at floor level for wave guides into the upper instrumentation rack and vacuum pair pump work area on top of the CMTF room. Unless sealed these could create ODH hazard for upper CMTF roof area for cryomodule fault. Five 12" diameter wall vent tubes are located along the north side upper platform wall at an elevation of 18" above the platform floor level. Three of these tubes directly communicate with an upper instrumentation rack room located along the upper north wall of the CMTF work space. The other two are HVAC duct work supplies which are routed through the same instrumentation rack room and also communicate with an office space on the top of the CMTF roof. If left unsealed, these can present the same ODH hazard as the CMTF in the event of a cryomodule fault. At the first floor northwest corner of the room, an approximate 12"x 12" unsealed trench is currently being used to bring control cabling and conduits in from the control room. The trench appears to travel under the floor of the control room. The trench has been used to bring in a 80 PSIG, ½ inch, gaseous source of nitrogen into the room. The trench has an fill percentage of approximately 40%. A unsealed block wall (visible openings in a cable tray and cryogenic transfer line) is located at the first floor northeast corner of the room. The

other side of the block wall is a non-ODH protected utility room. Multiple 3”-4” wall conduits along the east end of the north wall communicate outside the room with two feet of the rear emergency roof exit stair mid platform.

There are two entrances to the area. A standard door entrance at the east end of the north wall and a 8.5 foot wide main lift door at the west end. During beam operations both doors are closed. One or both doors may be open at other times. Because a test

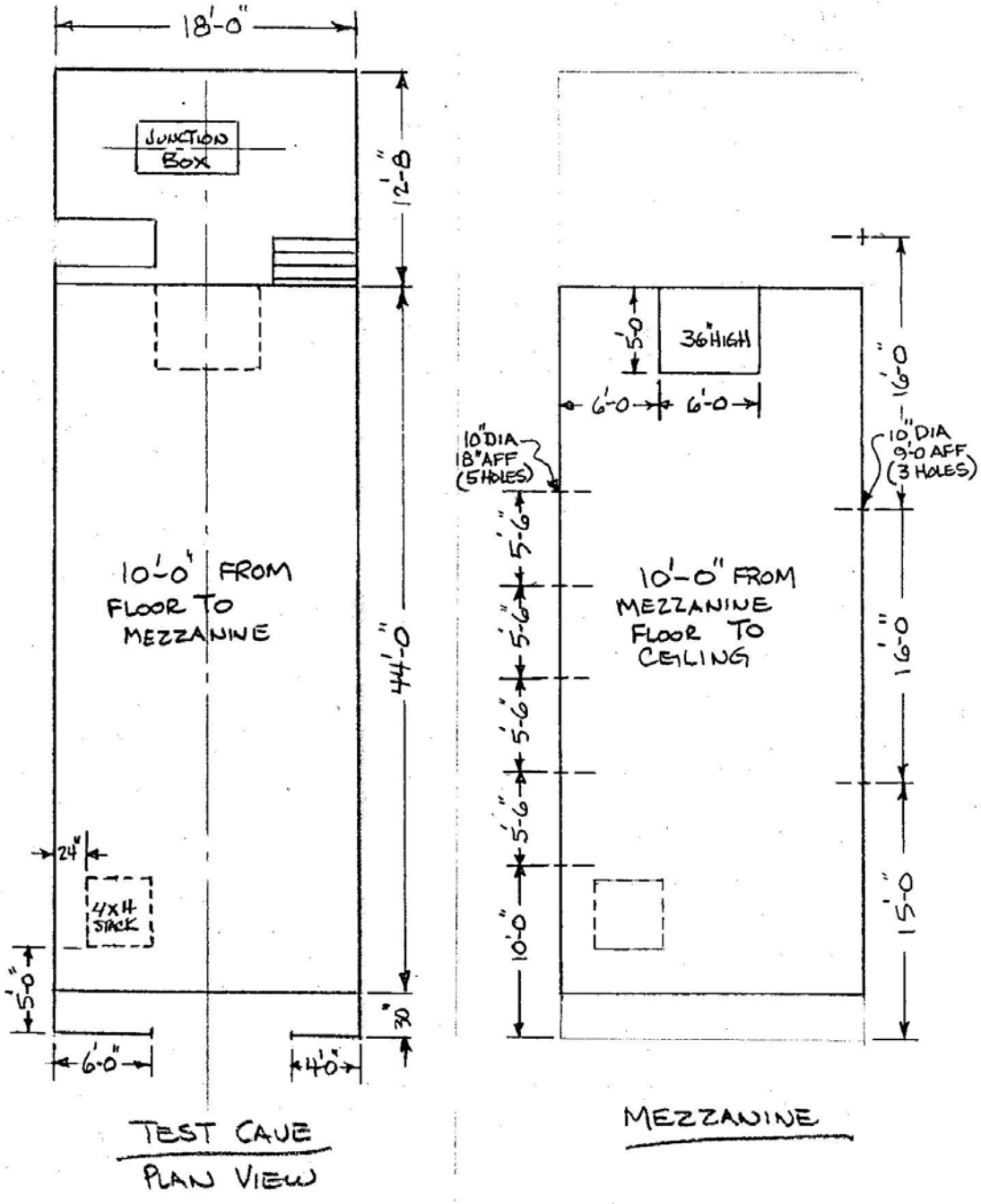
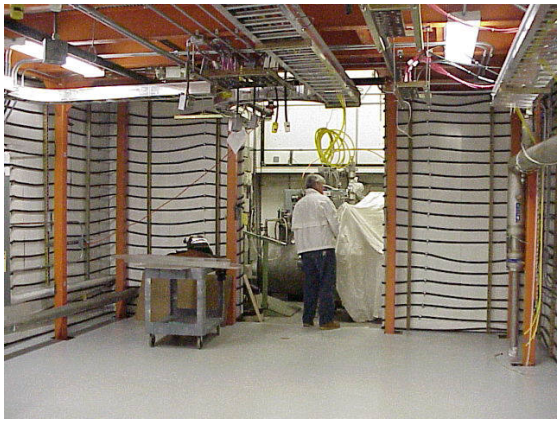


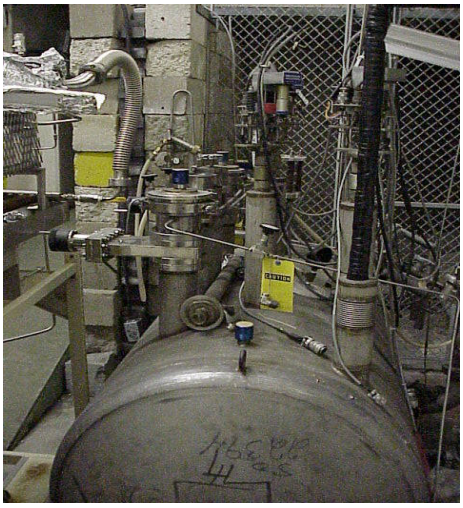
FIGURE 1

1st Floor Main Lift Door/Floor Trench

1st Floor CTA Supply Can



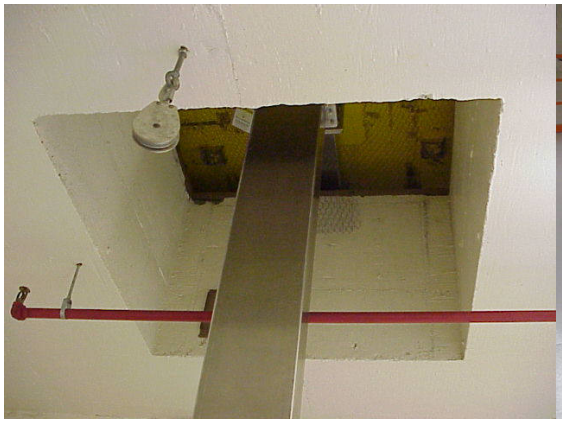
1st Floor, East End Passage Way



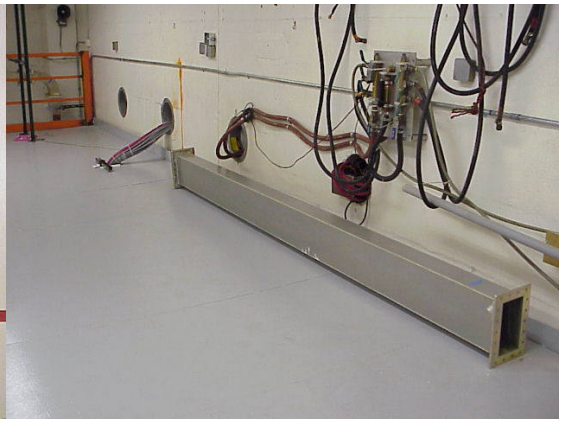
1st Floor Junction Box

2nd Floor Stairway

2nd Floor Facing West, can not see ODH light

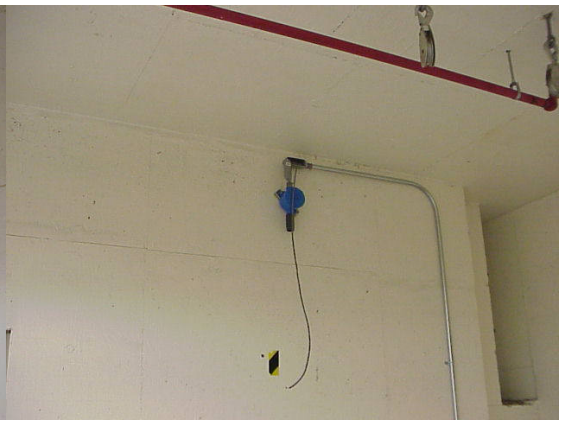


2nd Floor 4x4 Ceiling Vent, West End



2nd Floor Open Wall Vents to Instr Room

2nd Floor Open Waveguide Vent



2nd Floor ODH Head on Ceiling

cryomodule is positioned in the lower platform area with its major relief valves in close proximity to the 5'8" wide east opening, there may be difficulty in exiting the lower platform area and exiting via the northwest door in an ODH emergency if the lift door is closed and the source of the ODH is a cryomodule relief valve. This may be less than a 3 foot passageway pass a major spill vent of the cryomodule.

A cryogenic distribution junction box is located on the first floor at the east end of the room. The junction box has internal cryogenic supply and return process lines, bayonets, and control valves of 3 atm shield flow and 2K flow. A transfer line interconnects the junction box to the CTF and VTA areas. An additional cryogenic "CTA" supply/return can is located at the first floor level along the north wall. A transfer line connects this can to the distribution junction box.

Two ODH heads are located at two opposite ceiling corners of the 2nd floor. Two low ODH heads are located at the other two room corners at the floor level. It is planned that

the ODH heads will be tied to the 10K cfm ceiling fan. Two ODH horns are located at opposite corners on the second floor.

Sources of ODH are gaseous and liquid nitrogen and helium. The fatality factors are driven by the helium inventory of the cryomodule in the event of beam line vacuum, insulating vacuum, or waveguide vacuum failure. Unlike the JLAB tunnel design, the vaporized helium liquid is not adsorbed by a large 2K vapor return header. Instead, under the current CMTF design, it is vented directly into the room.

Vaporized Liquid Nitrogen Sources

Liquid nitrogen ODH is a result of utilization of an occasional 500 liter roll in dewar to break cryomodule vacuums. The vaporized liquid nitrogen represents approximately 12,600 CF of gas or 65% of the room volume.

Gaseous Nitrogen Sources

The gaseous nitrogen ODH source is a 80 PSIG , ½ inch Swagelok tubing source which comes into the room via a first floor trench at the northwest room corner. The 80 PSIG source is currently unregulated and limited only by the line size and the quantity of liquid nitrogen in the outdoor SRF LN2 dewar. The choked flow rate through the ½ inch supply tube with 300 feet of tube is approximately 25 CFM due to line breakage.

Vaporized Liquid Helium Sources

The source for vaporized helium liquid ODH is the cryomodule beam line or insulating vacuum loss. The 1600 liters of liquid at 2K represents 50K cubic feet of vaporized helium gas (250% of the room volume) or if the liquid is at 4K it represents 43K cubic feet of vaporized gas (220% of the room volume). Complete release durations for the vaporized liquid into the room varies from 1-1 ½ minutes for a beam line vacuum loss and 4-5 minutes for an insulating vacuum loss. The release location is the cryomodule return end can primary and secondary relief location at the lower platform 5’ 8” walkway opening.

Gaseous Helium Vent Sources

There are three sources of gaseous helium ODH.

One gaseous helium ODH sources is associated with a rupture or break in the warm 3 atm gaeous helium supply line into the room or a cryogenic line break in the transfer line, junction box, or supply can. The 3 atm warm gas source is a ½ inch tube supply of approximately 150 feet with a maximum source supply of 2.8 g/s or 74 CFM. The second gaseous helium ODH source is the 4K, 3 atm helium supply, which has a maximum supply rate of 20 g/s (an equivalent of 250 CFM for approximately 1-1/2 hours or 22,500 CF total release) from ether the ESR/CTF transfer line or CTF refrigerators. The third source is a 3atm shield line rupture or break at a flow rate of 15 g/s (188 CFM) for a total release of 22,500 CF.

ODH RISK ASSESSMENT

The following are the set of events and the associated probability and fatality factors.

JUNCTION BOX (normal ops, natural 4x4 roof vent opening)

EVENT	SPILL RATE, cfm	SPILL, cf	%O2	P_i	Fi
Valve Leak	12.5	22500	19.5(1)	5.2×10^{-6}	0
4K Line Rupture	250	22500	17(2)	3×10^{-6}	5.9×10^{-6}
Shield Line Rupture	188	22500	17(2)	3×10^{-6}	5.9×10^{-6}
Power Outage	0	0	21	1×10^{-4}	0
Relief Close Failure	12.5	22500	19.5(1)	1×10^{-4}	0
Blocked Shield Rtn	188	3760	17(2)	1×10^{-7}	5.9×10^{-6}

Super Scrip Notes:
Note 1: Not detected by upper ceiling ODH sensors
Note 2: Dectected by upper ceiling ODH sensors, affected area 4 feet down

CTA Supply Can (normal ops, natural 4x4 roof vent opening)

EVENT	SPILL RATE, cfm	SPILL, cf	%O2	P_i	Fi
Valve Leak	12.5	22500	19.5(1)	1.3×10^{-6}	0
4K Line Rupture	250	22500	17(2)	3×10^{-6}	5.9×10^{-6}
Shield Line Rupture	188	22500	17(2)	3×10^{-6}	5.9×10^{-6}
Power Outage	0	0	21	1×10^{-4}	0
Relief Close Failure	12.5	22500	19.5(1)	1×10^{-4}	0
Blocked Shield Rtn	188	3760	17(2)	1×10^{-7}	5.9×10^{-6}

Super Scrip Notes:
Note 1: Not detected by upper ceiling or under platform ODH sensors
Note 2: Dectected by upper ceiling ODH sensors, affected area 4 feet down

Cryomodule (normal ops, natural 4x4 roof vent opening)

EVENT	SPILL RATE, cfm	SPILL, cf	%O2	P_i	Fi
Valve Leak	12.5	22500	19.5(1)	2.6×10^{-6}	0
4K Line Rupture	250	22500	17(2)	3×10^{-6}	5.9×10^{-6}

Shield Line Rupture	188	22500	17(2)	3 x 10^{-6}	5.9x10^{-6}
Power Outage	0	0	21	1x10^{-4}	0
Relief Close Failure	12.5	22500	19.5(1)		0
Blocked Shield Rtn	188	3760	17(2)	1x10^{-7}	5.9x10^{-6}
Blocked 2K return	188	22500	17(2)	1x10^{-6}	5.9x10^{-6}
Insul Vac Loss	12500	50000	<9(3)	1x10^{-6}	1
Beam Line Vac Loss	49000	50000	<9(3)	1x10^{-6}	1
Waveguide Vac Fail	12500	25000	<9(3)	1x10^{-6}	1

Super Scrip Notes:

Note 1: Not detectable by upper ceiling or under platform ODH sensors
Note 2: Detectable by upper ceiling ODH sensors, affected area 4 feet down
Note 3: Major Helium Release with or without natural/powered existing ventilation. Room is pressurized by release rapid expansion out open doors, vents, etc. Would take a number of minutes for natural ventilation or fans to clear ODH. Oxygen level will be very low but only has to meet <9% for F_i factor.

Helium and Nitrogen Gas Supplies (normal ops, natural 4x4 roof vent opening)

EVENT	SPILL RATE, cfm	SPILL, cf	%O2	P_i	Fi
3 atm Helium	74	22500	18(1)	1.3 x 10^{-6}	0
80 psi Nitrogen	25	280,000	<9%(2)	3 x 10^{-6}	1

Super Scrip Notes:

Note 1: Not detected by upper ceiling or under platform ODH sensors
Note 2: Detected by lower ODH sensors, possible hazard spread to other areas via unsealed northwest floor trench and unsealed passages in northeast transfer line tunnel to CTF utility room.on first floor.

ODH Operational Mode Recommendations

Mode 1: CTF is operational (junction box, CTA can, TL to VTA), Gaseous He and N2 is available for use, No Beam, No installed Cryomodule, Ceiling Vent Locked Open, Lift door and rear access door locked open, LN dewar may be used, rear door and lift door posted ODH 0, Stairway to upper platform unlabeled or posted ODH 0, ODH alarm system fully operational

- Area is classified ODH 0, sum/product of all $P_i \times F_i < 10^{-7}$

Mode 2: CTF is operational (junction box, CTA can, TL to VTA, Gaseous He and N2 is available for use, No Beam, **cryomodule in place…can be warm or cold but with no liquid inventory**, Ceiling Vent Locked Open, Lift door and rear access door locked open, LN2 dewar may be used, rear door and lift door entrances posted ODH 0, kStairway to upper plateform unlabeled or posted ODH0, ODH alarm system tied to exhaust fan fully functional.

- Area is classified ODH 0, sum/product of all $P_i \times F_i < 10^{-7}$

Mode 3: CTF is operational (junction box, CTA can, TL to VTA, Gaseous He and N2 is available for use, No Beam, cryomodule in place…**cryomodule has liquid inventory**, Ceiling Vent Locked Open, Lift door and rear access door locked open, LN2 dewar may be used, rear door and lift door entrances posted ODH 1, Stairway to upper platform posted ODH 2 (egress difficulty), ODH alarm system tied to exhaust fan fully functional.

- First Floor Area is classified ODH 1, sum/product of all $P_i \times F_i < 10^{-5}$, $>10^{-7}$ for CMTF first floor.
- Second Floor Area is classified ODH 2, sum/product of all $P_i \times F_i < 10^{-5}$, $>10^{-7}$ is same as first floor but egress problem with upper range ODH1 classification range.

Mode 4: CTF is operational (junction box, CTA can, TL to VTA, Gaseous He and N2 is available for use, No Beam, **Cryomodule is in place with liquid, Lift door is closed, rear door is open for limited access,** Ceiling Vent Locked Open, LN2 dewar may be used, rear door and lift door entrances posted ODH 2, Stairway to upper platform posted ODH 2 (egress difficulty), ODH alarm system tied to exhaust fan fully functional**.**

- First and Second Floor classified ODH2, egress problems around cryomodule return end can and second floor stairway. Fan has reduced effect on clearing area of ODH hazard in a cryomodule event.

Mode 5: Emergency Repairs…..JT valve, relief valve, etc., CTF is operational, No Beam, cryomodule in place, Ceiling Vent Locked Open, Lift door and rear access door locked open, LN2 dewar may be used, rear door and lift door entrances posted ODH 1, Stairway to upper platform posted ODH 2 (with liquid in module) or ODH1 (without liquid in the cryomodule), ODH alarm system tied to exhaust fan fully functional. No standard cryo repairs (JT valve, Relief Valve, etc on cryomodule which has liquid inventory.

- First Floor Classified ODH1
- Second Floor classified ODH1 with no cyomodule liquid, ODH 2 with cryomodule liquid.

Mode 6: U-Tube Operations…..same conditions as Mode 5 but no liquid allowed to be present in the cryomodule.

Mode 7: Beam Operations…..Access not allowed, assumed cryomodule is full and CTF is running. Ceiling vent open or closed.

- ODH 2 classification for first and second floor…same as limited access classification.

OTHER RECOMMENDATIONS:

- Install 3 ODH warning lights inside the CMTF. One centrally located on first floor under the platform, second one centrally located on 2nd floor, third one in junction box area. Current ones can not be seen readily…

- Seal waveguide tubes and vent tubes to instrument rack room
- Seal 1st floor wiring trough….question of LN2 line under the control room
- Seal penetrations to CTF utility room or provide alarm.
- Marked shutoff valves for GN2 should be outside of enclosure
- Camera views of cryomodule end can, junction box and CTA Can/Cryomodule supply end can be valuable in determining ODH hazard source without entering.

RESULTS OF RECOMMENDATIONS (FINAL Report):

- OSP # A-01-001-OSP, "ODH Hazard Mitigation" in CMTF Cave, March 14, 2002 was developed which impose higher (more strict) ODH classifications that recommended in order to reduce the number of operating modes as outlined in "Recommended ODH Operational Mode Recommendations" listed above. The higher ODH classifications are outlined below in the Addendum.
- Action Items were conducted under Addendum below to address the "Other Recommendations" listed above from the Preliminary ODH Risk Assessment.

Addendum to the ODH Assessment:

Cryomodule Test Facility (CMTF)
April 2002

Issue	**Resolution**	**Signoff/ Date**
Louvres for the exhaust fan have to be locked open when cave is occupied under certain ODH modes.	Louvres for the exhaust fan located in the ceiling were removed. The fan is exposed, but a guard is not necessary because the fan is out of reach for all normal work in or around that fan outlet and only operates in the event of a helium release.	(Mutton)
Primary relief on return can vents at face level.	The direction of the primary relief on the return can has been rotated 90 degrees to face the ceiling	(Preble)
Control room is not isolated from the cave.	The trench leading to the CMTF control room is sealed to prevent nitrogen gas from entering the control room	(Preble)
There are three wall vents along the south side. The wall vent tubes currently vent to two work areas outside the cave: an nstrumentation rack and the vacuum pair pump area. The ductwork has to be extended at that area to a minimum of 7 feet from the ground in those areas, so that a helium accident would not affect personnel outside the cave, or the vents should be sealed.	Attach a listing of the vents and their status.	(Mutton/Merz)
The “Barn” area, located above the CMTF, has openings to the CMTF. This area needs to be isolated or also addressed as an ODH area	The Barn is an ODH 0 area. It is equipped with an ODH alarm system tied into one of the cave monitors.	(Mahoney)
Two air supply duct openings are approx 18" above the CMTF second floor.. There is an office area which shares this common air duct supply which connects the	Damper installed : in event of power failure, will close and remove ODH threat to the adjacent areas.	(Mutton)

barn, upper office, and CMTF at the CTMF upper level. During power outage circulator fan failure these areas may be subject to ODH should a spill event occur.		
A CTF utility room backs up to the CMTF. This room is not isolated. This area must be reviewed for only for ODH from the CMTF and the CTF.	The area has been posted ODH 2. Plans are in place to remove the makeshift wall and door that form the utility room.	(Arenius)
ODH beacons are not visible from all parts of the cave.	The ODH system has been installed and is visible from all locations in the cave. An additional beacon	(Mahoney)
There are 7 ODH modes for the cave. The scheme is too complicated for staff.	• The ODH modes for the cave have been simplified • A video camera will be position with screen located at the back access door so that personnel can see the status of the cryomodules and therefore the ODH status before	(Preble)

ODH Rating for the Cave

Conditions	**Rollup Door**	**First Floor**	**Mezzanine**
No cryomodule in cave	Open or closed	ODH 0	ODH 2
Cryomodule, no U tube stabbed	Open or closed	ODH 0	ODH 2
Cryomodule, U tube stabbed	Open	ODH 1	ODH 2
Cryomodule, U tube stabbed	Closed	ODH 2	ODH 2