BTeV Hazard Analysis Document

07-23-2004

DOCUMENT BteV-DOC-2829-v2

FERMI NATIONAL ACCELERATOR LABORATORY

Hazard Analysis Document Approval _______

Project Leader/Date: _________________________

Fermilab Division/Section Head(s)/Date: _________________________

Fermilab Senior Laboratory Safety Officer/Date: _________________________

Fermilab Associate Director for Operations Support/Date: ________________________

I. Introduction

At Fermilab, safety is important. It is the policy of this laboratory to protect the environment and all persons, be they employees or visitors, from accident or injury while they are on site. Nothing shall have a higher priority. The Fermilab Environmental, Safety and Health Manual (FESHM) specifies a set of physical and administrative conditions that define the bounding conditions for safe operation of accelerator facilities or portions thereof. Chapters 2010 Planning and Review of Accelerator Facilities and their Operations and 2060 Hazard Analysis for Fermilab Employees, call for identification of hazards and assessment and mitigation of risks at accelerator facilities, including experimental facilities such as BTeV. The goal is to demonstrate that there is reasonable assurance that operations can be conducted in a manner that will limit risks to the health and safety of employees and the public and will adequately protect the environment. Three reports are mandated; a Hazard /Risk Analysis Document, Preliminary Safety Assessment Document (PSAD) and a Safety Assessment Document (SAD). Operationally, the Hazard/Risk Analysis shall be performed and documented first, and the more detailed PSAD and SAD are developed subsequently. **Because of the fact that BTeV is a new facility still under construction, neither of these documents exists. However, conditions in BTeV are expected to approximate those of CDF, for which a full SAD (1) was developed to demonstrate the low risks associated with operations prior to the start of the last accelerator colliding beams operation period. This Hazard Analysis Document is based on the CDF Hazard Assessment Document published in 1994 and 2001. It is intended to achieve full compliance with the Requirements and formalize the hazard classification for BTeV.**

It is important to note that the Hazard Analysis required by the above Chapters is not an evaluation of the actual risk from BTeV operations, but is an evaluation of the potential hazards at BTeV in the absence of the engineered mitigations. Only passive mitigations are to be taken into account in evaluating the different hazards identified; it is to be assumed that engineered mitigations such as alarms, detectors, interlocks, ventilation, and operational procedures are all inoperative or compromised.

In Sections II and III, the hazard identification and assessment methodology used is described, and the results of applying the process to BTeV are detailed. Only local consequences in and adjacent to the BTeV facilities were considered; the off-site impact from operations at BTeV has already been reviewed and assessed as negligible. Section IV presents the conclusion that operations at BTeV are characterized as low hazard.

II. Methodology

The methodology used was selected to provide a uniform and thorough process for identifying and assessing the hazards present to personnel and the environment. The process consisted of three steps:

1) Development of a list of potential significant hazards
2) Surveying the BTeV facilities, existing and planned, for the presence of these potential hazards

3) Assessing the probability for a possible mishap or equipment failure and the severity of the consequences.

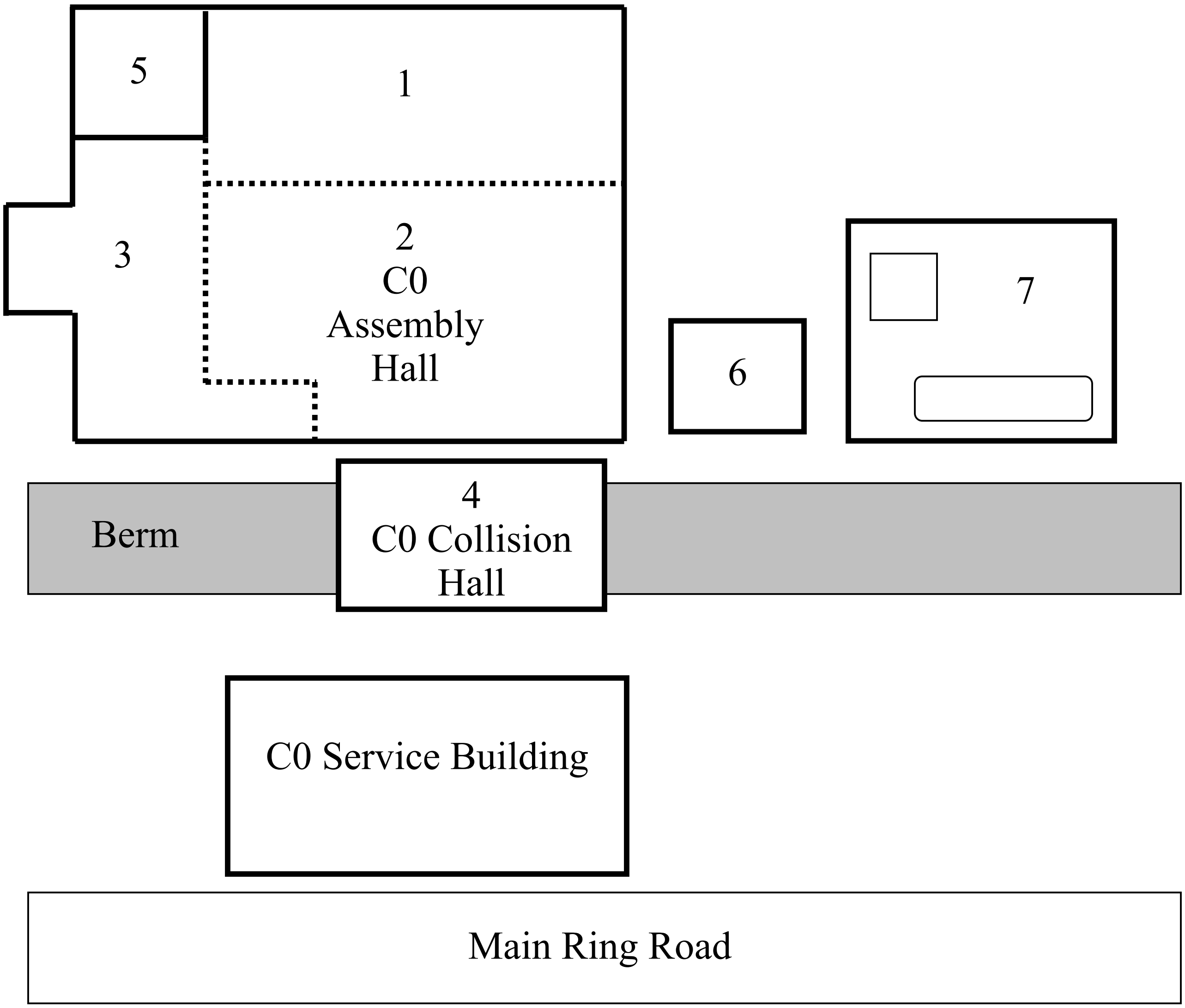
Each of the three steps is described further below.

A detailed list of potential hazards that may be encountered at a high-energy accelerator facility was obtained from the Work Smart Standards List. These standards are the result of Fermilab's analyses of the hazards present on the site and identified the statutory requirements, and external and internal standards to be followed in order to mitigate these hazards. A list of potentially significant hazards was then prepared from this master list for use in surveying BTeV. Hazards that are only of a magnitude and type routinely encountered and/or accepted by the general public were not included nor were hazards that are mitigated by code compliance (National Electrical Code, Uniform Building Code, etc.) or by OSHA compliance. The resulting potential hazard list is included here as Attachment A; it contains primarily risks that follow from the unusual technical aspects of high energy physics operations.

To facilitate the field survey of BTeV facilities and organize the findings, the area was divided into seven physically distinct zones using the natural features present. The zones are shown pictorially in the top half of Figure 1 and the principal occupancies are described below that. Office and laboratory occupancies were not included in the survey. In carrying out the hazard identification survey, assistance was provided by BTeV members and experienced Fermilab staff in identifying and then listing each of the hazards located in the seven zones.

Figure 1.

BTeV Area Zones



ZONE NO.	PRINCIPAL OCCUPANCIES
1	Shipping receiving, Storage and Upper Staging Area
2	Assembly Hall Deep Pit Service Area For Detector, Lower Staging Area and Alcoves
3	Technician Work Area and Computer rooms
4	Collision Hall
5	Mechanical Equipment Room
6	Gas Shed
7	Dewar Area

III. Results and Assessment

The results of the second step in the Hazard Analysis methodology, hazard identification, are presented in Table 1 using a matrix of hazard type versus BTeV geographical zone. As anticipated by the process of constructing the preliminary hazard list (Attachment A), potential hazards were identified in all areas of the facility. Within BTeV there are radioactive sources for calibration, residual activation of components, beryllium components, argon/ethane gas mixtures, 0.5-megawatt power supply, non-commercial electrical systems, cryogenic systems, crane equipment, many different gases, cryogens, and a high field magnet. Once identified, these hazards were subsequently ranked according to the ranking process listed in Appendix-A assessing various risk related to environment or safety and health activities.

Table 1.

BTeV Preliminary Hazard Identification

Zone No.	Zone Description	Radiation Hazards	Toxic Material Hazards	Flammable Materials	Electrical Energy	Thermal Energy	Kinetic Energy	Potential Energy	Flammable Gas Hazards	Oxygen Deficiency Hazards	Laser Hazards	Magnetic Field
1	Shipping receiving, Storage and Upper Staging Area	x	x	x	x	x	x	x	x	x		
2	Assembly Hall Deep Pit Service Area For Detector, Lower Staging Area and Alcoves	x	x	x	x	x	x	x	x	x	x	x
3	Technician Work Area and Computer rooms		x	x	x	x	x	x		x	x	
4	Collision Hall	x	x	x	x	x	x	x	x	x	x	x
5	Mechanical Equipment Room				x		x	x		x		
6	Gas Shed				x	x	x	x	x	x		
7	Dewar Area					x	x	x		x		

Classification of the identified hazards was documented through the use of a preliminary Hazard Analysis worksheet. Each identified hazard was characterized according to hazard type, mishap consequences, initiating event, and finally a risk ranking corresponding to the Risk-Based Priority Model given in Appendix A. Also included are descriptions of the installed hazard mitigation measures, both passive and active (engineered). Although no credit was taken in the assessment for the active mitigating techniques employed, these mitigating techniques are also listed for completeness. Credit was taken in the assessment for all passive mitigation features. The set of Hazard Analysis worksheets is included as Attachment B.

Upon examination of the results of the potential accident significance evaluations documented on the preliminary Hazard Analysis worksheets, the conclusion is clear that an unbreathable atmosphere incident (asphyxiation) or a flammable gas release (fire/deflagration) mishap are the most severe possible occurrences. Each of these potentialities, however remote the possibility in the actual BTeV configuration with engineered mitigations, could result in severe injury or death to employees or experimenters. No potential for significant environmentally damaging accidents was found in the full spectrum of BTeV operations. The potential for off-site impact from potential accidents at BTeV has already been investigated and assessed as negligible.

IV. Worst Case Unmitigated Accident Scenarios

On the basis of the results of the hazard identification and assessment investigation, two worst case accident scenarios are postulated. Each of these only presents risk to personnel in the immediate area of the affected zone. The first accident scenario involves exposure of personnel to an oxygen deficiency hazard (asphyxiation) condition in one of the zones identified as high risk without mitigation. The second accident scenario involves two potential flammable gas accidents in Zone 6 the remote gas shed area where inventories of ethane exist.

Accident Scenario 1: Oxygen Deficient Atmosphere

The worst case oxygen deficiency accident that could occur in BTeV might result in the asphyxiation of one or more persons. If an undetected leak of 50/50 argon/ ethane, liquid or gaseous nitrogen, or liquid or gaseous helium was allowed to persist for a sufficiently long period of time with no ventilation available, then an oxygen deficient atmosphere could be created. Upon entry into such an area, the person or persons entering would lose consciousness almost immediately and, if not discovered by unexposed personnel soon enough, would perish from lack of oxygen. Data on possible oxygen deficiency areas in each BTeV zone is given in Table 2 below. The time for the oxygen concentration to decrease to $O_2 < 12\%$ was found in each case by calculating the required volume of air to be displaced by the asphyxiant gas to achieve a 12% O_2 concentration and dividing that value by the maximum asphyxiant gas flow rate into the volume. In each case, the maximum gas flow rate is limited by passive mitigating devices only, flow restricting orifices and fail-safe pressure relief's; no credit is taken for active devices.

Table 2.

Possible Oxygen Deficiency Areas In Each BTeV Zone

Zone No.	Area Description	Area Volume, Cubic Feet	Normal Ventilation Rate, CFM	Maximum Gas Flow Rate, SCFM	Time to O_2 <12% Hours*	Comments
1	**Upper Staging Area Room**	251,789	700-5,000	560	4.2	Gas is not normally used in this area
2	**Assembly Hall Pit**	251,789	700 - 5,000	560	4.2	Gas is not normally used in this area
3	**Computer Room**	251,789	700 – 5,000	<560	>4.2	Gas is not normally used in this area
4	**Collision Hall**	55,616	700 – 5,000	560	.93	Worst case is failure of a LN2 or LHe line in the hall
5	**Mechanical Equipment Room**	10,752	Air infiltration only	0.217	462	Gas is not used in this area
6	**Gas Shed**	~1800	Air infiltration only	43	.39	Possibly open air gas shed.

* With no ventilation

As can be seen from the information in Table 2, the areas that can become oxygen deficient most quickly are Zones 4 and 6; Zone 4 due to the potentially large influx rate of asphyxiant, and Zone 6 due to the small volume of the Gas Shed and the moderately high influx rate of asphyxiant. Each of these risks is addressed in the ensuing paragraphs.

In Zone 4, the BTeV Collision Hall the potential for a large release of asphyxiant into the area from cryogenic lines entering and exiting the area. An analysis, including the probability of such failures, has been done elsewhere (Attachment C.) and concludes that the maximum asphyxiant release rate into the BTeV Collision Hall would be the 560 SCFM as listed in Table 2. At this rate with no mitigating actions taken and with no ventilation available, the time to reach and oxygen concentration of less than 12% would be .93 hours. The unmitigated hazard classification for this zone with these conditions is class 1C: likely to occur sometime during the lifetime of the project and having possibly fatal consequences. Clearly, mitigating actions must be undertaken to reduce the risk to an acceptable level.

Note “Preliminary Safety Assessment Document (P-SAD) Issues” significantly reduces the potential for Oxygen Deficiency Hazards (ODH) and electrical bus hazards associated with the Tevatron tunnel from adversely impacting the C0 experimental hall (Attachment D.).

The Zone 4 passive mitigating measures are:

1) All gas lines in this area are of metal construction, designed, constructed, and installed in accordance with ANSI B31.3.
2) All pressure vessels were designed and constructed in accordance with the ASME Pressure Vessel Code, Section VIII, Division 1, and
3) A non-removable flow restricting orifice is installed in the supply line, limiting the maximum flow to
    a) 43 SCFM for the 50/50 argon/ethane gas supply line.
    b) 560 SCFM for the liquid or gaseous nitrogen supply line.

The Zone 4 active mitigating measures are:

1) A situation awareness real-time display of the hazard status of the area is located at all of the entrances to the Collision Hall and in the BTeV main control room to alert personnel of any unsafe condition that may exist,
2) There are multiple flammable gas and oxygen sensors installed which alarm with visual and audible signals if flammable gas or oxygen deficiency conditions are detected,
3) Only trained personnel are permitted to conduct operations in this area,
4) Administrative procedures and check lists are in effect for the use of gas and cryogens in the area
5) The Collision Hall ventilation system supplies fresh air at a minimum rate of 700 SCFM and up to a maximum rate of 5,000 SCFM on demand or automatically from the oxygen sensor safety system. The rate of ventilation is monitored, and, upon loss of adequate ventilation, an evacuation alarm sounds to alert affected personnel, and
6) The BTeV Flammable Gas System and the BTeV Cryogenic System will have been independently reviewed and subsequently recommended for permits to operate by permanent Laboratory-appointed safety review subcommittees.

With consideration of the above mitigation measures, the hazard classification for Zone 4 would be reduced to one of very low risk as gas release has been made a very unlikely occurrence and the consequences of a leak alleviated by multiply redundant detection/annunciation safety systems and by the high volume fresh air capability of the ventilation system.

In the gas shed in Zone 6, an undetected leak of argon, ethane, nitrogen, or 50/50 argon/ethane that persisted at the rate shown in Table 2 would result in the creation of an oxygen deficiency condition of $O_2 < 12\%$ in .39 hours. Anyone entering the building after that time would loose consciousness almost immediately and, if not quickly removed from the building would perish from lack of oxygen. The unmitigated risk classification for this zone would be 1C: likely to occur sometime during the lifetime of the project and having possibly fatal consequences. Again, mitigating measures must be incorporated to reduce the risk to personnel.

The same mitigating measures as listed in the Zone 4 accident scenario apply with the following changes:

Passive mitigating measures;

3) Non-removable flow restricting orifices are installed in each supply line, limiting the maximum flow into the mixing building to
    a. 43 SCF/hr argon
    b. 43 SCF/hr ethane
    c. 68 SCF/hr nitrogen.

Active mitigating measures:

1) A situation awareness real-time display of the hazard status of the mixing building is located at the normally used (west) entrance to alert personnel of any unsafe condition that may be present in the building,
2) This zone has one ODH and one flammable gas sensor that will trigger an alarm with a visual and an audible signal if an oxygen deficiency or a flammable gas situation is present,
3) Normal ventilation to the mixing building is through outside air infiltration. In the event of a flammable gas or oxygen deficiency alarm, fresh air is automatically supplied at the rate of 1239 CFM, and
4) The entry to the mixing building is kept locked at all times.

Accident Scenario 2: Flammable Gas in Zone 6

Two possible accident scenarios involving flammable gas could occur in Zone 6, the Gas Mixing Area. Both accidents involve the quantity of ethane gas contained in a full tube trailer (approximately 5,000 gallons) and the delivery vehicle, a semi truck. In each case, only the driver of the truck and the gas technician on duty would be at risk. Severe burns and/or death could result from either mishap.

The first scenario would be if the truck driver attempted to move a full tube trailer that was still connected to the gas system. The most likely result would be the separation of the flexible connecting hose from the remainder of the system piping and the resultant escape of the tube trailer contents to atmosphere through the torn hose. Since the truck presents a convenient ignition source, it is likely that the escaping ethane would be ignited and continue to burn until the trailer contents were consumed. It is doubtful that an explosion would occur in this scenario, since it is not likely that a stochiometrically correct mixture of fuel and air would be achieved before the ethane ignited. As stated before, personnel injuries would be limited to the driver and the gas technician on duty. Equipment damage would be limited to loss of a portion of the system to which the trailer was connected, and possible loss of the truck and tube trailer from fire.

The second scenario would be similar in scope to the first scenario, involving the same personnel and equipment. The initiating event would be the loss of one or more high-pressure tube trailer rupture disks. Each tube of a tube trailer is protected from over-pressure by a single rupture disk installed at the front end (the truck end) of the trailer. If one or more of these rupture disks spontaneously failed at the exact time that a running truck was attached to the trailer, a fire could result with the same consequences as the first scenario.

Although the severity of consequences associated with either of the above scenarios is high, the probability of mishap is extremely remote; thus the combination results in a low hazard classification for either scenario.

V. Conclusion

A systematic process of hazard identification and assessment has been carried out for the BTeV experimental facility for hazards that are not routinely accepted. This process resulted in the determination of the worst-case potential accidents under the condition that engineered mitigation measures and operational safety procedures are disregarded. Accident scenarios were then developed for the two potential mishaps judged as the most severe in terms of both probability of occurrence and severity of consequences, a gas leak leading to an oxygen deficiency condition and an ethane spill leading to a fire.

This assessment concludes that BTeV is a low hazard facility based on a systematic analysis of worst-case accident scenarios involving risks that would exist if there were no engineered mitigation actions taken and no operational procedures in place.

References:

(1) Safety Assessment Document for the Collider Detector at Fermilab
Revision D, release date December 1, 1994
(2) FERMILAB Hazard Assessment Document
September 30, 1994

Attachments:

(A) Preliminary Hazard List
(B) Preliminary Hazard Analysis Worksheets
(C) C0 Oxygen Deficiency Hazard Ventilation Requirements
January 6, 2004
(D) Preliminary Safety Assessment Document (P-SAD) Issues
January 4, 2004

Appendix:

(A) Risk-Based Priority Model

Attachment A.

Preliminary Hazard List

The following list is a synopsis of potential hazards that are not usually encountered and are associated with operation of a high energy physics experimental facility. This list was assembled by consulting Work Smart Standards document and by using generic potential hazard groupings available in the common literature. The intent is to provide a check list that ensures potential hazards that might be encountered in high tech facilities and high energy physics in particular are certain to be identified. The list is in no way intended to substitute for a thorough on-site facility inspection; it serves as a catalogue of watchful experience and "mind jogging" alerts.

Radiation
- calibration source exposure
- creation of mixed waste

Toxic Materials
- beryllium components
- chemical agents
- lead and other heavy metals

Flammable Materials
- flammable gases
- flammable liquids
- wire and cable insulation and jackets

Electrical Energy
- stored energy exposure
- high voltage exposure
- low voltage, high current exposure
- electrical faults

Thermal Energy
- cryogens
- high temperature equipment
- vacuum pumps
- battery bank and UPS equipment

Kinetic Energy
- power tools and equipment
- movement of large objects
- overhead structures and equipment
- motor generator equipment and flywheels

Potential Energy
- crane operations
- compressed gases
- capacitor banks
- vacuum/pressure vessels

Asphyxiant
- cryogenic spill
- cryogen/gas/liquid leak
- ventilation failure
- sensor failure
- confined space

Magnetic Field
- quench effects
- fringe fields

Attachment B.

Preliminary Hazard Analysis Worksheet

This attachment presents the results of the Hazard Analysis process in the form of spreadsheet summaries, pages 14 through 24 following. The data is organized according to hazard type and BTeV Zone number. Presented are the initiating event, the consequences, and the risk classification. Comments and a listing of the hazard mitigation measures in place are provided for each entry.

Attachment B.

Preliminary Hazard Analysis Worksheet

Zone No.	Hazard Type	Consequence	Initiating Event	RPM Matrix	RPM Score	Comments and Hazard Mitigation Measures
1	Radiation	Accidental exposure	Unsafe practices	7D-0.0010 9D-0.0075	**0.0085**	**Passive Mitigation:** Non-detector located sources are Kept Locked in an identified storage cabinet when not in use. Detector-located sources are installed in a manner to limit personnel exposure. **Active Mitigation:** Sources are only utilized by trained personnel. Administrative procedures are in effect to restrict access to and limit personnel exposure to calibration sources.
1	Toxic Materials	Limited exposure	Detector or beam pipe installation or removal	7D-0.0010 11D-0.0001	**0.0011**	**Comments:** Exposure to passivated beryllium detector Components occurs only during construction and installation/servicing of the RICH Detector and Forward Tracking Beam pipe. The total amount of beryllium (beam pipe) is <2-4 pounds. Some beryllium Oxide hybrid printed circuits. Very small quantities of beryllium substrate attachments <2-4 oz. **Passive Mitigation:** All beryllium surfaces are passivated. The beam pipe is totally covered with kapton. **Active Mitigation:** Only trained personnel are allowed to Handle beryllium components. No machining, grinding, or welding of beryllium is permitted at Fermilab.
1	Flammable Materials	Personnel injury Property Loss	Unsafe practices or equipment failure	7D-0.0010 13D-0.0.0075	**0.0085**	**Comments**: This zone is classified as an industrial area. **Active Mitigation:** Administrative procedures are in effect for all welding and burning. The majority of materials are stored in metal cabinets. The area has sprinkler protection to control the spread of fire.
1	Electrical Energy	Personnel injury	Contact with energized equipment	4D-0.2 5D-0.02 6B-10 7A-10 12C-1.5 13C-0.75 15D-0.0015	**22.4715**	**Comments:** A variety of commercially available and some BTeV specific electrical equipment is located or utilized in this area. **Passive Mitigation:** All equipment meets applicable NEC and NEMA codes and FNAL Safety requirements. **Active Mitigation:** Administrative procedures are in effect for all work on electrical equipment and systems. Lockout/Tag out rules are in effect for all work on this equipment per OSHA requirements. System designs are reviewed by an independent Electrical Safety Review Committee.
1	Thermal Energy	Personnel injury due to burns	Contact with hot or cold surfaces	7D-0.0010	**0.0010**	**Comments:** Operation of soldering irons and heat guns, as well as Use of small amounts of liquid nitrogen for leak detector operations may occur in this area. **Active Mitigation:** Technical and safety training of personnel utilizing the equipment.
1	Kinetic Energy	Personnel Injury	Improper operation of machinery	4D-0.2 5D-0.02 6D-0.01 7D-0.001 11C-0.01	**0.241**	**Comments:** Operation of hand held power tools and manual tools as well as rotating machinery operations associated with small vacuum pumps may occur in this zone. **Active Mitigation:** Technical and safety training of Personnel utilizing tools and equipment.

Attachment B.

Preliminary Hazard Analysis Worksheet

Zone No.	Hazard Type	Consequence	Initiating Event	RPM Matrix	RPM Score	Comments and Hazard Mitigation Measures
1	Potential Energy	Personnel injury or equipment damage	Unsafe practices	4D-0.2 5D-0.02 6C-1 7A-10 11C-0.01 12C-1.5 13C-0.75 13D-0.0075 15D-0.0015	**13.489**	**Comments:** A 30-ton crane is available for use in this zone. Improper use of the crane or improper rigging practices could result in damage to property or injury to personnel. **Passive Mitigation:** None. **Active Mitigation:** Crane operation is restricted to trained Personnel only. The crane circuit breaker is off and locked out when the crane is not in use. Lifting fixtures are load tested and their design is reviewed by a Mechanical Safety Review Committee. All rigging equipment is periodically inspected for signs of wear and/or abuse. The crane is also periodically inspected.
1	Flammable Gas	Personnel injury	Unsafe practices or equipment failure	4D-0.2 5D0.02 6D-0.01 7D-0.001 13D-0.0075	**0.2385**	**Comments:** When the central detector is located in the adjoining Collision Hall, operational detector flow rates of 50/50 argon/ethane, argon/C02 and or nitrogen are permitted if standard operating requirements for the detector has been satisfied. **Passive Mitigation:** All gas and vent lines entering and exiting each room are of metal construction, designed, constructed, and installed in accordance with ANSI B31.3. Non-removable flow restricting orifices are installed in each gas supply line, limiting the maximum flow into each room to 43 SCFH. All over-pressure venting devices are piped to an exhaust point outside the Assembly Hall. **Active Mitigation:** All gas lines in each room have locking devices on the supply valving to prevent unauthorized use of the gas. In the highly unlikely event of a line break upstream of the flow restricting orifices, each supply line also has a mechanically actuated excess flow valve that closes if the flow exceeds 53 SCFH. All gas system components and subsystems are protected from over-pressurization by relief valves, which exhaust outside the building. A real time display board of the hazard status of the rooms is displayed at the normally used entrance to alert personnel of any unsafe condition that may be present. Each room has an ODH detector and a flammable gas detector installed which will alarm at 7%LEL with a visual and audible signal in the presence of a hazardous condition. Power is removed by shunt trip activation at 25% LEL. Administrative procedures and check lists are in effect For the use of gas the collision hall. Ventilation is supplied to each of the test rooms at rates shown in Table 2 of BTeV Hazard Analysis Document. System designs are reviewed by an independent Flammable Gas Safety Review Committee.
1	Oxygen Deficiency	Personnel injury	Unsafe practices or equipment failure	4D-0.2 5D-0.02 6D-0.01 7D-0.001	**0.231**	**Comments:** Due to the volume of the zone and the limited amount of cryogens available in the zone, an ODH condition is highly unlikely. **Passive and Active Mitigation:** Same mitigation items as Listed in Accident Scenario 1 of BTeV Hazard Analysis Document for Zone 4.

Attachment B.

Preliminary Hazard Analysis Worksheet

Zone No.	Hazard Type	Consequence	Initiating Event	RPM Matrix	RPM Score	Comments and Hazard Mitigation Measures
2	Radiation	Accidental exposure	Unsafe practices	7D-0.001 11D-0.0001 13D-0.0075	**0.0086**	**Comments:** Exposure to low level Fe-55 calibration sources are possible if administrative procedures are not followed. **Passive Mitigation:** Non-detector located sources are kept Locked in an identified storage cabinet when not in use. Detector-located sources are installed in a manner to limit personnel exposure. **Active Mitigation:** Sources are only utilized by trained personnel. Administrative procedures are in effect to restrict access to and limit personnel exposure to calibration sources.
2	Toxic Materials	Limited exposure	Detector or beam pipe installation or removal	6D-0.01 7D-0.001	**0.011**	**Comments:** Exposure to passivated beryllium detector components occurs only during construction and installation/servicing of the RICH Detector and Forward Tracking Beam pipe. The total amount of beryllium (beam pipe) is <2-4 pounds. Some beryllium Oxide hybrid printed circuits. Very small quantities of beryllium substrate attachments <2-4 oz. **Passive Mitigation:** All beryllium surfaces are passivated. The beryllium beam pipe is totally covered with kapton. **Active Mitigation:** Only trained personnel are allowed to handle beryllium components. No machining, grinding, or welding of beryllium is permitted at Fermilab.
2	Flammable Materials	Personnel injury	Unsafe practices or equipment failure	6D-0.01 7D-0.001 13D-0.0075 15D-0.0015	**0.02**	**Comments:** When the central detector is located in the Zone quantities of carbon fiber, rohacell, fiber-optic cables and large quantities of insulated cables are present. **Active Mitigation:** Administrative procedures are in effect for all welding and burning. Active incipient fire detection incorporating high sensitivity smoke detection and gas signature monitoring to parts per million. A multi-tiered alarm system, which will turn off power to the area.
2	Electrical Energy	Personnel injury	Contact with energized equipment	4D-0.2 5D-0.02 6B-10 7A-10 12C-1.5 13C-0.75 15D-0.0015	**22.4715**	**Comments:** A variety of commercially available and some BTeV specific electrical equipment is located or utilized in this zone. The central detector may be located in this zone for service and upgrades. **Passive Mitigation:** All equipment meets applicable NEC and NEMA codes and FNAL Safety requirements. **Active Mitigation:** Administrative procedures are in effect for all work on electrical equipment and systems. Lockout/Tagout rules are in effect for all work on this equipment per OSHA requirements. System designs are reviewed by an independent Electrical Safety Review Committee.
2	Thermal Energy	Personnel injury due to burns	Contact with hot or cold surfaces	7D-0.0010	**0.0010**	**Comments:** Operation of soldering irons and heat guns, as well as use of small amounts of liquid nitrogen for leak detector operations may occur in this area. **Active Mitigation:** Technical and safety training of Personnel utilizing the equipment.

Attachment B.

Preliminary Hazard Analysis Worksheet

Zone No.	Hazard Type	Consequence	Initiating Event	RPM Matrix	RPM Score	Comments and Hazard Mitigation Measures
2	Kinetic Energy	Personnel injury	Improper operation of machinery	4D-0.2 5D-0.02 6D-0.01 7D-0.001 11C-0.01	**0.241**	**Comments:** Operation of hand held power tools and manual tools as well as rotating machinery operations associated with small vacuum pumps may occur in this zone. **Active Mitigation:** Technical and safety training of Personnel utilizing tools and equipment.
2	Potential Energy	Personnel injury or equipment damage	Unsafe practices	4D-0.2 5D-0.02 6C-1 7A-10 11C-0.01 12C-1.5 13C-0.75 13D-0.0075 15D-0.0015	**13.489**	**Comments:** A 30-ton crane is available for use in this zone. Improper use of the crane or improper rigging practices could result in damage to property or injury to personnel. **Passive Mitigation:** None. **Active Mitigation:** Crane operation is restricted to trained Personnel only. The crane circuit breaker is off and locked out when the crane is not in use. Lifting fixtures are load tested and their design is reviewed by a Mechanical Safety Review Committee. All rigging equipment is periodically inspected for signs of wear and/or abuse. The crane is also periodically inspected.
2	Flammable Gas	Personnel injury	Unsafe practices or equipment failure	4D-0.2 5D0.02 6D-0.01 7D-0.001 13D-0.0075	**0.2385**	**Comments:** When the central detector is located in the adjoining Collision Hall, operational detector flow rates of 50/50 argon/ethane gas are permitted if standard operating requirements for the detector have been satisfied. **Passive and Active Mitigation:** Same hazard mitigation Measures as stated in Zone 1, "Flammable Materials" hazard of this assessment, with the exception of the excess flow valve and the total system flow. No excess flow valve is installed in this system. The flow restricting orifice installed in this system limits the total flow to 43 SCFH. Ventilation rates to this zone are listed in Table 2 of BTeV Hazard Analysis Document.
2	Oxygen Deficiency	Personnel injury	Unsafe practices or equipment failure	4D-0.2 5D-0.02 6D-0.01 7D-0.001	**0.231**	**Comments:** See Accident Scenario 1 in BTeV Hazard Assessment Document
2	Laser Hazard	Personnel injury	Improper operation of machinery	7C-0.1	**0.1**	**Comments:** Operation of optical links, calibration and Monitoring lasers may occur in this zone. **Active Mitigation:** Technical and safety training of personnel utilizing tools and equipment. (i.e. FESHM 5062)
2	Magnetic Field	Personnel Injury	Normal detector operation	4D-0.2 5D-0.02 6B-10 12D-0.015 13D-0.0075	**10.24**	**Comments:** Exposure to fringe field (<10 gauss) during Vertex Magnet operation in the Assembly Hall is possible. The majority of the magnetic field is contained within the iron of the Vertex Magnet . **Passive Mitigation:** None. **Active Mitigation:** Administrative procedures are in effect to limit personnel exposure during magnet operations in the Assembly Hall.

Attachment B.

Preliminary Hazard Analysis Worksheet

Zone No.	Hazard Type	Consequence	Initiating Event	RPM Matrix	RPM Score	Comments and Hazard Mitigation Measures
3	Toxic Materials	Limited exposure	Detector or beam pipe installation or removal	6D-0.01 7D-0.001	**0.011**	**Comments:** Exposure to Some beryllium Oxide hybrid printed circuits occurs only during construction and installation/servicing of the some circuit boards **Passive Mitigation:** All beryllium surfaces are passivated. **Active Mitigation:** Only trained personnel are allowed to handle beryllium components. No machining, grinding, or welding of beryllium is permitted at Fermilab.
3	Flammable Materials	Personnel injury	Unsafe practices or equipment failure	7D-0.0010 13D-0.0.0075	**0.0085**	**Comments: Q**uantities of fiber-optic cables and large quantities of insulated cables are present. **Active Mitigation:** Administrative procedures are in effect for all welding and burning. Active incipient fire detection incorporating high sensitivity smoke detection and gas signature monitoring to parts per million. A multi-tiered alarm system, which will turn off power to the area.
3	Electrical Energy	Personnel injury	Contact with energized equipment	4D-0.2 5D-0.02 6B-10 7A-10 12C-1.5 13C-0.75 15D-0.0015	**22.4715**	**Comments:** A variety of commercially available and some BTeV specific electrical equipment is located or utilized in this zone. The central detector may be located in this zone for service and upgrades. **Passive Mitigation:** All equipment meets applicable NEC and NEMA codes and FNAL Safety requirements. **Active Mitigation:** Administrative procedures are in effect for all work on electrical equipment and systems. Lockout/Tagout rules are in effect for all work on this equipment per OSHA requirements. System designs are reviewed by an independent Electrical Safety Review Committee.
3	Thermal Energy	Personnel injury due to burns	Contact with hot or cold surfaces	7D-0.0010	**0.0010**	**Comments:** Operation of soldering irons and heat guns, as well as use of small amounts of liquid nitrogen for leak detector operations may occur in this area. **Active Mitigation:** Technical and safety training of personnel utilizing the equipment.
3	Kinetic Energy	Personnel injury	Improper operation of machinery	4D-0.2 5D-0.02 6D-0.01 7D-0.001 11C-0.01	**0.241**	**Comments:** Operation of hand held power tools and manual tools as well as rotating machinery operations associated with small vacuum pumps may occur in this zone. **Active Mitigation:** Technical and safety training of personnel utilizing tools and equipment.
3	Potential Energy	Personnel injury or equipment damage	Unsafe practices	4D-0.2 5D-0.02 6C-1 7A-10 11C-0.01 12C-1.5 13C-0.75 13D-0.0075 15D-0.0015	**13.489**	**Comments:** Stored energy associated with compressed gases And pressurized liquid could cause injury or damage if Administrative procedures are not followed. **Passive Mitigation:** All equipment is designed to all applicable codes and standards governing this type of installation. **Active Mitigation:** Operator training and adherence to Established procedures. Operations are conducted by trained personnel only. The installation and the operating procedures have been reviewed by an independent cryogenic safety review committee.

Attachment B.

Preliminary Hazard Analysis Worksheet

Zone No.	Hazard Type	Consequence	Initiating Event	RPM Matrix	RPM Score	Comments and Hazard Mitigation Measures
3	Oxygen Deficiency	Personnel injury	Unsafe practices or equipment failure	4D-0.2 5D-0.02 6D-0.01 7D-0.001	**0.231**	**Comments:** Due to the volume of the zone and the limited amount of cryogens available in the zone, an ODH condition is highly unlikely. **Passive and Active Mitigation:** Same mitigation items as Listed in Accident Scenario 1 of BTeV Hazard Analysis Document for Zone 2.
3	Laser Hazard	Personnel injury	Improper operation of machinery	7C-0.1	**0.1**	**Comments:** Operation of optical links, calibration and Monitoring lasers may occur in this zone. **Active Mitigation:** Technical and safety training of personnel utilizing tools and equipment. (i.e. FESHM 5062)
4	Radiation	Accidental exposure	Unsafe practices	7D-0.001 11D-0.0001 13D-0.0075	**0.0086**	**Comments:** The potential for residual activation of some detector components during routine accelerator operation exist. **Passive Mitigation:** Non-detector located sources are kept locked in an identified storage cabinet when not in use. detector-located sources are installed in a manner to limit personnel exposure. **Active Mitigation:** Sources are only utilized by trained personnel. Potentially activated components are with-in interlocked area. Administrative procedures are in effect to restrict access to and limit personnel exposure to calibration sources and potentially activated components .
4	Toxic Materials	Limited exposure	Detector or beam pipe installation or removal	6D-0.01 7D-0.001	**0.011**	**Comments:** Exposure to passivated beryllium detector components occurs only during construction and installation/servicing of the RICH Detector and Forward Tracking Beam pipe. The total amount of beryllium (beam pipe) is <2-4 pounds. Some beryllium Oxide hybrid printed circuits. Very small quantities of beryllium substrate attachments <2-4 oz. **Passive Mitigation:** All beryllium surfaces are passivated. The beryllium beam pipe is totally covered with kapton. **Active Mitigation:** Only trained personnel are allowed to handle beryllium components. No machining, grinding, or welding of beryllium is permitted at Fermilab.
4	Flammable Materials	Personnel injury	Unsafe practices or equipment failure	7D-0.0010 13D-0.0.0075	**0.0085**	**Comments:** When the central detector is located in the Zone quantities of carbon fiber, rohacell, fiber-optic cables and large quantities of insulated cables are present. **Active Mitigation:** Administrative procedures are in effect for all welding and burning. Active incipient fire detection incorporating high sensitivity smoke detection and gas signature monitoring to parts per million. A multi-tiered alarm system, which will turn off power to the area.

Attachment B.

Preliminary Hazard Analysis Worksheet

Zone No.	Hazard Type	Consequence	Initiating Event	RPM Matrix	RPM Score	Comments and Hazard Mitigation Measures
4	Electrical Energy	Personnel injury	Contact with energized equipment	4D-0.2 5D-0.02 6B-10 7A-10 12C-1.5 13C-0.75 15D-0.0015	**22.4715**	**Comments:** A variety of commercially available and some BTeV specific electrical equipment is located or utilized in this zone. **Passive Mitigation:** All equipment meets applicable NEC and NEMA codes and FNAL Safety requirements. **Active Mitigation:** Administrative procedures are in effect for all work on electrical equipment and systems. Lockout/Tagout rules are in effect for all work on this equipment per OSHA requirements. System designs are reviewed by an independent Electrical Safety Review Committee.
4	Thermal Energy	Personnel injury due to burns	Contact with hot or cold surfaces	7D-0.0010	**0.0010**	**Comments:** Cold lines associated with argon and ethane supplies to the mixing system may be encountered. Operation of soldering irons and heat guns, as well as use of small amounts of liquid nitrogen for leak detector operations may occur in this area. **Passive Mitigation:** Insulation on cold lines and surfaces. **Active Mitigation:** Operating procedures are in effect for all equipment in the area. Operations are conducted by trained personnel only. The installation and the operating procedures have been reviewed by an independent safety review committee. Technical and safety training of personnel utilizing the equipment.
4	Kinetic Energy	Personnel injury	Unsafe practices	4D-0.2 5D-0.02 6D-0.01 7D-0.001 11C-0.01	**0.241**	**Comments:** Operation of hand held power tools and manual tools as well as rotating machinery operations associated with small vacuum pumps and leak detectors. Also possible injury to personnel if proper procedures are not followed during large detector component moving operations. **Passive Mitigation:** Equipment safety guards. **Active Mitigation:** Only trained personnel are allowed to Participate in detector moving operations. Administrative are utilized to govern detector-moving operations.
4	Potential Energy	Personnel injury or equipment damage	Unsafe practices	4D-0.2 5D-0.02 6C-1 7A-10 11C-0.01 12C-1.5 13C-0.75 13D-0.0075 15D-0.0015	**13.489**	**Comments:** Stored energy associated with compressed gases And pressurized liquid could cause injury or damage if Administrative procedures are not followed. **Passive Mitigation:** All equipment is designed to all applicable codes and standards governing this type of installation. **Active Mitigation:** Operator training and adherence to Established procedures. Operations are conducted by trained personnel only. The installation and the operating procedures have been reviewed by an independent cryogenic safety review committee.

Attachment B.

Preliminary Hazard Analysis Worksheet

Zone No.	Hazard Type	Consequence	Initiating Event	RPM Matrix	RPM Score	Comments and Hazard Mitigation Measures
4	Flammable Gas	Personnel injury or equipment damage	Unsafe practices	4D-0.2 5D0.02 6D-0.01 7D-0.001 13D-0.0075	**0.2385**	**Comments:** During routine detector operations, approximately >50 SCF of 50/50 argon/ethane is contained in the detector system in the Collision Hall. Best practices have been utilized during the construction of the detector components to minimize leakage. **Passive Mitigation:** All gas and vent lines entering and exiting Zone 4 are of metal construction, designed, constructed and installed in accordance with ANSI B31.3. The maximum flow to the Collision Hall is limited to 43 SCFM by a non-removable flow restricting orifice. **Active Mitigation:** A real time display board of the hazard status of the zone is displayed at the entrance to the Collision Hall to alert personnel of any unsafe condition that may be present. ODH detectors and flammable gas detectors are installed which will alarm with a visual and audible signal in the presence of a hazardous condition. Administrative procedures and check lists are in effect for the use of gas in the zone. Ventilation is supplied to the zone and is monitored and alarmed in the event it is lost. The gas system is subject to review by an outside safety review panel. The collision Hall has flammable gas detectors installed which will alarm at 7%LEL with a visual and audible signal in the presence of a hazardous condition. Power is removed by shunt trip activation at 25% LEL.
4	Oxygen Depletion	Personnel injury	Unsafe practices or equipment failure	4D-0.2 5D-0.02 6D-0.01 7D-0.001	**0.231**	Same comments and hazard mitigation measures as stated in Zone 4, "Flammable Gas" hazard on the preceding page of this assessment.
4	Laser Hazard	Personnel injury	Improper operation of machinery	7C-0.1	**0.1**	**Comments:** Operation of optical links, calibration and Monitoring lasers may occur in this zone. **Active Mitigation:** Technical and safety training of personnel utilizing tools and equipment. (i.e. FESHM 5062)
4	Magnetic Field	Personnel exposure	Normal detector operation	4D-0.2 5D-0.02 6B-10 12D-0.015 13D-0.0075	**10.24**	**Comments:** Exposure to fringe field (<10 gauss) during Vertex Magnet operation in the Collision Hall is possible. The majority of the magnetic field is contained within the iron of the Vertex Magnet . **Passive Mitigation:** None. **Active Mitigation:** Administrative procedures are in effect to limit personnel exposure during magnet operations in the Collision Hall

Attachment B.

Preliminary Hazard Analysis Worksheet

Zone No.	Hazard Type	Consequence	Initiating Event	RPM Matrix	RPM Score	Comments and Hazard Mitigation Measures
5	Electrical Energy	Personnel injury	Contact with energized equipment	4D-0.2 5D-0.02 6B-10 7A-10 12C-1.5 13C-0.75 15D-0.0015	**22.4715**	**Comments:** A variety of commercially available electrical equipment is located or utilized in this zone. The central detector may be located in this zone for service and upgrades. **Passive Mitigation:** All equipment meets applicable NEC and NEMA codes and FNAL Safety requirements. **Active Mitigation:** Administrative procedures are in effect for all work on electrical equipment and systems. Lockout/Tagout rules are in effect for all work on this equipment per OSHA requirements. System designs are reviewed by an independent Electrical Safety Review Committee.
5	Kinetic Energy	Personnel injury	Unsafe practices	4D-0.2 5D-0.02 6D-0.01 7D-0.001 11C-0.01	**0.241**	**Comments:** Operation of hand held power tools and manual tools as well as rotating machinery operations associated with small vacuum pumps and leak detectors. Also possible injury to personnel if proper procedures are not followed during large detector component moving operations. **Passive Mitigation:** Equipment safety guards. **Active Mitigation:** Only trained personnel are allowed to Participate in detector moving operations. Administrative are utilized to govern detector-moving operations.
5	Potential Energy	Personnel injury or equipment damage	Unsafe practices	4D-0.2 5D-0.02 6C-1 7A-10 11C-0.01 12C-1.5 13C-0.75 13D-0.0075 15D-0.0015	**13.489**	**Comments:** Stored energy associated with compressed gases And pressurized liquid could cause injury or damage if administrative procedures are not followed. **Passive Mitigation:** All equipment is designed to all applicable codes and standards governing this type of installation. **Active Mitigation:** Operator training and adherence to Established procedures. Operations are conducted by trained personnel only. The installation and the operating procedures have been reviewed by an independent cryogenic safety review committee.
5	Oxygen Depletion	Personnel injury	Unsafe prac-tices or equip-ment failure	4D-0.2 5D-0.02 6D-0.01 7D-0.001	**0.231**	Same comments and hazard mitigation measures as stated in Zone 4, "Flammable Gas" hazard on the preceding page of this assessment.

Attachment B.

Preliminary Hazard Analysis Worksheet

Zone No.	Hazard Type	Consequence	Initiating Event	RPM Matrix	RPM Score	Comments and Hazard Mitigation Measures
6	Electrical Energy	Personnel injury	Contact with energized equipment	4D-0.2 5D-0.02 6B-10 7A-10 12C-1.5 13C-0.75 15D-0.0015	**22.4715**	**Comments:** A variety of commercially available and some BTeV specific electrical equipment is located or utilized in this zone. The central detector may be located in this zone for service and upgrades. **Passive Mitigation:** All equipment meets applicable NEC and NEMA codes and FNAL Safety requirements. **Active Mitigation:** Administrative procedures are in effect for all work on electrical equipment and systems. Lockout/Tagout rules are in effect for all work on this equipment per OSHA requirements. System designs are reviewed by an independent Electrical Safety Review Committee.
6	Thermal Energy	Personnel injury due to burns	Contact with hot or cold surfaces	7D-0.0010	**0.0010**	**Comments:** Cold lines associated with argon and ethane supplies to the mixing system may be encountered. **Passive Mitigation:** Insulation on cold lines and surfaces. **Active Mitigation:** Operating procedures are in effect for all equipment in the area. Operations are conducted by trained personnel only. The installation and the operating procedures have been reviewed by an independent safety review committee
6	Kinetic Energy	Personnel injury	Improper operation of machinery	4D-0.2 5D-0.02 6D-0.01 7D-0.001 11C-0.01	**0.241**	**Comments:** Operation of rotating machinery associated the gas compressors or portable vacuum pumps used in the area. **Passive Mitigation:** Installed guards to limit personnel exposure to rotating parts. **Active Mitigation:** Operator training and adherence to procedures.
6	Potential Energy	Personnel injury or equipment damage	Unsafe practices	4D-0.2 5D-0.02 6C-1 7A-10 11C-0.01 12C-1.5 13C-0.75 13D-0.0075 15D-0.0015	**13.489**	**Comments:** Stored energy associated with compressed gases And pressurized liquid could cause injury or damage if Administrative procedures are not followed. **Passive Mitigation:** All equipment is designed to all applicable codes and standards governing this type of installation. **Active Mitigation:** Operator training and adherence to Established procedures. Operations are conducted by trained personnel only. The installation and the operating procedures have been reviewed by an independent cryogenic safety review committee.

Attachment B.

Preliminary Hazard Analysis Worksheet

Zone No.	Hazard Type	Consequence	Initiating Event	RPM Matrix	RPM Score	Comments and Hazard Mitigation Measures
6	Flammable Gas	Personnel injury or equipment damage	Unsafe practices	4D-0.2 5D0.02 6D-0.01 7D-0.001 13D-0.0075	**0.2385**	**Comments:** The gas storage area contains the compressors used to pressurize the storage tanks with the 50/50 argon/ethane gas mixture from the mixing area. The storage area contains two 2500 gallon ASME coded storage tanks, one of which contain gas at medium pressure (<300 psig) and the second is a low pressure (<24 psig) buffer tank. **Passive Mitigation:** All gas and vent lines entering and exiting Zone 6 are of metal construction, designed, constructed and installed in accordance with ANSI B31.3. **Active Mitigation:** A real time display board of the hazard status of the zone is displayed at the entrance to the mixing shed to alert personnel of any unsafe condition that may be present. ODH detectors and flammable gas detectors are installed which will alarm with a visual and audible signal in the presence of a hazardous condition. Administrative procedures and check lists are in effect for the use of gas in the zone. All gas system components, vessels, and equipment are protected from over-pressurization by relief valves which exhaust to safe outside locations. The gas system is subject to review by an outside safety review panel.
6	Oxygen Deficiency	Personnel injury	Unsafe practices or equipment failure	4D-0.2 5D-0.02 6D-0.01 7D-0.001	**0.231**	Same comments and hazard mitigation measures as stated in Zone 6, "Flammable Gas" hazard on the preceding page of this assessment.
7	Thermal Energy	Personnel injury due to burns	Contact with cold surfaces	7D-0.0010	**0.0010**	**Comments:** Stored energy associated with compressed gases And pressurized liquid could cause injury or damage if Administrative procedures are not followed. **Passive Mitigation:** All equipment is designed to all applicable codes and standards governing this type of installation. **Active Mitigation:** Operator training and adherence to Established procedures. Operations are conducted by trained personnel only. The installation and the operating procedures have been reviewed by an independent cryogenic safety review committee.
7	Kinetic Energy	Personnel injury	Improper operation of machinery	4D-0.2 5D-0.02 6D-0.01 7D-0.001 11C-0.01	**0.241**	**Comments:** Operation of rotating machinery associated the gas compressors or portable vacuum pumps used in the area. **Passive Mitigation:** Installed guards to limit personnel exposure to rotating parts. **Active Mitigation:** Operator training and adherence to procedures.

Attachment B.

Preliminary Hazard Analysis Worksheet

Zone No.	Hazard Type	Consequence	Initiating Event	RPM Matrix	RPM Score	Comments and Hazard Mitigation Measures
7	Potential Energy	Personnel injury or equipment damage	Unsafe practices	4D-0.2 5D-0.02 6C-1 7A-10 11C-0.01 12C-1.5 13C-0.75 13D-0.0075 15D-0.0015	**13.489**	**Comments:** Stored energy associated with compressed gases And pressurized liquid could cause injury or damage if Administrative procedures are not followed. **Passive Mitigation:** All equipment is designed to all applicable codes and standards governing this type of installation. **Active Mitigation:** Operator training and adherence to Established procedures. Operations are conducted by trained personnel only. The installation and the operating procedures have been reviewed by an independent cryogenic safety review committee.
7	Oxygen Depletion	Personnel injury	Unsafe practices or equipment failure	4D-0.2 5D-0.02 6D-0.01 7D-0.001	**0.231**	**Comments:** The dewar area is not an enclosed area. It is in an outside location backed by the south wall of the C0 Assembly Hall and has a shed style roof. The proposal is for it to be open on the other three sides. In the event of a very large leak in this area on a day with no air currents, it is conceivable that a localized ODH condition might exist in the vicinity of the leak. **Passive and Active Mitigation:** Same as those listed in Zone 6 "Flammable Gas" section.

Attachment C.

C0 ODH Ventilation Requirements

Robert Sanders
01/06/04

This document looks at sizing a ventilation system for C0 that would be adequate for an ODH emergency. The conclusion reached is that for ODH reasons C0 should have a ventilation system capable of delivering 5000 CFM of fresh air into the building. If an exhaust fan in a pit is required, it should be capable of drawing out 6000 CFM. These numbers are based upon conservative calculations that already have had a 50% safety factor added to them.

CALCULATIONS:
The worse emergency ODH situation would be a complete break in the liquid nitrogen transferline inside of the C0 building main hall or the collision hall. In both the main hall and the collision hall, the maximum sustained leak rate of nitrogen is for practical purposes, the same. There will be relatively small amounts of liquid nitrogen indoors. The source of nitrogen would be the outside dewar. The maximum nitrogen flow rate is determined by dewar pressure and the flow restriction of the transfer line between the dewar and the C0 building.

The operating pressure of the dewar is not known. It will most likely have to be about 5 psi above the suction pressure of the liquid nitrogen recirculating pump. If the pressure were much higher some of the liquid nitrogen would flash to vapor at the lower pump pressure and would have to be vented to atmosphere as waste. For the sake of simplicity and convenience assume a dewar operating pressure of :

p = 100 psia = 85.7 psig.

Therefore if there were a break in the transferline, discharging liquid to atmosphere, the pressure drop driving the flow would be 85.7 psi. Most likely, the dewar pressure will be lower.

Estimate the normal mass flow rate of liquid nitrogen. The heat load for the pixel cooling system (plus 10%) is

Qdot = 4000 W

The normal boil-off rate Wn of the liquid nitrogen at 100 psia will be in the pixel system"

Wn = 193.103 lb / hr

Next estimate the normal pressure drop. The transferline will be designed to keep the pressure drop at normal flow rates below 1psi. Assume, for the sake of illustration, the transfer line has the following components:

100 ft of 1/2"X0.35" tubing.
Cryolab 1/2" globe cryogenic valve, CV8 series, Cv:=6.6
ten 90 degree elbows

The normal pressure drop through the transfer line would be about:

dpn = 0.519064939 psi

This is a reasonable pressure drop to design the transfer line for during normal operating conditions.

However, during a hypothetical emergency condition, with the transfer line severed just after it enters the C0 building, the pressure driving the flow would be the gage pressure of the dewar dpe = 85.7 psi. Assume the flow in the flow in the pipe is completely liquid. This is a very conservative assumption. In reality, the pressure change would cause about 10% to 20% or so of the liquid to vaporize. The lower density vapor would significantly decrease the maximum flow rate, but the calculations would be difficult and inaccurate. The flow rate varies directly approximately with the square root of the pressure drop. So:

We/Wn = (pe/pn)^(1/2)

Where We is the emergency flow rate and:

We = 2481.2471179085 lb/hr

We may not use 100' of 1/2 tubing in the transfer line, however, if need be, a restriction such as an orifice may be placed in the transfer line that is big enough to permit normal flow at acceptable pressure drops but to restrict the maximum flow in emergency conditions.

Next consider the required ventilation rates. At standard conditions 60F and 1 atm the maximum liquid flow rate would be a nitrogen release of :

R = 33621 ft^3 / hr = 560 scfm

If we use fresh air blowing into the building Solve equation (2) of FESHM 5064TA-7 with time at infinity:

Q = -(Cr*R)/(Cr-0.21)

Where R is the release of cryogens into the building, and Q is the ventilation rate. Set the oxygen concentration Cr:= 0.18 to find the required ventilation rate.:

Q= 3362.12 cfm

For exhausting air from the building solve equation (4) of FESHM 5064TA-7 with time at infinity:

Q = -0.21*R/(Cr-0.21)

In which case, the required exhaust ventilation rate Is:

Q = 3922.49 cfm

Since there are many unknowns, and much of the BTEV system is not designed, it would be reasonable to put a significant safety factor of at least 50% to the required ventilation rates. Therefore C0 should have a ventilation system capable of delivering 5000 cfm of fresh air into the building. If an exhaust fan in a pit is required, it should be capable of drawing out 6000 cfm.

Attachment D.

Preliminary Safety Assessment (P-SAD) Issues

Preliminary Safety Assessment Document (P-SAD) Issues

From: Peter Garbincius

The installation of the straight section and the low-β* insertion do not present any new or unique ES&H challenges beyond standard Tevatron installation and operating issues. However, the following items are noted as likely requiring consideration in the Preliminary Safety Assessment Document (P-SAD).

The straight section and low-β* insertion configurations allow for the isolation of the C0 experimental hall from the Oxygen Deficiency Hazard (ODH) and electrical power bus hazards of the Tevatron tunnel. The HVAC system for the experimental hall will have to provide adequate fresh air and monitor and alarm on any reduction of oxygen concentration in the experimental hall. The hardware and procedures must be sufficiently flexible to provide for all open/closed configurations of the 400 ton shielding door and the tunnel isolation doors for equipment and alignment accessibility.

As at CDF and D0, the radiation access interlock system must be configured to provide controlled access to the C0 experimental hall, but not to the Tevatron tunnel, except for emergency egress.

When the SM3 analysis magnets, compensating dipoles, and muon toroid(s) are installed, lock-out/tag-out (LOTO) and interlocks on the magnet power systems will likely be required for access to the experimental hall.

For the low-β* insertion, the regular Fermilab cryogenic and pressure vessel standards will apply to the new LHC quads, corrector/trim packages, and other specialty cryogenic components.

Appendix A

Risk-Based Priority Model