BTeV Hazard Analysis Document

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FERMI NATIONAL ACCELERATOR LABORATORY

Hazard Analysis Document Approval ____

Project Leader/Date: ____

Fermilab PPD Senior Laboratory Safety Officer/Date: ___________________________

BTeV Hazard Analysis Document

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.

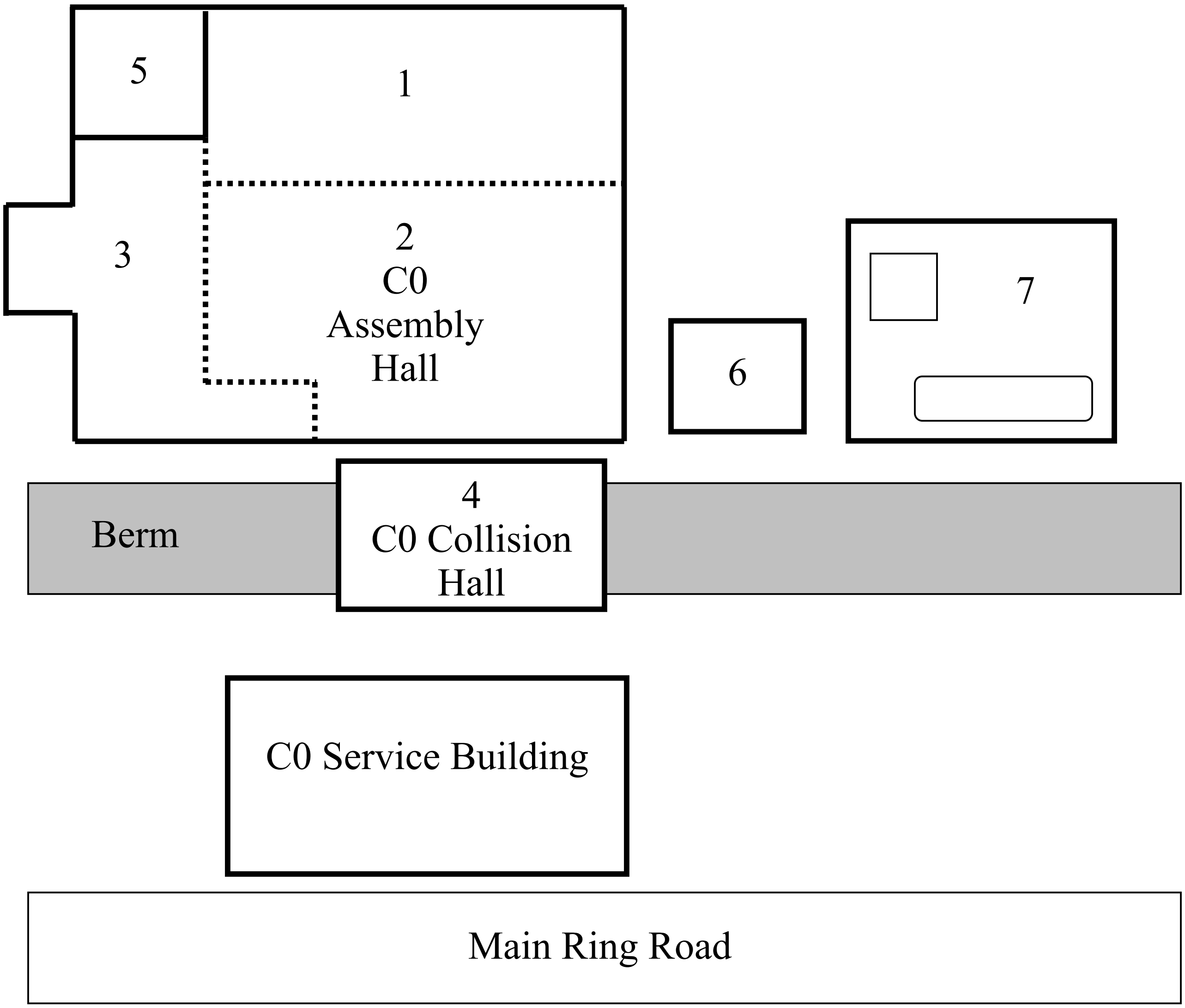
Each of the three steps is described further below.

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 Without mitigation	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	7C-0.10 10C-0.2 11C-0.01 12C-1.5 13C-0.75 14C-0.4 15C-0.15	**3.11**	**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. Beam pipe shall have protective sleeve and barriers to prevent damage. **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 Without mitigation	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 Without mitigation	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	7C-0.10 10C-0.2 11C-0.01 12C-1.5 13C-0.75 14C-0.4 15C-0.15	**3.11**	**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. Beam pipe shall have protective sleeve and barriers to prevent damage. **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 Without mitigation	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 9C-0.75	**0.85**	**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 9C-0.75 12D-0.015 13D-0.0075	**10.99**	**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 Without mitigation	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 6C-1 7C-0.1 12C-1.5 13C-0.75 15D-0.0015	**3.5715**	**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.
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 Without mitigation	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 9C-0.75	**0.85**	**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	4C-20 5C-2 6C-1 7C-0.1 8C-1.5 9C-0.75 11C-0.01 12C-1.5	**26.86**	**Comments:** The potential for residual activation of some detector components during routine accelerator operation exist. Anyone entering the collision hall during accelerator operations would be subject to sever radiation exposure. **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.
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.

Attachment B.
Preliminary Hazard Analysis Worksheet

Zone No.	Hazard Type	Consequence	Initiating Event	RPM Matrix	RPM Score Without mitigation	Comments and Hazard Mitigation Measures
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 Without mitigation	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	4C-20 5C-2 6C-1 7C-0.1 13C-0.75	**23.85**	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 9C-0.75	**0.85**	**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
5	Electrical Energy	Personnel injury	Contact with energized equipment	4D-0.2 5D-0.02 6C-1 7C-0.1 12C-1.5 13C-0.75 15D-0.0015	**3.5715**	**Comments:** A variety of commercially available 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.

Attachment B.
Preliminary Hazard Analysis Worksheet

Zone No.	Hazard Type	Consequence	Initiating Event	RPM Matrix	RPM Score Without mitigation	Comments and Hazard Mitigation Measures
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 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.
6	Electrical Energy	Personnel injury	Contact with energized equipment	4D-0.2 5D-0.02 6D-0.01 7D-0.001 12C-1.5 13C-0.75 15D-0.0015	**1.8075**	**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.
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.

Attachment B.
Preliminary Hazard Analysis Worksheet

Zone No.	Hazard Type	Consequence	Initiating Event	RPM Matrix	RPM Score Without mitigation	Comments and Hazard Mitigation Measures
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.
6	Flammable Gas	Personnel injury or equipment damage	Unsafe practices	4C-20 5C-2 6C-1 7C-0.1 13C-0.75	**23.85**	**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	4C-20 5C-2 6C-1 7C-0.1 13C-0.75	**23.85**	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	4C-20 5C-2 6C-1 7C-0.1 13C-0.75	**23.85**	**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 Without mitigation	Comments and Hazard Mitigation Measures
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.
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.

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.

RISK-BASED PRIORITY MODEL

The ES&H scoring and ranking process involves the assessment of various risks related to environmental or safety and health activities. Because risk consists of the product of impact severity (consequence) and likelihood, the process requires consideration and evaluation of all these factors in deriving a risk value. The ES&H Risk-based Priority Model (RPM), shown in Table 1, provides the framework for deriving activity priorities. This document describes the elements of the RPM and provides explanations and examples of use and interpretation of the model in the ranking process. The document is divided into the following sections:

1. Descriptions of each RPM matrix impact level (1 through 18) with examples to Illustrate situations to which different impacts apply.

2. Descriptions of each RPM matrix likelihood level (A through D).

3. Methodology for revising either RPM impacts or likelihood's to accommodate facility data.

Appendix A.
Risk-Based Priority Model

TABLE 1
ES&H RISK-BASED PRIORITY MODEL (RPM)

LIKELIHOOD OF OCCURRENCE

IMPACTS	A VERY HIGH	B HIGH	C MEDIUM	D LOW
CATEGORY: PUBLIC SAFETY AND HEALTH				
1. Immediate or eventual loss of life/permanent disability	3000	300	30	.03
2. Excessive exposure and/or injury	300	30	3	.003
3. Moderate to low-level exposure	30	3	0.3	0.003
CATEGORY: SITE PERSONNEL SAFETY AND HEALTH				
4. Catastrophic - Injuries/illnesses involving permanent total Disability, chronic or irreversible illnesses, extreme Overexposure, or death	2000	200	20	0.2
5. Critical - Injuries/illnesses resulting in permanent partial Disability or temporary total disability > 3 months, or serious Overexposure	200	20	0.2	0.02
6. Marginal - Injuries/illnesses resulting in hospitalization, temporary, reversible illnesses with a variable but limited period of disability of < 3 months, slight overexposure (e.g., 5-10 rem), or exposure near limits)	100	10	1	0.01
7. Negligible - Injuries/illnesses not resulting in hospitalization, temporary reversible illnesses requiring minor supportive treatment, or exposures below 20% of limits	10	1	0.1	0.0001
CATEGORY: COMPLIANCE				
8. Major noncompliance with Federal, State, or Local Laws; Enforcement Actions; or Compliance Agreements significant to ES&H and involving significant potential fines or penalties	150	15	1.5	0.015
9. Major noncompliance with Executive Orders; DOE Orders; Necessary and Sufficient Standards; or Secretary of Energy Directives (Notices or Guidance Memoranda) significant to ES&H but not involving significant potential fines and penalties	75	7.5	0.75	0.0075
10. Marginal noncompliance with Federal, State, Local	20	2	0.2	0.002

Appendix A.
Risk-Based Priority Model

TABLE 1
ES&H RISK-BASED PRIORITY MODEL (RPM)

LIKELIHOOD OF OCCURRENCE

IMPACTS	A VERY HIGH	B HIGH	C MEDIUM	D LOW
Laws; Enforcement Actions; Compliance Agreements; Executive Orders; DOE Orders; Necessary and Sufficient Standards; or Secretary of Energy Directives significant to ES&H				
11. Significant deviation from good management practices	1	0.1	0.01	0.0001
CATEGORY: MISSION IMPACT				
12. Serious negative impact on ability to accomplish major program mission	150	15	1.5	0.015
13. Moderate negative impact on ability to accomplish major 150program mission	75	7.5	0.75	0.0075
CATEGORY: COST-EFFECTIVE RISK MANAGEMENT				
14. Significant avoidable costs due to degrading infrastructure, inefficient management systems or program implementation, or accident-related capital loss (annual costs > $5M, or one-time costs > $25M)	40	4	0.4	0.004
15. Moderate avoidable costs due to degrading infrastructure, inefficient management systems or program implementation, or accident-related capital loss (annual cost $1M-5M/year, or one-time costs < $25M)	15	1.5	0.15	0.0015
CATEGORY: ENVIRONMENTAL PROTECTION				
16. Catastrophic damage to the environment (widespread and long-term or irreversible effects)	2000	200	20	0.2
17. Significant damage to the environment (widespread and short-term effects, or localized and long-term or irreversible effects)	200	20	2	0.02
18. Minor to moderate damage to the environment (localized and short-term effects)	20	2	0.2	0.002

Appendix A.
Risk-Based Priority Model

Section 1 RPM Matrix Impacts

The rows of the RPM matrix constitute the impacts used to score the risk benefits of activities. The matrix impacts are organized in six categories, representing the major types of risks important to ES&H activities:

1. Public Safety and Health includes potential adverse impacts on the health and safety of the *off-site* population surrounding a facility.

2. Site Personnel Safety and Health includes potential adverse impacts on the safety and health of individuals *inside the facility boundary.* This includes site workers and visitors.

3. Compliance includes failures to comply with laws, regulations, compliance agreements, Executive Orders, necessary and sufficient standards, and DOE Orders related to Environment, Safety and Health. Such failures may adversely affect the confidence of DOE or other agencies in the ability of the facility to operate while protecting the public, workers, and the environment.

4. Mission Impact includes potential adverse impacts on the ability to perform the research or production mission of the facility or the ability to carry out important parts of the mission.

5. Cost-Effective Risk Management includes potential accidental losses to a facility's capital investment (buildings, equipment) or an existing opportunity for cost savings, such as infrastructure upgrades, management systems upgrades, or improved program development.

6. Environmental Protection includes potential adverse harmful impact on natural resources (air, water, land, wildlife).

Each of the six categories includes two or more impacts representing different levels of severity within the category. For example the Site Personnel Safety category includes four impacts of decreasing severity: catastrophic, critical, marginal, and negligible. The following sections define the RPM impacts.

1.1 Public Safety and Health

Impact 1 Immediate or eventual loss of life/permanent disability

This impact should be chosen when a potential result of a condition being evaluated could lead to permanent disability (loss of limb, sight, hearing.) or loss of life by one or more members of the off-site population. This impact includes immediate deaths and disabling injuries, as well as future cancer deaths or genetic damage and effects that might result from releases of hazardous or radioactive materials that breach the site boundaries. Such releases could be the result of accidents that release hazardous materials within a building combined with failures in building confinement or containment, accidents during off-site transportation, or catastrophic events resulting in direct release of materials (*e.g.*, fire, explosion).

Example

A facility has proposed a set of seismic safety improvement projects to correct structural and equipment deficiencies that could contribute to building failures in case of an earthquake. Under current conditions, there is a high likelihood of building structural failure in a strong earthquake. Structural failure may result in a chemical release or fire that could spread off-site. Because a number of public facilities and private residences are in close proximity to the site boundary, public safety could be threatened and fatalities are possible.

Impact 2 Excessive exposure and/or injury

This impact indicates the potential for excessive exposure or injury to the off-site population, but without the potential for death or permanent disabling injury (*i.e.*, recovery from potential injuries is expected). Excessive exposures to radioactive or hazardous materials are those that exceed published acceptable limits.

Example

The example given for Impact 1, above, could apply to this impact if the volume of chemicals that could potentially be released was reduced such that death or permanent injury was not expected. However, public exposures to hazardous substances that exceed limits would still be expected.

Impact 3 Moderate- to low-level exposure

This impact indicates the potential for exposure of the off-site population to hazardous or radioactive materials, but these exposures are no greater than published acceptable limits. Immediate deaths or injuries are not expected. Rates of cancer incidence in the population would not detectably increase.

Example

A facility must purchase modern radiation survey equipment to comply with DOE Orders 5400.5 and 5480.11 and ANSI N323. Existing survey equipment does not meet requirements for lower limits of detection for release of equipment or materials from radioactive materials management areas at the facility. Because of this inadequacy in detection instrumentation, there is a chance that contaminated materials may be inadvertently released to uncontrolled areas and subsequently travel offsite. Because of the nature and volume of the potential released contaminated materials, however, the potential releases would not constitute a threat to public health, but could result in a minimal exposure of members of the public to radioactive material.

Impacts 1, 2, and 3 differ in the extent of potential off-site consequences. In considering the potential consequences of a condition at a facility, the following factors should be considered:

1) The nature of possible accidents that could occur at the facility;

2) The potential for off-site release of hazardous or radioactive material in case of an accident;

3) The amount and type of hazardous or radioactive material present; and

4) The potential for deaths, injuries, or exposures of the off-site population.

Impacts 1, 2, and 3 do not include deaths or disabling injuries that may be experienced by site visitors. Impacts on visitors are treated as equivalent to effects on site workers, as visitors to the site are considered to have accepted on-site risks when they entered the site boundary.

1.2 Site Personnel Safety and Health

Impact 4 *Catastrophic: Injuries/illnesses involving permanent total disability, chronic or irreversible illnesses, extreme overexposure, or death*

This impact encompasses potential permanent effects among the site worker population. Such effects may result from industrial accidents or excessive exposures to hazardous or radioactive materials. This impact includes immediate deaths and disabling injuries as well as future deaths from latent effects such as cancer.

Example

A facility has proposed a Line Item Project to bring site buildings into compliance with fire and life safety codes and to correct deficiencies found in a facility-wide fire protection engineering survey. Deficiencies include inadequate sprinklers, fire barriers, alarms, exit corridors, and exit doors. In case of fire in a site building with these deficiencies, fire and smoke can spread quickly through the building. Fire alarms cannot be heard in some parts of the buildings and some exit corridors are too long, poorly protected, or poorly marked. Under these conditions, a fire may lead to a fatality of a site worker in the affected building.

Example

A facility has proposed a set of seismic safety improvement projects to correct structural and equipment deficiencies that could contribute to building failures in case of an earthquake. Under current conditions, there is a high likelihood of building structural failure in a strong earthquake. Persons inside the deficient buildings would be at risk and fatalities are Possible.

Impact 5 *Critical: Injuries/illnesses resulting in permanent partial disability, temporary total disability (> 3 months), or serious overexposure*

This impact involves injuries, illnesses, or exposures that result in lengthy hospitalization and significant recuperation time, but are not expected to result in death or permanent total disability. This impact includes exposures to radioactive or hazardous materials that may exceed published acceptable limits.

Impact 6 *Marginal: Injuries/illnesses resulting in hospitalization, temporary reversible illnesses with a variable but limited period of disability (<3 months), slight overexposure, or exposure near limits (20-100%)*

This impact involves worker injuries, illnesses, or exposures that result in emergency room treatment, limited hospitalization, and lost work time. Time required for recuperation from these effects, however, is not extensive.

Example

A facility proposes a Line Item Project to improve pedestrian and vehicular safety through roadway modifications. This project will improve sight lines at turns and intersections and widen narrow portions of site roadways. Under current conditions, the facility experiences about two road accidents per year. These accidents are typically minor, but do occasionally result in injuries requiring limited hospitalization.

Impact 7 *Negligible: Injuries/illnesses not resulting in hospitalization, temporary reversible illnesses requiring minor supportive treatment, or exposures* *below 20% of limits*

This impact involves worker injuries, illnesses, and exposures that would be expected to result in no lost work time (unless the exposure resulted in a cumulative dose exceeding limits). Standard first aid is expected to be adequate treatment.

1.3 Compliance

Impact 8 *Major noncompliance with Federal, state, or local laws; enforcement activities; or compliance agreements significant to environment, safety, or health and involving significant potential fines or penalties*

This impact includes major violations of laws, regulations, codes, enforcement actions, compliance agreements, or standards. These noncompliances have the following characteristics.

1. Violation of the law, regulation, code, enforcement action, compliance agreement, or standard could result in the imposition of fines on DOE or the operating organization, imprisonment of DOE or operating organization personnel, liability for the payment of significant damages, or other legal penalties.

2. The existing situation must represent a *major, substantive* non-compliance with the law, regulation, code, or standard. If existing conditions are substantially in compliance with only minor exceptions, then this impact does not pertain (see definition of Impact 10 below)

3. The violated law, regulation, code, or standard must be significant to environment, safety, or health.

If an activity addresses a major non-compliance with an environmental law or regulation (such as the CAA, RCRA, or CERCLA), the compliance impact should be 8. If an activity addresses a major non-compliance with a rule subject to penalties under the Price-Anderson amendments act, then impact 8 also applies.

In general, non-compliance with a DOE Order or necessary and sufficient standard should be scored using Impact 9 or 10 below because fines or criminal penalties do not typically result from DOE Order non-compliance. Likewise, non-compliance with an OSHA requirement or a DOE OSH Order should be scored using Impact 9 or 10 below, unless OSHA has the force of law at a facility (which is not currently the case at most DOE facilities). If an activity addresses a major non-compliance with an environmental law and a DOE Order simultaneously, the applicable compliance impact with the highest potential risk reduction score should be chosen (in this case Impact 8).

Example

A facility has proposed a project to expand its hazardous waste storage *and disposal capability. Currently, hazardous waste handling capability is inadequate, so that waste remains in temporary storage locations for longer than 90 days. This is a violation of RCRA and the facility may be fined by the EPA. Because this example involves non-compliance with an environmental law, it would be scored with Compliance Impact 8.*

Example

A contractor radiation protection program requires several changes in order to comply with 10CFR-835 provisions. A large number of further changes are required in order to implement the DOE Radiological Control Manual. Impact 8 applies to those activities needed to achieve 10CFR-835 compliance, because non-compliance is subject to legal action under Price-Anderson. Impact 8 does not apply, however, to additional activities (beyond 10CFR-835 provisions) needed to implement the Rad Con manual.

The RPM compliance impacts that apply to Rad Con manual implementation depend on whether the activities needed for implementation have some other compliance driver. If the activities have a compliance driver, such as a DOE Order, then impacts 9 or 10 apply (see impact descriptions below). Otherwise, if the activities are best management practices or recommendations without a formal compliance driver, then impact 11 applies.

Impact 9 *Major noncompliance with Executive Orders; DOE Orders; necessary and sufficient standards; or Secretary of Energy Directives (Notices or Guidance Memoranda) that are significant to environment, safety, or health but not involving significant potential fines and penalties.*

This impact includes significant non-compliances with any DOE Order, necessary and sufficient standard, or Secretary of Energy Directive that is significant to ES&H. To distinguish Impact 9 from Impact 8, noncompliances included under Impact 9 cannot result in fines, imprisonment, or other legal penalties. Impact 9 also includes facility non-compliance with laws, regulations, codes, and standards (*e.g.*, OSHA, NFPA, ANSI, NEC, MSHA) that are referenced in DOE Orders, but do not have the force of law at the facility . As with non-compliance covered under Impact 1-8 above, conditions of non-compliance included in this impact must be *major, substantive* non-compliances and must relate to requirements that are significant to environment, safety, and health. The impact does not include marginal non-compliances, such as minor administrative discrepancies (see definition of Impact 10 below).

Example

A recent audit finding identified that the Hazards Communication Program at a Facility is not in compliance with the requirements of DOE Order 5480.10. All aspects of the program are lacking, including surveillance, communications, and record-keeping. A facility proposes to add 5 FTEs to upgrade the Hazards Communication Program.

Example

A facility proposes to increase staff in its industrial safety section to *support efforts for achieving full compliance with DOE-required OSHA standards (such as DOE Order 5483.01). Without this additional staffing, the facility will remain substantively out of compliance.*

Example

A facility has proposed a GPP project to upgrade electrical cable that does not comply with NEC requirements. Compliance with NEC requirements is needed for conformance with DOE Order 6430.1A.

Impact 10 Marginal noncompliance with Federal, state, and local laws; enforcement actions; compliance agreements; Executive Orders; DOE Orders; necessary and sufficient standard; or Secretary of Energy Directives that are significant to ES&H

This impact includes *minor* discrepancies in compliance with laws, regulations, codes, standards, Orders, or directives that are significant to ES&H (the same group of laws and orders, that are included in Impacts 8 and 9). It is differentiated from Impacts 8 and 9, which cover major noncompliance conditions. This impact pertains to conditions in which current ES&H programs largely conform to the requirements of applicable laws and Orders., but do not fulfill certain marginal or administrative aspects of the requirements.

For example, if a facility has fulfilled the actual substantive physical requirements of a law or Order, but has not completed all administrative requirements or paper work, then Impact 10 applies.

Example

A facility proposes to add 1 additional clerical employee to assist the IS Manager in support of the Hazards Communication Program which was recently upgraded as required by DOE Order 5480.10. The responsibilities of this new employee will be record keeping and clerical support for visiting assessment teams. Recent audits have indicated that the program is adequate, but to be in full compliance the Facility must keep better records of communication activities and provide better clerical support for visiting assessment teams to allow them to obtain a more comprehensive picture of the state of the Facility's compliance.

Example

DOE Order 5480.07 requires that facilities have adequate fire protection systems in buildings, that these systems be tested and inspected routinely, and that the facility maintain records of the fire system testing and surveillance. If a facility has adequate fire protection systems in each building and has routinely performed the required testing and surveillance on these systems, but has failed to keep timely records of the testing and surveillance, then the appropriate impact in this case would be Impact 10.

Impact 11 Significant deviation from good management practices

This impact indicates a significant deviation from accepted industry or DOE standards for the performance of activities in a given area. Such directives or good practices do not have the weight of a law or DOE Order, nor do they have the importance of a directive or instruction issued by the Secretary of Energy.

1.4 Mission Impact

Impact 12 *Serious negative impact on ability to accomplish major program mission*
This impact includes conditions that seriously curtail or prevent accomplishment of the mission of a major program at a site. The condition need not shut down the entire site, but must threaten the continuation of at least one of the facility's major research or production missions. Under this impact, the interruption of the affected program mission must be of sufficient duration to pose serious doubts about the feasibility of accomplishing yearly goals or objectives set for the program.

The program mission impact may be due to regulatory or administrative shutdown of part of a facility, a catastrophic accident preventing continued activities, or the unavailability of equipment, staff, or other resources required by the program.

Example

A facility has proposed a Line Item Project to bring site buildings into compliance with fire and life safety codes, and to correct deficiencies found in a facility-wide fire protection engineering survey. Deficiencies include inadequate sprinklers, fire barriers, alarms, exit corridors, and exit doors. In case of fire in a site building with these deficiencies, fire and smoke can spread quickly through the building and significant portions of the building may be damaged or destroyed. If so, research programs under way in this building will be severely disrupted and unable to continue before the replacement of necessary facilities. This disruption will impede progress in the research and may make it impossible to achieve goals set for the program.

Example

Radiological surveys of chemistry laboratories at a site have discovered previously unknown contamination outside of posted radiological areas. In order to fully comply with DOE Order 5480.11 and DOE ALARA guidelines, the facility is proposing to fund systematic, detailed surveys of the laboratories and management of any contamination that is discovered. If this work is not performed, then all chemistry division laboratories could be zoned as radiation areas. This would result in loss of effective use of the laboratory facilities and prevent progress in major programs that rely on the facilities.

Impact 13 *Moderate negative impact on ability to accomplish major program mission*
This impact includes conditions preventing accomplishment of major program missions at a site. However, the interruptions of programs

considered under this impact are shorter than those included under Impact 12 above. The interruptions included under Impact 13 may pose risks to the achievement of set program goals or objectives, but still allow the possibility that such goals or objectives may be met.

Example

A facility must institute a site roadway safety and stabilization program to meet Federal and State safety standards. This project will stabilize landslides adjacent to roads at the site. Without this work, the landslides threaten to displace roadways and underground utilities. If this occurred, access and utility supplies to some site buildings could be disrupted, interrupting programs in these locations. However, repairs to re-establish access and utilities are not expected to cause an excessive disruption of progress on these programs, however.

1.5 Cost-Effective Risk Management

Impact 14 *Significant avoidable cost such as degraded infrastructure, inefficient management systems or program implementation, or accident-related capital loss (total cost > $25M or annual cost > $5M)*

Impacts 14 and 15 involve either the loss of DOE capital investment due to accidents or an existing opportunity for cost savings (such as infrastructure upgrades, management systems upgrades, or improved program development). The difference between Impacts 14 and 15 is the dollar value shown to be at risk or the dollar value of the cost savings opportunity.

For Impact 14, the loss of investment could include loss of buildings, equipment, materials, finished products, or supplies, in which DOE had invested greater than $25 million. Such loss could be incurred by events such as fire, explosion, human errors, or natural occurrences. In addition to situations involving financial loss due to accidents, Impact 14 also includes opportunities for cost savings that would have a positive financial impact. Prominent among such opportunities are situations in which an immediate preventive investment can help avoid a potentially greater cost impact in the future. Examples include neglected facility infrastructure for which short-term expenditures on physical upgrades or increased maintenance or surveillance can help avoid increased long-term costs due to continued neglect or degradation or potential catastrophic damage. For Impact 14 to apply, the total cost savings must exceed $25 million. Impact 14 also includes annual cost impacts greater than $5 million incurred as a result of a condition causing losses to a facility's capital stock. Similarly, Impact 14 includes opportunities for recurring annual preventive or other positive financial impacts exceeding $5 million. Examples include opportunities to develop improved ES&H management systems that increase the efficiency of managing ES&H issues, thereby promoting the early identification of problems, the setting of appropriate priorities for addressing issues, and definition of cost-effective activities for addressing issues.

Example

A facility has proposed a Line Item Project to bring site buildings into compliance with fire and life safety codes and to correct deficiencies found in a facility-wide fire protection engineering survey. Deficiencies include *inadequate sprinklers, fire barriers, alarms, exit corridors, and exit doors. In case of fire in a site building with these deficiencies, fire and smoke can spread quickly through the building and significant portions of the building may be damaged or destroyed. If so, the cost of repair or replacement of the building and its contents could exceed $25M.*

Example

A site contractor has proposed launching a behavior-based safety process to improve worker safety and decrease the frequency of on-the-job injuries. The process includes workplace observation and feedback to workers to improve the safety of workplace behaviors. In addition to substantial expected safety improvements, the process is expected to yield substantial annual cost savings through reduction of workman's compensation expenses. The avoided costs could exceed $5M per year.

Example

A national laboratory has identified several site buildings that have not been maintained adequately for many years and are in need of immediate physical upgrades and/or enhanced maintenance and surveillance. Without short-term commitment of resources, these buildings are subject to continued deterioration and potential catastrophic damage that would require large expenditures to remediate. The remediation costs could top $25M if such damage occurs.
Impact 15 Moderate avoidable cost due to degraded infrastructure, inefficient management systems or program implementation, or accident-related capital loss (total cost <$25M or annual cost $1M-5M).
This impact is similar to Impact 14, with the exception of the dollar amounts of the loss of investment. This impact includes lower investment losses or cost savings opportunities.

Example

A facility proposes a Line Item Project for a site roadway safety and stabilization program to meet Federal and State safety standards. This project will stabilize landslides adjacent to roads at the site. Without this work, the landslides threaten to displace roadways and underground utilities. The damaged roadways and utilities would have to be repaired or replaced, but the cost of such work would be lower than $25M.

Example

A national laboratory and DOE Operations Office ES&H division propose coordinated development of an integrated issue management and commitment tracking system to improve the efficiency of ES&H management at the lab, increase accountability, and allow the Operations Office to perform its oversight role more productively. It is expected that *implementation of such a system will improve the cost-effectiveness of risk management activities. The savings that are expected to result are expected to be around $1.5M per year.*

Example

A production facility plans to perform a pollution prevention/ waste minimization opportunity assessment on one segment of the plant's process and to implement waste minimization activities based on the findings of the assessment. Preliminary evaluations have indicated that the resulting waste reduction would substantially reduce disposal costs. It is estimated that costs could be reduced by around $3M per year.

1.6 Environmental Protection

Environmental impacts are defined as damage to a significant public resource such as: air, water, land or wildlife. These impacts would primarily result from accidents involving the release or spill of radioactive or hazardous materials to the environment.

Impact 16 Catastrophic damage to the environment (widespread and long-term or irreversible effects)

This impact includes the most severe environmental effects, those with both of the following characteristics.

1. The effects are spread or may be spread over a wide area and are not easily containable in a limited area.

2. The effects are either irreversible or may only be reversed over a period of several years.

Example

A process at a facility involves the use of industrial solvents. The facility has proposed a project for better monitoring of the releases from the process. Under current conditions, solvents may be released, travel offsite, and contaminate ground water that serves as the drinking water supply for a nearby community. The water supply would be unusable and an alternative supply would be needed. Cleanup of the ground water is thought to require 30 years.

Impact 17 Significant damage to the environment (widespread and short-term effects, or localized and long-term or irreversible effects)

This impact includes serious environmental effects that are less severe than those considered under Impact 16 above. These impacts must have one of the following characteristics:

1. The effects are spread or may be spread over a wide area but may be reversed in no more than a year's time.

or

2. The effects are confined to a limited area but are either irreversible or require several years to reverse.

Impact 18 Minor to moderate damage to the environment (localized and short-term effects)

This impact includes less severe effects on the environment than those covered in Impacts 16 and 17. These effects include both of the following characteristics:

1. The effects are confined to a limited area.

and

2. The effects may be reversed within a year's time.

Example

A facility proposes a project to construct double containment of feed lines into a diesel fuel tank to help prevent leaks. Currently, the tank is vulnerable to leaks, which could spill fuel and contaminate the soil in the area surrounding the tank. Because of the volume and location of the tank, however, the contamination will not spread off-site and will not contaminate any water sources. Clean-up should require only a few weeks.

Section 2 RPM Matrix Likelihood

The RPM matrix columns (see Table 1) constitute the levels of likelihood used in assessing the risk reduction benefit of activities. The matrix uses four levels of likelihood, as given in Table 2. Each likelihood level has an associated numerical value, which is multiplied by the impact weights to derive the risk value for each matrix cell in the matrix column corresponding to the likelihood level.

TABLE 2
RPM MATRIX LIKELIHOOD LEVELS

Appendix A.
Risk-Based Priority Model

	A	B	C	D
Likelihood	Very High	High	Medium	Low
Numerical Value	1.0	0.1	0.01	0.0001
Expectation	1 in 1 Year	< 1 in 1 Year ~1 in 10 Years	<1 in 10 Years ~1 in 100 Years	<1 in 100 Years, ~1 in 10,000 Years

The likelihood levels are defined as:

A. **Very High** likelihood indicates an impact already exists with certainty or is expected to occur at least once per year. For example, if a facility is known to be out of compliance with a DOE ES&H Order, then the likelihood of this impact falls into the *very high* category. If a condition at a facility has historically resulted in one or more lost-time worker injuries per year and the condition has not been corrected, then the likelihood of this impact also fits this category.

B. **High** likelihood indicates that an impact is expected less frequently than once per year, but more frequently than once every 10 years. Such impacts are expected to occur within the operating history of the facility, but have not occurred regularly every year.

C. **Medium** likelihood indicates that an impact is expected less frequently than once every 10 years but more frequently than once every 100 years.
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Impacts with this likelihood are not expected frequently within the operating life of a facility, but may occur once in the facility's life.

D. **Low** likelihood impacts are unlikely to occur within the operating life of a facility, but are not completely precluded from occurring. For example, impacts in this category may occur once in the operating life of one facility out of a population of 100 similar facilities. Impacts with this likelihood are expected to occur less frequently than once per 100 years, but more frequently than once per 10,000 years.

The RPM columns represent four specific likelihood values that may be used in assessment of risks for activity scoring. In addition, the ES&H Management Plan Information System allows other likelihood values to be entered directly. Such values may be entered if information exists that supports other specific likelihood values for impacts in the risk scoring of an activity.

Example

A portion of a non-reactor nuclear facility Safety Analysis Report analyzes a scenario in which an extreme over-exposure of workers could occur. The likelihood of this scenario is estimated to be 10 per year. A fix has been defined to remove the possibility of this -3 scenario. In deriving the RPM score for an activity representing implementation of the fix, impact 4 (extreme over-exposure of workers) applies. Because the estimated likelihood of the scenario falls between the representative likelihoods for RPM columns C and D (10 and 10), this likelihood value may be entered directly in the Information -2 -4 System; the risk score for the impact-likelihood combination representing this scenario is 2 (=10 times 2000). Note that a likelihood value other than one of the RPM matrix -3 column likelihoods was used in this case because specific information was available (i.e., part of a facility SAR) to support a different value.

Section 3 Allowance for More Precise Values for Impacts and Likelihoods

The RPM matrix includes discrete values for severity of impact (the rows of the matrix) and the likelihood of experiencing these impacts (the columns of the matrix). These discrete values should be adequate to support prioritization of activities in most instances. However, if the facility has more precise risk assessment information available, the RPM can be modified to accommodate such information. More precise information can be incorporated in two ways:

- Instead of using the discrete likelihood levels discussed in Section 2, the RPM can accept any likelihood between 0.0001 and 1.0;

- A consequence multiplier can be applied to each impact to interpolate between or extrapolate beyond the discrete impacts levels of the RPM.

For example, the consequence multiplier can be applied to the Public Safety and Health or Site Personnel Safety and Health categories account for the size of the population impacted. The RPM weights in each RPM matrix cell in these categories have been assigned based on an assumption that each impact affects 10 persons. If a significantly higher or lower number of persons are affected by an impact, however, then different weights are appropriate. Specifically, the weight should vary proportionally to the number of affected persons.
The RPM cell weights may be used exactly as given in the matrix, without adjustment, if the activity scorers determine that the implicit assumption of ten persons being affected by the impact is sufficient to score an activity appropriately. If the number of persons expected to be affected by an impact diverges significantly (either higher or lower) from this assumption, so that the risk benefits of the activity are not represented appropriately by the RPM cell weights, the process allows for an additional factor to be specified to multiply by the RPM cell weights. The appropriate adjustment factor equals the number of persons expected to be affected divided by ten. For example, if 100 persons are expected to be affected by an impact, then the multiplier equals 10 (= 100 persons affected divided by 10 persons implicit in RPM weights). If no more than one person is expected to be affected, then the multiplier equals 0.1 (= 1 person affected divided by 10 persons implicit in RPM weights). The consequence multiplier can be applied for those impact categories with continuous impact scales (e.g. number of injuries, risk management investment dollars) and where additional quantitative risk assessment information is available to establish a basis for the more precise values. The multiplier should not be used to interpolate between levels of compliance. The ES&H Budget Plan Information System and ADS form includes fields in which the consequence multiplier may be entered when an activity is scored. These fields have default values of one, indicating no adjustment to the RPM weights.

Example

A national laboratory plans a program to reduce lost time injuries to lab workers. Currently, such injuries occur at a rate of 100 per year. The proposed program intends to reduce this rate significantly. An ADS is prepared to represent this program. In scoring this activity, Impact 6 (lost-time worker injuries) applies with a RPM likelihood category of A (greater than once per year). In addition, the number of persons affected by the impact significantly exceeds the 10 per year assumption implicit in the RPM weight for Impact 6. The appropriate multiplier for 100 injury victims per year is 10 (=100/10). This results in a scaled weight for the Site Personnel impact equal to 1000 (Impact 6, Likelihood A RPM weight equals 100, multiplied by a scaling factor of 10).

Example

A site proposes to upgrade safety analysis reports for a nuclear facility at the site. It is anticipated that the additional analysis of facility hazards will result in discovery of previously un-analyzed scenarios that could lead to release of radioactivity beyond the site boundary and exposure of the surrounding general population to potentially lethal doses. The likelihood of any of these scenarios occurring is very low (a total of around 0.0001 per year), but the site is adjacent to a town with a population of 10,000. If the postulated scenarios and releases occur, it is expected that 10% of this population could receive lethal doses. Thus in RPM scoring of these risks, Impact 1 (fatality to members of the public) and likelihood level D (1 in 10,000 years) apply. To account for the high number of potential victims, a scaling factor of 100 should be specified (=10% of 10,000 total population divided by 10). The adjusted RPM impact weight equals 30 (RPM Impact 1, Likelihood D, multiplier of 100).