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Idaho National Engineering Laboratory

Preliminary Safety Analysis Report for the Tokamak Physics Experiment

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Princeton Plasma Physics Laboratory

United States Department of Energy

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May 16, 1995

Milton D. Johnson, Area Manager
Princeton Area Office

SUBJECT: APPROVAL OF THE PRELIMINARY SAFETY ANALYSIS REPORT (PSAR) FOR THE TOKAMAK PHYSICS EXPERIMENT (TPX)

Reference: Memorandum, Krebs to Operations Office Managers, dated February 28, 1994, Subject: Office of Energy Research Delegation of Authority for Approval of Safety Documentation and Revisions Thereto

In accordance with the delegation of authority in the referenced memorandum, and the reviews performed by the Princeton Area Office and Environment, Safety, and Health Division (ESHD) personnel, I hereby approve the TPX PSAR.

If you have any comments or questions regarding this matter, they should be directed to Dr. Jeff Dooling, of ESHD, at (708) 252-2491.

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ACRONYMS

ALARA	as low as reasonably achievable
CAS	Controlled Access System
CFR	Code of Federal Regulations
D-D	deuterium-deuterium
D-T	deuterium-tritium
D&D	decontamination & decommissioning
DBA	design basis accident
DCG	Derived Concentration Guide
DOE	Department of Energy
DOT	Department of Transportation
EBA	evaluation basis accident
EGs	evaluation guidelines
EPP	Emergency Preparedness Plan
ES&H	Environment, Safety, and Health
ES&HD	Environment, Safety, and Health Division
FEC	field error correction
FED	Facilities Engineering Division
FONSI	finding of no significant impact
FSAR	Final Safety Analysis Report
GDC	glow discharge cleaning
GRD	General Requirements Document
HVAC	heating, ventilation, and air conditioning
I&C	instrumentation and control
IC	internal control
LEC	Liquid Effluent Collection
LOAEL	lowest observed adverse effect level
NEPA	National Environmental Policy Act
NESHAP	National Emissions Standard for Hazardous Air Pollutants
NOAA	National Oceanic and Atmospheric Administration
NSAR	Nuclear Safety Analysis Report
OSHA	Occupational Safety and Health Administration
PC2	Performance Category 2
PDD	Physics Design Description
PF	poloidal field
PIS	Personnel Interlock System
PPPL	Princeton Plasma Physics Laboratory
PSAR	Preliminary Safety Analysis Report
QA	Quality Assurance
RCRA	Resource Conservation and Recovery Act
RF	radio frequency
SAR	Safety Analysis Report
SDD	System Design Description
SSCs	structures, systems, and components
TBD	to be determined
TF	toroidal field
TFTR	Tokamak Fusion Test Reactor
TPX	Tokamak Physics Experiment
TSR	Technical Safety Requirement

Preliminary Safety Analysis Report for the Tokamak Physics Experiment

1. EXECUTIVE SUMMARY

This section summarizes the facility safety basis documented in detail in this Preliminary Safety Analysis Report (PSAR), including an indication of the magnitude of facility hazards, complexity of facility operations, and the stage of the facility life-cycle. It presents the results of safety analyses, safety assurance programs, identified vulnerabilities, compensatory measures, and, in general, the rationale describing why the Tokamak Physics Experiment (TPX) can be safely operated. It discusses application of the graded approach to the TPX safety analysis, including the basis for using Department of Energy (DOE) Order 5480.23 and DOE-STD-3009-94 in the development of the PSAR.

1.1 Facility Background and Mission

The TPX Project consists of the design, construction, and operation of the TPX within the existing Tokamak Fusion Test Reactor (TFTR) facility at the Princeton Plasma Physics Laboratory (PPPL). The TPX Project will develop a scientific basis for a compact and continuously operating tokamak fusion reactor and will contribute toward achieving a major goal of the U.S. fusion energy program, i.e., development of a tokamak demonstration reactor. The specific mission of the TPX is to develop the physics and technology needed to extend tokamak operation into the continuously operating (steady-state) regime, and to demonstrate advances in fundamental tokamak performance. The Project is the next major experiment in the DOE Magnetic Fusion Energy Development Strategy. The current plan is to operate the TPX with hydrogen and deuterium plasmas during the first phase of its operating lifetime. This PSAR addresses the deuterium-deuterium (D-D) phase of TPX operations. Any future upgrades will be addressed in supplements to the Final Safety Analysis Report (FSAR).

1.2 Facility Location and Description

The PPPL is located at the C and D sites of the James Forrestal Campus of Princeton University in Middlesex County in central New Jersey. New York, Trenton, and Philadelphia are approximately 64 km (40 miles) to the northeast, 19 km (12 miles) to the southwest and 56 km

(35 miles) to the southwest, respectively. The TPX is located at D-site, latitude 40° 20 min. 55 sec. north, longitude 74° 36 min. 0 sec. west.

Facilities on the 72-acre C/D site, which are dedicated to fusion energy research, include administrative offices, offices for physicists and engineers, small laboratories, a large high-bay experimental area, buildings for power supply systems and supporting craft shops, and maintenance and warehouse facilities. The size of the work force at PPPL varies, depending on activities, but is currently about 900. This total is made up of direct employees, subcontracted employees, graduate students, and visiting experimenters. Additional site characteristic information is provided in Section 3.

The TPX Project will utilize a number of existing TFTR facilities and equipment. The following TFTR facilities will be adapted and used by the TPX Project: TFTR Test Cell Complex, ventilation exhaust vent and intake shafts, mockup building, tritium cleanup and waste handling area, field coil power conversion building, neutral beam power conversion building (including process cooling water area), motor generator building, radioactive waste system space, computer and control rooms in the laboratory/office building, data transmission tunnel, office and technical support space, and miscellaneous PPPL support facilities. In addition to providing space for the TPX Project, the TFTR Test Cell Complex will provide shielding and provide for confinement and handling of tritium-contaminated and other radioactive components.

Existing PPPL utilities that will be used by the TPX Project include an intercommunication system, plant electrical power system, area lighting system, fire and security alarm system, sewage system, steam generation and distribution system, water supply and distribution system, and roads and parking areas.

The TPX Project will use existing TFTR support systems, including neutral beam lines; pulsed electrical power system; field coil power conversion system, neutral beam power conversion system; fueling system; heating, ventilation, and air conditioning (HVAC) system; and water cooling system.

New conventional facility construction includes TFTR Test Cell modifications, a new cryogenic equipment building, tank yards for water cooling, cryogenic tanks, and a new electrical substation. Additional TPX facility and process information is presented in Section 4.

1.3 Facility Hazard Classification and Basis

Hazard identification, categorization, and evaluation have been completed for TPX and are presented in Section 5. The hazards associated with TPX radioactive materials, hazardous chemicals, energy sources, and accident initiating events have been analyzed.

Based on the Environmental Assessment of the Project (DOE/EA-0813), the potential hazards associated with the D-D phase of TPX operation stem principally from the production of about 300 Ci per year of tritium (half-life of 12 years), 140 Ci per year of Ar-41 (half-life of 1.8 hr), and from generation of 6×10^{21} D-D neutrons per year. Based on the low levels of releasable radioactive materials generated during D-D operation and the potential for only local consequences if any hazardous inventory is released to the environment, the TPX is an activity that during an unmitigated accident presents less than a Category 3 nuclear hazard. Also, normal operation at the TPX, including construction activities, involves no unusual processes and has potential for only local consequences, and therefore presents less than a Category 3 nuclear hazard. The hazard categorization was performed in accordance with *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports,* DOE-STD-1027-92, December 1992.

1.4 Summary of Hazard/Accident Analysis Results and Basis, Including Significant Preventive/Mitigative Features

All credible generic hazards (i.e., having a frequency of occurrence equal to or greater than 1×10^{-6} per year) associated with the TPX were analyzed, including radiological, aircraft impact, chemical exposure, construction, cryogenic systems, electrical, flammable, gases, liquids, and dusts, flooding, high-intensity magnetic fields, high winds, material handling dangers, nonionizing radiation sources, seismic events, and temperature extremes. None of the radiological hazards exceed the TPX Evaluation Guidelines (EGs) presented in Table 6.1.

The hazards identified in Section 5 were systematically analyzed in relation to normal operations, accident initiators, and abnormal and accident conditions. Potential release of hazardous material inventories were analyzed and compared with the TPX EGs. Results show that the probability of exposure to hazardous chemicals (e.g., beryllium dust, diborane gas and SF_6) at TPX is unlikely or extremely unlikely and has a negligible risk. For explosion hazards (from ignition of diborane or hydrogen), results show that the probability is extremely unlikely and has a negligible risk.

For all other hazards, the TPX risk analysis demonstrates that for normal operation, the highest risk is presented by ionizing radiation exposure, and that risk is low. For abnormal operation or an accident, the highest risk for TPX is presented by fire, and those risks are also low. Risks for other evaluated hazards are negligible. The primary receptor for these risks is the worker. For normal-operation ionizing radiation exposure, it is expected that the worker would be primarily at risk during maintenance periods when the Test Cell is accessible. This preliminary safety analysis demonstrates that the risk presented by TPX operations during normal, abnormal, and accident conditions to the worker, public, and environment is acceptable. Comparison with TPX EGs demonstrates that no limits will be exceeded from any postulated normal operation, abnormal operation, or accident condition scenarios.

Significant preventive/mitigative features for the chemical hazards include administrative restrictions and controls on worker access to hazardous areas, and work is controlled by work authorization packages. TPX will have a fire suppression system, and the PPPL site has an Emergency Services Unit, which provides dedicated fire fighting services. Features to mitigate explosions include diborane and hydrogen leak detection systems and robust construction of the Test Cell. Exposure to ionizing radiation is controlled administratively, and doses to workers will be controlled and maintained below PPPL administrative limits and occupational exposure EGs (1,000 mrem per year, 600 mrem per quarter). Mitigative features include borated water shielding and borated concrete construction of the Test Cell floor for control of neutrons. Other mitigative features include Test Cell shielding, Test Cell access control, vacuum vessel construction materials, and remote maintenance capability. Further information regarding TPX accident analysis is presented in Section 11.

1.5 Summary of Safety-Significant Structures, Systems, and Components

In Section 4, it is determined that TPX will not have any safety class structures, systems, and components (SSCs) and will have only a few potential safety-significant SSCs. Safety-significant SSCs have no special design criteria placed on them, but may be subject to certain surveillance and operational requirements. Potential safety-significant SSCs are being evaluated and final determination will be presented in the FSAR.

Since the TPX has been classified as less than a Category 3 nuclear facility (radiological facility), compliance with DOE Order 5480.22, Technical Safety Requirements, is not mandated.

This PSAR has been written to comply with DOE Order 5481.1B, Safety Analysis and Review System, and incorporates the guidance of DOE Order 5480.23, Nuclear Safety Analysis Reports. Consistent with PPPL best management practices, administrative controls and operating procedures will be developed to ensure the operability of any safety-significant structures, systems, and components (see Section 16).

1.6 TPX and PPPL Organizations Involved in Safety Functions

Information relating to safety management policies and programs are largely contained in the PPPL Policy/Organization Manual and the PPPL Environment, Safety, and Health Manual, ES&HD-5008. The manuals show that the TPX operating organization is a part of a network of supporting management, technical, and support functions sufficient to ensure that hazard and safety issues are identified, communicated, evaluated, resolved, and documented.

The PPPL Policy manual enumerates the requirement used to develop the safety management programs and includes descriptions of the responsibilities of and the relationship between the nonoperating organizations having a safety function and their interfaces. It describes the TPX line operating organization and demonstrates that the facility operations are embedded in a safety conscious environment.

These constitute part of the TPX integrated safety-management programs that control and discipline operations that contribute to Defense-in-Depth. Other parts of the safety management programs are described in Section 2 Applicable Statutes, Rules, Regulations, and Departmental Orders; Section 6 Principal Health and Safety Criteria; Section 7 Radioactive and Hazardous Material Waste Management; Section 9 Radiation Protection; Section 10 Hazardous Material Protection; Section 12 Management, Organization, and Institutional Safety Provisions; Section 13 Procedures and Training; Section 15 Initial Testing, In-Service Surveillance, and Maintenance; Section 16 Operability of Safety-Significant Structures, Systems, and Components; Section 17 Operational Safety; Section 18 Quality Assurance; Section 19 Emergency Preparedness Program; and Section 20 Provisions for Decontamination and Decommissioning.

1.7 Application of the Graded Approach

According to DOE-STD-1027-92 (DOE 1992b), TPX is classified as a Below Hazard Category 3 facility (i.e., nonnuclear radiological facility) provided the total tritium inventory in the TPX facility [other than the sealed sources, commercially available product, and Department of Transportation (DOT) shipping containers] is less than 1,000 Ci (as is planned for TPX). The format and content of the TPX Preliminary Safety Analysis Report follows the requirements of DOE Order 5480.23, Nuclear Safety Analysis Reports, using the guidance of DOE-STD-3009-94 (DOE 1994a), Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports. In particular, because TPX will be a nonnuclear (radiological) facility during its D-D operations phase, the guidance of DOE-STD-3009-94 on minimum acceptable Safety Analysis Report (SAR) content and the graded approach regarding Category 3 facilities is emphasized.

DOE-STD-3009-94 distinguishes safety-significant SSCs from among those structures, systems, and components contributing to Defense-in-Depth. To effectively use the graded-approach concept, focus is put on the most important items of Defense-in-Depth whose failure could result in the most adverse uncontrolled releases of hazardous material. The Standard maintains that all SSCs with a safety function do not require categorization as equipment requiring detailed description in the SAR (i.e., safety-class SSCs and safety-significant SSCs). This is one of the principle reasons for the emphasis on programmatic commitments.

2. APPLICABLE STATUTES, RULES, REGULATIONS, AND DEPARTMENTAL ORDERS

This section identifies the applicable federal statutes, DOE rules, standards, and orders binding upon the safety basis and operation of the facility. These include state and local statutes, ordinances, and other requirements when they establish safety constraints on facility operation. The applicability of each of these statutes, regulations, and orders is discussed, and a commitment is made to comply with each of the applicable regulations. Included in this section are safety basis rules and orders, operational basis rules and orders, and technical references.

2.1 Safety Basis: Rules and Orders

This section lists the regulatory design basis of the TPX facility, which is to be initially configured to provide 1,000-second pulses with hydrogen and deuterium plasmas and must be designed for and capable of being upgraded to provide pulses with Deuterium-Tritium (D-T) plasmas (PPPL 1993a). Included are all federal rules and DOE orders and state and local statutes that establish safety constraints on the design and construction of the facility. These are shown in Table 2-1.

2.2 Operational Basis: Rules and Orders

This section lists the federal rules, DOE orders, and state and local statutes that establish safety constraints on the operation of the facility. This PSAR covers the TPX Project for operation with hydrogen and deuterium plasmas. Table 2-2 presents federal, DOE, and state requirements applicable to TPX safety basis for operation.

2.3 Technical Documents

This section references additional material, that has been developed to support the design, construction, or operation of the facility but which has not been included directly as part of the Safety Analysis Report. This includes such items as the environmental assessment, operating procedures, emergency procedures, training manuals, and various TPX requirements and description documents. Table 2-3 presents a list of these technical references.

2.4 Exceptions

Any exceptions to specific DOE orders and/or regulatory requirements, taken for TPX in accordance with approved criteria for such exceptions, will be documented in Section 2.4 of the FSAR.

Table 2-1. Federal, DOE, and State requirements applicable to the TPX envelope of safe design and construction.

Code	Description	Criteria	Applicable PSAR section	Compliance analysis
DOE 4700.1	Project Management System	Establishes the requirements for DOE project management.	12. Management, Organization, and Institutional Safety Provisions	Implemented by the Budget Manual; Accounting Manual; PMS Appraisal; TPX Mgt. Plan; ES&HD-5008; QA Manuals; Procurement Manual; TPX Config. Mgt. Plan; TPX Cost & Schedule Baselines.
DOE 5480.7	Fire Protection	Establishes requirements for an "improved risk" level of fire protection sufficient to attain DOE objectives.	17. Operational Safety	Implemented by ES&HD-5008. Applicable requirements are evaluated and incorporated into the design of the TPX.
DOE 5480.9A	Construction Safety and Health Program	Establishes construction safety and health program requirements for DOE construction projects.	6. Principal Health and Safety Criteria	Implemented by ES&HD-5008. Impacts all TPX construction activities.
DOE 5480.28	Natural Phenomena Hazards Mitigation	Establishes DOE policy and requirements for natural phenomena hazard mitigation for DOE sites and facilities using the graded approach.	5. Hazard Analysis and Classification of the Facility	Requires TPX structures, systems, and components to be designed to mitigate potential hazards due to natural phenomena. This issue is addressed by the TPX General Requirements Document.
DOE 5700.6C	Quality Assurance	Prescribes QA requirements and provides implementation guidelines.	18. Quality Assurance	Implemented by the TPX QA Plan and Institutional QA Plan.
DOE 6430.1A	General Design Criteria	Establishes requirements for DOE facilities to be designed and constructed to be reasonable and adequate for their intended purpose and consistent with health, safety, security, and environmental protection requirements.		Implemented by TPX General Requirements Document, the specific system design description documents, and preliminary and final design documents.

Table 2-2. Federal, DOE and State requirements applicable to TPX envelope of safe operation.

Code	Description	Criteria	Applicable PSAR section	Compliance analysis
10 Code of Federal Regulations (CFR) 835	Occupational Radiation Protection	Establishes radiation protection standards and program requirements for DOE and contractor operations for workers.	9. Radiation Protection	10 CFR 835 requirements are implemented by ES&HD-5008 and individual TPX project procedures.
29 CFR 1910	Occupational Safety and Health Administration (OSHA) Standards	All industrial safety operations shall comply with the applicable OSHA requirements.	6. Principal Health and Safety Criteria	29 CFR 1910.120 requirements are adhered through PPPL ES&H Directives, ES&HD-5008 ES&H Manual.
40 CFR 61	National Emissions Standard for Hazardous Air Pollutants (NESHAP)	All airborne radiological constituents shall comply with the requirements of NESHAP.	7. Radioactive and Hazardous Material Waste Management.	Air emissions are modeled and monitored to comply with ambient radiological exposure standards.
40 CFR 260-265	Resource Conservation and Recovery Act (RCRA) Standards for Hazardous Wastes	Generation of hazardous waste shall conform to the applicable RCRA requirements.	1. Executive Summary and 7. Radioactive and Hazardous Materials Waste Management	Packaging, storage, treatment, and disposal of RCRA characteristic waste complies with RCRA substantiative requirements.
40 CFR 171-179	Department of Transportation (DOT) Hazardous Material Transportation Act Regulations	Regulates safe packaging and transportation of hazardous materials.	7. Radioactive and Hazardous Material Waste Management	A Hazardous Material Transportation Safety Plan (reviewed/approved by DOE and PPPL) is a required document.
New Jersey Adm. Code	New Jersey Environmental Laws	Radioactive discharges, nonradioactive air pollution, nonradioactive water pollution, nonradioactive solid waste.	9. Radiation Protection and 7. Radioactive and Hazardous Material Waste Management	Implementation through ES&HD-5008.
DOE 1540.1A	Materials Transport and Traffic Management	Establishes DOE policies and procedures for the safe management of material transportation activities.	7. Radioactive and Hazardous Material Waste Management	A Hazardous Material Transportation Safety Plan (reviewed/approved by DOE and PPPL) is a required document. Radioactive waste management is covered in ES&HD-5008.
DOE 1540.2	Hazardous Materials Packaging for Transport-Administrative Procedures	Establishes administrative safety procedures for the certification and use of radioactive and other hazardous materials packaging by DOE.	10. Hazardous Material Protection and 7. Radioactive and Hazardous Material Waste Management	A Hazardous Material Transportation Safety Plan (reviewed/approved by DOE and PPPL) is a required document.

Code	Description	Criteria	Applicable PSAR section	Compliance analysis
DOE 4330.4B	Maintenance Management Program	Establishes requirements for a maintenance management program.	15. Initial Testing, In-Service Surveillance, and Maintenance	Implemented by the Site Maintenance Management Plan, FED Procedures, and TPX Procedures.
DOE 5000.3B	Occurrence Reporting and Processing of Operations Information	Establishes reporting of unusual occurrences with programmatic significance for DOE operations.	19. Emergency Preparedness Program	Compliance is provided in PPPL Procedure GEN-006 and in PPPL Emergency Preparedness Implementation Plan Supplements.
DOE 5400.1	General Environmental Protection Program	Establishes the environmental protection program for DOE operations.	6. Principal Health and Safety Criteria	Implemented via Environmental Monitoring Plan, Environmental Implementation Plan, Site Environmental Report, and ES&HD-5008.
DOE 5400.2A	Environmental Compliance Issue Coordination	Provides DOE requirements for coordinating the resolution of significant environmental issues.	6. Principal Health and Safety Criteria	Implemented via Environmental Monitoring Plan, Environmental Implementation Plan, Site Environmental Report, and ES&HD-5008.
DOE 5400.5	Radiation Protection of the Public and the Environment	Establishes standards and requirements for DOE and contractor operations with respect to protection of members of the public and the environment against undue risk from radiation.	5. Hazard Analysis and Classification of the Facility and 9. Radiation Protection	Compliance is implemented by ES&HD-5008, plans and procedures and by TPX General Requirements Document. Analysis indicates very low exposure to the public or environment.
DOE 5440.1D	National Environmental Policy Act (NEPA) Compliance Program	Establishes DOE responsibilities and procedures to implement the NEPA of 1969.	3. Site Characteristics	Implemented by PPPL Procedure ESH-014. An Environmental Assessment (DOE/EA-0813) was prepared and a finding of no significant impact (FONSI) issued for the TPX Project.
DOE 5480.1B	Environment, Safety and Health (ES&H) Program for DOE Operations	Establishes ES&H Program for DOE Operations.	6. Principle Health and Safety Criteria	Requirements are implemented through ES&HD-5008.

Code	Description	Criteria	Applicable PSAR section	Compliance analysis
DOE 5480.3	Safety Requirements for the Packaging and Transportation of Hazardous Materials, Hazardous Substances, and Hazardous Waste	Establishes requirements for the safe packaging and transporting of hazardous materials, hazardous substances, and hazardous wastes.	7. Radioactive and Hazardous Material Waste Management and 10. Hazardous Material Protection	Implemented by material control policies and procedures, Sections 4 and 15, and ES&HD-5008, Sections 8 and 10.
DOE 5480.4	Environmental Protection, Safety and Health Protection Standards	Specifies and provides requirements for the application of environmental protection, safety, and health standards applicable to DOE and contractors.	2. Applicable Statutes, Rules, Regulations, and Departmental Orders.	Requirements are implemented through PPPL Health and Safety Directives.
DOE 5480.8	Contractor Occupational Medical Program	Establishes the minimal Occupational Medical Program requirements for the DOE.	10. Hazardous Material Protection	Implemented by the PPPL Occupational Medicine Policy P-019.
DOE 5480.10	Contractor Industrial Hygiene Program	Establishes the requirements and guidelines applicable to DOE contractor operations for maintaining an effective industrial hygiene program.	6. Principal Health and Safety Criteria and 10. Hazardous Material Protection	Compliance with 29 CFR 1910.120 and 1926 industrial hygiene surveillance requirements are assured by adherence to ES&HD-5008, administered by industrial hygiene staff in the PPPL Safety Branch.
DOE 5480.11	Radiation Protection for Occupational Workers	Establishes radiation protection standards and program requirements for DOE and contractor operations for workers.	9. Radiation Protection	10 CFR 835 requirements are implemented by ES&HD-5008 and individual TPX project procedures.
DOE 5480.15	DOE Laboratory Accreditation Program for Personnel Dosimetry	Provides requirements for evaluating DOE Laboratory Personnel Dosimetry Accreditation Program.	9. Radiation Protection	DOE evaluates PPPL dosimetry program for compliance with DOE 5480.11.
DOE 5480.19	Conduct of Operation Requirements for DOE Facilities.	Provides requirements and guidelines for developing directives, plans, and/or procedures relating to the safe conduct of operation at DOE facilities.	13. Procedures and Training and 17. Operational Safety	Implemented by TPX Operating Procedures, which will be similar to TFTR Operating Procedures.
DOE 5480.20	Personnel Selection, Qualification, Training, and Staffing Requirements at DOE Reactor and Non-Reactor Nuclear Facilities	Establishes the selection, qualification, training, and staffing requirements for personnel involved in the operation, maintenance, and technical support of DOE owned nonreactor nuclear facilities. Applies to TPX if Tritium inventory becomes $\geq$ 1,000 Ci.	13. Procedures and Training	Implemented by Training Implementation Matrix, training manuals, procedures and operator certification packages.

Code	Description	Criteria	Applicable PSAR section	Compliance analysis
DOE 5480.21	Unreviewed Safety Questions (USQ)	Establishes the definition and basis for determining the existence of an USQ.	11. Analysis of Normal, Abnormal, and Accident Conditions	Section 11 provides bounding accident analysis for this project. Applies to TPX if tritium inventory becomes ≥ 1,000 Ci.
DOE 5480.22	Technical Safety Requirements (TSR) [Note: TPX will use administrative controls and operating procedures to ensure the operability of safety-significant SSCs.	Establishes the requirements to have TSRs prepared for DOE nuclear facilities and to delineate the criteria, content, scope, format, approval process, revisions, and reporting requirements of these documents.	16. Operability of safety-significant Structures, Systems, and Components	Section 16 provides the approach for the project. It is anticipated that operability of safety-significant SSCs will be controlled by a PPPL procedure, as they are at present for TFTR. TSRs, controlled by DOE, would be required if the TPX tritium inventory is ≥1,000 Ci.
DOE 5480.23	Nuclear Safety Analysis Report (NSAR)	Establishes the requirements for contractors responsible for the design, construction, operation, decontamination, or decommissioning of nuclear facilities to develop safety analyses that establish and evaluate the adequacy of the safety bases of the facilities. The NSAR required by this order documents the results of the safety analysis.	1. Executive Summary	This PSAR uses a graded approach based on DOE-STD-3009-94, and addresses the 21 topics in DOE Order 5480.23.
DOE 5480.28	Natural Phenomena Hazards Mitigation	Requires Structures, Systems, and Components (SSCs) at DOE facilities to be designed to mitigate potential hazards due to natural phenomena.	4. TPX Facility and Process Description and 5. Hazard Analysis and Classification of the Facility	DOE Standards have been promulgated to apply the requirements of this order; they include DOE-STD-1020, 1021, and 1024. For TPX, this compliance is addressed in the TPX General Requirements Document and will apply to TPX modifications during operations.
DOE 5482.1B	Environmental Safety and Health Appraisal Program	Provide requirements for internal and external appraisals of ES&H compliance.	12. Management, Organization, and Institutional Safety Provisions	Implemented by PPPL policy (P.026) and procedures (QA-002, 017); internal appraisals are performed by PPPL Quality Assurance (QA) division.

Code	Description	Criteria	Applicable PSAR section	Compliance analysis
DOE 5483.1A	Occupational Safety and Health Program for DOE Contractor Employees at Government-Owned Contractor-Operated Facilities	Establishes requirements and procedures to ensure that occupational safety and health standards prescribed pursuant to the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974, and the DOE Organization Act of 1977 provide occupational safety and health protection for DOE contractor employees in government-owned contractor-operated facilities.	6. Principal Health and Safety Criteria and 10. Hazardous Material Protection	Implemented by PPPL ES&HD-5008 and project specific procedures. Prescribes compliance to OSHA standards at contractor facilities and provides information and instructions on requesting variances from requirements, instructing employees, and conducting OSHA type inspections.
DOE 5484.1	Environmental Protection, Safety, and Health Protection Information Reporting Requirements	Establishes the requirements and procedures for the information reporting of ES&H significance for DOE operations.	19. Emergency Preparedness Program	Emergency preparedness and occurrence reporting requirements are adhered through PPPL Policy and Organization Document 0-036 Security and Emergency Preparedness Division Charter.
DOE 5500.2B	Emergency Categories, Classes, and Notification and Reporting Requirements	Establishes DOE emergency categories, classes, and notification and reporting requirements to facilitate the communication and reporting of emergency events.	19. Emergency Preparedness Program	Emergency preparedness and occurrence reporting requirements are implemented by the PPPL Emergency Preparedness Plan.
DOE 5500.3A	Planning and Preparedness for Operational Emergencies	Establishes safety requirements for planning and preparedness for operational emergencies involving DOE or requiring DOE assistance.	19. Emergency Preparedness Program	Emergency preparedness and occurrence reporting requirements are implemented by the PPPL Emergency Preparedness Plan, and Emergency Preparedness Implementation Plan Supplements.
DOE 5633.4	Nuclear Materials Transactions: Documentation and Reporting	Provides reporting requirements for shipments of deuterium and tritium.	7. Radioactive and Hazardous Material Waste Management	Compliance is addressed by Health Physics Radioactive Waste Procedures, HP-RW-001 and 010.
DOE 5633.5	Nuclear Materials Reporting and Data Submission Procedures	Provides reporting requirements for shipments of deuterium and tritium.	7. Radioactive and Hazardous Material Waste Management	Compliance is addressed by Health Physics Radioactive Waste Procedures, HP-RW-001 and 010.
DOE 5700.6C	Quality Assurance	Prescribes QA requirements and provides implementation guidelines.	18. Quality Assurance	Implemented by the TPX QA Plan and Institutional QA Plan.

Code	Description	Criteria	Applicable PSAR section	Compliance analysis
DOE 5820.2A	Radioactive Waste Management	Establishes requirements by which DOE safely manages radioactive and mixed waste.	7. Radioactive and Hazardous Material Waste Management	Waste management requirements are incorporated through PPPL procedures.

Table 2-3. Technical references developed to support TPX design, construction, and operation.

Title	Description	Applicable PSAR sections
DOE/EA-0813	The environmental assessment for the TFTR decontamination and decommissioning and the TPX projects that supported a FONSI.	TPX design, construction, and operation; all sections.
Potential Off-Normal Events and Releases for the TPX, EGG-FSP-10710, Aug. 1993	A preliminary analysis of potential off-normal radiological and hazardous material release performed to address the environmental impact and safety concerns of TPX operation.	TPX operations, Sections 5, 7, 10, and 11.
Methodology for Assessing the Consequences of Radioactive Releases During Normal Operation of the TPX Facility at PPPL	The assumptions and methodology used to assess the impact to members of the public from normal operational releases of radioactive material from TPX are described.	TPX operations, Sections 5, 7, 10, and 11.
Operating Procedures	To be determined (TBD)	TBD
Emergency Procedures	TBD	TBD
Training Manuals	TBD	TBD
TPX Structural and Cryogenic Design Criteria	The TPX Structural and Cryogenic Design Criteria defines the structural and cryogenic design criteria of the TPX device.	Sections 4, 5, and 6.
TPX General Requirements Document (GRD)	The GRD provides top-level performance requirements for TPX.	Sections 4, 5, and 6.
TPX Physics Design Description (PDD)	The PDD provides key design features and major parameters of TPX.	Sections 4, 5, and 6.
TPX System Design Descriptions (SDDs)	The TPX SDDs describe the systems which make up the machine and support systems.	Sections 4, 5, and 6.

3. SITE CHARACTERISTICS

This section briefly describes the location and characteristics of the PPPL site. The unmitigated consequences of an accident scenario at TPX would not result in consequences beyond the immediate facility; therefore, detailed descriptions of site characteristics largely consist of the minimum required by DOE-STD-3009-94 (DOE 1994a), i.e., specifying the location of PPPL, the location of the TPX facility on the overall site, and identifying the location of the facility and site boundaries. However, a sufficient amount of site information is provided in order to identify and evaluate potential external accident initiators (e.g., nearby facilities), and for addressing potential environmental threats to the TPX facility.

3.1 Site Location

The PPPL is located at the C and D sites of the James Forrestal Campus of Princeton University. This is in Middlesex County in central New Jersey. The municipalities of Princeton, Plainsboro, Kingston, West Windsor, and Cranbury are within 8 km (5 miles) of PPPL. The closest urban centers are New Brunswick, 23 km (14 miles) to the northeast, and Trenton, 19 km (12 miles) to the southwest. New York City is approximately 64 km (40 miles) to the northeast, Newark is approximately 56 km (35 miles) to the northeast, and Philadelphia is approximately 56 km (35 miles) to the southwest. Figure 3-1 presents the general layout of PPPL facilities at the C and D sites and the PPPL site boundary; the TPX is located at D-site. The D-site coordinates are latitude 40° 20 min 55 sec. north, longitude 74° 36 min 0 sec. west.

3.2 Site and Surrounding Area

The 72 acre C/D site is dedicated to fusion energy research; facilities include administrative offices, offices for physicists and engineers, small laboratories, a large high-bay experimental area, buildings for power supply systems, and supporting craft shops, maintenance, and warehouse facilities. A private road extending through Forrestal Campus provides primary access to C site. The size of the work force at PPPL varies, depending on current activities, but is currently about 900. This total is made up of direct employees, subcontracted employees, graduate students, and visiting experimenters. The majority of the work force will eventually be supporting the TPX project.

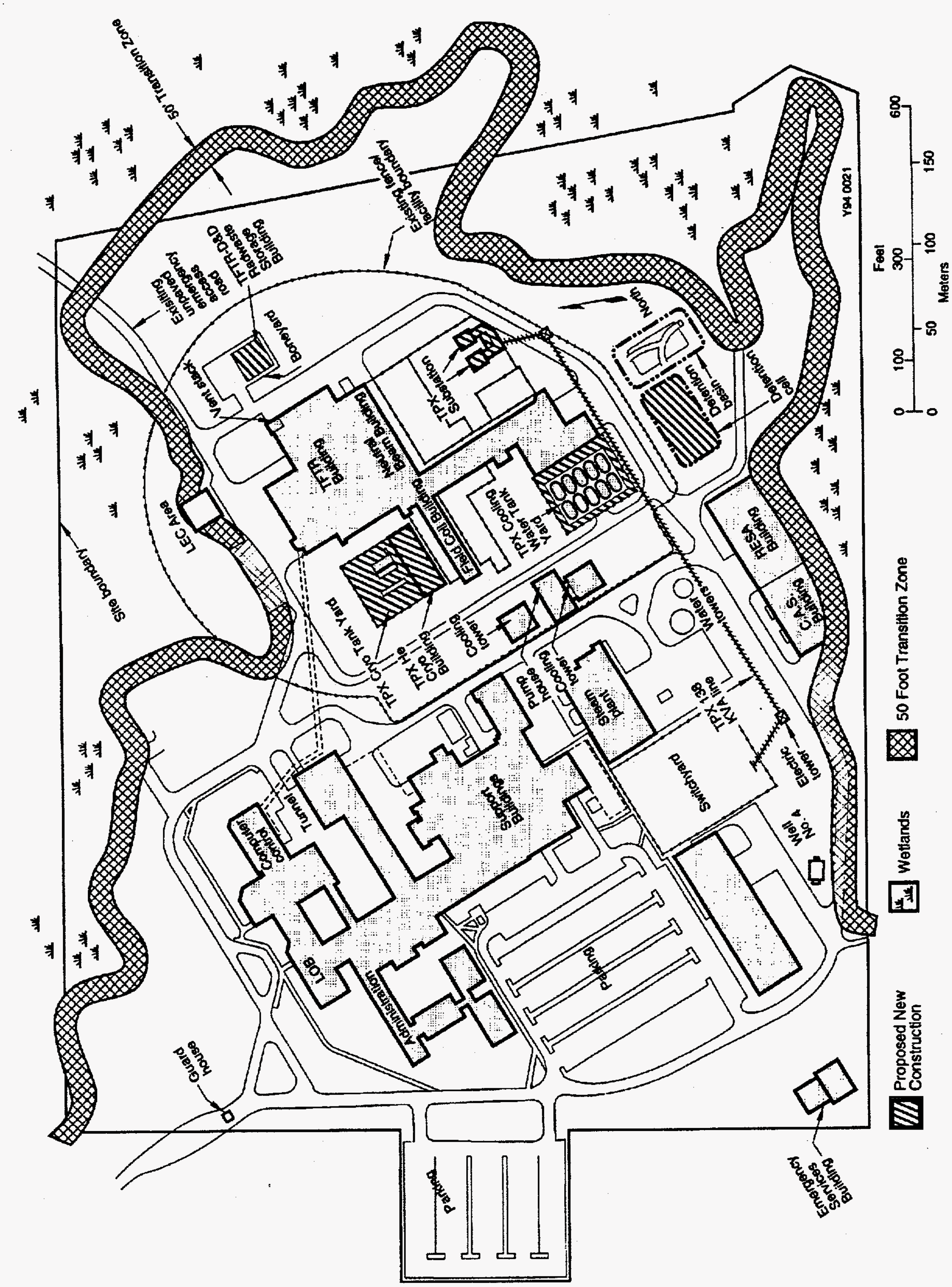


Figure 3-1. General PPPL site plan with proposed new construction and wetlands location relative to PPPL facilities.

The PPPL is surrounded by other research and development and light industrial facilities. The area surrounding PPPL, including Mercer, Middlesex, and Somerset counties, is characterized by a combination of suburban and rural land uses. Population estimates based on 1980 census data have been prepared previously for the PPPL site (Bentz and Bender 1987). Estimates based on the 1990 census have also recently been prepared (McKenzie-Carter and Anderson 1993), and the estimated 1990 resident population within 16 km (10 mi) of PPPL is approximately 446,000 (DOE 1994b). The area surrounding PPPL has a well developed local road and street system and is serviced by four state highways. The principal service route to the TPX site is U.S. Route 1, a 4-lane highway between Trenton and New Brunswick. A discussion of other transportation facilities (e.g., airports and railroads) and utility services (gas and electrical) in the vicinity of PPPL can be found in Bentz and Bender (1987) and PPPL (1993b).

3.3 Nearby Facilities

Numerous research and development and light-industrial facilities are located in the vicinity of PPPL. These include electronics research firms, chemical development and research firms, and publishing companies. McGuire Air Force Base is approximately 35 km (22 miles) south of the PPPL, and there are heavy-aircraft airways in the vicinity of PPPL. These nearby industries and facilities, and evaluations of accidents involving them, are discussed in PPPL (1993b). Evaluations of accidents involving hazardous materials at nearby industrial facilities and transported on nearby highways and railroads found no anticipated effects on the TFTR facility (which is the same facility TPX will use). The probability of a heavy aircraft [> 6,810 kg (15,000 lbs)] crashing into the TFTR/TPX Test Cell is estimated to be 3×10^{-8} per year (PPPL 1993b).

3.4 Meteorology

An onsite meteorological monitoring system has been in operation at PPPL since December 1983. It consists of a 60-meter (197-ft) tower to collect horizontal wind speed, horizontal wind direction, temperature, dew point, temperature difference between the upper and lower level of the tower, and the standard deviation of the horizontal wind direction. Details of the monitoring program, including equipment, system maintenance and calibration, and data processing and analysis are in PPPL (1993b). Measurements from the PPPL meteorological tower are summarized in Finley and Wieczorek (1994) and PPPL (1993b); additional data are contained in McKenzie-Carter and Anderson (1993).

The highest wind speed recorded in the area between 1913 and 1975 was 117 km/h (73 mph) in 1914 (PPPL 1993b). Characteristics of the Most Intense Tornado and the Most Probable Tornado are given in PPPL (1993b). The maximum 10-minute average windspeed for a hypothetical Probable Maximum Hurricane and a Standard Project Hurricane moving over the PPPL site has been calculated as 201 km/h (125 mph) and 138 km/h (86 mph), respectively (PPPL 1993b). Additional information on meteorological extremes is available (PPPL 1982, 1993b).

The National Oceanic and Atmospheric Administration (NOAA) conducted a series of tests in 1988 to characterize the atmospheric dispersion characteristics at PPPL. The results of these tests are recommended site boundary dispersion values (X/Q) for short-term (99.5 percentile) roof and ground-level releases, as well as long-term (annual average) releases, as shown in Table 3-1. A summary of the NOAA tests can be found in PPPL (1993b), and details of the tests are in Start et al. (1989).

Table 3-1. Recommended atmospheric dispersion factors for TPX.

	X/Q values (sec/m^3)	
Type of release	Stack release	Ground-level release
Routine (Annual average)	1.77×10^{-5}	-
Accident (Short-term)	1.7×10^{-4}	4.8×10^{-4}

3.5 Hydrology, Geology, and Seismology

Surface drainage from the PPPL site is to Bee Brook, a small permanent stream located east and northeast of the TPX site. A report (Envirosphere 1987) provides flow data, water quality data, and other information regarding Bee Brook and Drainage Ditch 5. The TPX site is not considered susceptible to flooding from nearby surface water bodies (PPPL 1993b). Other potential sources of site flooding are discussed in PPPL (1993b), which concludes that the water levels associated with the Probable Maximum Flood will not present a hazard to the TPX site. Any potentially contaminated liquids from TPX will be collected in liquid effluent collection tanks on the site; the liquid in these tanks may be released to the sanitary sewer system if effluent concentrations and quantities comply with DOE and state requirements. Information regarding groundwater characteristics near PPPL is available, including regional groundwater users (Lewis and Spitz 1987; PPPL 1993b). There is no volcanism near PPPL. Complete descriptions of other aspects of the geology of the PPPL area (ERDA 1975; PPPL 1982, 1993b) are available.

A seismic hazard analysis for the PPPL site was conducted in 1989 by Lawrence Livermore National Laboratory (Savy 1989); the results of this analysis are given in Table 3-2.

Table 3-2. Maximum predicted horizontal ground surface acceleration at PPPL for various probabilities of exceedence.

PPPL ground surface acceleration	59 cm/s^2 (0.06 g)	78 cm/s^2 (0.08 g)	128 cm/s^2 (0.13 g)	186 cm/s^2 (0.19 g)
Hazard annual probability of exceedance (per year)	2×10^{-3}	1×10^{-3}	4×10^{-4}	2×10^{-4}

In addition to the analysis in Savy (1989), the probabilistic seismic hazard results for PPPL given in another DOE guidance document (DOE 1992a) indicate a higher peak horizontal ground acceleration of 118 cm/s^2 (0.12 g) for a probability of 1×10^{-3} per year, which is the probability required for a Performance Category 2 (PC2) facility (DOE 1993). To meet this requirement, TPX SSCs that meet the PC2 criteria in DOE-STD-1021-93 (DOE 1993) will be designed for seismic loads associated with the Most Intense Earthquake, as described in Kennedy et al. (1989) and consistent with DOE Orders 5480.28 and 6430.1A. The Most Intense Earthquake for the TPX site has a maximum horizontal ground acceleration of 128 cm/s^2 (0.13 g) and a maximum vertical ground acceleration of 83 cm/s^2 (0.085 g) (PPPL 1993b). Analysis also indicates that the existing Test Cell can withstand the acceleration associated with a Most Intense Earthquake (PPPL 1993b). Additional information on the seismicity of the region, the development of seismic design criteria, and chronology of seismic evaluations for the PPPL is discussed in PPPL (1993b).

4. TPX FACILITY AND PROCESS DESCRIPTION

This section provides an overall description of the TPX facility and processes, and identifies and describes those SSCs that are, or may be, safety-significant from the standpoint of their role as major contributors to Defense-in-Depth and/or worker safety as defined in DOE (1994a).

Based on the analysis of the radioactive material inventory at TPX described in Section 5, TPX will be designated as a less than Category 3 nuclear facility, which is considered to be a radiological facility. In addition, based on analysis presented in Section 11 and information on TPX Evaluation Guidelines (EGs)[1] shown in Table 6-1, it has been determined that there will be no adverse offsite consequences to the environment or the safety and health of the public from any postulated TPX accidents. In view of these facts, there will be no TPX safety-class SSCs and a few potential TPX safety-significant SSCs. TPX SSCs will be further assessed during the design phase and final results will be presented in the TPX FSAR.

4.1 Overview

The TPX will be located and operated in the existing TFTR complex, which will be modified and upgraded to accommodate TPX requirements. A site plan, Figure 3-1, shows the general arrangement of the TPX site and facilities, including the location of the site and TPX facility boundaries. A description of the TPX, new and existing facilities, and utilities is given in Section 4.3. Those TPX SSCs which are considered to be potentially safety-significant based on Defense-in-Depth and worker safety criteria are identified and described in Sections 4.4 and 4.5. Additional information on TPX systems is given in the TPX System Design Description documents. Detailed information on existing TFTR facilities and utilities is given in the TFTR FSAR (PPPL 1993b).

4.2 TPX Fusion Process

In the operation of TPX, a plasma will be created and sustained within a torus-shaped vacuum vessel. The fusion reactions that will occur in this plasma will primarily involve combinations of hydrogen and deuterium. Byproducts of these fusion reactions include neutrons, tritium, and a net energy release. Some fusion reactions involving the deuterium fuel and tritium byproduct will also occur. The fuel must be heated to high temperatures for the reactions to take place. This high temperature fuel is referred to as plasma because the atoms are in an ionized state. The charged particles that constitute the plasma are constrained to move along certain paths inside the vessel,

[1] Guidelines expressed in terms of dose (radiation) or exposure (hazardous materials) for the purpose of evaluating the adequacy of the results associated with design basis accidents/evaluation basis accidents (DBA/EBA). Offsite EGs are related to the protection of the offsite public and define needed safety-class SSCs (DOE 1994a).

defined by a strong toroidal magnetic field generated by large superconducting toroidal field (TF) coils and poloidal field (PF) coils, which surround the vessel. Other smaller water-cooled copper coils within and outside of the vacuum vessel will provide additional control and positioning of the plasma. Systems designated as divertors, limiters, or armor will be installed within the vacuum vessel and will further control the position and shape of the plasma as well as protect the vessel walls from direct interactions with the high-temperature plasma.

In order to produce the fusion reaction, the plasma must be heated and compressed to produce an extremely high temperature. To do this, a current is induced in the plasma by means of a changing magnetic field in the central section of the PF coils, referred to as the central solenoid assembly. This current heats and compresses the plasma to achieve the high temperatures necessary for the fusion reaction to occur. Further heating and current drive will be provided by the injection of beams of neutral particles (deuterons) from neutral beam injectors and by ion cyclotron and lower hybrid radio frequency wave heating.

Fusion reactions that occur in the high-temperature plasma will release energy in the form of charged particles, neutrons, and gamma radiation, the properties of which will be measured by various diagnostic systems. These measurements will supply information for physics studies and provide real-time data for control of the tokamak.

4.3 TPX Nonsafety-significant Structures, Systems and Components

4.3.1 Tokamak Systems

Figure 4-1 presents a cross sectional view of the tokamak. The design features a torus-shaped vacuum vessel that contains the plasma, surrounded by 16 superconducting TF magnet coils, that encircle the vacuum vessel, and 14 superconducting PF coils symmetrically located above and below the plasma midplane. The eight inner PF coils that form the central solenoid assembly will generate the plasma current drive. All of the superconducting TF and PF coils are enclosed in a cryostat that will limit heat transfer to the cryogenic coil sets. The TF assembly and vacuum vessel will be assembled in quadrants with four TF coils per quadrant.

Each quadrant will include three large horizontal ports for heating and current drive systems, diagnostics, and remote maintenance access. Vertical ports will be provided for vacuum pumping

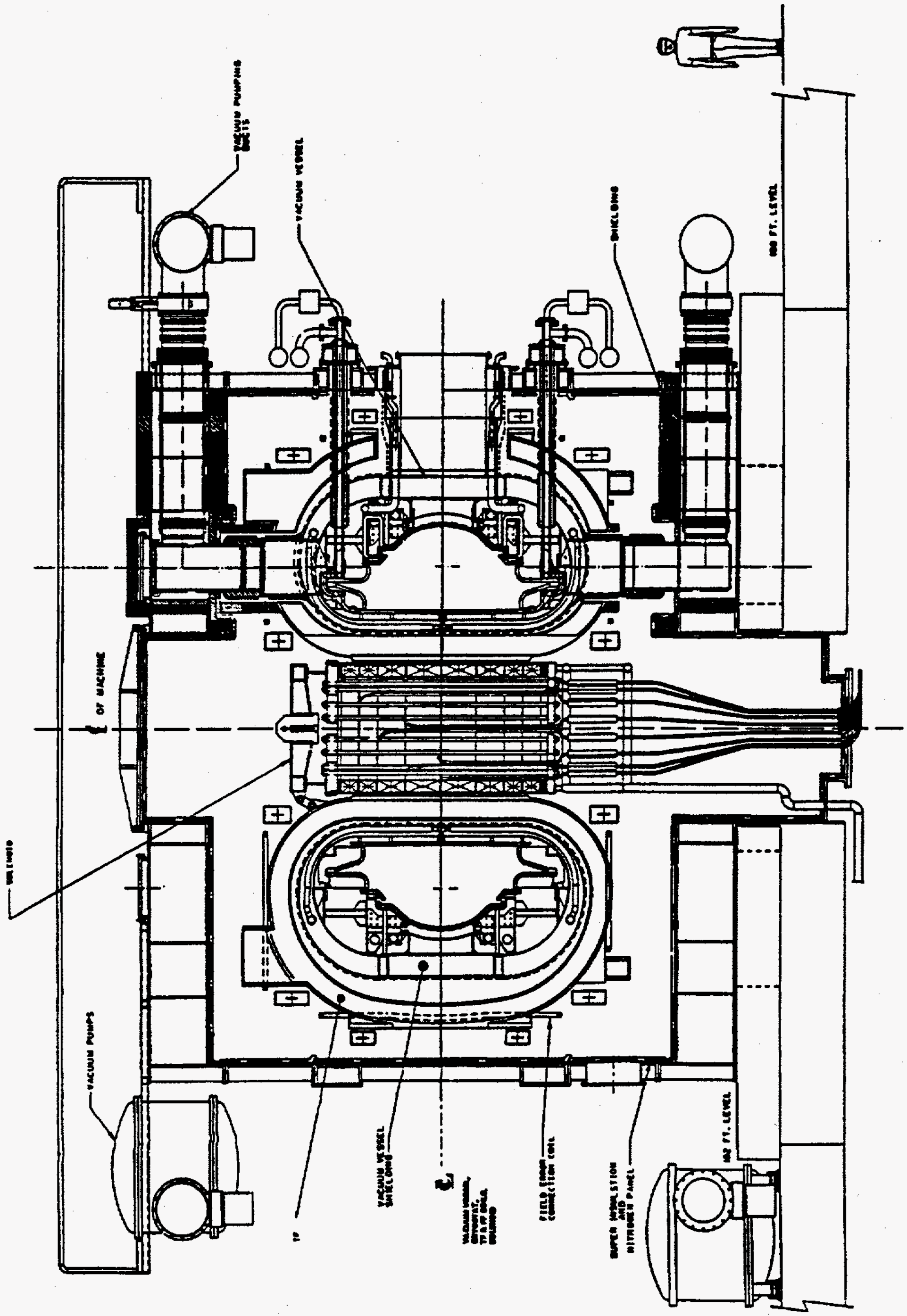


Figure 4-1. Cross section of preliminary design of superconducting TPX (adapated from PPPL drawing TPXE-94-10001).

and additional diagnostic access. Plasma facing components within the vacuum vessel include divertors, limiters, and armor, which will be used for heat removal, density control, and to protect the vacuum vessel inner wall. Also contained within the vacuum vessel are the internal control (IC) coils, which will be used to position the plasma. Additional plasma control will also be achieved by the field error correction (FEC) coils located on the external surface of the vacuum vessel. The IC and FEC coils are of conventional copper construction, cooled with water (IC coils) or another medium (e.g., liquid nitrogen or gaseous helium) (FEC coils). Neutron and gamma shielding will be provided to limit nuclear heating of the super conducting magnets, to provide biological shielding, and to limit activation of components outside of the shield. The shielding system will be divided into three regions, including shielding around the vacuum vessel, shielding around ducts and penetrations, and shielding in and around the radial ports.

4.3.2 Supporting Systems and Equipment

A machine protection system will be installed to safeguard the machine during unusual operating occurrences. The function of the machine protection system is to detect abnormal operating conditions (e.g., temperatures or coolant flows out of allowed operating limits) and to generate a plasma and neutral beam shutdown signal.

Auxiliary heating systems include the neutral beam injection system, the ion cyclotron resonance heating system, and the lower hybrid heating system. The TPX will employ the existing TFTR neutral beam system modified for 1,000-second operations. The neutral beam system will provide plasma heating and current drive, and will fuel the plasma. The ion cyclotron resonance heating system consists of two antennas in adjacent ports and will provide ion heating and centrally peaked current drive. The lower hybrid system is installed in a horizontal port and will provide off-axis heating and current drive.

The existing TFTR nontritium gas delivery system will be used to provide gas to the plasma and to the neutral beams. This system consists of four similar systems, two for hydrogenous gases and two for miscellaneous gases such as helium and nitrogen. The TPX vacuum system will provide vacuum pumping of the torus, the cryostat, neutral beams and for certain diagnostic equipment. The vacuum pumping system consists of eight cryopumps and sixteen turbopumps located above and below the torus, external to the cryostat.

The existing TFTR radiation monitoring system will be used and will provide real-time and passive tritium, gamma, and neutron monitoring capabilities. Tritium monitoring in the TPX facility will consist of process, area, and stack monitors and associated alarms. In addition, portable hand-held tritium monitors will be used to supplement area monitoring. Area monitors will alarm on elevated room tritium concentrations to warn personnel to take protective action (e.g., evacuate the room if necessary).

The HVAC for the Test Cell and for certain areas surrounding the Test Cell have been designed to operate with a negative pressure gradient between areas such that leakage flows from less hazardous areas to potentially more hazardous areas. Air is drawn through a high-efficiency particulate air filter and is exhausted to the facility stack. Low negative pressure in these areas will alarm in the local HVAC control room as well as in the TPX control room. Redundant negative pressure fans are provided for these areas; the standby fan will automatically start if the operating fan fails.

High-efficiency particulate air filters are installed in the Test Cell HVAC ducting. These filters are arranged such that airborne particulate materials are removed from the exhaust air stream prior to exhausting through the facility stack to the environment.

The HVAC system for the experimental area comprises eight separate systems, all of which are exhausted through a single facility stack. The stack is provided with two 10.6 m^3/s (22,500 cfm) booster fans located at the discharge point of the eight exhaust systems and which impart an increased velocity to the combined exhaust flow. This increased velocity results in an increased effective stack height, which increases the dispersion of air emissions and results in a reduction of the potential dose at the site boundary. One of the booster fans operates continuously and, in the event of failure, an alarm is sounded in the local and TPX control rooms and the second fan is automatically started.

The electrical power system will comprise a multiple of integrated subsystems that provide power for the following equipment or systems: TF coils, PF coils, IC coils, FEC coils, auxiliary heating systems, control system, dummy load, and D-site house power. The existing TFTR motor generator sets will provide PF power. The TF power system and the auxiliary heating system power systems will be new loads off of the utility system.

In-vessel remote maintenance will be performed using two in-vessel vehicles remotely positioned on rails within the vacuum vessel which will traverse around its interior. One vehicle is equipped with a power arm manipulator; the other is equipped with a dexterous servo-manipulator. Maintenance external to the vacuum vessel will be done employing hands-on operations or in a semi-remote mode using long handled tools and local shielding.

Diagnostic systems will measure plasma parameters over a wide range of operating conditions in order to supply information for physics studies and to provide real-time data for control and optimization of advanced tokamak regimes. This will include the diagnostics needed to monitor and control plasma shapes, current profiles, and disruption precursors.

The TPX central instrumentation and control (I&C) system will provide supervisory level remote control, monitoring, data acquisition, and data handling for the TPX. In addition, it will support the TPX synchronization system, the controlled access system, the safety interlock system, the control room facility audio/video equipment, and the associated networks. For the purposes of the conceptual design, the overall I&C system will be divided into the process control system and the physics support system.

4.3.3 Buildings, Modifications, and Site Improvements

The TPX will make extensive use of existing TFTR buildings and utilities; however, certain new or upgraded buildings and utilities will also be required. Primary existing TFTR buildings that will be used include the TFTR Test Cell Complex, the Field Coil Power Conversion Building, the Neutral Beam Power Conversion Building, the Motor Generator Building, radioactive waste handling areas, computer and control rooms in the Laboratory Office Building, the data transmission tunnel, and other miscellaneous PPPL support facilities. New facilities required include a cryogenic equipment building and tank yard, a cooling water pump house and tank yard, and an electrical substation and transmission line. Existing and new facilities are shown in Figure 3-1. Primary existing TFTR utilities and support systems that will be modified as necessary and used by TPX include neutral beam lines, pulsed electrical power system, field coil power conversion system, fueling system, HVAC system, and cooling water systems. Fire protection for TPX will be provided by the existing C and D site system. Fire suppression systems for the individual buildings include automatic sprinkler systems and CO_2 systems. All buildings have detection equipment that provides local and remote alarm.

4.4 Determination of Potential TPX Safety-Significant Structures, Systems, and Components

As stated in Section 4, accidental occurrences postulated for TPX will result in no hazardous material exposures to the public that exceed the EGs. On this basis, TPX will not have any safety class SSCs, and all SSCs will be either safety-significant or nonsafety-significant, as described in Section 4.4.1 below.

Based on guidance in DOE 1994a, TPX safety-significant SSCs do not have special design criteria placed on them but will be subject to certain surveillance and conditions for operation. These conditions will collectively define the minimum performance level required for operability of the TPX facility. The project will also compile a list of TPX systems/equipment required to be operable and conditions required to perform certain TPX operations (see Section 16).

4.4.1 Definition of Safety-Significant and Nonsafety-significant Structures, Systems, and Components

Certain TPX SSCs may be considered to be safety-significant. Such SSCs are defined as follows:

> Safety-significant SSCs consist of those structures, systems, and components that do not meet the threshold requirements for safety class designation but whose preventive/mitigative function is a major contributor to Defense-in-Depth (i.e., prevention of uncontrolled releases) and/or worker safety as determined from hazard analysis (DOE 1994a).
>
> Defense-in-Depth, consists of two components:
>
> - Equipment and administrative features providing preventive or mitigative functions so that multiple features are relied on for accident prevention or mitigation to a degree proportional to the hazard potential.
>
> - Integrated safety-management programs that control and discipline operations.

As a general rule of thumb, safety-significant SSC designations based on worker safety are limited to those structures, systems, and components whose failure is estimated to result in an acute worker fatality or serious injuries to workers. Serious injuries, as used in this definition, refers to medical treatment for immediately life-threatening or permanently disabling injuries (e.g., loss of eye, loss of limb) from other than standard industrial hazards. It specifically excludes potential latent effects (e.g., potential carcinogenic effects of radiological exposure or uptake).

Other nonsafety-significant SSCs that involve hazards and equipment routinely found in industry are designated as Standard Industrial Hazards, defined as follows:

> "Standard industrial hazards consist of those hazards that are routinely encountered in general industry and for which national consensus codes and/or standards (e.g., OSHA, transportation

safety, etc.) exist to guide safe design and operation, without the need for special analysis to define safe design and/or operational parameters." (DOE 1994a)

4.4.2 Evaluation of TPX Structures, Systems, and Components for Safety Significance

All TPX SSCs potentially having an impact on safety were identified and evaluated by the following steps.

A. Hazard Identification. General hazards anticipated to be present at TPX include

- Ionizing radiation
- Nonionizing radiation
- Electrical hazards
- Chemical hazards
- Mechanical hazards
- Fire and explosion hazards
- Cryogenic hazards.

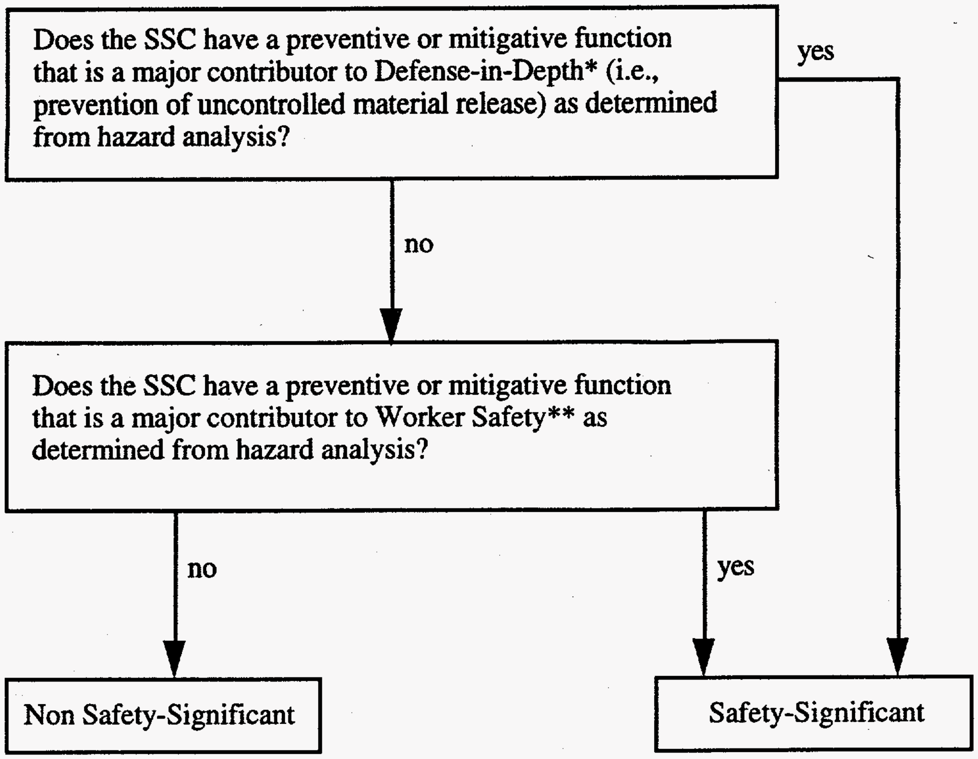
B. Potential Targets. TPX personnel and other onsite personnel at PPPL who potentially can be exposed to these hazards were identified.

C. Preventive and Mitigative Mechanisms. For each hazard and potential target, the preventive and mitigative mechanisms that will provide Defense-in-Depth and protection for workers were identified.

D. Evaluation for Safety Significance of Preventive and Mitigative Mechanisms. All preventive and mitigative mechanisms identified in C above were screened in accordance with the logic diagram shown in Figure 4-2 and were determined to be either (potentially) safety-significant or nonsafety-significant for the specific hazard being addressed.

4.4.3 Results of the Evaluation Process

The results of the process described above are summarized in Table 4-1. This table lists the basic hazards and identifies SSCs determined to be potentially safety-significant for each specific hazard. In addition, the table lists information relating to the basis for determining safety-significance of SSCs.



	Includes:	Excludes:
*Defense-in-Depth	• equipment to prevent or mitigate accidents leading to uncontrolled release of hazardous material, e.g., - shields and barriers - alarms - filtered exhaust - safety systems - outer defense layer	• administrative features • safety-management programs • low hazard accidents
**Worker Safety	• equipment to prevent or mitigate acute fatalities or serious injuries	• standard industrial hazards • latent effects • procedures

Figure 4-2. Criteria for Safety-Significant SSCs per DOE Standard 3009-94.

4.5 Description of the TPX Potentially Safety-Significant Structures, Systems, and Components

As shown in Table 4-1, TPX SSCs determined to be potentially safety-significant include the Test Cell access control system and the diborane monitors, alarms, and shutdown system.

Table 4-1. Potential TPX safety-significant structures, systems, and components.

Hazard and safety-significant SSCs	Safety function (Defense-in-Depth or Worker Safety)	Safety-significant consequences	Accident prevented or mitigated
Ionizing radiation			
Test Cell Controlled Access System	Protects against inadvertent entry into the Test Cell	Excessive dose to workers	TBD
Chemical			
Diborane monitors, alarms, and shutdown system	Prevents worker exposure to toxic/flammable diborane gas	Excessive worker exposure to toxic material	TBD

The potential safety-significant SSCs are described in Sections 4.5.1 and 4.5.2. The final determination of safety significance will be based on detailed analyses that will be reported in the TPX FSAR.

4.5.1 Test Cell Controlled Access System

The TPX Central I&C system will control and monitor the overall TPX Controlled Access System (CAS). Its function will be to control access to the Test Cell when electrical, mechanical, toxic or radiation hazards exceed allowable limits. The primary means of control will be the Personnel Interlock System (PIS) which will include door locks, door switches, emergency stops, and hazardous equipment interlocks such as those found on magnet systems, power supplies, radio frequency systems, and neutral beams. The system will be configured to limit entry when such equipment is in operation or energized, however, it will also have a permissive interlock which will allow access under special conditions. The Test Cell CAS will also have a "no access" mode, and in this mode any attempt to access the Test Cell will interrupt the PIS which will result in the activation of the alarm system and an automatic shutdown of all hazardous equipment. Egress from the Test Cell will be allowed for personnel safety. Monitors, alarms, door switches, and equipment interlocks in the PIS system which will control access to the Test Cell under the no access mode may be designated as safety-significant, however, the final determination of safety significance will be based on further analysis which will be reported in the TPX FSAR.

4.5.2 Diborane Monitors, Alarms, and Shutdown System

A gas mixture containing diborane may be injected into the TPX torus during the glow discharge sequence in order to produce a carborane film on the inner walls of the vacuum vessel and internal components. The purpose of the film is to reduce outgassing of impurities during subsequent operations of the Tokamak. The functions of the diborane supply system are to store diborane gas mixtures and to deliver, inject, and recover the unused gas mixtures. Since diborane is toxic and flammable, special safety features are required.

The diborane gas mixture is contained in a cylinder that conforms to DOT Regulation 49 CFR 172.400, subpart E. The cylinder, along with a commercially available gas cabinet is housed outdoors under a rain shed. The sides of the shed and cabinet are open to provide ample air circulation in order to prevent the build-up of an explosive concentration. The diborane shed is enclosed by a fence 16.5 x 15.2 m (54 x 50 ft) and is 3.0-m (10-ft) high. The fenced enclosure is 18.3 m (60 ft) from the Mockup Building.

A chain of safety features is arranged in an electrical loop to monitor various parameters. The loop is connected to the gas delivery controller, which shuts down the delivery system under alarm conditions. There are three diborane detectors included in the loop. One samples air at the gas cabinet; one samples air at the torus injection point; and one samples air at the torus pumping station. If any of these detectors detect diborane at 0.1 ppm, the diborane delivery system will be shut off. In addition, three shut-off switches are strategically located around the system. A coaxial line delivers the gas mixture to the Test Cell. The inner space of this line is pressurized with gaseous nitrogen such that any leak into or out of the system will result in an alarm and will halt flow. Further details about the diborane safety system monitors and alarms are given in PPPL (1993b).

Failure of the alarm system and the automatic shutoff function may result in an excessive exposure of workers to diborane, and, therefore, the alarm and shutoff systems may be designated as safety-significant. The final determination of safety significance will be based on further analyses, which will be reported in the TPX FSAR.

5. HAZARD ANALYSIS AND CLASSIFICATION OF THE FACILITY

This section systematically identifies and assesses the inventory of hazardous materials associated with the TPX facility and evaluates the potential events that can cause the hazard to develop into an accident. The potential hazards include radioactive materials and chemical materials. The radioactive materials inventory is used to determine the facility hazard classification.

This section covers the topics of hazard identification, hazard categorization, and hazard evaluation. Included is a description of the analysis methodology, identification of the hazardous material inventory, and energy sources present at the facility. Hazard categorization is in accordance with DOE (1992b). Significant worker-safety features identified by the hazard analysis are included.

5.1 Radioactive Materials

5.1.1 Inventory Location and Amount

The radioactive material inventory at TPX will consist of radionuclides generated during D-D operations scheduled to take place over a 9-year period. These will include tritium, air activation products, activated TPX machine products, and activated TPX cooling and shielding water. The tritium will be adsorbed in the first walls of the vacuum vessel and will also be found in the diagnostics, neutral beams, and plasma exhaust systems. The activated air will be in the atmosphere of the Test Cell. Activated metals produced during D-D operations will be in the vacuum vessel, magnets, and other components located close to the torus. Removed radioactive components will be stored in the shielded storage area of the hot cell next to the Test Cell or in the Radioactive Waste Handling Building located near the TPX facility within D-site. In accordance with DOE (1992b), the postulated releasable TPX radionuclide inventory is compared to threshold values to determine the hazard categorization of the facility (Category 1, 2, 3, or less than 3).

The D-D reaction will produce neutrons and small amounts of tritium in the plasma. The neutrons will activate Test Cell air, the vacuum vessel, and structural and component materials. It is expected that tritium produced during D-D operations will not exceed 300 curies (Ci) per year (DOE 1994b). For activated Test Cell air, roughly 16 Ci of N-16, 0.7 Ci of Ar-41, and less than 1 Ci each of N-13, Cl-40, and S-37 will be produced during each pulse of the TPX machine (DOE 1994b,

Appendix A). Except for Ar-41, these isotopes have half lives less than 10 minutes,[1] and inventories in the Test Cell atmosphere will decay to insignificant levels before access to the Test Cell is allowed. For activated structural and component materials, information contained in Cadwallader and Motloch (1993, Table 5) was used to generate an expected list of radionuclides that could be released during an accident.[2]

The generated TPX radionuclide inventory was compared to the Category 3 threshold values of DOE (1992b). Table 5-1 presents the calculational results, which demonstrate that the TPX project is less than a Category 3 nuclear facility.

5.1.2 Release Barriers

The vacuum vessel system and magnet cases will provide the primary passive release barrier for activated metal in the vacuum vessel and magnets. The secondary barrier will be provided by the Test Cell. Tritium and activated air will be released in a controlled manner to the environment via the facility exhaust stack.

5.2 Hazardous Chemicals

5.2.1 Inventory Location and Amount

Hazardous chemicals to be used for TPX operations will consist of those used in typical chemistry laboratories for water chemistry analysis (e.g., sulfuric acid). Amounts will be in typical small laboratory quantities, which do not present a hazard to the public or an undue hazard to trained personnel.

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[1] Radioactive half lives of air activation isotopes are as follows: Ar-41, 1.8 hr; N-13, 9.97 min; S-37, 5.05 min; Cl-40, 80.6 sec; and N-16, 7.1 sec.

[2] DOE (1992b, Section 3.1.2) discusses final categorization as being "based on an 'unmitigated release' of available hazardous material. For the purposes of hazard categorization, 'unmitigated' is meant to consider material quantity, form, location, dispersibility and interaction with available energy sources,..." By nature of form and dispersibility, solid activated metals bind the contained radionuclides and they could only be released by vaporization of the metal, which would require an intense energy source. The only such TPX energy source is the stored energy in the magnets. Cadwallader and Motloch (1993) describe the accidental releases of radioactive tokamak dust and magnet material, which is a fraction of the total of all activated material. That releasable quantity is used for the TPX radionuclide source term for comparison to DOE (1992b) threshold criteria. Radionuclides bound in metallic structural and component materials that would not be released during an accident are not considered to be part of the inventory used for hazard categorization.

Table 5-1. Releasable TPX radioactive materials inventory and threshold values.

Radioactive isotope	TPX total curie inventory	Category 3 threshold value[d] (curies)	Screening ratio[a]
Tritium (H-3)[b]	$< 1.0 \times 10^{3}$	1.0×10^{3}	< 1.0
Sodium-24[c]	2.6×10^{-2}	3.0×10^{2}	8.7×10^{-5}
Scandium-47[c]	3.0×10^{-7}	5.8×10^{3}	5.2×10^{-11}
Chromium-51[c]	6.5×10^{-2}	2.2×10^{4}	3.0×10^{-6}
Manganese-56[c]	3.9×10^{-1}	2.8×10^{3}	1.4×10^{-4}
Iron-55[c]	4.5×10^{-2}	5.4×10^{3}	8.3×10^{-6}
Cobalt-57[c]	9.0×10^{-2}	6.0×10^{3}	1.5×10^{-5}
Cobalt-58[c]	6.5×10^{-1}	9.0×10^{2}	7.2×10^{-4}
Cobalt-58m[c]	1.0×10^{0}	4.3×10^{5}	2.3×10^{-6}
Nickel-57[c]	3.2×10^{-2}	6.0×10^{2}	5.3×10^{-5}
Cobalt-60m[c]	2.6×10^{-1}	4.3×10^{5}	6.0×10^{-7}
Argon-41[e,f]	$< 1.4 \times 10^{2}$	6.0×10^{2}	$< 2.3 \times 10^{-1}$
		Ratio sum total	< 1.0

a. The sum of the ratios must be less than one (DOE 1992b).

b. D-D operations will generate no more than 300 curies of tritium per year (DOE 1994b). The tritium inventory will be administratively controlled to restrict the total inventory not in Type B shipping containers to less than 1,000 curies to ensure that TPX remains less than a Category 3 nuclear facility.

c. These values are from Cadwallader and Motloch (1993, Table 5) for 9-year D-D operation.

d. Threshold values are from DOE (1992b, Table A.1 of Attachment 1) and Mossman (1994)

e. D-D operations will generate no more than 140 curies of argon-41 per year (DOE 1994b). Less than half of this amount will be released because of its short half life (1.82 hours) and ventilation hold up. Shorter lived nitrogen isotopes (N-13 and N-16) will also be produced but are not listed because of their short half lives.

f. The maximum argon-41 inventory of 140 curies corresponds only to 200,000-second pulse operation of the TPX tokamak. The maximum argon-41 inventory for all other operational sequences (e.g., 1,000-second pulses is 1.8 curies, which would result in a screening ratio for argon-41 of 3×10^{-3}.

Neutron shielding of the vacuum vessel in the Test Cell may employ boric acid in a water solution for the neutron absorbing properties of boron. Concentration will be on the order of 5,000 parts per million of boric acid, based on solubility properties. Dilute boric acid is considered a weak acid (0.08 molarity, pH of 5.1) and will not present a hazard to the public or an undue hazard to workers. Sulfur hexafluoride (SF_6) gas is used for electrical equipment insulation. The amount of SF_6 used is (TBD). SF_6 is an asphyxiant like many other common gases (e.g., nitrogen, argon, etc.) and is considered to be a standard industrial hazard. Standard precautions will include purging components of SF_6 prior to any maintenance activities and providing supplementary ventilation.

Diborane gas may be injected into the vacuum vessel during glow discharge evolutions to help maintain plasma purity. Diborane is explosive and toxic. The amount of diborane stored at TFTR currently is 100g (0.22 lb), and the location is as described in Section 4. Based on design estimates, the interior walls of the vacuum vessel may be coated with up to 1,000 kg (2205 lb) of beryllium. Because diborane and beryllium are not considered to be standard industrial hazards in their application, their hazards are analyzed in Section 11.

5.2.2 Release Barriers

The vacuum vessel structure will provide the primary passive release barrier for borated water. The diborane gas delivery system and vacuum vessel will provide the primary passive release barrier for diborane gas. Electrical equipment confinement will provide the primary passive release barrier for SF_6 gas. The vacuum vessel will provide the primary passive release barrier for beryllium dust. The secondary barrier for these hazards will be provided by the Test Cell and/or other equipment barriers as described in Section 4.

5.3 Energy Sources and Accident Initiating Events

Energy sources within TPX include sensible heat within the structural materials and the plasma, decay heat, electrical energy of the plasma and in the magnets, combustible and explosive fuel, and pressurized gases. These energy sources, when combined with potential release mechanisms, could result in uncontrolled releases of radioactive and hazardous material inventories. Postulated release mechanisms include loss of vacuum vessel cooling, severe plasma disruptions, magnet arcing, fires in the TPX Test Cell, and hydrogen explosions. Also, pressurized diborane and SF_6 could be released as a result of equipment failure.

Accident initiating events can be classified as internal or external. Internal events would be those that originate in the facility itself and could include spills, fires, equipment failure, and possible breach of inventory confinement. External events originate outside of the facility and could include natural phenomena (e.g., earthquake or windstorm), or a man-made accident such as a fire or transportation mishap.

5.4 Preventive and Mitigative Features

Safety features of the TPX include special equipment, process design, and operational administrative controls. Design features include titanium vacuum vessel construction for reduced activation, location of the TPX machine in the shielded Test Cell with filtered ventilation, and remote handling equipment for maintenance of activated TPX machine components. Administrative controls that will act as preventive and mitigative features include personnel safety training, project health and safety program, safety equipment training, process operations and waste monitoring, and possibly operational parameter requirements as derived from the safety analysis.

5.5 Hazards Analysis

Table 5-2 presents a list of credible generic hazards (*credible* is defined as having a frequency of occurrence equal to or greater than 1×10^{-6} per year). Each specific hazard from this table was analyzed with input from TPX Project design personnel and reviews of project documentation (e.g., Potential Off-Normal Events and Releases for the Tokamak Physics Experiment, EGG-FSP-10710, August 1993). These hazards were then screened to eliminate incredible and standard industrial hazards. The rationale for eliminating a particular hazard is presented in the following sections. Those hazards remaining after the screening are analyzed in Section 11 and include chemical exposure, explosion, fire, and ionizing radiation sources. Potential impacts from loss of cooling, plasma disruptions, and magnet arcing are also addressed in Section 11.

5.5.1 Aircraft Impact

The TFTR FSAR assessed the probability of a large airplane crash into the Test Cell as incredible (Cadwallader and Motloch 1993). The exhaust stack is designed to withstand a small airplane crash of 6,810 kg (15,000 lb) mass traveling at 161 kph (100 mph) (PPPL 1993b); the Test Cell walls and roof thicknesses are 4 to 5.5 times thicker than the walls of the stack, and can thus withstand an even greater airplane crash impact.

5.5.2 Chemical Exposure

Laboratory operations will occur for TPX support and consist of cooling water analysis and environmental sampling and analysis. As such, small laboratory quantities of chemicals are used. Other sources of hazardous chemicals include sulfuric acid used as battery electrolyte, acids and alkaline cleaning and pickling solutions used in machine shops, SF_6 gas for electrical equipment

Table 5-2. Screened generic TPX hazards.

Aircraft impact	Screened[a]
Chemical exposure	Analyzed[a,b,c]
Compressed gases	Screened[b]
Construction hazards	Screened[a,b]
Cryogenic systems	Screened[a,b]
Electrical hazards	Screened[a,b]
Explosion	Analyzed[c]
Fire	Analyzed[c]
Flammable gases, liquids, and dusts	Screened[a,b]
Flooding	Screened[a]
High-intensity magnetic fields	Screened[a,b]
High noise levels	Screened[b]
High winds	Screened[a]
Inadequate illumination	Screened[b]
Inadequate ventilation	Screened[b]
Ionizing radiation exposure	Analyzed[c]
Low oxygen atmosphere	Screened[b]
Material handling dangers	Screened[a,b]
Mechanical and moving equipment dangers	Screened[b]
Nonionizing radiation sources	Screened[a,b]
Seismic events	Screened[a]
Temperature extremes	Screened[a,b]
Volcanism	Screened[a,d]
Working at heights	Screened[b]

a. See text for discussion.

b. These hazards are of a standard industrial nature and are controlled by compliance with OSHA requirements and/or TPX equipment specifications and/or TPX operating procedures.

c. See Section 11, Analysis of Normal, Abnormal, and Accident Conditions.

d. There is no volcanism near PPPL. See Section 3.5.

insulation, and freon used in refrigeration equipment. Mitigative features for chemical exposure include properly trained personnel handling chemicals, detection and evacuation alarms, the PPPL site Spill Prevention Countermeasures and Control Plan for a spill of petroleum products, and PPPL Hazardous Material Storage Facility Contingency Plan for spills of hazardous chemicals. Chemical exposure to these sources presents only a standard industrial hazard.

Other chemical hazards include the beryllium coating of the vacuum vessel interior and diborane gas used for torus glow discharge evolutions. Beryllium as a coating is not a health threat but is toxic if inhaled in the form of dust or aerosol. Cadwallader and Motloch (1993) conservatively estimate that 33 g (0.073 lb) of beryllium could be released to the Test Cell while workers are present in the event of a vacuum vessel rupture. This could result in beryllium concentrations of 1.4 mg/m^3 which is 700 times the American Conference of Government Industrial Hygienists Threshold Limit Value (see Section 11.5). However, this is below the lowest observed adverse effect level (LOAEL) for animals for a 14-day exposure to respirable beryllium, i.e., 4.3 mg/m^3 (DOE 1994b). Since the torus vacuum is monitored, personnel in the Test Cell would be alerted to evacuate if loss of vessel vacuum occurred. The second hazardous chemical is diborane gas which is toxic and flammable. The diborane gas storage is located in a fenced open area outside and away from the Test Cell, and the double walled piping injection system is monitored for leakage and has shutoff features should leakage develop. Because beryllium and diborane are not standard industrial hazards with respect to their application, their hazards will be analyzed in Section 11.

5.5.3 Construction Hazards

The approximate 3-year period of facility construction will present hazards to personnel which will be controlled by adherence to Occupational Safety and Health Administration (OSHA) requirements for assembly activities. The nonstandard hazard will be residual sources of ionizing radiation within the TFTR Test Cell. It is estimated that the expected radiation level will be approximately 0.1 mrem per hour. This could result in a worker in the Test Cell receiving a maximum of 200 mrem per year (DOE 1994b) which is below the TPX EG.

5.5.4 Cryogenic Systems

Several cryogenic systems will be used for cooling of TPX machine components. These include liquid nitrogen and liquid helium systems. Equipment may be operated either locally or from the TPX control room. These systems present only standard industrial hazards. Mitigative features include the restriction of equipment operation by only trained and qualified personnel.

5.5.5 Electrical Hazards

TPX will require high voltages (> 600 V) for operation of various electrical equipment. PPPL site electric service of 138 kV at 600 amps is provided to the onsite electric substation, where it is transformed down to 13.8 kV and lesser voltages as per various electrical equipment operating requirements. The use of electrical equipment complies with the National Fire Protection Association, National Electrical Code, the National Electric Safety Code, National Electrical Manufacturers Association requirements, ES&HD-5008 Section 2 (Electrical Safety), and the TPX Grounding Specification (PPPL 1994a). These systems present only standard industrial hazards and/or will preclude hazards through design in accordance with the TPX Grounding Specification. Electricians are required to have additional training for working on any equipment or circuits of > 250 V. The electrical safety criterion applicable to all PPPL electrical apparatus and systems stated in ES&HD-5008, Section 2 is that it shall take two simultaneous failures of high voltage barriers or a single failure of a low voltage barrier to endanger workers while they are performing their work processes.

5.5.6 Flammable Gases, Liquids, and Dusts

Flammable gas (propane and natural gas) is used at PPPL for heating services. Flammable liquid (gasoline and diesel fuel) is also used for transportation activities and emergency diesel generators. Hydrogen and deuterium will be used for experiments and solvents (e.g., acetone) will be used to clean components. These items present only standard industrial hazards (see Section 5.5.2 for diborane). Flammable dusts are not expected to be present at TPX.

5.5.7 Flooding

Flooding has been analyzed for the TFTR facility and the analysis (PPPL 1993b) demonstrates that flood water levels associated with the probable maximum flood (frequency of 1×10^{-4} per year) will not present a hazard to the facility. TFTR is built on higher ground than the Probable Maximum Flood level and TPX is using the TFTR Test Cell. The hazard from flooding for the TPX project is therefore negligible (DOE 1994b).

5.5.8 High-intensity Magnetic Fields

The TPX test machine will use superconducting magnets which generate magnetic fields for heating, confining, and shaping of the fusion plasma. Personnel exposure is controlled by not allowing access to the Test Cell during pulsing operations and controlled personnel access during magnet testing. These magnet systems present only standard industrial hazards.

5.5.9 High Winds

As discussed in PPPL (1993b), the TFTR Test Cell has been designed to withstand a Most Probable Tornado and has been analyzed as being capable of withstanding the Most Intense Tornado. The Most Probable Tornado has a corresponding maximum windspeed of 177 km/h (110 mph) (annual probability of occurrence of 2.7×10^{-5}). The Most Intense Tornado has a corresponding maximum windspeed of 394 km/h (245 mph) (annual probability of occurrence $< 1 \times 10^{-7}$). The highest recorded wind in the area is 117 km/h (73 mph) (July 1914). The median windspeed is 6-11 km/h (4-7 mph). The hazard from high winds for the TPX project is negligible (DOE 1994b).

5.5.10 Material Handling Dangers

Material handling includes activities such as movement of heavy loads and transportation. These activities will predominate during the construction phase of the TPX and will be diminished during the operational phase. These activities present only standard industrial hazards.

5.5.11 Nonionizing Radiation Sources

The TPX tokamak will use radio frequency (RF) generators, which produce electromagnetic radiation for heating the fusion plasma. Personnel exposure is controlled by not allowing access to the Test Cell during pulsing operations when this equipment is in operation. Magnetic fields are discussed in Section 5.5.8. Laser and microwave systems will be used at the TPX for diagnostics. These RF generator, laser, and microwave systems present only standard industrial hazards.

5.5.12 Seismic Events

As discussed in PPPL (1993b), the PPPL site is not earthquake prone, and the area has not experienced a severe earthquake in recorded history. The TFTR Test Cell has been designed to withstand a Most Probable Earthquake and has been analyzed as being capable of withstanding the Most Intense Earthquake. The TPX SSCs required to be seismically qualified will be designed to the Most Intense Earthquake. The hazard from seismic events for the TPX project is negligible (DOE 1994b).

5.5.13 Temperature Extremes

Temperature extremes will present a hazard to workers. Cryogenic systems present extremes of cold. Personnel are protected by thermal shielding of cryogenic piping and components. This is only a standard industrial hazard.

5.6 Environmental Impact

The TPX Environmental Assessment (DOE 1994b) demonstrates that the TPX project located at the PPPL site will not result in any significant adverse environmental impacts. Current environmental quality and monitoring programs conducted for TFTR will be maintained and improved when required to ensure that TPX activities comply with all applicable federal, state, and local regulations, standards, and guidelines.

5.7 Facility Hazard Classification

Based on the analysis in this section, the TPX is classified as a less than Category 3 facility and is considered to be a radiological facility, per DOE (1992b).

6. PRINCIPAL HEALTH AND SAFETY CRITERIA

This section outlines the principal health and safety criteria applicable to TPX SSCs, equipment, and processes through references to published codes and standards. The section also discusses operating safety criteria, which have been derived or adopted from safety and related requirements contained in statutes, rules, regulations, and U.S. DOE directives, together with DOE and PPPL safety policy and goals.

6.1 Safety Criteria for Structures, Systems, and Components

The SAR for TPX must demonstrate that the Test Cell and other TPX facilities can safely house the activities associated with operation of TPX without undue risk to the public, site workers, or the environment. This section identifies the applicable design codes and standards important to SSCs in their function of preventing or mitigating hazards due to the TPX Project activities. The DOE requires that designs follow DOE and nationally recognized codes and standards. The top level design standard is DOE 6430.1A, General Design Criteria (DOE 1989), which states that "all department facilities are to be designed and constructed to be reasonable and adequate for their intended purpose and consistent with health, safety, security, and environmental protection requirements."

TPX will be designed and operated in accordance with DOE and nationally recognized codes and standards. A list is provided under Division 1 General Requirements of DOE 6430.1A. This list is a useful reference source for potentially applicable codes and standards. However, the references provided in DOE 6430.1A are generally not applicable to tokamak design. Tokamak systems (including the TF and PF magnets, vacuum vessel, and plasma facing components) shall be designed in accordance with TPX Structural and Cryogenic Design Criteria (Heitzenroeder 1991). The codes and standards used in the design of TPX will be described in individual System Design Descriptions.

6.1.1 Design of Nonsafety Class Items

The design of SSCs that are not safety class items shall, as a minimum, be subject to conventional industrial design codes and standards [as specified in the TPX System Design Descriptions or in Heitzenroeder (1991)] and appropriate quality assurance standards.

6.1.2 Design of Safety-Significant Items

Safety-significant SSCs can be designed to conventional industrial design codes and standards, as applicable, or to special criteria as specified in the TPX Structural and Cryogenic Design criteria; however, they may need to be further addressed in specific procedural and administrative controls to ensure that their preventive/mitigative functions will be operable, i.e., functional performance tests, engineering calculations, or comparison with similar SSCs that are known to meet similar criteria.

6.1.3 Design of Safety Class Items

It is not anticipated that any of the TPX SSCs will be classified as *Safety Class* items, since the site boundary radiation dose in a worst-case accident scenario would be well below the limits stipulated in Brynda et al. (1986) and offsite TPX EGs for radiological hazards presented in Table 6-1.

6.2 Operating Safety Criteria

The operating safety criteria for TPX are to ensure that

- Normal operations result in insignificant radiological impacts at or beyond the site boundary
- Radiological impacts of design basis accidents at TPX result only in localized consequences.

The operating condition, probability of occurrence, and operational criteria are summarized in Table 6-1, which presents the radiological EGs for TPX.

Table 6-1. TPX Evaluation Guidelines for radiological hazards.

Condition		P, probability of occurrence in a year	Public exposure[a] Regulatory limit	Public exposure[a] Design objective	Occupational exposure Regulatory limit	Occupational exposure Design objective
Routine operation[b]	Normal operations	$P \geq 1$	0.1 total 0.01 airborne[c] 0.004 drinking water	0.01 total	5	1
	Anticipated events	$1 > P \geq 10^{-2}$	0.5 total (including normal operation)	0.05 per event		
Accidents[d]	Unlikely events	$10^{-2} > P \geq 10^{-4}$	2.5	0.5	e	e
	Extremely unlikely events	$10^{-4} > P \geq 10^{-6}$	25	5[f]	e	e
	Incredible events	$P < 10^{-6}$	NA	NA	NA	NA

a. Evaluated at the PPPL site boundary (unless otherwise indicated).

b. Dose equivalent to a person from routine operations (rem per year unless otherwise indicated).

c. Compliance with this limit is to be determined by calculating the highest effective dose equivalent to any member of the public at any offsite point where there is a residence, school, business, or office.

d. Dose equivalent to a person from an accidental release (rem per event).

e. Refer to PPPL ES&HD-5008 Section 10, Chapter 12 for emergency personnel exposure limits.

f. For design basis accidents, i.e., postulated accidents or natural forces and resulting conditions for which the confinement structure, systems, components, and equipment must meet their functional goals, the design objective is 0.5 rem.

7. RADIOACTIVE AND HAZARDOUS MATERIAL WASTE MANAGEMENT

This project is expected to generate very small quantities of radioactive and hazardous materials. These quantities will be managed by existing PPPL organizations that have procedures in place to handle radioactive and hazardous material wastes.

This section describes the radioactive and hazardous waste management program; describes the waste sources and characteristics; summarizes predicted worker exposure; specifies standards and criteria with which the program must comply; identifies the responsible organizational structure; references generic plans and procedures; and identifies training requirements.

The level of detail provided in this section will reflect the outcome of the hazard and accident analysis. In general, the complexity of waste systems and the management of waste will be related to the quantities and types of wastes associated with the TPX Project Operations.

7.1 Waste Management Policy, Objectives, and Philosophy

This information is provided in detail in the PPPL ES&HD-5008, Section 10, Chapter 10, Radioactive Waste Management and Laboratory Procedures Manual EWM-001 for Hazardous Waste (PPPL 1993e). The policy, objectives, and philosophy provided in these documents have proven successful for the TFTR D-T Program.

7.2 Waste Sources and Characteristics

Waste sources and characteristics are expected to be similar to those experienced during the TFTR D-T Program. These are extensively identified in the TFTR-DT EA and will provide an upper bound for any TPX wastes projected.

7.3 Summary of Predicted Worker Exposure

Worker exposure to radiation at PPPL will be limited as indicated in Table 6-1. Chemical exposure limits will be in accordance with the PPPL ES&HD-5008, Section 8, Chapter 1. These limits are all well below national limits for exposure to radiation and chemicals.

7.4 Specific Standards and Criteria

The TPX Project radioactive and hazardous material waste will be handled in accordance with all federal, state, and local standards. These include, but are not limited by, those specified in Sections 2 and 6 of this PSAR.

7.5 Responsible Organizational Structure

The TPX Project has in place an approved organizational structure that includes PPPL support organizations responsible for radioactive and hazardous waste management. This structure is shown by the PPPL Organization Chart (PPPL 1994b), and the TPX Project Management Plan (PPPL 1993c).

7.6 Reference Generic Plans and Procedures

The generic plans and procedures for the TPX Project are identified in the TPX Project Management Plan (PPPL 1993c).

7.7 Training Requirements

Personnel involved in radioactive and hazardous material waste management will require training as appropriate. Training is required by the PPPL Policy Organization Manual No. 0-28, Training Advisory Committee Charter, and Laboratory Training Policy P-008 (PPPL 1993d).

8. INADVERTENT CRITICALITY PROTECTION

This section is not applicable to the TPX Project because there will be no fissile materials present to initiate criticality.

9. RADIATION PROTECTION

This section summarizes the radiological hazards expected at TPX and describes the salient features of the PPPL radiological protection program as it relates to the TPX facility. It also describes the relationship to other PSAR sections, such as Sections 17 and 20, where these sections contain relevant information.

The TPX Project will be located within the existing TFTR facility at PPPL. TPX radiological hazards will be very similar to TFTR radiological hazards, and the TPX operation will incorporate existing safeguards and procedures for safely handling radioactive materials. The radiation safety program currently in effect at PPPL has been designed to ensure that laboratory activities comply with applicable DOE orders and all other applicable federal, state, and local regulations, standards, and guidelines (DOE 1994b). Section 2 of this PSAR identifies the applicable federal statutes, DOE rules, orders, standards and criteria with which the radiation protection program is designed to comply. Radiological evaluation guides are tabulated in Section 6 of this PSAR. A list of applicable standards is also provided in the PPPL ES&HD-5008, Section 10, Chapter 2.

9.1 Design Features, Programs, and Procedures

The radiation protection design features, programs, and procedures at PPPL are detailed in PPPL ES&HD-5008, Section 10 (PPPL 1993e). The design features, programs, and procedures for the TPX Project will be derived from those generated and proven successful for the TFTR operations.

9.2 Radiation Sources

TPX radioactive sources generated during D-D operations will include direct radiation (i.e., neutron and gamma radiation), tritium, air activation products, and activated TPX machine products. Section 5 of this PSAR identifies and describes the inventory of radioactive materials from the TPX Project. Section 7.2 addresses waste sources and their characteristics.

9.3 ALARA

Radiation exposure of the TPX workers and public will be controlled to prevent exposure to ionizing radiation in excess of administrative limits and limits specified in 10 CFR 835 and DOE

Order 5480.11 (DOE 1988; PPPL 1993e). The policy concerning radiation exposure follows an *as low as reasonably achievable* (ALARA) philosophy. A detailed description of this policy is provided in the PPPL ES&HD-5008 manual, Section 10, Chapter 4.

9.4 Radiation Monitoring

The TPX Project will employ the radiation monitoring programs currently being used at PPPL. A detailed description of the radiation monitoring devices and instruments used for personnel dosimetry, air and environmental monitoring, and the radiological environmental monitoring program is provided in the PPPL ES&HD-5008, Section 10, Chapters 8 and 9.

9.5 Internal and External Dosimetry

The TPX Project requirements for personnel monitoring will be based on the assessments of PPPL Health Physics. This organization is responsible for providing radiological assessments of internal and external pathways to occupational workers from radioactive material (PPPL 1993e). A detailed description of the TPX internal and external dosimetry program and the radiation exposure limits are provided in the PPPL ES&HD-5008, Section 10, Chapter 3.

9.6 Exposure and Contamination Control

To minimize internal and external worker exposure and radiation contamination, the TPX Project will require radiation work permits for entry into all controlled radiological areas. Procedures for identifying these areas and details of the controls are provided in the PPPL ES&HD-5008, Section 10, Chapter 4. DOE Order 5480.4 (DOE 1991) mandates the requirements contained in ANSI Z88.2 (ANSI 1980) and 29 CFR 1910.134 (DOL 1993) for implementation of a respiratory protection program and associated training of workers. Respirators will be issued only to workers trained, fitted, and medically qualified to wear the specific type of respirator.

9.7 Recordkeeping

The PPPL health physics procedures specify the practices and requisite recordkeeping that ensure compliance with PPPL ES&HD-5008, Section 10, Chapters 3-12 and applicable DOE orders. The TPX Project records of radiation sources, monitoring, and internal and external exposure will be generated and maintained as required by 10 CFR 835, DOE Order 5480.11, (DOE 1988) and DOE Order 5484.1 (DOE 1981). Records of exposure are available and will be provided to occupational workers, and all records will be retained for the life of the PPPL facility.

9.8 Organization

Safety is an integral and inseparable part of every endeavor at PPPL and requires the commitment of each member of the organization to perform tasks safely. At PPPL, the responsibility for safety extends from the Laboratory Director through all levels of management and supervision to the individual worker (PPPL 1993b). Section 12 of this PSAR contains information relating to safety management and organization and identifies topics addressed in the PPPL Policy/Organization Manual and PPPL ES&HD-5008.

9.9 Training

The basic objective of PPPL radiation safety protection training is to enable facility workers to work safely, efficiently, knowledgeably, and confidently with radioactive sources and materials and in areas where occupational radiation exposure may exist. To accomplish this, workers are instructed on procedures, practices, and regulations designed to minimize exposures and to inform them of the nature of radiation and its potential biological effects. A detailed description of the existing PPPL training program is provided in PPPL ES&HD-5008, Section 10, Chapter 6.

9.10 Nonionizing Radiation and Magnetic Fields

Sources of nonionizing radiation and magnetic fields at TPX will include lasers, TPX field coils, diagnostics, and RF plasma heating systems. The nonionizing radiation and magnetic field safety policies and procedures for the TPX Project are detailed in PPPL ES&HD-5008, Section 4.

10. HAZARDOUS MATERIAL PROTECTION

This section summarizes the hazardous materials concerns expected at TPX and describes the salient features of the PPPL hazardous materials protection program as it relates to the TPX facility. It also describes the relationship to other PSAR sections, such as Sections 17 and 20, where these sections contain relevant information.

The TPX hazardous material protection program will be an extension of the existing PPPL Environmental Safety and Health program that was generated and proven successful for the TFTR operations.

10.1 Policy, Program, and Procedure

The PPPL policy to protect workers and the public from hazardous material is implemented through the industrial hygiene and radiation safety programs. The policies, programs, and procedures currently being followed by the PPPL are provided in detail in the PPPL ES&HD-5008, Sections 8 and 10 (PPPL 1993e). The TPX procedures and policies will be based on and incorporate this existing program.

10.2 Facility-Specific Material

The TPX hazardous materials will consist of both radioactive materials and chemical materials and will be similar to those present for TFTR. Section 5 of this PSAR identifies and describes the inventory of the radioactive and chemical materials associated with the TPX Project. Section 7.2 addresses the waste sources and their characteristics.

10.3 Design and Controls

The PPPL hazardous material protection design and controls program incorporates requirements from DOE Orders 5480.4 (DOE 1991) and other federal regulations and standards. A summary of the design, administrative controls, and supporting equipment and controls that will be used by the TPX hazardous material protection program is provided in detail in the PPPL ES&HD-5008, Sections 8 and 10.

10.4 Standards

The primary requirements for occupational health and safety programs are found in U.S. DOE directives, OSHA standards, and other applicable guidance specified in DOE Order 5480.4. Section 2 of this PSAR identifies the applicable federal statutes, DOE rules, orders, standards, and criteria with which the hazardous material protection program is designed to comply.

10.5 Worker Exposure

For workers at TPX, chemical exposure limits will be in accordance with the PPPL ES&HD-5008 manual, Section 8, Chapter 1. These limits are all well below the national limits for exposure to chemicals.

10.6 Training

TPX Project workers will require hazardous material protection training, as appropriate for their job requirements and duties. Detailed descriptions of the existing PPPL training programs are provided in the PPPL ES&HD-5008, Section 8, Chapter 10 and Section 10, Chapter 6.

11. ANALYSIS OF NORMAL, ABNORMAL, AND ACCIDENT CONDITIONS

The objective of this section is to systematically analyze the hazards identified in Section 5 and to determine how they apply to normal operations, accident initiators, and abnormal and accident conditions. Release of the hazardous material inventories at risk during these conditions is analyzed. Comparison with relevant EGs is made.

The scope of this section covers the topics of impacts of normal operations, abnormal operating events, and accident analysis. Normal operations are those operations during which the facility systems are operating within the normal parameters envelope. Abnormal operating events include process and support systems upsets but with no additional failures that would lead to an accident. Accident events are those unplanned failure events that result in undesired consequences. Included is a description of the systematic methodology used for the analyses. A risk determination is then made concerning TPX operations.

Since TPX is categorized as less-than-a-category 3 facility, by definition, an unmitigated release of the inventory at risk (e.g., tritium) will not result in offsite consequences exceeding TPX EGs. The accidents that are assessed are considered to be evaluation basis accidents for comparison with evaluation guidelines. Evaluation basis accidents are those that are postulated for the purpose of confirming that safety structures, systems, and components can limit accident consequences to less than EG values (DOE 1994a). In contrast, evaluation of beyond design/evaluation basis accidents is performed to gain insight into the magnitude of consequences. Beyond design basis accidents were analyzed in DOE (1994b) and found to be all low-consequence events. Hence, beyond design/evaluation basis accidents are not addressed further in this PSAR.

11.1 Methodology

Analysis of the hazards at TPX consists of estimating a probability of occurrence based on the definitions (adapted from DOE 1994a) presented in Table 11-1 for normal and abnormal operations and for accident conditions. Determination of probability levels is based on expert judgement and the environmental assessment (DOE 1994b) concerning operations to be conducted at TPX. The hazards are then analyzed for consequences of normal and abnormal operations and for accident conditions and given a consequence rating based on definitions (adapted from DOE 1994a) presented in Table 11-2.

Table 11-1. Probability of occurrence criteria.

Probability Level	Symbol	Description	Estimated range of occurrence rate per year
Incredible	A	Probability of occurrence is so small that a reasonable accident scenario is not conceivable. These events are not considered in the SAR accident analysis.	$< 10^{-6}$
Extremely unlikely	B	Event is not expected to occur during the life of the facility. Events are limiting faults considered in evaluation basis accidents.	$> 10^{-6}$ to 10^{-4}
Unlikely	C	Event is not expected to occur but may occur during the life of the facility.	$> 10^{-4}$ to 10^{-2}
Anticipated	D	Event is likely to occur during the life of the facility.	$> 10^{-2}$ to 10^{-1}
Likely	E	Event is likely to occur several times during the life of the facility.	$> 10^{-1}$

Table 11-2. Consequence rating categories.

Consequence level	Description	Maximum consequences
1	High	Serious impact on or offsite. May cause severe off-site injuries or a total loss of the facility with worker fatalities. Major impact on the environment.
2	Moderate	Major impact onsite or minor impact offsite. May cause severe injury or illness to personnel, major damage to the facility, or minor impact on the environment. Facility will be capable of returning to operation.
3	Low	Minor impact onsite with no offsite impact. May cause minor personnel injury or illness or negligible impact on the environment.
4	No Impact	Will not result in significant personnel injury or illness. No significant impact on the environment.

The risk for normal operations and of the postulated abnormal operating events and accidents is then determined by combining the probability and consequence levels in a risk matrix. Section 11.6 presents the risk assessment for TPX operations.

11.2 Hazards Screening

The hazards at TPX were screened in Section 5 to eliminate those considered not credible and those of a standard industrial nature. The hazards remaining that are analyzed in the following sections include chemical exposure, fire, explosion, and ionizing radiation exposure.

11.3 Impacts of Normal Operations

11.3.1 Chemical Exposure

Specific nonstandard industrial chemicals used at TPX that could result in chemical exposure to personnel include beryllium and diborane gas. Event initiators include equipment failure and operator error. Mitigative features to minimize personnel exposure include Test Cell and other locations monitoring and alarm systems and equipment safety features (see Section 4). A chemical exposure during normal operation has a probability level of "unlikely." A chemical exposure during normal operation that did not escalate into, or was caused by, an abnormal operation or accident condition has a consequence level of "no impact." Such an exposure would be small, would not result in significant personnel injury, and would not have significant impact on the TPX facility or equipment. Specific EGs for beryllium and diborane gas will be developed and analyzed in the TPX FSAR. Table 11-3 presents probability and consequence levels for normal operation conditions. (Section numbers in the table correspond to sections in the text.)

Table 11-3. Probability and consequence levels for normal operating conditions.

		Probability		Consequence	
Section	Condition	Level	Symbol	Level	Symbol
11.3.1	Chemical exposure	Unlikely	C	No impact	4
11.3.2	Fire	Anticipated	D	No impact	4
11.3.3	Explosion	Extremely unlikely	B	No impact	4
11.3.4	Ionizing radiation exposure	Likely	E	No impact	4

11.3.2 Fire

Fire is an event that could occur during the life of TPX, so precautions and safeguards are implemented. Mitigative features for the Test Cell include heat and smoke detection and a sprinkler system. The Test Cell is designed with 3-hour rated fire wall and door construction. The PPPL site has an Emergency Services Unit that provides dedicated fire fighting services and is capable of responding to a fire in a few minutes. Also, PPPL has a mutual aid memorandum of understanding with the town of Plainsboro, and their response time is estimated to be less that 30 minutes. Accident initiators for fire include primarily electrical system malfunction from either natural or manmade causes. A fire during normal operation has a probability level of "anticipated." A fire during normal operation that did not escalate into, or was caused by, an abnormal operation or accident condition has a consequence level of "no impact." Such a fire would be small, would not result in significant personnel injury, and would not have significant impact on the TPX facility or equipment.

11.3.3 Explosion

An explosion is not expected to occur during normal operations. Further, if an explosion did occur during normal operations, it would likely be minor. (Other potential explosions are addressed in Sections 11.4.3 and 11.5.3.) Event initiators could include diborane or hydrogen delivery system malfunction. Mitigative features include diborane and hydrogen concentration monitoring systems and robust construction of the Test Cell. An explosion during normal operation has a probability level of "extremely unlikely" and a consequence level of "no impact."

11.3.4 Ionizing Radiation Exposure

Ionizing radiation will be produced during normal operation by the interaction of neutrons generated during D-D operation, which will activate Test Cell air and TPX machine structures. Ionizing radiation exposure from all sources for a maximally exposed person at the nearest site boundary is estimated to be 4.2 mrem per year (DOE 1994b), which is much less than the public exposure EG (design objective) limit of 10 mrem per year. The individual doses resulting from the exposure pathways are shown in Table 11-4. Low doses to workers within the PPPL site from exposure to airborne releases, direct and scattered radiation, and radioactive waste are expected. The doses to workers will be controlled and maintained below PPPL administrative limits and occupational exposure EGs (1,000 mrem per year, 600 mrem per quarter). Mitigative features for control of neutrons include borated water vessel shielding, Test Cell floor borated concrete construction, and the Test Cell walls and roof. Radiation present during maintenance activities are expected to constitute the primary source of occupational exposures. Mitigative features include Test Cell shielding, Test Cell access control, vacuum vessel materials of construction, and remote maintenance capability. Ionizing radiation exposure during normal operation has a probability level of "likely" and a consequence level of "no impact."

Table 11-4. Maximum calculated radiological doses to a hypothetical member of the public from normal operations of the TPX facility at PPPL, compared with design objectives and regulatory limits.

		TPX Project	
Exposure pathway	Limit and regulatory source	Design objective	Calculated impact (maximum individual) D-D operations
Drinking water	2 µCi/L (H-3) DOE Order 5400.5	0.2 µCi/L[a]	< 0.01 µCi/L[b]
" "	4 mrem/year EPA 40 CFR 141	-	0.02 mrem/year[b]
Air	10 mrem/year[c] EPA 40 CFR 61	-	1.2 mrem/year[d]
All pathways	100 mrem/year DOE Order 5400.5	10 mrem/year	4.2 mrem/year[e]

a. This design objective is for tritium concentration in water discharged to the sanitary sewer system.

b. Values calculated for water at the point of discharge to the sanitary sewer system, and based on a total annual release to the sanitary sewer of 1 Ci per year tritiated water.

c. This limit is for a dose calculated for an individual at the residence, school, business or office having the highest effective dose equivalent to a member of the public.

d. Dose is calculated for a hypothetical individual residing at the site boundary, and results primarily from an annual release of 300 Ci per year tritiated water and 61 Ci per year Ar-41.

e. Sum of 1.2 mrem per year from airborne releases and 3 mrem per year from direct radiation.

11.4 Abnormal Operating Events Analysis

11.4.1 Chemical Exposure

Chemical exposure could occur during abnormal operations or result in an abnormal condition. Event initiators could include equipment failure and operator error. Chemical exposure during abnormal operation has a probability level of "unlikely." Chemical exposure during abnormal operation, or that resulted in an abnormal condition, would have a higher consequence than one occurring during normal operation and has a consequence level of "low." Table 11-5 presents probability and consequence levels for abnormal operation conditions.

Table 11-5. Probability and consequence levels for abnormal operating conditions.

		Probability		Consequence	
Section	Condition	Level	Symbol	Level	Symbol
11.4.1	Chemical exposure	Unlikely	C	Low	3
11.4.2	Fire	Anticipated	D	Low	3
11.4.3	Explosion	Extremely unlikely	B	Low	3
11.4.4	Ionizing radiation exposure	Anticipated	D	No impact	4

11.4.2 Fire

Fire may occur during abnormal operations or result in an abnormal condition, and this hazard is anticipated and planned for. Mitigative features and event initiators are discussed in Section 11.3. A fire during abnormal operation has a probability level of "anticipated." A fire during abnormal operation or that resulted in the abnormal condition would have a higher consequence than one occurring during normal operation and has a consequence level of "low." Such a fire could cause minor personnel injury and onsite impact but would have no offsite consequences.

11.4.3 Explosion

An explosion is not expected to occur during abnormal operations but would still be minor and not escalate to an accident condition. Event initiators and mitigative features are discussed in Section 11.3. An explosion during abnormal operation has a probability level of "extremely unlikely." Since the consequence would be expected to be worse than that occurring during normal operation, the consequence level is "low".

11.4.4 Ionizing Radiation Exposure

Ionizing radiation exposure could occur during abnormal operation. Mitigative features are discussed in Section 11.3. The primary receptor for the exposure would be a worker, and the exposure would probably occur during maintenance periods from activated material. The probability level for a near miss situation that could result in ionizing radiation exposure to the worker or public is "anticipated." The consequence level for such an exposure is "no impact."

Radiological consequences to the public and workers resulting from abnormal TPX events will be calculated and presented in the FSAR.

11.5 Accident Analysis

11.5.1 Chemical Exposure

A release of chemicals during accident conditions would result in the highest chemical exposure hazard to personnel. Calculations will be performed for the TPX FSAR to evaluate accident exposures of a diborane release. A release of the vacuum vessel interior beryllium coating, that is being considered for TPX, has been evaluated (Cadwallader and Motloch 1993). It is estimated that if a worker were exposed to the Test Cell atmosphere for one hour, the worker would be exposed to 1.4 mg/m^3 of beryllium dust, which is 700 times the American Conference of Government Industrial Hygienists Threshold Limit Value. However, this is below the LOAEL for animals for a 14-day exposure to respirable beryllium, i.e., 4.3 mg/m^3 (DOE 1994b). For public exposure at the nearest site boundary, it is estimated that a 1-hour exposure would be 2.6 $\mu g/m^3$ (the threshold limit value is 2.0 $\mu g/m^3$). Chemical exposure during accident conditions has a probability level of "extremely unlikely" because of the use of monitoring and alarm systems. Chemical exposure during accident conditions has a consequence level of "moderate," as bounded by a Test Cell beryllium dust release. Table 11-6 presents probability and consequence levels for accident conditions.

Table 11-6. Probability and consequence levels for accident conditions.

		Probability		Consequence	
Section	Condition	Level	Symbol	Level	Symbol
11.5.1	Chemical exposure	Extremely unlikely	B	Moderate	2
11.5.2	Fire	Unlikely	C	Moderate	2
11.5.3	Explosion	Extremely unlikely	B	Low	3
11.5.4	Ionizing radiation exposure	Extremely unlikely	B	Low	3

11.5.2 Fire

A fire occurring under accident conditions for the TPX Test Cell has been evaluated and has an estimated frequency of occurrence of 5×10^{-3} per year (Cadwallader 1993), which is a level of probability of "unlikely." The fire is assumed to be conventional and fueled from wood scaffolding, polymer insulation on electrical cables, and/or paraffin wax dispersed in several scintillation detectors.

Amounts of any fuel sources that may be present would be expected to be small, as fuel would be prohibited or strictly administratively controlled in the Test Cell. The consequences from a fire under accident conditions would be expected to be greater than that for normal or abnormal operations because of severity and has a consequence level of "moderate." A fire could cause major damage to the facility, but no offsite consequences are expected for a fire occurring under accident conditions.

11.5.3 Explosion

Explosions at TPX could be caused by water mixing with cryogens or buildup of hydrogen. Water mixing with cryogens can cause an explosive phase change. However, this event is precluded by separation of liquid nitrogen and helium from water by multiple physical barriers and monitoring systems. Hydrogen collected on neutral beams and torus cryopumps will be administratively controlled to prevent explosive levels from developing.

Hydrogen could be generated within the tokamak during certain postulated in-vessel and ex-vessel loss of cooling accident scenarios. Hydrogen generation was calculated for a graphite-water reaction and a beryllium-water reaction occurring on the divertor structure and the first wall of the vacuum vessel (Cadwallader and Motloch 1993). (Beryllium is proposed as a potential material for the TPX divertor and first wall.) Calculated hydrogen concentrations for the in-vessel coolant leak scenarios were below detonation threshold. In contrast, the ex-vessel coolant leak scenarios lead to the highest hydrogen concentrations within the tokamak with maximums exceeding the detonation threshold. However, if a hydrogen explosion did occur, the windows in the vacuum vessel would likely blowout and relieve pressure, preventing further damage to the tokamak. Further, the robust construction of the Test Cell would mitigate any danger from such an explosion to any workers. For D-D operation, such an accident is estimated to result in a dose at the nearest site boundary of approximately 1 mrem. The loss of cooling accident scenarios have an estimated frequency of 1×10^{-5} per year, i.e., extremely unlikely. Mitigative features include design steps to ensure divertor and first wall temperatures remain sufficiently low to minimize hydrogen generation and an active machine protection system designed to avoid thermal damage to the divertor and first wall during accidents. The required plasma interrupt response times to limit hydrogen generation to less than the ignition concentration of 4% are less than 5 seconds for the graphite-water reaction scenarios and less than 60 seconds for the beryllium-water scenarios. The consequences from an explosion under the described accident condition has a consequence level of "low" since the Test Cell would not have any personnel present during these accident conditions, and the Test Cell would not rupture.

11.5.4 Ionizing Radiation Exposure

Ionizing radiation exposure can occur during accident conditions and could result from release of D-D produced tritium, activated materials, and activated gases in the Test Cell. Failure of equipment is considered the primary initiating event for an accident.

Radioactive gases in the Test Cell result from the neutron activation of Test Cell air and will normally be released in a controlled manner from the stack. These gases could be released in an uncontrolled manner as a result of equipment malfunction (cryogen release in Test Cell). The site boundary dose resulting from the unmitigated ground level release of the maximum inventory of activated air is estimated to be 0.1 mrem (DOE 1994b).

Assuming the maximum quantity of 300 Ci of tritium per year is generated by TPX operations, about 45% of this tritium or 135 Ci per year could be retained in the graphite tiles inside the torus vacuum vessel (OPR-R-12, 5/93, page 1-42). If this tritium is removed by He-O glow discharge cleaning (GDC) once a year, the maximum inventory available for release in an up-to-air accident would be 135 Ci. With no leak mitigation for the torus during the D-D phase, the probability of a release to the Test Cell is 0.04 per year (DOE 1994b, Figure B-6). Tritium would be released up the stack with a maximum site boundary dose of 0.8 mrem. Concurrent failure of the stack booster fans [probability of 5×10^{-4} per year (DOE 1994b, page B-3)] would result in a ground level release of 135 Ci with a probability of 2×10^{-5} per year, and a maximum site boundary dose of 2.1 mrem. If He-O GDC is not performed a least once per year, as much as 135 Ci per year x 9 years = 1,215 Ci of tritium could be entrained in the graphite tiles at the end of the D-D program. However He-O GDC would be performed often enough so that the torus inventory would not reach or exceed 1,000 Ci. The maximum site boundary doses for the up-to-air accident would then be 5.6 mrem for the stack release (probability of 0.04 per year) and 15.7 mrem for the ground level release (probability of 2×10^{-5} per year). The projected exposures are less than the public exposure evaluation guidelines for these events (50 mrem and 5,000 mrem, respectively).

Activated metals in the cryostat, magnets, and vacuum vessel result from neutron activation. These metals could be released from such initiating events as electrical arc vaporizing magnet material, plasma disruption vaporizing vacuum wall material, or an air inlet into the torus mobilizing tokamak dust. The site boundary dose resulting from the unmitigated stack release of the maximum inventory of releasable activated solids at the end of D-D operation is estimated to be 2.5 mrem (Cadwallader and Motloch 1993). Further, TPX may operate at a proposed upgrade for conducting steady state D-D operation for 200,000 seconds. The site boundary dose resulting from the unmitigated stack release of the maximum inventory of releasable activated solids at the end of the upgrade D-D operation is estimated to be 8 mrem (DOE 1994b). These exposures are less than the public radiological exposure evaluation guidelines presented in Table 6-1. Further calculation of doses to workers will be performed and evaluated for the TPX FSAR. These accident events have a probability level of occurrence of "extremely unlikely." The consequences of these events have a rating of "low."

Water in the TPX radiological shield and in the TPX cooling system (as well as impurities in the water) will become activated due to the neutron fluence. The probability and consequences of postulated accidents involving activated water will be determined and reported in the TPX FSAR. Activated water released in an accident would be directed to one of three Liquid Effluent Collection (LEC) Tanks via the facility drainage system. The contents of the tank would be sampled for radionuclides to determine the disposition of this water. If radionuclide concentrations are less than the DOE Derived Concentration Guides (DCGs) for ingested water, and the cumulative annual discharge would not exceed 1 Ci, the contents of the tank could be discharged to the sanitary sewer system. Otherwise, solidification of the tank contents could be necessary, with disposal at an approved DOE site (e.g., Hanford).

11.6 Risk Assessment

Risk is defined as the product of the probability and consequences of an event. Probability and consequences levels were determined in Sections 11.3, 11.4, and 11.5 using criteria defined in Section 11.1. Table 11-7 presents the risk levels determined for each normal, abnormal, and accident condition using the risk matrix (adapted from DOE 1994a) for TPX operations presented as Figure 11-1 (risk matrix numbers correspond to text sections discussing specific hazards). Risks defined as high are not acceptable. Risks defined as moderate require further evaluation before being acceptable. Low or negligible risks are acceptable.

Table 11-7. Risk levels for normal, abnormal, and accident conditions.

	Risk Level		
Hazard	Normal condition	Abnormal condition	Accident condition
Chemical exposure	Negligible	Negligible	Negligible
Fire	Negligible	Low	Low
Explosion	Negligible	Negligible	Negligible
Ionizing radiation exposure	Low	Negligible	Negligible

The risk matrix demonstrates that for normal operation, the highest risk is presented by ionizing radiation exposure, and that risk is low. For abnormal operation or an accident, the highest risk for TPX is presented by fire, and those risks are also low. Risks for other evaluated hazards are negligible. The primary receptor for these risks is the worker. For normal-operation ionizing radiation exposure, it is expected that the worker would be primarily at risk during maintenance periods when the Test Cell is accessible.

11.7 Conclusions

This safety analysis demonstrates that the risk presented by TPX operations during normal, abnormal, and accident conditions to the worker, public, and environment is acceptable. Comparison with TPX EGs demonstrates that no limits will be exceeded from any of the postulated normal operation, abnormal operation, or accident condition scenarios.

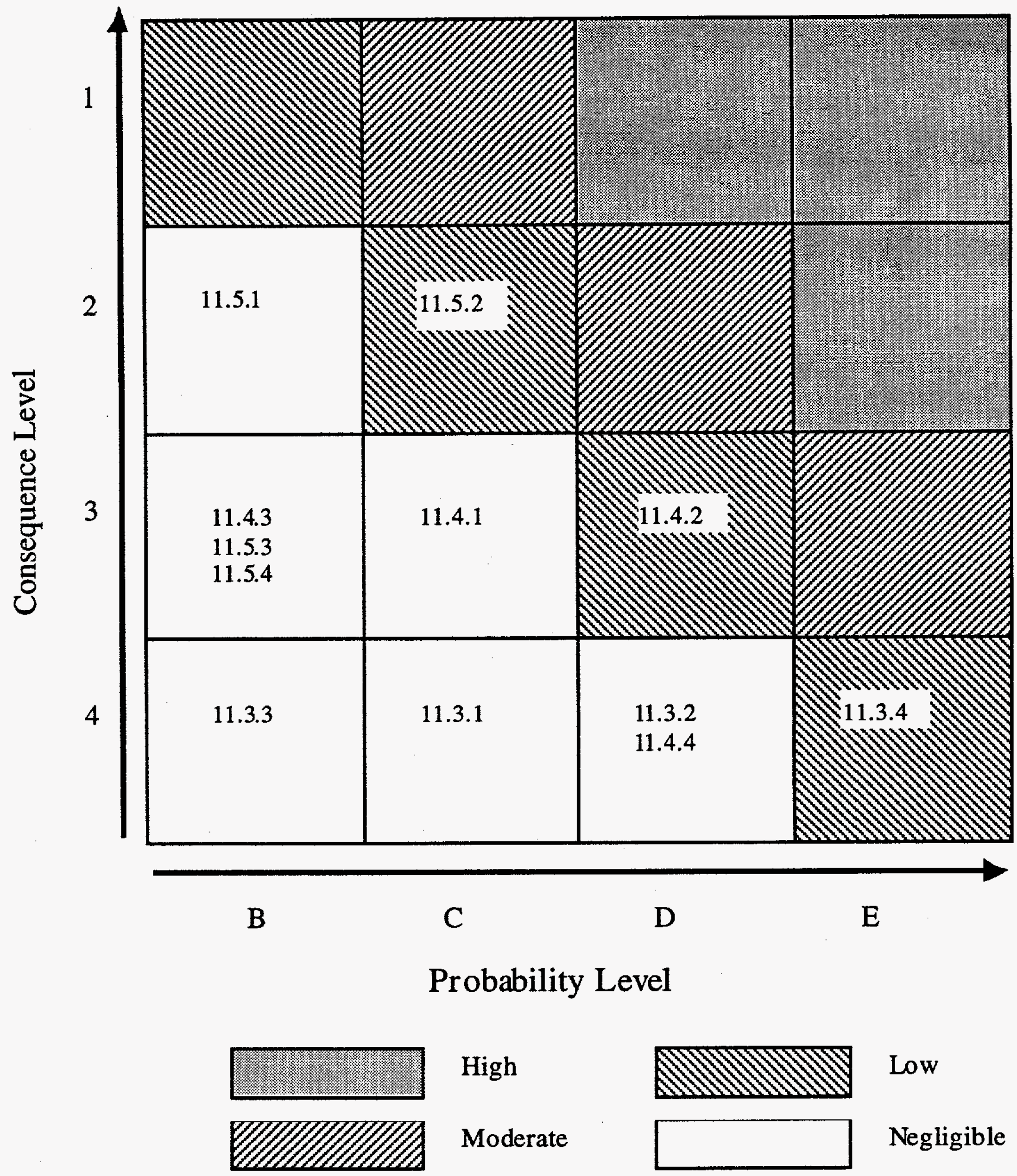

Figure 11-1. Risk matrix for TPX operations.

12. MANAGEMENT, ORGANIZATION, AND INSTITUTIONAL SAFETY PROVISIONS

Information relating to safety management policies and programs other than those described under Section 17, "Operational Safety," are largely contained in the PPPL Policy/Organization Manual and the PPPL Environment, Safety and Health Manual, ES&HD-5008. The chapters in the manual indicate that PPPL operations, including TPX are a part of a network of supporting management, technical, and support functions that is sufficient to ensure that hazards and safety issues are identified, communicated, evaluated, resolved, and documented.

The PPPL Policy manual enumerates the requirements used to develop the safety management programs and includes descriptions of the responsibilities of and relationship between the nonoperating organizations having a safety function and their interfaces with the TPX line operating organization and demonstrates that the facility operations are embedded in a safety conscious environment. Examples of topics included in the PPPL Policy Manual include:

- Environmental protection
- Environment, health, and safety policy
- Quality assurance/reliability
- Conduct of operations
- Staff training
- Stop work authority
- Use of procedures
- Radioactive and hazardous waste minimization
- Occupational medicine policy
- Self-assessment and oversight
- ALARA
- Hierarchy of documents
- Control of hazardous energy sources
- Hazard analysis and controls
- Vital records protection program
- Safety analysis and review system program
- Review and approval of policies, procedures, plans and manuals

The PPPL Policy/Organization Manual details the Laboratory mission, purpose, organization, and responsibilities. It contains department, division, board, and committee charters that detail department purpose, organization, and responsibilities. Responsibilities, requirements, codes, and standards are also provided in PPPL Environment, Safety, and Health Manual, ES&HD-5008. Topics covered in the manual include the following:

- Construction safety
- Electrical safety
- Laser safety
- RF microwave and magnetic safety
- Fire protection
- Nuclear safety
- Industrial hygiene
- Occupational safety
- Radiation safety
- Environmental protection.

13. PROCEDURES AND TRAINING

The TPX project is committed to establishing procedures and training programs as a necessary part of safety assurance. This section covers the topics of TPX facility procedures and training programs and the standards that apply.

13.1 Procedures

Tokamak Physics Experiment procedures will consist of test procedures for specific TPX experiment tests, operations procedures for conduct of operations during other times, and maintenance procedures for the TPX equipment. Operations procedures will be further divided into administrative procedures, general operations procedures, alarm response procedures, emergency operations procedures, and system operation procedures. Administrative procedures will be concerned with items such as work permits, radiation work permits, and confined space entry permits. General operations procedures will be concerned with activities such as TPX bakeout and establishment of TPX vacuum conditions. Alarm response procedures will be concerned with items such as control room annunciator alarms response. Emergency operations procedures will cover conditions such as an uncontrolled radioactive material release and TPX equipment damage. System operations procedures will cover specific system operations such as motor generator set operation and cryogenic plant operation. Operational procedure development, content, changes and revisions, approval, availability, and use will be performed in accordance with DOE Order 5480.19, Conduct of Operations Requirements for DOE Facilities.

13.2 Training

The TPX training program will consist of specific training for operations, maintenance, and technical support personnel. All site employees will receive environmental, safety, and health training as part of General Employee Training.

13.3 Program Implementation

Implementation of TPX procedures and training will be the process that provides for developing, maintaining, and modifying written procedures and training materials (including training records). A program will be developed to provide feedback from operations experience, new analyses, and SAR changes to the procedures and training programs. Information concerning administrative controls and operating procedures for safety-significant SSCs (see Section 4) will also be factored into the TPX training program.

14. HUMAN FACTORS

This section is not applicable to the TPX Project because the TPX is a below Hazard Category 3 (radiological) facility and has no safety-class SSCs. Further, none of the TPX safety-significant SSCs depend upon a human-machine interface to ensure that the mitigative or preventive feature of the SSC is functional.

15. INITIAL TESTING, IN-SERVICE SURVEILLANCE, AND MAINTENANCE

The TPX Project is committed to establishing initial testing, surveillance, and maintenance programs as an integral part of safety assurance. It is PPPL's policy (P-006, Conduct of Operations) that the conduct of operations at the Laboratory will be managed consistently in conformance with DOE Order 5480.19, Conduct of Operations and 4330.4B, Maintenance Program Management. Further, PPPL's environment, safety, and health directives are detailed in the Environment, Safety, and Health Manual, ES&HD-5008.

Initial or confirmatory testing, in-service surveillance, and maintenance programs will be established for all relevant SSCs and all safety-significant SSCs identified in Section 4. This program and its requirements will be described and documented in TPX conduct of operations procedures. Standards and criteria and structure and interfaces with which the program is designed to comply in the context of overall safety management will be specified.

The initial testing, in-service surveillance, and maintenance programs and the requirements necessary to ensure the operability of safety-significant SSCs (as determined based on detailed analyses to be reported in the FSAR) will be reported in the FSAR and will address the following:

- TPX management, plant oversight procedure
- TPX conduct of operations
- Development and control of installation procedures
- Development, control and implementation of test procedures
- Operator aids control
- Operator logkeeping at TPX
- Shift turnover at TPX
- Control of equipment and system status
- TPX lockout/tagout implementation procedure
- Control of hazardous energy sources via lockout/tagout of energy isolation devices
- Development and control of maintenance procedures
- Development and control of repair maintenance procedures
- TPX work permit system
- Tritium area work permit system
- Maintenance on tritium contaminated (containing) equipment.

16. OPERABILITY OF SAFETY-SIGNIFICANT STRUCTURES, SYSTEMS, AND COMPONENTS

Administrative controls and operating procedures will be developed to ensure the operability of all TPX safety-significant SSCs. These controls and procedures will define what operability means for the TPX safety-significant SSCs, how operability is to be verified, and will indicate, as necessary, any TPX operations that cannot commence or continue if these SSCs are inoperable. Specifics on these controls and procedures will be provided in Chapter 16 of the FSAR.

17. OPERATIONAL SAFETY

Information relating to TPX operational safety and conduct of operations will be found in the TPX Conduct of Operations manual, PPPL Environment, Safety and Health Manual, ES&HD-5008, and the PPPL Policy/Organization Manual. Information in the manuals enumerate the bases for the programs, plans, and procedures used to ensure that operation of the TPX facility is managed, organized, conducted, and controlled in a safe manner in accordance with the requirements of DOE 5480.19 and other applicable DOE directives.

The hazards to workers depend upon the quantities, physical and chemical state, and potential for release into the workplace of the hazardous materials. The hazard magnitude (i.e., the potential to exceed DOE prescribed limits) and the complexity of the controls and monitoring programs will dictate the level of detail required. Results of the Hazards Analysis presented in Section 5 show that TPX operations present less than a Category 3 hazard, which classifies TPX as a radiological facility. Further, the analysis of normal, abnormal, and accident conditions presented in Section 11 shows that there are no high or moderate risk operations associated with TPX. The potential for fire and exposure to ionizing radiation are low, and all other risks associated with TPX operations are negligible.

Details of TPX operation safety practices and procedures will be developed and presented in the FSAR. Brief descriptions and/or references will be provided for the following topics, as relevant to the TPX facility during D-D operations, consistent with the hazard analysis in Section 5 and the analysis of normal, abnormal, and accident conditions presented in Section 11.

- Safety policies and performance standards instituted by the operations (TPX Project) organization, including discussions of the operating organization and its administration
- Development and use of operating procedures and manuals for normal and emergency operation. The description will include the processes in place to develop, approve, and control the documents.
- Shift routines and operating practices that ensure safety
- Control area activities necessary to support safe and efficient facility-operations
- Facility program for audible communications within the facility
- Operator training programs
- Abnormal events reporting programs and the facility abnormal event investigation program
- Facility equipment and system status control programs
- Hazardous materials and fire protection control programs

- Facility-independent verification practices
- Facility operations turnover practices
- Standards and criteria with which the operational safety program is designed to comply
- Control of onshift training

18. QUALITY ASSURANCE

TPX management has established the TPX QA Program, which is described and documented in the TPX Quality Assurance Plan (Malinowski 1993). This DOE-approved TPX QA Program has been established to achieve and ensure safety and environmental protection and to control the work or activities described in the PSAR.

TPX management's policy and/or approach to achieving and ensuring safety and quality is summarized in the TPX QA Policy Statement (Malinowski 1993). It states that quality is an essential element of any construction project. For this reason, emphasis has been placed on organizing a strong QA Program as part of the TPX Project. The most important role in quality for the TPX Project is played by the individual worker. The individual's role in TPX quality will be fostered by the TPX management team. The TPX QA Program is applicable to all activities undertaken for the TPX Project.

The assurance of quality in TPX activities, especially as quality relates to the safety of personnel and the public, is a primary concern of TPX management. Additional concerns are environmental integrity, compliance to applicable regulatory standards, and the success of the project's research mission. These goals are achieved by ensuring that designs are valid; that each system meets specified design requirements; that hardware is fabricated and assembled according to design criteria; that testing is performed in a manner that confirms adequacy and conformance to design; that programs effectively monitor the environment, the health of personnel, and overall safety; and that hazardous materials and waste-handling activities are effectively established and implemented.

To help ensure that safety-significant work, processes, and SSCs are controlled in accordance with QA program requirements, all TPX workers, line management, and immediate supervisors are assigned direct responsibility for the quality of the project's efforts. Personnel independent of the activities being performed are assigned the responsibility of verifying and validating that the project's efforts are commensurate with project standards. All personnel have a responsibility to identify quality problems and to recommend solutions.

The scope of TPX and PPPL QA Programs (PPPL 1993f) includes full compliance with the requirements of DOE Order 5700.6C, Quality Assurance, and follows the 10 Criteria format of the Order. The TPX QA Plan approval process includes approvals by TPX and PPPL management and by DOE-Princeton Area Office. The effective implementation date of the TPX QA Plan is December 1993.

The key administrative and technical implementing documents, besides the TPX QA Plan, are the TPX Project Definition Statement, the TPX General Requirements Document, the TPX Project Management Plan, and the TPX System Design Descriptions.

The ES&H/QA organizational structure and interfaces to ensure implementation of the management programs are shown in the TPX QA Plan. Consistent with the collaborative nature of the TPX Project, the TPX QA Plan describes a multi-level effort. The total program involves three levels of documents: The TPX QA Plan and associated procedures; the Lawrence Livermore National Laboratory, Oak Ridge National Laboratory, and PPPL QA Plans with associated procedures; and subcontractor QA Plans with their procedures.

The TPX QA Plan requires that personnel training and qualification programs be established to ensure that capable and qualified personnel are available to perform their assigned work. Personnel shall be provided continuing training to ensure that job proficiency is maintained with special attention to address safety-significant elements.

The TPX QA Plan requires that processes and procedures be established and implemented to identify problems and improve quality. These processes also will be used to focus on planning and problem prevention, and to encourage quality improvement through the reduction of variables related to processes. Processes used for quality improvement include

- Design review/configuration control
- Peer reviews
- Reliability, availability, and maintainability analyses
- Staff meetings
- Tracking and trend analysis systems
- Safety analysis reports
- Management assessment programs
- Independent audits, inspections, and surveillance.

The TPX QA Plan requires that a document control and records management program be established by the TPX Project Management to ensure that documented evidence of safety-significant work or activities is maintained. Documents will be prepared, reviewed, approved, issued, used, and revised to prescribe processes, specify requirements, or establish design. Quality records will be specified, prepared, reviewed, approved, and maintained in accordance with the TPX QA Plan.

Record retention requirements in the plan are consistent with DOE Order 1524.2A, Records Disposition.

The TPX QA Plan requires that work be performed to established technical standards and administrative controls. Work will be performed under controlled conditions using approved instructions, procedures, or other appropriate means. Items will be identified and controlled to ensure their proper use. Items will be maintained to prevent their damage, loss, or deterioration. Equipment used for process monitoring or data collection will be calibrated and maintained.

The TPX QA Plan requires that management at all levels will periodically assess the integrated quality assurance program on its performance. Problems that hinder the organization from achieving its objectives will be identified and corrected. Planned and periodic independent assessments will be conducted to measure item quality and process effectiveness and to promote improvement. The organization performing independent assessments will have sufficient authority and freedom from the line organizations to carry out its responsibilities. Persons conducting independent assessments will be technically qualified and knowledgeable in the areas assessed.

19. EMERGENCY PREPAREDNESS PROGRAM

An Emergency Preparedness Plan (EPP) (PPPL 1993g) has been prepared for PPPL in compliance with the DOE Order 5500.3A.

It is PPPL's policy to operate its facilities and conduct its activities in a safe, responsible manner, thereby ensuring the safety of onsite personnel, members of the public, and the environment. The EPP provides the final barrier of the Laboratory's Defense-in-Depth concept for protecting the health and safety of Laboratory personnel, the public, and the environment. It enables the Laboratory to respond to an emergency in a more timely manner and to mitigate the consequences more effectively than possible on an ad hoc basis. The plan was developed and is maintained to ensure an adequate response for most accident scenarios and also to provide the framework to readily extend response efforts for accident scenarios not specifically considered. This plan covers three basic areas of operation: planning, preparedness, and response.

19.1 Planning

Planning includes the development and preparation of PPPL's Emergency Preparedness Plan along with implementing procedures and systems, and the identification of necessary personnel and resources to provide an effective response.

19.2 Preparedness

Preparedness includes the training of personnel, acquisition and maintenance of resources, and exercising of the plan, procedures, personnel, and resources essential for an emergency response.

19.3 Response

Response represents the implementation of planning and preparedness and involves the decisions, actions, and effective coordination by personnel in the performance of their emergency duties and the use of resources under emergency conditions. An effective response involves the timely mitigation of an event and the bringing of an emergency event under control.

19.4 Supplements to the EPP

The EPP describes the basic structure established to mitigate and control various types of emergencies. Detailed information required for those who control responses to the emergency is contained in supplements to the Plan, (PPPL 1994d). These supplements will be revised to incorporate responses to any additional hazards identified with the TPX Project.

20. PROVISIONS FOR DECONTAMINATION AND DECOMMISSIONING

This Section provides information relating to decontamination & decommissioning (D&D) of TPX. Brief descriptions and/or references are provided for the topics relevant to D&D aspects of TPX facility design and operation. Included are design features related to D&D, operational considerations related to D&D, evaluation of vulnerabilities relating to design and to the spectrum of events during D&D, and standards and criteria with which the D&D Program is designed to comply.

20.1 Design Features

TPX design includes features that will implement the eventual D&D activities. These features include the use of low-activation materials, the use of remote maintenance capability which will implement the TPX disassembly operations, and use of fasteners that promote ease of remote disassembly (PPPL 1994c).

20.2 Operational Considerations

TPX is being designed to be capable of upgrade for operations with tritium. However, initial operations will be with hydrogen and deuterium. These fuels will result in low levels of material activation and low tritium contamination. The tritium contaminated structures will be cleaned by glow discharges during shutdown operations in order to minimize the residual tritium to be encountered during D&D operations.

20.3 Evaluation of Vulnerabilities Relating to Design

During TPX design, the materials to be used will be evaluated as to the vulnerabilities of future D&D requirements. Low activation materials will be evaluated as to cost versus risk of use. Also the use of remote maintenance capability will be evaluated as to the advantage for future TPX D&D.

20.4 Standards and Criteria

Sections 2 and 6 of this PSAR describe pertinent requirements applicable to the TPX Project. These will all be applied to the TPX D&D.

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