SSG-RS-02-201

# 12 GeV Upgrade Project

# DESIGN CRITERIA DOCUMENT

## WBS 641

## *Machine Protection Systems*

**Revision 0**

**May 3, 2007**

**Technical Custodian: JLab Safety Systems Group**

# DESIGN CRITERIA DOCUMENT

## *Machine Protection System*

## Approvals

**Approved by:**

| | |
|---|---|
| Kelly Mahoney | Date |
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# ACRONYMS

| | |
|---|---|
| AC | Alternating current |
| ALARA | As Low As Reasonably Achievable |
| BLIC | Beam Loss Ion Chamber |
| BLM | Beam Loss Monitor |
| CEBAF | Continuous Electron Beam Accelerator Facility |
| DC | Direct Current |
| DOE | Department of Energy |
| EHS&Q | Environment, Health, Safety, and Quality |
| FPGA | Field Programmable Gate Array |
| FSD | Fast Shutdown |
| GeV | Giga-electron Volt = Billion electron volts |
| HPA | High Power Amplifier |
| HV | High Voltage |
| JLab | Thomas Jefferson National Accelerator Facility |
| Linac | Linear accelerator |
| MPS | Machine Protection System |
| PSS | Personnel Safety System |
| rf/RF | Radio frequency |
| SRD | System requirements document |
| SSG | Safety Systems Group |
| V&V | Verification and Validation |

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# 1 Scope

This report identifies the codes, standards, practices and methods to be used in the design of the Machine Protection Systems (MPS) for the Continuous Electron Beam Accelerator Facility (CEBAF) 12 GeV Upgrade Project. In summary, the 12GeV project will involve:

- Adding five new cryomodules and RF HPAs to each linear accelerator (linac).
- Adding a fifth pass dipole electromagnet string (Arc 10) to the West Arc.
- Replacing several electromagnet power supplies to support higher energy beam transport.
- Upgrading experimental equipment in the existing experimental Halls A, B, C.
- Construction of a photon Tagger and experimental Hall D complex.
- Expansion of existing infrastructure, e.g. power, service buildings, conduits, to support doubling the beam energy to 12GeV.

Additions and modifications to the existing CEBAF MPS are required to ensure continued protection of equipment from beam related damage.

# 2 System Description and Introduction

The machine protection systems are engineered hardware and software functions that protect equipment from beam related mishaps. They work in conjunction with other engineering controls and administrative procedures to reduce the risk of equipment damage from the following events:

- Vacuum loss due to beam burn through
- Vacuum loss due to beam heating of vacuum components or connections
- Beam interception on components not designed for it
- Beam current higher than the rated limit for a given piece of equipment
- Damage to superconducting RF systems from interception or continued operation under quench conditions.
- Damage to equipment by prompt ionizing radiation caused by beam loss
- Beam damage to equipment in a failed or fault state
- Beam damage to equipment where a contributing cause is another piece of equipment in a failed or fault state.

The MPS also serves an ALARA function by verifying beam containment and thus minimizing activation of beamline components.

The MPS achieves these objectives in two ways:

- By detecting beam loss and shutting down the beam when needed
- By providing an infrastructure whereby any appropriately equipped subsystem can shut down the beam

# 3 References & Standards

This section contains references, regulations, and standards implemented fully or in part at JLab. The responsible engineer determines the extent to which each of these industrial standards is applied. In the event of a conflict between Industrial and Laboratory standards, the Laboratory standard supersedes the Industrial standard.

## 3.1 Jefferson Laboratory requirements, Standards, and Guidelines

### 3.1.1 Jefferson Lab EH&S Manual

#### 3.1.1.1 Appendix 2410-T2 TJNAF Work Smart Standards Set

#### 3.1.1.2 Chapter 3210 Hazard Identification and Characterization

#### 3.1.1.3 Chapter 6200 Jefferson Lab's Electrical safety program

### 3.1.2 Jefferson Lab Machine Protection System 12GeV Systems Requirement Document

### 3.1.3 Requirements for 2nd Generation Machine Protection Beam Current Monitor/Accounting System

### 3.1.4 Jefferson Lab Quality Assurance Plan

## 3.2 Jefferson Lab Reports and Notes

| | | |
|---|---|---|
| 3.2.1 | CEBAF-TN-92-046 | Time Response Requirements for the BLM/FSD System |
| 3.2.2 | CEBAF-TN-93-055 | EGS Analysis of a mode of beam damage to the extraction septa |
| 3.2.3 | CEBAF-TN-94-024 | Beam Loss Monitor Performance Requirements |
| 3.2.4 | CEBAF-TN-95-034 | CEBAF Beam Loss Accounting |
| 3.2.5 | SLAC-TN-63-57 | The use of a long coaxial ion chamber along the accelerator |
| 3.2.6 | SLAC-PUB-0272 | The SLAC long ion chamber for machine protection |
| 3.2.7 | CEBAF-TN-90-193 | Description and interfacing guide for the CEBAF fast shutdown system |

# 4 Design Requirements and Standards

## 4.1 Lifecycle Management

The 12 GeV MPS systems shall be managed under the existing SSG lifecycle model for non-PSS systems. This model includes design basis documentation, requirements management, systems specifications, commissioning, ongoing operations, and decommissioning.

## 4.2 Drawing and Document Numbering

MPS documents shall be uniquely numbered using the existing JLAB document numbering requirements. All MPS drawings, specifications, requirements, and user documentation shall fall under JLab configuration control.

Drawing numbers are based on the JLAB standard documentation numbering guidelines. All MPS drawings start with the letter 'Y' or 'Z' and are numbered sequentially. The first four digits identify each drawing. The fifth character denotes the original drawing size, e.g. ANSI A, B, C, D. The final two characters denote the drawing level such as "assembly" and "schematic diagram." An example of a complete drawing number is: Y0002D01

The drawing title hierarchically describes the following:

| Title Level | Example |
|---|---|
| Major System | Machine Protection |
| Area or Major Assembly | Fast Shutdown System |
| Subsystem | FSD Master |
| Drawing Type | Schematic Diagram |

**Table 1: JLab MPS Drawing Number Scheme**

Where ever practical, existing MPS drawings shall be modified to reflect changes associated with the addition of the 12GeV MPS system. This is to avoid duplication of functions among several drawings.

Documents other than drawings that form the design basis of the Machine Protection Systems shall be managed under the JLab Safety System Group design guidelines.

## 4.3 Principal Design Tools

Several design tools are used in the design, modeling, and development of the Personnel Safety Systems. The primary tools are:

4.3.1 AutoCad version 2006 or later (Autodesk): All drawings other than electrical circuits

4.3.2 Aldec Active HDL: Design and simulation of FPGA based circuits

4.3.3 PCAD version 2006 or later: Printed Circuit design, simulation, and layout

4.3.4 Xilinx : Design and simulation of FPGA based circuits

4.3.5 Excel (Microsoft) version 2003 or later: Calculation of reliability, beam burn-through, ion chamber response

4.3.6 Geant version 4.0 or later: Calculation of beam damage to arbitrary structures

# 5 Quality Assurance and Testing

The 12GeV Machine Protection Systems shall be designed, developed, and managed under the JLab Quality Assurance Plan. This plan, based on ISO-9000-2000, identifies key requirements pertaining to work processes and output.

Personnel involved in the management and design of the 12GeV MPS upgrade shall be qualified to do so as evidenced by a combination of education and experience. Likewise, personnel performing the installation and maintenance of MPS systems shall also be trained and qualified to do so.

Unless justified by analysis and transmitted in writing, the fail-safe state of machine protection functions shall shut off the electron beam.