THE DUAL AXIS RADIOGRAPHIC HYDRODYNAMIC TEST (DARHT) FACILITY PERSONNEL SAFETY SYSTEM (PSS) CONTROL SYSTEM*

E. Jacquez, LANL, Los Alamos, NM 87545, U.S.A.

Abstract

The mission of the Dual Axis Radiograph Hydrodynamic Test (DARHT) Facility is to conduct experiments on dynamic events of extremely dense materials.

The PSS control system is designed specifically to prevent personnel from becoming exposed to radiation and explosive hazards during machine operations and/or the firing site operation. This paper will outline the Radiation Safety System (RSS) and the High Explosive Safety System (HESS) which are computer-controlled sets of positive interlocks, warning devices, and other exclusion mechanisms that together form the PSS.

BASIC OPERATIONAL OVERVIEW

Physical barriers and alarms are interlocked to the PSS. Door interlocks are located throughout the building. Other physical barriers include the Firing Point boundary fence, interlocked firing point gates, and perimeter warning lights and sirens.

The PSS logic is shown in Figure 1. The PSS is passive in that no external arming, conditioning, or operator intervention is required other than selecting the operational mode and executing the sweep.

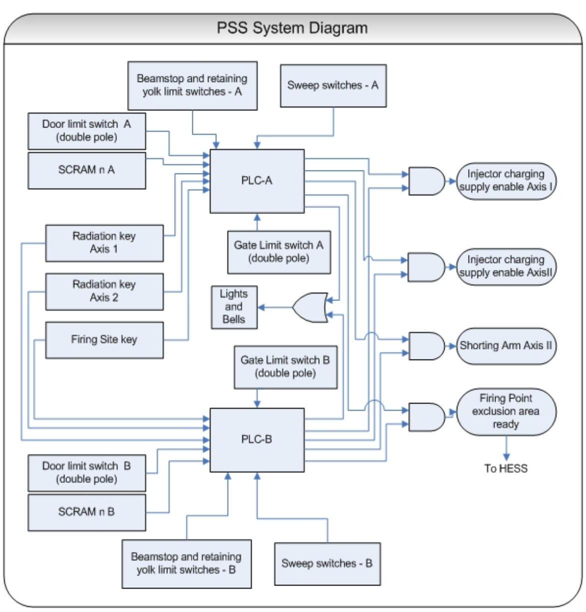

Figure 1: System diagram of PSS.

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A physical inspection, or sweep, of all exclusion areas ensures that affected hazardous areas are clear of personnel before any hazardous operation begins.

SCRAM actuators that inhibit radiation production are located throughout all potential radiation areas.

Located before the beam exit of each accelerator hall, the beamstop is designed to block the beam from reaching beyond the thick-walled accelerator halls. The beamstops allow beam production internal to the accelerator halls and inhibit radiation from reaching the firing point.

The PSS inhibits radiation production and explosive permissions depending on the modes of operation selected. The modes of operation for each axis are described below in Table 1.

Table 1: Operations Modes

Mode	Activities
0	beam off
1	beam in the accelerator hall
2	beam in the hall and on the firing point
3	beam in the hall on the firing point in combination with explosives operations on the firing point

The entire facility operation must be defined by the mode for each axis i.e., Mode 1, 1 (Axis I Mode 1, Axis II Mode 1; Mode 1, 3 (Axis I Mode 1, Axis II Mode 3); etc). The mode of operation defines the requirements for personnel exclusion in an area and therefore procedural sweep patterns. The PSS software controls are programmed to allow certain modes for each axis depending on the mode of the other axis. The modes of operation are shown below in Figure 2.. Up to two modes may be selected simultaneously, depending on the modes selected in Table 1 of this document.

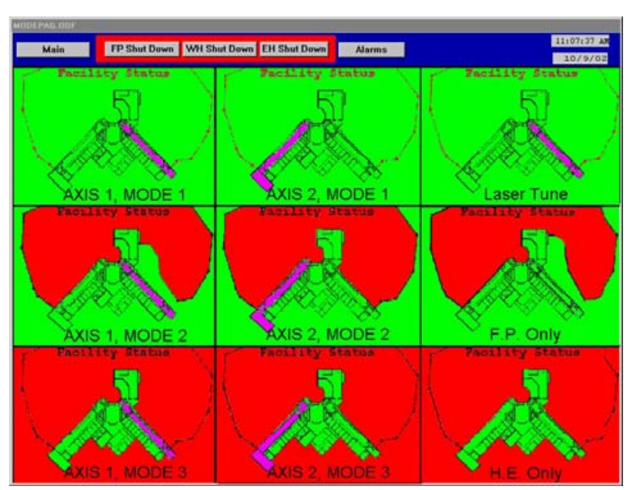

Figure 2: Mode select page.

PSS CONTROL FUNCTION OVERVIEW

The two safety systems (RSS / HESS) that make up the PSS share hardware, software, and have similar sweep protocols. Input hardware mechanically fails in the safe position or condition. The PSS has three subcomponents: 1) the computer systems; 2) the field device hardware, including the interlocks and wiring for buttons and switches; and 3) redundant Programmable Logic Controllers (PLC's). (Operator PCs interface with PLCs.)

The PSS ensures that proper exclusion areas are secured and boundaries are maintained, depending on the mode of operation. The RSS maintains the exclusion areas around the accelerator where radiation production is the hazard. The HESS limits the manner in which the DARHT Detection Chamber (DDC) executes arming and detonation hardware for explosive tests.

The system provides a signal to inhibit beam production if access control to exclusion areas is lost. Requirements associated with these functions are determined by modes of operations in Table 1 of this document.

Radiation Safety System

The RSS is integral to both axes of DARHT. When combined with administrative controls, the RSS eliminates the potential of personnel accessing areas in which they may receive exposure during beam production.

The RSS consists of those elements of the PSS that limit access to areas around the accelerator. Included in the RSS are: administrative controls, Standard Operating Procedures, Hazard Control Plans (HCPs), and a passive computer-based series of hardwired interlock devices.

The system monitors the physical barriers that prevent personnel from entering a radiation area while the injector is capable of producing radiation as illustrated in Figure 3. The RSS provides an interface between the operators and the machine environment to ensure that the hazard area is clear of personnel when a radiation hazard is present and monitors and detects access after a sweep and search process. The safety relays that permit the charging of each injector is controlled by redundant PLC units. These units must agree before the relay permits charging of the injector.

High Explosive Safety System

When combined with administrative controls, the HESS limits the potential of injury to personnel from high explosives by monitoring interlocks.

The high explosive firing system uses a conventional modular capacitive discharge unit (CDU) system. The modular CDU system contains up to 12 CDUs, or 24 CDUs when two units are used together. The system fires only when commanded and with no time delay to meet the usual demands on a CDU system. The safety features prohibit charging of the capacitor until safety interlocks are complete. If an interlock is breached or control of the exclusion area is lost, the safety features discharge the capacitor, and the detonator will not fire. The CDU control system stops on any error and must return to the start of the control sequence.

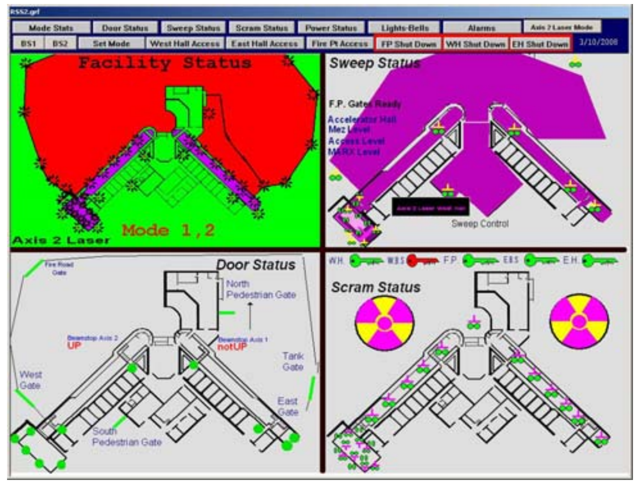

Figure 3: Facility status page.

PSS SYSTEMS, SUBSYSTEMS, AND MAJOR COMPONENTS

Several of the PSS major subsystems and components are described in the following subsections.

PLC Hardware

The dual PLC hardware system consists of two identical Modicon PLCs and I/O field interface hardware that provide redundant inhibit paths. The PLCs provide protection for both axes in an integrated fashion, depending on the mode selected. Each PLC executes identical programmed logic which manages the interlock hardware.

The computerized PSS control hardware is based on Modicon "Quantum" PLC's and remote "Quantum" I/O hardware from Schneider Electric. The PLC executes safety-system logic independently of the DARHT PSS display screen (HMI).

Software

The software consists of Concept by Schneider Electric for the PLCs, GE Fanuc® iFIX™ automation software for the Human-Machine Interface (HMI), Windows®XP, and I/O driver software. Application specific software is developed in-house. The modular programming software, Concept, provides the platform for application specific software. The HMI software, iFIX™, provides operator visibility. Together, the PLC and HMI software monitor such activities as doors opening and engagement and disengagement of other interlocks and switches. HMI software allows process visibility to the operators. The HMI graphically presents the condition of the interlocks, progress of the sweep, SCRAM button status, beamstop position, and other elements of the safety system in the control room.

The HMI applications software has been successfully used at the integrated test stand during development and on Axis I and Axis II of the DARHT Facility. The HMI software offers third-party integration compatibility for even greater application potential such as VP-Link, simulator software used to test modifications offline and to qualify the PSS software on the integrated test stand. It is flexible and reliable configurable for I/O management and visibility.

The software was developed using DOE Order 1330.1D as a guideline. Documentation includes a software Development Plan, HMI/PLC Test Procedure, and a Software Backup Plan. A Functional Verification Checklist is used to ensure that the system functions as intended.

Hardware

PSS Hardware and ANSI colored signs mark entrances to hazard areas. Hardware is verified during semiannual testing of the PSS. Lights and bells overlap in their visible and audible coverage and are evaluated for operation during each sweep in addition to the semiannual verification.

The PSS uses a dual set of I/O communication lines and applies error checking to ensure the integrity of communication to the I/O as seen in Figure 3. Two separate and independent configurations of the interlock hardware are installed to provide redundant inhibit paths. A power loss will result in a PSS fail-safe position that inhibits the high explosive and accelerator interlocks.

Keys

There are individual keys for each axis and a separate key for the firing point that in conjunction with the PSS provide protection for authorized entries into exclusion areas, inadvertent production of radiation, and or high explosive events. The beamstop locks are a separate core.

Each accelerator axis has a Radiation Key that must be properly positioned before charging of the respective injector can take place. The Axis I or Axis II Radiation Keys lock/unlock the doors to the Axis I or Axis II accelerator halls. For radiation production, the Axis I or Axis II key must be inserted in a PSS cored switch located in the accelerator control room at the main console. The Axis I and Axis II keys have unique lock cores.

A Firing Point Key is used to control access to the mode 2 exclusion area. This key locks/unlocks the pedestrian/vehicle gates around the outside perimeter. The core is unique from the Axis I and Axis II Radiation Keys. The key must be inserted in a PSS cored switch located in the accelerator control room at the main console before charging of the injectors can take place in modes 2 or mode 3 for either axis. This key is not used if both accelerator axes are in Mode 0 or 1.

The beamstop keys are used at the location of the Axis I and Axis II beamstops to allow the raising of the respective beamstop. Its core is also unique from that of the other three keys. When the beamstop is lowered into the path of the electron beam for Mode 1 operation, the key is removed from the beamstop core and will remain inserted into the beamstop DARHT operations key control console. For Mode 0, the keys remain in the controlled key lockbox located in the accelerator control room. For mode 2 and mode 3, the respected beamstop key remains in the beamstop lock located on the side of the beamstop.

SUMMARY

The PSS is designed specifically to include a combination of engineering and administrative controls. The hardware is designed in a redundant fail-safe manner that ensures optimal safety of DARHT personnel. The system is verified on a semiannual basis or whenever a modification is made. The multiple modes of operation allow for each axis to run independently or in combined modes of operation which benefits the diverse experiments which occur at the DARHT facility.

REFERENCES

[1] W. Spencer, D. Schmitt, E. Jacquez, “DARHT Personnel Safety System Design Description”, HX6, May 2007, p. 1-34.