PROGRESS ON THE UPGRADE OF THE CYCLOTRON RADIATION SAFETY SYSTEM

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During the past fourteen years the NSCL radiation safety system employed a conventional programmable logic controller (PLC, SquareD SyMax Model 400) and off-the-shelf microswitches. The system monitored the states of accelerator and experimental vault interlock switches and radiation detector relays, and provided a programmable platform for safety logic. The system issued appropriate signals to the cyclotron rf programmable logic controller and several rf power supplies. We are in the process of updating the radiation safety system to include more redundancy and components having safety-specific design and function (*e.g.* see Fig. 1). Our progress is outlined below.

Figure 1: Emergency-stop buttons are placed at the exits of all shielded vaults.

The programmable logic controller has been replaced by a Pilz Model PSS 3100 programmable safety system [1] (PSS). This system has a “failsafe” section, which is triply redundant: the failsafe section uses three “voting” processors from different manufactures to analyze signals and logic conditions. It also has a “standard” section, which may be utilized as a standard PLC. The PSS system was initially installed for K500 commissioning, and has now been expanded using decentralized I/O modules to the K1200, A1900, and Transfer Hall personnel access interlocks, and to include neutron monitor relays. In the coming year, the PSS system will be expanded to include safety devices experimental vault areas.

The decentralized I/O modules are of two types. One type, Pilz model DI8O8, has eight inputs and eight outputs, with two test-pulse outputs (see Fig. 2). The second type, Pilz model DI16, has 16 inputs. The decentralized I/O communicates with the PSS 3100 using SafetyBus-p [1], an open bus system design for the

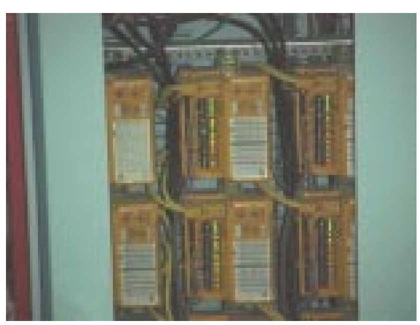

Figure 2: Pilz model DI8O8 decentralized input/output modules are shown.
The yellow cable is the SafetyBus-p bus communications cable.

serial transmission of safety–related information. The safety processor and decentralized I/O modules provide monitored pulse trains to selected functions, those considered higher risk, such as door switches, rf bypass functions, emergency stops, and ion source injection line beam stops. I/O failures, open or shorted switch contacts or cables may then be detected by the processor, which halts its process in a known way. Safety to Category 4 as per EN 954-1 [2] can be achieved for these systems.

A vendor-provided class for programming the radiation safety processor was held in mid-January. It was attended by three radiation protection staff and two operations staff members. The vendor provided the initial logic program for coupled-cyclotron operations up to the A1900, and will expand the program to include the A1900, Transfer Hall, and experimental vaults.

All interlock switches were replaced by ones designed for safety applications, for example, positive-break-contact key switches with redundant contacts and positive-mode mounting where possible (*e.g.* see Fig. 3).

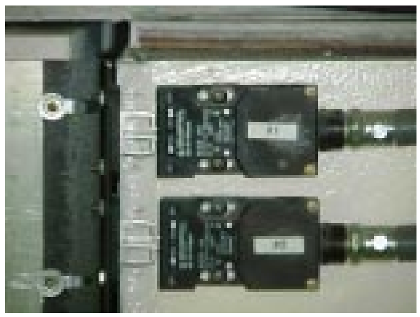

Figure 3: Shield door interlock switches are shown. The mounting is positive-mode, whereby the keys that engage the switch move with the door. Each switch has two redundant contacts. The safety processor monitors pulse trains that travel through the cable and contacts, enabling discovery of both open and short failure modes..

Beam stopping devices outfitted with HD18 [3] beam stops with scintillators for beam viewing were designed and are now being constructed and placed in the Transfer Hall (Fig. 4). These will serve with existing wall plugs as a redundant system to ensure beam is not delivered to an experimental area that is open to personnel.

Six new neutron area monitors were purchased and installed for K500 cyclotron and coupling line commissioning. The detectors, Eberline model SWENDI-II's [4], are ^{3}He-filled tubes moderated by polyethylene and tungsten, providing dose response for up to 40 MeV neutrons (Fig. 5). The control boxes are connected in a local Ethernet LAN so that dose rate displays are not only provided locally but also are available at server and client computers. We purchased 22 additional control boxes for the existing NSCL BF3 neutron detectors. These detectors are connected to the control boxes by 20 feet of 75-ohm low-loss cable.

Figure 4: A neutron area monitor by Eberline Corp. is shown. The detector, model SWENDI-II, is shown on the right. The control unit is Eberline's model RMS-3.

Figure 5: Vacuum vessel containing beam stopping/viewing device is shown.
The device position is monitored by an interlock switch.

A human-machine-interface (HMI) computer display of safety system device status was developed using LabView [5]. The Pilz vendor furnished a program that reads out the safety computer fail-safe register information and sends it when polled to the NSCL control system, using ModBus protocols. Register information is stored in the control system master database and EPICS channel addresses are assigned. The LabView application is programmed to display desired address statuses graphically, as shown in Fig. 6.

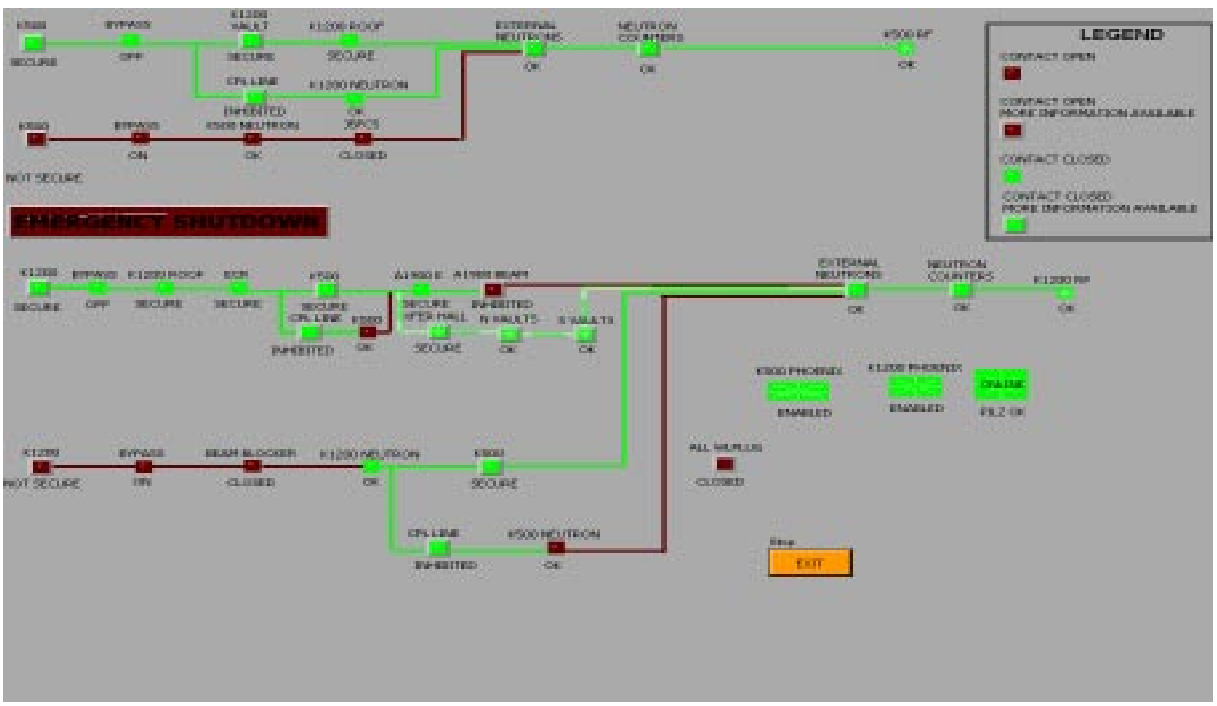

Figure 6: A HMI application screen developed using LabView is shown.

Construction continued to near-completion on the lead shielding module (Fig. 7) that will be used for personnel protection during target maintenance operations. This module will also serve as interlocked access control for the A1900 entrance from the K1200 vault. Remote tools will be used in conjunction with this module to remove and store activated targets (Fig. 8). Shielding target storage boxes were designed and ordered, and now placed. They are located in the shielding wall just south of the target vacuum box (Fig. 9).

Figure 7: The lead shielding module is shown. The white hemispherical objects in the center accept remote handling tools.

Figure 8: A remote handling tool allows one to remove an activated target from the A1900 production target chamber and to place it into a storage box.

Figure 9: Three lead-shield target storage boxes are shown.

References

1. Pilz Automation Safety L.P., Pilz North American Headquarters, 24850 Drake Rd., Farmington Hills, MI 48335.
2. European Standard EN 954-1: *Safety of Machinery – Safety-related Parts of Control Systems Part 1: Design of Control Systems.*
3. HD18, by Mi-Tech Metals, Inc., 1340 N. Senate Ave., Indianapolis, IN 46202; HD18 is 95% tungsten, 3.5% Ni, and 1.5% copper, and has a density of 18 g/cm^3.
4. Eberline Instruments, 504 Airport Road, Santa Fe, NM 87505.
5. National Instruments Corporation, 11500 N Mopac Expwy, Austin, TX 78759-3504.