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# BEAM SWITCHYARD EQUIPMENT PROTECTION INTERLOCK SYSTEM

I. C. Lutz

## INTRODUCTION

The equipment in the beam switchyard can be damaged by the beam in two ways: (a) radiation damage due to total integrated dosage, and (b) localized heating caused by the beam hitting components inadvertently.

The localized heating in a component could cause serious damage in a short time when operating with a high beam current and a high repetition rate.

The function of the equipment protection interlock system is to detect when the beam may be hitting some of the equipment and to give an alarm signal before damage can occur. This alarm signal can be used to interrupt operation if required.

## PARAMETERS AND ASSUMPTIONS

The following parameters and assumptions were used in the design of the interlock system.

1. The maximum beam current is 50 milliamps peak.
2. Beam pulse lengths between 0.1 and 2 microseconds.
3. Maximum repetition rate of 360 pulses per second.
4. All of the equipment, including the various sections of vacuum pipe, can stand to be hit by one 50 milliamp beam pulse without damage.
5. More than one 50 milliamp pulse at the higher repetition rates will cause damage and must be prevented.
6. The various deflecting magnets will have current or field monitors to determine if the field in the magnets is the proper value.

## DESIGN APPROACH

One method of detecting when the beam is hitting some of the equipment is to place a sufficient number of detectors along the beam channel such that no matter where the beam went astray, it would always be detected and cause an alarm. A second method is to monitor the beam in the proper channels and use the signals to indicate a satisfactory condition. The loss of a signal would indicate that the beam had gone astray.

The first method is not very satisfactory because of the number of detectors required, and it is not a fail-safe system in that signals are produced only during a malfunction.

The second method has the advantage of being fail-safe but it has the disadvantage of not indicating what happened to the beam. This disadvantage can be over come by:

(a) Using several beam monitors along a beam channel, (b) using thermal indicating devices on the various components to indicate an abnormal temperature rise due to the beam hitting them, (c) using pulsed radiation detectors to detect abnormal radiation levels, and (d) the information obtained from the magnet current or field monitors.

The proposed interlock system is based upon monitoring the beam in its proper channel. Beam current transformers are planned to be used where possible because (a) they are a simple, reliable, low impedance device, (b) they give adequate signal levels, and (c) the installation and alignment is less critical than beam scrapers or secondary-emission beam position detectors. Secondary-emission beam scrapers and pulsed radiation detectors have been planned for a few locations where transformers are impractical.

Monitoring locations have been chosen so that the signals from at least two transformers are of equal amplitude under normal conditions. These signals are compared and if equal within a specified per cent no alarm would be given.

The beam monitors used to detect total loss of beam need to operate fast enough to give an alarm in less than 2.5 milliseconds so that the next pulse can be interrupted if desired.

The complete interlock system consists of a combination of beam current transformers, beam scrapers and pulsed radiation detectors or secondary-emmission foil beam position monitors, and thermal sensing devices monitoring the temperature of some components.

PULSE-TO-PULSE TYPE DETECTORS

The location and type of detector being proposed to detect total loss of beam will be discussed first and listed as one progresses along the beam channels. Reference is made to print GP 863-306 R2 for component location and designation.

1. A small, 1 3/16" diameter, section of beam pipe is located between Station 100 + 77 and Station 100 + 82 for the differential pumping system.(1) The beam can hit the beam pipe at this transition section if the steering through the last section of the accelerator is not correct. It is proposed to install a ring type secondary emission monitor at this location in the vacuum pipe or to let the beam hit the vacuum pipe and detect the pulsed radiation with a radiation detector such as an ionization chamber.

2. The steering coils A-3, A-4, AP-3 and AP-4 are capable of deflecting the beam enough to hit the beam pipe and the beam monitoring equipment upstream of collimator C-1. Since the beam could be deflected at any angle, a ring type monitor surrounding the beam is proposed to be located somewhere between AP-4 and the beam monitoring equipment I-1, P-1, and RP-1.

3. The pulsed magnets PM-1 through -5 are capable of deflecting the beam into the ceramic beam pipe if low energy pulses inadvertently come through. Beam current transformers are proposed to be located at the entrance and exit of the pulsed magnets to detect beam loss through them. The two signals would be compared and if they were within a specified value of each other no alarm would be given.

4. For beam channel "A", a beam current transformer can be located between the quadrupole magnet Q-11 and the first bending magnet B-10 to monitor the beam at that point. By comparing this signal with the signal from the transformer at the exit of the pulsed magnets a loss of beam between these points can be detected. This signal is necessary to indicate if the beam entered beam pipe "A" from the transition section.

5. For beam channel "N" the signal from a beam current transformer located just upstream from target T-10 can be compared with the signal from the transformer at the exit of the pulsed magnets to indicate any beam loss in entering the beam pipe for channel "N".

6. For beam channel "B" a beam current transformer located after quadrupole Q-31 can be used in a similiar manner to that for Channel "A".

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(1) L. Schwarcz, Hoyt and Thingstad, "ESY Vacuum System", Draft copy 11-15-63.

7. Continuing with beam Channel "A", a transformer is proposed at the exit of the fourth bending magnet B-13. The beam is spreading out too much to make it feasible to locate the transformer further downstream. Comparing the signal from this transformer with the one upstream of the bending magnets will indicate loss of beam through the first bend.

8. To detect loss of beam through the second group of four bending magnets beam current transformers are to be located just upstream from B-14 and at the exit of B-17.

9. To protect the vacuum pipe and equipment downstream from B-17, a set of beam scrapers or another transformer should be located near the end of the beam channel.

10. A beam current transformer may be required after the dump magnets, depending upon the final design of equipment in that area.

11. For beam Channel "B" a set of beam current transformers is proposed at the entrance and exit of the group of bending magnets B-33, -34, and -35.

12. Downstream from B-35 in Channel "B" is a situation similar to that in Channel "A". What is required for protection will depend upon further design there.

## THERMAL SENSING DETECTORS

Thermocouples and resistance wire thermometers are two thermal detectors which appear to be suitable to monitor the temperature of components in a high radiation field. These monitors need not be fast enough to respond to pulse-to-pulse operation, but should have thermal time constants fast enough to follow the temperature rise of the critical areas of the components being monitored.

1. All of the collimators and the slits should incorporate temperature monitors to indicate excessive heating at least on a "go" - "no-go" basis. It may be desirable to provide means of continuously recording the temperatures if desired.

2. The corners of the vacuum chamber at the transition section to three beam pipes should be monitored to detect excessive heating from any low energy tail of the pulse which does not enter the beam pipe.

3. The outer edge of the vacuum pipe in Channel "A" downstream from magnet B-13 should be monitored for excessive heating from low energy electrons deflected into the wall of the vacuum pipe. Thermocouples or resistance thermometers can be located at several points along the pipe between magnet B-13 and collimator C-11.

4. Similarly, on Channel "B" downstream from bending magnet B-32.

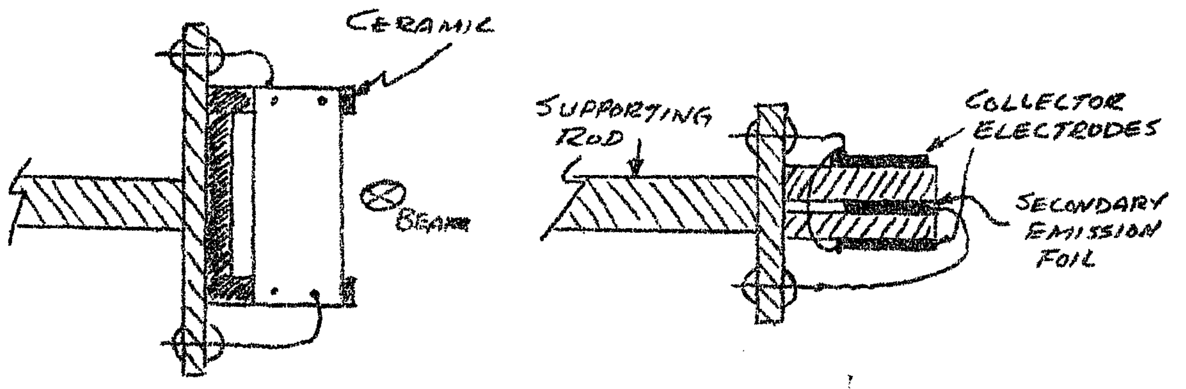
INTERLOCK CIRCUITRY

The signals from the beam current transformers would be fed to a discriminator and coincidence circuit set such that an output signal will occur only if the input signals are present and are equal to within a specified per cent. This output signal would indicate a normal situation.

The signals from the secondary-emission foils or the pulsed radiation detector would indicate an abnormal situation since they would occur only if the beam went astray.

It is proposed to use bistable networks such as a flip-flops for storing the information from the beam detectors, for controlling indicator lights on a visual display board, for controlling an electronic gate in the "pulse permissive signal". This signal would indicate that the status of all interlocks in the beam switchyard is satisfactory and permission is given to the accelerator central control to start pulsing.

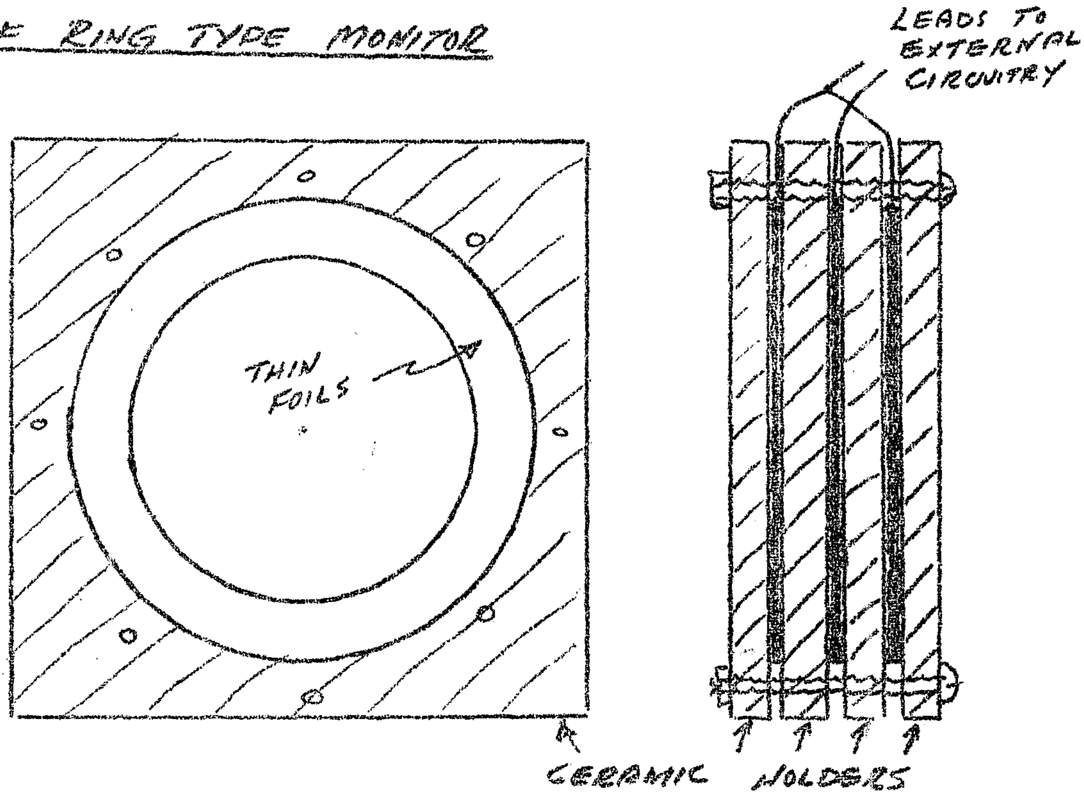
## SKETCH OF SECONDARY EMISSION BEAM SCRAPER




SIDE VIEW TOP VIEW

SUPPORTING ROD TO BE CONNECTED TO ADJUSTABLE BELLOWS — DETAILS OF MOUNTING TO BE DESIGNED

## SKETCH OF RING TYPE MONITOR

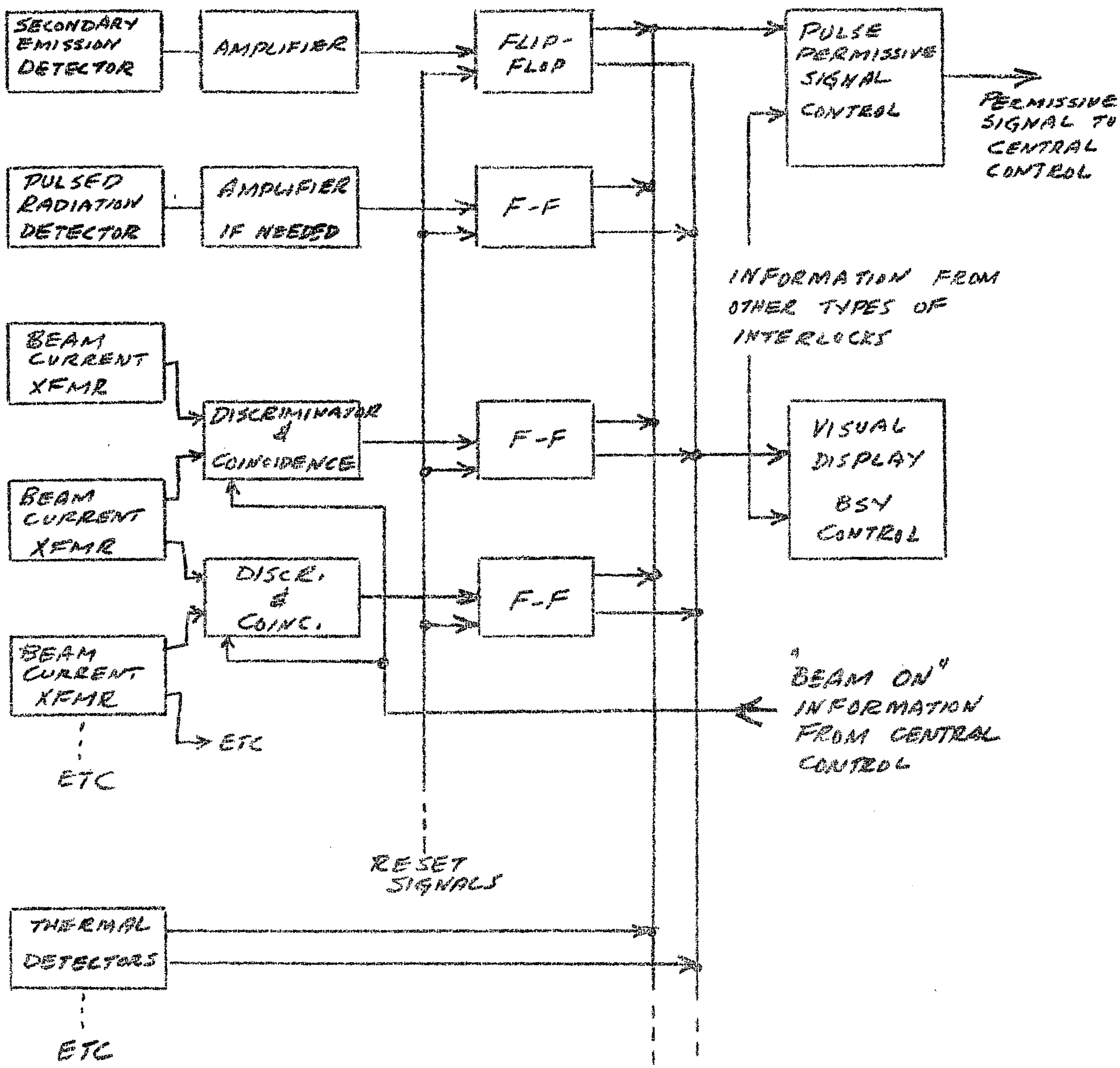



METHOD OF SUPPORTING IN VACUUM PIPE TO BE DESIGNED AS NEEDED.



JCL

## BLOCK DIAGRAM OF INTERLOCK SYSTEM




TYPICAL OF ALL DETECTOR CIRCUITS
AC & DC POWER NOT SHOWN



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