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THE CERN RADIATION MONITOR AND ALARM SYSTEM FOR EXPERIMENTAL AREAS

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Abstract

The philosophy, implementation, and operational experience with a radiation monitor and alarm system provided for the experimental areas around the CERN high-energy proton accelerators are described.

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1. INTRODUCTION

At CERN beams of protons, pions and other short-lived particles having energies up to several hundred GeV are made to interact in targets of liquid hydrogen, copper, etc., in order to study the elementary particles of which all matter is composed. Experimental areas can contain many such beams; if particle intensities are below some 10^6 s^{-1}, then the beams are allowed to run in open-topped zones bounded often by only a meshed fence. Close to collimators and around beams whose intensity is greater than 10^7 s^{-1} concrete and steel are normally used to shield the targets and beam lines. These beams operate independent of each other, so that in a zone adjacent to or downstream of an operating beam there could be persons installing the apparatus for a separate experiment. The geography of a typical experimental area is illustrated schematically in Fig. 1. Inside the area there are zones of "permanent" occupation where physicists control the functioning and data-taking of their experiments. In addition there are many corridors and equipment-handling areas. This variety in the utilization of an experimental area imposes great versatility on an installed radiation monitor and alarm system. Full details of the monitor and alarm system are given elsewhere (Ref. 1); only a brief description is given here.

The layout and shielding of the experimental zones in an area are designed on the assumption that the radiation levels in critical or occupied areas will be continuously monitored and that alarm information is readily available in the area control rooms. The composition of the radiation field in an area is a function of position inside the area and the different possible beam operations. The three most important fields found are :

a) that due to a "direct view" of a target or beam interaction point in a sideways direction, normally through a relatively thick hadron shield (points marked A in Fig. 1); this field is dominated by the hadron cascade generated in the shield and contains protons, neutrons and pions having energies of up to several GeV;

b) that downstream of a primary beam interaction point or a secondary beam line where muons of energies greater than 10 GeV form the dominant component (points marked B in Fig. 1);

c) that dominated by $\leq$10 MeV neutrons which can be found outside the openings in a thick shield for access ways, cable ducts, etc. (points marked C in Fig. 1). This field also occurs at larger distances from shields where the dominant radiation component arrives at the point of interest by scattering and diffusion in the air or at the ground-air interface.

2. THE MONITORING FUNCTION

The radiation detectors and associated electronics have been selected according to the physical nature of the field. The time structure of the field (often in bursts of several microseconds duration with inter-burst intervals of up to 15 seconds) excludes the use of pulse-counting systems (GM tubes, BF_3 counters, etc.) with their finite resolution time. All detectors are ionization chambers. Argon-filled, high-pressure (5 litre, 20 atm) ionization chambers are provided for monitoring the dose-equivalent rates from photons, muons and other charged particles. Similar hydrogen-filled chambers are preferable where hadron fields dominate and the ionization chamber version of the Andersson-Braun counter is used for low-energy neutron monitoring.

The electronics associated with these ionization chambers is of the charge-digitizing type now in common use for low-level current measurement. The input current from the chamber is applied to a low-leakage solid-state integrator which, upon reaching a given threshold voltage, triggers a charge-pump circuit causing it to subtract from the integrator input a known amount of charge, i.e. to inject a fixed charge of opposite sign to that of the chamber current. This charge can be adjusted by regulating the length of the trigger pulse so that it corresponds to a defined amount of dose-equivalent, referred to a specific calibration condition, e.g. exposure to an Am-Be neutron spectrum. Consequently a defined quantity of radiation must be incident on the chamber before the threshold is again passed and the charge injection re-occurs. By counting the number of re-injections that take place in a simple scaler system and by using a long time-constant ratemeter both integrated dose-equivalent and dose-equivalent rate can be monitored. The digitizer control circuitry ensures that in the event of very high radiation levels a continuous pulse train is emitted and not a DC level (Ref. 2).

Pulses from the digitizers are transmitted along multicore cables to a central control point located in or near the experimental area. A microprocessor-based Digital Data Logger, DDL (Ref. 3,4), accepts pulses from up to sixteen monitors, multiplies the value of the pulse by a field-quality factor (determined from more detailed field measurements using different detectors), accumulates the dose-equivalent readings for periods of one hour, determines the dose-equivalent rate averaged over a period of about 100 seconds, acts as the interface between the monitor and the Radiation Protection (RP) computer where the main data base is kept, and provides signals to alarm matrices when preset dose-equivalent rates are exceeded. This alarm function will be described in more detail below. Direct interrogation of the monitors via the DDL by an RP surveyor is also possible.

A dedicated RP computer provides the link between the user and some 30 DDLs distributed around the CERN sites. Its data base contains, for each monitor, the accumulated dose-equivalent for the last 72 hours on an hourly basis, for the last 30 days as dose-equivalent per day, and for the last 55 weeks as dose-equivalent per week. Graphical displays of these data are available in the RP building and in Accelerator Main Control Rooms; simpler displays of the same data can be obtained on terminals in any experimental area through the CERN control-computer network. Special programs can be run to monitor the dose-equivalent rate at intervals of 120 seconds for specified monitors. It is also possible to ask for the dose rate of any monitor at any time. In this way effective control of radiation levels can be maintained over the many experimental areas at CERN.

3. THE RADIATION ALARM SYSTEM

Each experimental area can be divided into up to some 30 alarm-display areas. A radiation alarm is given locally by flashing lights indicating that either persons should leave the area, or immediate efforts should be made to reduce the radiation level by improved beam steering. There is also an audible signal. This warning (A-alarm) simply follows the radiation level read by one or several monitors guarding a display area. When the level falls, the alarm disappears automatically. The link between the monitors and the areas is made via a matrix connected to the alarm outputs from the DDL. An additional complication is given by the fact that the dose-equivalent rate in a beam line zone is normally above the alarm level during operation of the respective beam. During operation these zones are cleared of personnel before beam operation is allowed. An audible alarm in these circumstances would be annoying and unnecessary. Thus a signal is obtained from the access control system for the zone in question which is used to suppress the sonalert in that display area. The same displays are activated whenever beam is authorized in a beam-line zone. Any A-alarms occurring in occupied areas are also displayed in the control rooms governing the particular experimental area.

The interconnection between the monitors and alarm displays is illustrated in Fig. 2. Also shown is a second matrix connected to another, higher alarm level (the B-alarm). This matrix attempts to associate an unwanted, high radiation level with a particular beam in an area. The alarms from these monitors are latched and coupled with a "good working-conditions" signal from the monitor before being sent to the matrix. The output from the matrix is an executive rather than warning signal and is sent only to the area control room. There it is used to cut off the offending beam, using the same interlocked beam-line magnets that are used to make a zone "safe-for-access". These alarms can only be cleared from the area control room by resetting the latches of the individual monitors causing the alarms; this will not succeed if the radiation level is still high! It is thus possible to diagnose mistakes caused by including a monitor in the wrong line of the matrix.

4. CONCLUSIONS

The radiation monitor and alarm system described here was first installed in an experimental area of the 450 GeV proton accelerator at CERN, the SPS, in 1978. Since then identical systems have been installed in the remaining six experimental areas of the CERN accelerators. These systems have proved extremely reliable in operation, the computer surveillance of the "good working-conditions" signal from the DDL allowing quick identification of a monitor fault. The ease of interrogation of the monitors and alarms via the computer system is much appreciated by the users. However, it must be remembered that the computer is mainly a book-keeper and the alarm function is ensured by hard-wired signals from the DDL. The "firm" rather than "hard" logic provided by the DDL is acceptable in the CERN experimental areas because the design philosophy of the areas must make it impossible for lethal or dangerously high (>0.1 Sv/h) radiation levels to occur in an occupied area under any condition.

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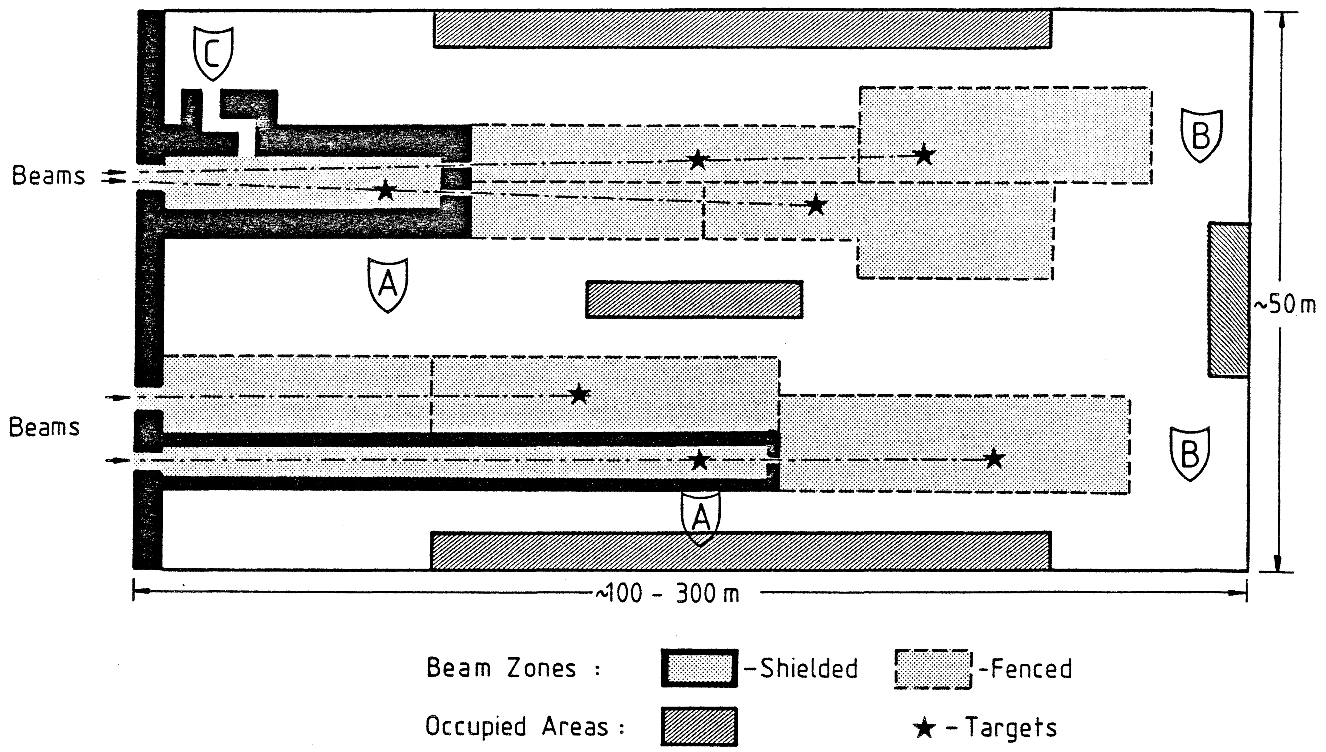

Fig. 1. Schematic layout of an experimental area.
See text for meaning of letters A, B and C.

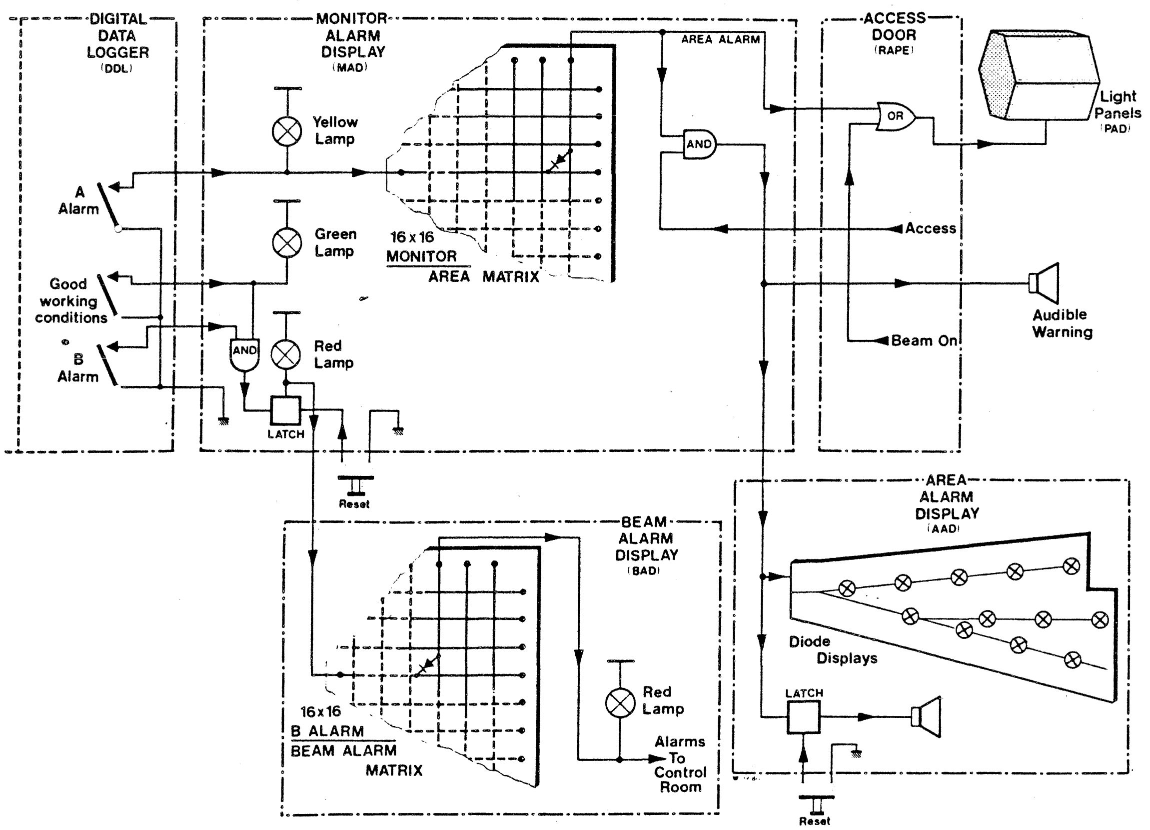

Fig. 2. Simplified functional diagram of the radiation alarm system.