MAIN ACCELERATOR ABORT SYSTEM

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Summary

The main accelerator abort system is designed to dump the unwanted beam only around the abort system and to reduce the residual radioactivity around the accelerator. The system consists of a 9-ft long aluminum target, a pair of 20-ft long steel collimators, and a pair of fast bump magnets. The beam is aborted within a few milliseconds after the arrival of a trigger signal.

Purpose of the Beam-Abort System

The main accelerator of the National Accelerator Laboratory was designed for experimental utilization exclusively with extracted beams with a beam intensity of 5×10^{13} protons per pulse. An external beam dump is used to dispose of extracted beams not reaching or going beyond the experimental targets. During acceleration, a small part of the beam is used parasitically on internal targets.

There are, however, pulses on which the beam is not fully extracted. The loss of significant fractions of the high intensity beam around the ring would create undesirable radioactivity. Indeed, radioactivity has become a nonnegligible problem even at our present intensity of 10^{12} protons per pulse. The beam-abort system[1,2] is utilized to dispose of unused beam in the least obnoxious way possible.

The design objectives for the beam-abort system are therefore to dump the accelerated beam on passive elements under the following circumstances:

i. if some beam is left after extraction, at the end of the flat-top;

ii. if the extraction system is not ready or operative, for example, if an element has tripped off;

iii. if the main-ring magnet power supply trips off, so that the cycle cannot be completed;

iv. if the main-ring rf accelerating system trips off, so that beam cannot be accelerated to the top of the magnet ramp;

v. if there is an unpredicted beam loss, as indicated, for example, on the beam-loss monitors around the ring.

The following sections describe the system, its operation, and its present status.

Description

Figure 1 is a schematic plan of the system shown in its relationship to the main ring. The symbols below the elements are their main-ring station designations. The system is centered around one of the six long straight sections, D0, halfway around the ring from the injection and extraction point. Aside from the beam-abort system, the D0 straight-section tunnel is used only as one of the two storage and staging areas for spare magnets, a few of which are kept upstream of the beam-abort system.

The general scheme of operation is that a local radial closed-orbit oscillation is induced by a pair of bump magnets which, then, brings the beam onto the target. Radiation from the target is absorbed in the two absorbers downstream of the target.

Bump Magnets

Two pulsed bump magnets are installed in the 7-ft "mini" straight sections at C46-1 and D17-1. Figure 2 is a photograph of the C46 bump magnet. The radial betatron-oscillation phase advance between these two points is close to 360°, so that two magnets are sufficient to induce a local closed-orbit oscillation. The phase advance between the C-46 bump magnet and the target is 97° and the closed-orbit displacement at the target is almost maximum.

Each bump magnet is 40-in long and is operated at a peak field of 9 kG. At this field, they give a 300-GeV proton a 2.2-in orbit displacement, driving the beam radially outward to the target. The magnet cores are constructed of 16-gauge (62.5 mils) steel to support a 5-msec field rise. The upper and lower coils each containing 20 turns of 0.265-in^2 copper are connected in parallel. The inductance of each magnet is 1.75 mH.

The bump magnets are pulsed by a single triggerable power supply (located outside the tunnel in the D1 building) in a 10-msec half sine wave, that is, 5 msec from start to peak. A regulated solid state energy discharge power supply is used. The peak current is 1360 A at 2600 V charging voltage and a stored energy of about 8.6 kJ. Firing signals for the abort system are transmitted along a single multi-input trigger line circulated all around the main accelerator. Machine conditions for the firing are stored in and can be scanned by the control system of the accelerator.

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Target

The target is a 9-ft long aluminum rod approximately 6 in by 5 in cross section. It is mounted inside a shielded block located just downstream of the quadrupole doublet at at the beginning of the D0 long drift space (see Figure 1). The target assembly is shown in Figure 3. The target is placed radially beyond the normal betatron-oscillation aperture, 1.5 in outward from the center line.

Absorbers

The absorbers are two modified main-ring B2 magnet cores. The copper coils are replaced by steel, leaving a 2 in by 5 in aperture. Each is approximately 21 ft long and has a steel thickness of at least 6 in in any transverse direction from the beam. They are shown in Figure 4.

The upstream absorber is positioned to intercept any particles coming off the target at angles outward and upward with respect to the center line. The downstream absorber is positioned to intercept any particles coming off the target at angles inward and downward with respect to the center line.

Positioning of the Abort System Elements

The positions of the abort target and both absorbers can be electromechanically adjusted locally in the machine enclosure, or remotely from the D1 building or the main control room.

Linear motion potentiometers are used for position feedback. Voltages from the pots are offset and scaled and presented to the local A/D converter for monitor by the control system. Closed loop accuracy of the positioning system is better than 10 mils for all motions. All motors are ac driven and are directly controlled by solid state relays. Electrical and mechanical limits for the extremes of travel are provided.

The position of the abort target is controlled by two Slo-Syn motors, one located at each end of the target. The radially outward aperture from the beam center line may be adjusted from 0 to 2.5 in. Skew of the abort target with respect to the center line can be corrected by independent driving of the motors.

The upstream absorber may be positioned to give a radially outward aperture of from 0 to 2.5 in and a vertical aperture above the center line of from 0 to 1 in. Two three-phase, 208-volt motors provide the drive for each aperture and are located at each end of the absorber. Linear motion potentiometer pots are mounted at each end of the absorber thus permitting measurement of the skew if desired. The downstream absorber is arranged in the same manner controlling the radially inward aperture and the vertical aperture below the beam center line.

Operation and Status

The physical system as described above is in operation. It is used at the end of every main-ring cycle to dump unextracted beam. It operates regularly at 300 GeV and has operated up to 400 GeV. That is operates successfully is shown by the significant amount of radioactivity in the absorbers measured after shutdown and by the diminution of the general background of radiation around the main ring since the beam-abort system was put into operation. Figure 5 is an oscilloscope tracing showing that the circulating beam is aborted in about 4 turns.

Only the first design objective above has been realized. A sophisticated control system has been built to trigger the abort system for the other objectives, but there has not been time for its installation and commissioning. A new power supply and magnets with a 1-millisecond rise time will be built to meet these objectives.

References

1. L.C. Teng, NAL report FN-195 (1969).

2. J.A. MacLachlan, Jr., T.A. Borak, L.C. Teng, F.C. Shoemaker, IEEE Trans. Nucl. Sci. NS-18, 981 (1971).

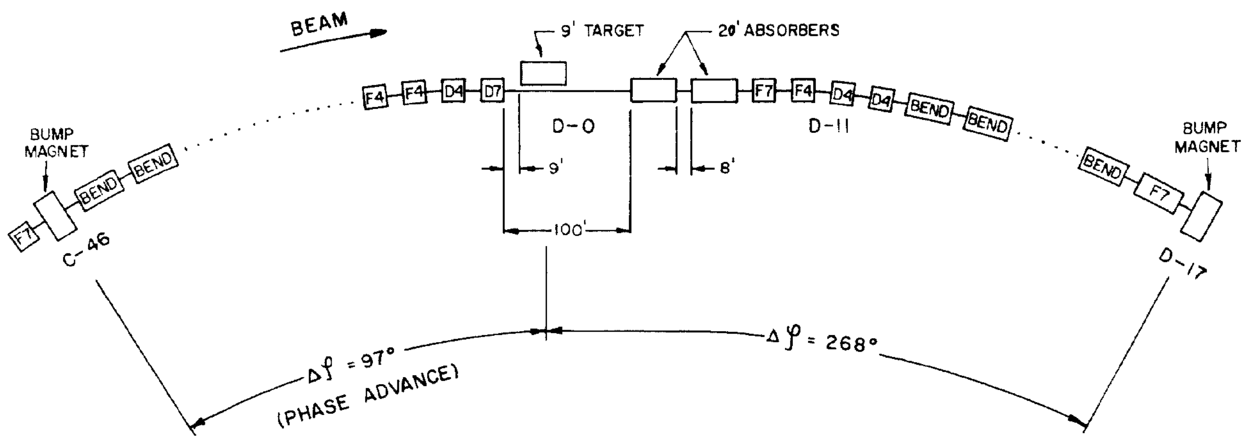

Figure 1. A schematic plan of the abort system.

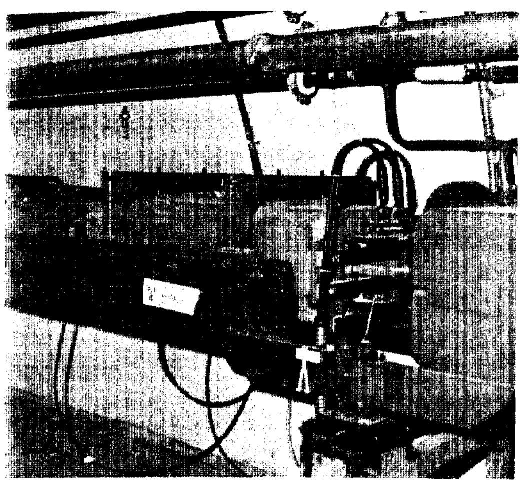

Figure 2. C-46 bump magnet.

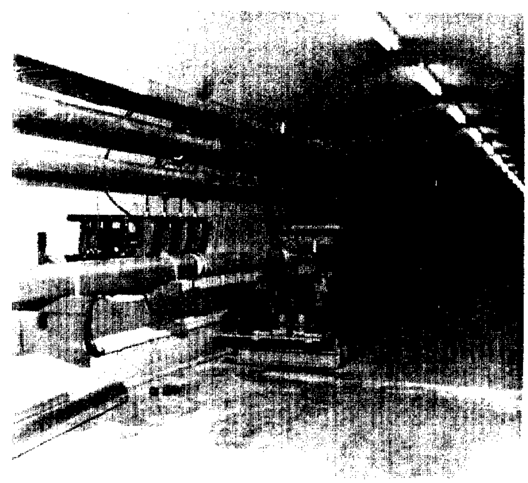

Figure 4. Abort absorbers.

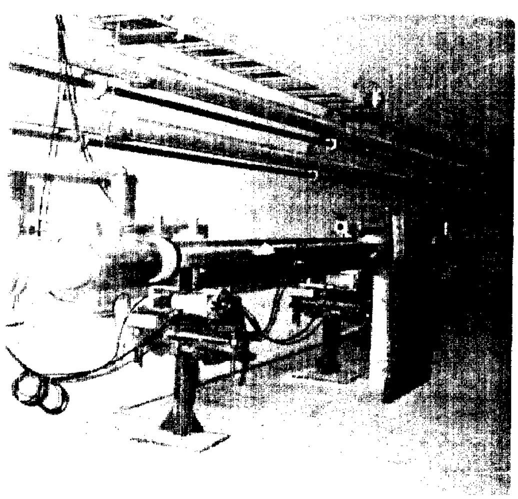

Figure 3. The abort target.

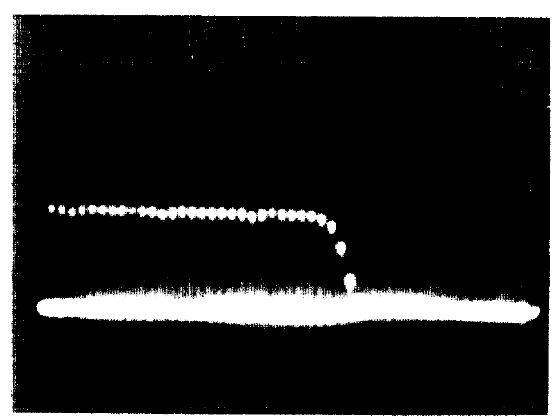

Figure 5. An oscilloscope tracing of the circulating beam at the abort time.