# Construction of a New Tevatron Collider Beam Abort Dump

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## Abstract

As part of the Collider upgrade a new abort system is to be installed in the Tevatron at A0. It consists of two sets of fast kickers and two 90% full aperture graphite beam dumps. This system will abort both protons and antiprotons. Details of the beam dump design and construction are presented.

## Introduction

During past Collider runs beam was aborted at the long straight section C0. Protons were aborted using the already existing external beam dump[1] while antiprotons were aborted via kicker magnets at C17 and an internal "block" located at the downstream end of the C0 long straight section. For the upcoming Collider run new abort systems will be installed at A0 long straight for both protons and antiprotons. There are three compelling reasons for doing this: 1) the space in the C17 warm section is to be used exclusively for Separators , 2) the abort kicker power supplies used two stage thyratron tubes which were susceptible to prefires and 3) 36 x 36 bunch operation requires the kickers to be as close to one another as possible.

The new system to be installed consists of 10 steel cored kickers, 5 at each end of the straight section, 2 internal beam absorbers and 2 sets of beam position monitors one set in front of each absorber. The kickers are each 88.06" long while each absorber is 188" long. Before a Collider run can begin all devices in A0 used for Fixed Target extraction must be removed. The abort system will be mounted on moveable plates and rolled in after the extraction devices are moved out.

## Design Parameters

The requirements of the abort system are detailed in Reference [2]. All the calculations were based on the following intensities:

150 GeV Intensity = 4.4E12 protons
1 TeV Intensity = 2.6E12 protons
1 TeV Intensity = 2.6E12 antiprotons

As for the number of aborts; it was assumed that during the setup time, when the energy is 150 GeV that the abort would be fired once every 2 minutes for up to 4 hours; that protons would be aborted 6 times a day at 1 TeV and that antiprotons would be aborted 2 times a day at 1 TeV.

Given the above intensities the abort must be designed such that it contains most of the beam energy. Excess energy escaping the abort material would be deposited in superconducting magnets and could result in quenching the magnet. Approximately 1mJ/gram deposited in a superconducting coil will result in a quench[1,2]. In addition the material must be able to withstand both the instantaneous thermal shock and the steady state temperature. Consideration must also be given to the levels of residual radioactive activity as well as to the radiation levels outside the tunnel enclosure. Since this is an internal beam dump it must be compatible with the tevatron beam tube vacuum requirements and consideration must be given to accident conditions, ie what if the aborted beam goes through the beam pipe in the absorber?

The design chosen for the absorber mimics the already existing TeV abort dump[1]. Figures 1 and 2 show a cross section and the longitudinal view of the absorber. Specifically

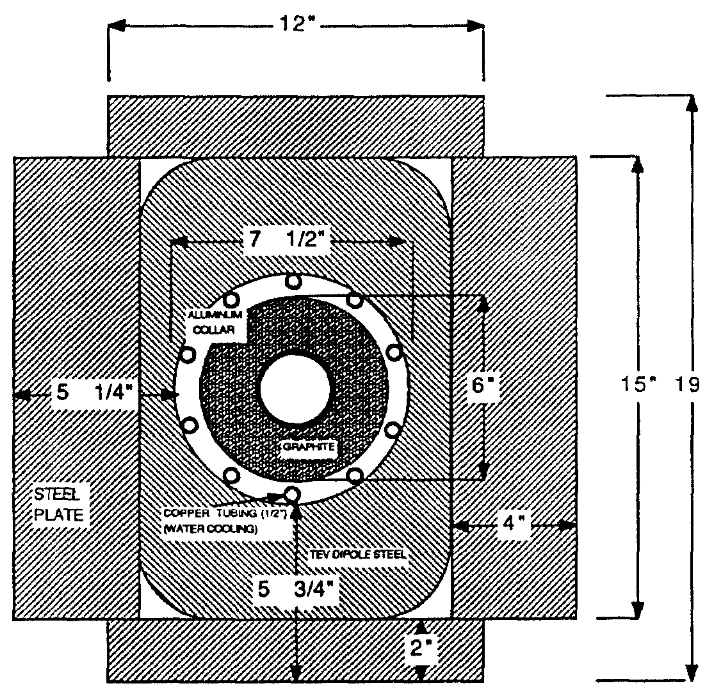


Figure 1. Cross section of the Absorber. From reference[2].

there is 350 cm of graphite followed by 75 cm of aluminum and finally 25 cm of steel. All the absorber material is in the

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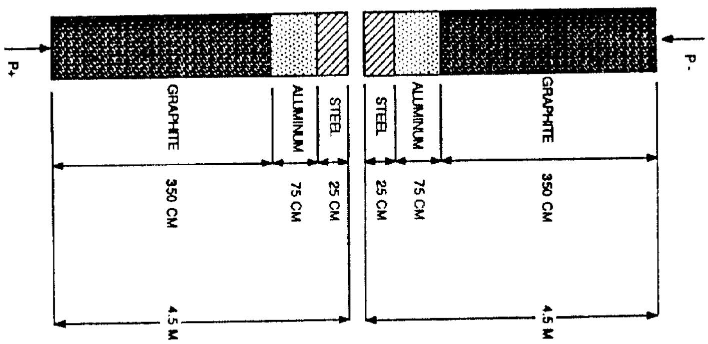


Figure 2. Longitudinal structure of the Absorber. From Ref[2].

form of 1" disks; this laminated approach minimizes the chances of damage due to instantaneous thermal effects. Using the MARS10 Monte Carlo program for this design it was determined that less than .002mJ/gram of energy would be deposited in the coils of the downstream superconducting devices at 1Tev and 5.3E12 particles[2]. Under these same beam intensity and energy conditions the maximum energy deposited in the graphite was determined to be 678 Joules/gram[2]. This leads to a instantaneous temperature rise of 350 degrees C ,well within the limits of the graphite . To estimate the steady state temperature the following 1 hour cycle was used: 30 150 GeV pulses 2 minutes apart and one 1 TeV pulse. Given this cycle the time averaged energy deposited is 162 watts/meter at the hottest longitudinal location. From this the maximum steady state temperature is found to be 116 degrees C in the graphite where the beam hits[2]. The calculations assumed no water cooling. A test was done with a short module having the same cross section as the actual absorber. A heating rod was placed where the beam would go and was powered using a transformer such that 162 watts/meter of power was dissipated in the rod. Thermocouples were placed in the graphite (1.75 cm from the heater), in the Aluminum Collar( in the middle of the collar) and at several locations on the iron yoke around the collar. As was the case for the calculations there was no water cooling. Figure 3 shows the calculations and measurements.

In order to calculate the induced radioactivity on the surface of the assembly a MARS10 calculation was done. The results indicated that the levels would be less than 100mR at contact 24 hours after beam was turned off.

## Design

The absorber consists of 6 parts: the Aluminum collar, the disks, the beam tube, the end pieces, radiation shielding and temperature instrumentation.

The Aluminum collar is the vessel that contains the graphite, aluminum and steel disks and acts as a heat sink to the disks (and is water cooled). The end pieces mount directly on the collar making a vacuum tight seal so that the disks, especially the graphite , can have a rough vacuum pulled on it. The vacuum is maintained via a rotary pump. There are two

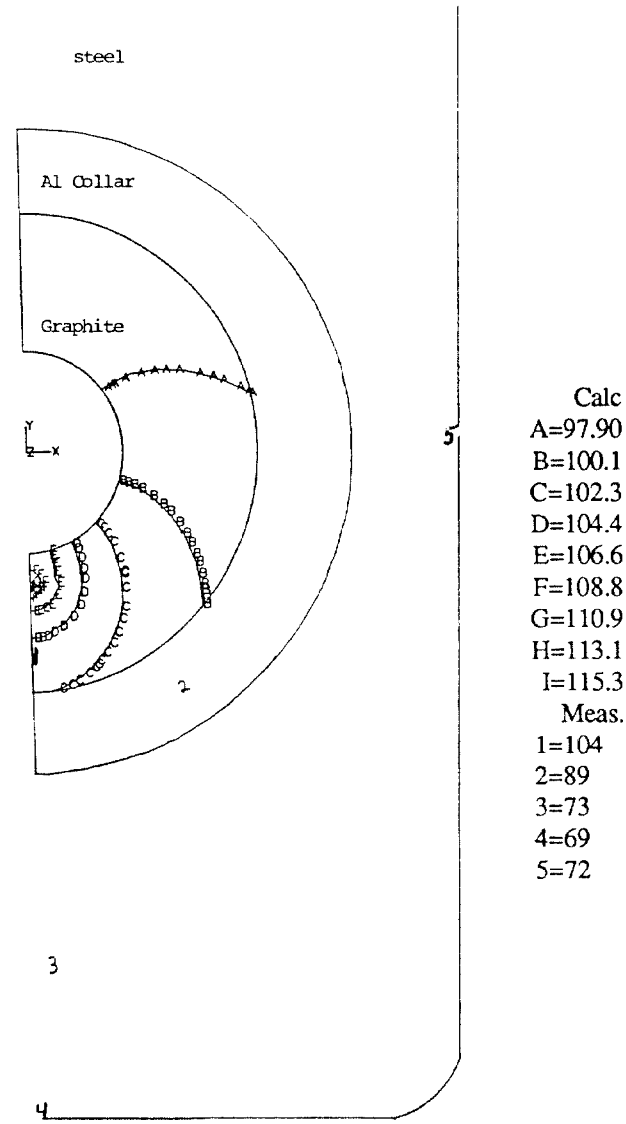


Figure 3. Calculated and measured temperature distribution for the steady state case. All temperatures in degrees C. From Ref[2].

reasons for keeping the disks in vacuum; first this will minimize the loss of graphite due to oxidation which occurs at elevated temperatures and second by removing the atmospheric pressure the forces on the beam tube are eliminated so that if the beam hit the beam pipe the resulting heating up of the beam pipe would not damage it. For water cooling eight 1/2" grooves are cut in the collar and these are fitted with aluminum tubes which connect to the LCW system. The inside surface is machined to a tolerance of 1/64". The collar is 180" long, has an OD of 7.47" and an ID of 5.56" It is made from 6061-T6 aluminum.

The three types of disks all share a common design: they are 1" thick, have a 2.5" diameter hole in the center for the beam pipe and are 5.35" in diameter. These disks are not circular but have the flat top. This area is used to mount a spring loaded brass bullet which provides a downward force, of magnitude 2 pounds, on the disk to increase the contact between the disk and the collar. This provides for better heat transfer to the Aluminum collar.

The beam tube is made of 6061-T6 aluminum and is .049" thick. The reason for such a thin beam pipe is due to the above mentioned accident condition of the beam hitting the beam pipe. Under worse possible conditions it is predicted that the maximum temperature this beam pipe could reach would be 311 degrees C. This is well below the melting point and, since there is no atmospheric pressure, the beam tube will suffer no deformation (although calculations show that even with atmospheric pressure deformation would not occur until over 400 degrees C[4]). Vacuum in the beam tube should be better than 1E-9 Torr.

The end pieces are used to make the seal for the rough vacuum in the absorber. A vacuum of 1E-3 Torr would be quite adequate. O-Rings made of ethylene-propylene (for radiation resistance) are used. Each end piece is composed of three parts: an Aluminum to Stainless transition piece, a face plate and an O-ring collar. The aluminum side of the transition piece is welded onto the aluminum beam pipe. The upstream transition piece also has a "window" machined out of it for the beam to go through; the beam only sees 1 mil of aluminum. The window itself is .75" wide and extends in a circular path 15 degrees to either side of the center. While the beam tube is 2.5" in diameter this end of the absorber is 4.5" in diameter in order to accommodate both circulating and aborted beam. The face plate bolts directly to the Aluminum collar and contains an O-ring which seals to the collar face. The O-ring collar bolts to the face plate and has one O-ring which seals around the beam pipe.

The radiation shielding is composed of two parts. First the absorber is placed in a shortened Tevatron dipole iron yoke. Secondly this assembly is surrounded by steel plates; 4" thick plates on the sides and 2" plates on top and bottom. The net result is that there will be 5.25" of steel on the sides and 5.75" of steel on the top and bottom.

In order to insure that the absorber is performing as expected temperature readbacks have been included. To monitor the temperature a set of four K type thermo-couples will be placed at various points along the absorber. There were two criteria for placement: first they should be placed on the bottom near shower maxima and second there must be some way to get the thermocouple in contact with the aluminum collar. Since the absorber is encased in a TeV magnet iron yoke we can take advantage of the "smart bolt" holes already in the iron, and, by carefully specifying where to cut the iron, appropriate holes are made available. To mount the thermocouples, modified TeV "smart bolts" will be used and the thermocouple will be spring loaded to improve thermal contact. Readbacks can be monitored in the Control Room via a system identical to that used for existing equipment. In addition thermostats will be placed in additional "smart bolt" holes. Their purpose will be to inhibit any beam injection if the temperature goes above 90 degrees C.

## Construction Problems

The construction of three absorbers (two for use and 1 spare) proceeded smoothly taking 2 months total to build all of them. Only two problems arose during this time. The first was welding the upstream transition piece to the thin walled aluminum beam tube. This transition piece is rather large (7/8" wide) and thus massive compared to the wall of the beam tube. Indeed at first we experienced a great deal of trouble making this aluminum to aluminum joint vacuum tight. Two changes made the most improvements: 1) a design change to include a 1/8" weld relief with a curvature of 1/32" and 2) cleaning all surfaces and welding rods with a solution (Weld-O) containing hydroflouric acid immediately before welding. We also clamped a heat sink around the beam tube. After these changes no further welding problems occurred.

The second problem concerned the alignment of the disks when inserted into the aluminum collar. Since it is desirable to have the best possible thermal contact to the collar as near to where the beam is as possible it is important that the force exerted by the springs exert a downward force. If a disk was rotated then there would be a sideways force as well and the location of best thermal contact would be rotated away from where the beam would go. In order to keep all the disks in the same upright orientation we used a single thin strip of aluminum (1/2" wide by 1/16" thick) that ran the length of the aluminum collar as a guide. The brass bullets that sit on top of the springs would follow this strip thus keeping all the disks upright. The strips were held in place via counter sunk screws on the inside of the collar. Tension was maintained on the strip during installation to minimize bowing when inserting the disks. Rotation in the other direction is prevented by the disks themselves; the length of the flat part of the disk from the spring to either edge is 1/2" so the strip is close to touching one of the edges.

## Acknowledgements

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## References

[1] J.Kidd , et al., "A High Intensity Beam Dump for the Tevatron Beam Abort System," IEEE Transactions on Nuclear Science , Vol NS- 28, pp 2774-2776,June 1981.

[2] C.Crawford., "The A0 Abort System for the Tevatron Upgrade", TM-1564,Fermilab Internal Memo ,March 1989.

[3] C.Crawford., "TEV Abort Upgrade Design Note; Absorber Beam Tube", Fermilab Internal Memo, November 1988 .