Estimated Future Energy Deposition in the Pbar Dump

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1/19/99

The pbar dump in the AP-0 vault is scheduled to receive high intensity beam this year from Main Injector slow spill commissioning and a NuMI prototype target test. To fully commission the Main Injector, 120 GeV resonant extraction of up to 2.0E13 must be demonstrated. The AP-0 dump has been chosen to receive the resonantly extracted beam. For the NuMI test a pair of prototype targets are expected to be tested with high intensity 120 GeV beam. One concern with regards to the tests is the ability of the pbar dump to handle the heat load from the particle beam.

For the slow spill commissioning, beam will be resonantly extracted over about 100 ms from the Main Injector. The beam will follow the same path as that used for pbar production, down the P1, P2 and AP-1 beamlines into the target vault. Despite the high intensity requirement for the milestone, intensity will be significantly lower through most of the tune-up phase. Since there is no spot size requirement for the test, an AP-1 quadrupole tune can be used that will decrease the beam size in AP-1 and increase the spot size on the dump core. This will reduce the peak energy deposition in the dump core.

During the NuMI target test, two target segments, one made of graphite and the other beryllium, will be separately tested within a sealed housing suspended from a target station module The graphite segment is 2 cm in height, 1.78 mm. in width and is 10.0 cm in length. The beryllium segment has the same height and length but is 2.29 mm. thick. The beam spot size will be about double that used in collider run 1b. Because of the increased spot size, peak heating in the dump core should actually be somewhat lower than in collider operation despite the increase in beam intensity.

The Pbar dump design[1] was based on a 150 GeV energy beam with an intensity of 3.0E12 and a cycle time of 2.0 seconds. Beam parameters for the NuMI prototype target test is an energy of 120 GeV with an expected intensity of 1.0E13 and a cycle time of 2.4 seconds. The Main Injector resonant extraction commissioning will require intensity as high as 2.0E13 per pulse, but the cycle time with that intensity will be only 15 seconds. For comparison, the highest intensity beam on the pbar target to date was 3.4E12 with a 2.4 second cycle time (120 GeV). In the future, the Main Injector is expected to deliver 5.0E12 120 GeV protons with a cycle time of 1.5 seconds.

AP-0 Dump

The beam dump in the AP-0 target vault is made up of a dump core surrounded by a large steel mass. The dump core is comprised of a graphite cylinder contained in a water-cooled aluminum box. The graphite cylinder is 15.24 cm. in diameter and is shrink-fit into a 29.85 cm. aluminum box. The graphite is 120 cm. length while the entire dump core is 220 cm. (see figure 1). Drawings of the dump

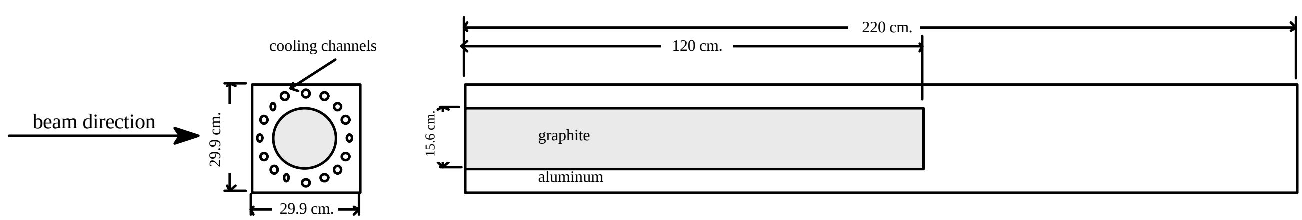


Figure 1: Pbar dump core

as built indicate that there is one deviation from the original design. The amount of steel shielding downstream of the dump core is 252 cm. instead of 490 cm. (the Tevatron dump, which the pbar dump is modeled after, has 405 cm.). The steel shielding around the dump core has been arranged so that there is at least a 137 cm. thickness in the transverse directions. In most places there is greater than 137 cm. of steel, for instance 259 cm. of steel underneath the dump core. In addition, most of the steel in the dump is further surrounded by concrete blocks to augment the radiation shielding.

A closed-loop cooling water system located at AP0 is used to cool the dump core. The dump cooling water is heat exchanged with chilled water that nominally has a temperature of about 10°c. The cooling water system typically flows 6.6 - 7.0 gallons per minute (GPM) through the dump core. Instrumentation of the dump core and cooling system includes seven temperature sensors on the core, three temperature sensors on the water system plus water flow, water pressure and hydrogen pressure.

CASIM Summary

The program CASIM[2] was run to model the particle cascade from the prototype target into the dump. For the case of resonantly extracted beam, the proportion of energy deposited in the dump core and entire dump is similar. Changing target dimensions or material does not drastically change the amount of heat deposited in the dump core. The geometry of the dump used in the model closely follows the actual dump dimensions with the exception that the steel was represented as a 137 cm. cylinder. This is the shortest dimension of the steel shielding surrounding the dump core, in most cases there is additional steel. CASIM was run with 20,000 particles which is more than adequate to produce statistically significant results. Table 1 lists the amount of energy deposited in GeV per incident particle, the total energy deposited based on 1E13 particles and the total power based on a 2.4 second cycle time for the target and dump. GeV per incident particle was converted to total energy through the following relationship:

	Energy GeV/particle	Total Energy kJ (1E13 particles)	Total Power kW (2.4 sec. cycle)
Prototype Target (beryllium)	0.067	0.107	0.045
Dump core, graphite	15.1	24.6	10.25
Dump core, aluminum	33.5	53.6	22.33
Dump core Total	48.6	77.8	32.59
Dump steel	51.9	83.0	34.60
Dump Total	100.5	160.8	67.17

Table 1

Total Energy (Joules)=Energy (GeV/incident particle)*(1.6E−10 Joules/GeV)*(1E13 incident particles)

Comparison

The proposed intensity and repetition rate for the NuMI target test would deposit nearly three times more beam energy into the dump core than the previous peak. Table 2 summarizes the calculated energy and power deposition into the pbar dump under various conditions. Since the Pbar dump was modeled closely after the Tevatron dump, energy and power deposition estimates for the Tevatron dump were included as well. Existing documentation for the Tevatron dump[3] made the conservative assumption that all of the beam energy would be deposited in the dump core. To make a valid comparison between dumps, a CASIM run was made for the Tevatron dump to estimate the heat deposition.

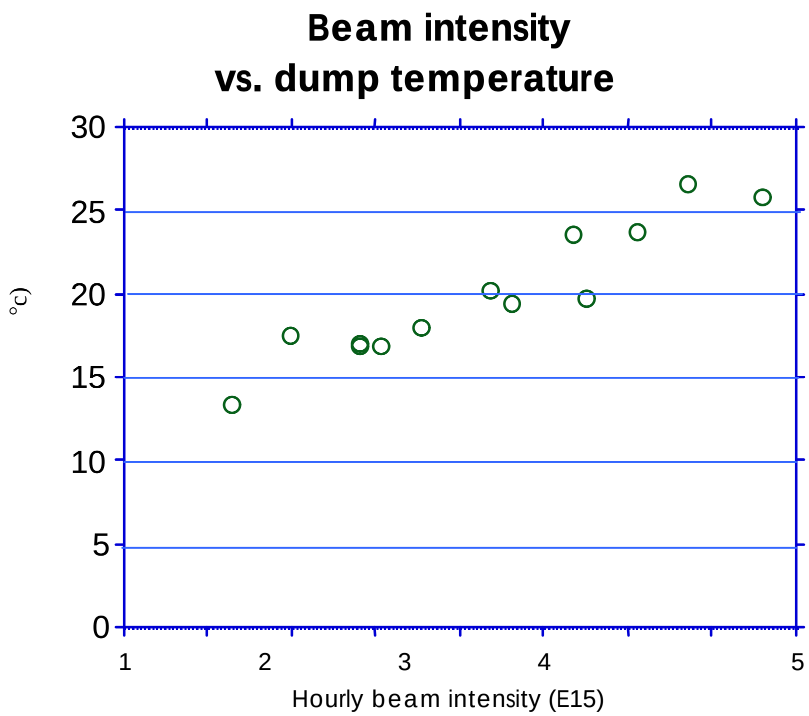
Pbar note #357 does not provide an upward limit to protons on target or total dump heat deposition. It does, however, estimate a local temperature increase of 115°c in the graphite core with 3.0E12 of intensity and a "worse case" scenario with no target. The Pbar dump design closely followed the Tevatron dump and was considered adequate because of the relatively modest amount of deposited energy. The Tevatron dump was estimated to have a peak temperature in the graphite of 880°c, far below its melting point of 3,827°c. It was estimated that up to 5.7E13 protons per pulse (1 TeV) could be delivered to the Tevatron dump without fracturing the graphite (beam σ about 1mm). Because of uncertainties in the calculation, an upper limit of 4.0E13 is more realistic. This would suggest that the beam parameters of 2.0E13 at 120 GeV for the resonant extraction test would be well below the threshold that would damage the graphite core of the Pbar dump.

	Cycle Time seconds	Total Energy (Power) Dump Core	Total Energy (Power) Entire Dump
Pbar design (note #357) (150 GeV, 3.0E12)	2.0	28.8 kJ (14.4 kW)	61.9 kJ (31.0 kW)
Peak pbar (120 GeV, 3.4E12)	2.4	26.5 kJ (11.0 kW)	57.7 kJ (24.0 kW)
Pbar, M.I. era (120 GeV, 5.0E12)	1.5	39.0 kJ (26.0 kW)	84.8 kJ (56.5 kW)
Tevatron design (1,000 GeV, 2.0E13)	23.0	2,101 kJ (87.4 kW)	2,810 kJ (122.2 kW)
Peak Tevatron (800 GeV, 2.7E13)	60.0	2,151 kJ (35.9 kW)	3,033 kJ (50.5 kW)
NuMI test (pbar) (120 GeV, 1.0E13)	2.4	77.8 kJ (32.6 kW)	160.8 kJ (67.2 kW)
M.I. slow spill (120 GeV, 2.0E13)	15	155.4 kJ (10.4 kW)	321.4 kJ (21.4 kW)

Table 2

Temperature increases in the surrounding aluminum and steel portions of the dump are considerably less. With the design 3.0E12 protons delivered to the dump, less than a 15°c increase was anticipated, far below the melting points of these materials (660°c for aluminum and 1,536°c for iron). The increase in intensity for the slow spill and NuMI target tests should not push the aluminum and steel temperatures high enough to cause local melting.

The other remaining issue is the ability of the cooling water system to transmit heat from the dump core. The NuMI prototype target test could deposit as much as 32.6 kW of power in the dump core, much greater than the 14.4 kW anticipated in the original design. In the Main Injector era 26.0 kW of power would be deposited into the pbar dump core. The Pbar dump water system flows about 6.5-7.0 gallons per minute (gpm) through the dump core. Below is a plot of the dump temperature in Collider run 1b as a function of hourly beam intensity. A linear extrapolation of the data yields a dump temperature of 65.1°c for the NuMI target test, 26.3°c for the slow spill test and 53.7°c for Main Injector operation. These temperatures would appear to be safely away from the boiling point of water. As always, one should exhibit caution when extrapolating outside the data end points. Beam intensity should be increased gradually, and the dump temperature monitored during the process.



The Tevatron cooling water system was designed to dissipate at least 139.0 kW of power, though operationally it has received only a peak of about 50.5 kW. The cooling water for the Tevatron dump is Main Ring LCW which has a nominal temperature of 37°c. The cooling water for the Tevatron dump has a flow rate of 72 gpm. The 139 kW of power input to the cooling loops leads to an estimated temperature rise of 7.2°c.

References

1. W.S. Freeman, "Energy Deposition in the Pbar Target Hall Proton Beam Dump," Pbar Note #357, Fermilab (1984).

2. A. VanGinneken, "CASIM", FN-292, Fermilab (1975).

3. J. Kidd, N. Mokhov, T. Murphy, M Palmer, T. Toohig, F. Turkot and A. VanGinneken, "A High Intensity Beam Dump for the Tevatron Beam Abort System," IEEE Transactions on Nuclear Science, Vol. NS-28 No. 3 (1981).

4. F. Turkot, "Energy Doubler Beam Abort System", UPC #20, Fermilab (1979).