An Air-Cooled FMI Abort Dump?

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The recent DOE review committee recommended the examination of the possibility of a non-water-cooled abort dump. This note discusses the thermal implications of such an abort dump.

The graphite core box is 15 cm x 15 cm x 240 cm = 54000 cm^3 = 92000 g. This has a heat capacity of 73000 J/�C. The nominal FMI intensity is 3 x 10^{13} protons/pulse at 120 GeV, which is 576 kJ. Approximately one-half of this energy is deposited in the graphite, or roughly 300 kJ. Therefore, the graphite core will heat up, averaged over the entire graphite, at a rate of about 4 �C per pulse, or about 125 �C per minute at a maximum repetition rate of 1.8 seconds (neutrino fast spill running.) This level of heating is likely to be acceptable for periods of a few minutes, at which point the beam would have to be (and should be!) inhibited.

Assume a steady state running mode in which one pulse per minute is aborted. Essentially all the energy is deposited in the graphite and the inner part of the steel. Neglecting the aluminum box, which is relatively thin and a good thermal conductor, this means approximately 10 kJ/sec must be conducted out of the graphite/inner steel area. The thermal gradient across the steel (1 m thick) would be about 30 �C; the thermal gradient across the concrete (also 1 m thick) would be about 200 �C. The heat transfer from the concrete to the air (< .1 W/sq in) requires about 25 �C, and the air transfer required to carry away the heat is small, on the order of 1 cubic meter per second (for 8 �C rise). Hence the assumed steady state condition has the core box running at about 300 �C. This is well below the 2300 �C region (the "cracking temperature" of graphite).

The main problem with this scenario is the relatively large thermal stresses in the steel and concrete, the associated thermal expansion and almost certain cracking of the concrete. Subdividing everything into smaller units would reduce this problem, but that has additional costs associated with fabrication and installation. The time for the steel to reach thermal equilibrium is on the order of ten days. Likewise, the cooldown time has that same time scale initially, but one must wait several times that for the core to reach temperatures at which it can be handled.

While this analysis is not a detailed one, and based upon aborted beam assumptions which are subject to debate, it gives a reasonable basis for deciding that the water cooling system as previously proposed (estimated cost = $74,000) should be reaffirmed as the design choice.