AP4 Beam Dump and Allowed Beam Intensity Limit during the Construction Phase of the MI-8GeV Beam-line

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Ap4 beam-dump is situated in the Fermilab Booster tunnel off MI-8GeV beam-line. This Beam dump is used during (a) Booster startup, (b) dedicated studies to tune the beam in the Booster and (c) Tevatron collider studies (In this mode , about 7/8th of the 8GeV beam will be dumped for every batch of the Booster beam injected into the Main Ring.). In all these cases one expects significant increase in radiation level near the AP4 beam dump due to prompt neutrons and high energy gamma rays and, due to muons produced in the dump and soil. The range of muons being long the radiation level due to muons may be significantly large even far away from the beam dump. However, during the construction phase of the MI-8GeV beam line the modes of use of the AP4 beam dump (a) and (b) are of major concern to us. In this note we estimate the radiation level down stream of the beam dump. We also estimate the required shielding to make the down stream area of the beam dump radiation safe and suggest the necessary measures to be taken to reach a goal of unlimited occupancy limit of radiation level.

To estimate the radiation level rise due to the interaction of an 8 GeV proton from the Booster on to the beam dump, Monte Carlo calculations have been performed using computer code CASIM and MUSIM (A. Ginneken). The first code determines the radiation levels arising from prompt neutrons and the later code gives the radiation level rise due to muons. Figure 1 gives the view of the area around the beam dump. Fig. 2 displays the actual geometry of the beam dump. We have taken these geometry (modeled to a cylindrical geometry) into our calculations.

Following assumptions are done about the radiation limit and the beam intensity:

1. The unlimited occupancy limit for radiation level = 0.025 mrem/hr.
2. The maximum intensity of the beam to be dumped on to the beam dump: 8.5×10^{15} protons per hour. (from Booster Beam Safety Envelope, MCR issued 11/11/93, see Appendix I).

Figure 3 displays the results of Monte Carlo calculations from CASIM. The curves are contours of equal radiation level. The Table I gives the radiation level down stream of the dump at various distances.

Table I. Radiation level down stream of the AP4 beam dump. Here we assume that the AP4 beam line and down stream of the beam dump is plugged in with shielding iron. Rad to rem conversion factor for muons is assumed to be 1.0. In the case of neutrons we follow FERMILAB RADIOLOGICAL CONTROL MANUAL to convert star density to rem. Number of proton = 8.5×10^{15}p/hr.

Distances from the back of the dump (ft)	Neutron Radiation Level	Muon Radiation Level
0.0 ft	8.5 rem/hr (@1e-15 rem/p)	–
3.3 ft of soil	0.5 rem/hr (6e-17 rem/p)	–
6 ft of soil	0.043 rem/hr (0.5e-17 rem/p)	–
9 ft of soil	4.3 mrem/hr (about 0.5e-18 rem/p)	0.85 mrem/hr (1.0e-19 rad/p)
12 ft of soil	0.43 mrem/hr (about 0.5e-19 rem/p)	≈ 0.45 mrem/hr (≈0.5e-19 rad/p)

We have also calculated the muon energy attenuation in the beam dump assuming muons highest energy = 8 GeV. A plot of E_μ and dE/dX versus depth of the beam dump is shown in the Fig. 4. This suggests that the muon produced in the Be target will be completely stopped. However, to determine the muon dose down-stream of the beam dump the results from MUSIM calculations are used. We find that within the errors the muon dose rate is comparable to that arising from the hadrons.

Based upon the above calculations it has been suggested to build atleast a 12ft thick wall downstream of the AP4 beam dump during the construction of 8 GeV beam line. From our estimations it is clear that even 12 ft thick concrete wall is not be enough to achieve unlimited occupancy radiation level of 0.025 mrem/hr. The contributions to radiation dose from hadrons it self is about 0.43 rem/hr. Therefore we suggest that some additional radiation safety measure should be taken during the construction stage of the MI-8GeV beam line in the vicinity of the AP4-beam dump.

Above calculations suggest that the total beam aborted on to the AP4 Beam dump should not exceed 2.45E14/p @8 GeV. The following table gives some operating scenario of the beam dump.

Table II. Suggested operating scenario of the AP4 beam dump abort.

Scenario of Beam Intensity	Number of Aborts/hour
5×10^{12}	50
4.05×10^{12}	62
2×10^{12}	124
0.5×10^{12}(one Booster turn)	500

Conclusions :

We suggest that number of 8 GeV protons to be dumped on the AP4 beam dump should be limited to the 2.45×10^{14} per hour instead of 8.5×10^{15}/hour during the construction phase of the MI-8GeV beam line to keep radiation level below acceptable limit of 0.025 mrem/hr. Also we suggest to implement interlock detectors to monitor the radiation levels.

Appendix-I

Fermilab

Booster Beam Safety Envelope

The maximum hourly beam power transmitted through the Booster accelerator is limited to that provided by 1800 pulses of 5 x 10^{12} protons per pulse at 8 Gev kinetic energy in any one hour.

No accelerator or beam line will transmit beam without an operational beam interlock safety system

Booster Beam Operating Limits

The maximum beam energy is limited to 8 Gev.

The maximum charge transmitted through the Booster is limited to 8.5 x 10^{15} protons per hour at 8 Gev kinetic energy

Examples: Charge/hr = number of pulses/hr x number of protons/pulse

#1 1700 pulses per hour at 5x10^{12} protons per pulse = 8.5x10^{15} protons per hour.

#2 2100 pulses per hour at 4.05x10^{12} protons per pulse = 8.5x10^{15} protons per hour.

#3 4250 pulses per hour at 2x10^{12} protons per pulse = 8.5x10^{15} protons per hour.

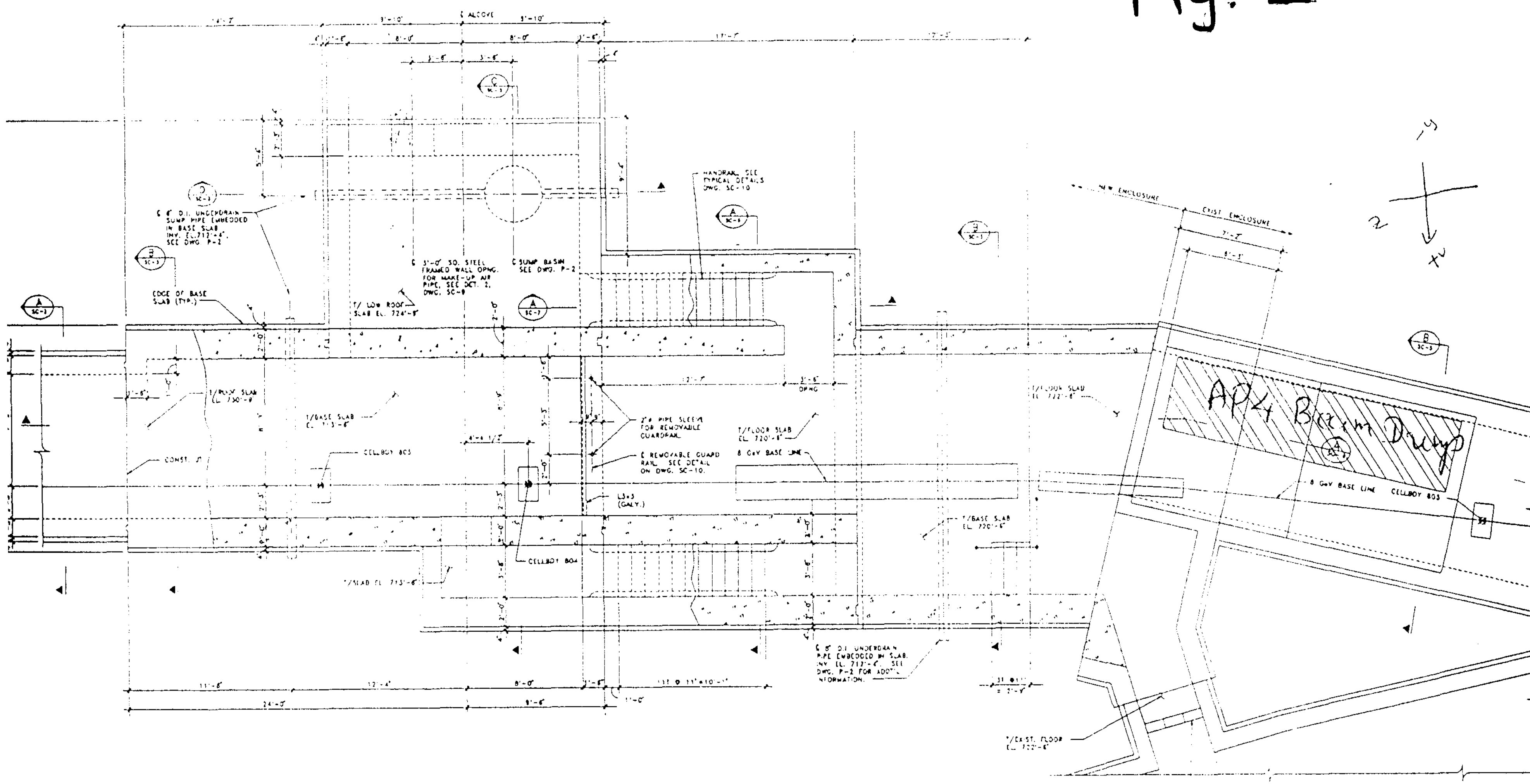
Special conditions and comments:

Perpared By [signature] 11/11/93 [signature] 11/11/93
Operations and Booster Department Heads/Date

Reviewed by [signature] 11/11/93
Associate Accelerator Division Head for Systems/Date

Approved by [signature] 11/11/93
Accelerator Division Head/Date

Fig. 1



ENLARGED PLAN @ EXIT STAIR & ALCOVE
NOTE: ROOF SLAB PARTIALLY REMOVED FOR CLARITY

AP4 Beam Dump (the AP4 beam line will be plugged with steel)

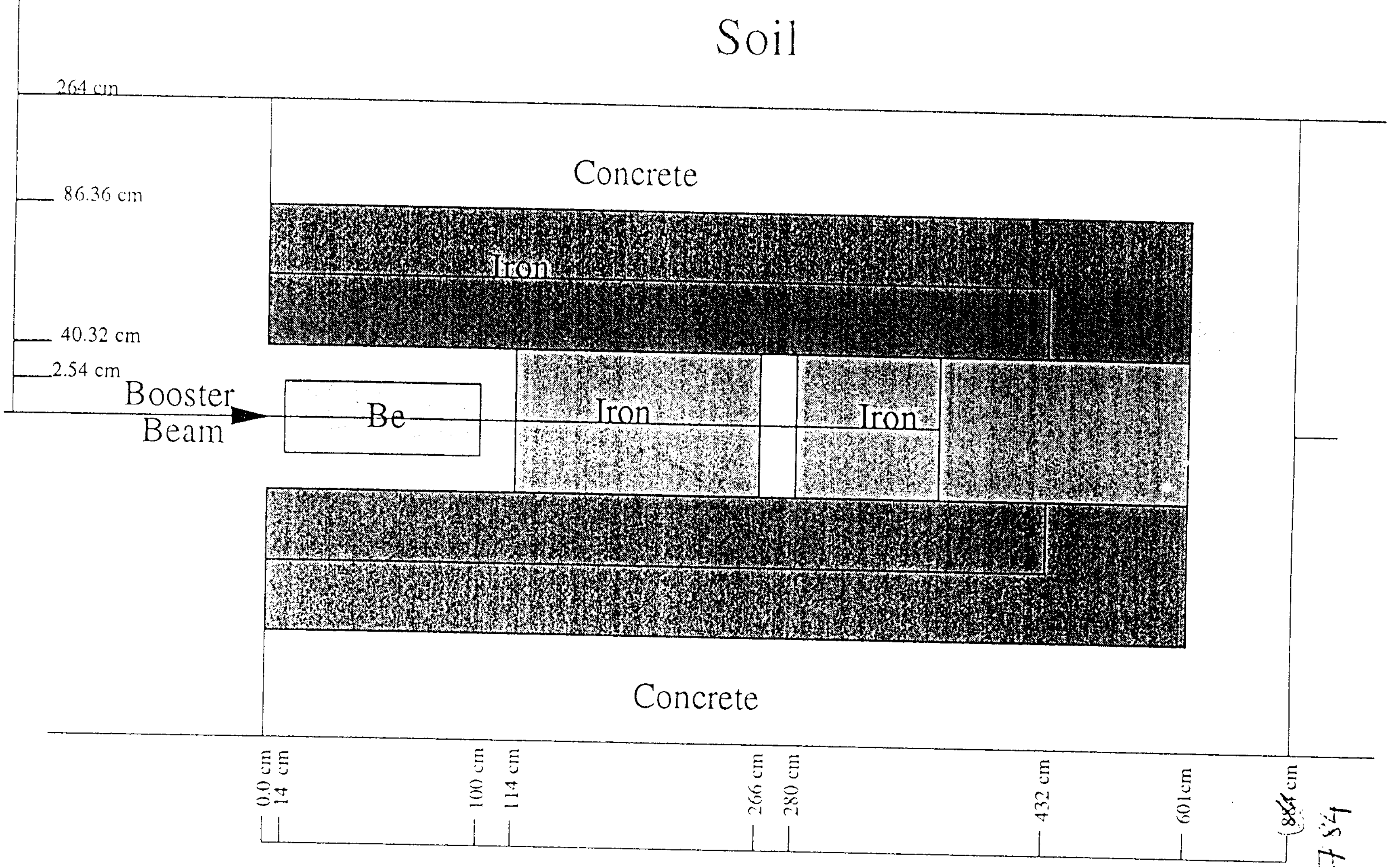
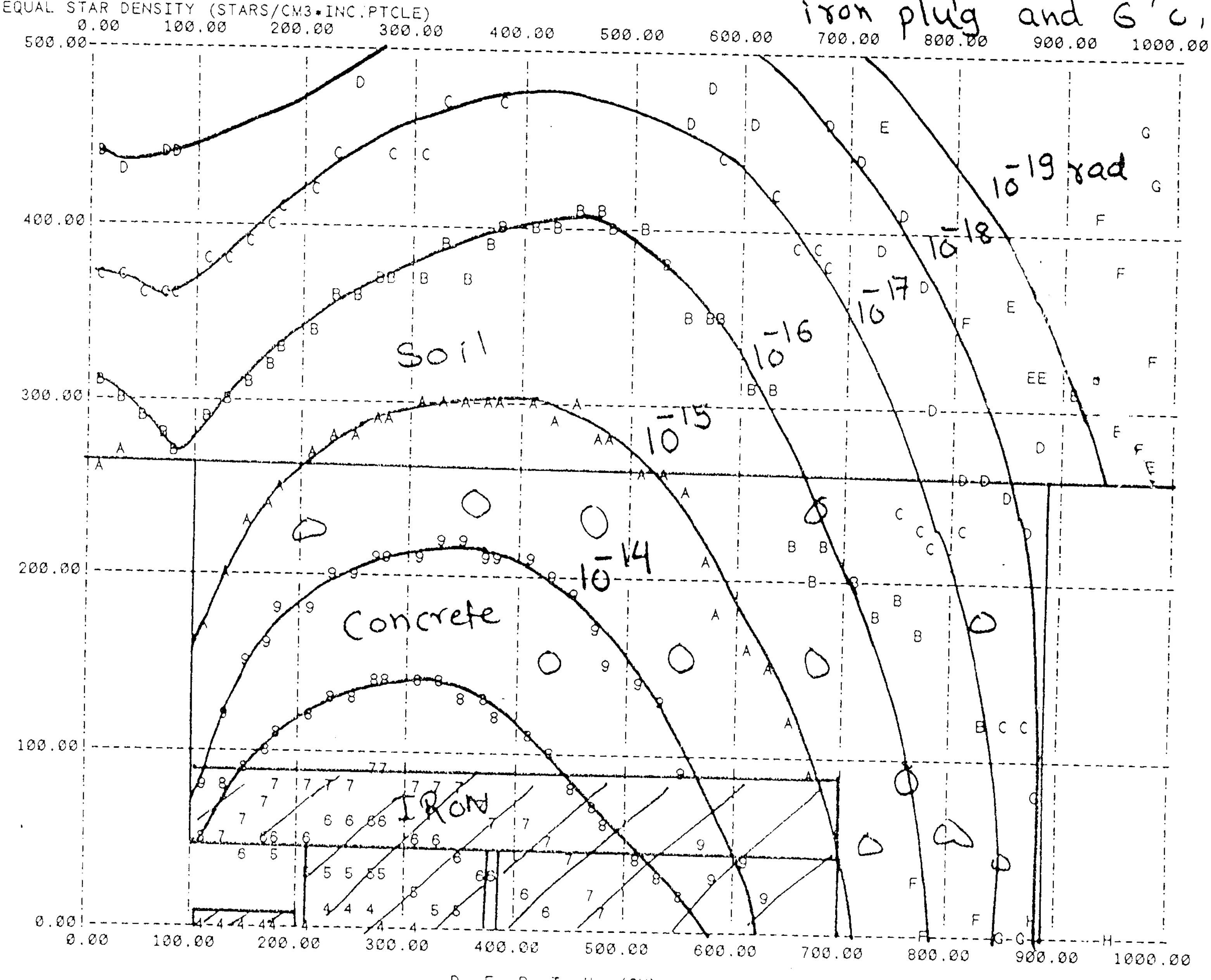


Fig 2

AP4 Beamdump with iron plug and G'c, concrete

Fig 3



R-LABELS REFER TO SMALLER VALUES OF CORRESPONDING BINS
LEGEND : NUMERICAL SYMBOLS REFER TO THE NEGATIVE POWER OF 10 OF THE STAR(ENERGY) DENSITY E.G., 5 REFERS TO THE 10**-5 CONTOUR
OTHER POWERS OF 10(SYMBOLS) :-10(A),-11(B),-12(C),-13(D),-14(E),-15(F),-16(G),-17(H),-18(I),-19(J),-20(K),-21(L),-22(M)
-23(N),-24(O),-25(P) 1(Z),2(Y),3(X),4(W),5(V),6(U),7(T),8(S),9(R),10(Q)