

Attachment B

Dugan's Criteria " Radiation Shielding Calculations for
Booster Operations with Main Injector", Memo to Vinod
Bharadwaj (July 29, 1991)



Vinod Bharadwaj

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**Accelerator Division
Headquarters**

Monday, July 29, 1991

To: Vinod Bharadwaj

From: Gerry Dugan *G. Dugan*

**Subject: Radiation Shielding Calculations for Booster
operations with Main Injector**

Using the beam intensities and cycle rates appropriate for Main injector operation, I have run the spreadsheet which was used to establish the requirements for the recent shielding assessment. It is attached to this memo.

Although the Booster shielding assessment was done empirically, a comparison of this spreadsheet with the previous version indicates some of the problems which will have to be addressed. For example, for the case of minimal occupancy, "magnet in enclosure", the Main Injector operating conditions indicate a need for about 2.4 ft of additional shielding.

cc:

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Booster Shielding/MI era

Calculation of soil-equivalent shielding for 8 GeV Booster						
Calculation of reference shielding						
Reference conditions: 8 GeV, 2×10^{13} protons/pulse, 60 pulses/hr						
Relation between dose/proton (x, mrem/ 10^{13}) and ft of soil-equivalent shielding (y)						
$y = a - b \cdot \log(x)$						
				Conditions		
				Magnet	Pipe	Buried
Constants				In Encl.	In Encl.	pipe
a				13.411	10.403	14.76
b				2.99	2.894	3.009
No interlocked detectors						
Reference case	D	x(mr/10^{13})=		Soil-equivalent shielding (ft)		
	(mr/hr)	D/120				
No occupancy limit	1	0.008		19.6	16.4	21.0
Minimal occupancy	10	0.083		16.6	13.5	18.0
Signs and ropes	100	0.833		13.6	10.6	15.0
Signs, fences, locked gates	500	4.167		11.6	8.6	12.9
Signs, fences, interlocked gates	1000	8.333		10.7	7.7	12.0
Interlocked detectors						
Reference case	D	x(mr/10^{13})=		Soil-equivalent shielding (ft)		
	(mr)	D/2				
No occupancy limit	0.25	0.125		16.1	13.0	17.5
Minimal occupancy	2.5	1.25		13.1	10.1	14.5
Signs and ropes, min. occ.	10	5		11.3	8.4	12.7
Signs, fences, locked gates	50	25		9.2	6.4	10.6
Signs, fences, interlocked gates	100	50		8.3	5.5	9.6
8' high fences	250	125		7.1	4.3	8.5

Booster Shielding/MI era

Scaling rules:							
Ft of shielding for x10 attenuation (8 GeV):					2.95		
					Soil-equivalents, in feet		
Reference 1:	Energy	Intensity	Rate	Current	Magnet	Pipe	Buried
No occupancy limit	(GeV)	(prot/cy)	(cy/hr)	(prot/hr)	In Encl.	In Encl.	pipe
D<1	8	2E+13	60	1.2E+15	19.6	16.4	21.0
Scaled case:							
Booster:							
extraction areas, and extraction beam lines	8	5E+12	11400	5.7E+16	24.6	21.4	26.0
					Soil-equivalents, in feet		
Reference 2:	Energy	Intensity	Rate	Current	Magnet	Pipe	Buried
Minimal Occupancy	(GeV)	(prot/cy)	(cy/hr)	(prot/hr)	In Encl.	In Encl.	pipe
1<D<10	8	2E+13	60	1.2E+15	16.6	13.5	18.0
Scaled case:							
Booster:							
extraction areas, and extraction beam lines	8	5E+12	11400	5.7E+16	21.6	18.5	23.0
					Soil-equivalents, in feet		
Reference 3:	Energy	Intensity	Rate	Current	Magnet	Pipe	Buried
Signs and ropes	(GeV)	(prot/cy)	(cy/hr)	(prot/hr)	In Encl.	In Encl.	pipe
10<D<100	8	2E+13	60	1.2E+15	13.6	10.6	15.0
Scaled case:							
Booster:							
extraction areas, and extraction beam lines	8	5E+12	11400	5.7E+16	18.6	15.6	19.9
					Soil-equivalents, in feet		
Reference 4:	Energy	Intensity	Rate	Current	Magnet	Pipe	Buried
Signs, fences, locked gates	(GeV)	(prot/cy)	(cy/hr)	(prot/hr)	In Encl.	In Encl.	pipe
100<D<500	8	2E+13	60	1.2E+15	11.6	8.6	12.9
Scaled case:							
Booster:							
extraction areas, and extraction beam lines	8	5E+12	11400	5.7E+16	16.5	13.6	17.8

Booster Shielding/Mi era

					Soil-equivalents, in feet		
	Energy	Intensity	Rate	Current	Magnet	Pipe	Buried
	(GeV)	(prot/cy)	(cy/hr)	(prot/hr)	In Encl.	In Encl.	pipe
Reference 5:							
Signs, fences, interlocked gates	8	2E+13	60	1.2E+15	10.7	7.7	12.0
500<D<1000							
Scaled case:							
Booster:							
extraction areas, and extraction beam lines	8	5E+12	11400	5.7E+16	15.6	12.7	16.9
	Energy	Intensity			Soil-equivalents, in feet		
	(GeV)	(prot/cy)			Magnet	Pipe	Buried
					In Encl.	In Encl.	pipe
Reference 6:							
No occup. limit, interlocked detectors	8	2E+13			16.1	13.0	17.5
D<0.25							
Scaled case:							
Booster:							
extraction areas, and extraction beam lines	8	5E+12			14.3	11.2	15.7
	Energy	Intensity			Magnet	Pipe	Buried
	(GeV)	(prot/cy)			In Encl.	In Encl.	pipe
Reference 7:							
Minimal occup., interlocked detectors	8	2E+13			13.1	10.1	14.5
0.25<D<2.5							
Scaled case:							
Booster:							
extraction areas, and extraction beam lines	8	5E+12			11.3	8.3	12.7
	Energy	Intensity			Soil-equivalents, in feet		
	(GeV)	(prot/cy)			Magnet	Pipe	Buried
					In Encl.	In Encl.	pipe
Reference 8:							
Minimal occup., signs and ropes, interlocked	8	2E+13			11.3	8.4	12.7

Booster Shielding/MI era

detectors								
2.5<D<10								
Scaled case:								
Booster:								
extraction areas, and extraction beam lines	8	5E+12			9.5	6.6	10.9	
					Soil-equivalents, in feet			
	Energy (GeV)	Intensity (prot/cy)			Magnet In Encl.	Pipe In Encl.	Buried pipe	
Reference 9:								
Signs, fences								
Locked gates	8	2E+13			9.2	6.4	10.6	
Interlocked detectors								
10<D<50								
Scaled case:								
Booster:								
extraction areas, and extraction beam lines	8	5E+12			7.5	4.6	8.8	
					Soil-equivalents, in feet			
	Energy (GeV)	Intensity (prot/cy)			Magnet In Encl.	Pipe In Encl.	Buried pipe	
Reference 10:								
Signs, fences	8	2E+13			8.3	5.5	9.6	
Interlocked gates								
Interlocked detectors								
50<D<100								
Scaled case:								
Booster:								
extraction areas, and extraction beam lines	8	5E+12			6.6	3.7	7.9	
					Soil-equivalents, in feet			
Reference 11:	Energy (GeV)	Intensity (prot/cy)			Magnet In Encl.	Pipe In Encl.	Buried pipe	
8 ft high fences etc.,etc								
Interlocked detectors	8	2E+13			7.1	4.3	8.5	
100<D<250								
Scaled case:								
Booster:								
extraction areas, and extraction beam lines	8	5E+12			5.4	2.6	6.7	