Fermilab

TM-623
0450.000

RADIATION LEVELS IN THE FERMILAB MAIN RING ENCLOSURE DURING ACCELERATOR OPERATION

by

J. H. McCrary and D. D. Jovanovic

November 11, 1975

On November 8, 1974, one hundred film badges* were exposed in the "D" sector of the Fermilab main ring during ten hours of accelerator operation at 300 GeV. The purposes of these measurements were:

1. to obtain an estimate of the radiation level in the main ring during accelerator operation,
2. to correlate beam-on radiation levels with beam-off residual radioactivity, and
3. to determine the relative radiation intensity as a function of position downstream from a proton loss point.

D sector was selected as the site for these measurements because of the proton beam abort device located in the D-0 straight section and also because of the relatively isolated proton loss point at D-17. The abort target is essentially a series of beam stops located radially outward onto which a small amount of beam (1 or 2%) is dumped at the end of slow spill extraction. Most of the protons lost at this point have the maximum energy, 300 GeV. No details are available concerning the D-17 loss point. Figure 1 is a portion of the main ring rover (1) strip chart showing the radiation intensity from residual radioactivity in part of D sector at 9:40 a.m. on November 7. The proton beam was turned off the preceding midnight.

The film badges were clipped onto the cable tray ($\sim$ 3 feet above the beam line) at 25-foot intervals beginning at the D-C sector gate. The one-hundredth badge was

---

*Landauer holders, each containing one packet of Kodak Type 2 β,γ film and one packet of Kodak Neutron Monitoring film Type A.

located above the D-36 quadrupole magnet. The badges were put in place shortly before noon on November 7, 12 hours after the main ring beam had been turned off. At each badge position the ambient radiation level from residual radioactivity was measured and recorded. These ambient radiation levels are plotted in Figure 2. Proton acceleration began in the main ring at 11:30 p.m. on November 7 and continued until 9:45 a.m. on November 8 at which time the badges were retrieved. During this 10¼ hour exposure period approximately 2×10^{16} protons were accelerated in the main ring. Of the order of 5×10^{14} of these protons were lost in the D-0 abort device. The mean intensity in the main ring beam was 5×10^{12} protons per pulse.

The badges were processed by R. S. Landauer, Jr. and Company. The results are listed in Table 1 along with the ambient (beam-off) intensities. It should be pointed out that the ambient intensities are in units of mR/hr as measured with a geiger counter. The beam-on doses are in units of mrem absorbed during the exposure period. Doses greater than 100 rem of β,γ were not reported by Landauer. Neutron films which received more than 4 rem of β,γ also could not be read. The beam-on β,γ doses are plotted in Figure 2 in units of mrem/hr. (measured dose divided by ten). Much of the beam-on data was lost due to saturation of the film caused by the long exposure. The most important feature of Figure 2 is the similarity in the shapes of the ambient and the beam-on β,γ intensities. Even the "fine structure" within the broad peaks is reproduced in both plots. This is a remarkable result considering the complexity of the nuclear reactions, cascades, and decays which lead to the emission of both the prompt and the delayed radiations.

It has been noted that the radiation intensity at positions downstream from a proton loss point decreases exponentially with the distance from the loss point (2). Figures 1 and 2 exhibit this behavior downstream from the D-0 and from the D-17 loss points. Over distances approaching 200 meters the intensity can be accurately described by the equation:

$$I/I_0 = \exp(-mx) \qquad (1)$$

where I/I_0 is the decrease in radiation intensity over the distance x. The slope (m) of the curves in Figure 2 is nearly the same for both beam-on and beam-off conditions. It was found empirically to be 0.033 m^{-1}, which means that the radiation intensity decreases by a factor of two in 21 meters.

The following conclusions were made as a result of these measurements.

1. Radiation levels in the main ring enclosure with beam-on range from a few mR/hr to perhaps 1000 R/hr at high loss points.

2. The beam-on β,γ intensity is higher than the ambient residual radioactivity levels by a factor of 10^3 to 10^4. The neutron intensity exceeds that of the beam-on β,γ radiation by a factor of about 5.

3. The beam-on radiation pattern closely resembles that of the residual radioactivity even over distances as short as 10 meters. Large variations in the residual radioactivity along the accelerator tunnel replicate the actual radiation field during beam-on operation.

4. The loss pattern is stable and prevails over long periods (months); otherwise the beam-on and beam-off results would not be so strongly correlated. The ambient activity is related to the long-term history of accelerator operation.

5. Downstream from a loss point the radiation intensity decreases exponentially with distance with a half-length of 21 meters.

REFERENCES

1. R. E. Shafer and D. D. Jovanovic, IEEE Trans. Nuc. Sci. NS-20, 499 (1973).

2. J. Ranft, Paticle Accelerator 3, 129 (1972).

TABLE 1

Film Badge Position	Film Badge Number	Ambient Radiation mR/hr	Total Beam-On Dose mrem	
			β,γ	Fast Neutrons
1	3806	0.2	1,300	6,770
2	3959	1.0	8,260	-
3	3868	1.0	4,620	11,680
4	3891	1.5	12,350	-
5	3937	2.5	25,610	-
6	3934	3.5	65,000	-
7	3601	50	-	-
8	3770	25	-	-
9	3943	20	-	-
10	3803	18	-	-
11	3913	15	-	-
12	3740	16	-	-
13	3932	9	-	-
14	3619	5	-	-
15	3747	5	-	-
16	3582	3	-	-
17	3921	2.5	-	-
18	3735	3	-	-
19	3751	2	-	-
20	3598	1.5	-	-
21	3947	1.0	-	-
22	3650	1.5	-	-
23	3927	1.0	-	-
24	3896	1.0	-	-
25	3741	.5	-	-
26	3592	.4	12,488	-
27	3704	.4	54,340	-
28	3572	.4	37,700	-
29	3762	.2	16,380	-
30	3955	.15	15,990	-
31	3946	7.0	-	-
32	3914	.7	62,400	-
33	3597	.15	14,040	-
34	3949	.1	11,570	-
35	3754	.2	8,260	-
36	3672	.35	7,250	-
37	3804	1.0	13,000	-
38	3847	10	-	-
39	3706	6	-	-
40	3655	4	-	-
41	3611	1.5	-	-
42	3763	1.5	-	-
43	3928	1.5	-	-
44	3808	1.0	-	-
45	3938	1.0	98,150	-
46	3641	.8	75,400	-
47	3756	.7	59,670	-
48	3569	.5	40,950	-
49	3550	.4	30,550	-
50	3935	.2	29,120	-

Table 1 Cont'd

51	3911	.4	23,270	-
52	3910	.1	14,430	-
53	3922	.1	12,680	-
54	3659	.25	14,430	-
55	3761	2.0	56,160	-
56	3952	.6	7,670	-
57	3888	.4	6,730	-
58	3945	.1	2,860	18,060
59	3903	.2	2,930	20,650
60	3856	.1	890	2,070
61	3807	.1	1,720	4,700
62	3936	.25	16,250	-
63	3898	1.0	16,380	-
64	3892	.2	4,290	-
65	3871	.2	7,670	-
66	3594	.1	3,170	14,650
67	3864	.1	2,000	17,020
68	3768	.05	1,820	14,190
69	3912	.05	4,510	-
70	3954	.05	750	3,120
71	3855	.05	430	2,080
72	3688	.05	250	1,290
73	3852	.05	340	980
74	3749	.05	280	720
75	3890	.05	310	1,900
76	3887	.1	610	2,980
77	3745	.15	3,060	12,170
78	3953	.35	3,890	-
79	3615	.15	2,910	13,800
80	3916	.15	1,140	13,530
81	3771	.1	3,060	4,130
82	3951	.05	450	2,050
83	3930	.05	330	1,090
84	3846	.05	380	2,450
85	3743	.05	750	1,710
86	3909	.05	520	2,320
87	3483	.05	150	550
88	3484	.05	140	520
89	3798	.05	100	460
90	3958	.05	640	4,060
91	3899	.05	180	1,330
92	3907	.05	100	440
93	3769	.05	80	260
94	3750	.05	70	280
95	3635	.05	50	120
96	3744	.05	40	120
97	3950	.05	50	210
98	3648	.05	110	500
99	3843	.05	50	260
100	3642	.05	190	400

FIGURE CAPTIONS

Figure 1: Portion of the main ring rover strip chart taken in D sector at 9:40 a.m. on 11/7/74.

Figure 2: Plots of residual radioactivity in mr/hr and of beam-on β,γ dose in mrem/hr vs. film badge position.

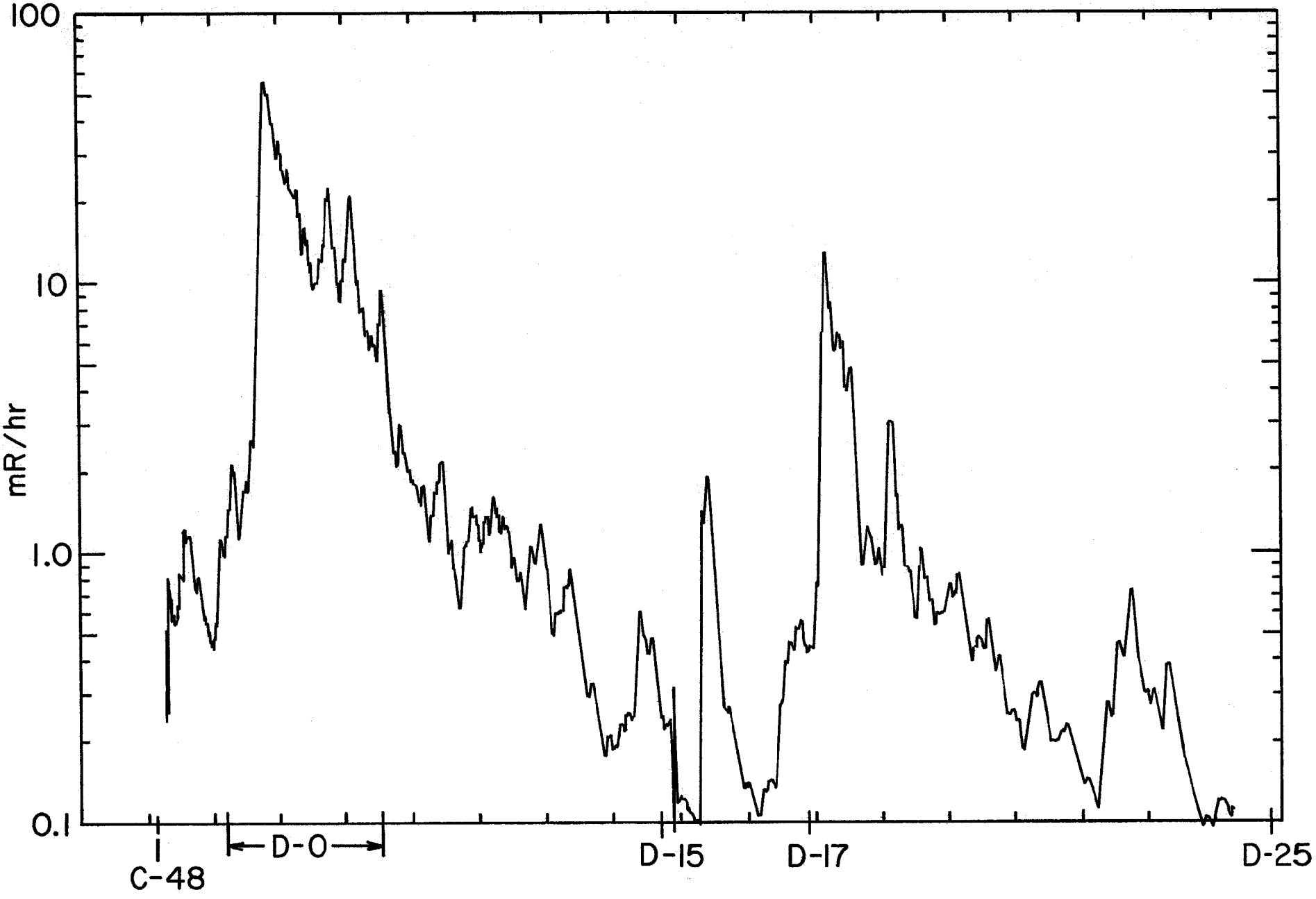
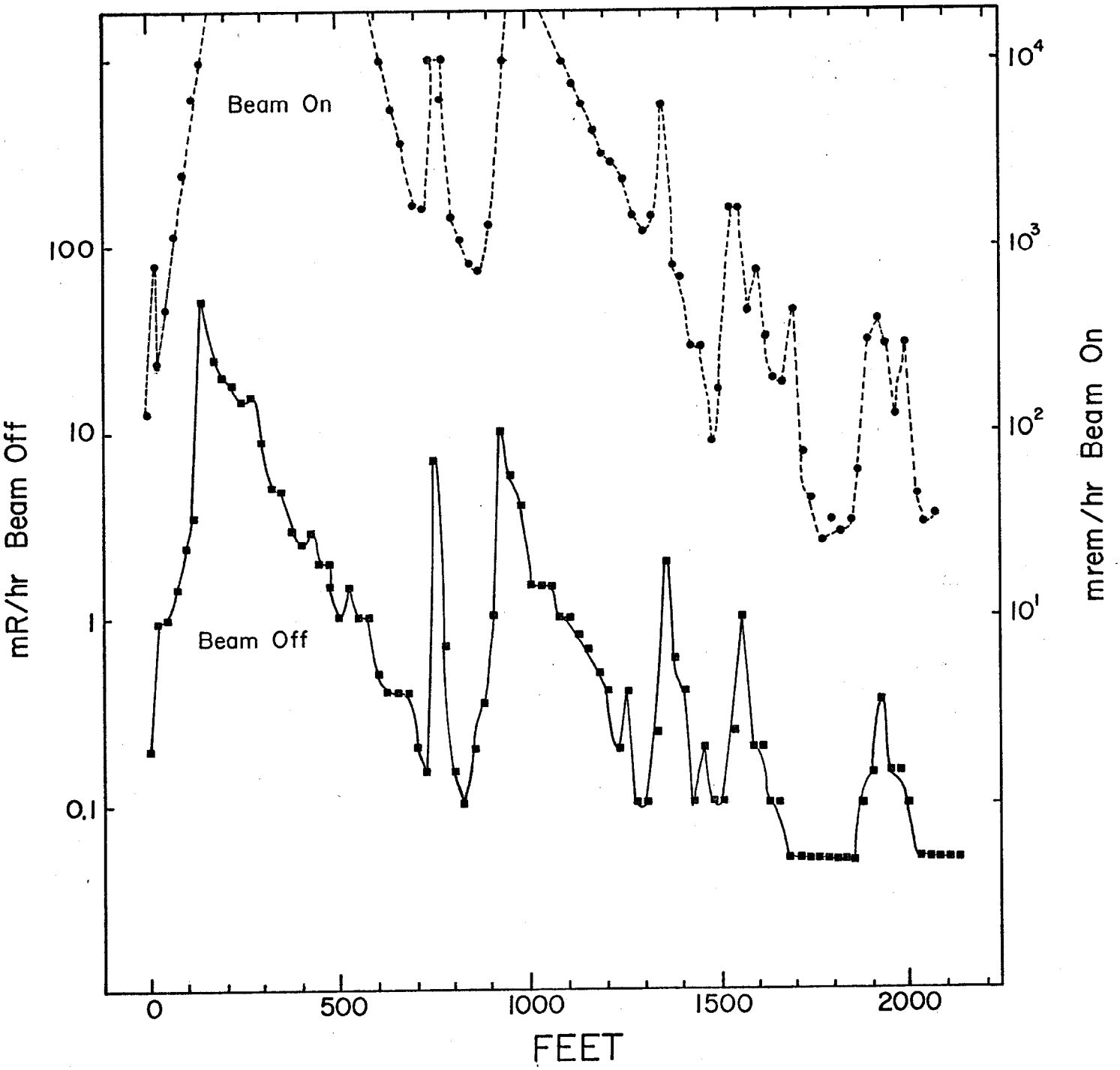


FIGURE 1

Figure 2


Beam On
Beam Off
100
10
1
0.1
mR/hr Beam Off
10^4
10^3
10^2
10^1
mrem/hr Beam On
0
500
1000
1500
2000
FEET