national accelerator laboratory

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1101.2

LATERAL SHIELDING OF 0.2, 8 AND 200 GeV PROTON BEAMS INSIDE ACCELERATOR ENCLOSURES

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INTRODUCTION

In the process of designing beam scrapers, beam abort systems, extraction septa, etc., the need arises to estimate the required amount of lateral shielding that will lead to reasonable exposure rates in the vicinity of the device under consideration.

At NAL's request, Dr. R. G. Alsmiller's group at ORNL has made calculations useful to this end. The assumptions made, the geometry considered and the results of these calculations are described below.

Assumptions & Geometry

1. The incident protons are monoenergetic. E_i = 0.2, 3 and 200 GeV.

2. There is axial symmetry. The protons are lost uniformly in time and space along the axis of a steel cylinder. Irradiation times of 1 day, 1 month, 1 year and infinity are considered.

3. The calculations are "exact" for 0.2 GeV protons. This means that the protons interact at a point and at that

point an intranuclear cascade is calculated by a Monte Carlo method. The ensuing cascade protons and neutrons are then followed until they make interactions ("stars"). The hadron yield of each "star" is calculated again by the intranuclear cascade. This intranuclear cascade not only gives the hadron yield ($d^2N/d\Omega\, dp$), but also gives the remanent nucleus. Hence, no explicit activation cross-sections are needed in these calculations.

4. The calculations are also "exact" in the above sense, at 3 GeV. The results of the 3 GeV calculation are multiplied by (8/3) to get 8 GeV predictions. This extrapolation may be somewhat crude but it is the best available right now. Extrapolating the 3 GeV results to 200 GeV by this method one gets "good" agreement with the 200 GeV calculation. "Good" means

(200 GeV/3 GeV) = 1.33×10^2

(Expos. Rate, 200 GeV)/(Expos. Rate, 3 GeV) = 1.1×10^2.

5. The basis of calculations are less satisfactory at 200 GeV. For this calculation Ranft's version of the Trilling formula is used to predict the hadron yield for all energies down to 100 MeV. No good evidence exists to believe that the low end of the momentum spectrum or the large angle yields are accurate. Protons and pions are neglected. When the secondary neutron energy becomes 3 GeV or less, the yield from the "stars" is calculated using an intranuclear cascade calculation.

Ranft's yield formula is normalized in a conservative way.

The rule that the total number of stars be equal to $2E_i$ (GeV) is used and equated only to those stars created by neutrons with $E>3$ GeV, and $\theta<3$ degrees.

6. The calculation of "star" formation is terminated when the neutron energy becomes less than 25 MeV since the activation cross-sections become very small.

7. The exposure rate is calculated using a Monte Carlo photon transport code.

Results

The unit for exposure rate is the (roentgen/hr). The (rem/hr) is to be used for absorbed dose rates with all necessary correction factors included. It is wrong to talk about exposure rates and use the (rem/hr) as a unit. Here the understanding is that for given geometry a person would absorb dose at the given rate.

The results are given in four figures.

Figures 1-3 give the exposure rate in (rem/hr) per (p/cm sec), after a "cooling" time of 1 hour and infinitely long irradiation times.

The solid lines give exposure rates on contact with the iron cylinder. The dashed lines are extrapolations to larger distances from the axis using a (1/R) dependence.

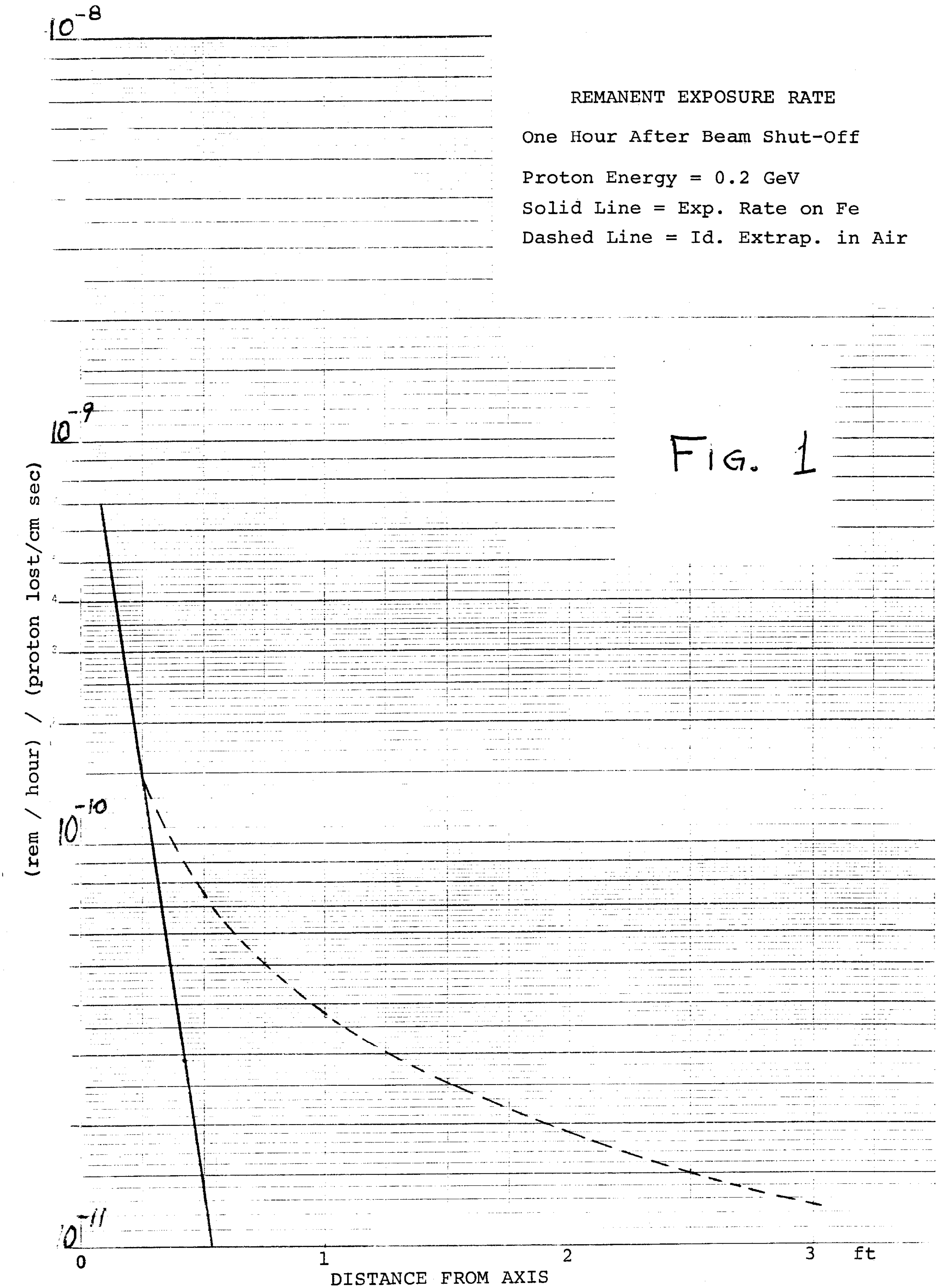
Figure 4 gives cooling-off curves for 0.2 and 3 GeV incident energy protons. The 3 GeV curve is to be used for the 8 and 200 GeV cases.

References

[1] T. W. Armstrong and J. Barish, ORNL-TM-2583 (May 2, 1969).

[2] T. W. Armstrong and R. G. Alsmiller, ORNL-TM-2498, (February 10, 1969).

[3] H. C. Claiborne and D. K. Trubey, ORNL-TM-2574, (April 28, 1969).


REMANENT EXPOSURE RATE
One Hour After Beam Shut-Off
Proton Energy = 0.2 GeV
Solid Line = Exp. Rate on Fe
Dashed Line = Id. Extrap. in Air
Fig. 1
(rem / hour) / (proton lost/cm sec)
10^-8
10^-9
10^-10
10^-11
0
1
2
3
ft
DISTANCE FROM AXIS

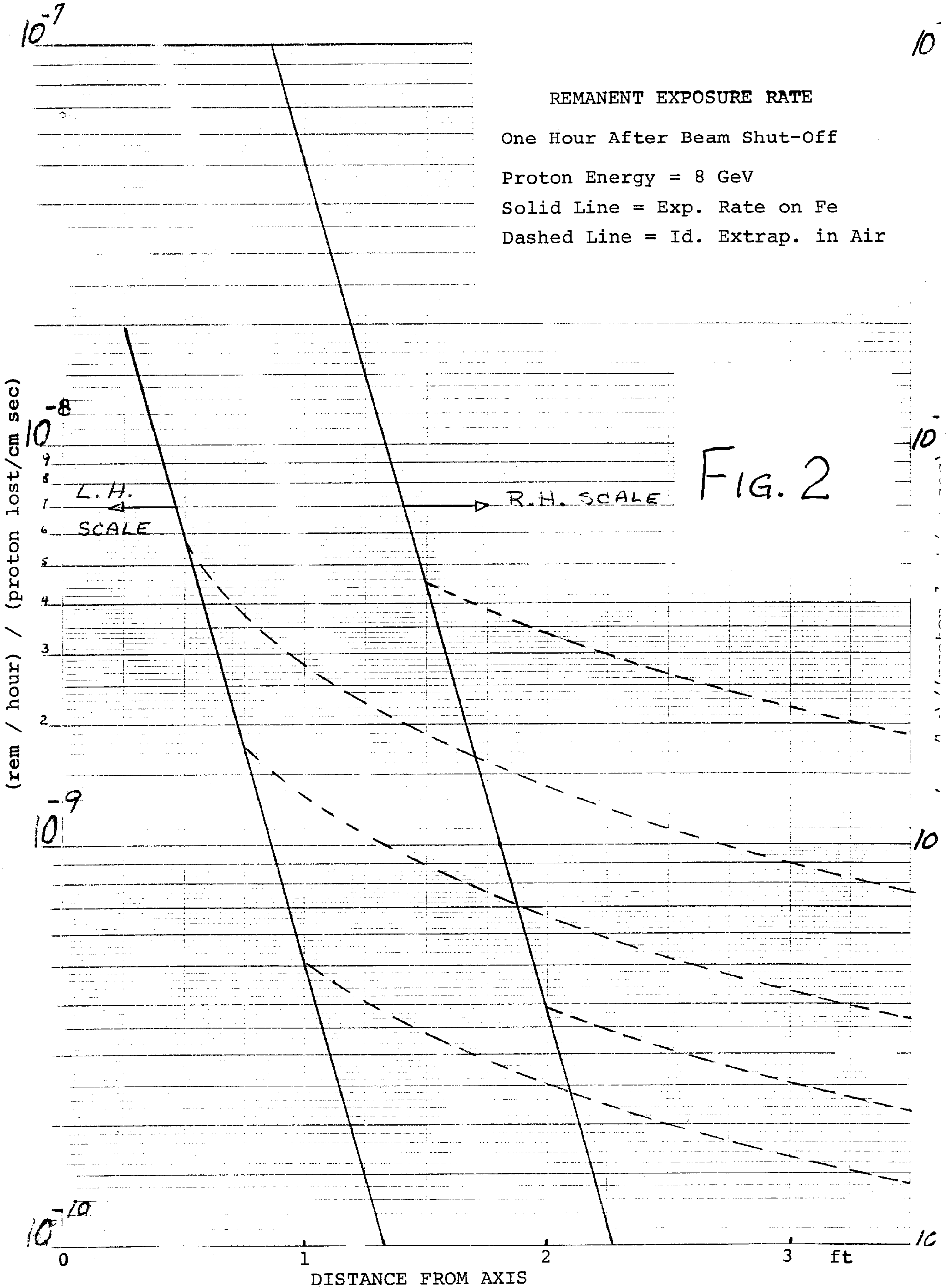
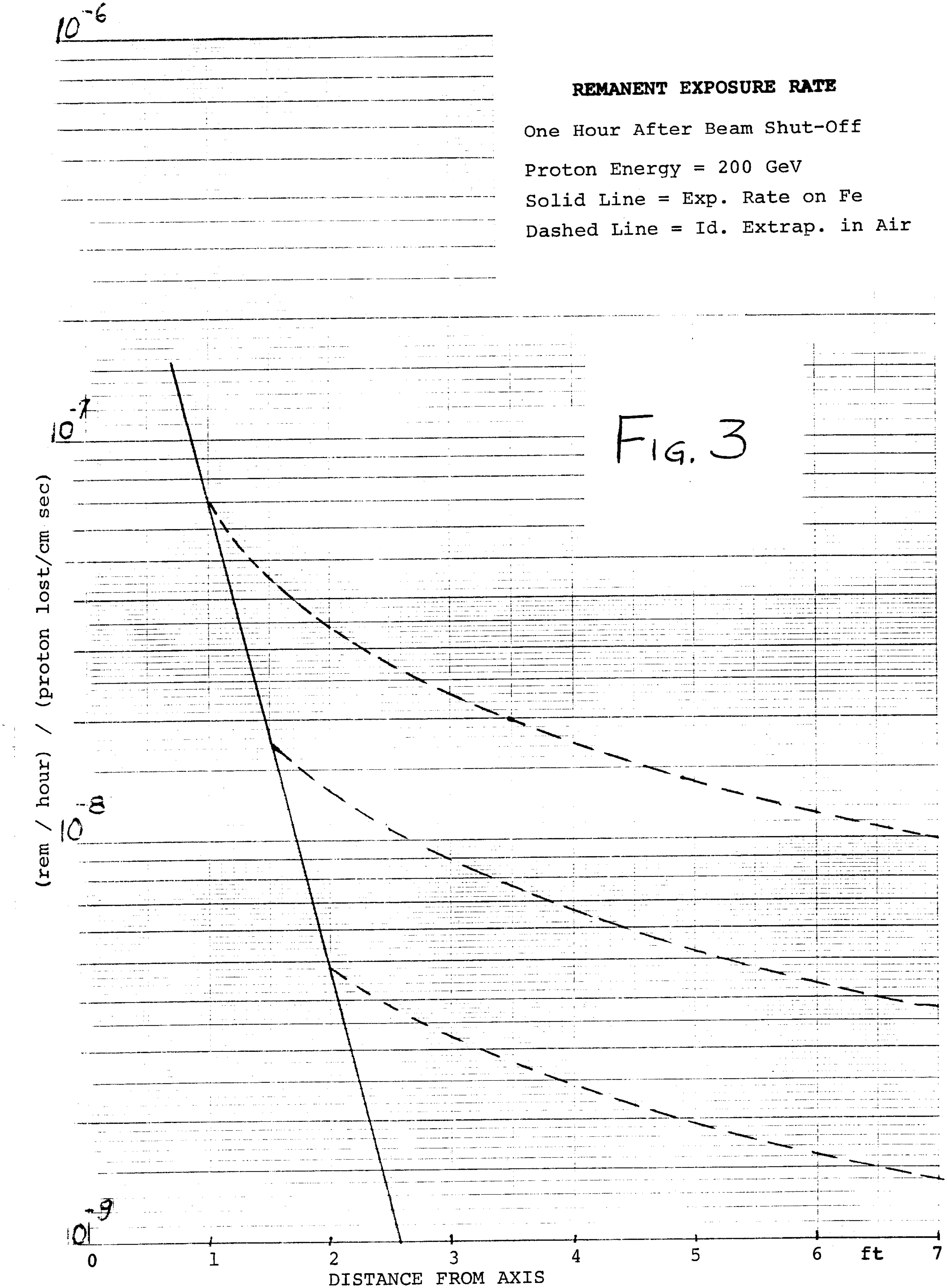

REMANENT EXPOSURE RATE
One Hour After Beam Shut-Off
Proton Energy = 8 GeV
Solid Line = Exp. Rate on Fe
Dashed Line = Id. Extrap. in Air
L.H. SCALE
R.H. SCALE
(rem / hour) / (proton lost/cm sec)
DISTANCE FROM AXIS
0
1
2
3
ft
10^{-7}
10^{-8}
10^{-9}
10^{-10}

FIG. 2



REMANENT EXPOSURE RATE
One Hour After Beam Shut-Off
Proton Energy = 200 GeV
Solid Line = Exp. Rate on Fe
Dashed Line = Id. Extrap. in Air
FIG. 3
(rem / hour) / (proton lost/cm sec)
10^-6
10^-7
10^-8
10^-9
0
1
2
3
4
5
6
ft
7
DISTANCE FROM AXIS

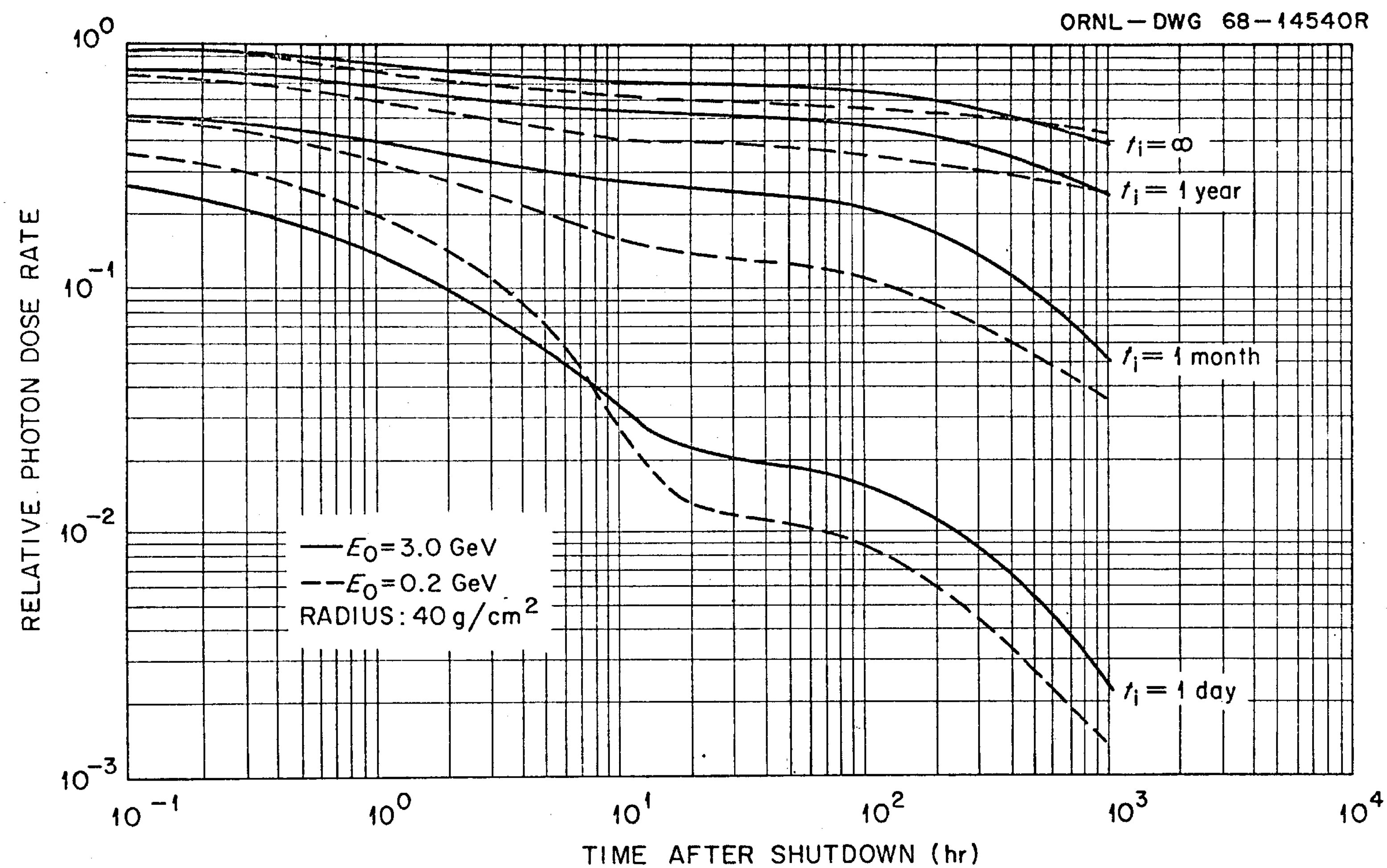


FIGURE 4. t_i = Irradiation Time