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COCKPIT AIR FILTRATION REQUIREMENTS OF THE B-1 IN A NUCLEAR DUST ENVIRONMENT

Rayford P. Patrick, et al

Air Force Weapons Laboratory
Kirtland Air Force Base, New Mexico

July 1973

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AIR FORCE WEAPONS LABORATORY
Air Force Systems Command
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Results are presented which will aid in determining cockpit filtration requirements for the B-1 Environmental Control System when the B-1 penetrates radioactive dust clouds generated by surface detonations of nuclear weapons. The ionizing doses accumulated from being surrounded by the radiating cloud and the dust mass and associated ionizing doses from dust trapped in the filter and in the cockpit are presented. A technique for determining the filter point design conditions is discussed. Representative candidate filters are investigated, and an optimum filter is selected from the candidates. The evaluation techniques presented here may be used to investigate the adequacy of any proposed filter.

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FOREWORD

This research was performed under Program Element 62301F, Project 8809, Task 03.

Inclusive dates of research were July 1972 through April 1973. The report was submitted 18 May 1973 by the Air Force Weapons Laboratory Project Officer, Major Rayford P. Patrick (SAA).

This technical report has been reviewed and is approved.

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ABSTRACT

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Results are presented which will aid in determining cockpit filtration requirements for the B-1 Environmental Control System when the B-1 penetrates radioactive dust clouds generated by surface detonations of nuclear weapons. The ionizing doses accumulated from being surrounded by the radiating cloud and the dust mass and associated ionizing doses from dust trapped in the filter and in the cockpit are presented. A technique for determining the filter point design conditions is discussed. Representative candidate filters are investigated, and an optimum filter is selected from the candidates. The evaluation techniques presented here may be used to investigate the adequacy of any proposed filter.

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ABBREVIATIONS AND SYMBOLS

E_D	Relative dose effectiveness
FE(r)	Filter Efficiency
L_F	Weapon loading factor, MT/km^2
L_{F_o}	Baseline weapon loading factor, MT/km^2
$M_c(r,t)$	Cumulative mass function, gm
R	Cloud radius, km
TF	Cloud exit time, hours after detonation
TI	Cloud entry time, hours after detonation
TSF	Time scaling factor
Y	Weapon yield, MT
d	Distance, m
m_i	Element i of mass, gm
m_t	Total mass, gm
m(r,t)	Dust mass distribution function, gm/μ
r	Particle radius, μ
$\bar{r}$	Critical particle radius, μ
s_i	Distance of the ith mass element from a receiver, m
t	Time, hours after detonation
ΔT	Cloud penetration duration, min
ρ(r,t)	Dust density distribution function, gm/cm^3-μ
$\rho_o(r,t)$	Baseline dust density distribution function, gm/cm^3-μ

SECTION I

INTRODUCTION

The B-1 could be exposed to dust environments caused by nuclear weapon detonations because of its requirement to operate in a nuclear environment. This dust is contaminated by fission products and neutron-activated material and is a source of radiation dose to the air crew and sensitive electronic equipment. Because outside air must be used for pressurization and air conditioning, this radioactive dust could be introduced into the interior of the aircraft, unless completely or partially trapped by a filter. This report (1) aids in the selection of a point design condition for filter design, (2) provides information to support the selection of filter design criteria, and (3) introduces techniques for evaluation of candidate filters.

This report is directed primarily toward the filtration requirements of the cockpit air-conditioning system. A similar investigation dealing with the filtration requirements of the avionics air-conditioning system should be performed. If the B-1 Program Office requests this additional effort, it must be performed. However, this effort is less critical than the cockpit filtration analysis because electronics are less sensitive to low radiation doses than is the crew. Therefore, this report will not be delayed in order to include a complete avionics air-conditioning filtration analysis.

The primary purpose of a filter is to reduce to tolerable levels the dose to the crew and sensitive electronics from radioactive dust entering the air-conditioning system. In this regard the B-1 designer has control over three major parameters. The first is the filter location, which is important because the filter collects radioactive debris and becomes a source of radioactivity. The resulting dose to crew/electronics is inversely proportional to the square of the distance from the filter to the crew/electronics. Thus, this separation distance is of major importance. The second major factor over which the filter designer has control is filter efficiency as a function of particle size. Since all radioactive dust particles not collected by the filter will enter the cockpit and become a detrimental part of the internal cockpit environment, the filter should provide the necessary protection but should not be grossly overdesigned. Finally, the filter designer has control over the size of the filter. Therefore, he must know the amount and particle size distribution of the dust which may be collected during the mission.

As with any nuclear survivability/vulnerability analysis, one must first postulate a reasonable threat model. In this analysis the starting point is the dust densities and associated radioactivity levels calculated by W. A. Whitaker for surface detonations of relatively large nuclear weapons (ref. 1). The B-1 might be exposed to such a contaminated dust environment during flush and fly out after a massive nuclear first strike attack on the continental United States. Based upon Whitaker's data, the general hazard associated with the late-time flythrough of any aircraft through the dust clouds was examined in reference 2. The present work addresses a particular aircraft, namely the B-1.

For detailed information on cloud characteristics and the assumptions and models used in the analysis, the reader is referred to references 1 and 2. For continuity and clarity the major assumptions are outlined below.

The dust particle size-distribution function is presented in figure 1. It is a function of both time after weapon detonation and particle size, since fallout has been taken into account. Figure 2 presents the same data in terms of a dust mass distribution function rather than a particle size-distribution function. Particle activity level as a function of particle size was assumed to be proportional to r^3 for very small particles ($r < 20\mu$), and to r^2 for larger particles. This is to account for the assumption that small particles are predominately condensed bomb debris; whereas, larger particles are composed of an inert core of soil covered with a surface coating of weapon debris. The associated specific activity (the particle activity divided by particle mass) is a function of particle size and time after detonation to account for the radioactive decay of the fission fragments and neutron activited material.

Since the specific activity of the dust particles and the dust density distribution function are both functions of time after weapon detonation, one of the most important parameters in the analysis is the cloud entry time (TI) of the B-1 measured from time of weapon detonation. As might be expected the penetration duration (ΔT), which is a function of aircraft speed and the size of

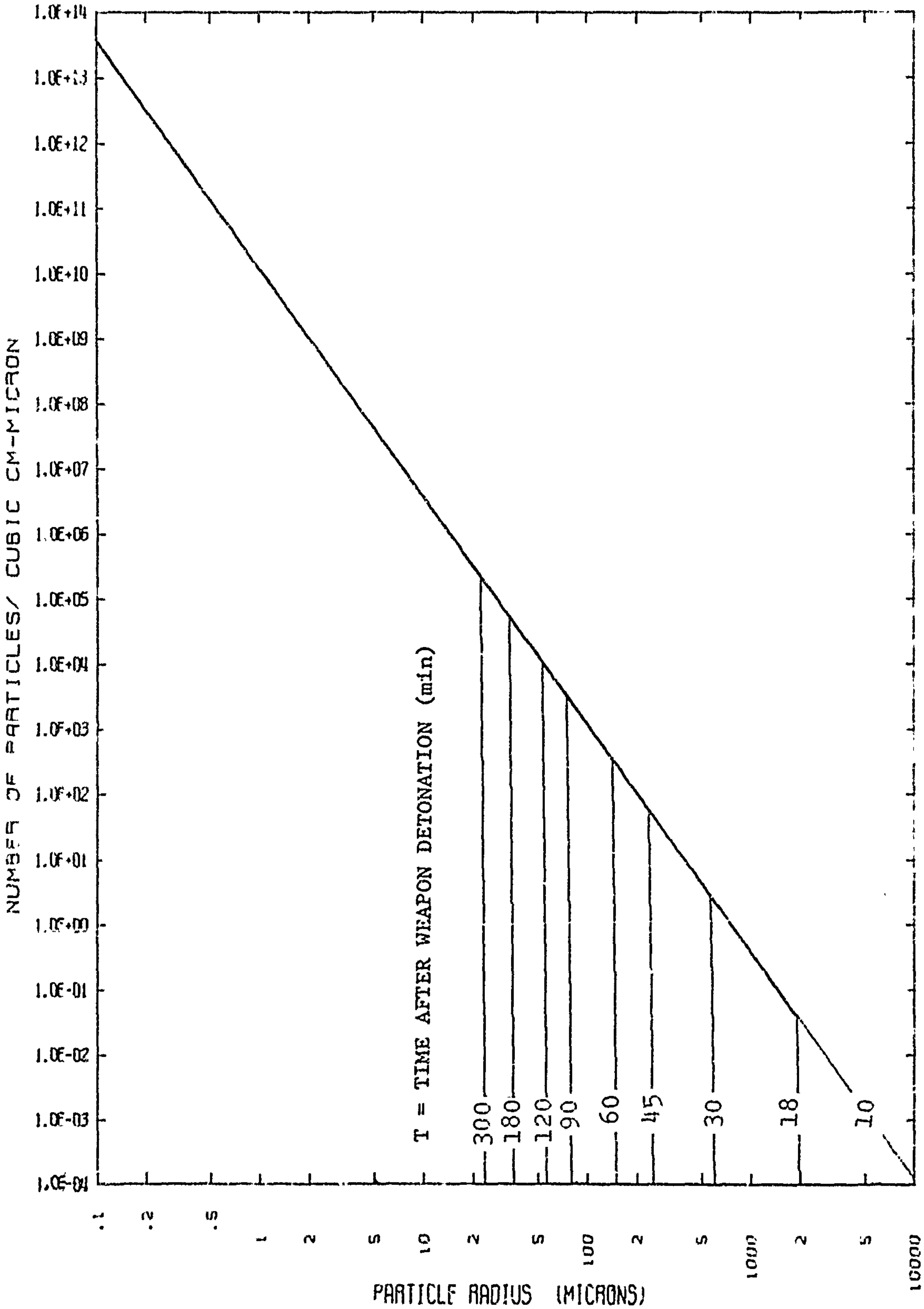

Figure 1. Particle Size Distribution Function

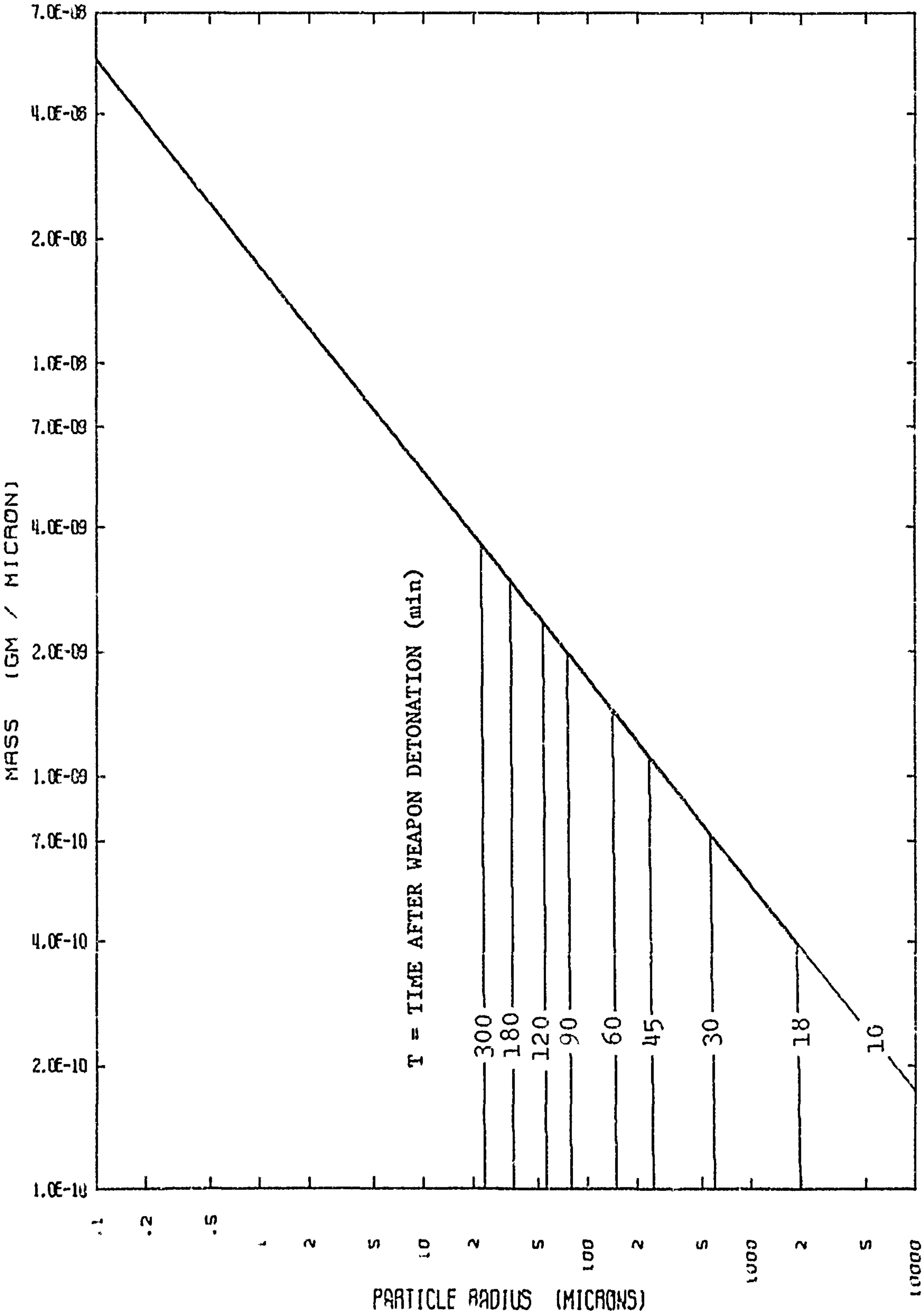

Figure 2. Particle Mass Distribution Function

the cloud, is also a parameter of major importance. Finally, any radioactive particles collected during cloud penetration which remain with the aircraft after it finally leaves the radioactive cloud (at TF = TI + ΔT) contribute to crew/electronics dose throughout the remainder of the mission.

All the dose results contained in this report are presented in units of rads (tissue) because it is primarily concerned with crew protection. The electronic equipment dose, usually presented in rads(Si), can be obtained by multiplying rads (tissue) by the factor 0.922 for the 1-Mev photons considered in this report.

Two extreme cases bearing upon the filter design are analyzed. The first involves a perfect filter, which collects all particles entering the air-conditioning system, regardless of particle size. The second is an "imperfect" filter* which allows all particles, regardless of particle size, to enter the cockpit of the aircraft. In the former case the mass of dust collected by the filter (and its distribution as a function of particle size) and the associated dose "at 1 meter" to crew/electronics are calculated as a function of the parameters, TI, TF, ΔT, and particle size. A correction factor for each crew member's actual distance, d, from the filter (which is simply the factor $[1\ \text{meter}/d\ \text{meters}]^2$) must be multiplied by the pertinent results from the figures for filter dose. In the case of the imperfect filter, the major output of the study is a cockpit dose, which is the dose to crew/electronics due to dust settling in the cockpit and on crew members. These results are also provided as a function of time and particle size and in terms of the parameters TI, TF, and ΔT. A comparison of the results of these two extreme case calculations provides information useful to the filter designer.

*The "imperfect" filter is the limit case where no filtration of the particles takes place. This corresponds to the actual situation where no filter at all is installed. This limit case is an opposite extreme to the perfect filter limiting case. These two extremes are quite useful in the analysis of a real filter.

SECTION II

POINT DESIGN SELECTION CRITERIA

Before a meaningful filter design can be analyzed, it is necessary to specify a specific dust environment to which the system is to be exposed without undue degradation in performance. This dust environment is one aspect of the specific point design condition upon which the filter design is to be based. The selection of a point design condition depends on many factors including weapon system basing, mission routing, mission profiles and time lines, allowable crew dose during the penetration, an assessment of potential nuclear threats which the B-1 fleet might encounter during a nuclear war environment, etc.

Such a selection is not made here because that is the responsibility of the B-1 System Program Office. Rather, this report provides a portion of the data upon which the selection of a suitable point design condition can be based, and the means of translating the point design condition into a detailed specification of filter design requirements. Therefore, it is necessary to relate the dust environment to specific mission and threat dependent parameters.

DUST ENVIRONMENT MODELS

Several factors should be understood at the outset which bear directly on the relation of the dust environment to specific mission and threat dependent parameters.

First, surface bursts maximize the dust environment, and for this reason they are emphasized here. Second, we restrict our attention for the dust problem to late times, i.e., aircraft cloud entry times at least 10 minutes after weapon detonation. This restriction is based primarily on the practical consideration that at early times one would be more concerned with encountering dust particles with sizes in the centimeter to meter range rather than filtering small size dust particles. Third, at these late times the major part of the detonation-induced turbulence has subsided. The dust cloud is generally localized around the burst point and has a relatively homogeneous spatial density distribution as a result of prior mixing. Finally, the effect of any spatial density gradients which exist within the cloud would be of little importance to the B-1 systems, because integral effects (e.g., total mass collected and associated dose therefrom) rather than instantaneous values (e.g., mass flow rates or dose rates) are important. Therefore, dust environment models are constructed which relate mission and threat-dependent parameters to dust density distributions.

The cornerstone of these models is the work done by Whitaker (ref. 1). This work included an analysis, based on SHELL/DUSTY computer code results, which yielded dust densities, associated activity levels, and spatial extents of dust clouds generated by large (megaton range) single and multiple surface bursts.

The threats included a single surface burst of a 4-megaton weapon and a massive simultaneous surface detonation of four hundred 5-megaton warheads distributed uniformly over a 200 x 200-km surface. The latter threat might correspond to a first strike attack on the Minuteman fields. These results were used in reference 2 to obtain dust density and activity levels in the dust cloud. In addition, a particle size dependent fallout model was developed. Conservatively, it is assumed that there is no wind to cause additional spreading and movement of the dust cloud.

From these data the following general models of the dust environment were developed. For a single burst in the megaton range we assume that the dust cloud has a height of 15 km and a cloud radius given by

$$R = 5.7Y^{0.4} \tag{1}$$

where R is in kilometers and Y is the weapon yield in megatons. For a massive simultaneous attack of megaton weapons the cloud height is also assumed to be 15 kilometers, but the spatial extent is governed predominantly by the grid size covered by the bursts. Exterior to the cloud the dust density is zero. However, interior to the cloud the average dust density distribution function is given by $\rho(r,t)$ gms/cm^3-micron, where r is particle radius in microns and t is time (hours) after weapon detonation.

This dust density distribution function is, of course, dependent on both the weapon yield and the volume of space containing the dust particles. The massive multiburst attack is selected as the baseline case, and the associated dust density distribution function is presented in figure 2. However, means of extrapolating to other conditions will now be presented. For this purpose a weapon loading factor, L_F, is introduced.

$$L_F = \frac{\text{Total Megatons of Weapon(s)}}{\text{Area of Dust Cloud in km}^2} \tag{2}$$

Defining $\rho_0(r,t)$ as the baseline dust density distribution function and L_{F_0} as the baseline weapon loading factor, we obtain the dust density distribution function, $\rho(r,t)$, for a different threat situation from

$$\rho(r,t) = \frac{L_F}{L_{F_0}} \rho_0(r,t) \tag{3}$$

where L_F is the weapon loading factor for the case of interest. For the baseline case equation (2) yields

$$L_{F_0} = \frac{400 \times 5}{200 \times 200} = 0.05 \frac{\text{MT}}{\text{km}^2} \tag{4}$$

The factor L_F/L_{F_0} can be calculated for any case of interest and is simply a scale factor applied to figure 2 and the rest of the figures in this report (excepting figure 3). The specific activity level of the dust, figure 3, is given per gram of dust, and this is not affected by the weapon loading factor.

With these data it is possible to relate the dust density distribution, imposed on the B-1 environmental control system, to the corresponding mission dependent parameters of the B-1 system for any specific threat of combination of threats. For each specific event the density scaling factor, L_F/L_{F_0}, can be calculated and applied to the presented results.

Irrespective of filter design, the crew/electronics will receive a cloud immersion dose just from being surrounded by the radioactive dust cloud. This cloud immersion dose, depicted in figure 4 for the baseline dust density distribution function, can be appreciable and should be considered in the selection of a point design condition. It does not appear prudent to select a filter point design condition at which the crew would already be in serious difficulty from a cloud immersion dose standpoint irrespective of filter design considerations.

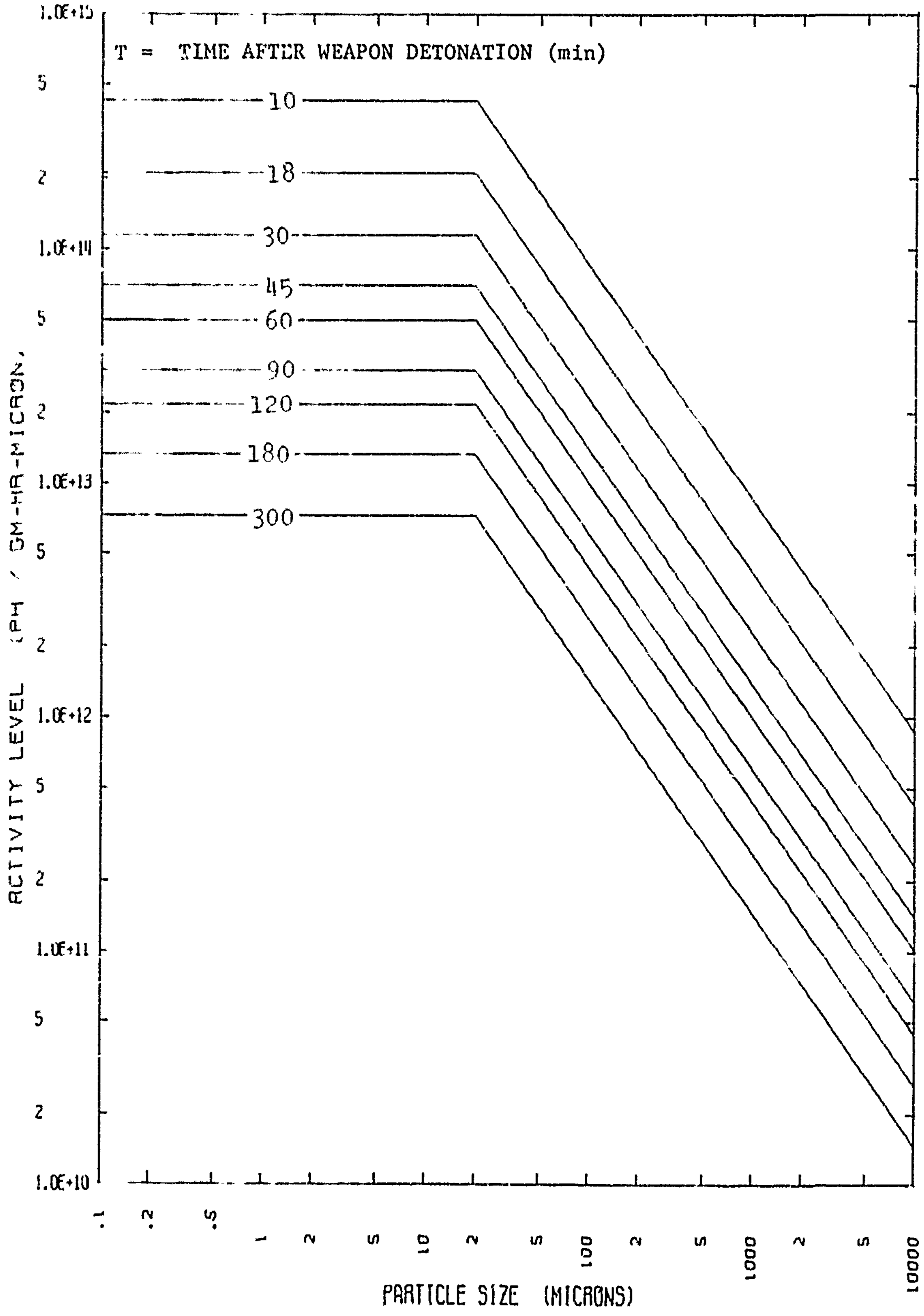

Figure 3. Specific Activity Distribution Function

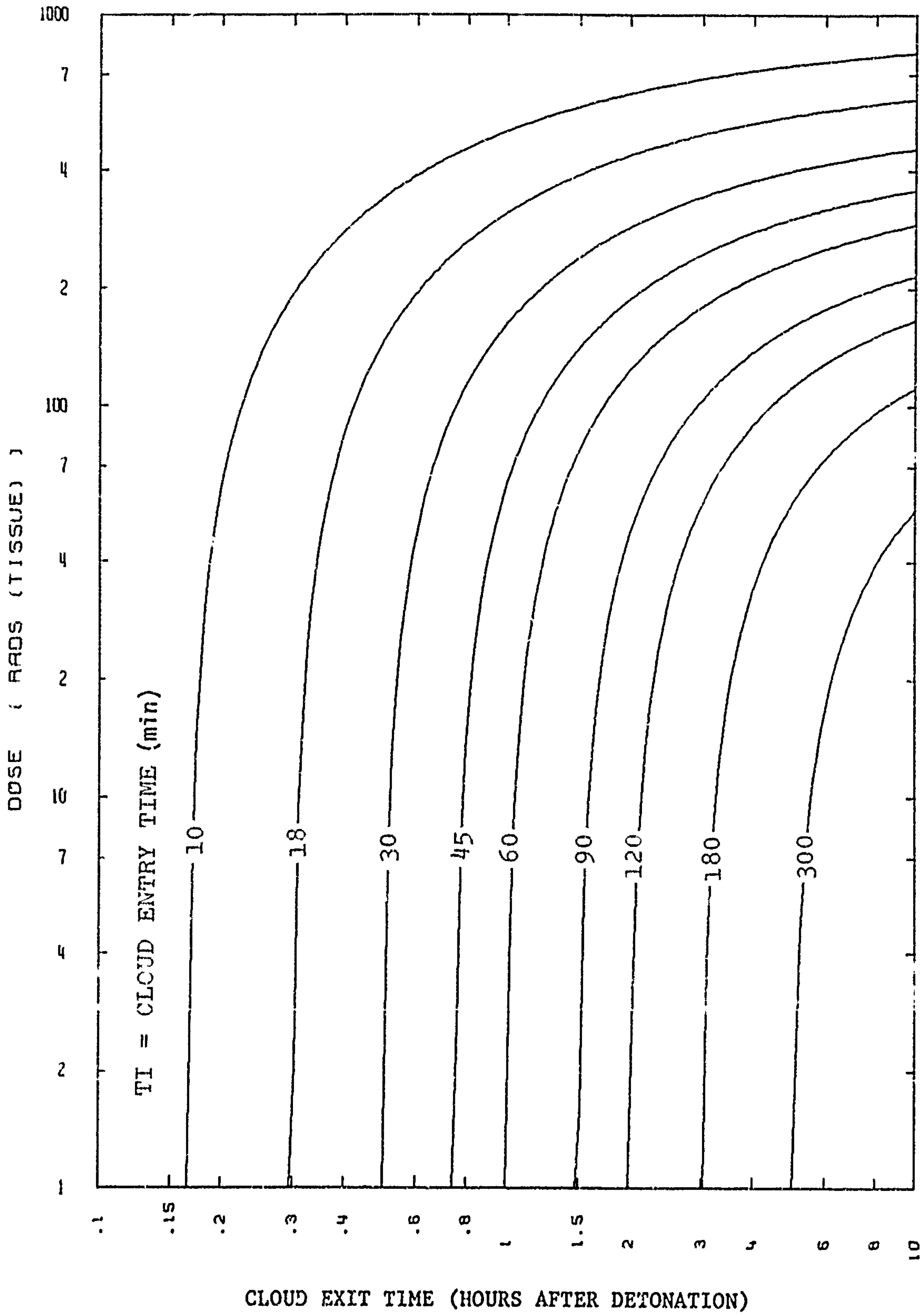

Figure 4. Cloud Immersion Dose

For purposes of presenting detailed filter design data and results, a baseline case for analysis is selected. A dust density distribution function corresponding to the massive multiburst over a 200 x 200-km square area (L_F = 0.05 MT/km^2, L_F/L_{F_0} = 1) was chosen for this purpose. The cloud entry time TI = 30 minutes after weapon detonation and, in addition, a penetration duration of ΔT = 30 minutes is selected. Thus, TF = TI + ΔT = 60 minutes. It can be noted from figure 4 that the crew would receive 150 rads (tissue) due to the cloud immersion dose for this example. For convenience we select a mission duration of 29 hours after cloud exit. These baseline numbers are used for illustrative examples throughout this report. Sufficient data are included for analysis of other cases, and appropriate scaling laws are presented and explained.

SECTION III

ANALYSIS OF LIMITING FILTER CASES

In examining the filtration requirements of the B-1 environmental control system it is instructive to analyze two extreme cases. The first case of interest is the perfect filter which collects all the dust particles, regardless of size, to which it is exposed. At the other extreme is the "imperfect" filter which collects no particles at all and allows every particle (regardless of size) entering the system to be admitted to the cockpit. These two extreme cases will be analyzed, and in the next section a comparison of the results will provide information useful for the selection of filter efficiency.

To focus the analysis on the B-1 system, certain parameters must be specified. First, the mass rate of flow of air to the B-1 environmental control system is $\dot{m}_{af}$ = 47.6 lbm/min (ref. 3)*. In addition we selected the B-1 altitude of 30,000 feet where the ambient density has the value of 4.6 x 10^{-4} gm/cm^3.

PERFECT FILTER

The model used in this analysis assumes that after cloud penetration at TI, the filter collects all ingested dust particles for the penetration duration ΔT, and when the aircraft exits the cloud at TF = TI + ΔT, no more particles are collected. Numerically integrating the outside dust distribution function (figure 2) and multiplying by the appropriate constants (ref. 2) yields information on the mass collected by the filter as a function of particle size. These results are shown in figures 5 through 13. Each graph presents the dust mass collected by the filter as a function of particle size for a particular TI and with penetration duration, ΔT, as a parameter. Each graph considers ΔTs of 2, 5, 10, 15, 30, 60, 120, and 300 minutes. These figures are for cloud entry times ranging from 10 minutes to 5 hours after weapon detonation, which should cover the range of interest for most analyses. Particle size distributions range from 0.1 micron to 10,000 microns radius. A comparison of figure 5 for a

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*We have chosen a worst-case air flow rate. Results for other flow rates can be obtained by scaling the results in this report by $\dot{m}_{af}$/47.6.

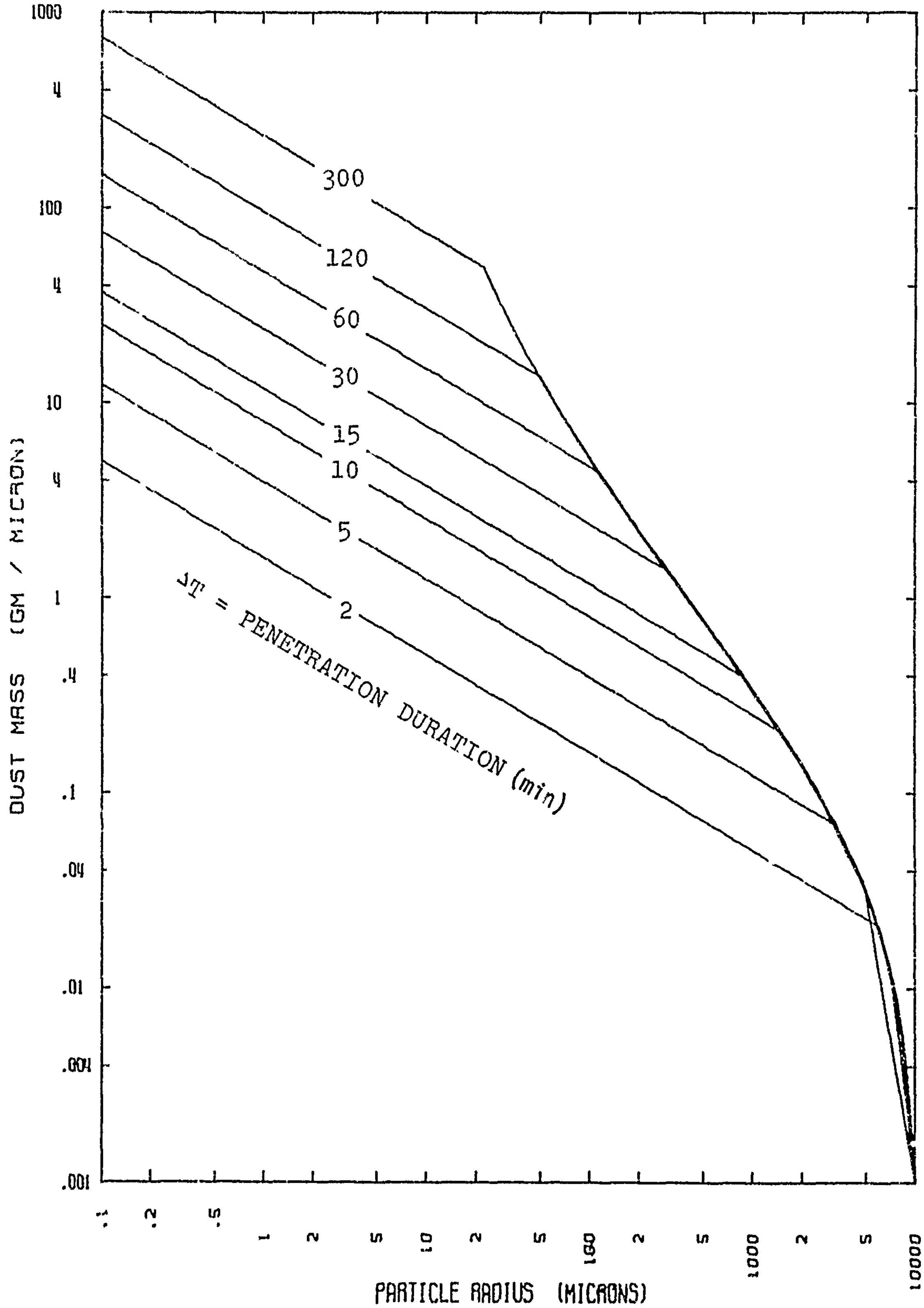

Figure 5. Perfect Filter Mass Distribution Function, TI = 10 Minutes

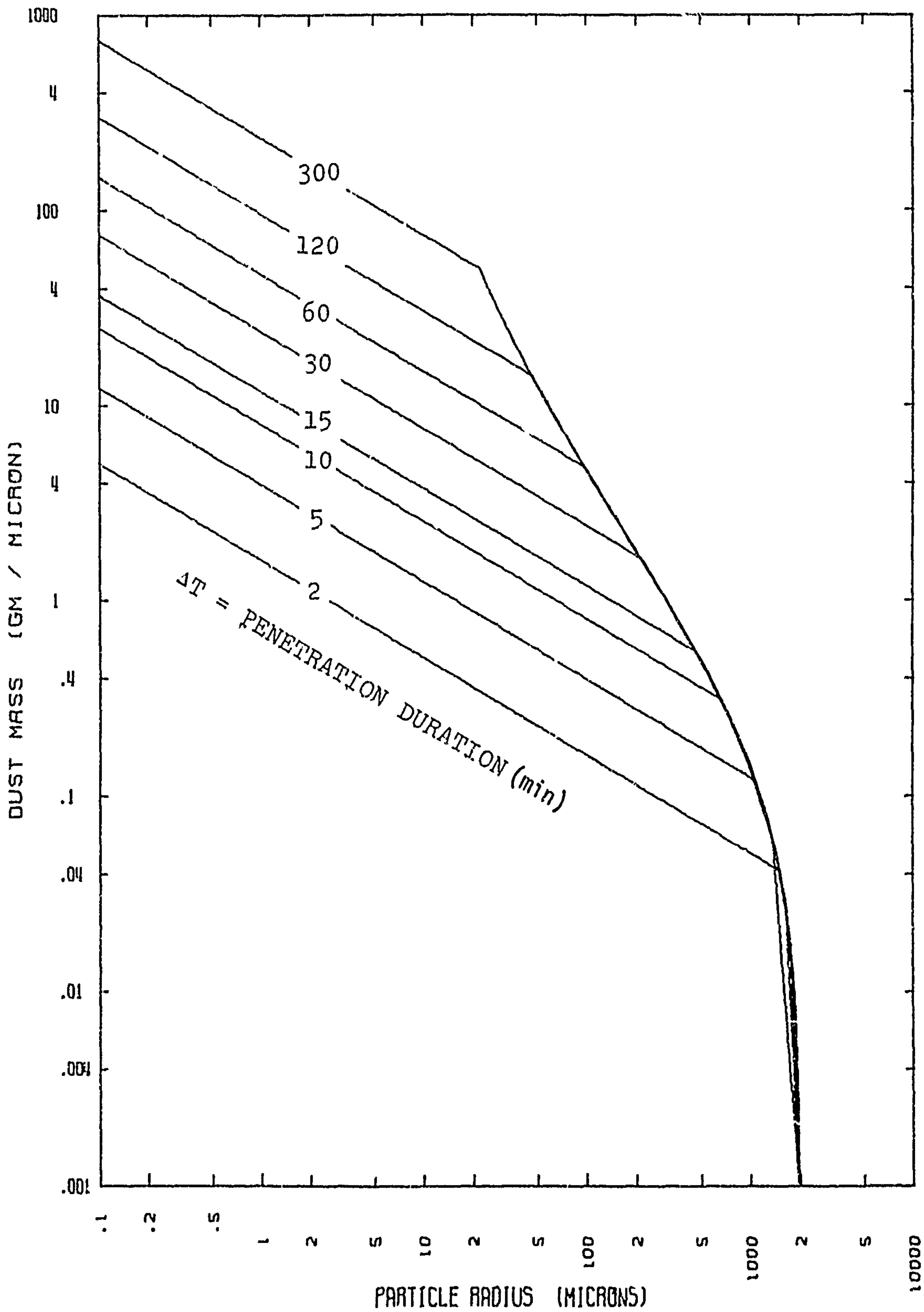

Figure 6. Perfect Filter Mass Distribution Function, TI = 18 Minutes

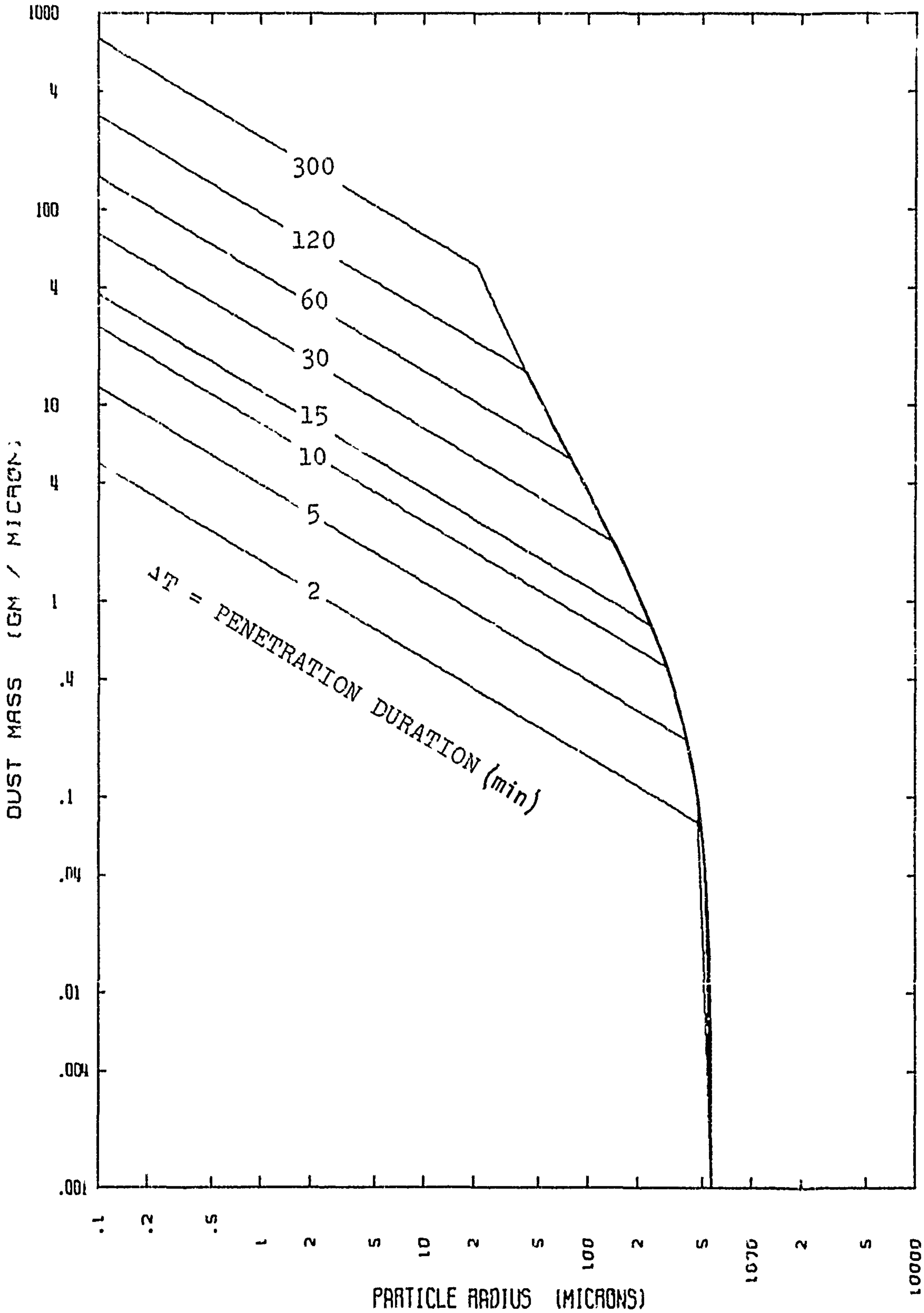

Figure 7. Perfect Filter Mass Distribution Function,
TI = 30 Minutes

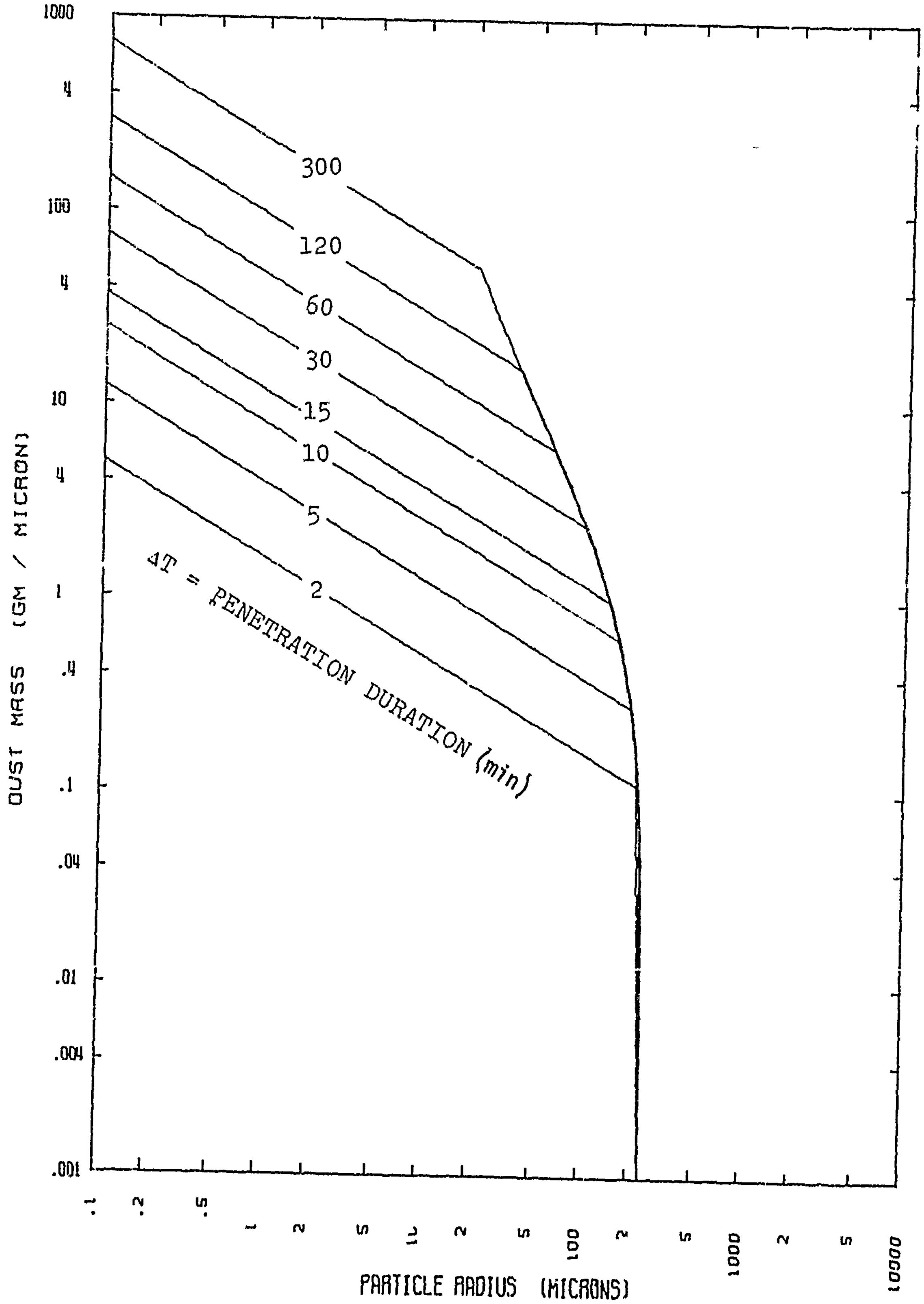

Figure 8. Perfect Filter Mass Distribution Function, TI = 45 Minutes

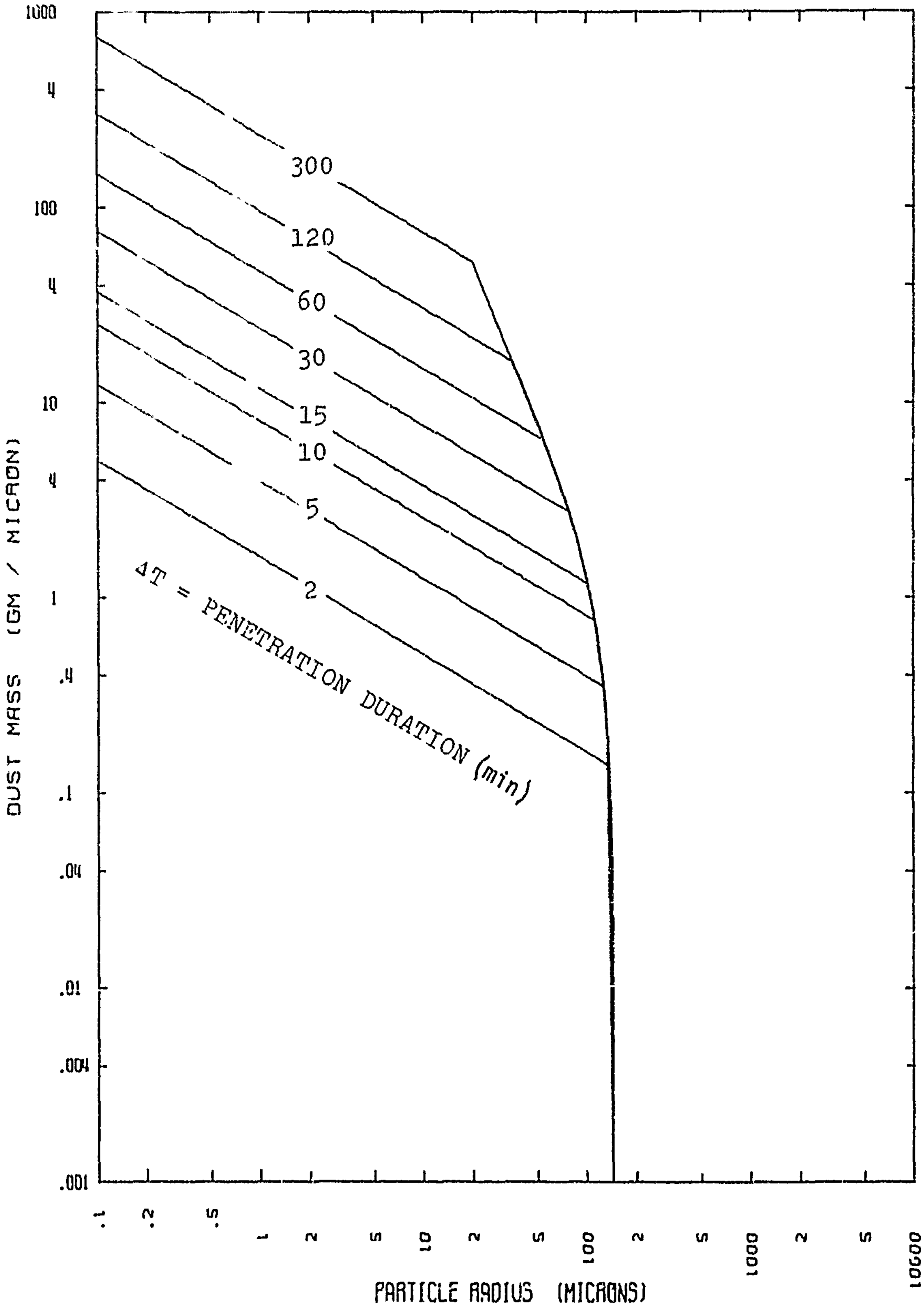

Figure 9. Perfect Filter Mass Distribution Function, TI = 1 Hour

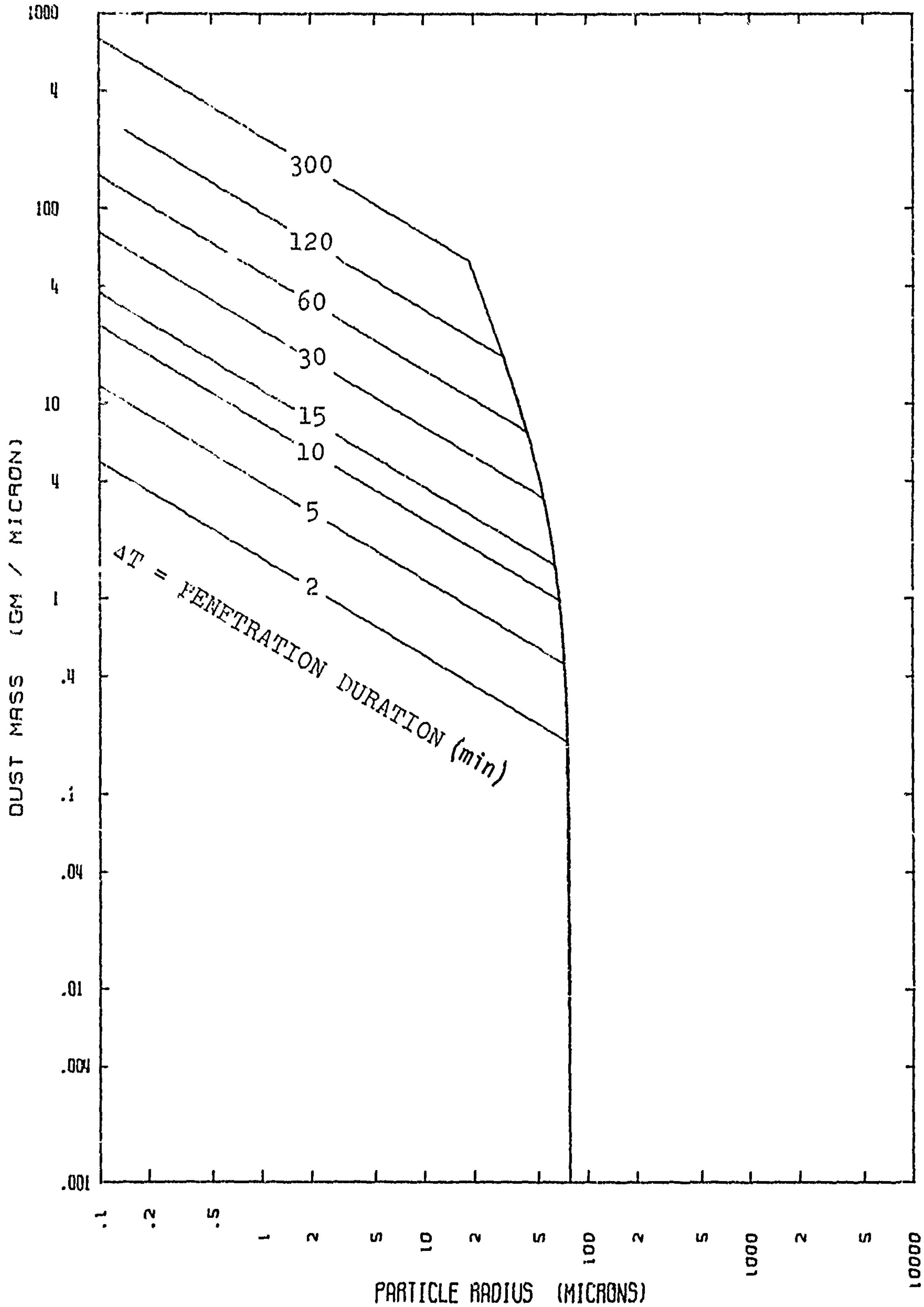

Figure 10. Perfect Filter Mass Distribution Function, TI = 1.5 Hours

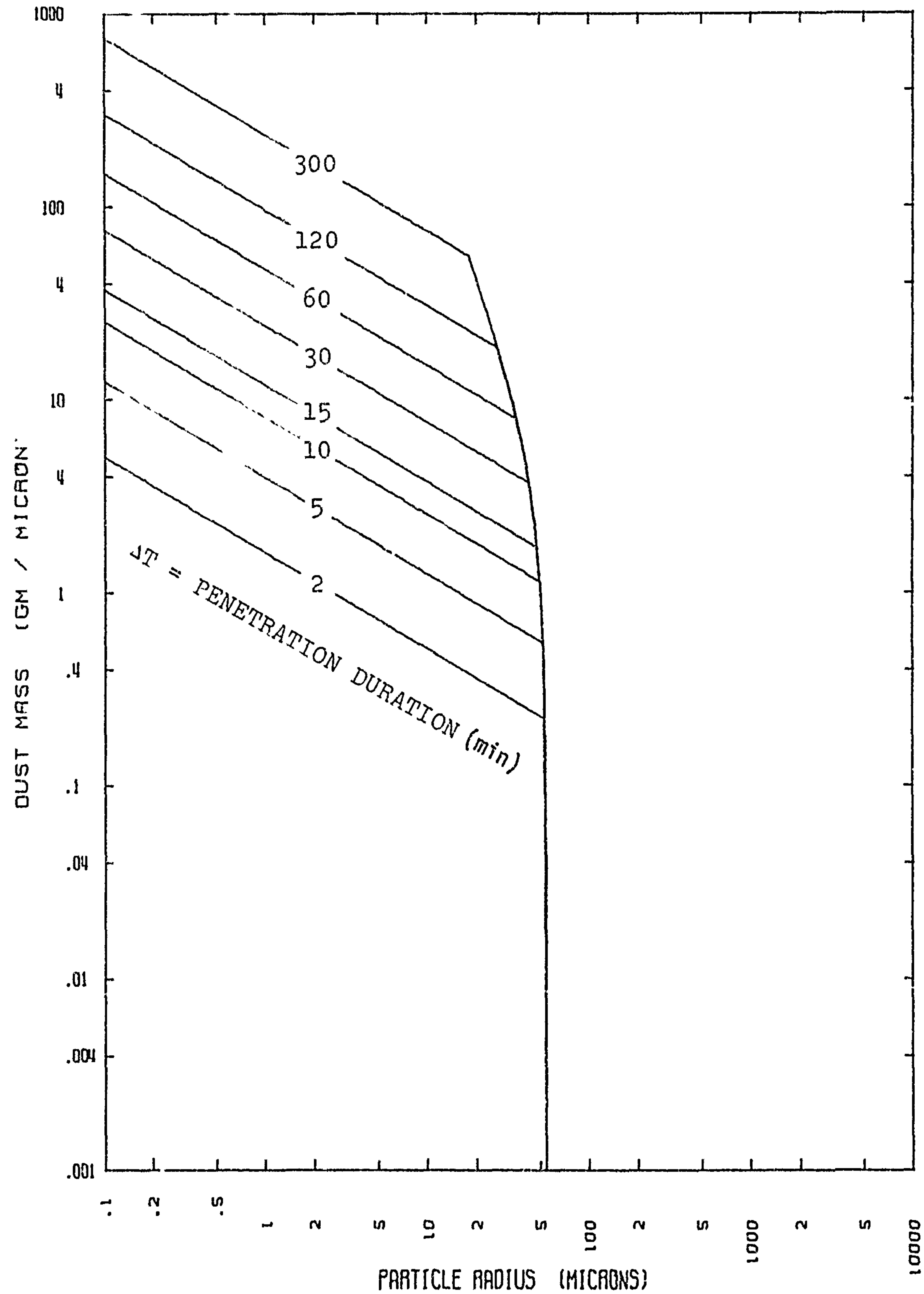

Figure 11. Perfect Filter Mass Distribution Function, TI = 2 Hours

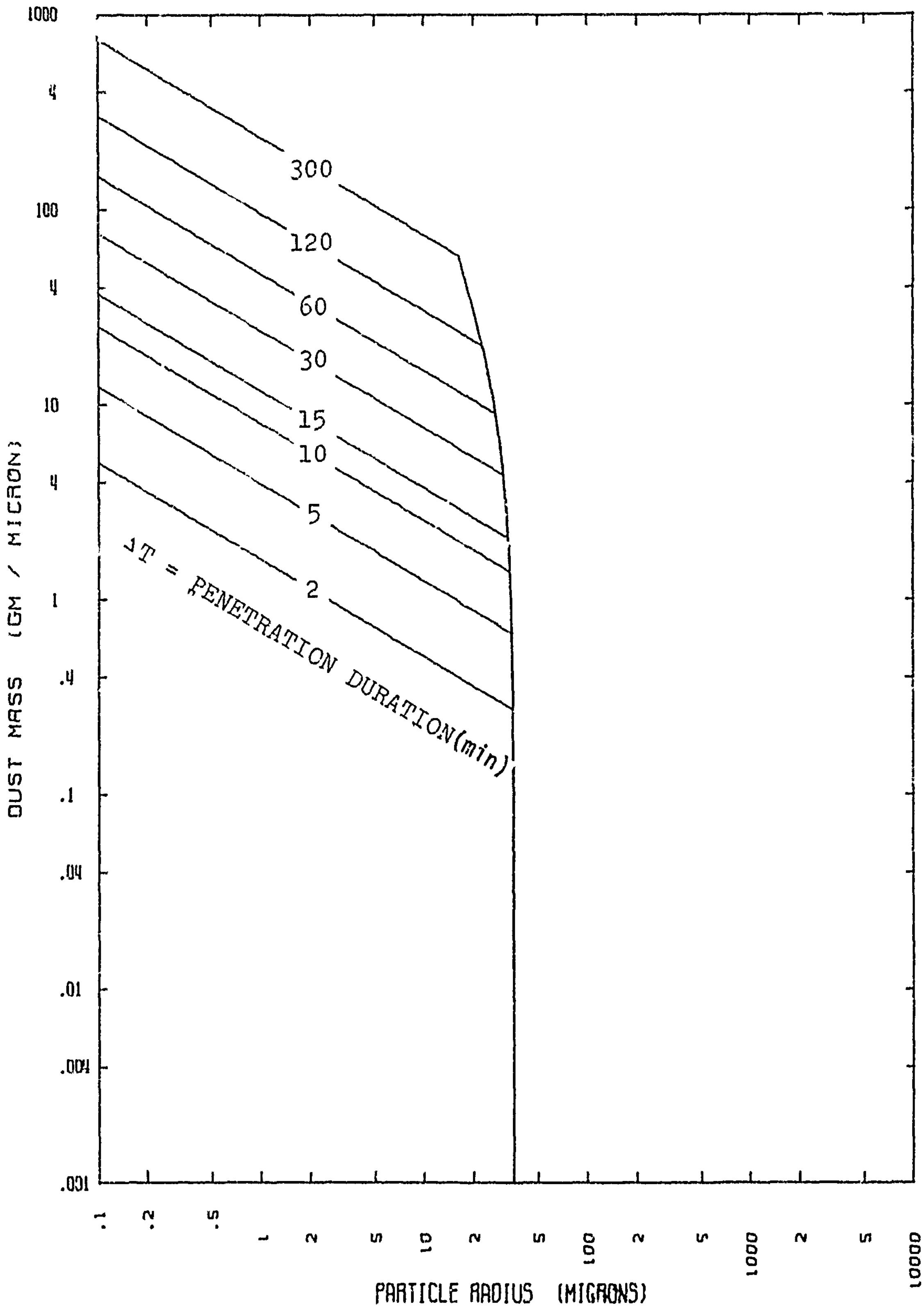

Figure 12. Perfect Filter Mass Distribution Function, TI = 3 Hours

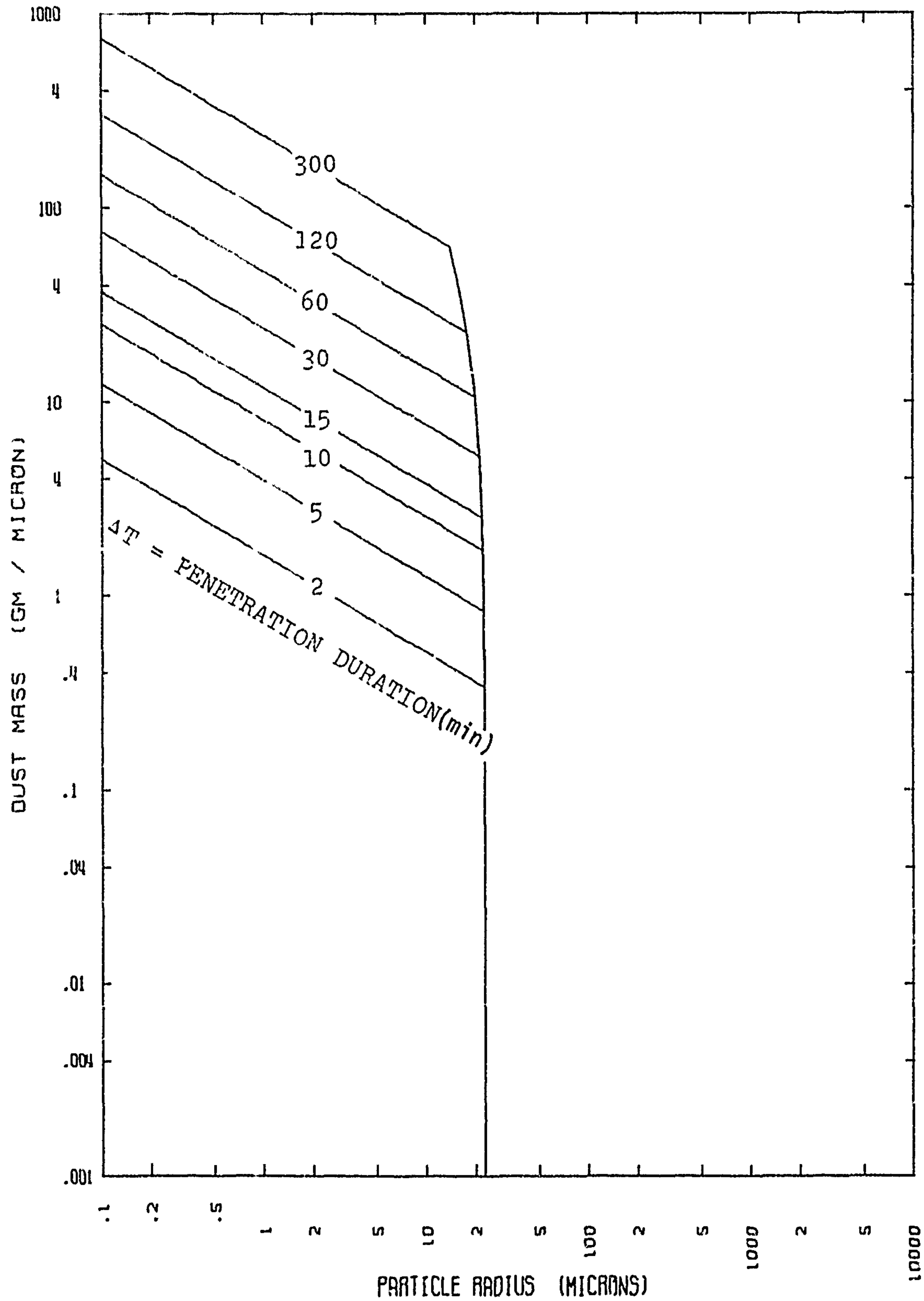

Figure 13. Perfect Filter Mass Distribution Function,
TI = 5 Hours

cloud entry time of 10 minutes and figure 13 for a cloud entry time of 5 hours shows the appreciable effect of fallout on the results. At TI = 10 minutes a sizable portion of the mass consists of particles with $r > 10$ microns; whereas, for TI = 5 hours all of these particles have fallen out prior to aircraft entry, and thus no particles in this size range are collected by the filter.

The second series of perfect filter graphs presents the cumulative mass collected by the filter, for a particular TI, as a function of particle size and in terms of the same range of parameters ΔT. Cumulative mass, $M_c(r,t)$ means the dust mass collected by the filter represented by dust particles which have sizes less than or equal to r. If $m(r,t)$ represents the dust mass distribution function for the filter as a function of particle size r at time t, then

$$M_c(r,t) = \int_0^r m(r,t)\, dr \tag{5}$$

Figures 14 through 22 present these results for cloud entry times ranging from 10 minutes to 5 hours. To further clarify the meaning of these figures, consider for a moment figure 14. This figure gives the cumulative mass collected by the filter as a function of particle size for a cloud entry time of TI = 10 minutes. For illustration purposes select a penetration duration of $\Delta T = 30$ minutes, then focus on the question of how many grams of dust will be collected which have particle sizes ranging up to 50 microns. Entering the abscissa at 50 microns and moving up to the curve corresponding to $\Delta T = 30$ minutes, a mass of 325 gms is obtained from the ordinate. Similarly 1000 grams of dust particles with sizes up to 500 microns have been collected by the perfect filter for the same entry time of 10 minutes and penetration duration of 30 minutes.

The cumulative mass collected for particle sizes up to 10,000 microns represents the total mass collected by the filter since this represents the upper limit of particle sizes considered in the analysis. Figure 23 presents the total mass collected by the perfect filter as a function of time after weapon detonation with cloud entry time as a parameter. Results for cloud entry times of 10, 18, 30, 60, 90, 120, 180, and 300 minutes are included on this figure. As an example of the utility of this figure consider the following: How many grams of dust would be collected by a perfect filter in the B-1 environmental control system if the B-1 entered the cloud at TI = 30 minutes and exited the

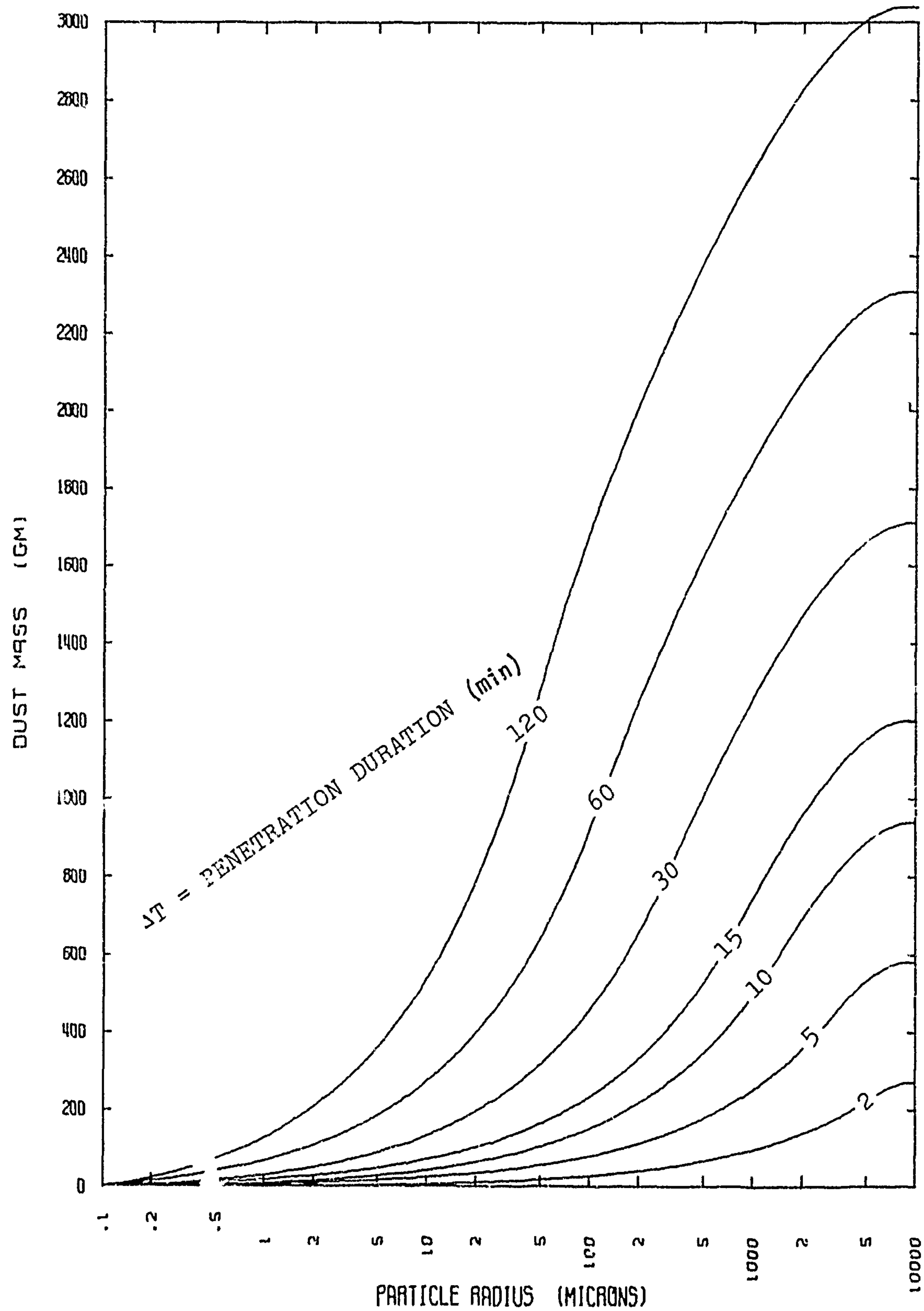

Figure 14. Cumulative Mass As Function of Size, TI = 10 Minutes

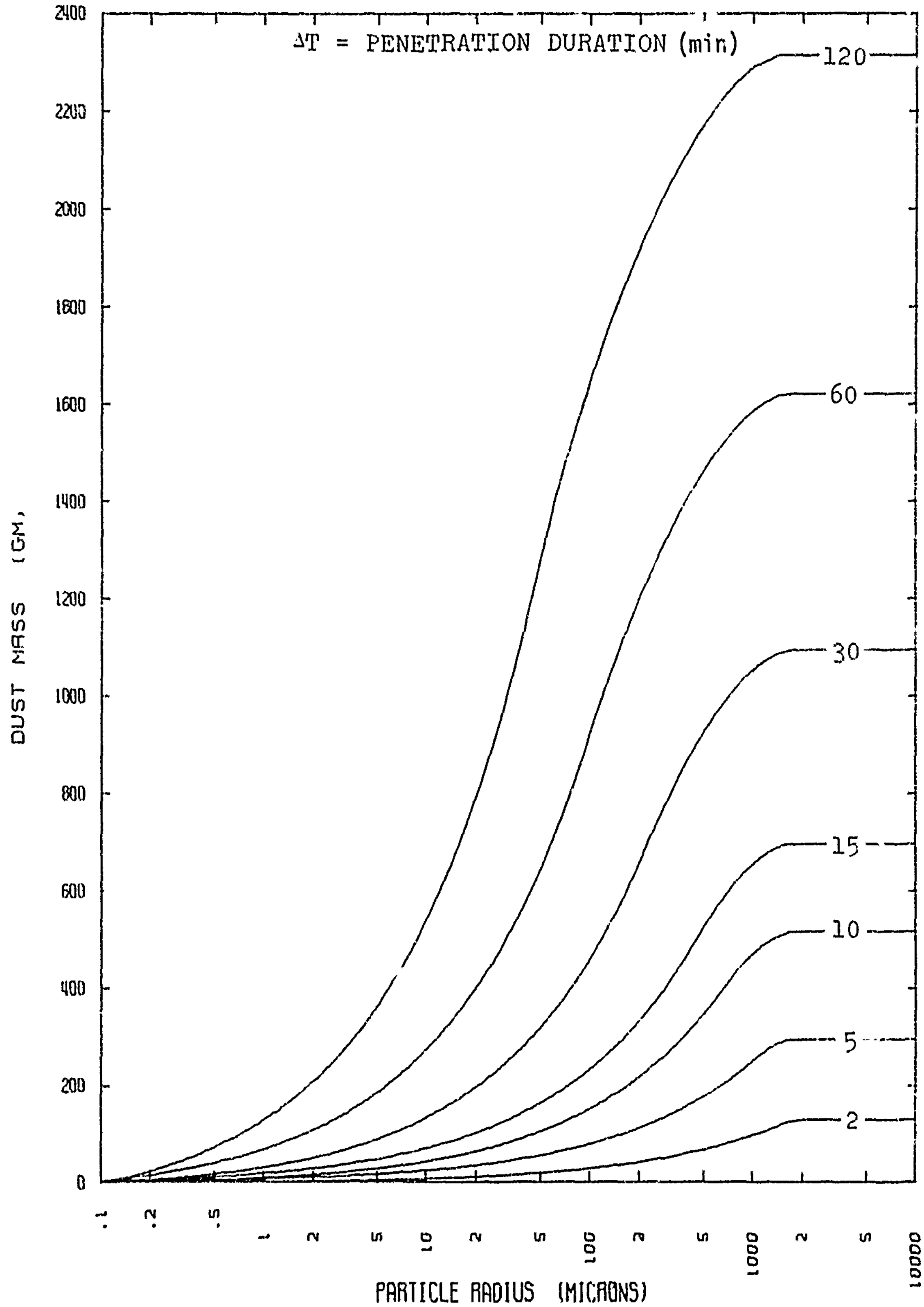

Figure 15. Cumulative Mass As Function of Size,
TI = 18 Minutes

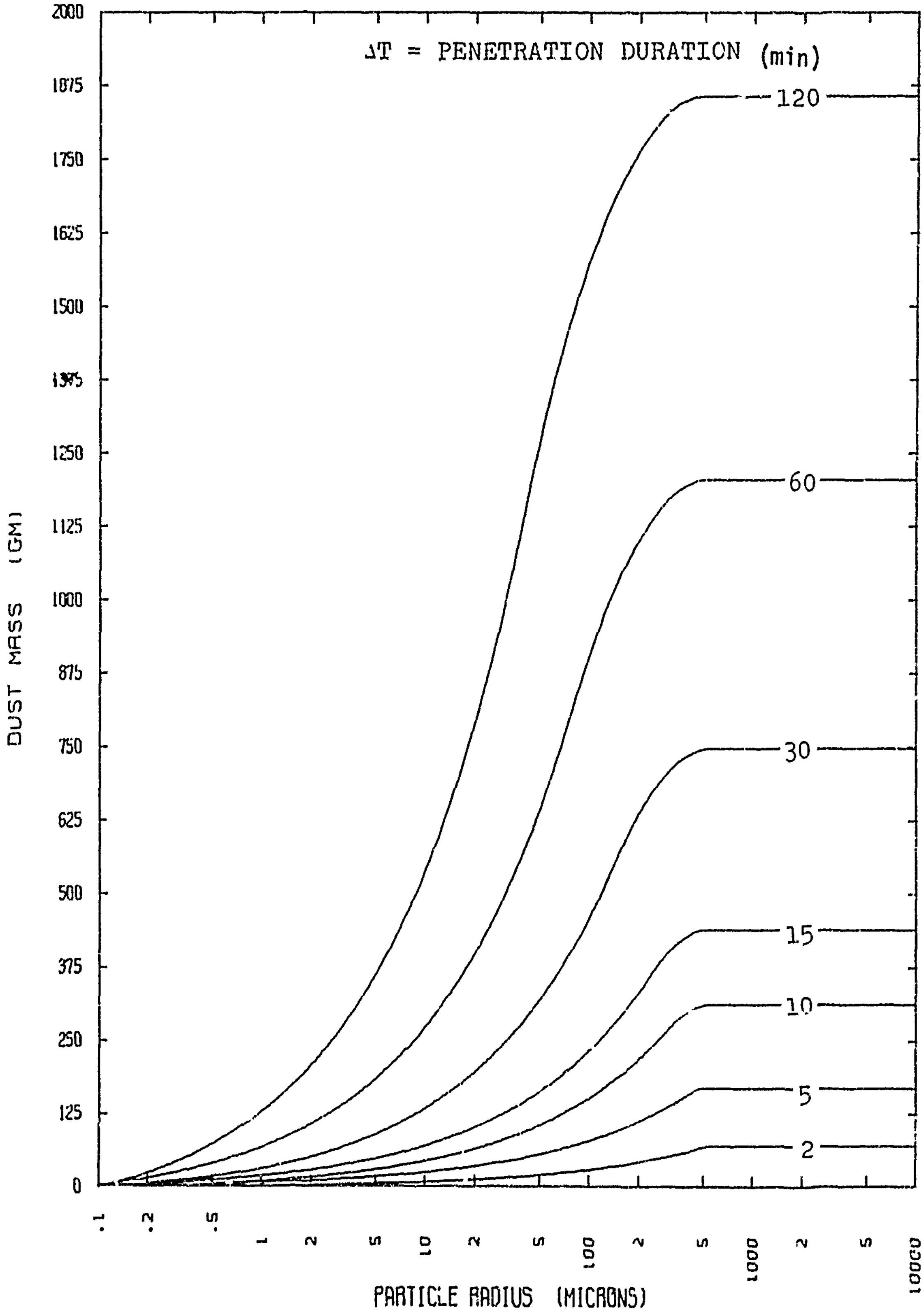

Figure 16. Cumulative Mass As Function of Size, TI = 30 Minutes

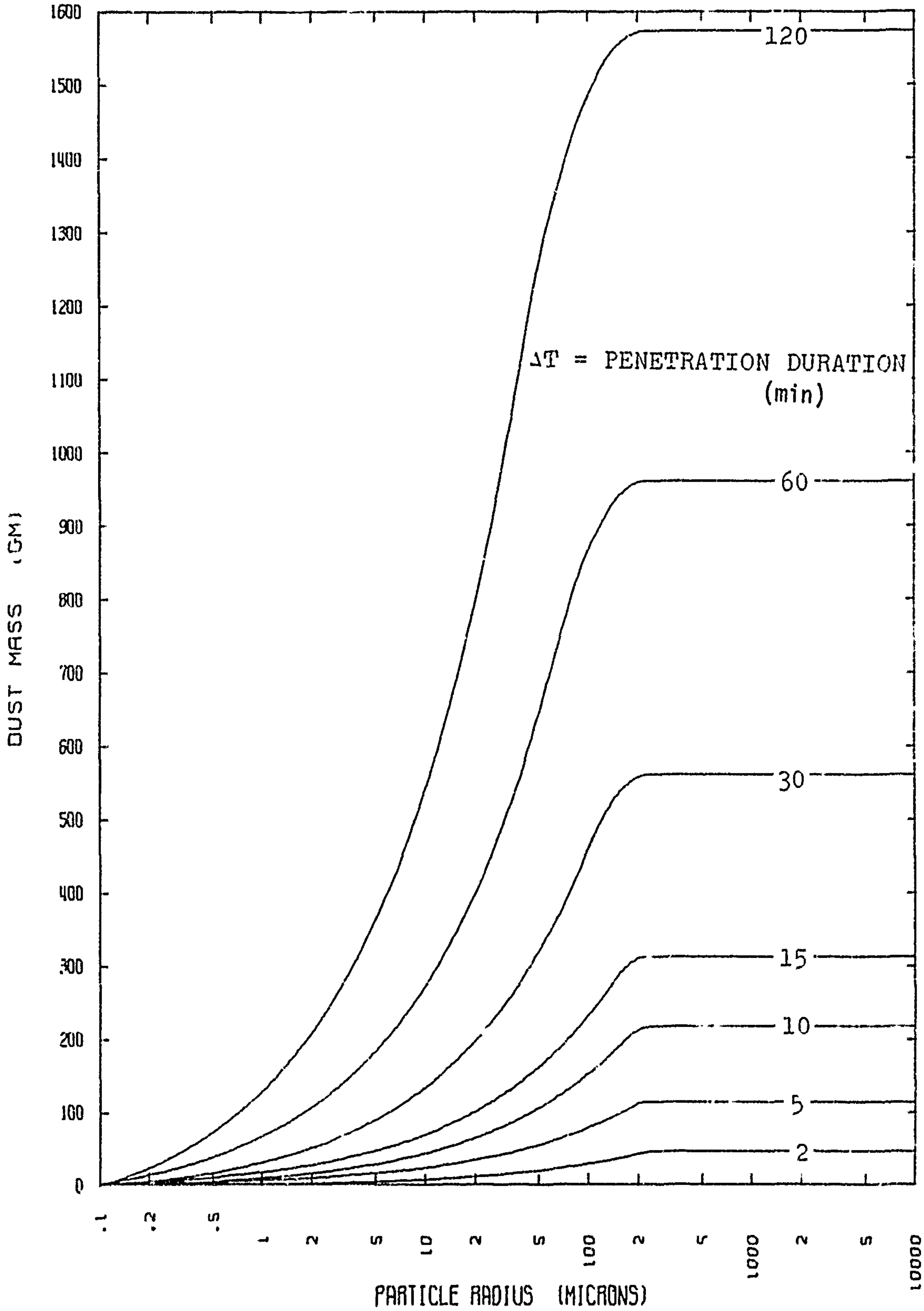

Figure 17. Cumulative Mass As Function of Size, TI = 45 Minutes

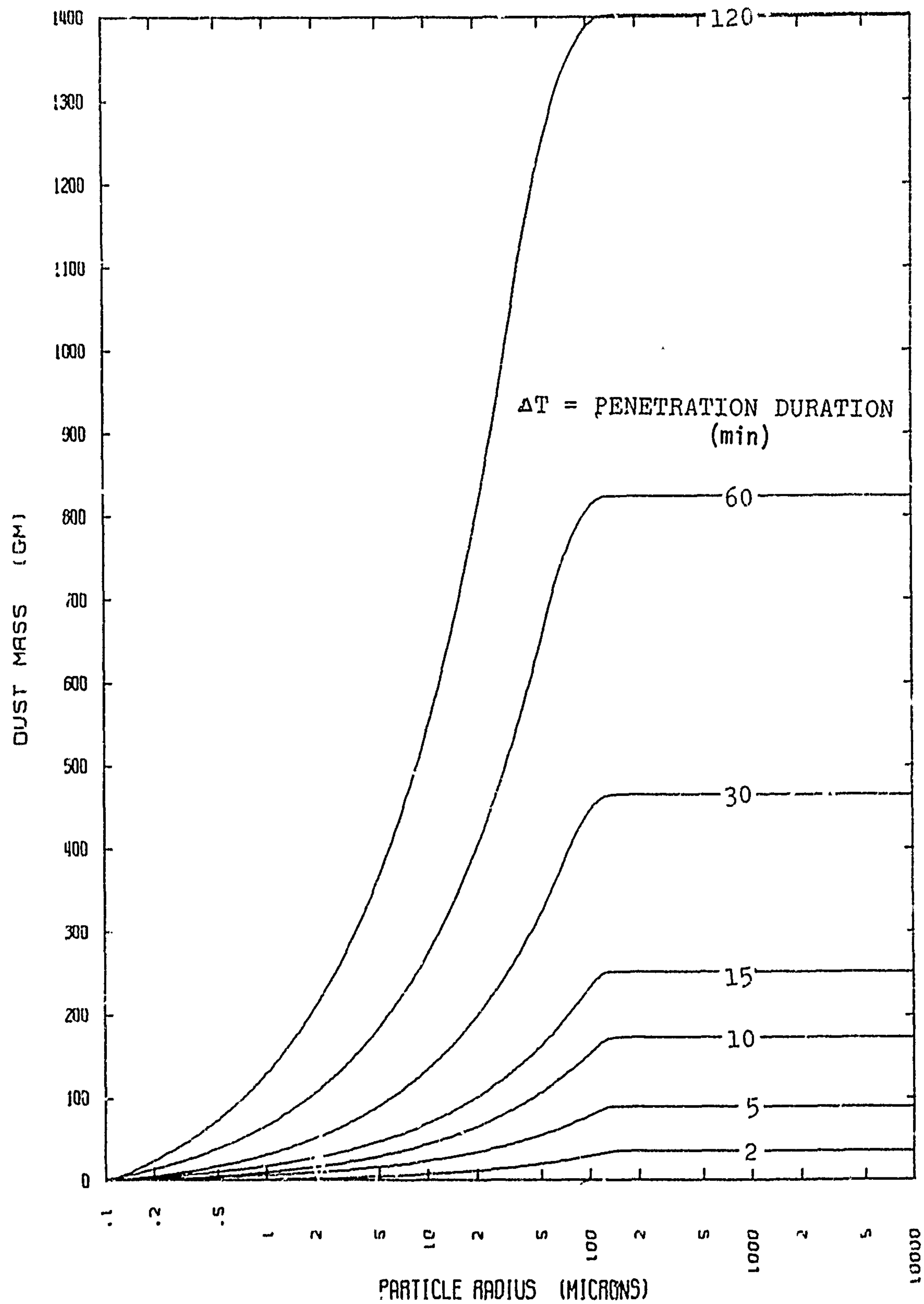

Figure 18. Cumulative Mass As Function of Size, TI = 1 Hour

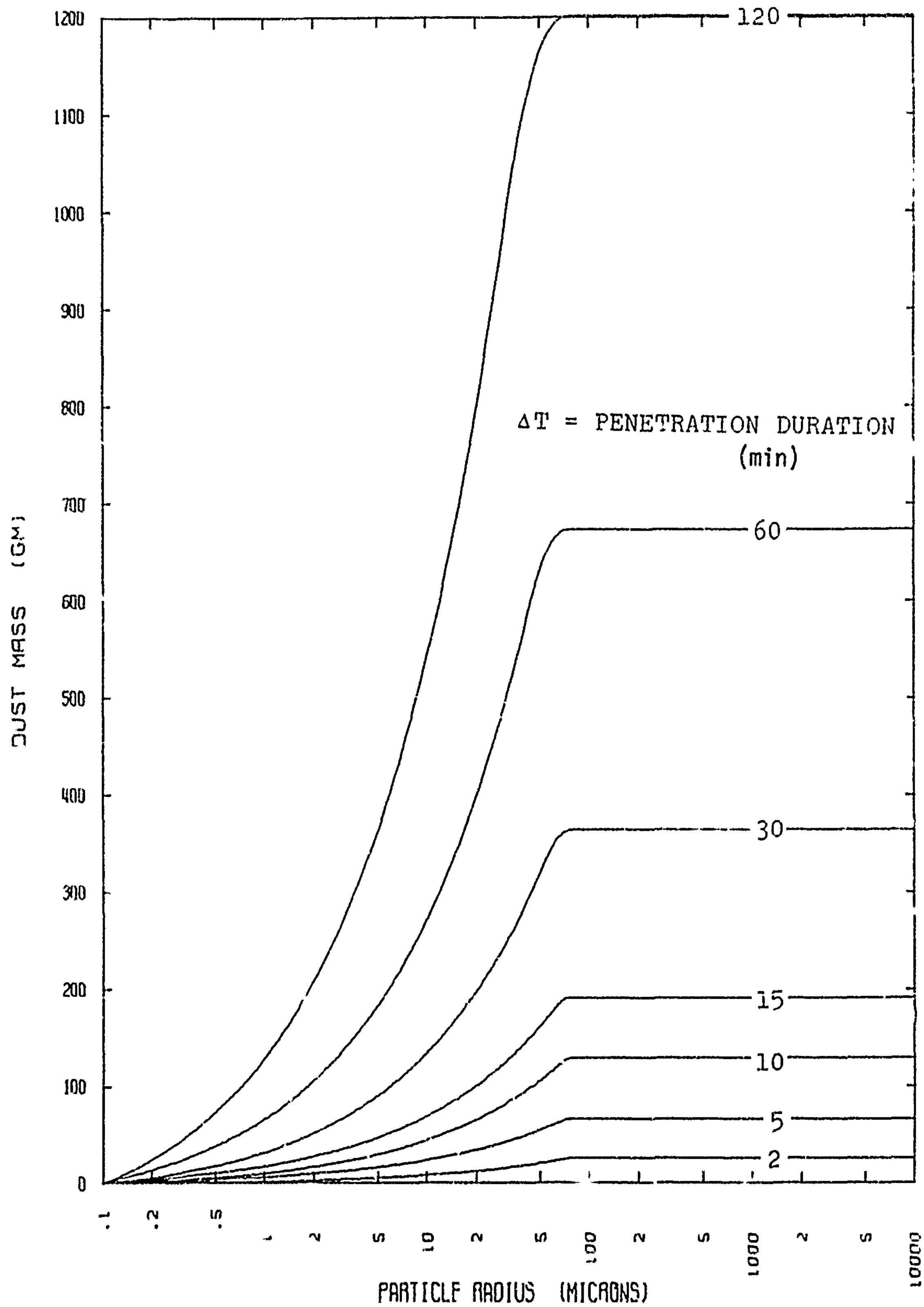

Figure 19. Cumulative Mass As Function of Size,
TI = 1.5 Hours

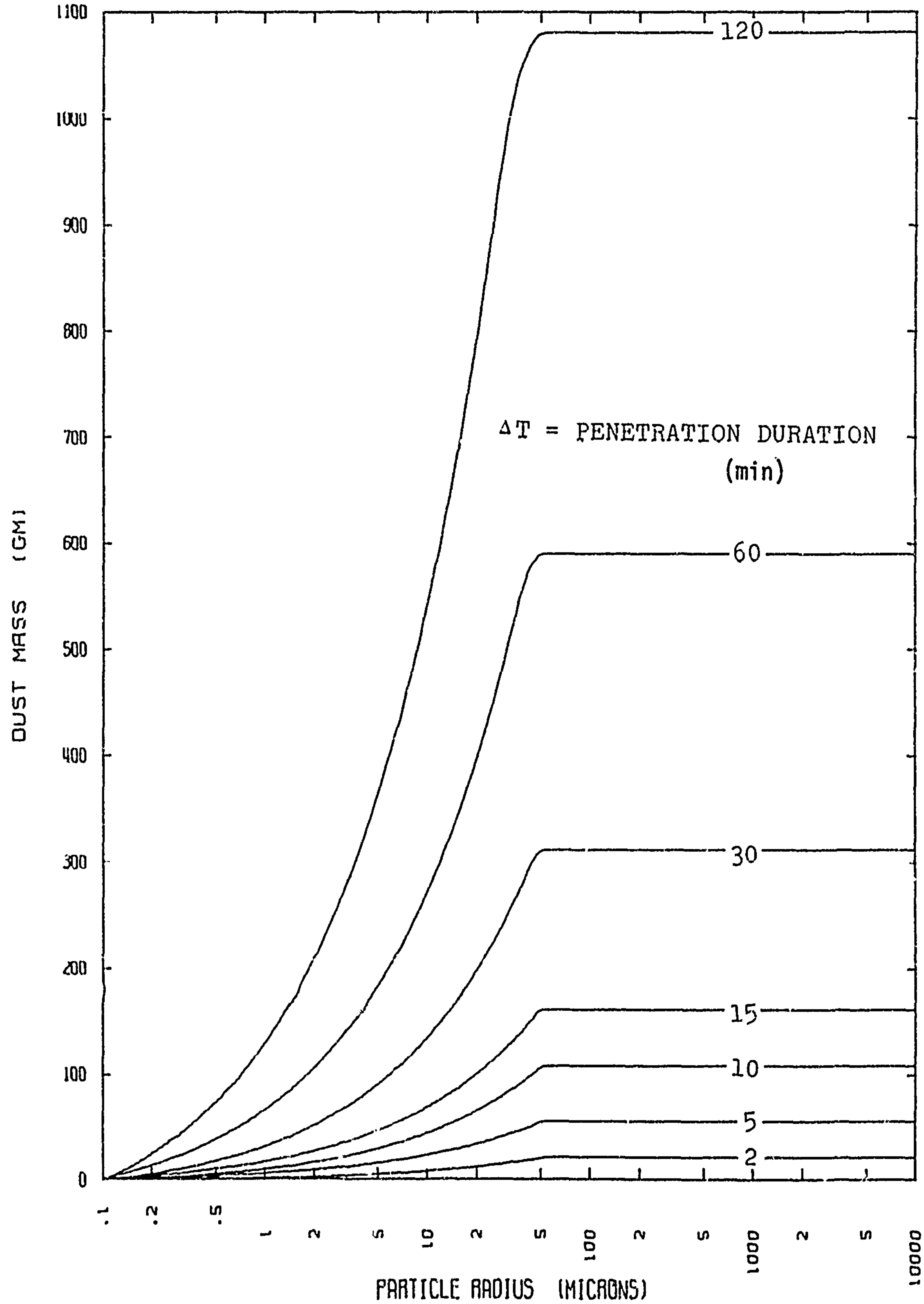

Figure 20. Cumulative Mass As Function of Size,
TI = 2 Hours

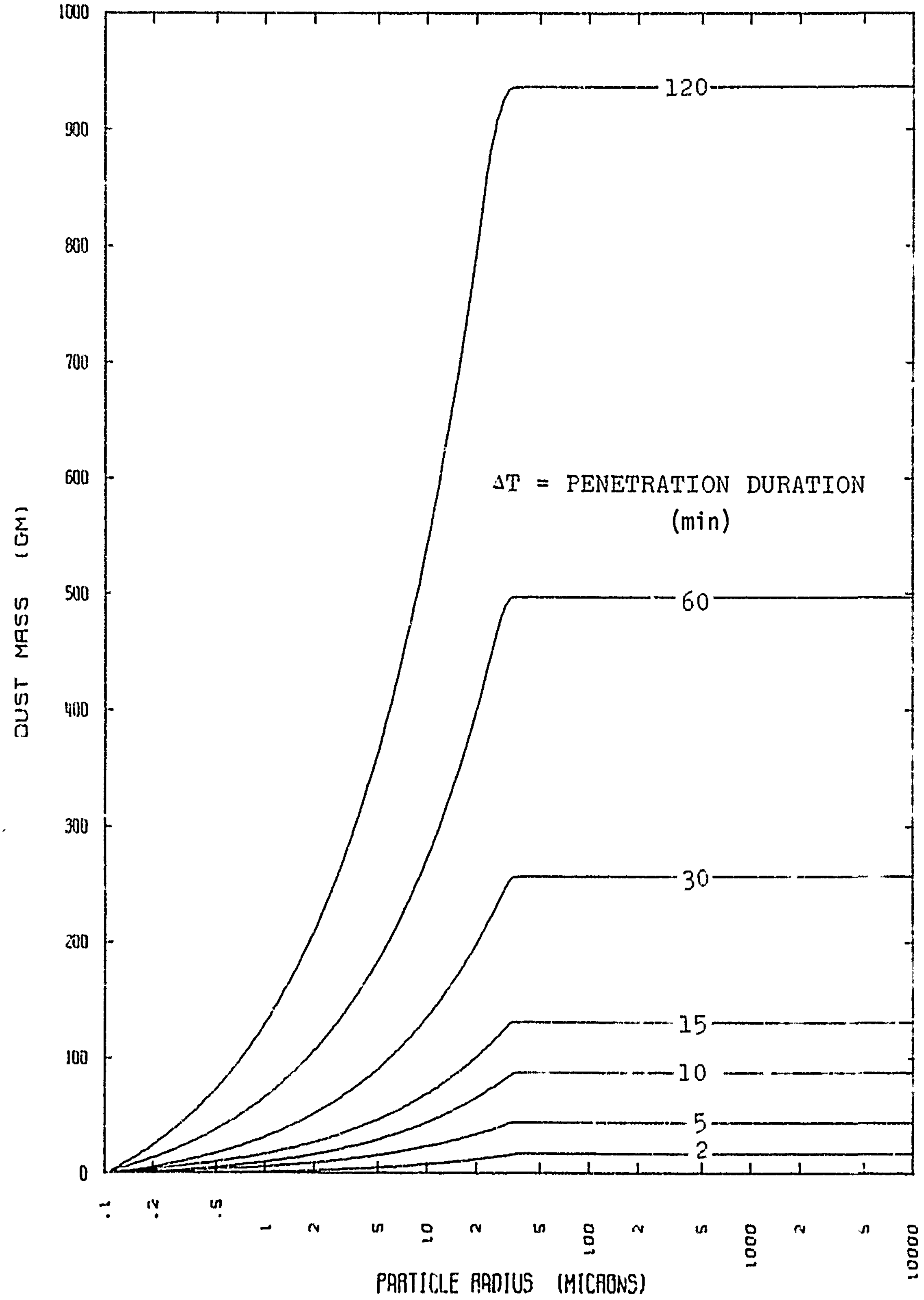

Figure 21. Cumulative Mass As Function of Size,
TI = 3 Hours

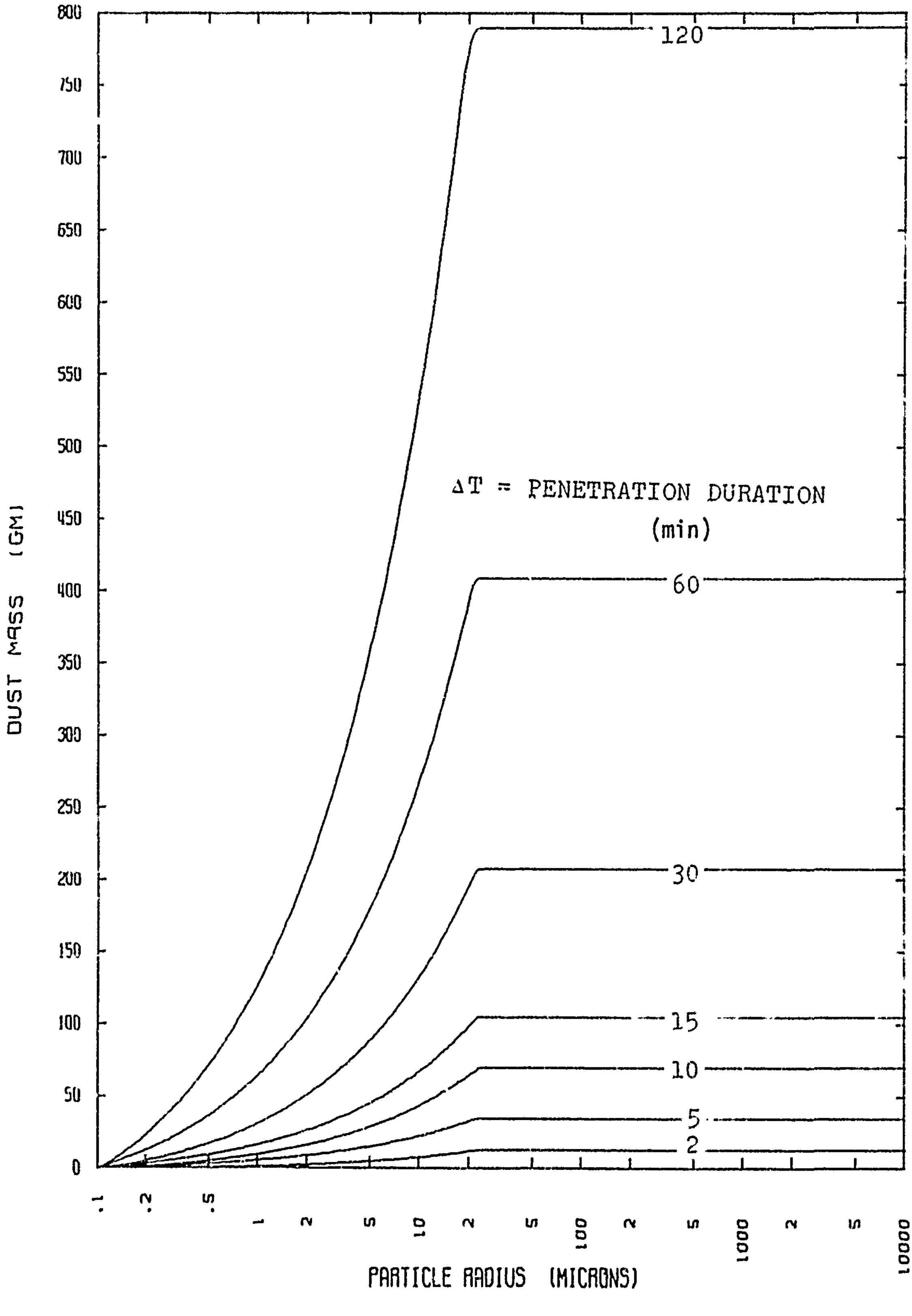

Figure 22, Cumulative Mass As Function of Size,
TI = 5 Hours

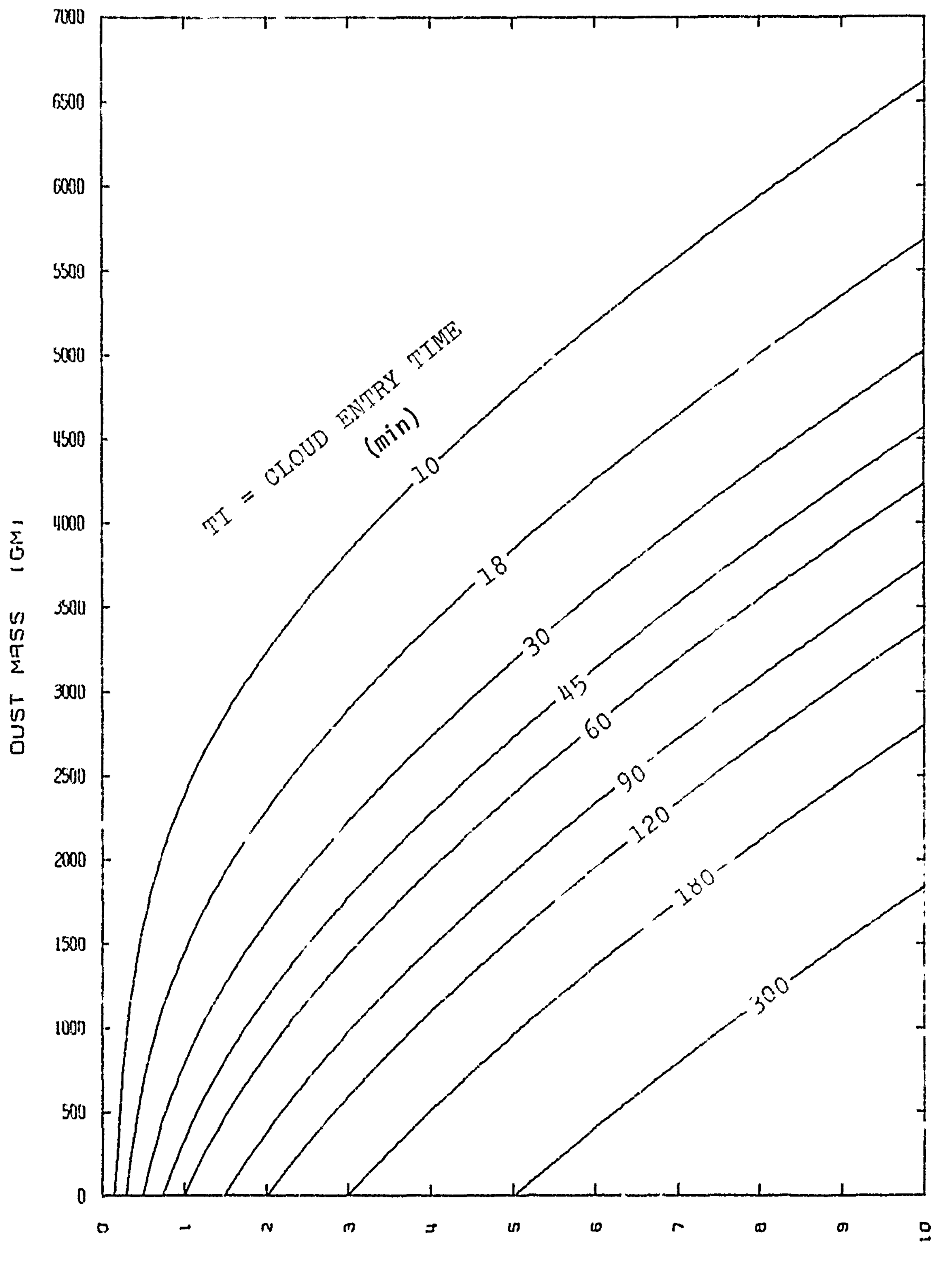

Figure 23. Filter Dust Mass As a Function of Time

cloud after a penetration duration ΔT = 30 minutes? In this example, which corresponds to the baseline case, note that the B-1 exits the cloud at TF = TI + ΔT = 60 minutes = 1 hour after weapon detonation. Enter the abscissa at TF = 1 hour and move up to the parametric curve for TI = 30 minutes and read from the ordinate the fact that 750 grams of dust have been collected by the filter. The total mass of dust collected is an extremely strong function of cloud entry time, which again attests to the fact that fallout effects are significant in the analysis.

Curves pertaining to the filter dust mass distribution function, cumulative mass, and total mass collected by the filter are in themselves useful from a filter design standpoint. However, another major factor must be considered. The dust particles collected by the filter are a source of radioactivity which is carried with the aircraft and contributes dose to the crew/electronics in the vicinity of the filter. Dose calculations from this source have been made and are based upon several assumptions. The filter is assumed to be a point source of radioactivity emitting gamma rays with an average energy of 1 MeV. The resultant dose calculated corresponds to a dose "at-one-meter" so that a simple correction factor of $(1 \text{ meter}/d \text{ meters})^2$ can be applied to the results to correct for actual separation distance of crew/electronics from the filter.

The product of the mass distribution function (figure 2) and the specific activity distribution function (figure 3) is involved in the filter dose calculations. In addition after the aircraft exits from the cloud, the dust previously collected continues to contribute to the dose until the mission is completed. Thus, to present the results a particular time after weapon detonation must be selected as a baseline, and in this work the dose data is presented at a time of 30 hours after weapon detonation. These results can be scaled to other times, as will be demonstrated.

Figures 24 through 32 present the resultant perfect filter dose distribution function as a function of particle size and with penetration duration as a parameter for a particular cloud entry time, TI. The penetration durations presented on each figure are 2, 5, 10, 15, 30, 60, 120, and 300 minutes, and each separate curve presents results for a particular cloud entry time in the range from 10 minutes to 5 hours. Again the effects of fallout can be easily observed by a comparison of early and late cloud entry data, for there is no

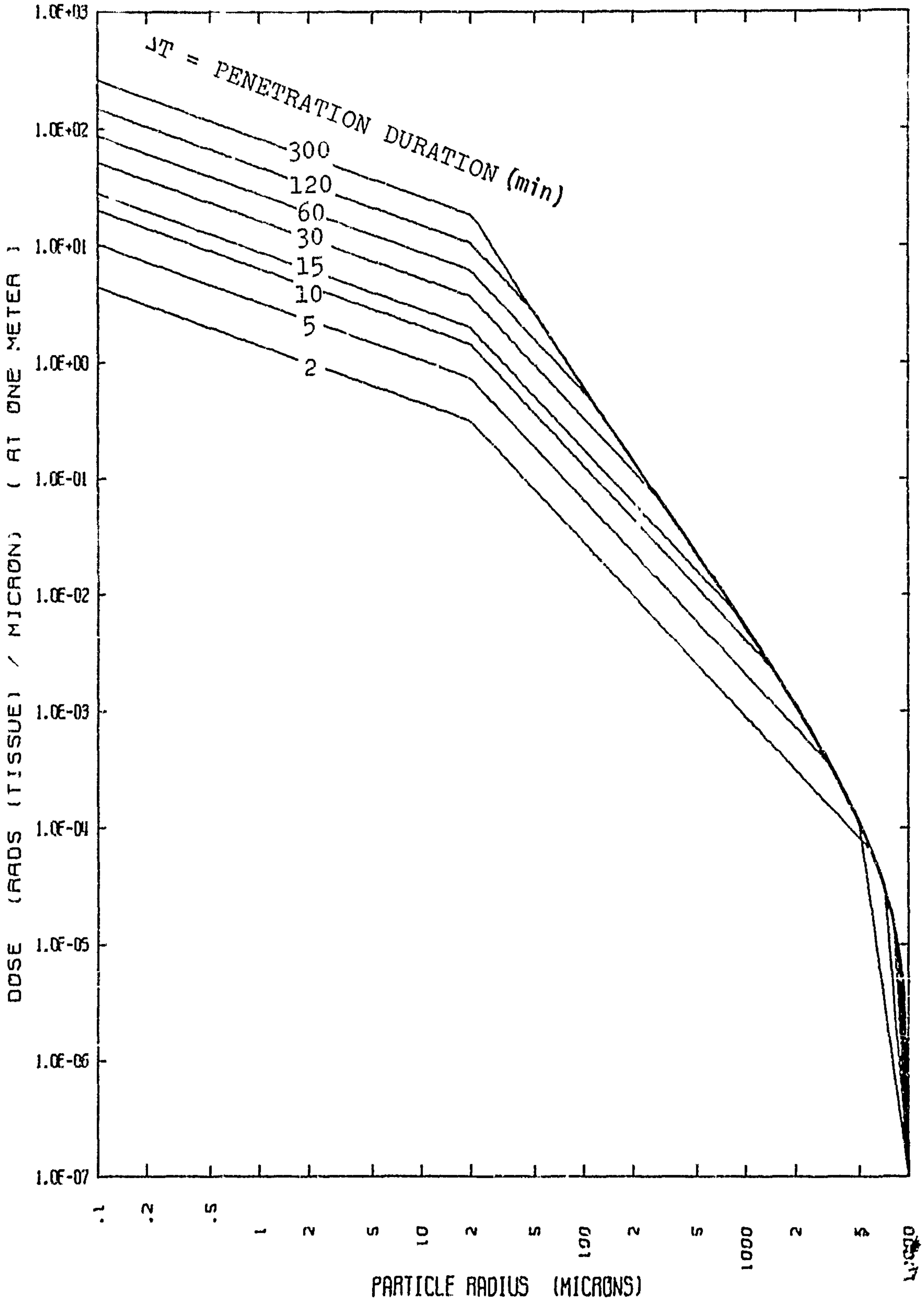

Figure 24. Dose from Filter Dust at 30 Hours,
TI = 10 Minutes

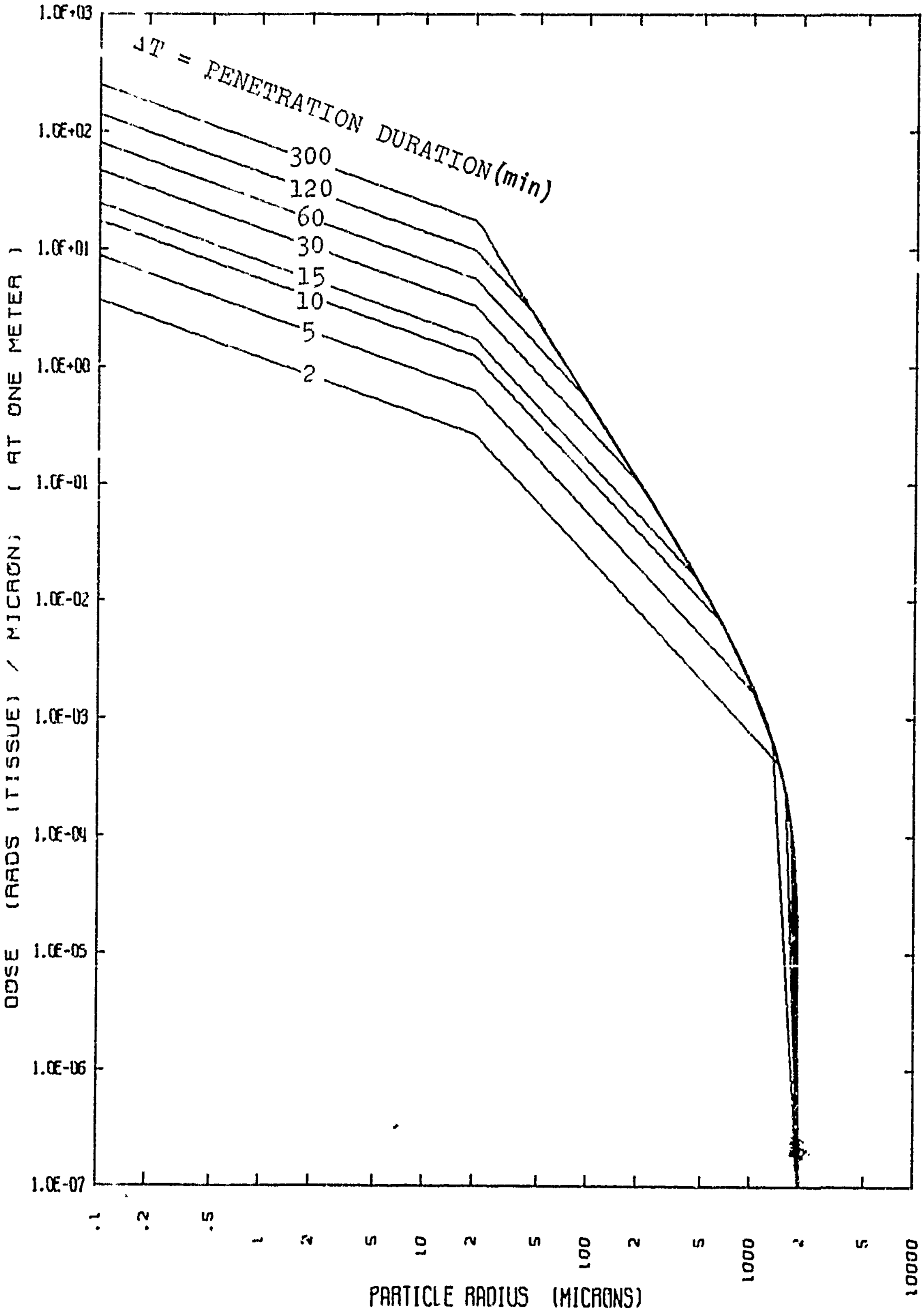

Figure 25. Dose from Filter Dust at 30 Hours, TI = 18 Minutes

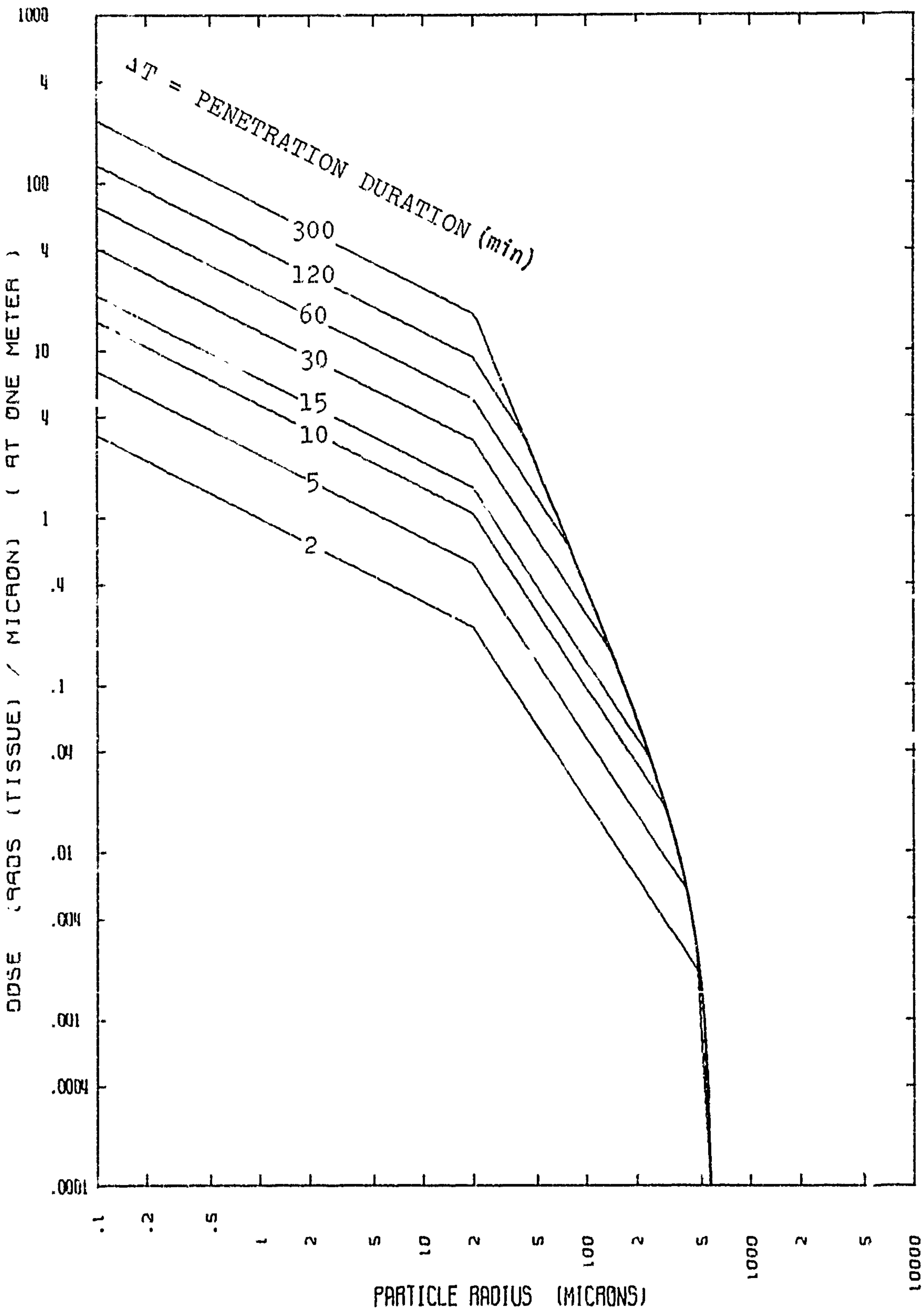

Figure 26. Dose from Filter Dust at 30 Hours, TI = 30 Minutes

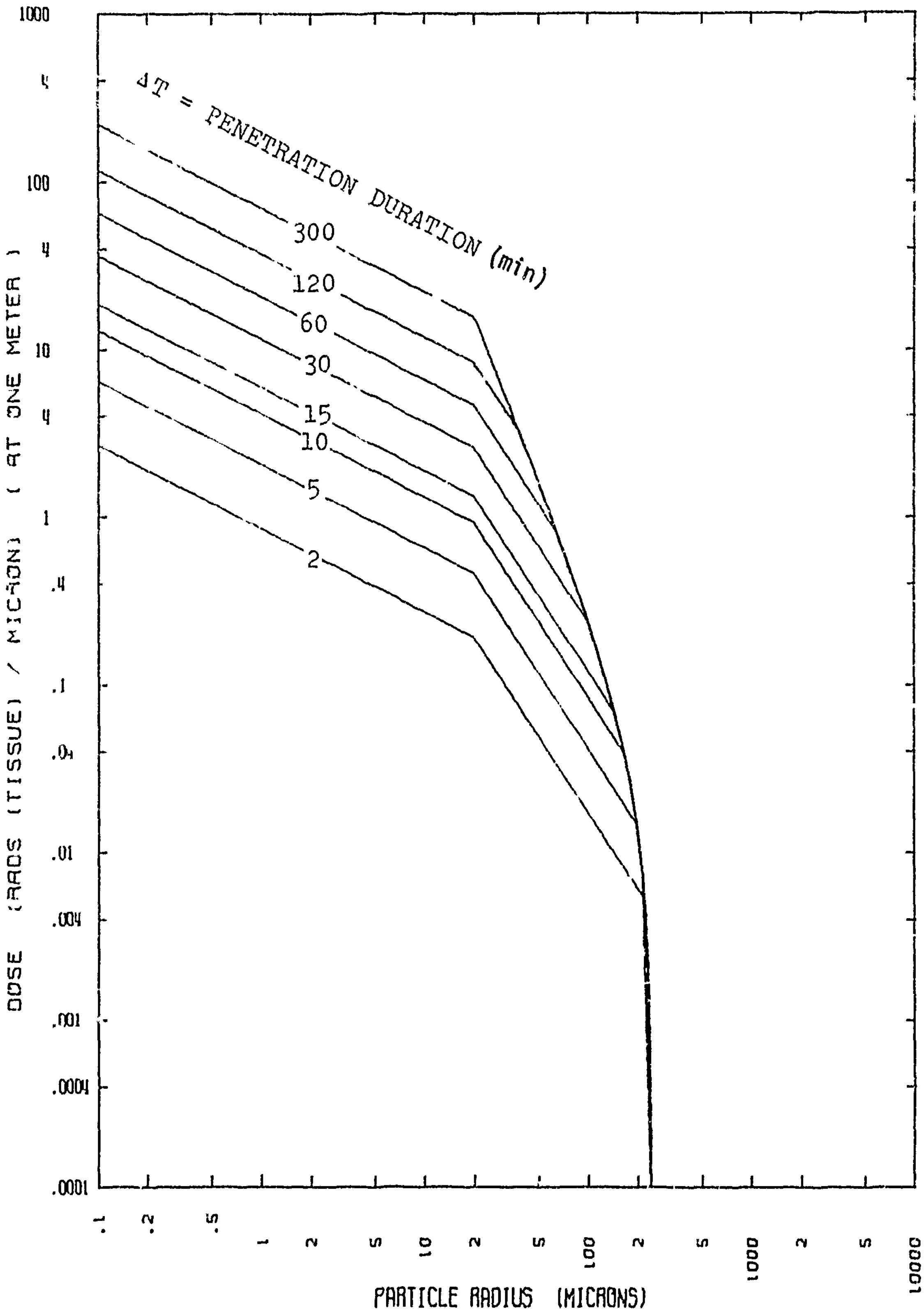

Figure 27. Dose from Filter Dust at 30 Hours, TI = 45 Minutes

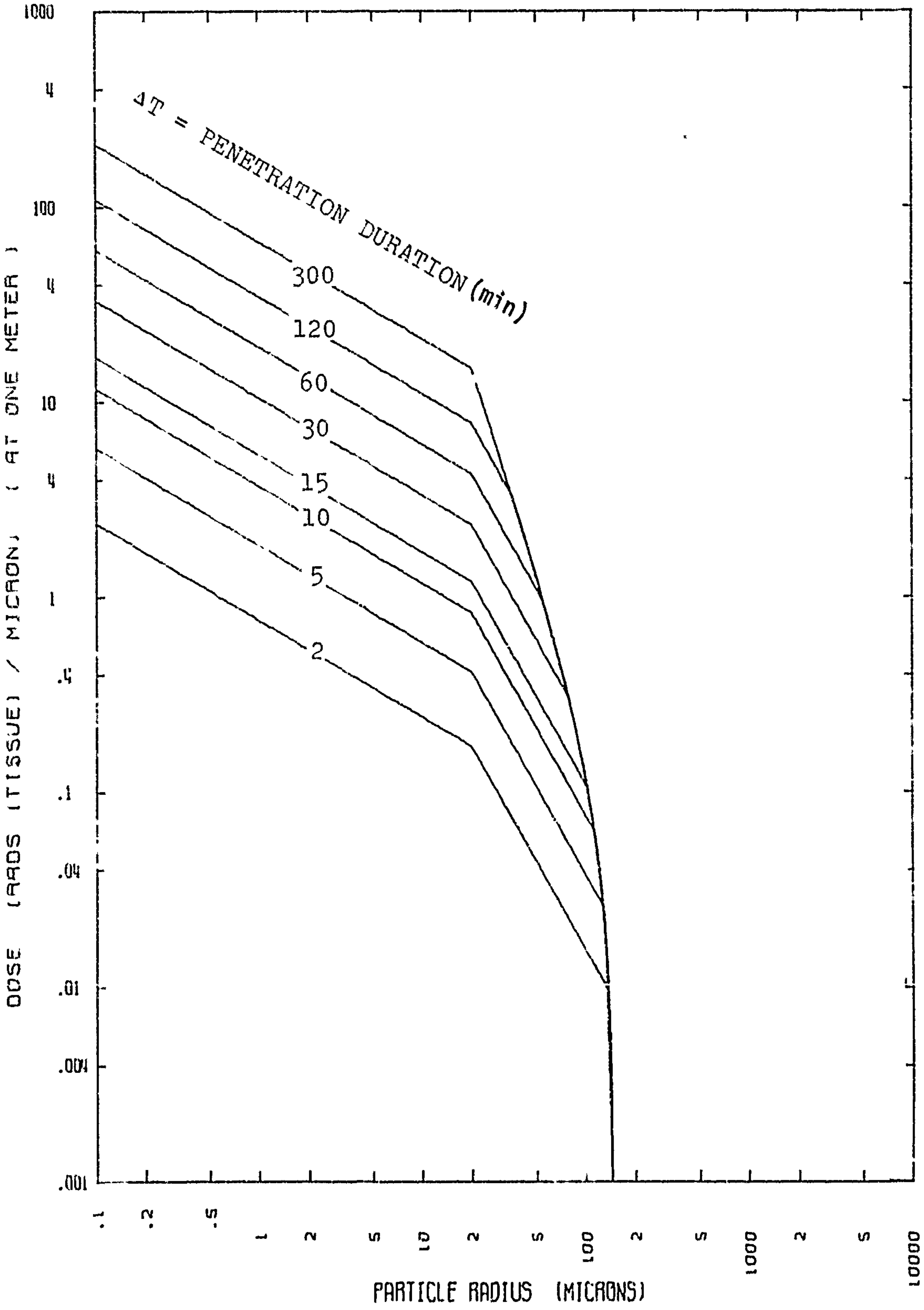

Figure 28. Dose from Filter Dust at 30 Hours, TI = 1 Hour

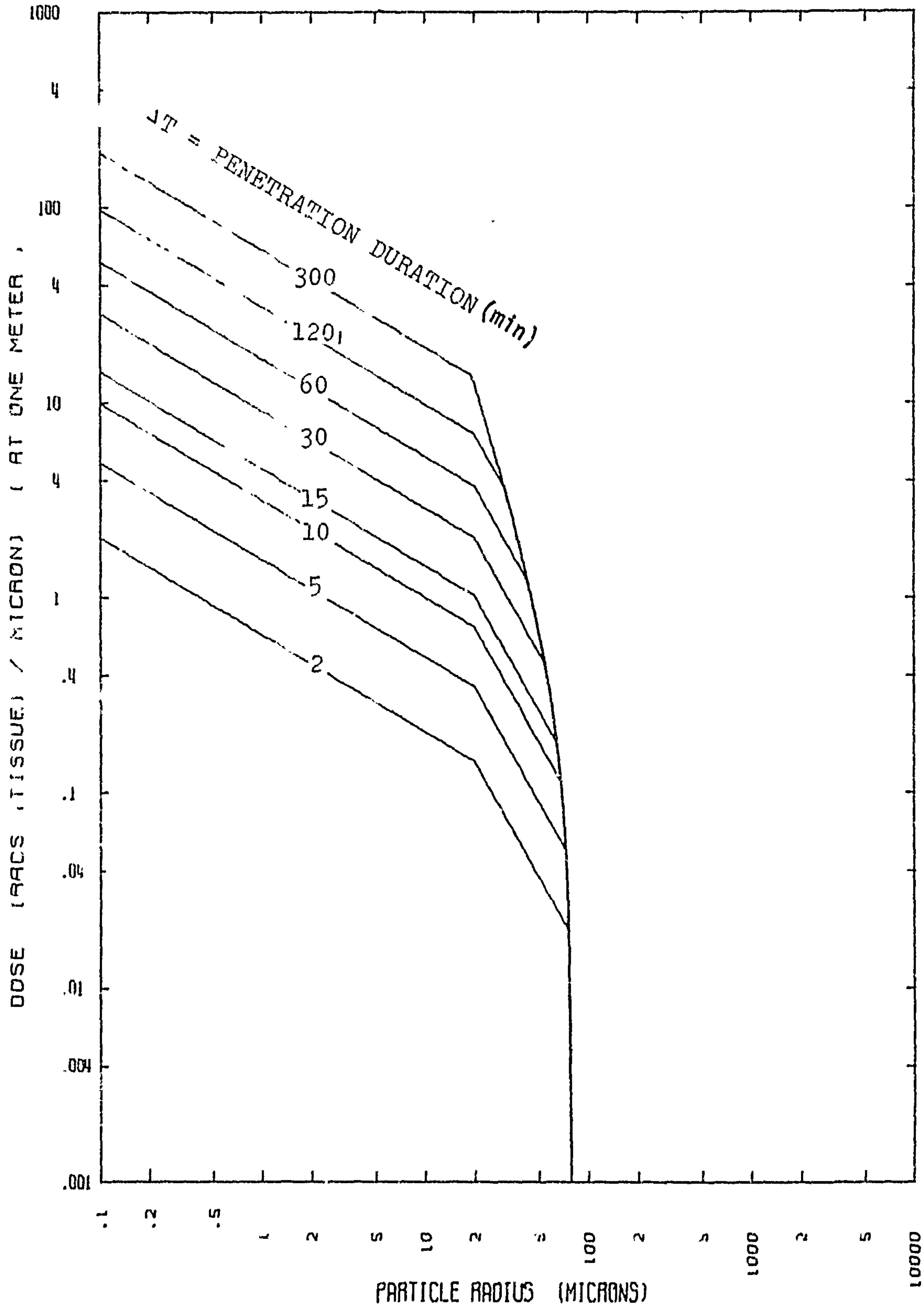

Figure 29. Dose from Filter Dust at 30 Hours,
TI = 1.5 Hours

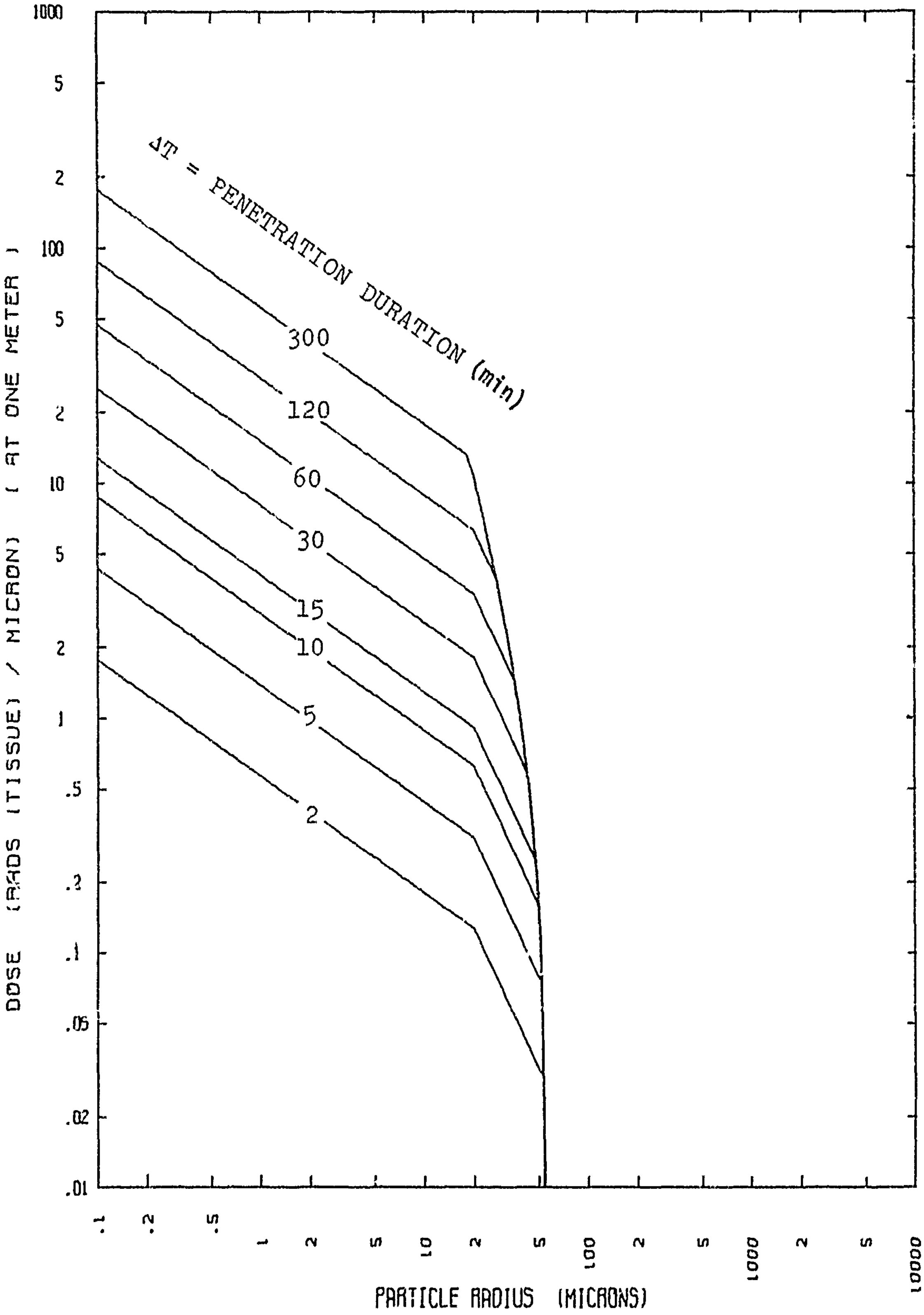

Figure 30. Dose from Filter Dust at 30 Hours,
TI = 2 Hours

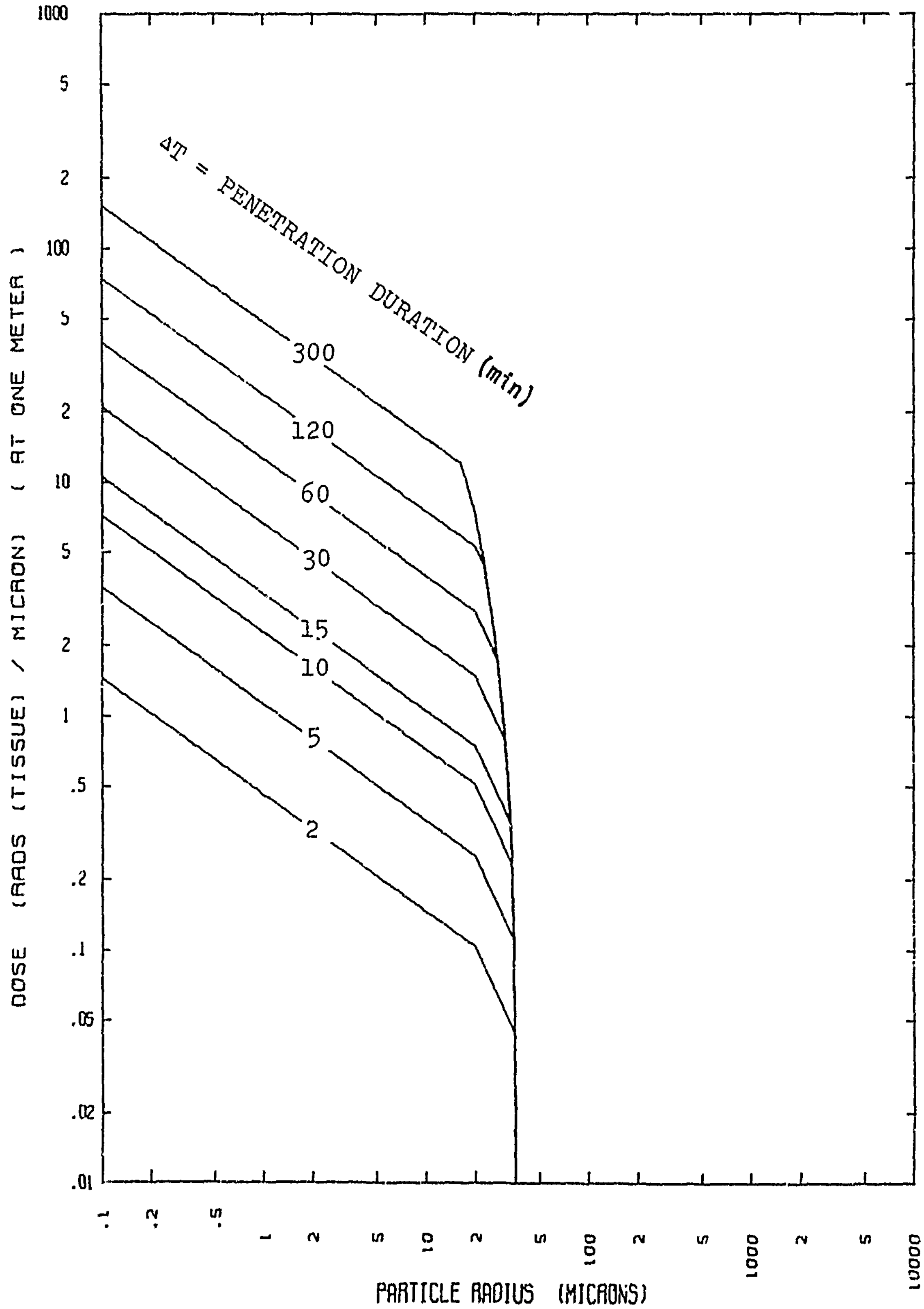

Figure ?1. Dose from Filter Dust at 30 Hours, TI = 3 Hours

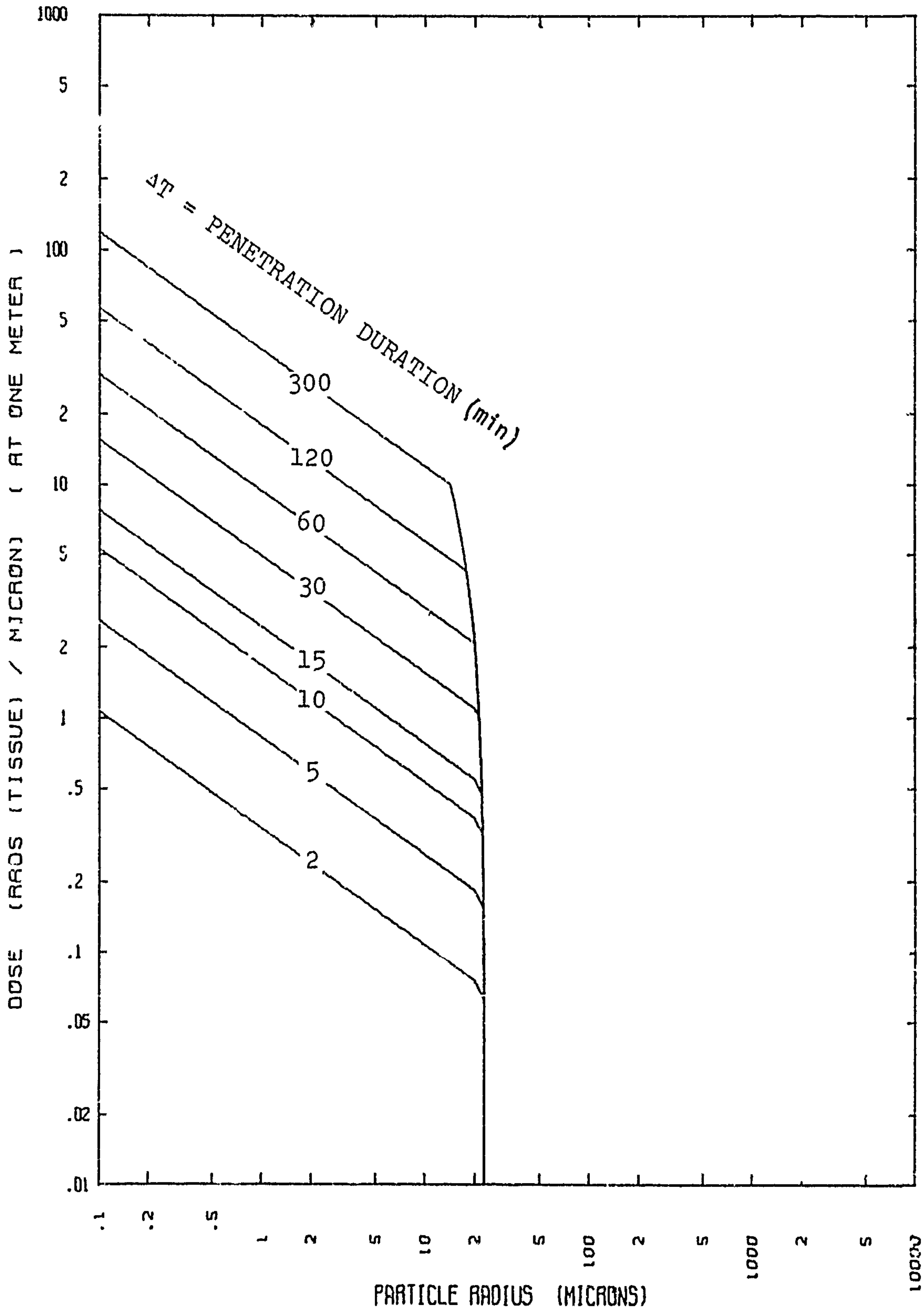

Figure 32. Dose from Filter Dust at 30 Hours, TI = 5 Hours

dose contribution from large particle sizes for late cloud entry time. Although not as noticeable it can be also observed that the exponential radioactive decay law has been included in the analysis.

The next series of figures, figures 33 through 41, presents data on the cumulative filter dose at 30 hours after weapon detonation as a function of particle size. The term cumulative filter dose is defined as that portion of the total dose attributable to all particles collected which have sizes less than or equal to r. These figures present this cumulative dose for cloud entry times from 10 minutes to 5 hours, and in each figure results are presented over the range of penetration durations of 2, 5, 10, 15, 30, 60, and 120 minutes. As an example of the use of these curves consider the following question: For a cloud entry time of 10 minutes and a penetration duration of 15 minutes, how much of the "at-one-meter" filter dose collected during the 30 hours after weapon detonation is attributable to particles with particle sizes of 10 microns radius or less? In figure 33 enter the abscissa at 10 microns, move up to the parametric curve for a 15-minute penetration duration, and read the filter dose of 52 rads (tissue). The dose attributable to all particles for these same conditions is 149 rads (tissue) so that the particles with size of 10 microns or less contribute approximately 1/3 of the total dose. From figure 41, for later entry times, i.e., 5 hours, and for the same 15-minute penetration duration, the smaller particles with $r \leq 10$ microns contribute 15 rads (tissue) out of 22 rads (tissue). The final series of figures, figures 42 through 50, for the perfect filter case provide the total dose "at-one-meter" due to all particles collected by the filter as a function of time after weapon detonation and with penetration duration as a parameter. In these figures results are presented for penetration durations ranging from 2 minutes to 120 minutes, and each figure is for a particular entry time in the range from 10 minutes to 5 hours. For the baseline case of TI = 30 minutes and ΔT = 30 minutes, note from figure 44 that 190 rads (tissue) would be accumulated by a crew member located "at-one-meter" from the filter at 30 hours after weapon detonation due to dust collected by the filter.

This final set of figures, figures 42 through 50, for the perfect filter case also provides the basis for scaling the previous dose results (i.e., figures 24 through 41) which were presented at 30 hours after weapon detonation to earlier times. A time scaling factor (TSF) can be obtained from this series of

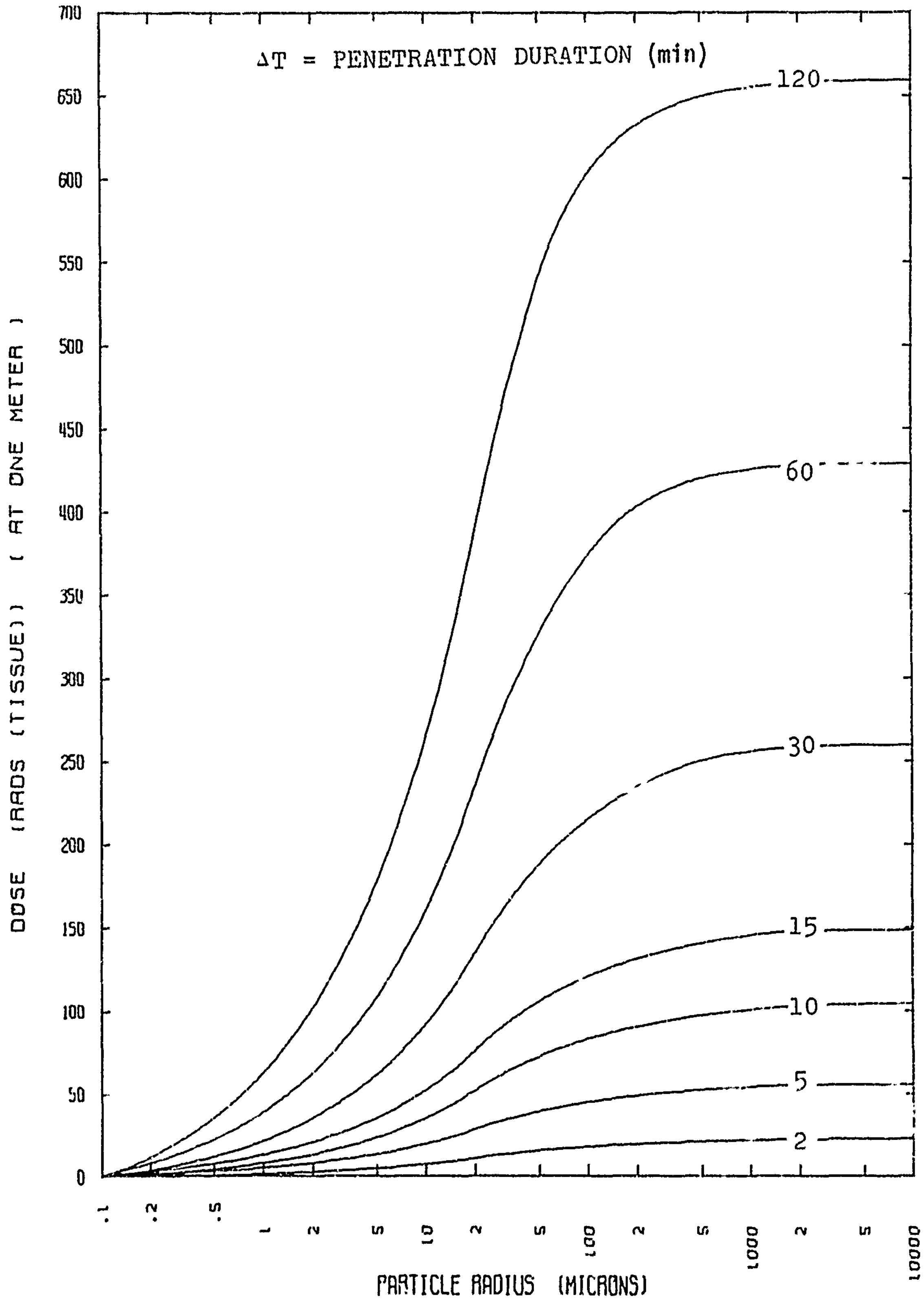

Figure 33. Cumulative Filter Dose at 30 Hours,
TI = 10 Minutes

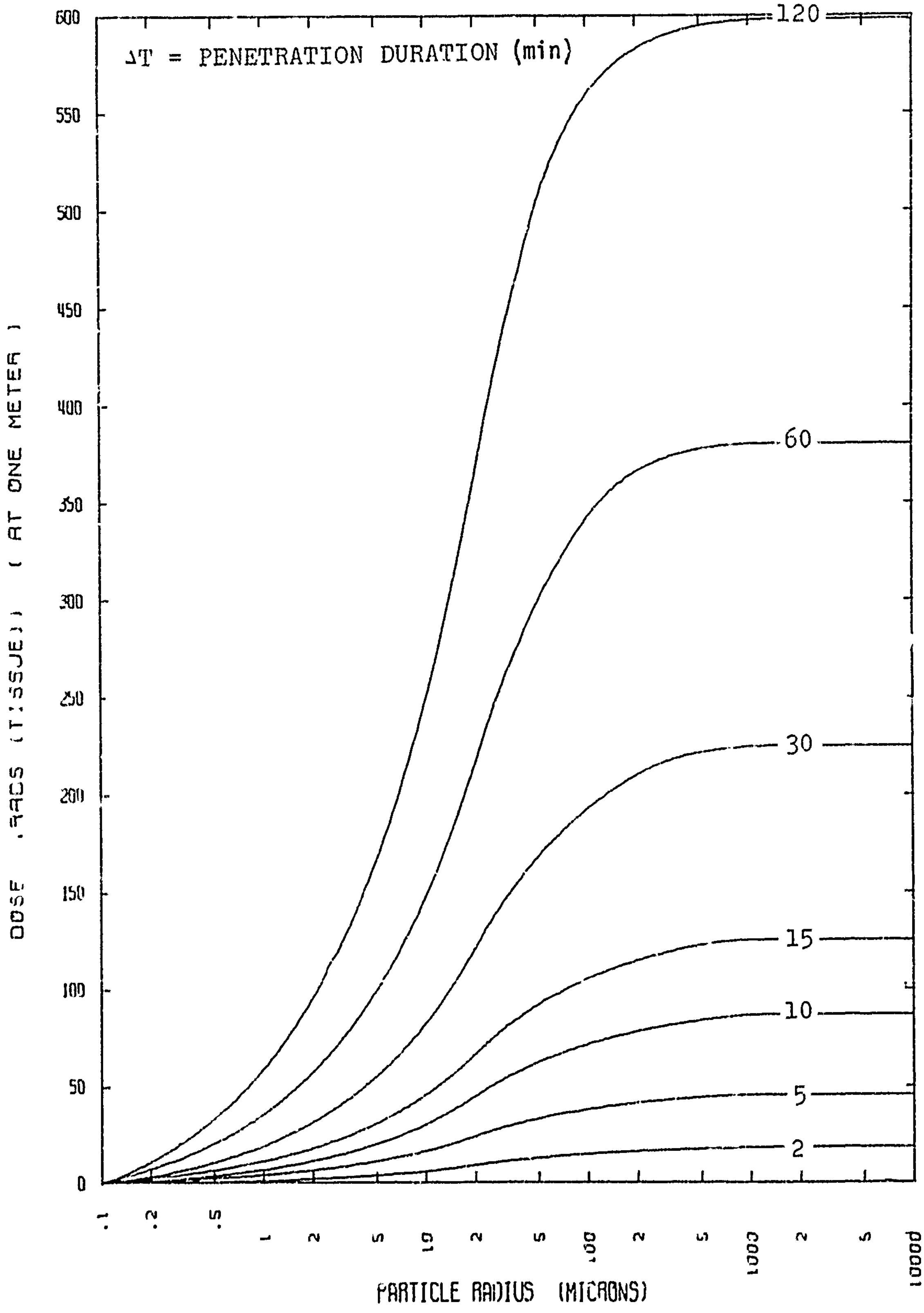

Figure 34. Cumulative Filter Dose at 30 Hours, TI = 18 Minutes

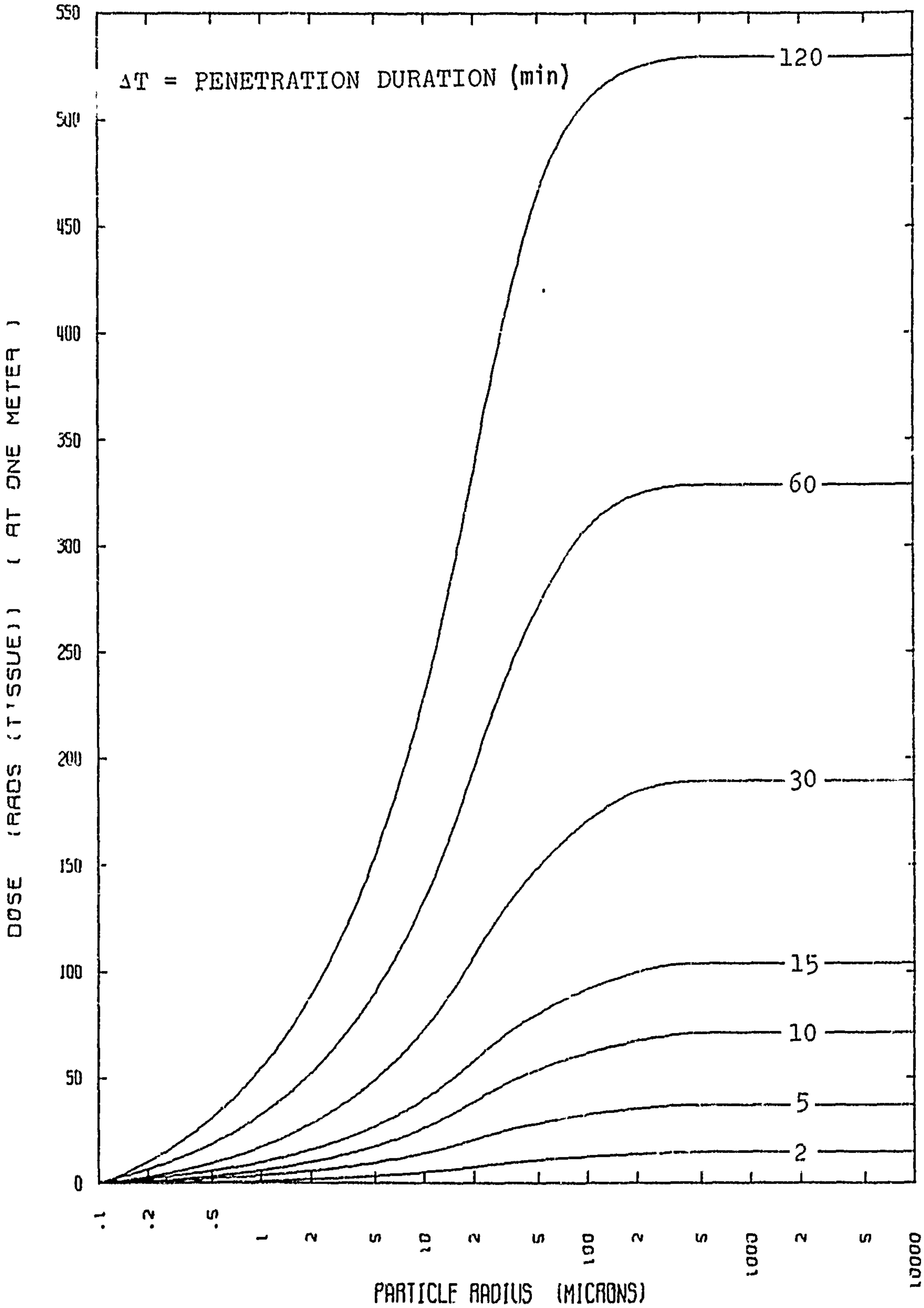

Figure 35. Cumulative Filter Dose at 30 Hours,
TI = 30 Minutes

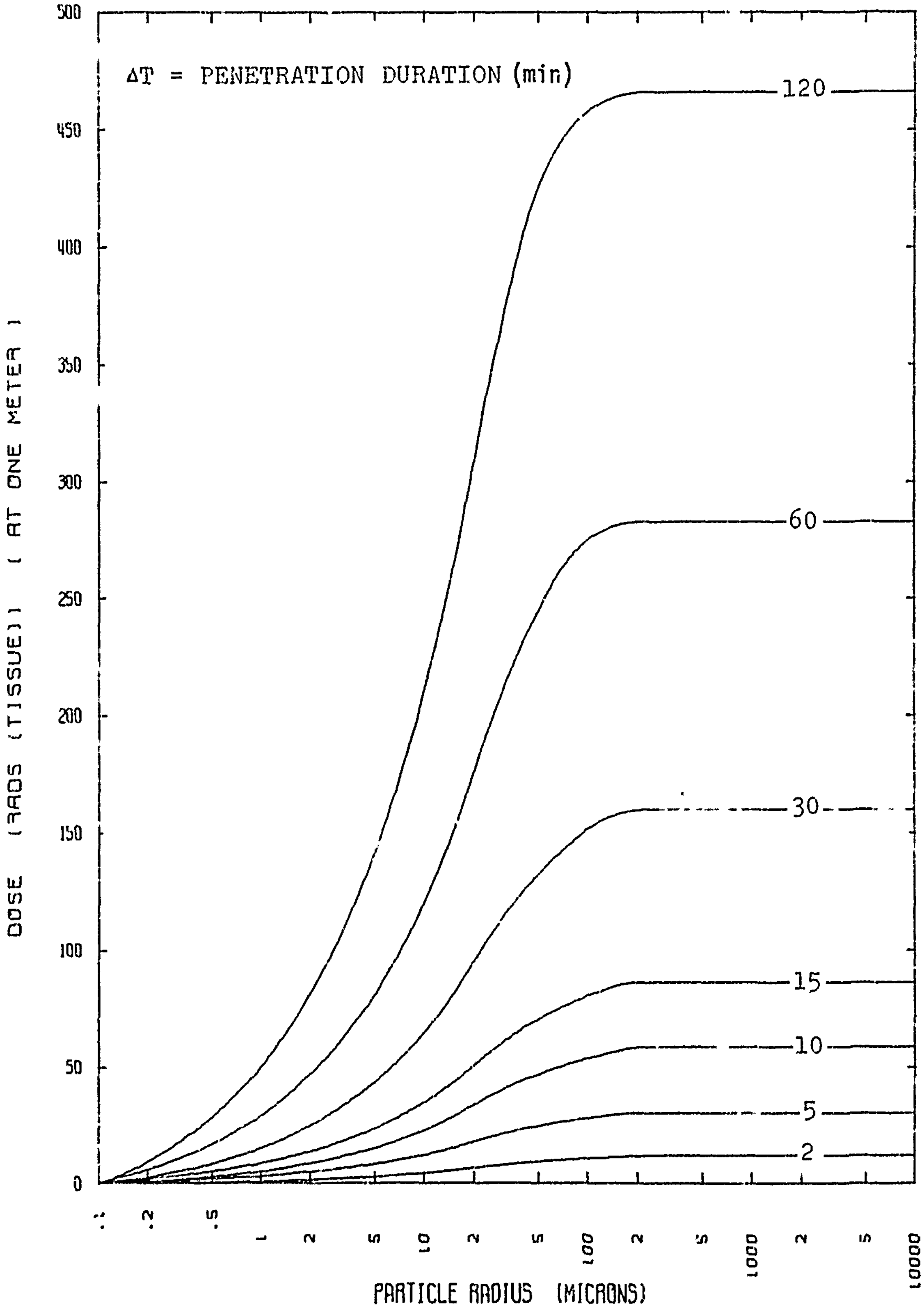

Figure 36. Cumulative Filter Dose at 30 Hours, TI = 45 Minutes

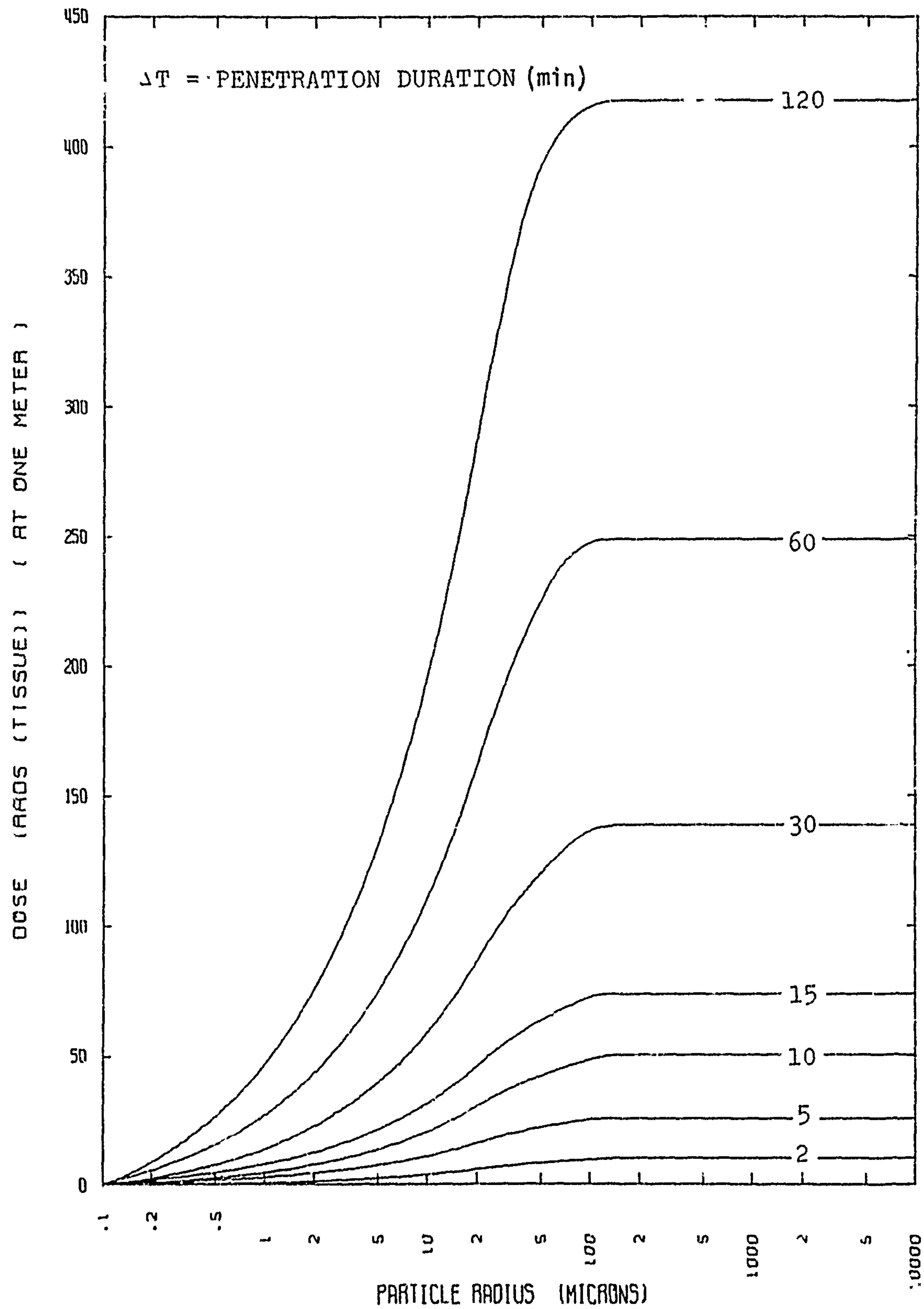

Figure 37. Cumulative Filter Dose at 30 Hours, TI = 1 Hour

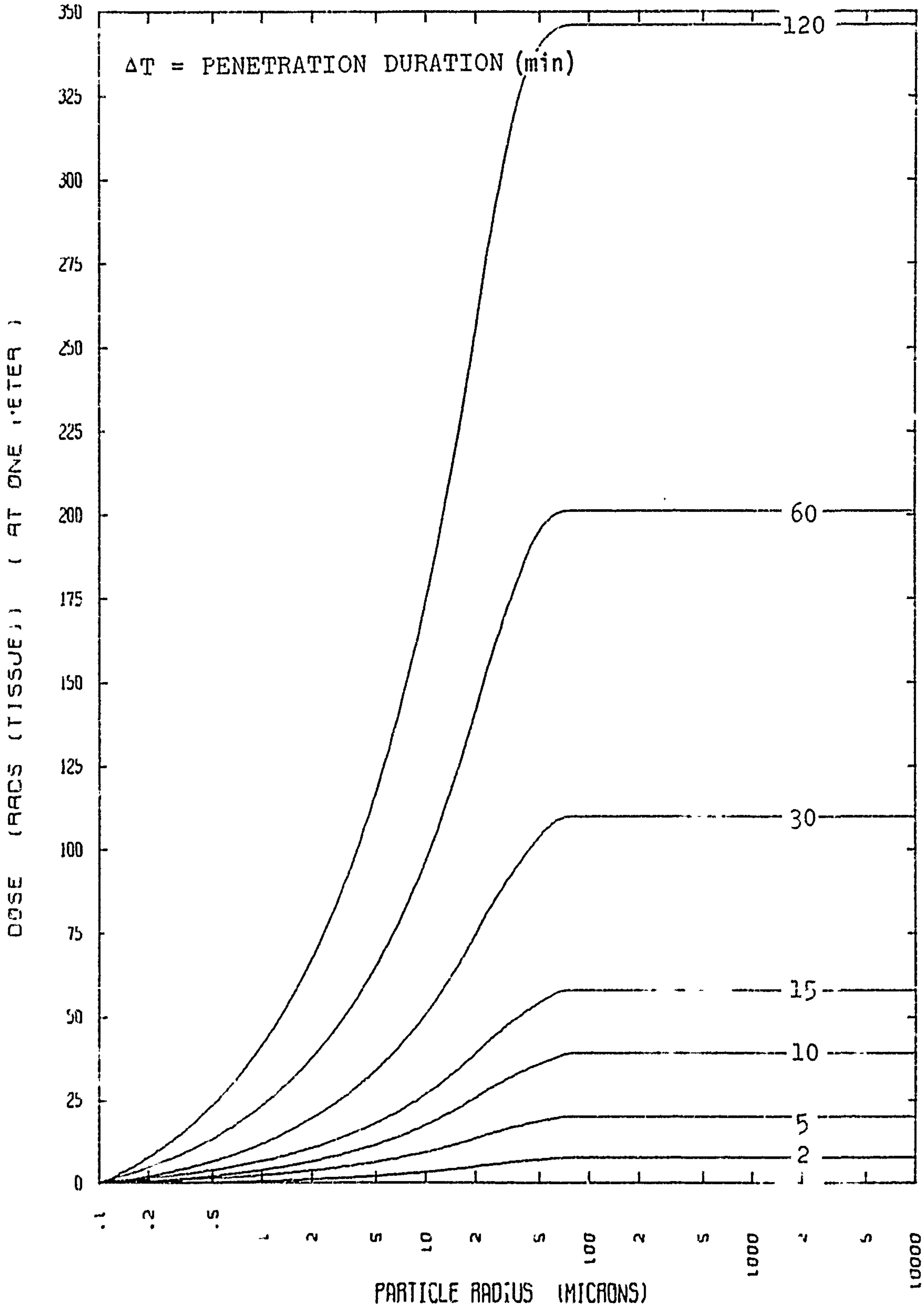

Figure 38. Cumulative Filter Dose at 30 Hours,
TI = 1.5 Hours

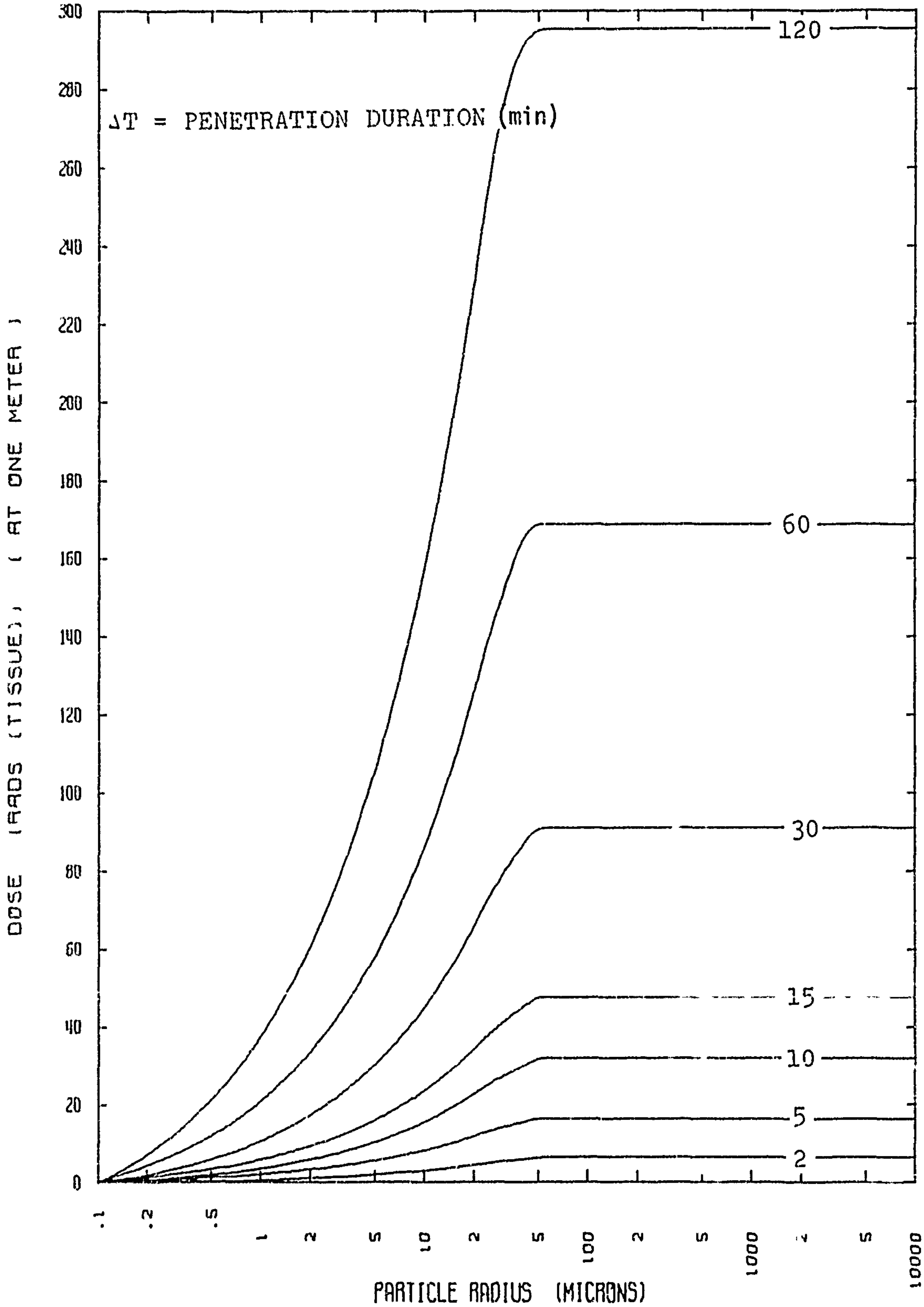

Figure 39. Cumulative Filter Dose at 30 Hours,
TI = 2 Hours

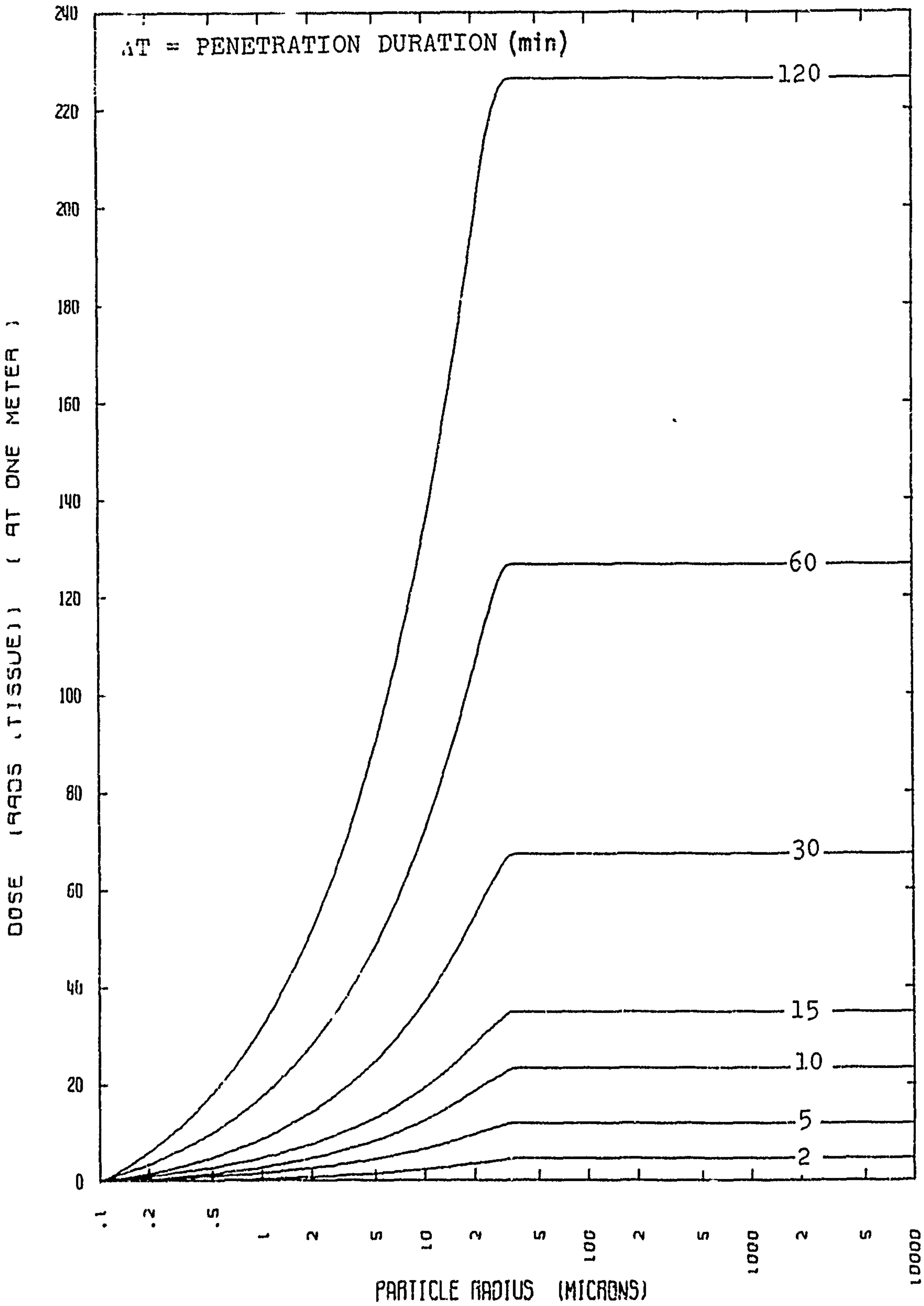

Figure 40. Cumulative Filter Dose at 30 Hours,
TI = 3 Hours

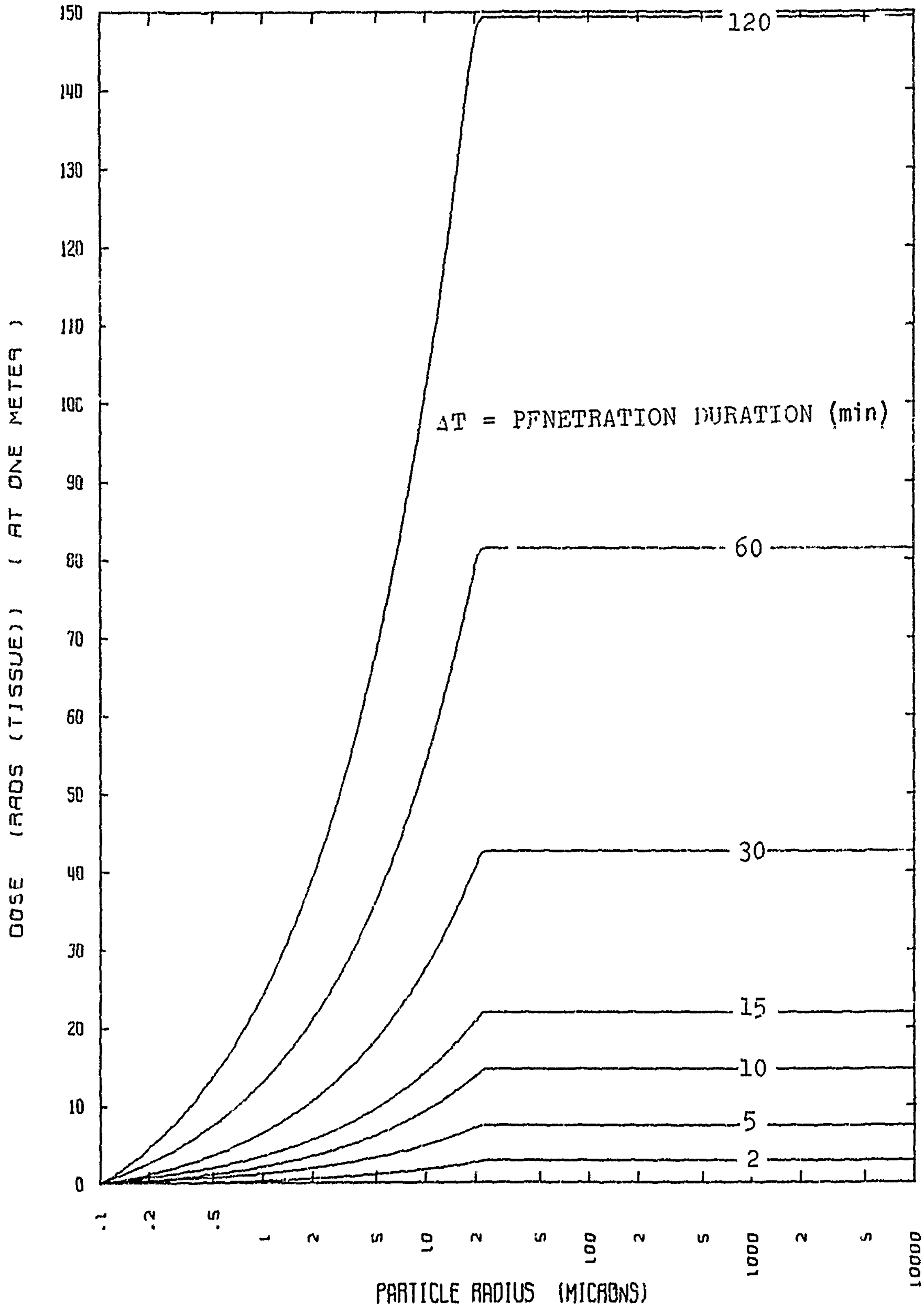

Figure 41. Cumulative Filter Dose at 30 Hours, TI = 5 Hours

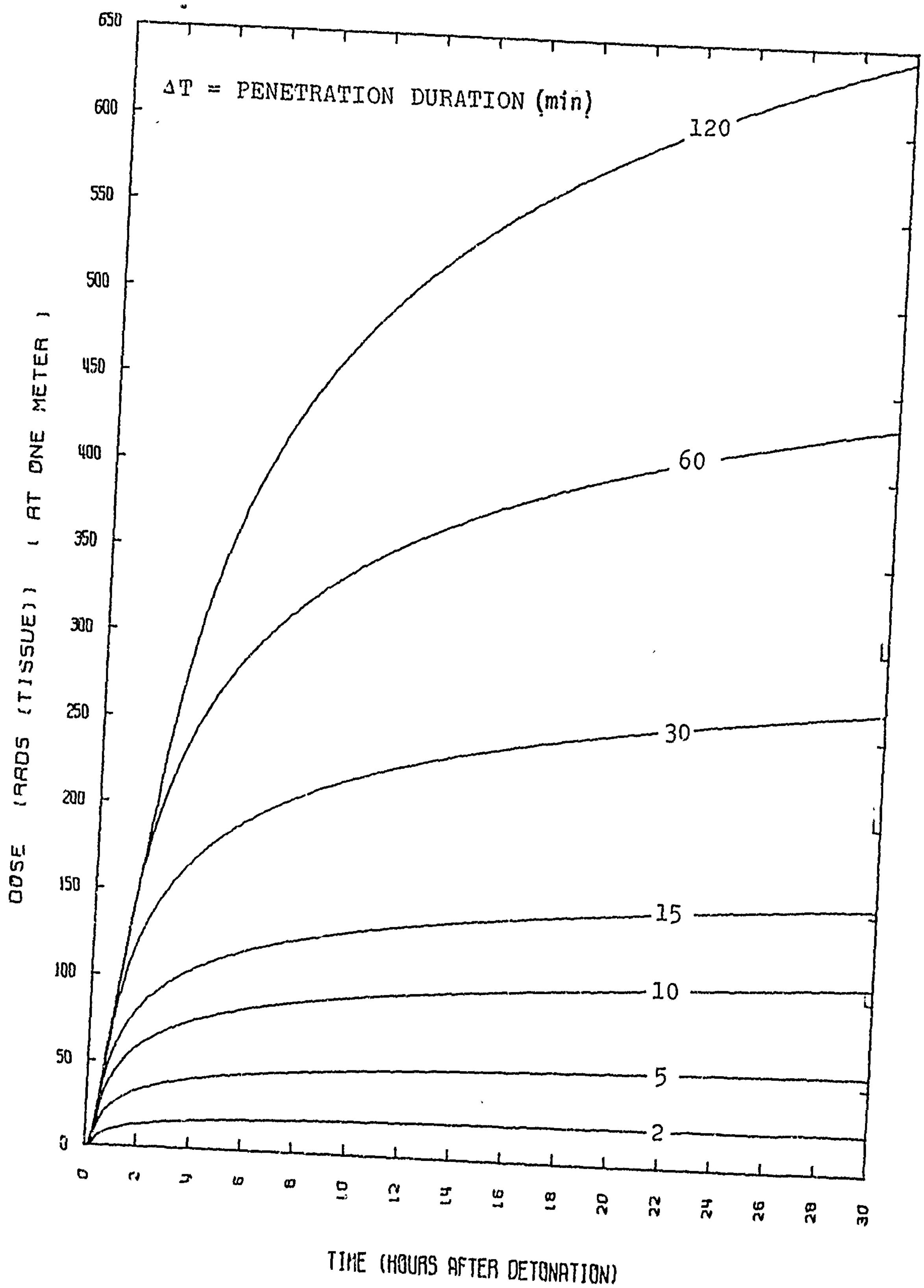

Figure 42. Filter Dose as a Function of Time, TI = 10 Minutes

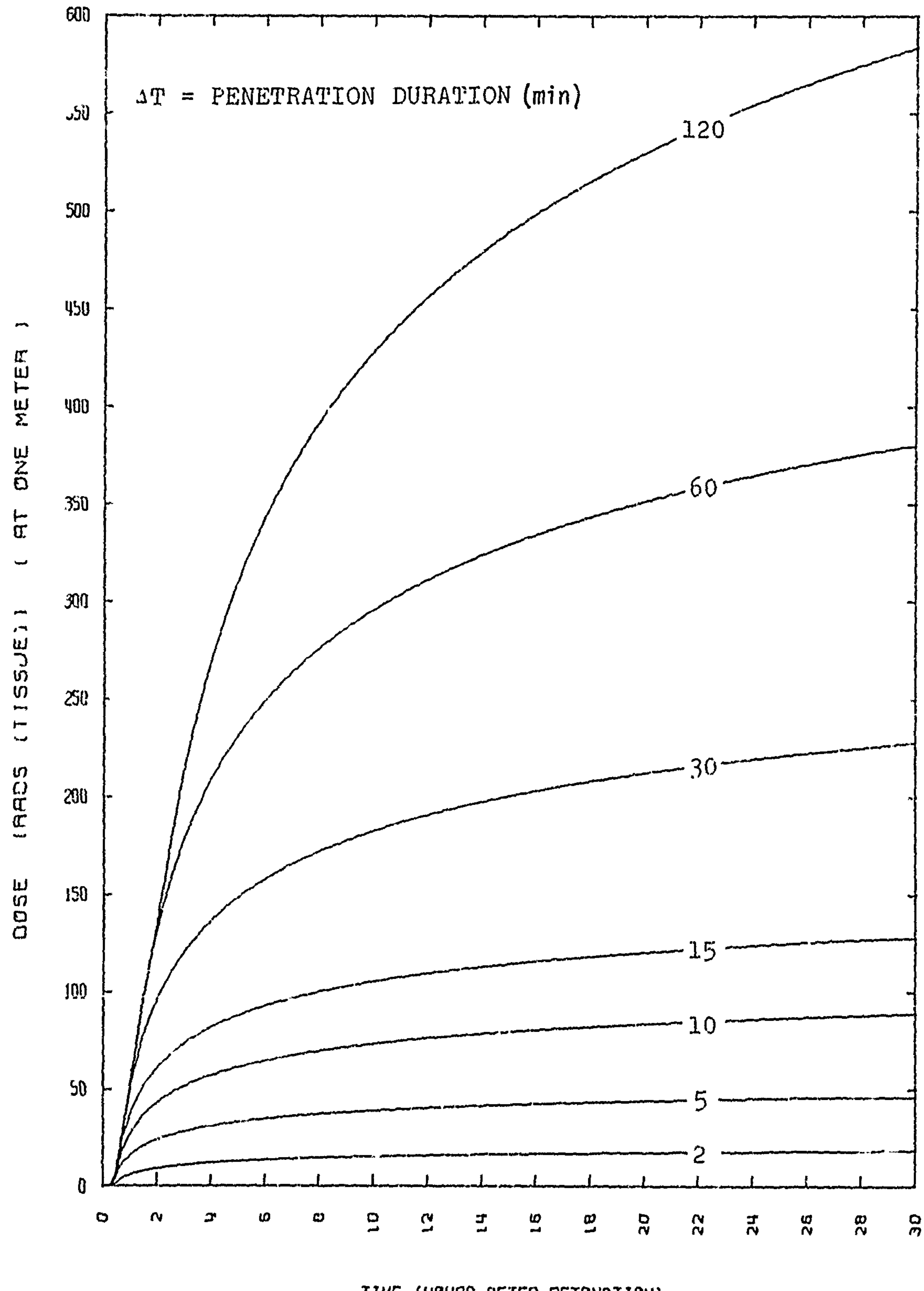

Figure 43. Filter Dose as a Function of Time, TI = 18 Minutes

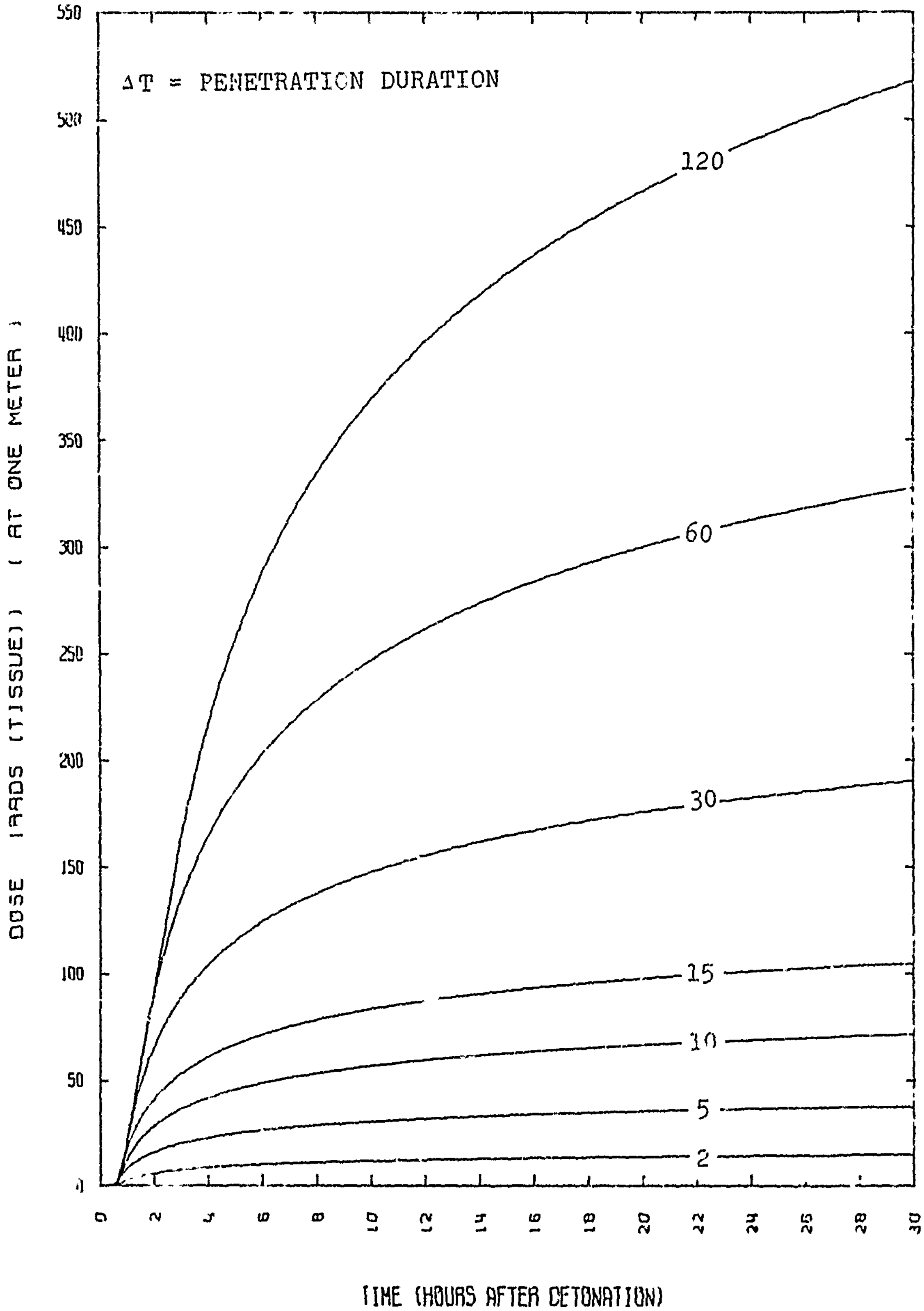

Figure 44. Filter Dose as a Function of Time,
TI = 30 Minutes

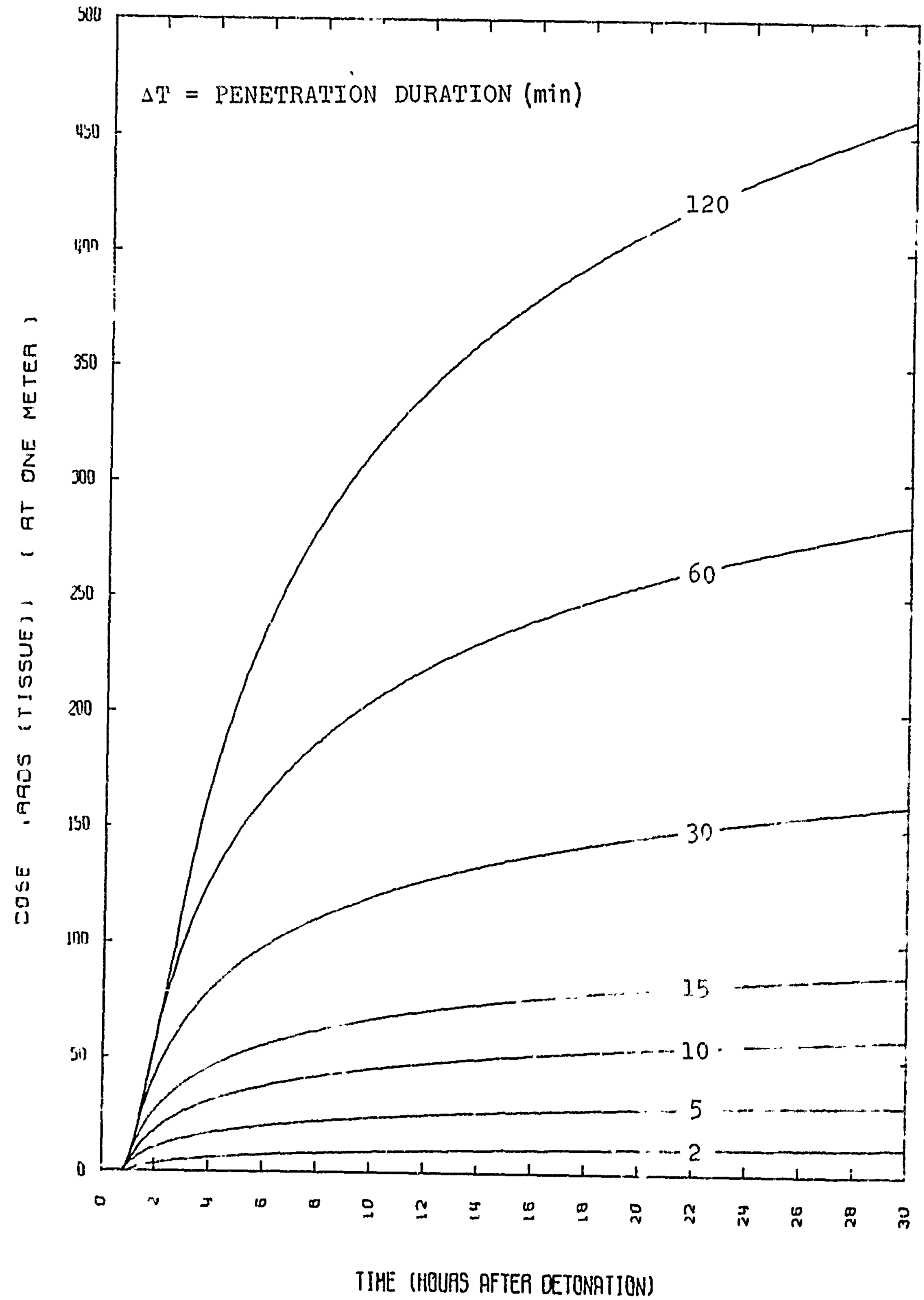

Figure 45. Filter Dose as a Function of Time,
TI = 45 Minutes

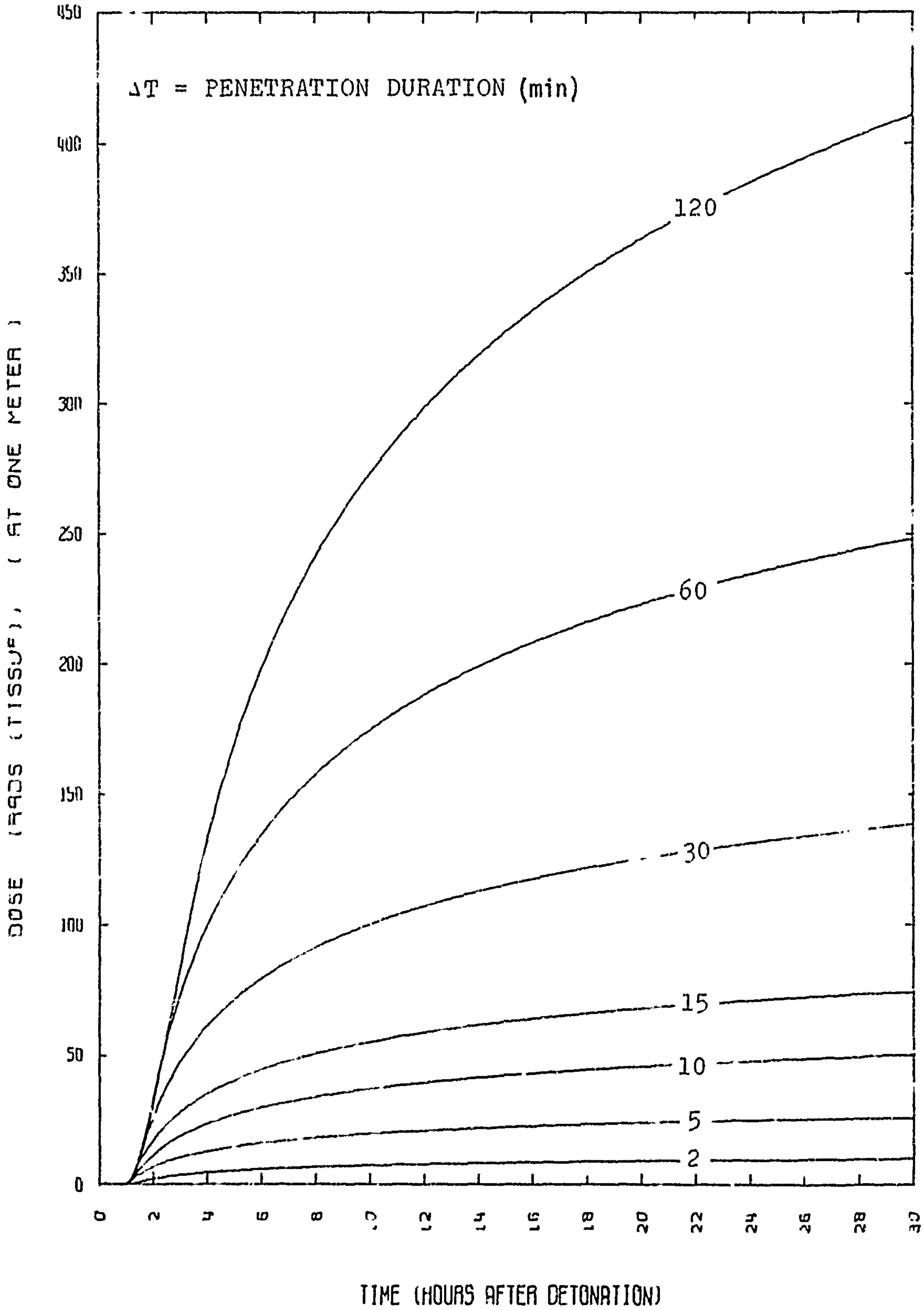

Figure 46. Filter Dose as a Function of Time, TI = 1 Hour

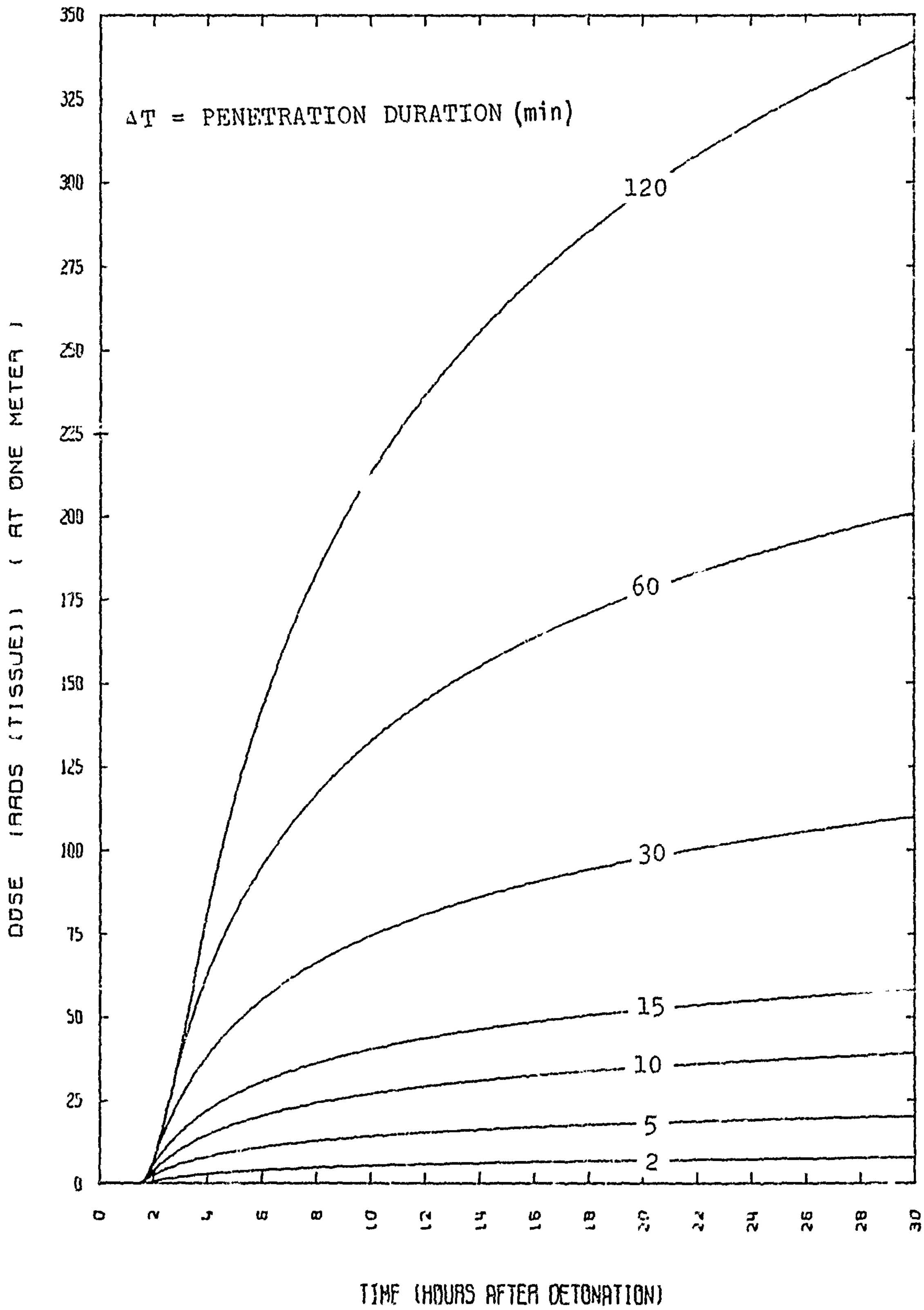

Figure 47. Filter Dose as a Function of Time,
TI = 1.5 Hours

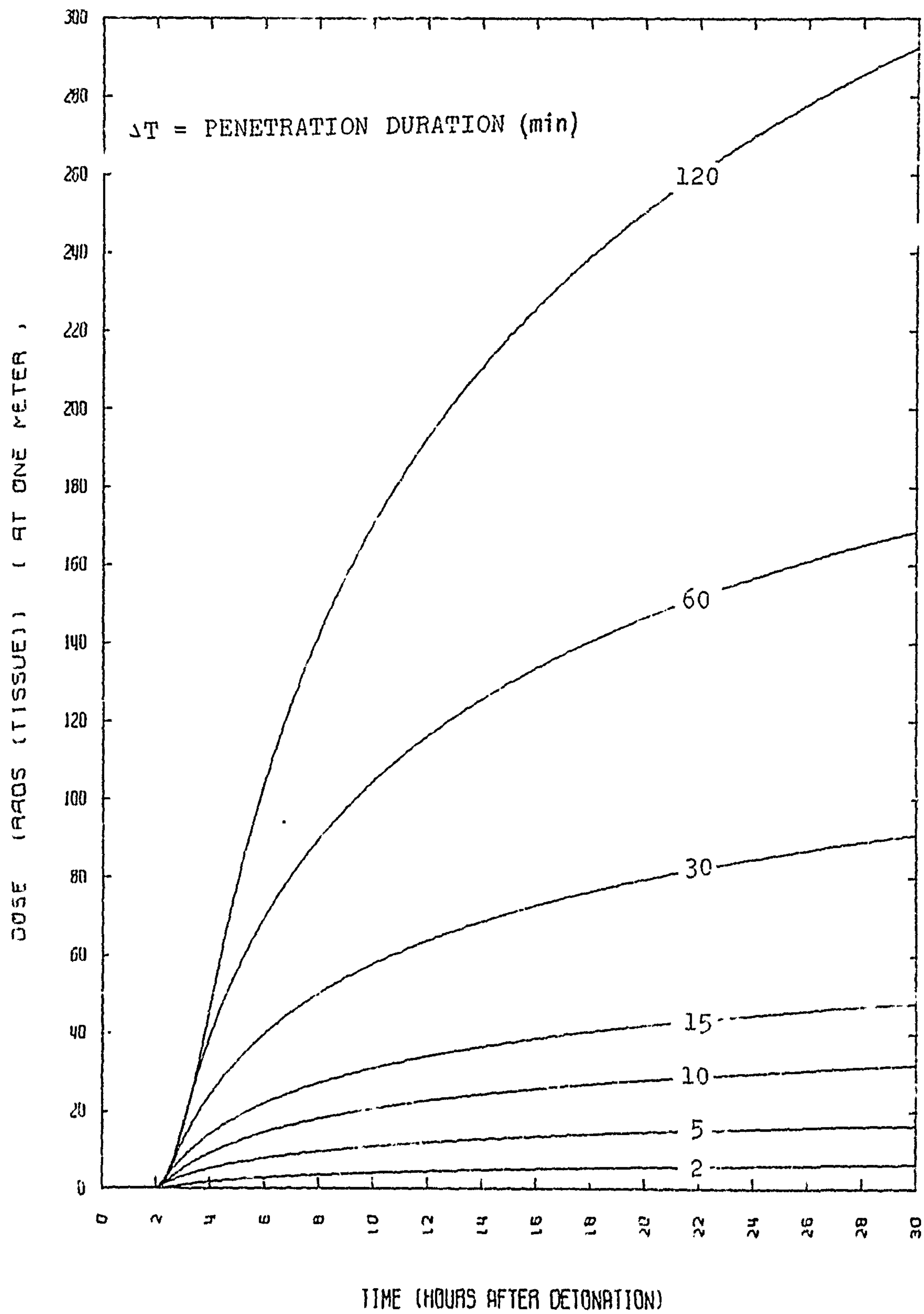

Figure 48. Filter Dose as a Function of Time, TI = 2 Hours

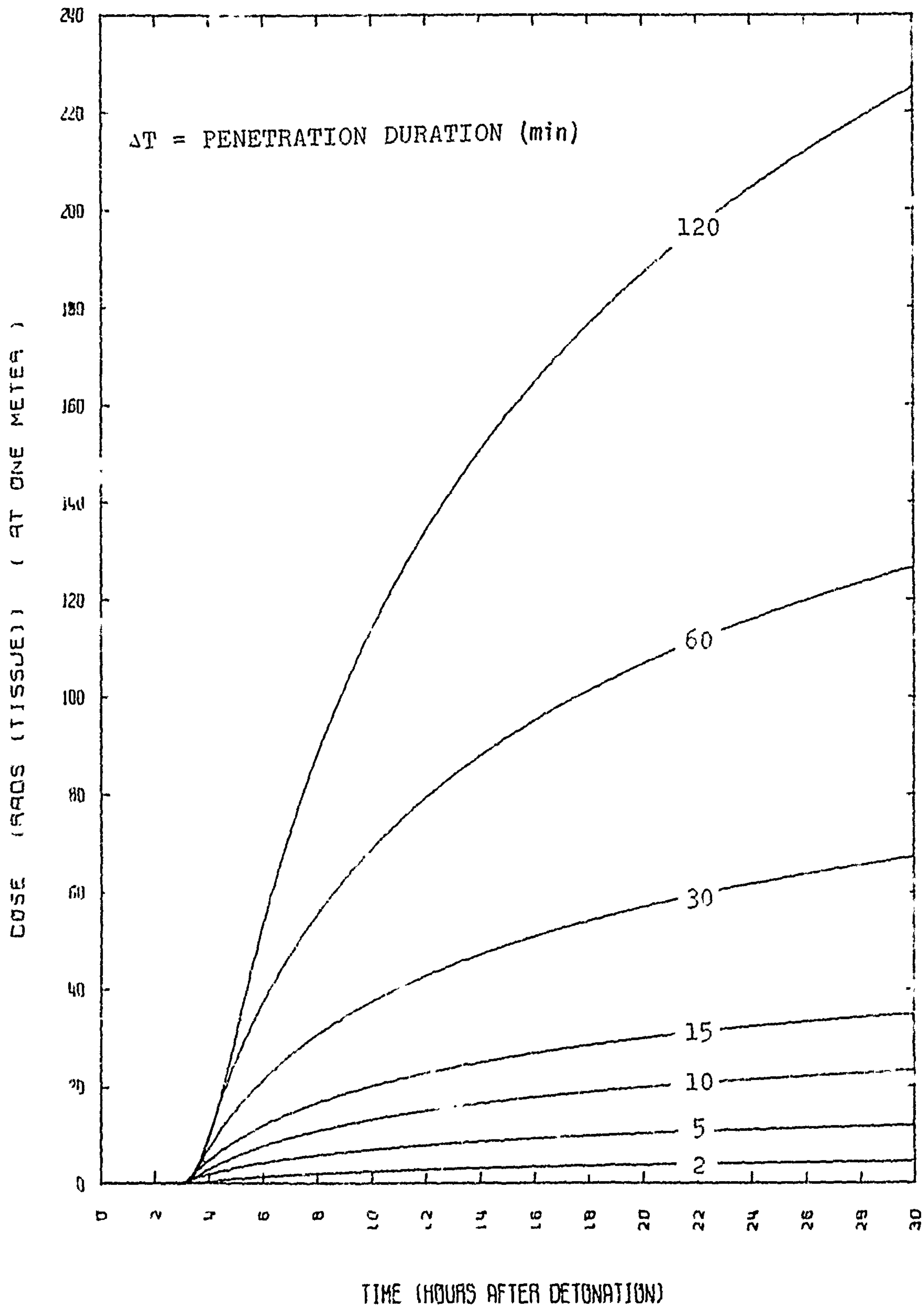

Figure 49. Filter Dose as a Function of Time,
TI = 3 Hours

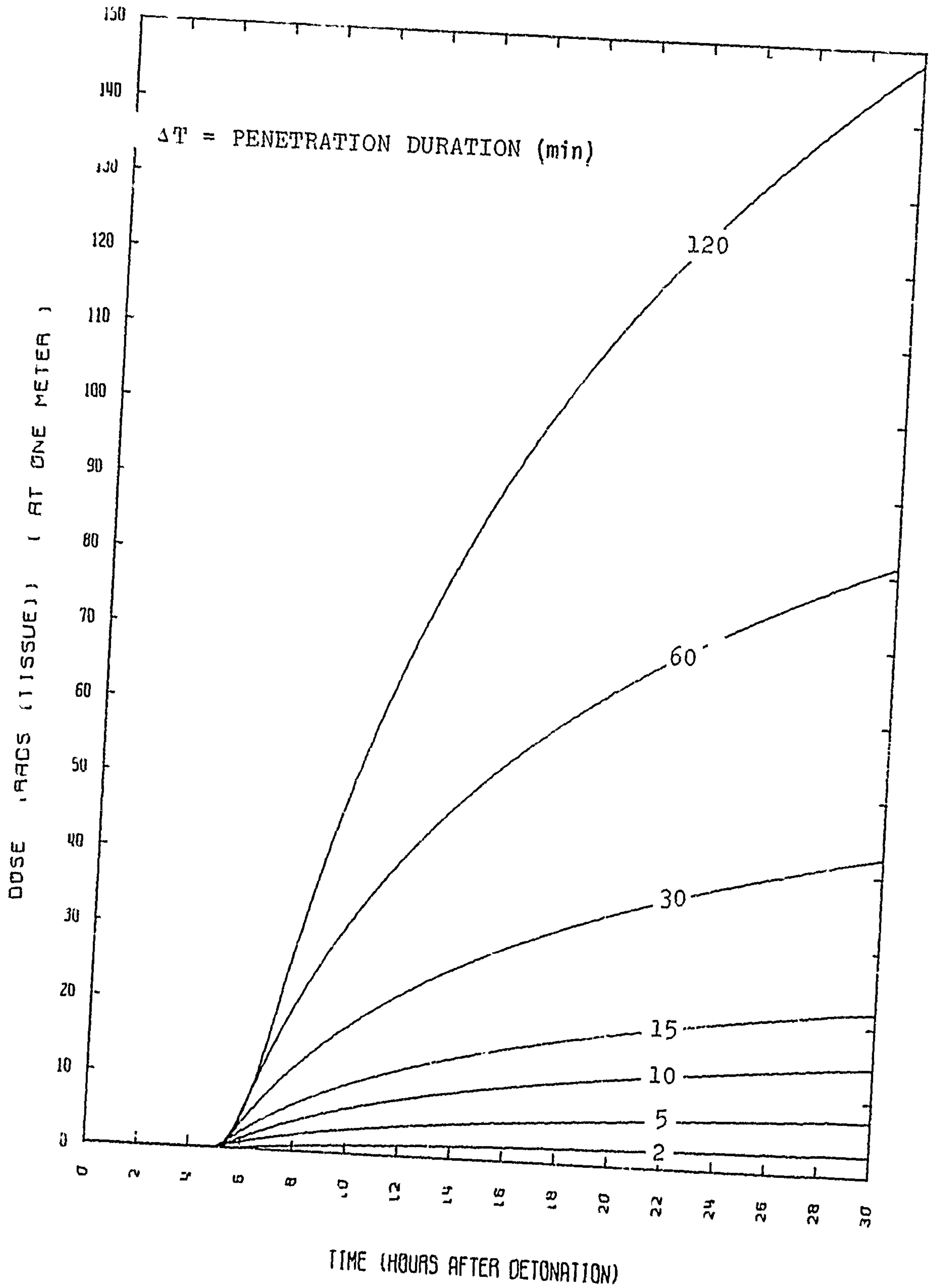

Figure 50. Filter Dose as a Function of Time, TI = 5 Hours

curves and used to scale the 30-hour results to the particular time of interest. The time scaling factor is defined as

$$TSF = \frac{D(t)}{D(30\ hrs)} \tag{6}$$

where D(t) is the filter dose at time t after detonation (TF $\leq$ t $\leq$ 30 hrs), and D(30 hrs) is the filter dose at 5 = 30 hours. Both doses are obtained from the appropriate figure (figures 42 through 50) for a particular case of interest (defined by a particular TI and ΔT). To obtain the filter dust dose distribution function or the cumulative filter dose at some time t other than 30 hours, multiply the ordinate of the appropriate figure by the time scaling factor.

To further clarify the use of the time scaling factor, consider the following example. Assume that the aircraft lifts off at midnight and at 0600 it enters a radioactive dust cloud resulting from the baseline massive multiburst dust environment. Assume further that the weapons were detonated at 0530. Thus, the aircraft cloud entry time is 30 minutes after detonation. Assume also that at 0630 the aircraft exits the cloud. Thus, the penetration duration ΔT = 30 minutes and cloud exit time is TF = TI + ΔT = 60 minutes after weapon detonation. Assume finally that the aircraft completes its mission and lands at a base at 1200 hours. The landing time corresponds to a time of t = 6.5 hours after weapon detonation. Figure figure 44, D(30 hours) = 190 rads (tissue) and D(t) = D(6.5 hours) = 127 rads (tissue). The 127 rads (tissue) is the filter dose (at-one-meter) which would be accumulated by the crew. The time scaling function (TSF) is 127/190 = 0.67. The 6.5-hour dose distribution as a function of particle size and the 6.5-hour cumulative dose as a function of particle size are obtained by scaling the 30-hour results in figures 26 and 35 by the time scale factor, 0.67.

IMPERFECT FILTER

At the opposite extreme from the perfect filter is the case where there is no filter (i.e., "imperfect" filter) in the B-1 Environmental Control system. All the particles, regardless of size, would then enter the cockpit. To determine how much dust is involved, examine the results of the perfect filter cases. Specifically, observe from figure 23 that for a cloud entry time of 10 minutes and a penetration duration of roughly 2 hours, 3.3 kg of dust would be collected by the perfect filter. Thus, for the imperfect filter, this 3.3 kg of radioactive dust would enter the cockpit.

The impact of such direct exposure of crew/electronics to such an environment was considered in reference 2, and the conclusions reached therein are summarized here for continuity. There are essentially four concerns. The first concern is the consequence of crew inhalation of dust particles. The second is the consequence of direct contact of radioactive dust particles with the skin of the crew because these particles cause skin burns and attendant problems. The third concern is the consequence of airborne dust within the cockpit, which is a source of crew/electronics immersion dose. The fourth concern is the consequence of dust settled out in the cockpit and on crew/electronic equipment, which could be a major source of dose.

It is concluded in reference 2 that there is little concern about short-term incapacitation of crew members over typical mission durations due to inhaled dust, although it might prove fatal over a period of weeks or months. More important from a short-term standpoint would be skin burns due to direct radioactive dust contact with unprotected skin. In particular over time periods of several hours such skin burns could be painful, cause local swelling, hamper movement, and, in case of skin burns in the preorbital areas, the attendant swelling could hamper vision. However, the simple expedient of a warning system to alert the crew members to the danger and the implementation of the procedures of donning gloves, helmets, and oxygen masks with 100 percent oxygen, particularly during cloud penetration, would alleviate these concerns.

In examining the dose due to immersion of the crew/electronics in the airborne dust within the cockpit, it was determined that this immersion dose is small in comparison to other sources. In fact, in the analysis of the dose due to immersion in the radioactive cloud (figure 4), this cockpit airborne dust dose has already been included for conservatism and amounts to less than 1 percent of the values provided in this figure.

The dust particles of most concern are those which settle within the cockpit and on and around the crew members. These particles continue to contribute to the dose throughout the mission. In addition, those particles which settle on the crew members' clothing and nearby surfaces, because of their nearness and the ($1/d^2$) nature of the phenomenon, can contribute substantially to the total dose to crew members. Thus, it is important to determine the amount of dust settled in the cockpit, to determine its distribution relative to the crew member, and to determine its contribution to the total crew/electronics dose.

This problem is examined in some detail in reference 2, and while the calculational model developed is simplistic in nature it yields results which are adequate. It is based on the Stokes law of settling particles. The probability of a particle settling within the cockpit as a function of particle size, cockpit dimensions, and the mass rate of flow of air through the cockpit is obtained.

As presented in reference 2, particles with radius r above some critical particle size, $\bar{r}$, are all deposited within the cockpit because their settling velocities are so high that they would all fall to the floor during their transit time through the cockpit. The critical size depends only on cockpit dimensions and the mass flow rate through the cockpit. Particles with radius r less than this critical size are found to have a probability of settling proportional to r^2. This probability of settling is essentially a cockpit filter efficiency.

To point the analysis to the B-1 system a cockpit volume of 645 ft^3 (from reference 4) and an effective cockpit height of 6 feet is selected. It is determined that $\bar{r}$ is about 20 microns and this value is used through the cockpit dust deposition analysis.

The calculation of the dust mass distribution function consists of numerically integrating the product of the cockpit filter efficiency and the dust density distribution function, and multiplying by appropriate constants (reference 2). These results are presented in figures 51 through 59. Each curve provides, for a particular cloud entry time, the dust mass distribution function as a factor of particle size for various penetration durations, namely 2, 5, 10, 15, 30, 60, and 120 minutes. The entry times presented range from 10 minutes to 5 hours.

The results show that for $r > \bar{r} = 20\mu$ all particles are collected and in this range of r the results are identical to the perfect filter results. For example, figures 51 and 5 show that for $r > 20\mu$ the results are identical. For $r < \bar{r}$ there is a marked difference in the two figures, demonstrating the fact that small particles tend to be carried through and out of the cockpit without settling.

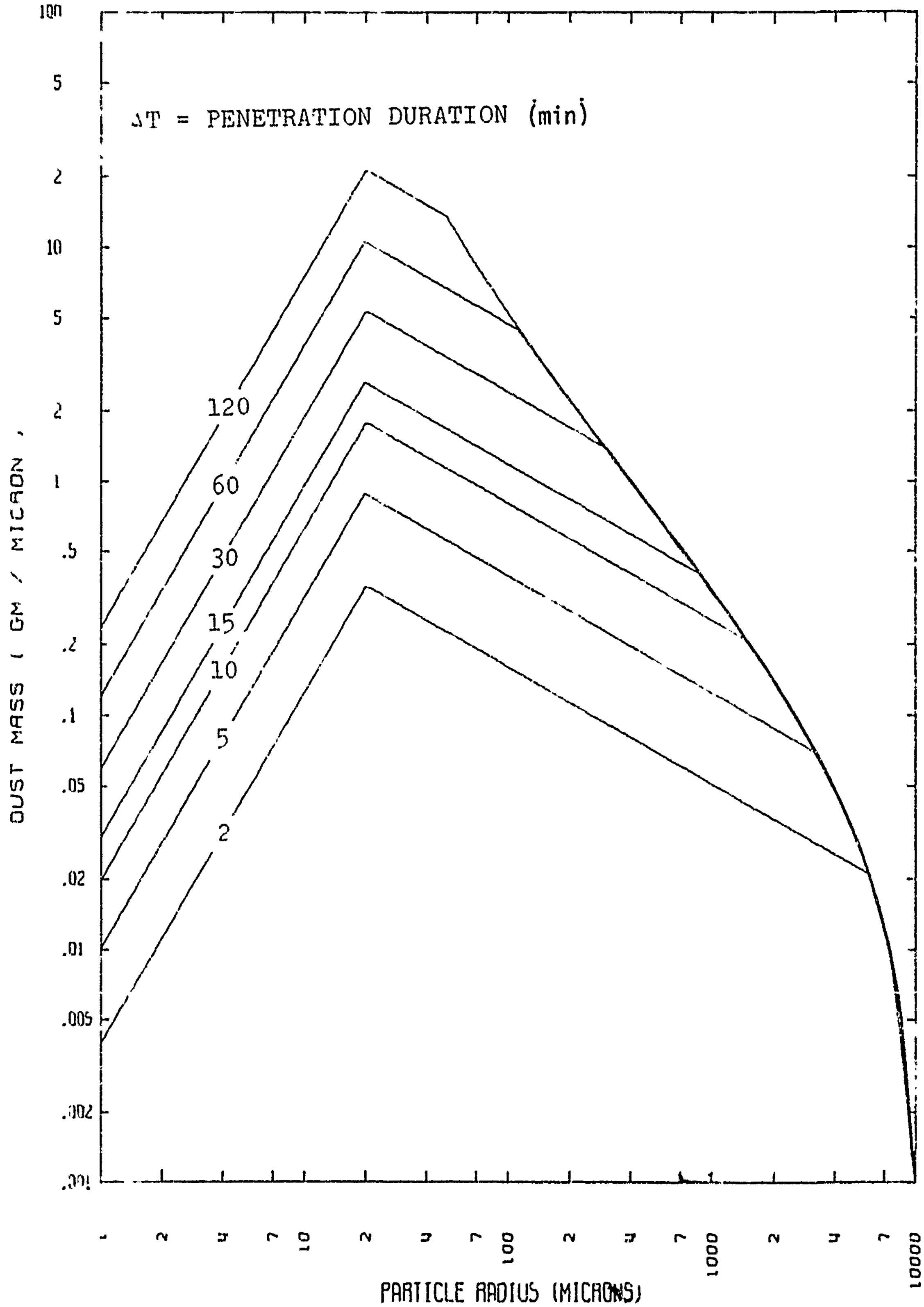

Figure 51. Cockpit Dust Mass Distribution Function,
TI = 10 Minutes

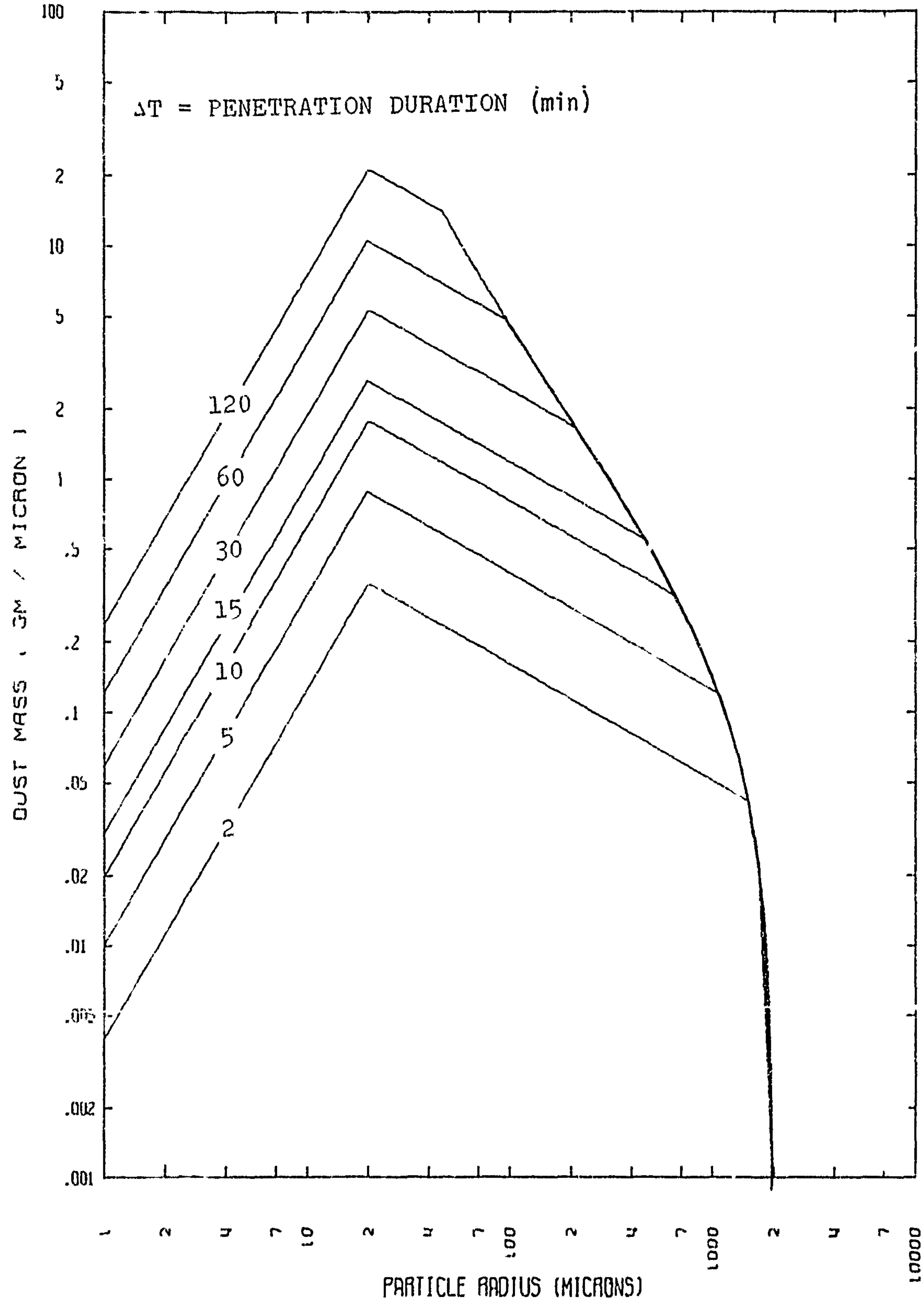

Figure 52. Cockpit Dust Mass Distribution Function,
TI = 18 Minutes

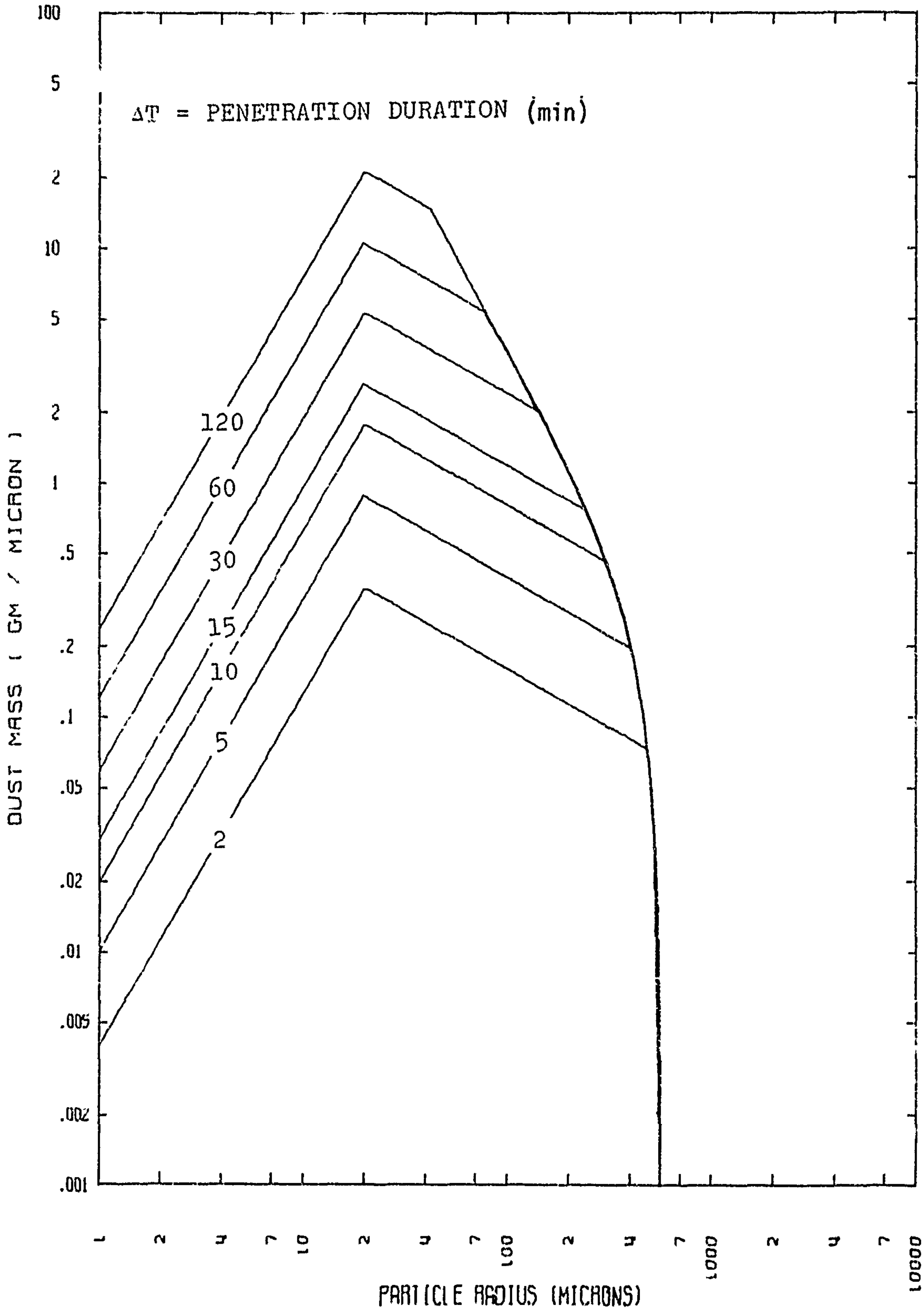

Figure 53. Cockpit Dust Mass Distribution Function, TI = 30 Minutes

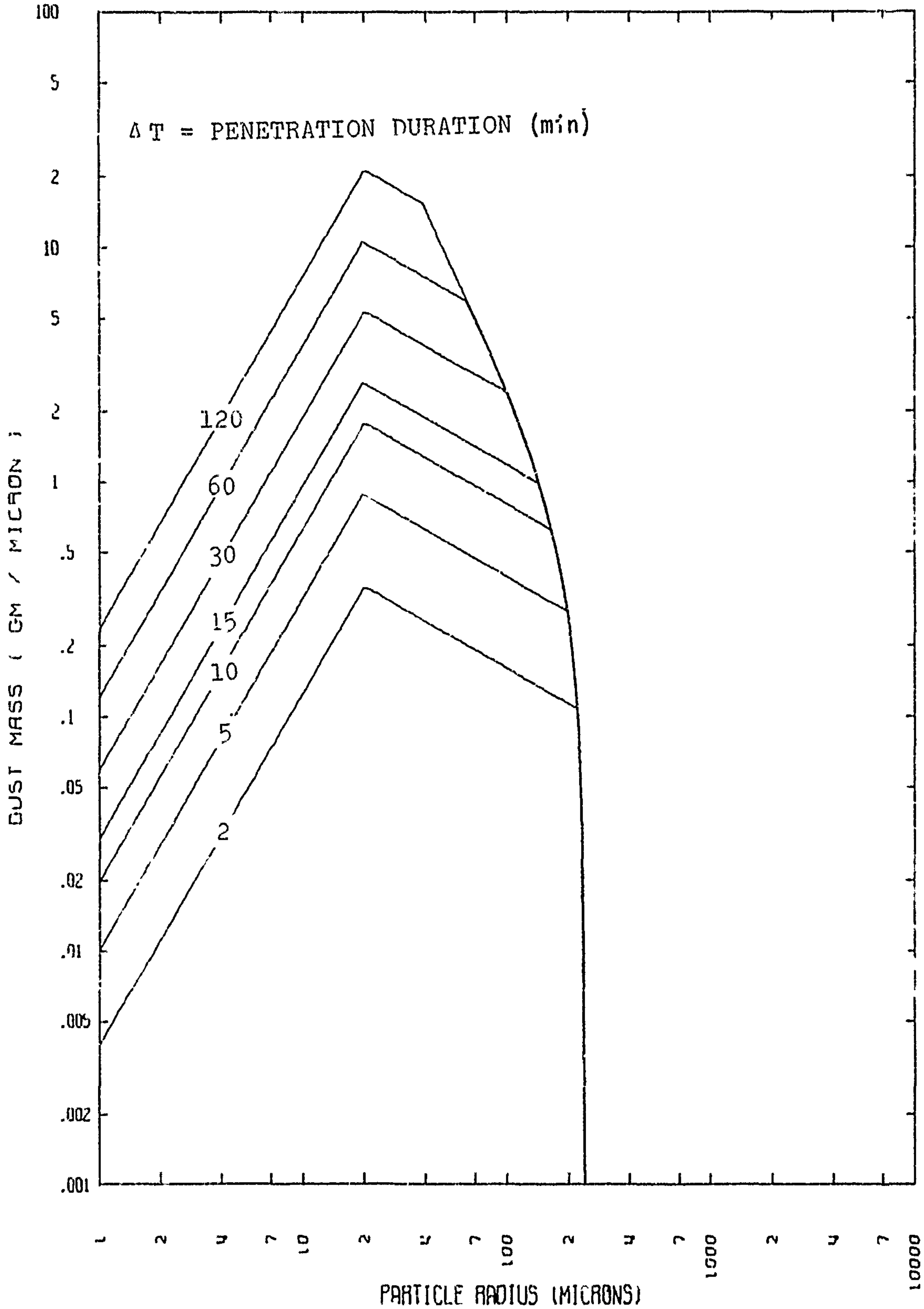

Figure 54. Cockpit Dust Mass Distribution Function, TI = 45 Minutes

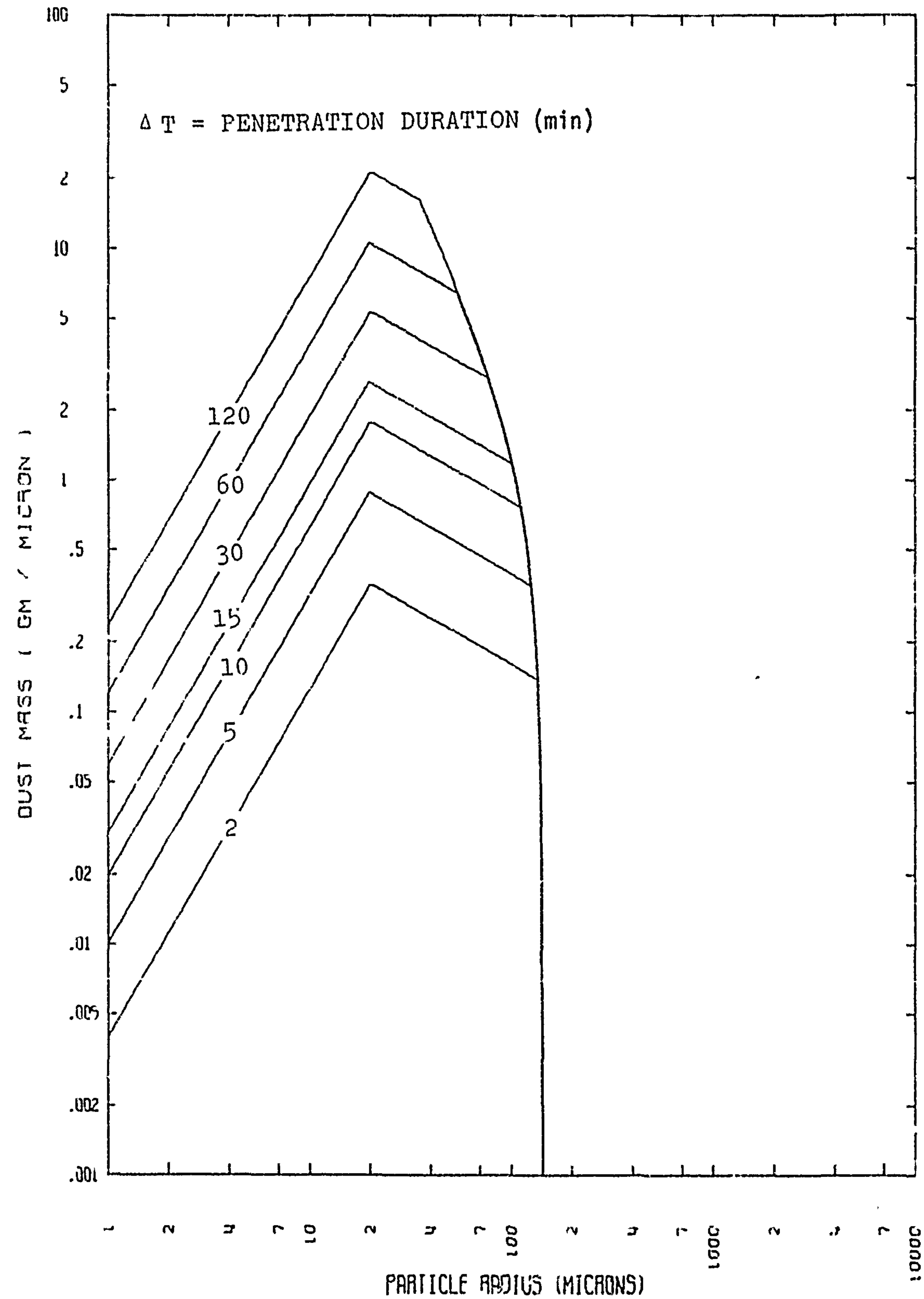

Figure 55. Cockpit Dust Mass Distribution Function,
TI = 1 Hour

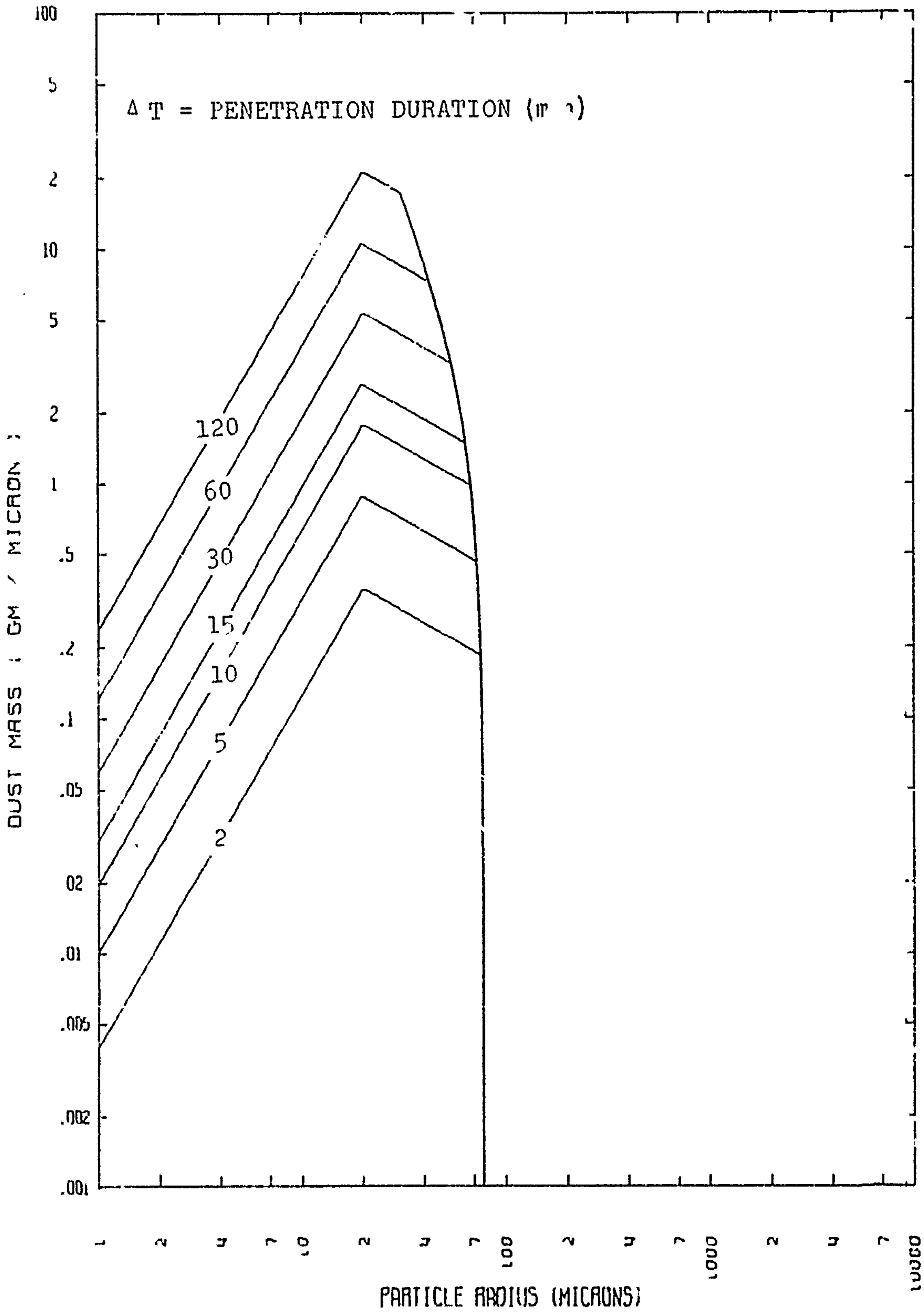

Figure 56. Cockpit Dust Mass Distribution Function, TI = 1.5 Hours

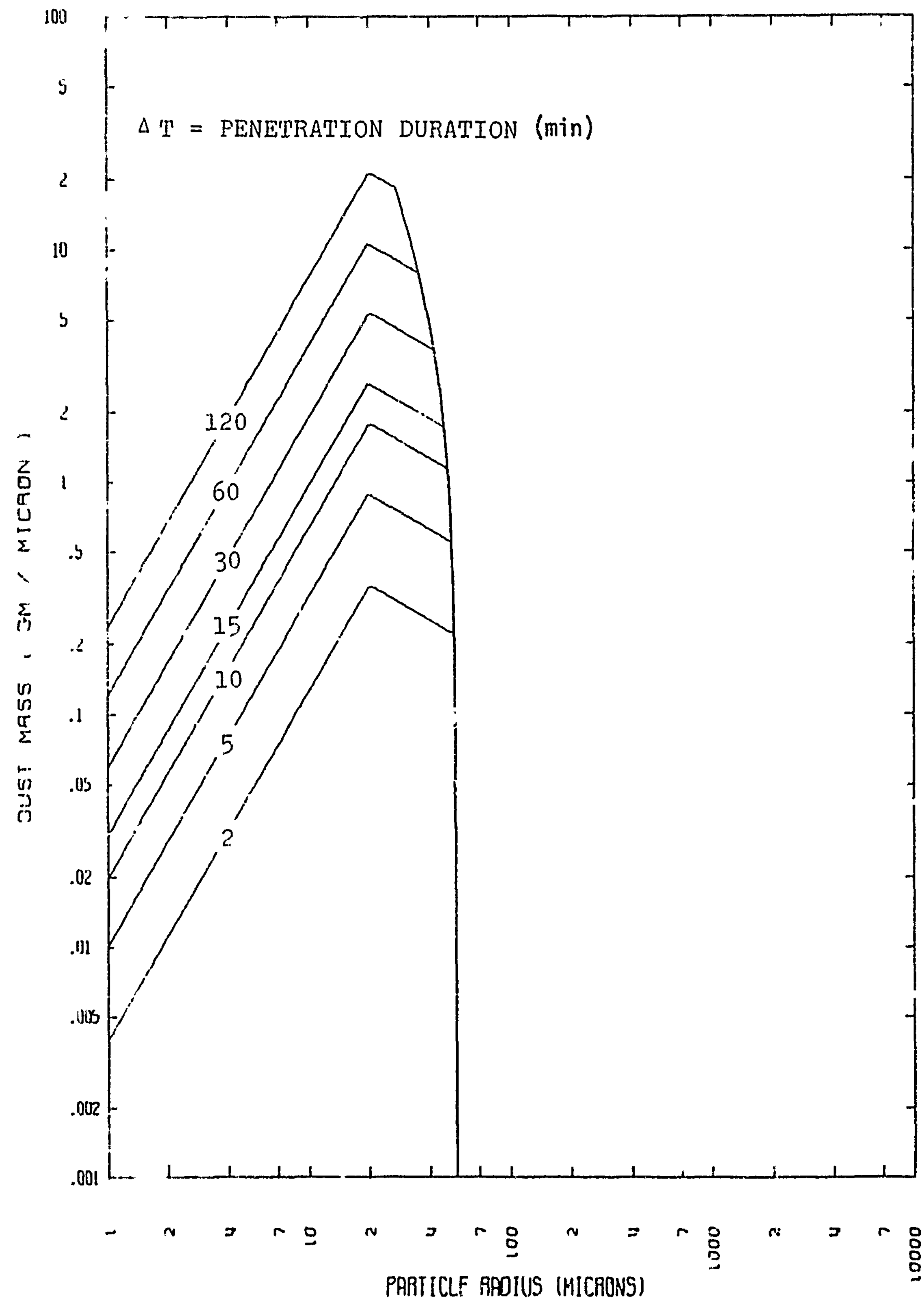

Figure 57. Cockpit Dust Mass Distribution Function,
TI = 2 Hours

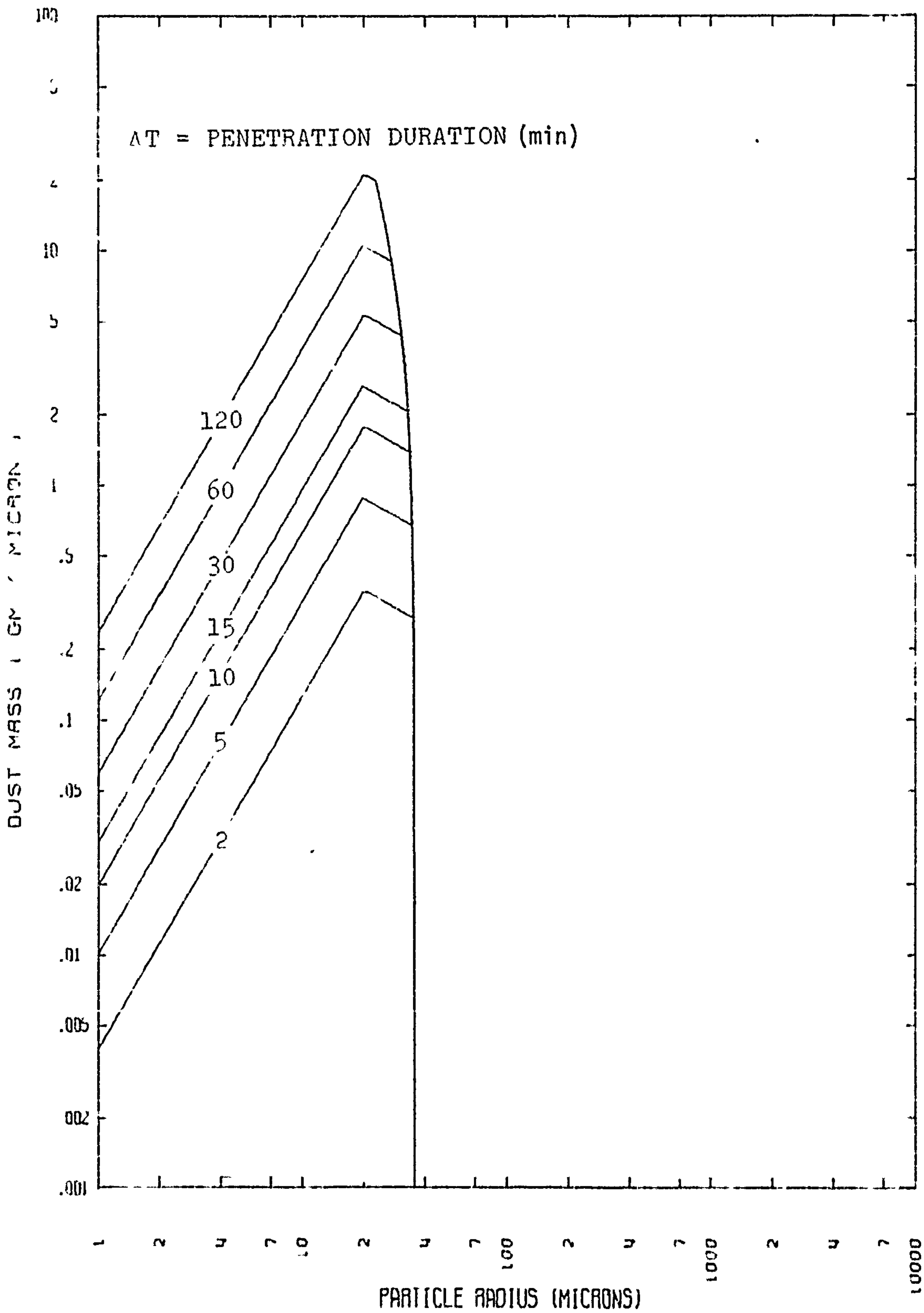

Figure 58. Cockpit Dust Mass Distribution Function,
TI = 3 Hours

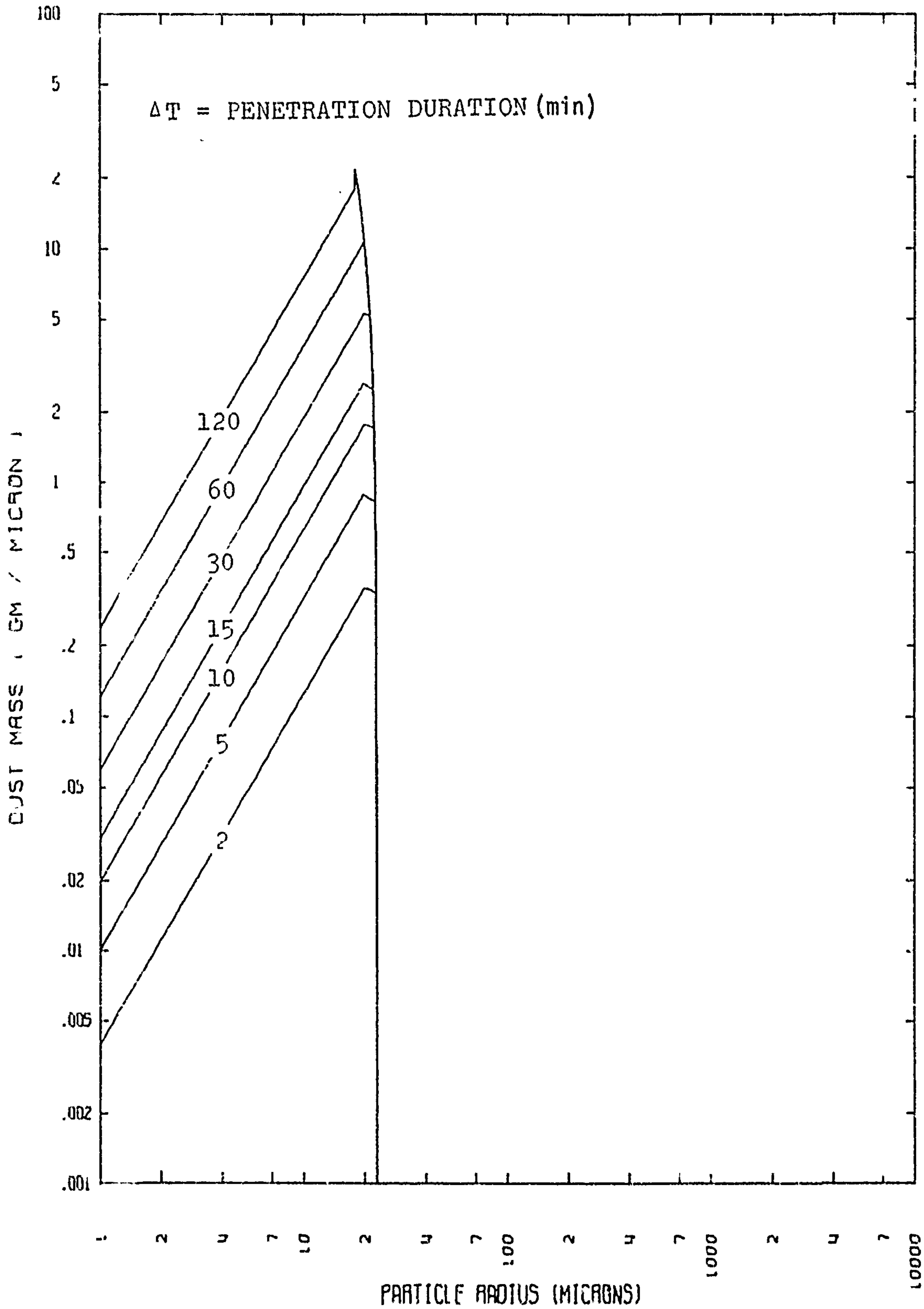

Figure 59. Cockpit Dust Mass Distribution Function, TI = 5 Hours

The next series of figures, figures 60 through 68, displays the cumulative dust mass collected in the cockpit, where cumulative mass is defined as the contribution to the cockpit mass attributable to all particles of size less than or equal to r. These figures present this cumulative mass as a function of particle size for a particular cloud entry time and with penetration duration as a parameter. The same ranges of entry times and penetration durations are presented. It is observed that since the small particles tend to be carried out of the system with the air the cumulative mass is small for small particles. The effect of fallout can also be observed, particularly at late times, because the lines of constant penetration duration become horizontal in the larger particle size range, indicating that there are no particles ingested into the system in these larger size ranges.

The cumulative mass evaluated at r = 10,000 microns is equal to the total mass deposited in the cockpit, and figure 69 presents this total mass as a function of time after detonation with cloud entry time as a parameter. A comparison of figure 69 and the similar perfect filter results, given by figure 23, shows that an appreciable number of small particles are not retained in the cockpit. The differences between figure 69 and figure 23 are entirely attributable to the ejection of the small particles with $r < 20\mu$ from the cockpit with the air. For example, for the case of TI = 10 minutes, the dust collected by a perfect filter at 2 hours after detonation would be 3.25 kg (from figure 23), whereas, if the cockpit had been exposed to this environment it would collect only 2.7 kg (from figure 69). At later times this effect becomes even more pronounced. For example, at 10 hours after detonation the filter would collect 6.6 kg of dust particles, whereas, the cockpit would collect only 3.55 kg. At these later times the fallout has drastically depleted the population of larger particles which the cockpit collects with high efficiency, and the majority of the ingested particles are the smaller ones which tend to be carried out with the air.

Since the smaller particles have higher specific activity and the cockpit is less efficient in collecting these "hottest" particles, one might expect that the resultant cockpit dose would be less than the perfect filter dose. However, the filter dust represents a localized source of radioactivity, whereas the settled dust in the cockpit is distribution over surfaces within the cockpit and on crew members and electronics. Because of the nearness of some of the particles to crew/electronics, their effectiveness from a dose standpoint is greatly enhanced.

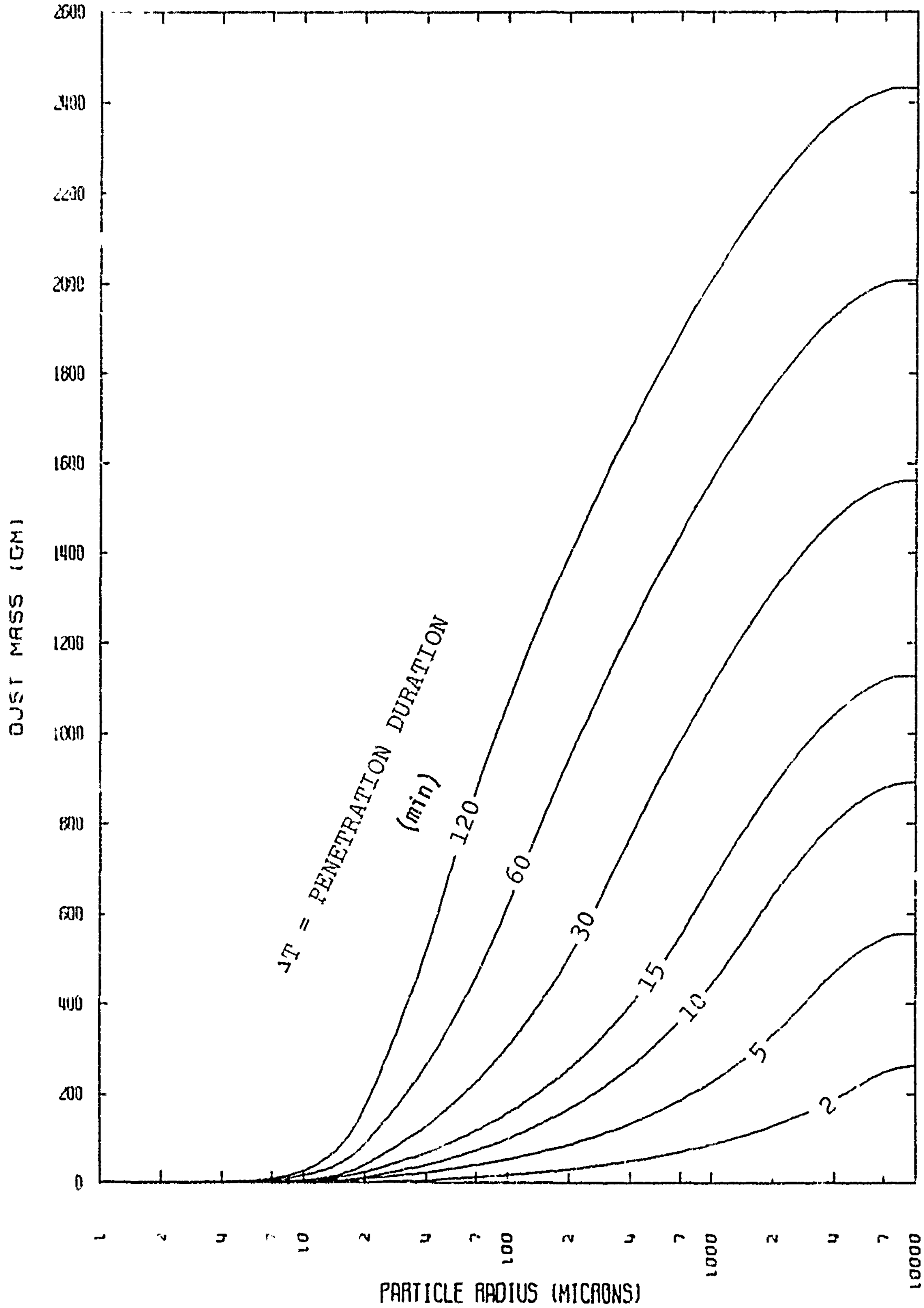

Figure 60. Cumulative Dust Mass in Cockpit, TI = 10 Minutes

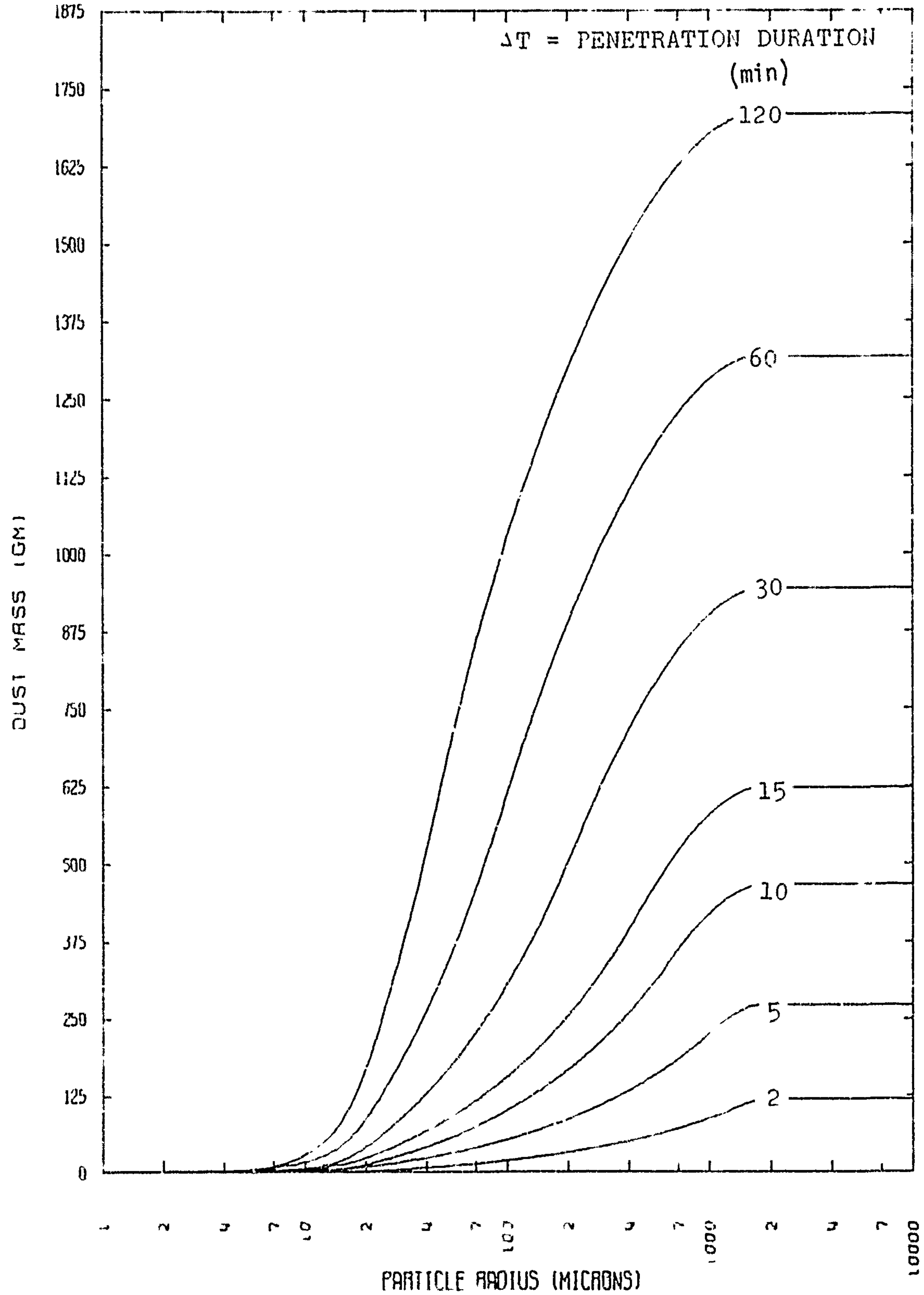

Figure 61. Cumulative Dust Mass in Cockpit,
TI = 18 Minutes

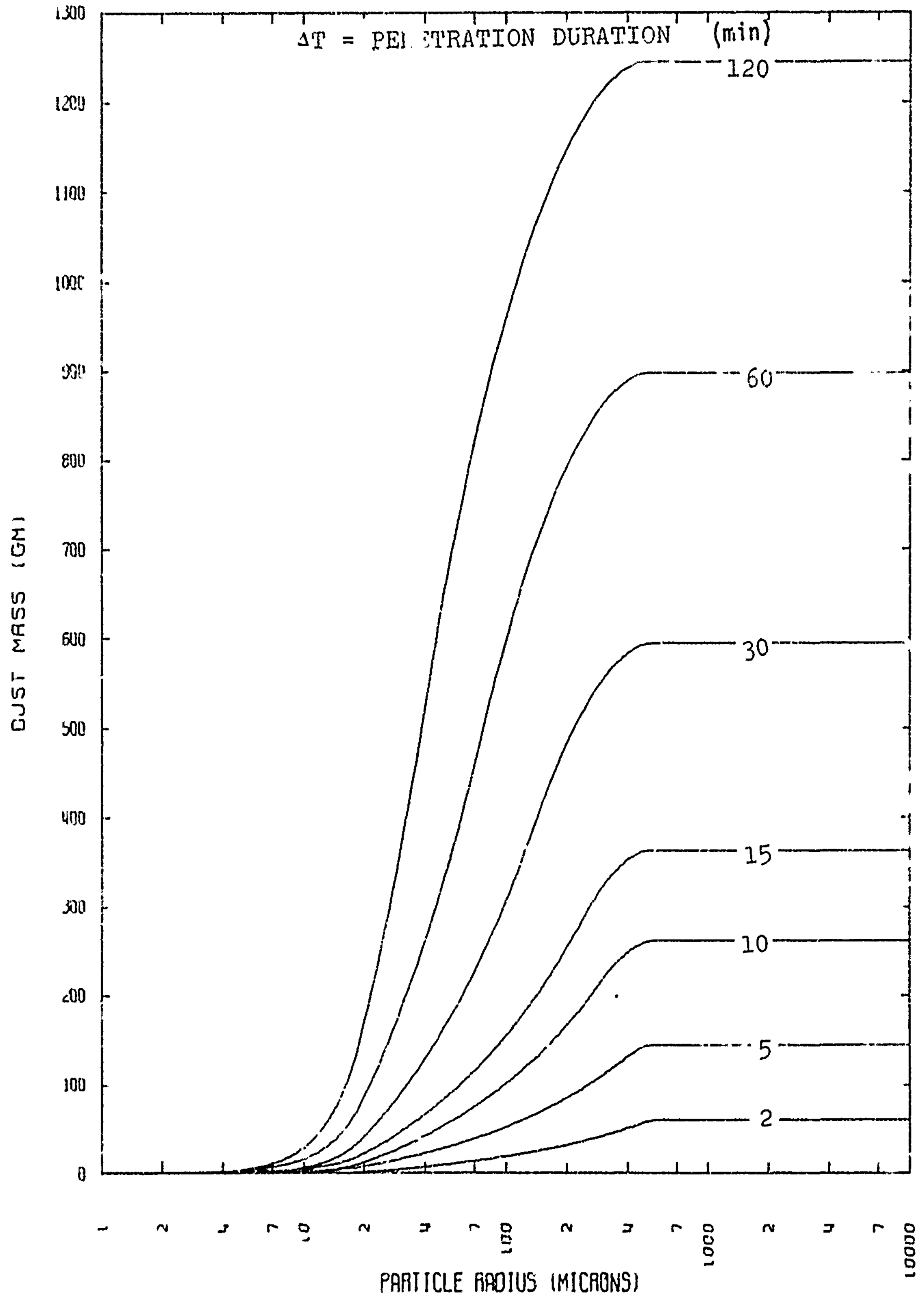

Figure 62. Cumulative Dust Mass in Cockpit,
TI = 30 Minutes

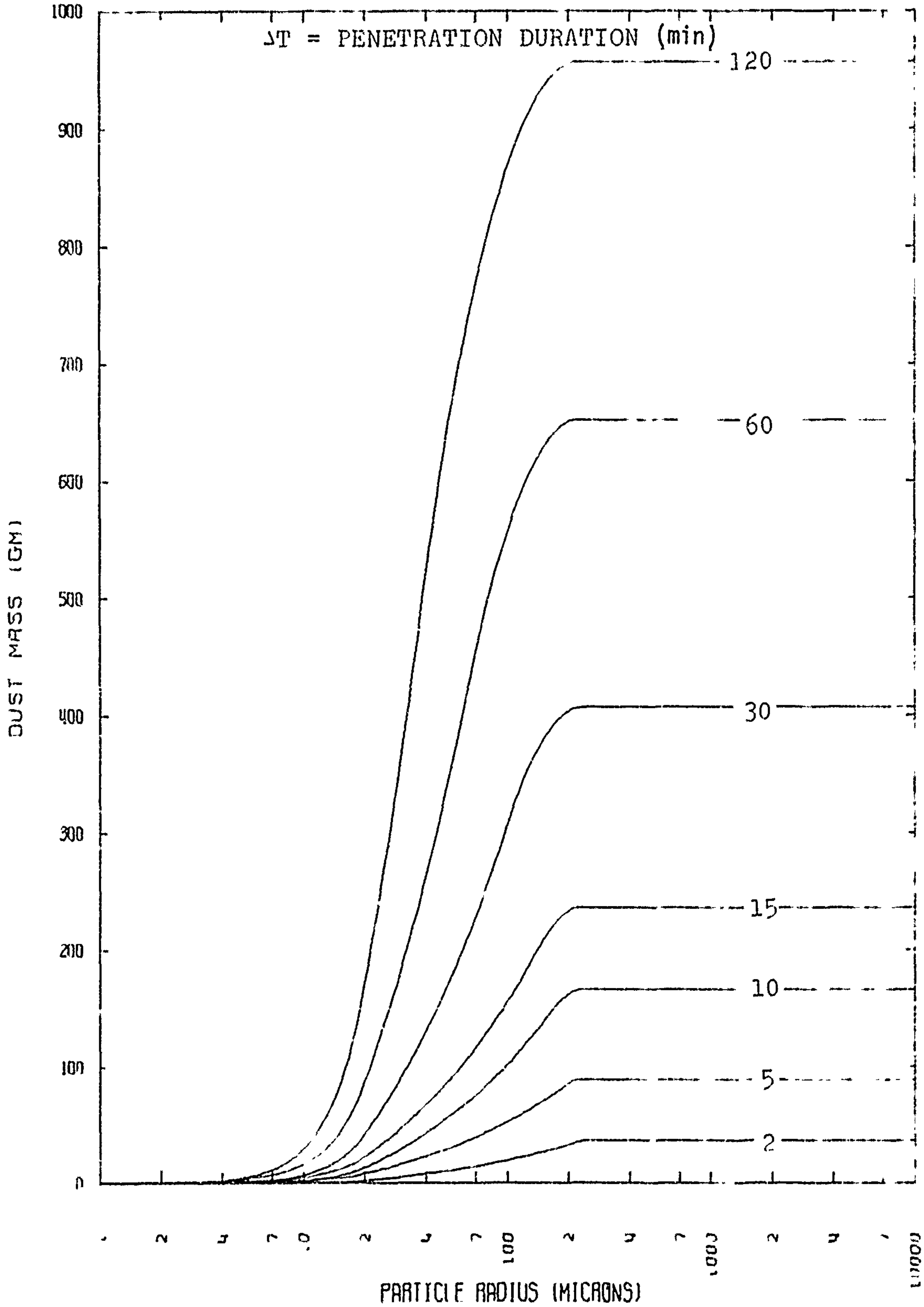

Figure 63. Cumulative Dust Mass in Cockpit, TI = 45 Minutes

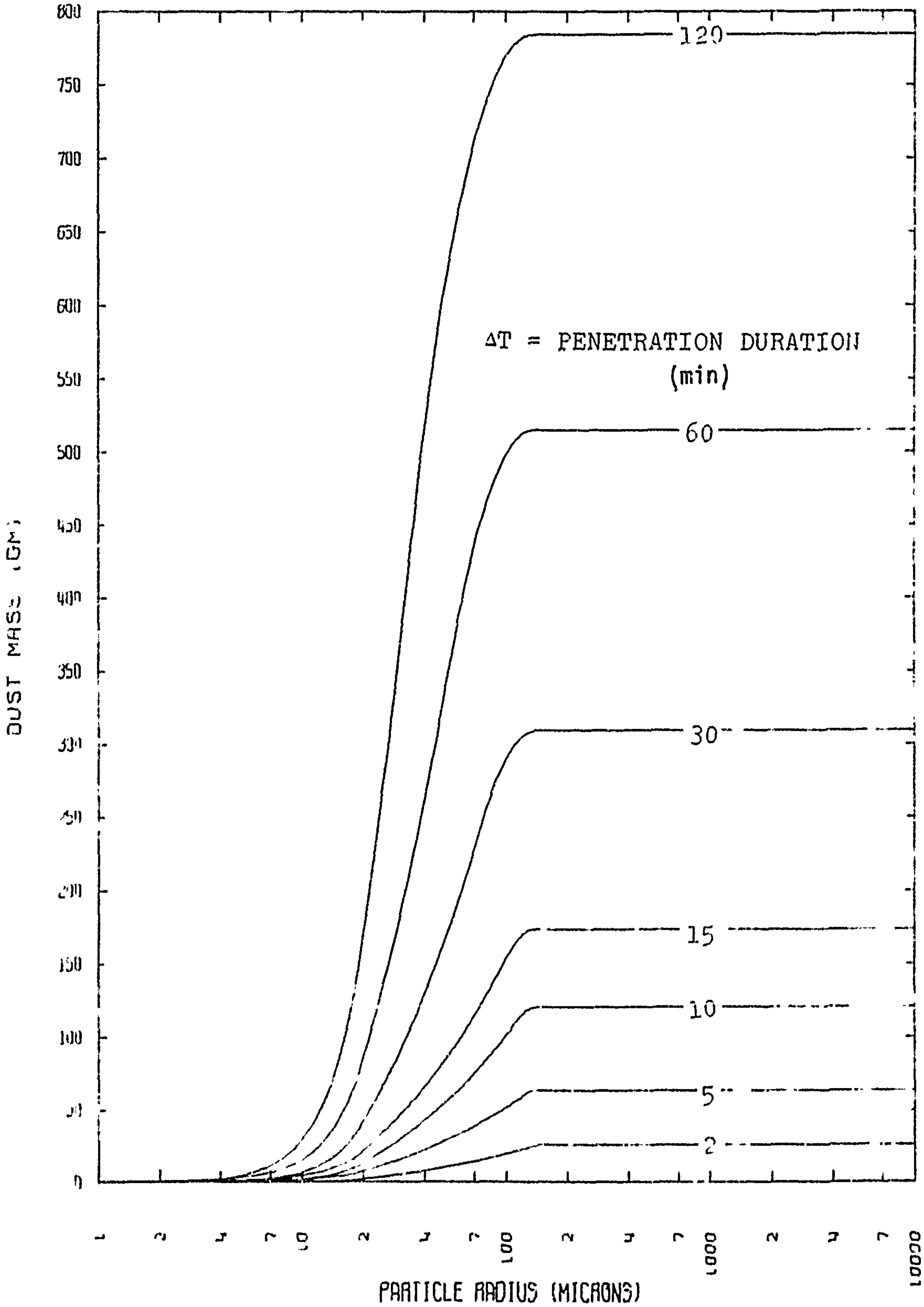

Figure 64. Cumulative Dust Mass in Cockpit, TI = 1 Hour

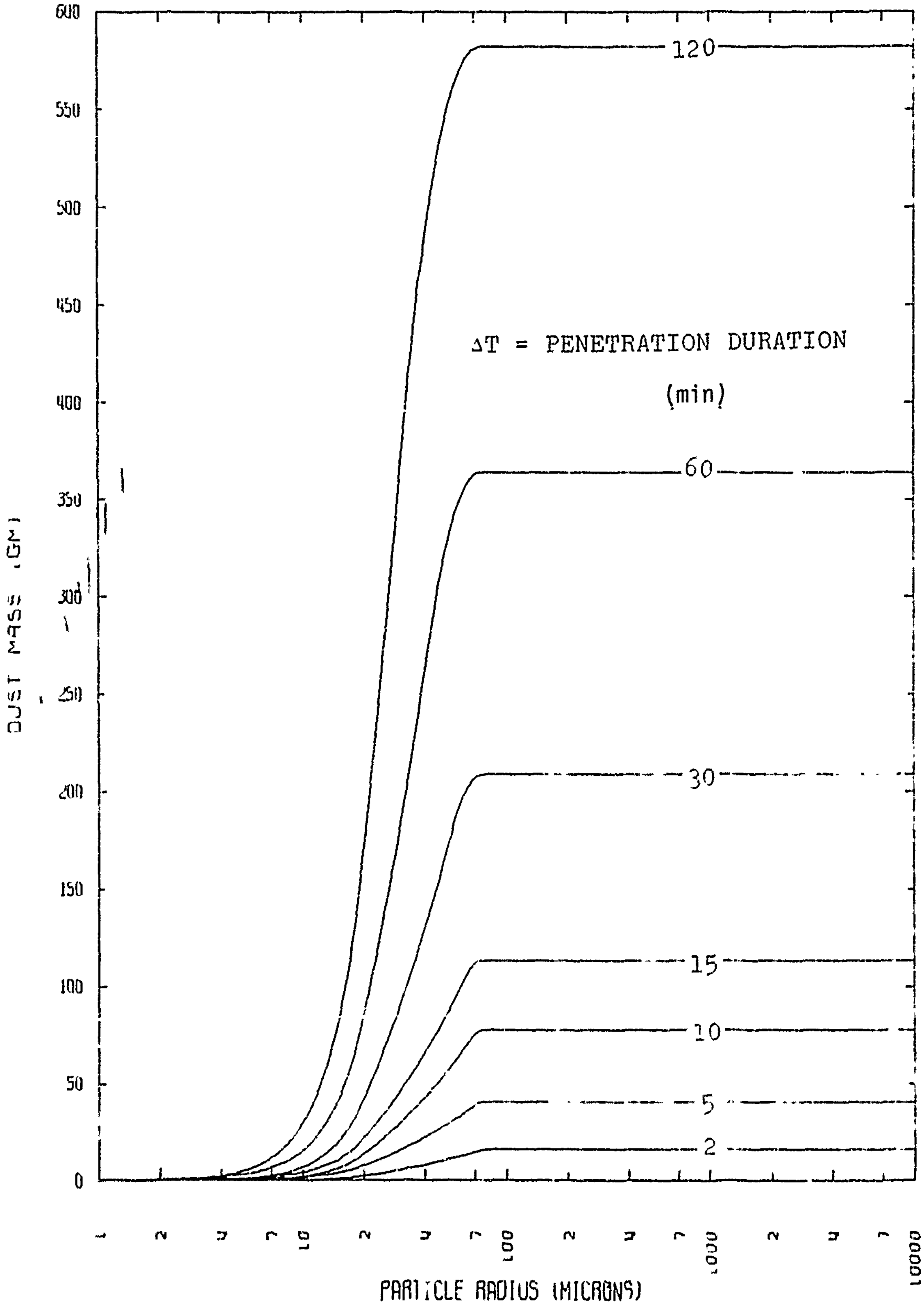

Figure 65. Cumulative Dust Mass in Cockpit,
TI = 1.5 Hours

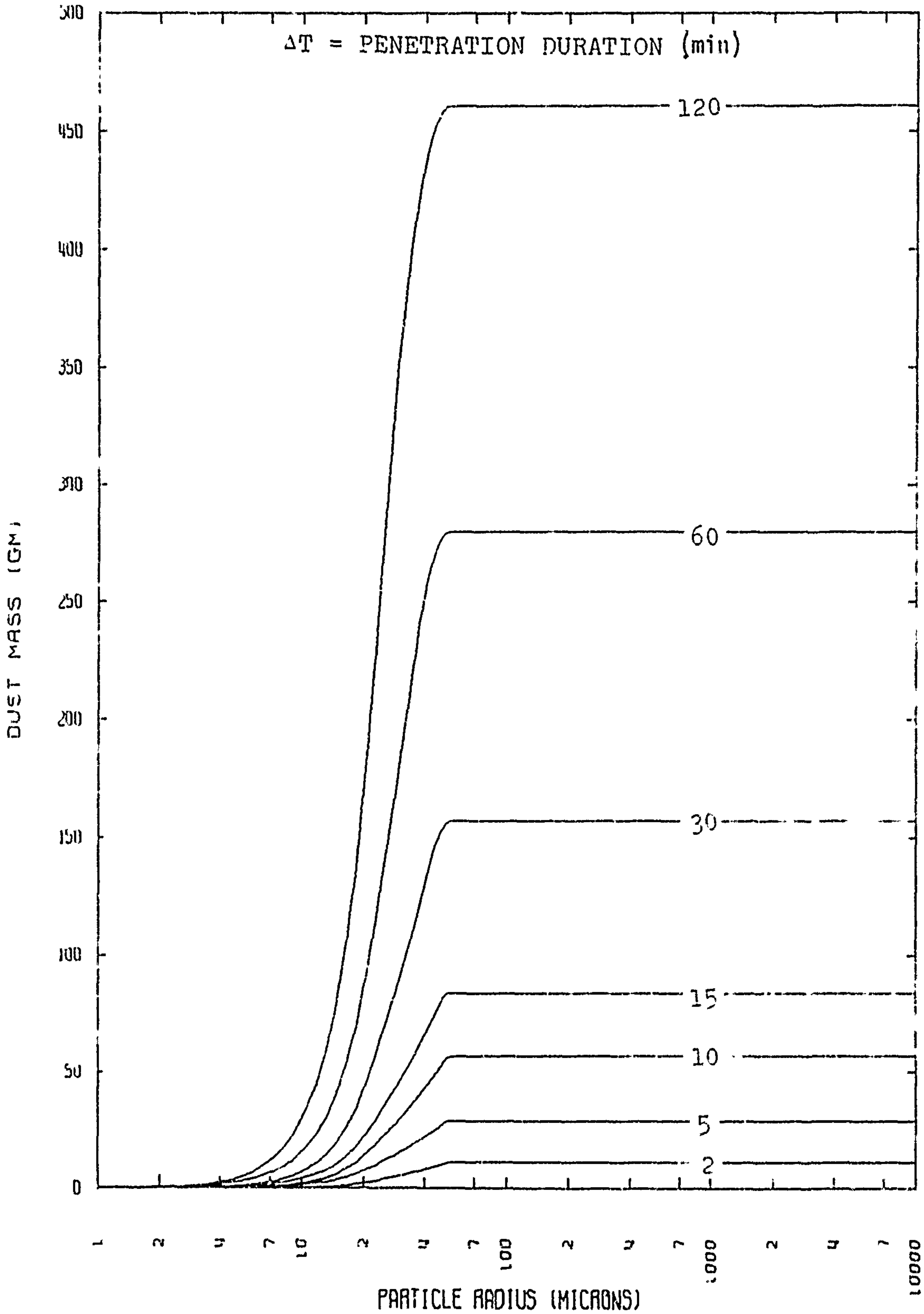

Figure 66. Cumulative Dust Mass in Cockpit,
TI = 2 Hours

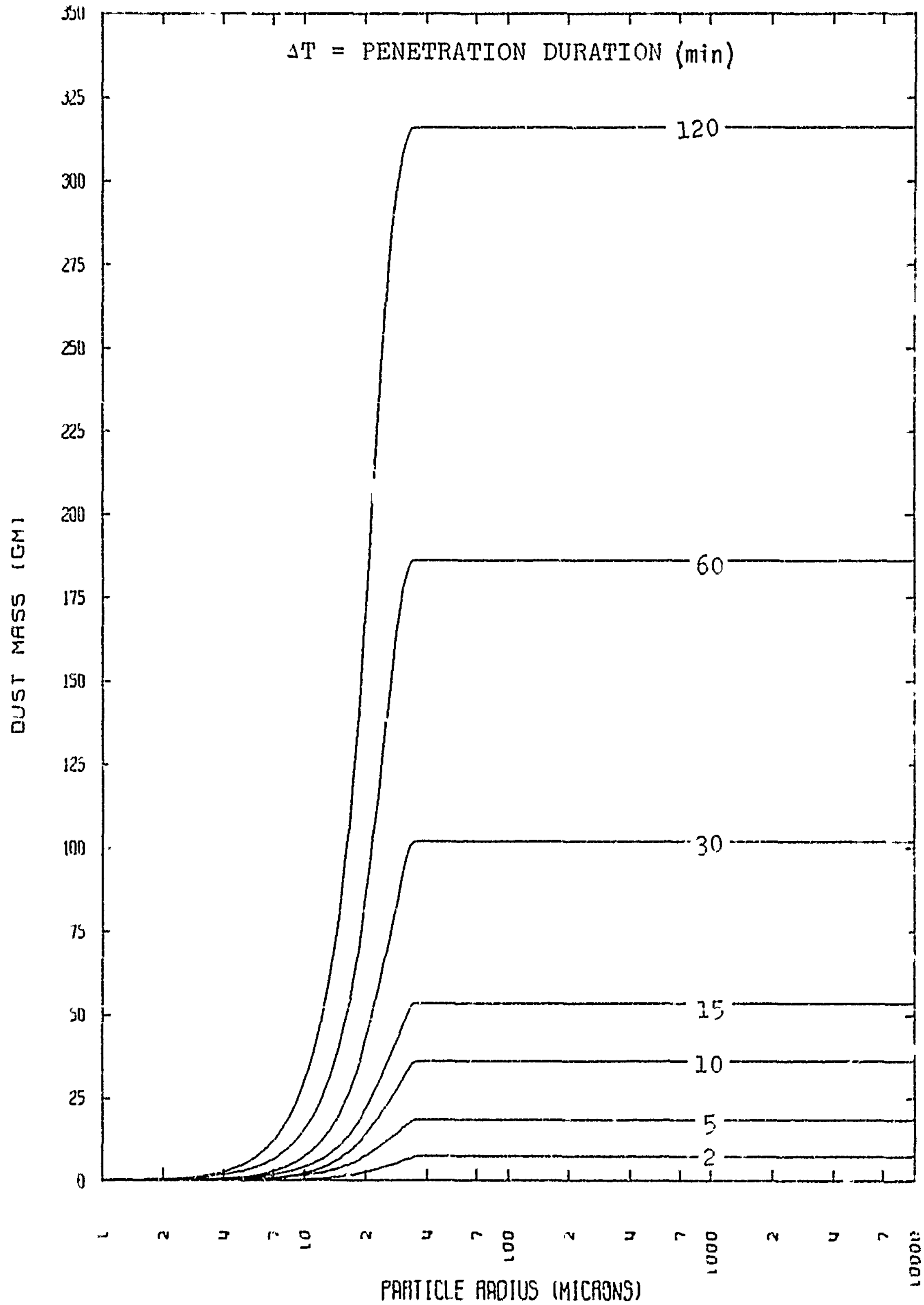

Figure 67. Cumulative Dust Mass for Cockpit, TI = 3 Hours

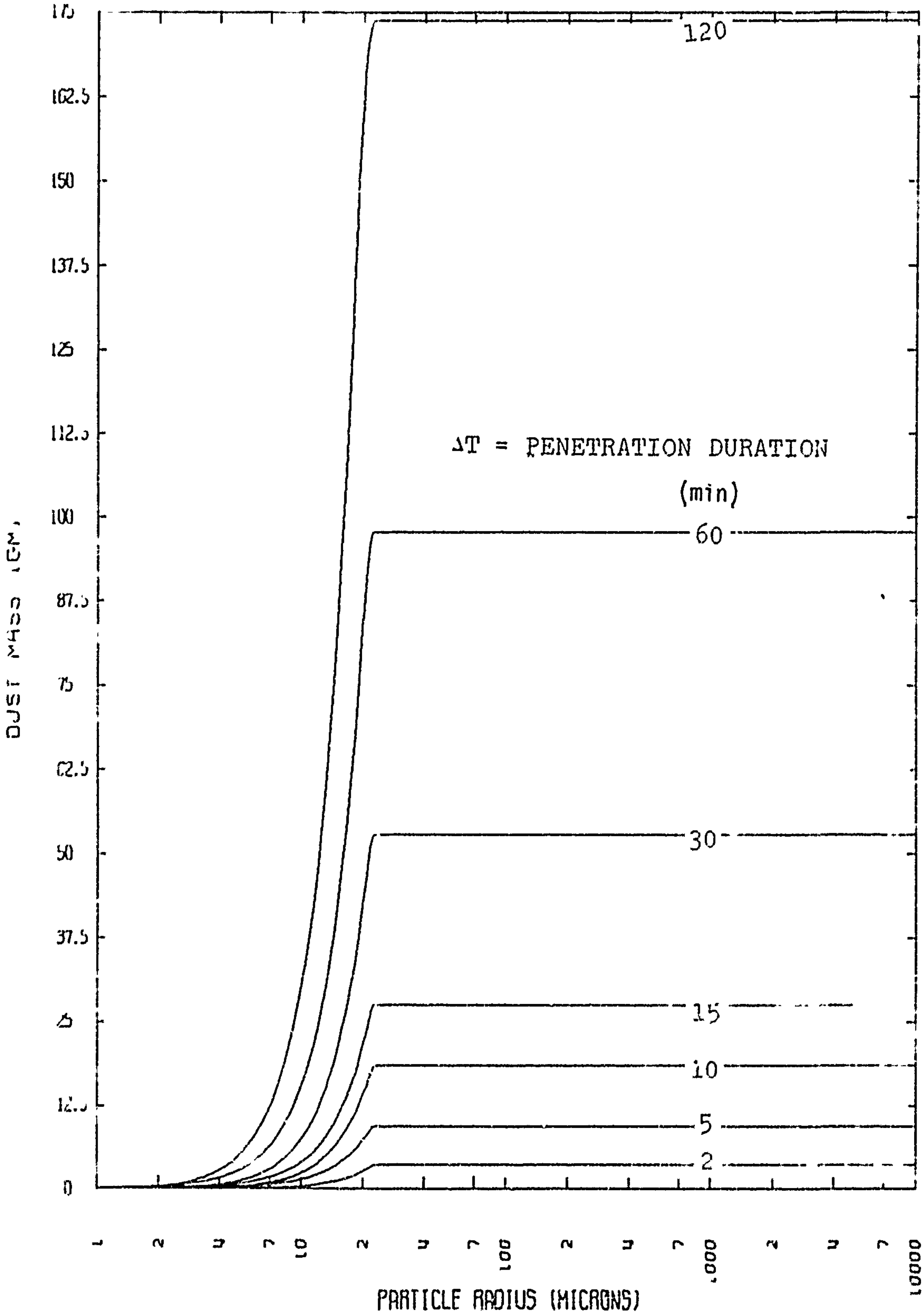

Figure 68. Cumulative Dust Mass for Cockpit, TI = 5 Hours

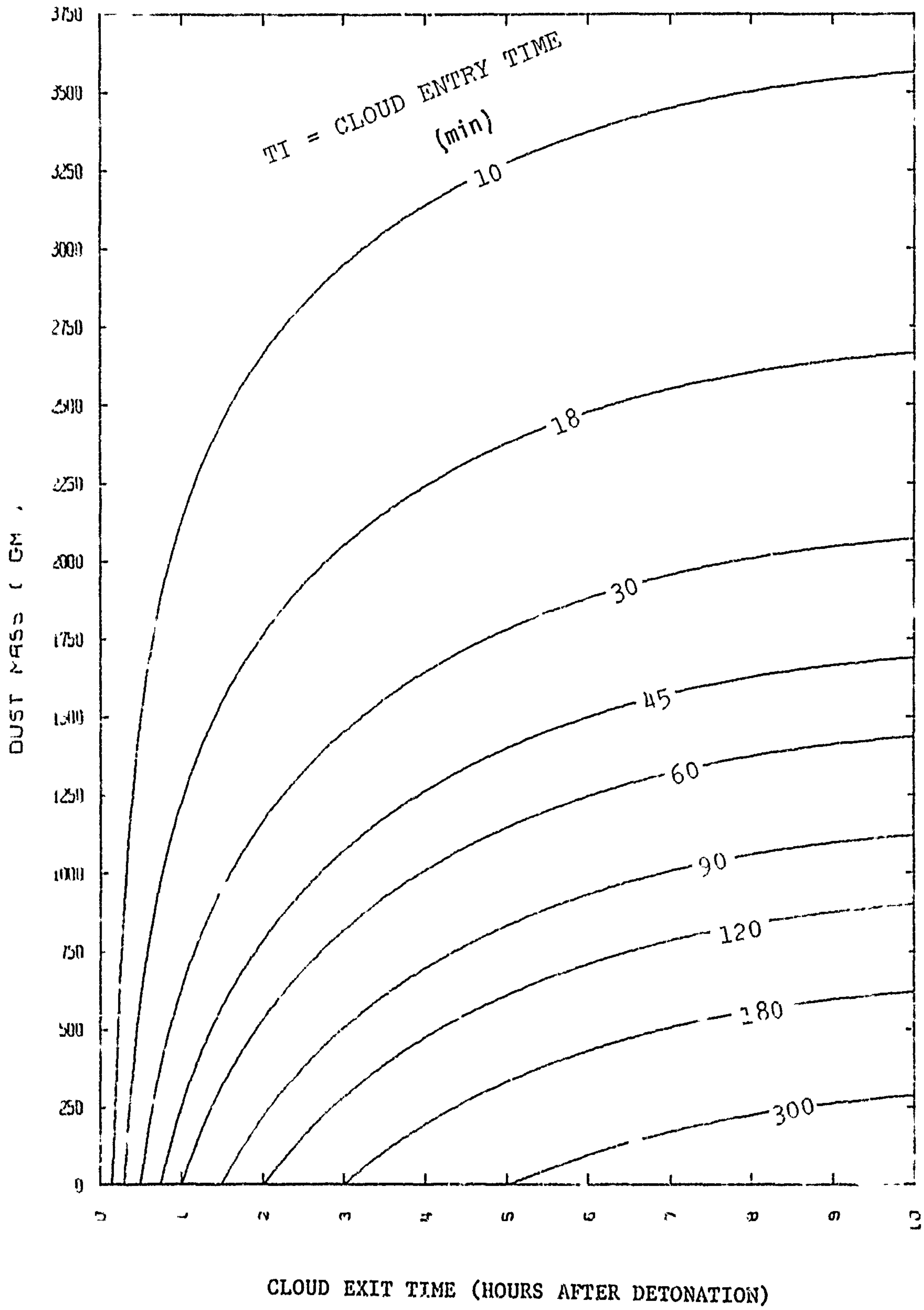

Figure 69. Dust Mass Collected in the Cockpit

Recall that the filter dose was calculated as an "at-one-meter" dose, to provide ease in considering the effect of alternate filter locations on crew/electronics dose. A similar approach is also desirable in the case of cockpit dose. A reasonable model of the dust distribution in the cockpit has been selected. The results presented are scalable to other dust distributions applicable to other specific cases.

From a dose contribution standpoint, the effectiveness of an element of mass, m_i, located some distance s_i from the receiver is proportional to m_i/s_i^2. A relative dose effectiveness, E_D, is defined for any mass distribution as

$$E_D = \frac{\sum_i \left[m_i/s_i^2\right]}{m_t} = \sum_i \left(m_i/m_t s_i^2\right)$$

If the entire mass, m_t, were located at a distance of 1 meter, the dose effectiveness would be one. Thus, to apply the results to other situations, calculate the dose "at-one-meter" and multiply by the relative dose effectiveness, E_D, of the dust distribution of interest to obtain a reasonable estimate of the actual cockpit dose.

In this work the spatial dust distribution model assumes that 98 percent of the dust is located at an effective distance of 1 meter (the approximate distance from the critical mid-epigastric region of the crew member to the cockpit floor) and that 2 percent of the dust is located at an effective distance of 10 cm (to account for dust deposited on clothing and nearby surfaces). The mass percentages are estimated roughly from surface area considerations. The relative dose effectiveness of this dust distribution is 2.98 or roughly 3. This value has been used in cockpit dose calculations for this report. The cockpit dose results for any other specific dust distribution models can be obtained by scaling. To do so, calculate the relative dose effectiveness for the dust distribution of interest, divide by 3 and multiply this result times the cockpit dose read directly from the appropriate figures.

The cockpit dose data, comparable to the perfect filter dose data, are given in three series of graphs. Each series covers the range of cloud entry times from 10 minutes to 5 hours and penetration durations ranging from 2 minutes to 120 minutes. The dose presented refers to the dose at 30 hours after weapon detonation. The first series of figures (figures 70 through 78) present the cockpit dust dose distribution function as a function of particle size for a particular cloud entry time and with penetration duration as a parameter. The second series (figures 79 through 87) presents the cumulative cockpit dose, i.e., the cumulative dose due to all particles which have size r or less as a function of r for a particular cloud entry time and with penetration duration as a parameter. Finally, the last series (figures 88 through 96) presents the total cockpit dose due to all dust particles which have settled in the cockpit as a function of time after weapon data for a particular cloud entry time and with penetration duration as a parameter.

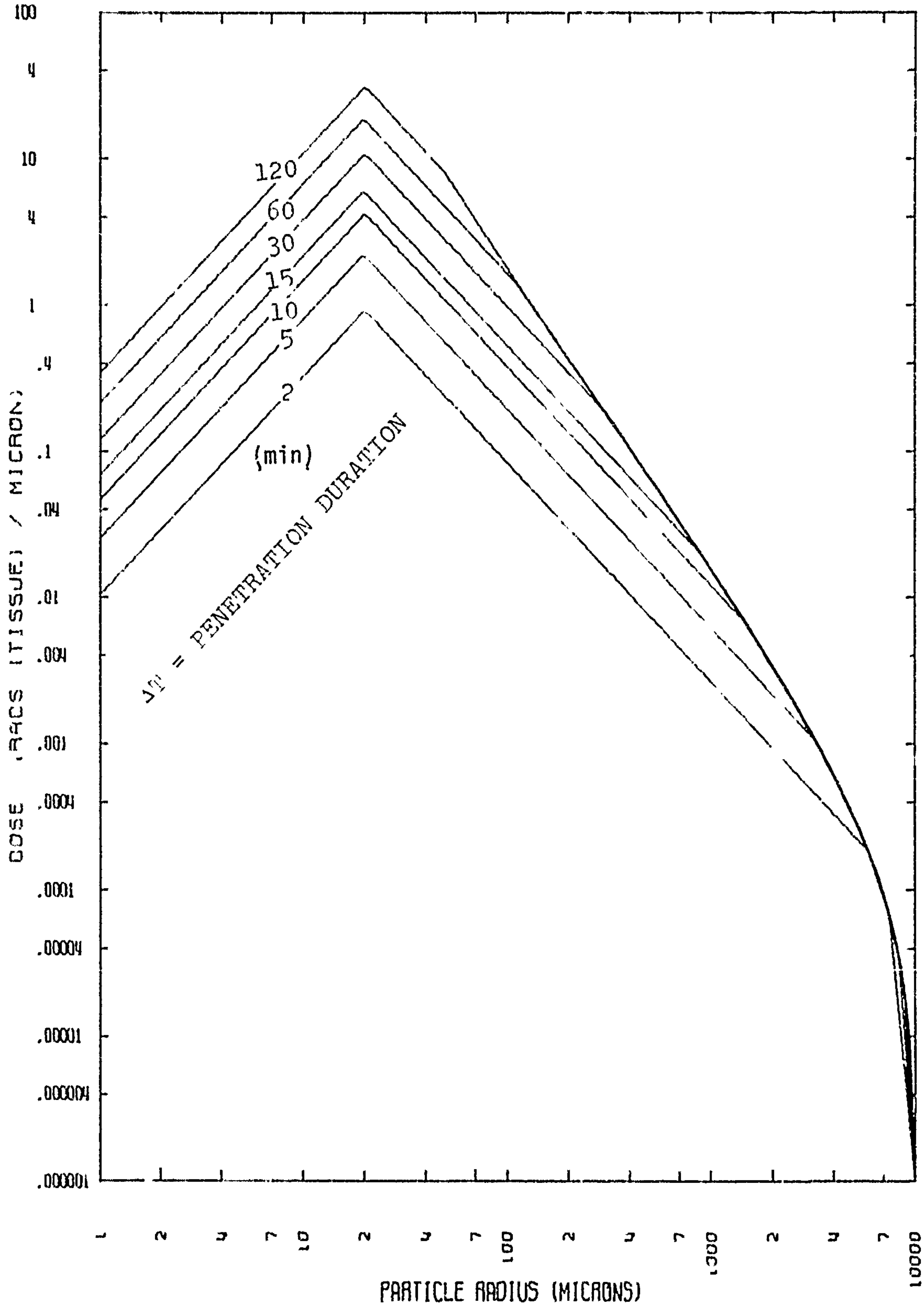

Figure 70. Cockpit Dust Dose Distribution at 30 Hours, TI = 10 Minutes

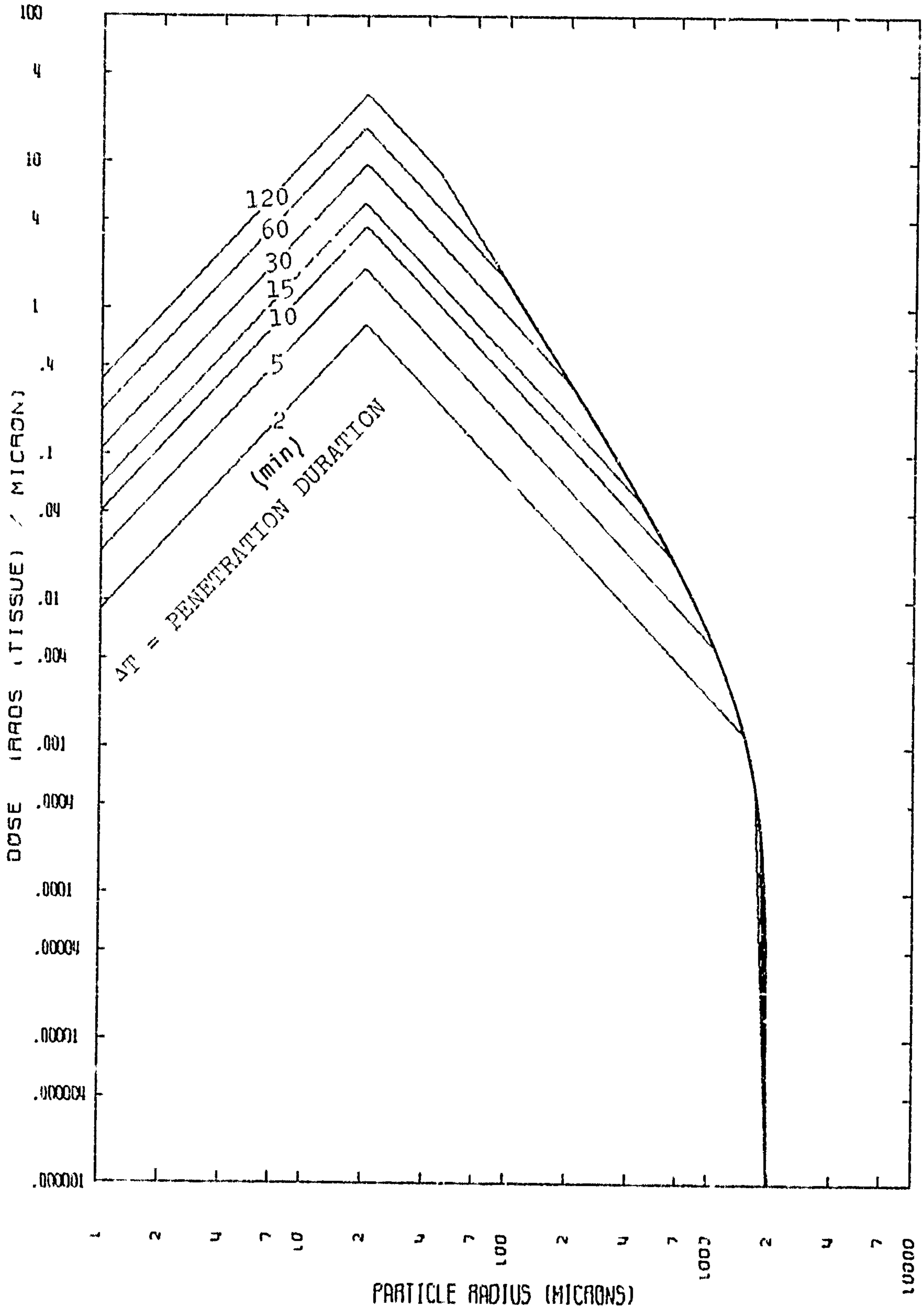

Figure 71. Cockpit Dust Dose Distribution at 30 Hours, TI = 18 Minutes

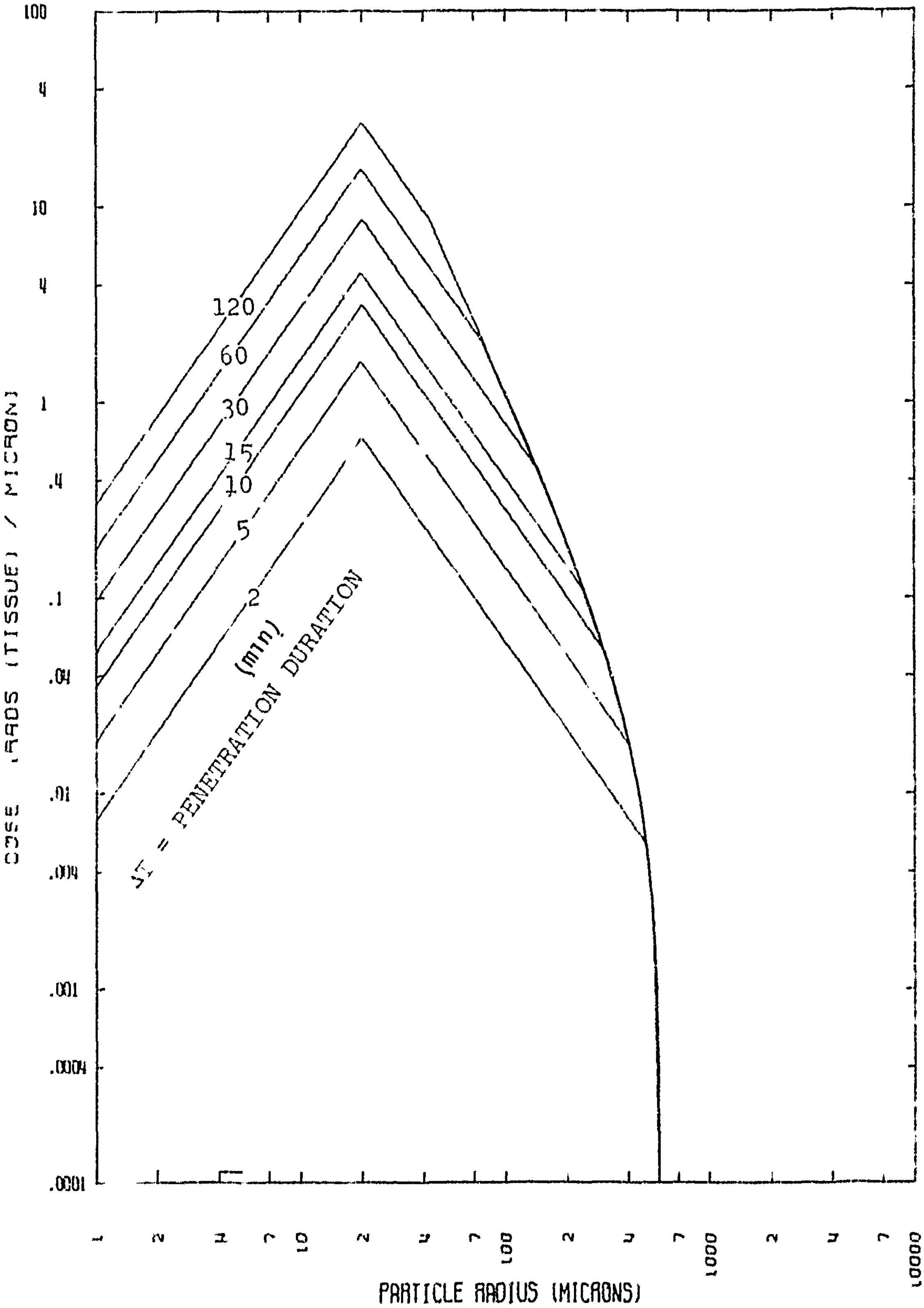

Figure 72. Cockpit Dust Dose Distribution at 30 Hours, TI = 30 Minutes

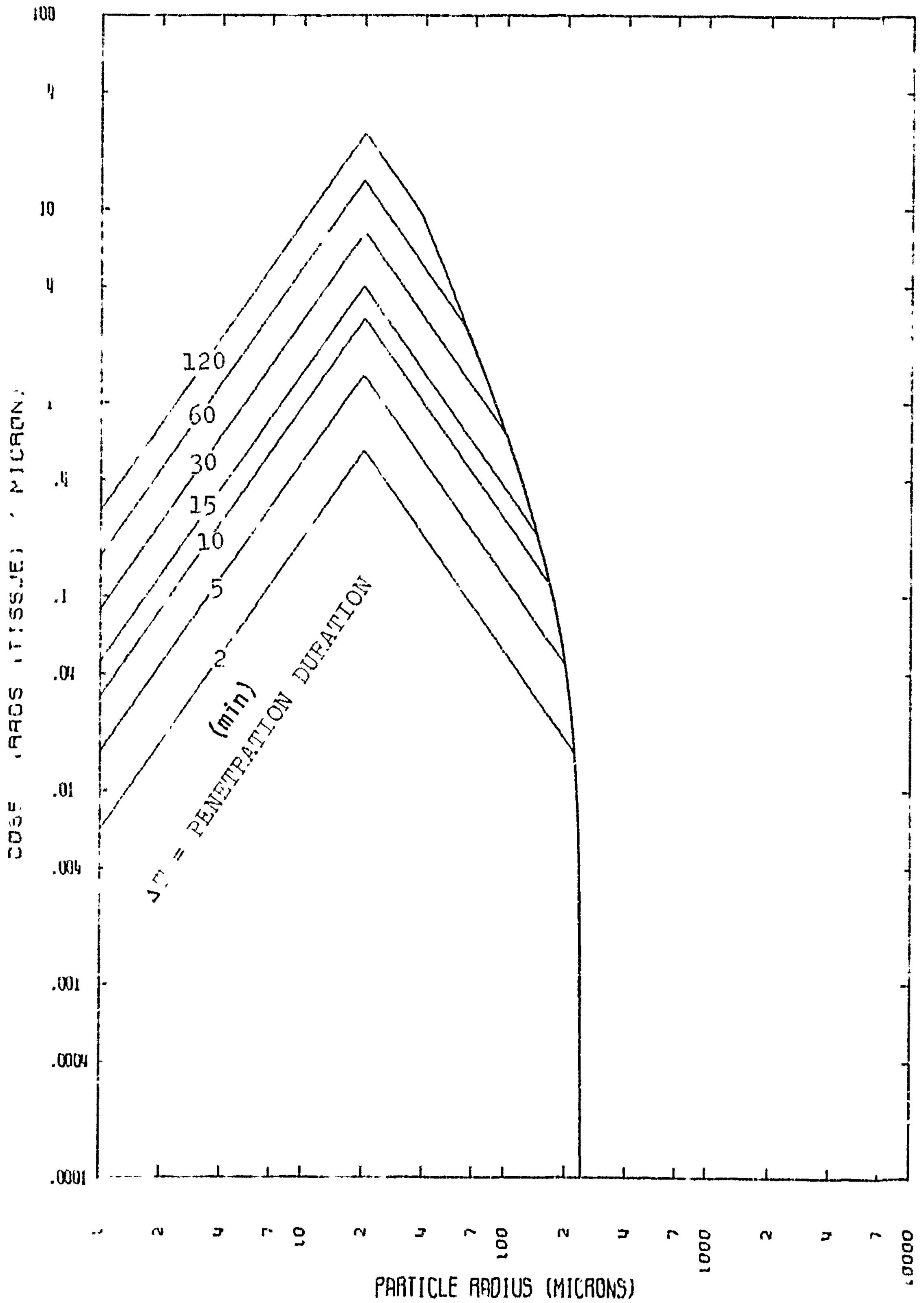

Figure 73. Cockpit Dust Dose Distribution at 30 Hours, TI = 45 Minutes

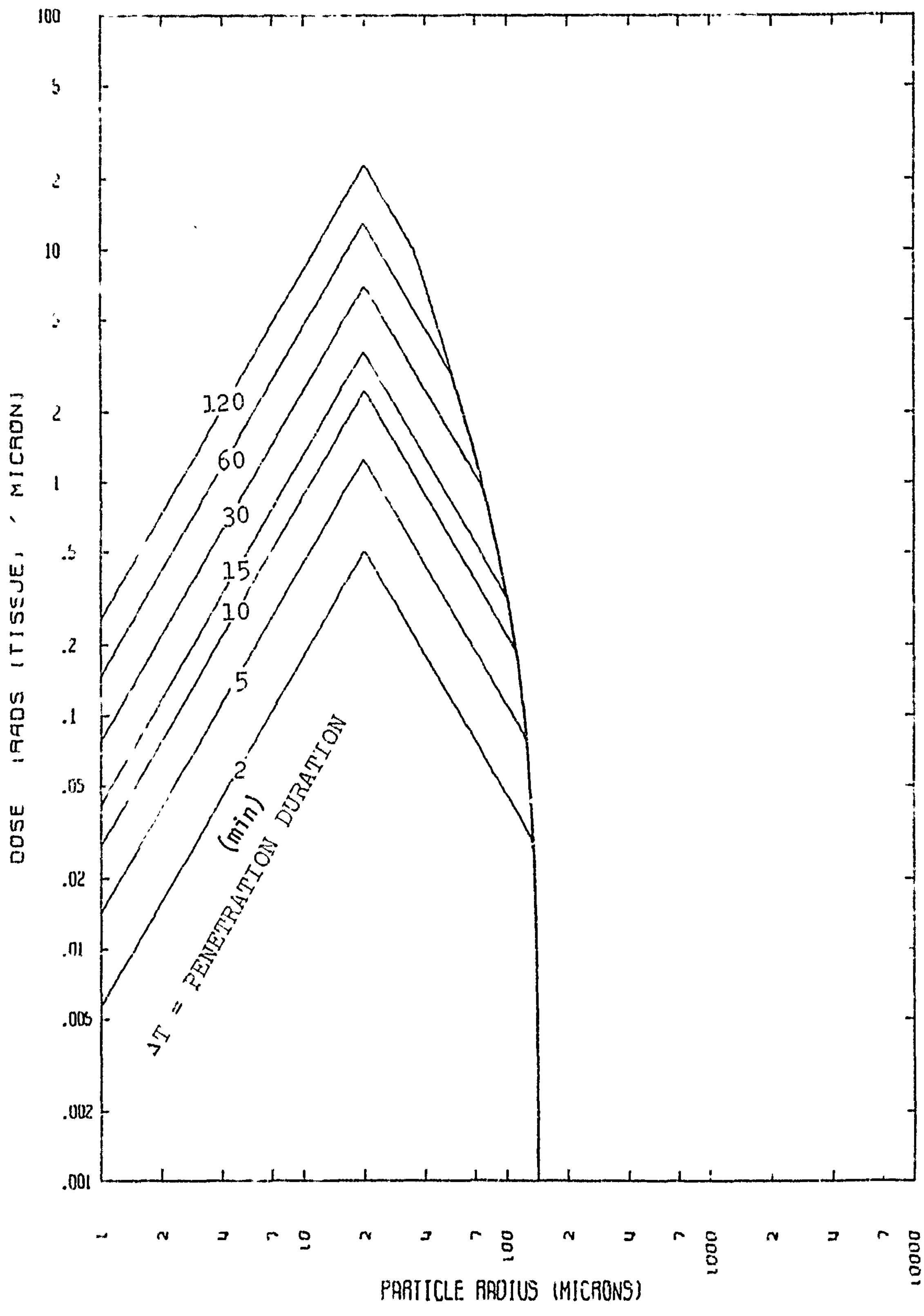

Figure 74. Cockpit Dust Dose Distribution at 30 Hours, TI = 1 Hour

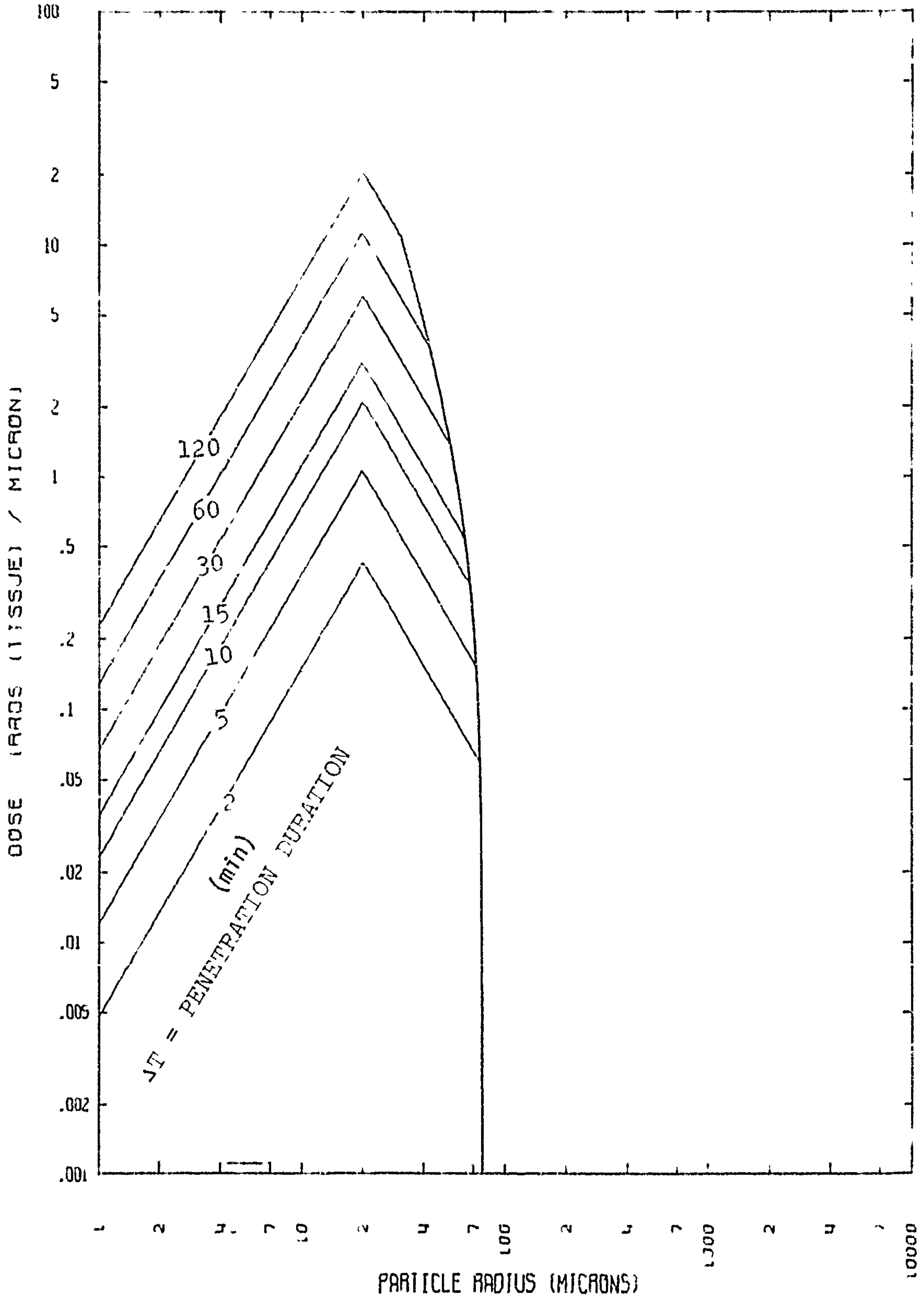

Figure 75. Cockpit Dust Dose Distribution at 30 Hours, TI = 1.5 Hours

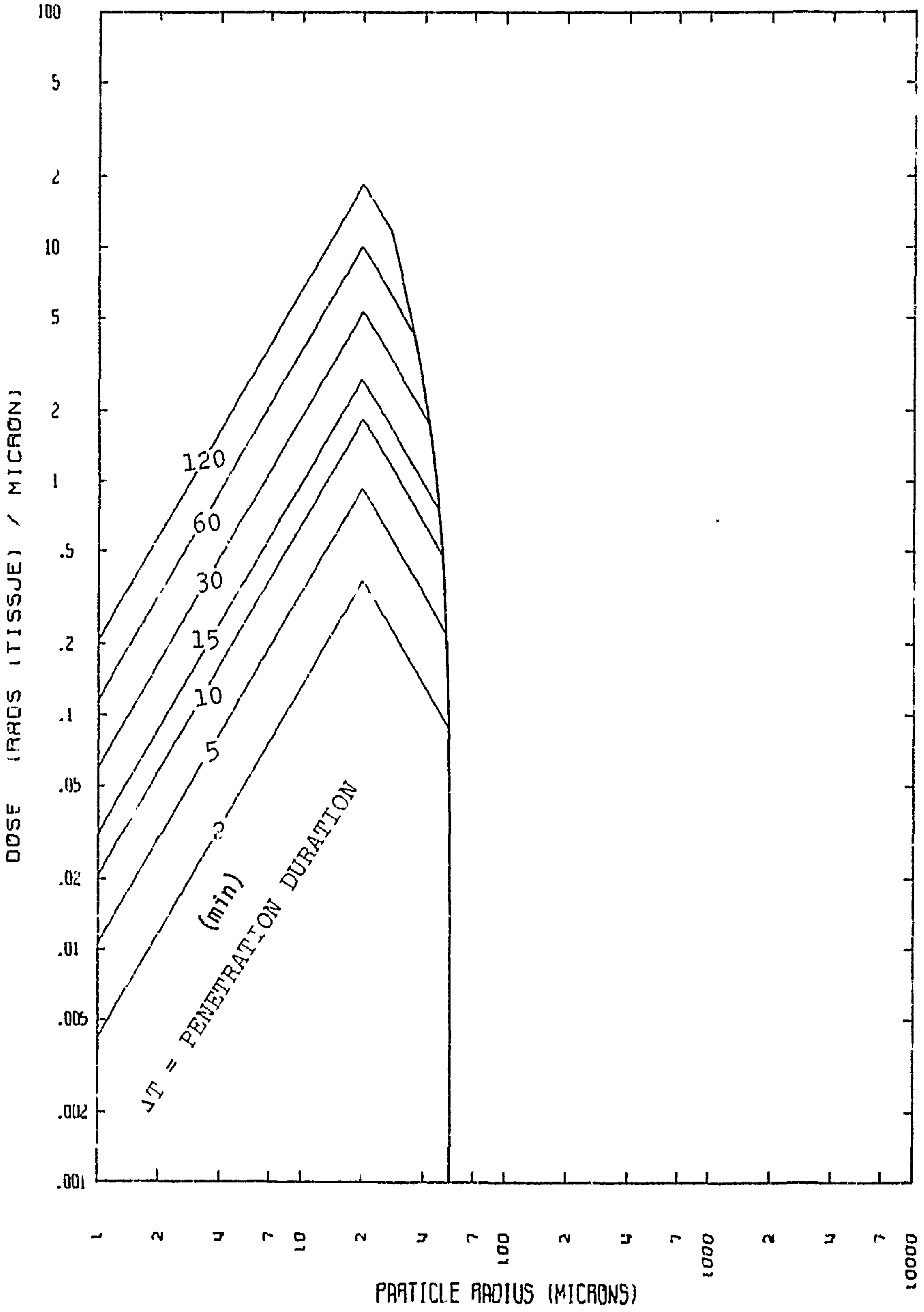

Figure 76. Cockpit Dust Dose Distribution at 30 Hours, TI = 2 Hours

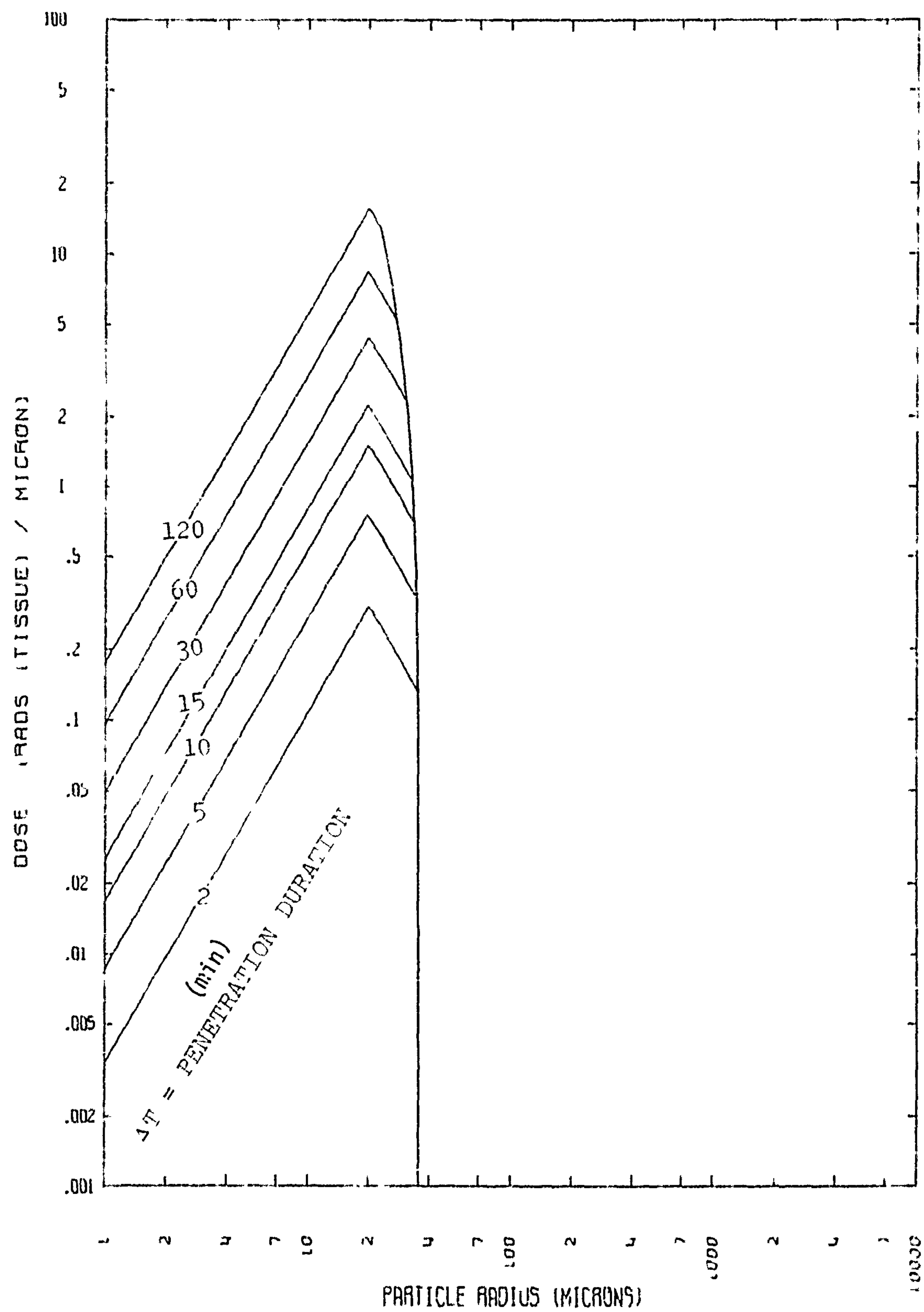

Figure 77. Cockpit Dust Dose Distribution at 30 Hours, TI = 3 Hours

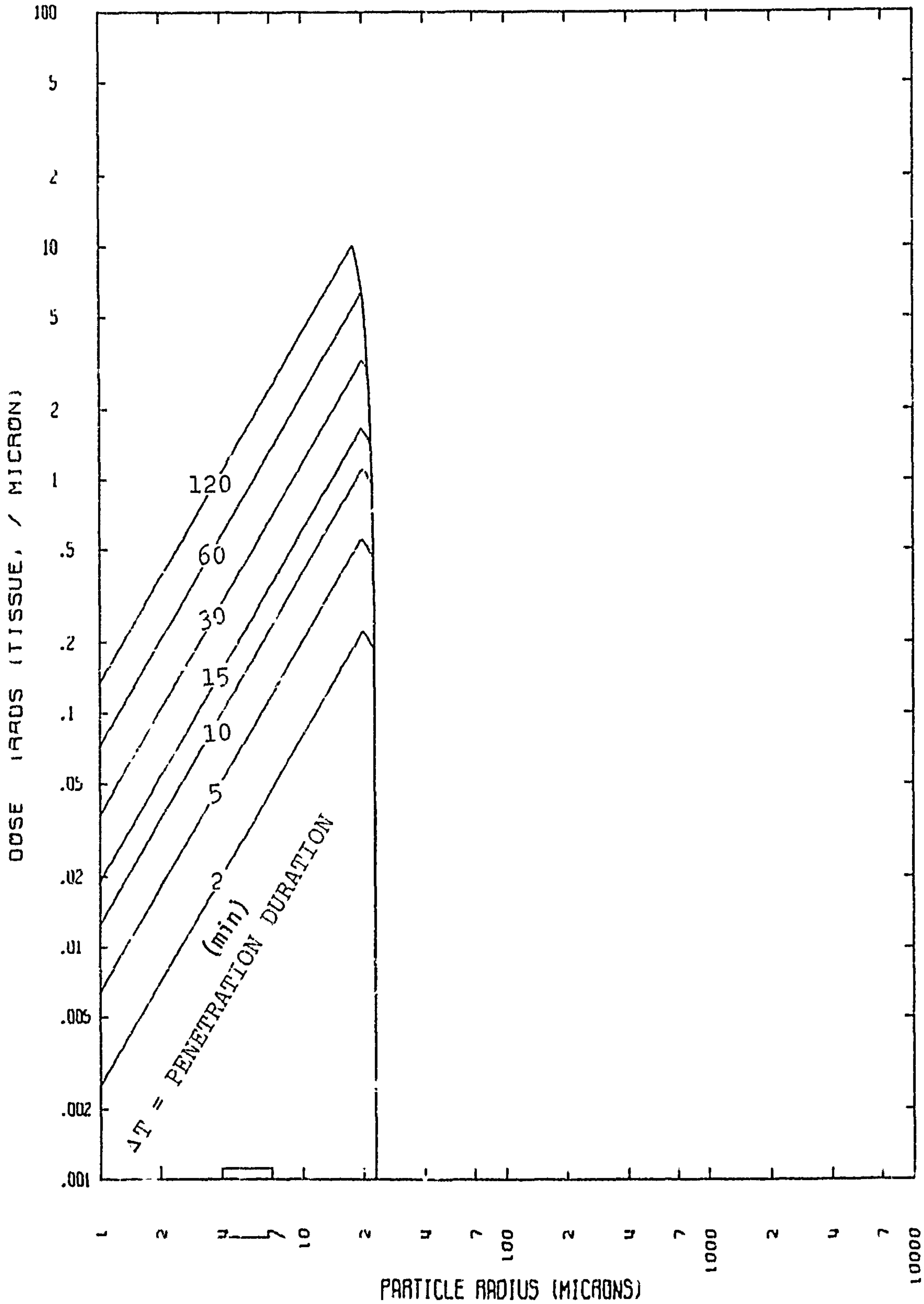

Figure 78. Cockpit Dust Dose Distribution at 30 Hours, TI = 5 Hours

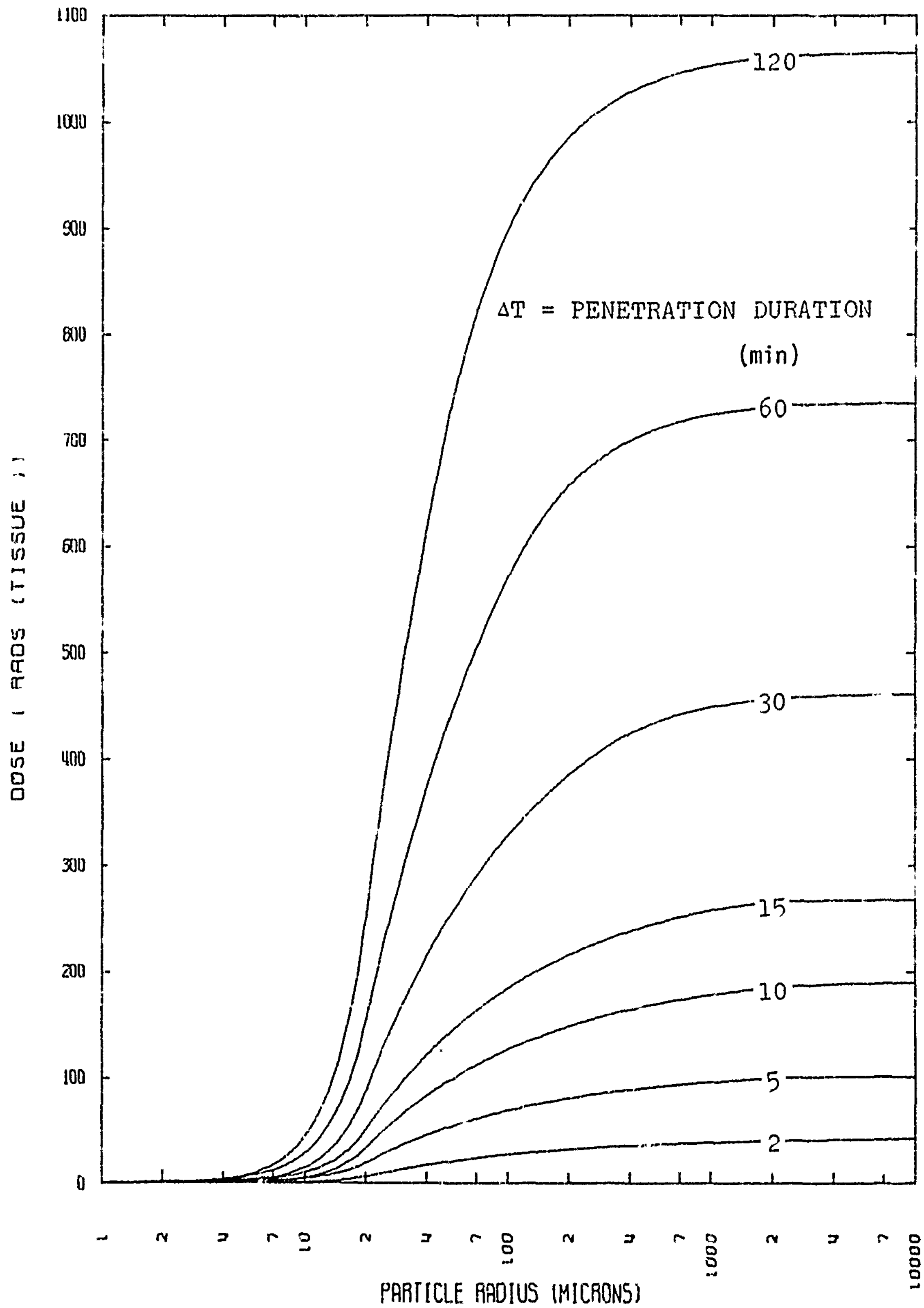

Figure 79. Cumulative Cockpit Dose at 30 Hours, TI = 10 Minutes

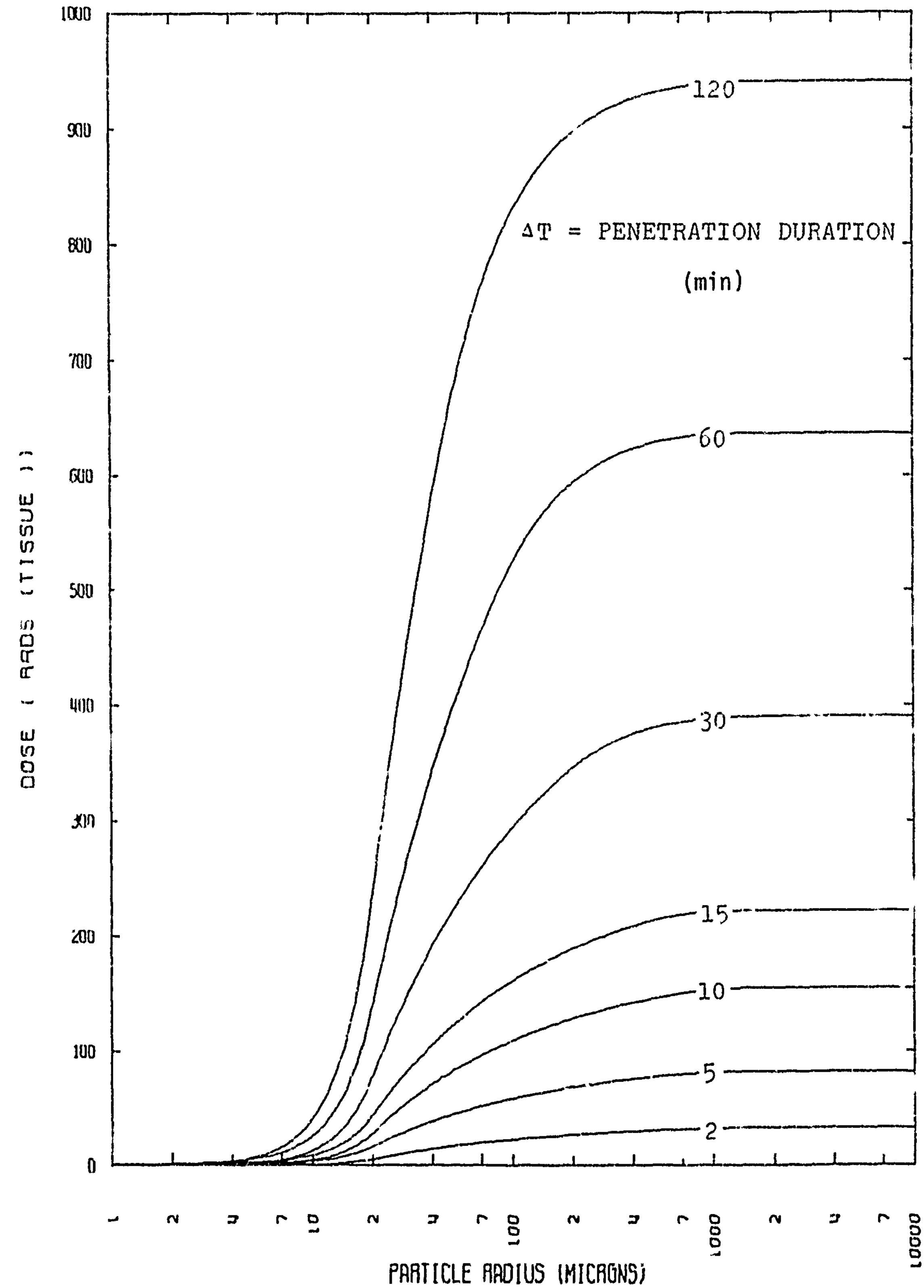

Figure 80. Cumulative Cockpit Dose at 30 Hours,
TI = 18 Minutes

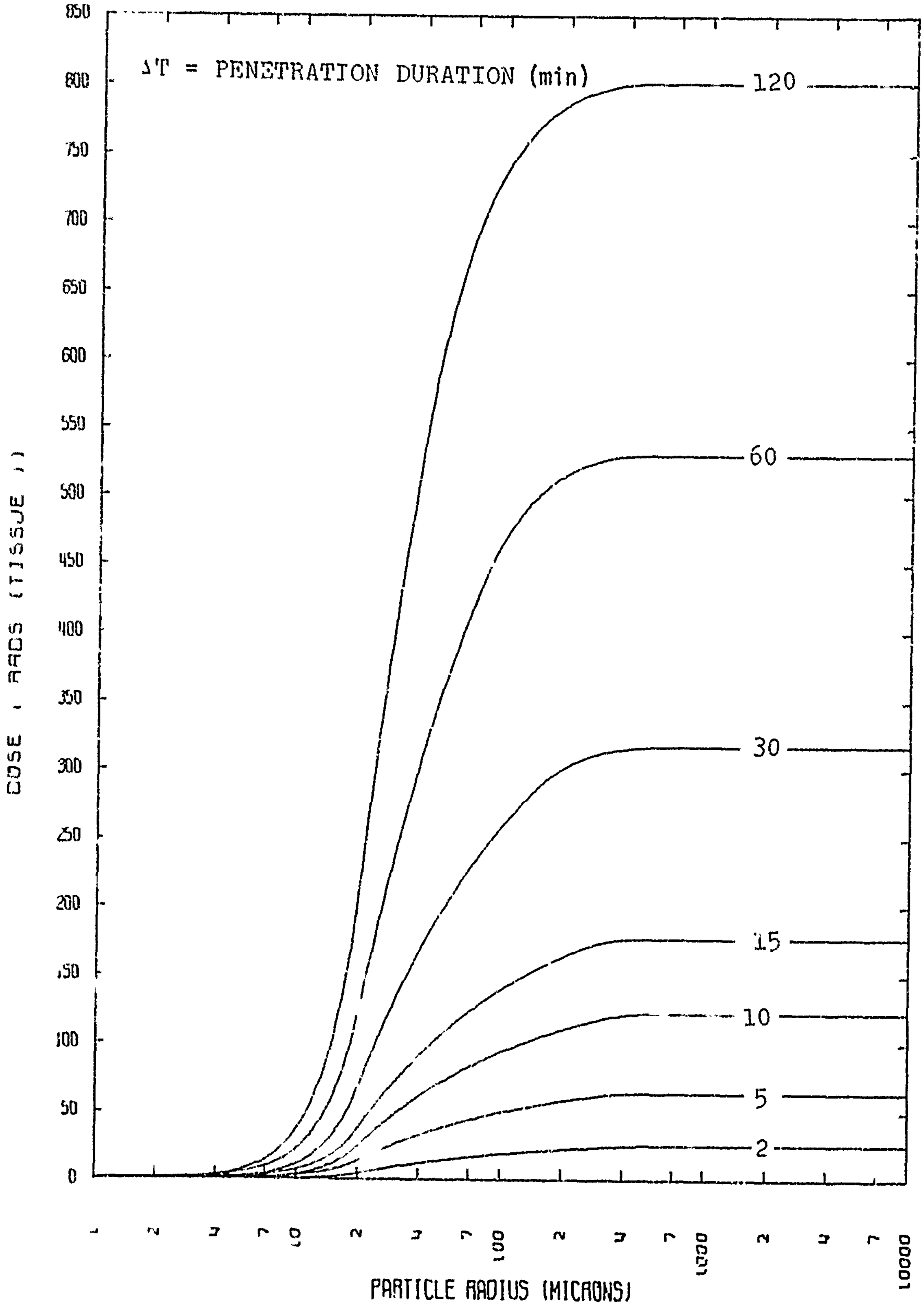

Figure 81. Cumulative Cockpit Dose at 30 Hours, TI = 30 Minutes

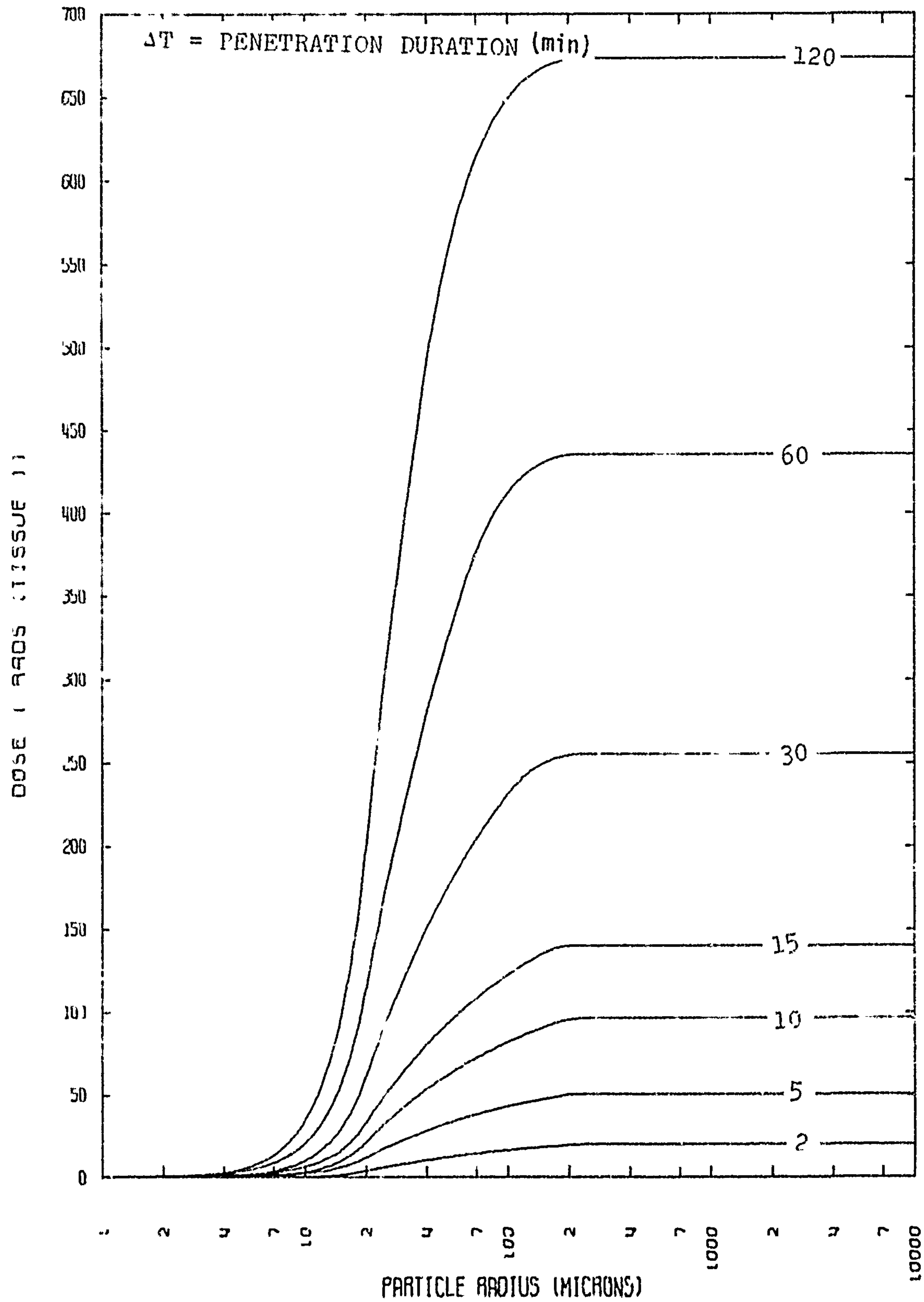

Figure 82. Cumulative Cockpit Dose at 30 Hours, TI = 45 Minutes

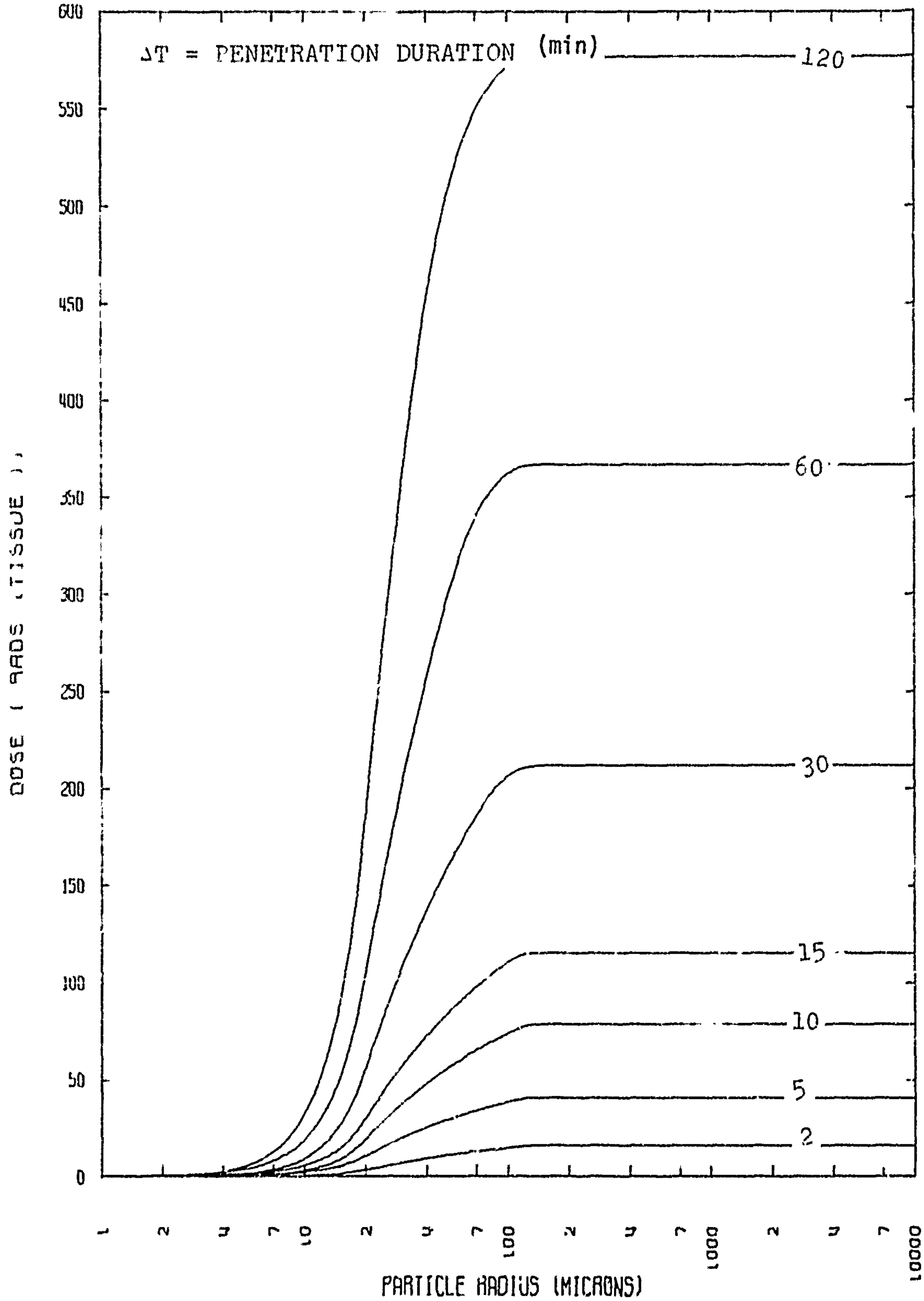

Figure 83. Cumulative Cockpit Dose at 30 Hours, TI = 1 Hour

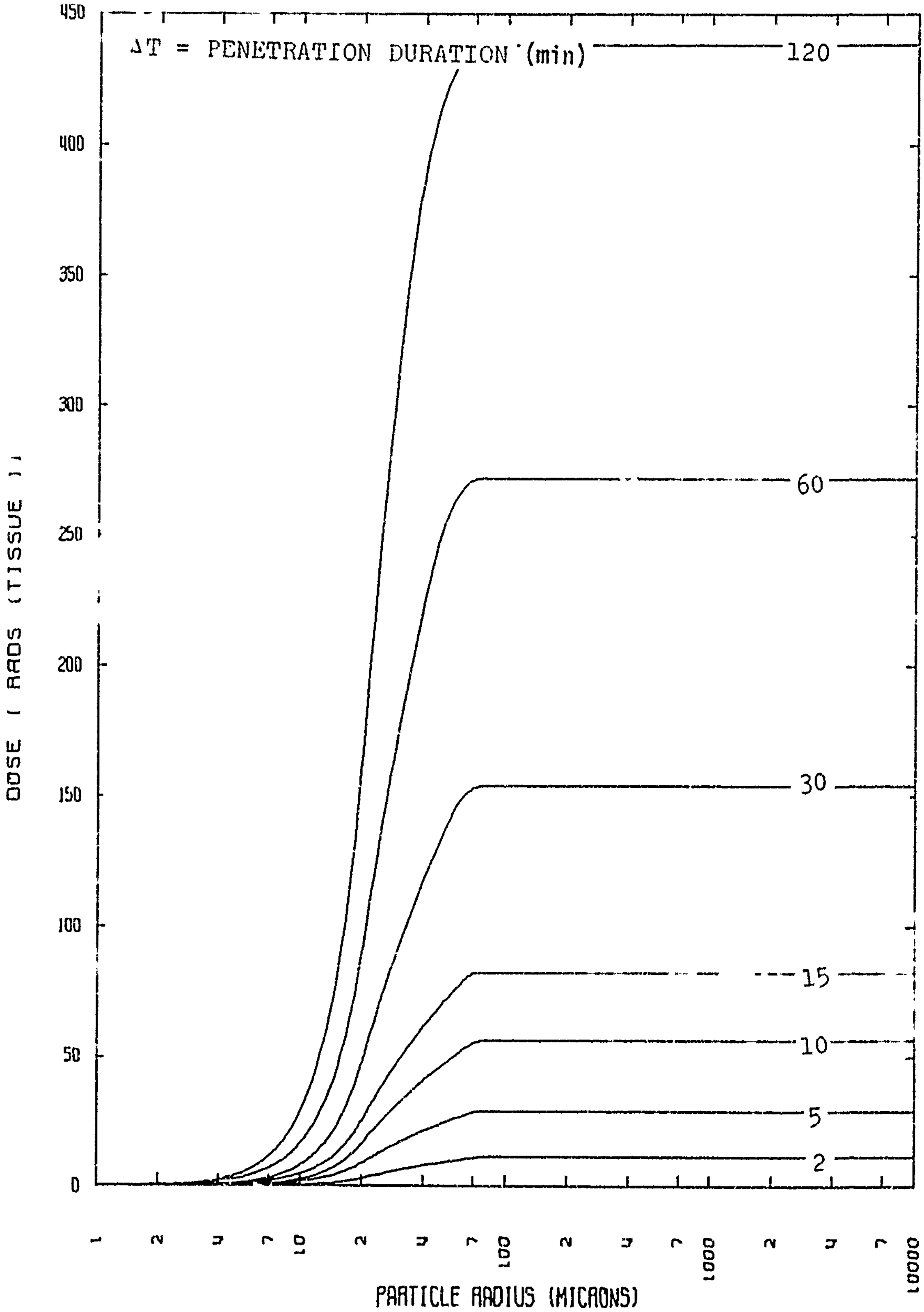

Figure 84. Cumulative Cockpit Dose at 30 Hours, TI = 1.5 Hours

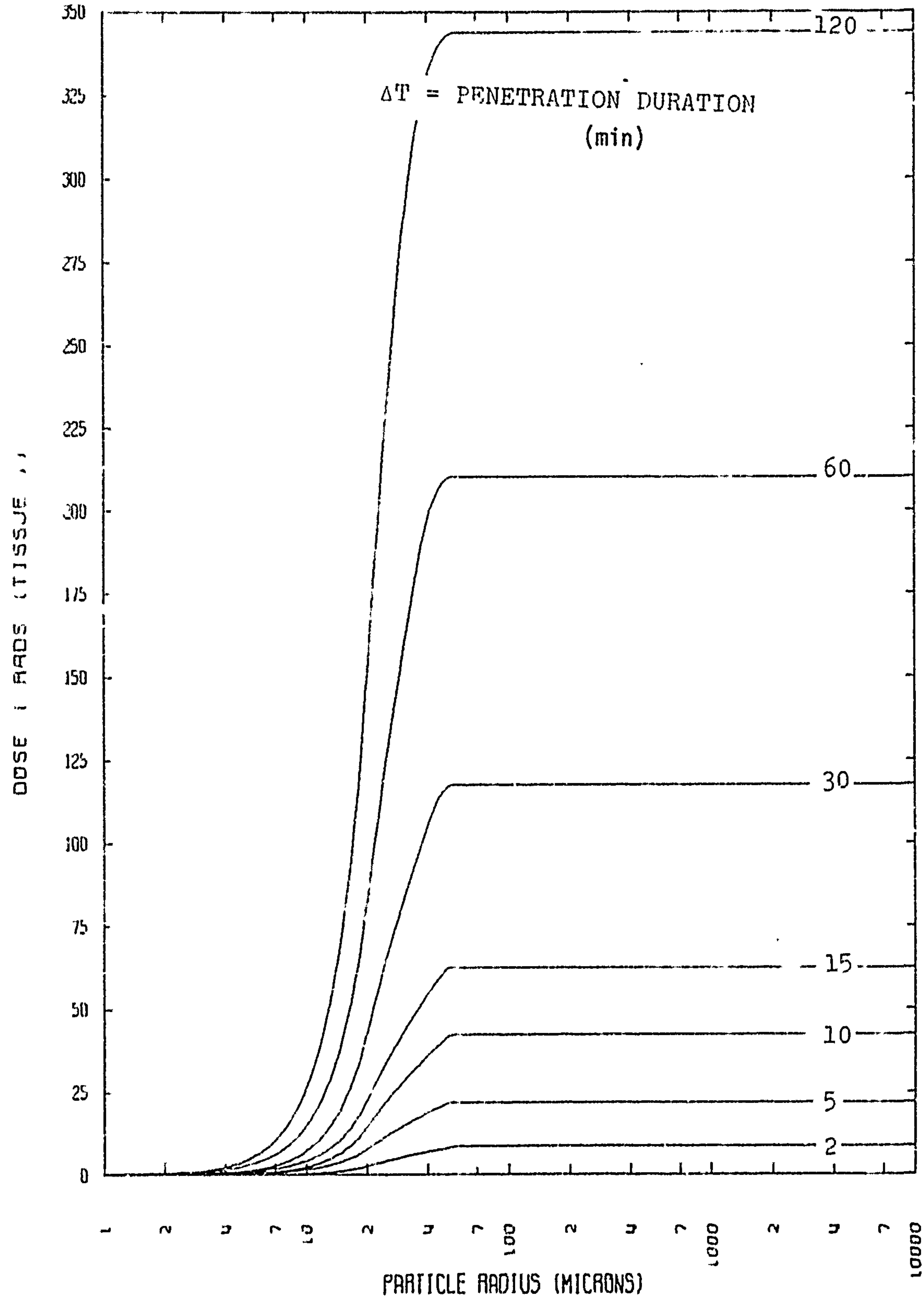

Figure 85. Cumulative Cockpit Dose at 30 Hours, TI = 2 Hours

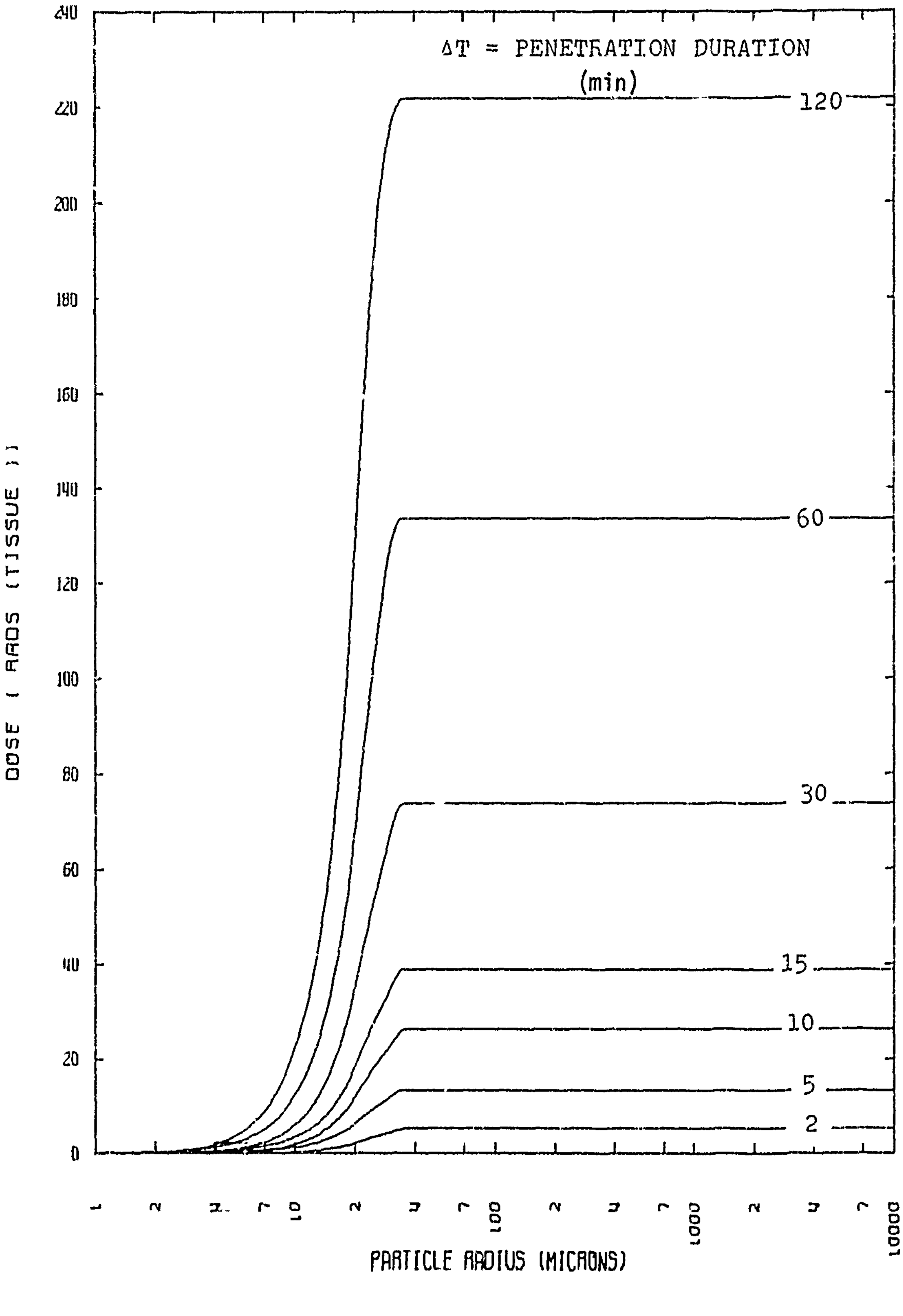

Figure 86. Cumulative Cockpit Dose at 30 Hours, TI = 3 Hours

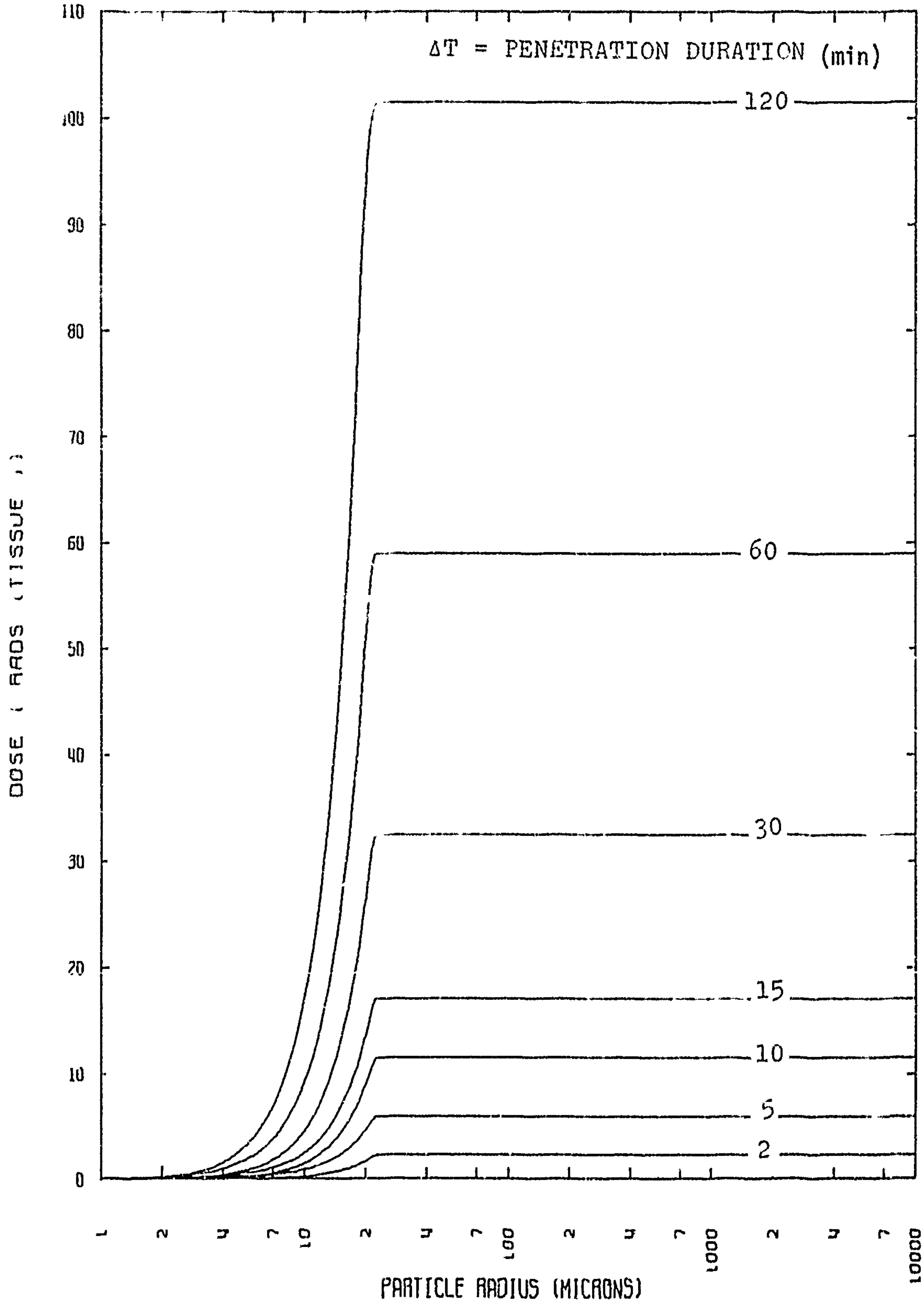

Figure 87. Cumulative Cockpit Dose at 30 Hours, TI = 5 Hours

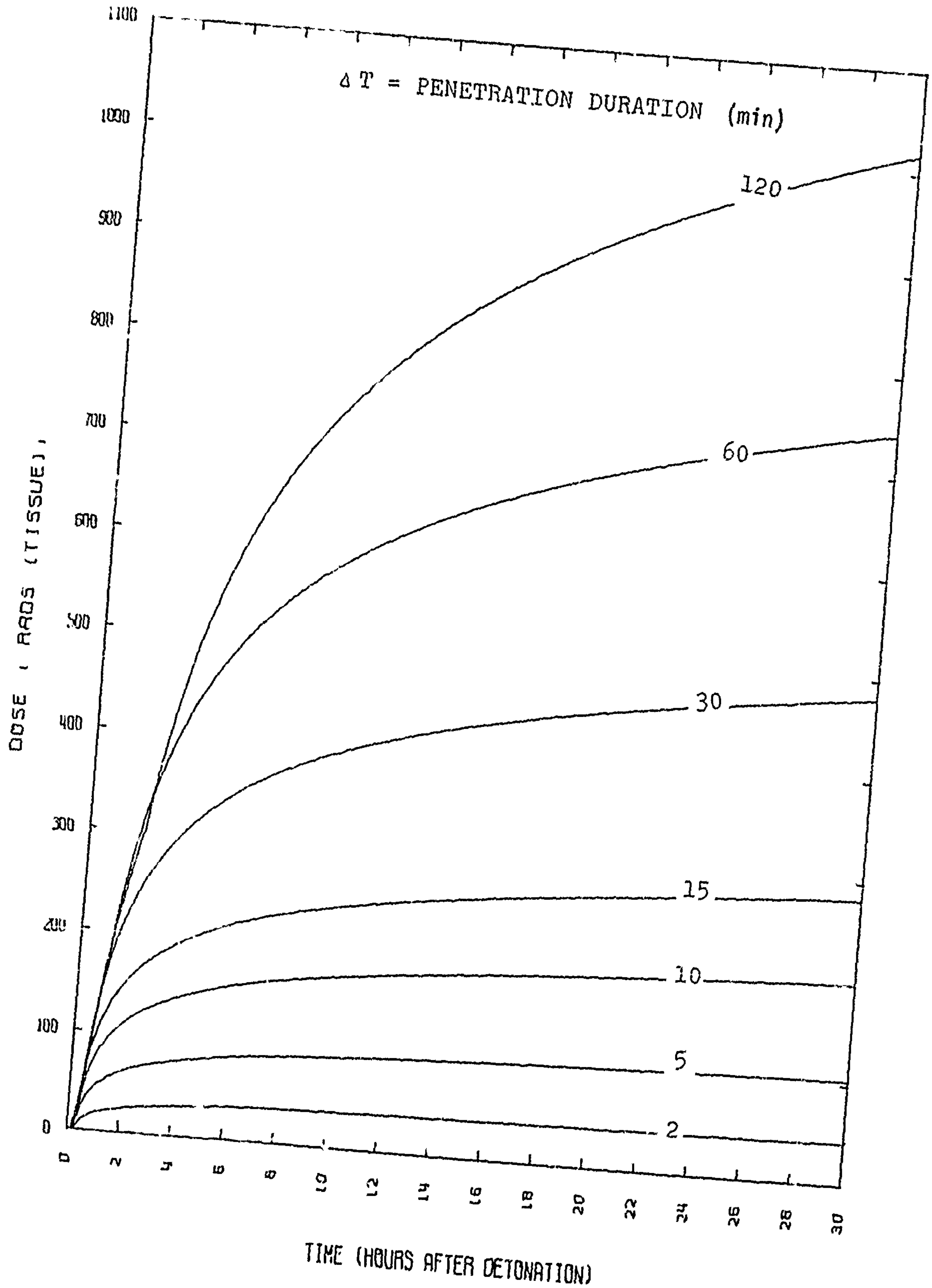

Figure 88. Cockpit Dust Dose,
TI = 10 Minutes

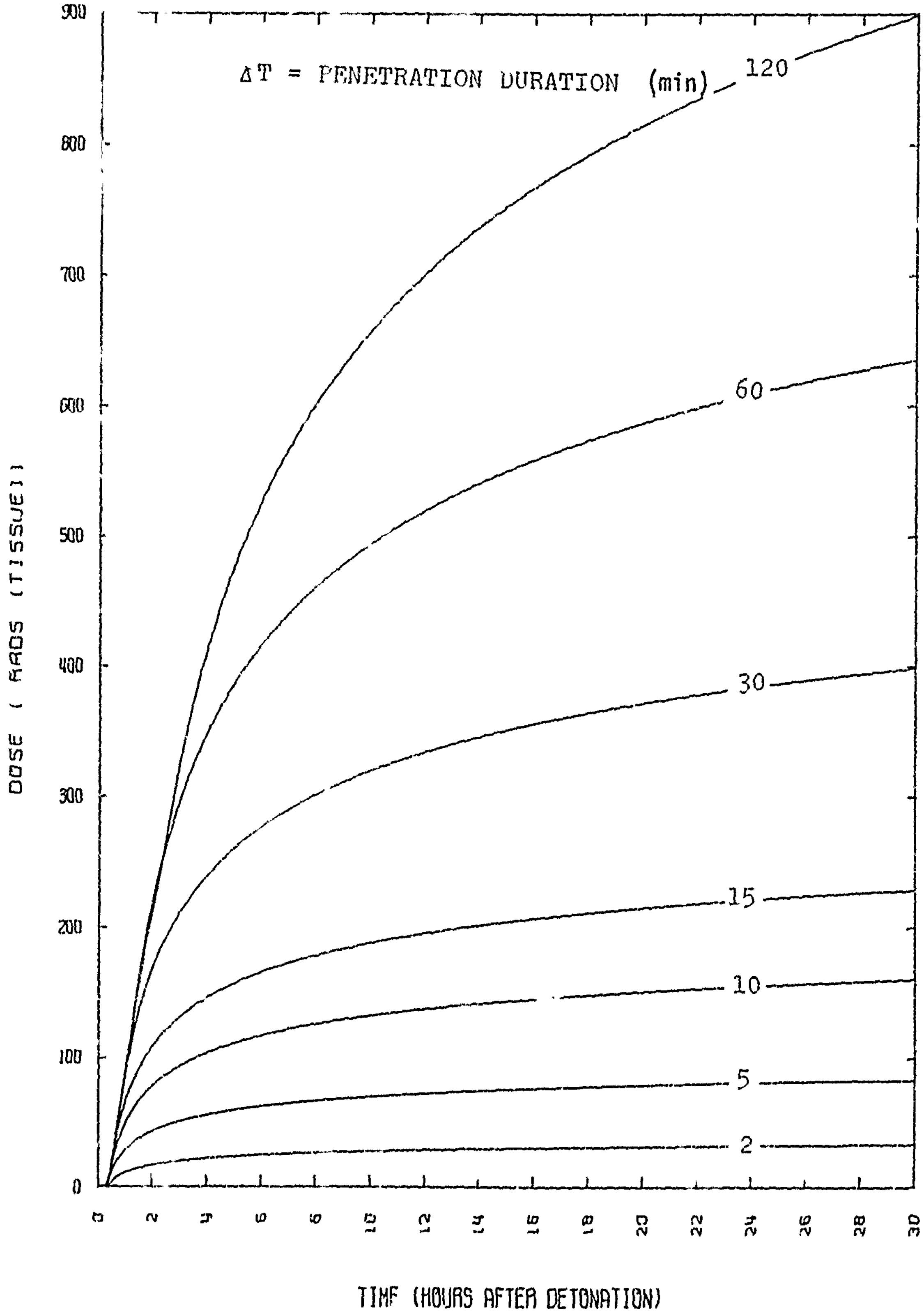

Figure 89. Cockpit Dust Dose,
TI = 18 Minutes

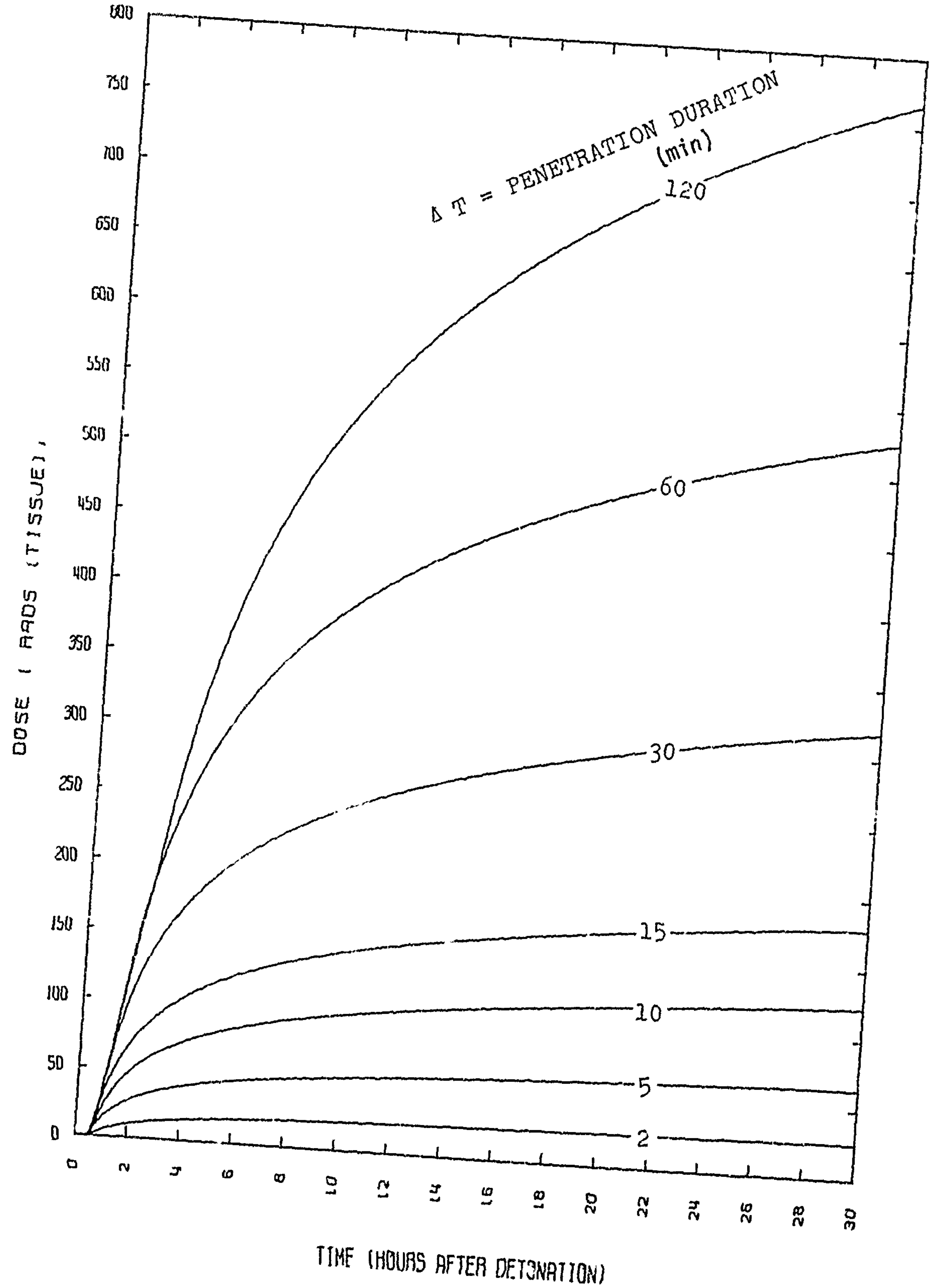

Figure 90. Cockpit Dust Dose,
TI = 30 Minutes

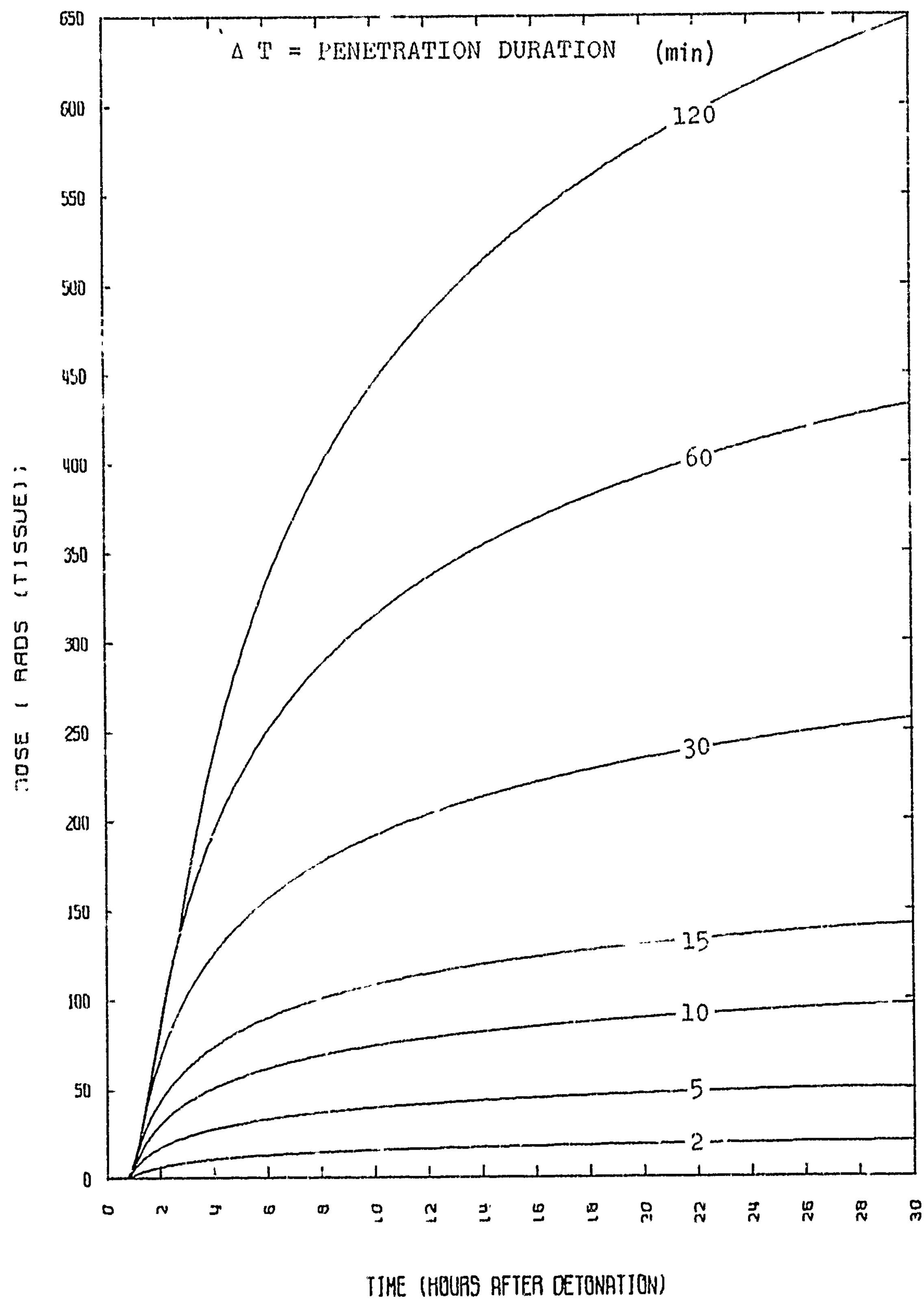

Figure 91. Cockpit Dust Dose,
TI = 45 Minutes

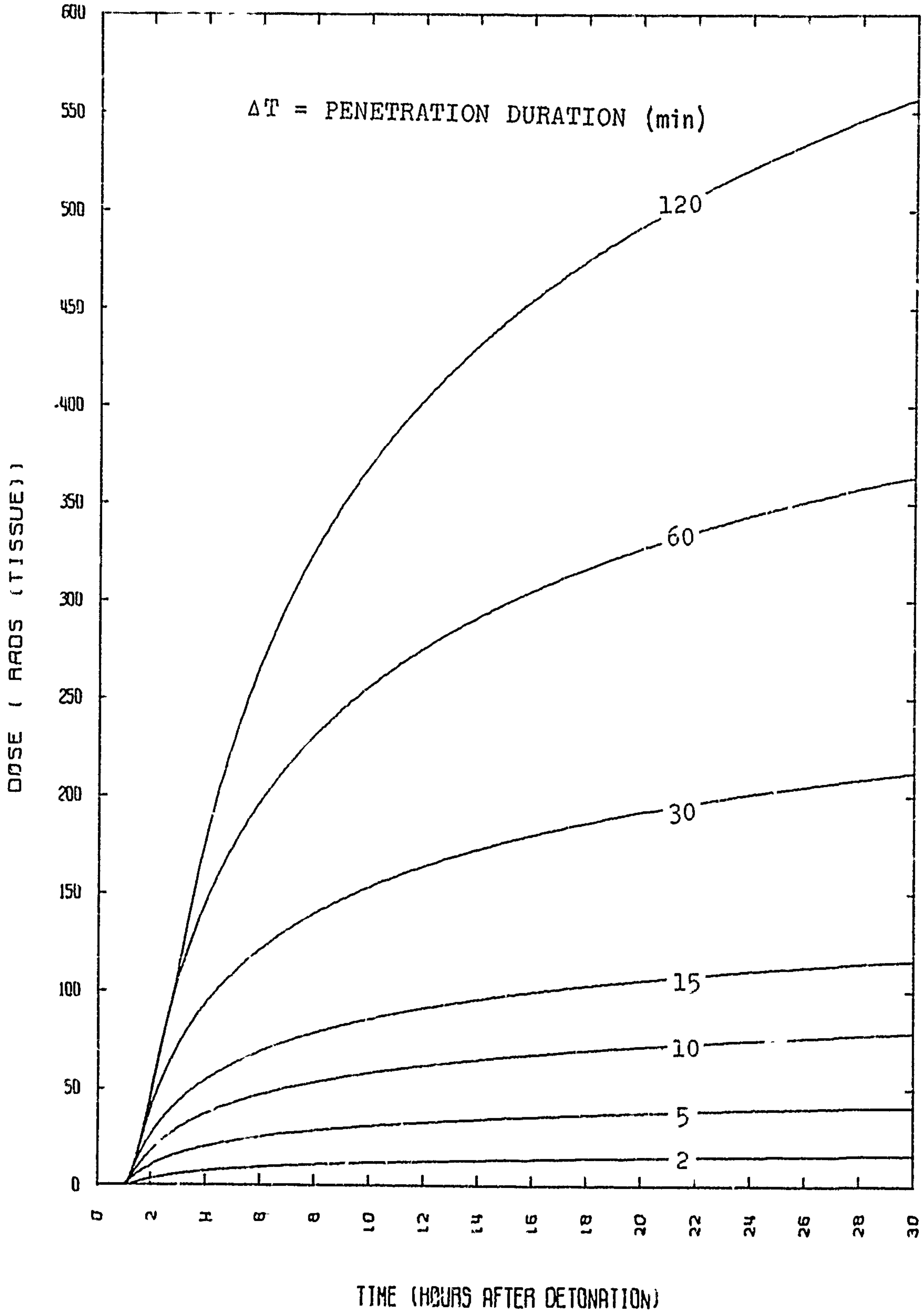

Figure 92. Cockpit Dust Dose,
TI = 1 Hour

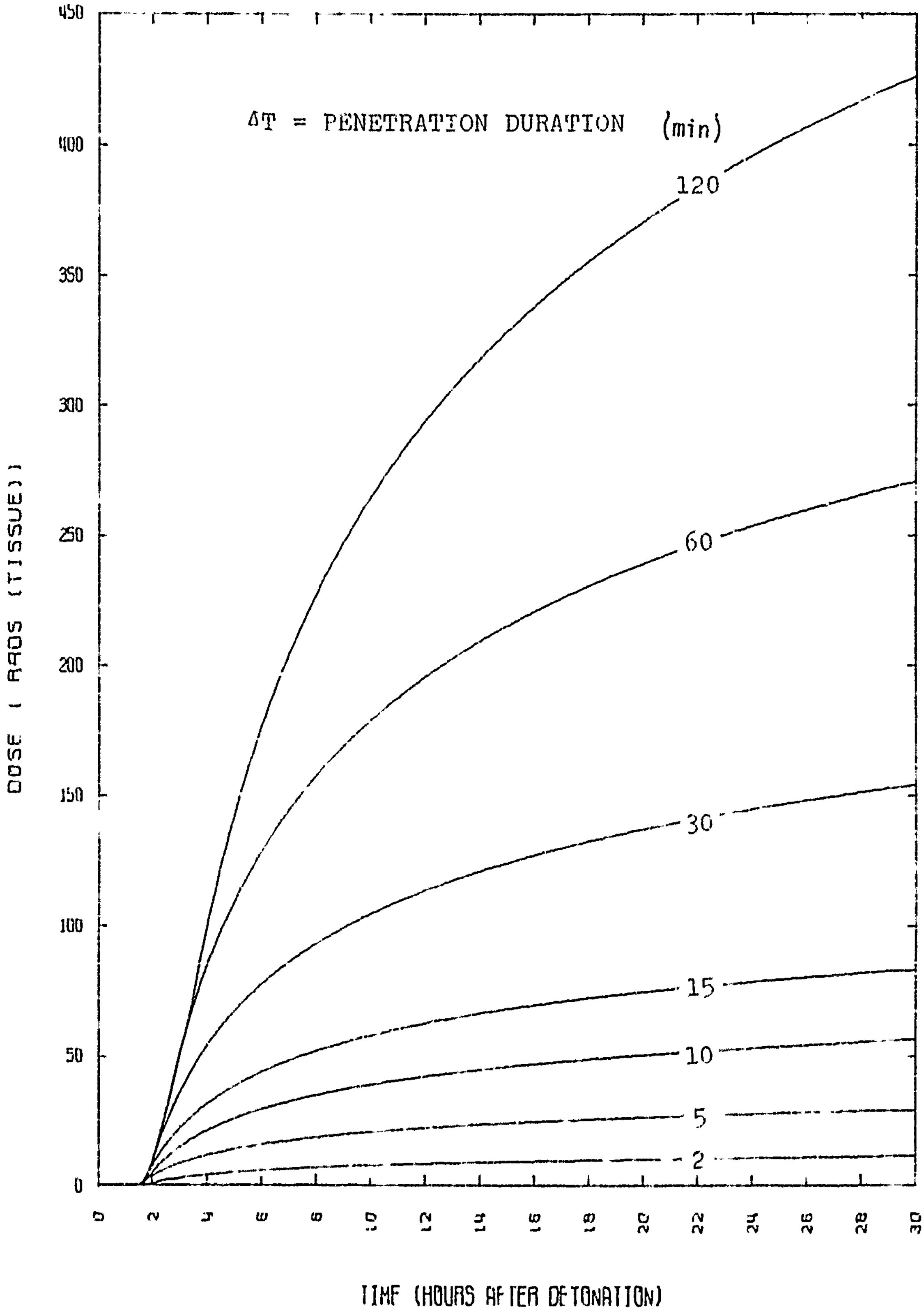

Figure 93. Cockpit Dust Dose,
T1 = 1.5 Hours

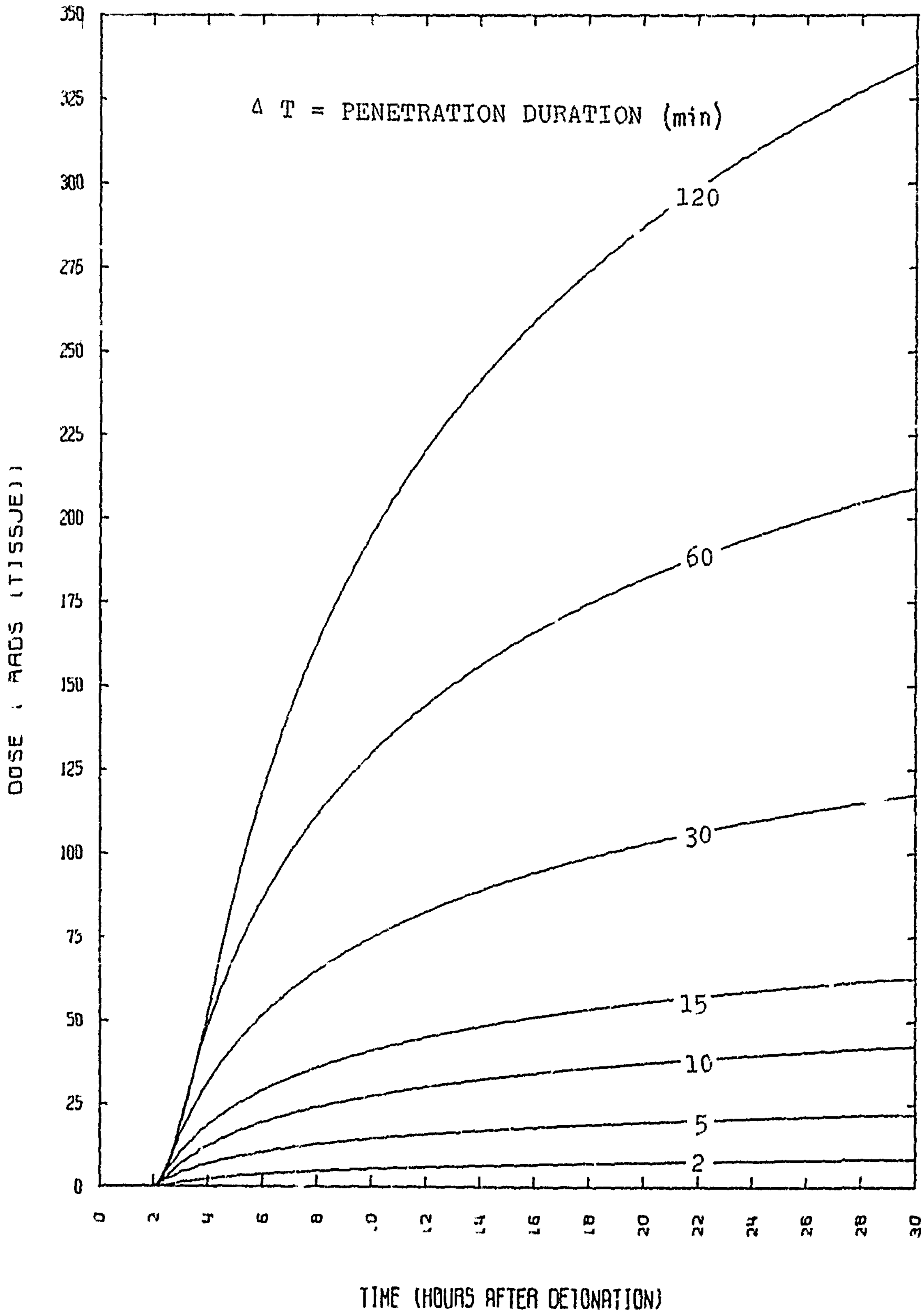

Figure 94. Cockpit Dust Dose,
TI = 2 Hours

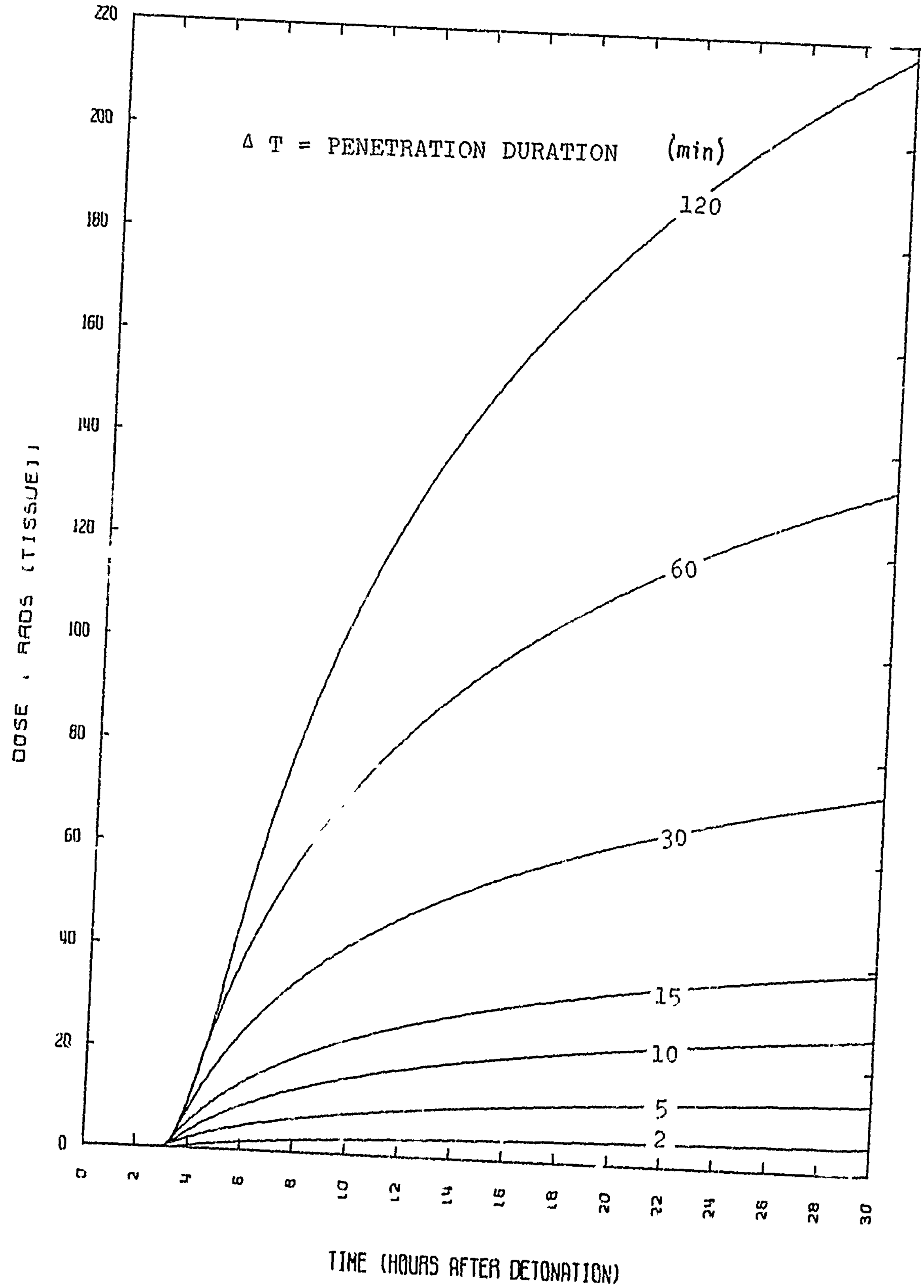

Figure 95. Cockpit Dust Dose,
TI - 3 Hours

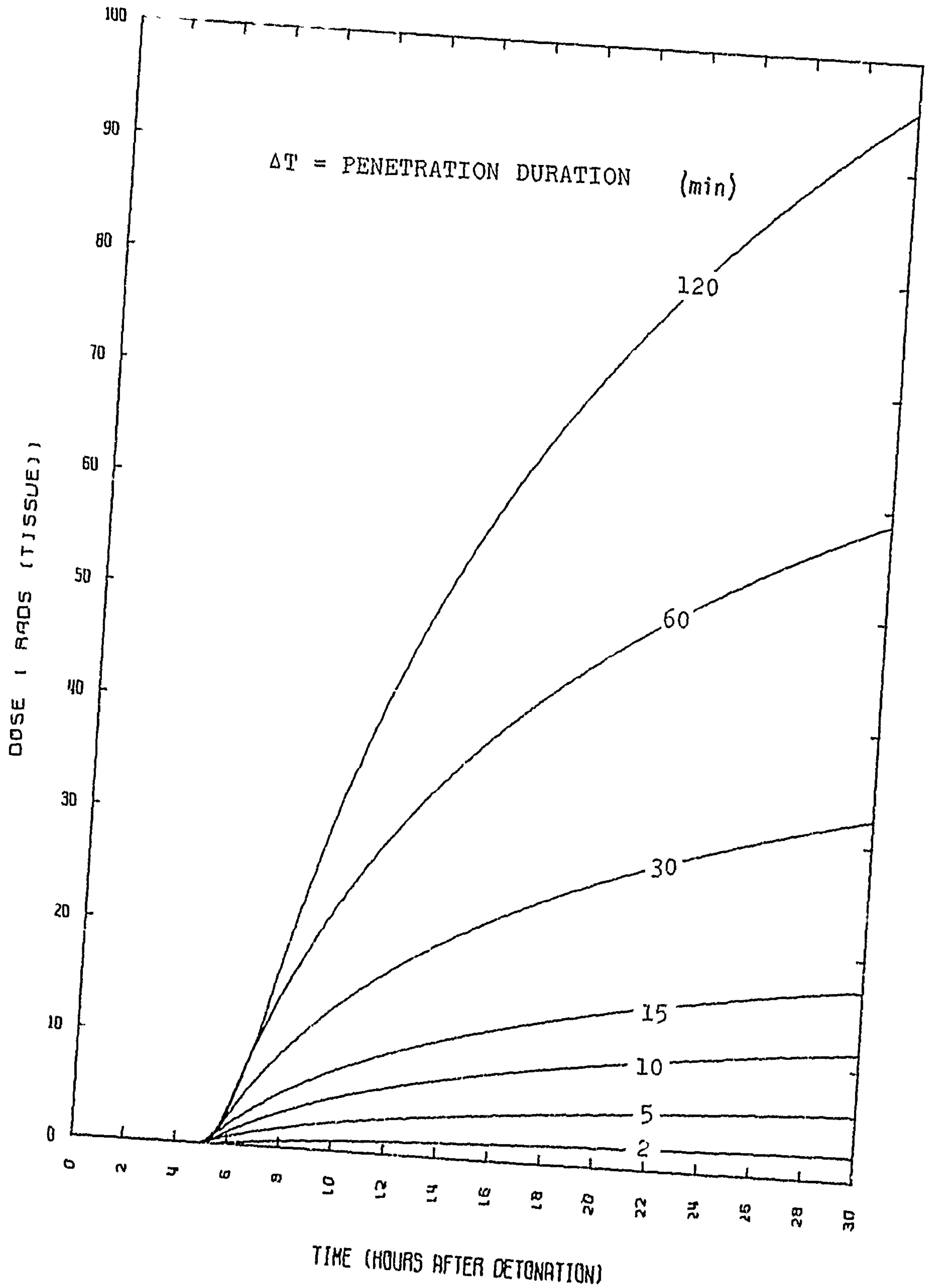

Figure 96. Cockpit Dust Dose, TI = 5 Hours

SECTION IV

FILTER ANALYSIS

In the previous section of this report the procedure required to fix a point design condition has been presented, and for illustrative purposes the set TI = 30 minutes, ΔT = 30 minutes, altitude of 30,000 feet, and the B-1 physical characteristics have been selected as a baseline point design condition. The results for two extreme cases, i.e., perfect filtration and zero filtration, which are interesting because they are limit conditions, have also been presented. However, these results can be used as standards of comparison when any filter is evaluated against the point design condition, and as a basis for general conclusions about the filter efficiencies required.

Once the point design condition has been specified the dust mass which enters the filter is known as a function of particle size and time. This mass distribution is the curve corresponding to the point design condition contained in the results presented for the perfect filter. For the particular point design chosen, this curve is the ΔT = 30 minute curve in figure 7. The first step in the evaluation of a given filter is to determine whether or not the filter efficiency is adequate to protect the crew and electronics in the cockpit. The filter efficiency is defined to be

$$FE(r) = \frac{\text{Total mass due to particles of radius r trapped}}{\text{Total mass of radius r entering filter}}$$

Two filters will be investigated. Both are physically large enough to accommodate the trapped dust with no change in filter efficiency. Of course, the capacity of the filter under consideration must be considered in an actual evaluation of a real filter. The information was not available, however, for this depth in this example. However, in an actual evaluation, if the filter efficiency did change with mass accumulation, this same procedure could be repeated using the new filter efficiency, which is likely to be empirically determined. The filter efficiencies of the two filters to be evaluated are

The micron filter:

$$FE(r) = 0 \qquad r < 1\mu$$

$$FE(r) = 1 \qquad r \geq 1\mu$$

The standard filter (ref. 5):

$$FE(r) = 0 \qquad r < 6\mu$$

$$FE(r) = 0.98 \qquad 6\mu \leq r \leq 18$$

$$FE(r) = 1 \qquad r > 18\mu$$

The micron filter results are obtained first. Because particles smaller than 1 micron in radius do not settle out, but remain suspended in the air almost indefinitely, there is little or no accumulation of these particles in the cockpit. Since all particles larger than 1 micron in radius are trapped, essentially there is a zero dust mass accumulation in the cockpit. The mass and associated dose trapped in the filter then are identical to the perfect filter results with the submicron portion deleted. The total mass accumulated for the point design condition is, from figure 16, $M_c(r = 10{,}000) - M_c(r = 1)$ or $750 - 35 = 715$ grams, with a mass distribution given by the $\Delta T = 30$ minute curve of figure 7, with the submicron part deleted. The dose at 1 meter associated with the trapped dust is $190 - 20 = 170$ rads (tissue) from figure 35. This dose is distributed as shown in figure 26 with the submicron part deleted. These dose results are applicable to the B-1 at T = 30 hours which entered the cloud at TI = 30 minutes and exited the cloud at TF = 60 minutes, where all times are measured from the time of weapon detonation. Scaling these results to other times, other than the T = 30 hours, was discussed in section III and incorporated the use of a time scaling factor (TSF).

The standard filter results will now be considered. For $r > 18\mu$, the standard filter results are the perfect filter results, and for $6\mu \leq r \leq 18\mu$ are the perfect filter results multiplied by 0.98. These two sets of results must be added to obtain the mass trapped in the standard filter and the dose associated with this mass. For these regions the following results are obtained for the total mass and associated dose for T = 30 hours from figures 16 and 35.

Ranges	Mass (gms)	Dose (at 1 meter) (rads (tissue))
$r > 18\mu$	750 - 188 = 562	190 - 104 = 86
$6\mu \leq r \leq 18\mu$	0.98 (188 - 100) = 86.2	0.98 (104 - 54) = 49
Total mass/dose trapped in filter	648.2	135

The dust which is not trapped in the filter enters the cockpit. The mass and associated dose which accumulates in the cockpit is determined using the imperfect filter results for the applicable regions, i.e., $r < 6\mu$ and $6\mu \leq r \leq 18\mu$. The imperfect filter results are directly applicable in the range $r < 6\mu$. The imperfect filter results in the range $6\mu \leq r \leq 18\mu$ must be multiplied by the factor 0.02 and then added to the $r \leq 6\mu$ results to obtain the total mass and associated dose accumulated in the cockpit. These results are obtained from figures 62 and 81 and are summarized below.

Ranges	Mass (gms)	Dose (rads (tissue))
$r < 6\mu$	1	3
$6\mu \leq r \leq 18\mu$	0.02 (30 - 1) = 0.58	0.02 (51 - 3) = 0.78
Total mass/dose accumulated in cockpit	1.58	3.78

These results are significantly less than the "imperfect" filter results, i.e., 593 grams and 320 rads (tissue) for the mass and dose, respectively.

For the purposes of comparison, the results associated with the two limit cases and the two filters being evaluated are presented as follows.

Filter	Filter: Mass Accumulated (gms)	Filter: Dose (at 1 meter) (rads (tissue))	Cockpit: Mass Accumulated (gms)	Cockpit: Dose (rads (tissue))
Perfect	750	190	0	0
Micron	715	170	0	0
Standard	648	135	1.58	3.78
Imperfect	0	0	593	320

These results reveal that some filtration is required because the cockpit dose of 320 rads (tissue) for the baseline case with no filter is unacceptable. Either the standard filter or the micron filter would be acceptable from a cockpit standpoint as there is negligible difference in the dose. However, because the standard filter would be much more cost effective it is the optimum choice of the two filters under evaluation. However, this filter would have to be designed to handle the 648.2 grams of dust which would be collected for the baseline case.

An examination of the cumulative cockpit dose curves, figures 79 through 87, reveals that for a worst case of TI = 10 minutes and ΔT = 2 hours a crew dose due to cockpit dust of less than 25 rads (tissue) would be accumulated at 30 hours after weapon detonation for a filter with a particle cutoff of 8 microns radius. For the baseline case (TI = 30 minutes, ΔT = 30 minutes) such a filter would result in a dose of less than 10 rads (tissue), which is not excessive. Above this 8-micron cutoff the dose curves increase rapidly with increase in particle size. For example, a 10-micron cutoff would result in a cockpit dust dose of 40 rads (tissue) to the crew for the worst case considered (TI = 10 minutes, ΔT = 2 hours). Below this 8-micron particle size cutoff, the dose falls off with particle size, but not very rapidly. For example, a 6-micron filter cutoff would still result in a dose of 15 rads (tissue) to the crew for the worst case condition. These facts, coupled with the fact that filter costs increase as the filter cutoff decreases, leads to the conclusion that a filter cutoff of about 8 microns would be optimum from both cost and crew protection standpoints.

There should also probably be a filter in the system which provides cooling air to the electronics equipment to ensure that the dust accumulation in the ducting and in the black boxes themselves does not act as a source of electronics disabling doses. The importance of this dust from a dose standpoint is that its near proximity to sensitive electronic components can cause an amplification of 10^3 or more over the "at-one-meter" doses calculated. Although a large portion of the electronics is cooled by means of a closed loop system, there are highly critical electronics (for example the Station Logic Units for the SRAM and nuclear bombs) which are cooled by open loop air. Therefore, a filter of some type is probably required, although the filtration and filter capacity requirements might be less stringent than those for the cockpit filter. The analysis to determine the filter requirements must be based on the equipment's susceptibility to the delayed dose, the point design conditions, and relative locations of dust accumulation points. A detailed analysis of the B-1 avionics air-conditioning filtration requirements will be accomplished if desired by the B-1 Program Office.

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Based on the analytical results presented in this report, the following conclusions are drawn.

1. A filter which traps all the particles with radii above 8 microns would provide adequate protection to the B-1 crew and cockpit electronics for the assumed point design conditions.

2. Regardless of the filter chosen for the cockpit air-conditioning system, some micron and submicron particles will enter the cockpit. Precautions should be taken to minimize potential difficulties associated with inhalation of these particles and their contact with exposed skin. These precautions could be as simple as using oxygen masks during the penetration of a radioactive cloud and the wearing of helmets, long sleeved garments, and gloves during and after the cloud penetration.

RECOMMENDATIONS

Based on the results in this report, it is recommended that

1. The crew air-conditioning system be equipped with a filter with a particle trapping cutoff of 8 microns.

2. This filter be located at least 4 meters from crew members.

3. A warning system be incorporated into the Environmental Control System to warn the crew that radioactive dust is being ingested. This would prompt the crew to don oxygen masks, helmets, and gloves to provide maximum protection against skin burns and inhalation of the radioactive particles.

4. An investigation be conducted to determine the filtration requirements of the B-1 avionics.

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1. Whitaker, W., Personal communication.

2. Patrick, R. P., Arnett, G. D., and Yingling, W. A., Aircraft Penetration of Clouds Generated by Nuclear Bursts, AFWL-TR-73-82, Air Force Weapons Laboratory, Kirtland AFB, NM, to be published.

3. TFD-72-1116, B-1 Environmental Control System Performance Status, October 1972.

4. TFD-71-1501, B-1 Crew Module Emergency Ventilation Analysis, November 1971.

5. MIL-E-38453, Environmental Control, Environmental Protection, and Engine Bleed Aircraft Systems, Aircraft, General Specification for.