# RADIOLOGICAL TARGET ANALYSIS PROCEDURES

Prepared for:
Department of Defense
Office of Civil Defense
Washington 25, D. C.

Contract No. OCD-OS-62-207
Report No. VP-1699- G-1
June 28, 1963

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"This report represents the author's views, which in general are in harmony with the technical criteria of the Office of Civil Defense. However, a preliminary evaluation by OCD indicates that further study of the subject area is desirable."



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"Qualified requestors may obtain copies of this report from Defense Documentation Center, Arlington Hall, Virginia."

ACKNOWLEDGEMENTS

The research project personnel wish to gratefully acknowledge the inspiration, guidance and help provided to them by Dr. Carl Miller, Mr. W. J. Lacy and Mr. J. Greene who represented the Office of Civil Defense with respect to the research reported herein.

The following people of Cornell Aeronautical Laboratory provided direct contributions for this report:

Mr. J. Rinaldo
Mr. W. P. Sewell
Mr. R. M. Scamurra
Mr. C. Groenewoud
Dr. S. Stern
Dr. W. J. Walbesser
Mr. E. E. Heckroth
Mr. M. Kamrass

In addition, Mr. R. Koegler and Mr. J. Kline generously supplied research effort, without compensation, on a related project for the Erie County Civil Defense Office; their work was very valuable to the present research.

The project engineer wishes to thank the above individuals for their contributions and also wishes to acknowledge the encouragement and support of Mr. R. M. Stevens and Mr. A. Stein.

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Appendix I

The principal value of a study of reclamation procedures is to aid civil defense planners to estimate, before an attack, the effects of various operational procedures in dealing with various forms of the threat, and thus to develop contingency plans and standard operational procedures which can be implemented expeditiously after an attack, conditioned by measurements of the actual situation. Thus, the emphasis herein was on identifying the important estimates required and developing computational procedures for producing them, recognizing that situations will vary from city-to-city as well as will the effort devoted to planning activities.

The approach to the problem was to study decontamination as an activity over a large populated area, with the object of finding the implications of the large operation for small areas. For small areas, analytical and computational procedures were developed to handle detailed factors such as structural shielding due to buildings, process programming, and personnel scheduling. Results are available for a number of simple examples to demonstrate the techniques that have been developed.

RESULTS AND RECOMMENDATIONS

he following accomplishments were made in the research:

Simple techniques have been demonstrated in a local .e result that a populated area of 700, 000 people exposed to MT attack outside of the area can be restored in roughly ttack. (Chapter IV)

2) Analysis was conducted of scheduling the entry of operators into a radioactive field. Techniques similar to dynamic programming were applied, with the result that for certain circumstances specific optimal start times can be specified. (Chapter VII)

3) Computational procedures and computer programs have been evolved for testing procedures in simulated environments. A hypothetical case was considered to test the mathematics and the computer program. (Chapter VI)

4) Substantial analysis was performed on the shielding effect of structures in a target area. The following types of target areas were analyzed:

a) Single building on flat plane
b) Residential complex
c) Plaza
d) Downtown city

A computer program is available for evaluating a complex downtown city area. This can now be applied rather easily to abstracted areas from the center of any major city. (Chapter VIII)

The research program was slanted towards the development of analytical and computational tools rather than the solution of some special problems.

The following follow-on work is now in order, either as a continuation of this research, or as a separate project:

1) Apply the computational tools to the analysis of a variety of target areas of each type to develop knowledge of variations and average effects of structural shielding in target areas. This information should be generalized.

2) Continue with analysis of several specified typical attack situations, postulating in each case the effort required, and applying available equipment to each situation.

3) Study the effect of equipment distribution in a populated area. Postulate optimal placement of equipment and optimal pre-fallout positioning.

4) Study the reclamation of specific places of high priority such as power stations, water plants, and hospitals.

5) Examine the management-communication structure of the reclamation system with the purpose of specifying their requirements for efficient action of the reclamation system.

6) Study numerically process ordering techniques applicable to small areas in which structures appear.

7) Develop a simple method for scheduling the entry and exit of operating personnel into and out of radioactive areas.

The above-mentioned items are logical follow-ups for the work already done. The long range objective is to provide methods of putting together good reclamation systems. The remaining work should follow the procedures set out in the present report, namely to have or develop a clear idea of a large unit system, and to postulate subsystems and suboperations to fit in with the major unit.

# III. RESEARCH OBJECTIVES

## INTRODUCTION

After a nuclear attack the intensity and duration of fallout in many areas may necessitate extremely long stays in shelter for the general population, unless the contaminant is removed. Considerable work has already been done on the physical methods of decontamination. The immediate purpose of the work reported herein is to extend knowledge on the operational aspects of this problem. The ultimate objective of this work is to develop sufficient knowledge for the design of optimum decontamination systems and the determination of optimal decontamination procedures. Also it is to help in assessing the equipment and facilities needed, on a nationwide basis, to perform the job adequately after nuclear attack. Finally, the information is to lead to a set of specific instructions to civil defense personnel in all. localities on how to perform large scale decontamination after an attack.

## THE DECONTAMINATION PROBLEM

Basically the decontamination problem stems from the following factors.

a) Radiation is harmful to humans, even in small amounts.

b) A nuclear attack, especially a massive one, will inundate the country with fallout so dangerous that life will be in jeopardy for those who don't proceed to shelter and stay there for long periods of time.

c) There are no easy methods for removing or neutralizing contaminants to the extent that it is harmless.

These three points are only the beginning of the problem. It is further complicated by the following factors:

a) There are not enough fallout shelters for everyone, and those which are available are not uniformly distributed according to population.

b) The weapon explosion will destroy many of the shelters making them useless against fallout.

c) Very many people will be killed and injured as a result of the bomb attack, making it necessary for others to perform rescue work just when they need to be in shelter.

d) The extreme sound and light of the weapon explosion may drive masses of people out of their wits with the result that they will run around aimlessly, rather than to a safe place.*

e) Many people will be away from their families at the moment of attack. They will be motivated to rejoin their families when their best move is to take shelter. Even after they are in shelter they will still want to join their families as soon as possible.

* Von Greyerz, Psychology of Survival

f) The attack will have disruped the utilities; water, power and gas will most certainly be off if the explosion has occurred nearby. These utilities will be essential for many people who have not prepared themselves for this emergency. Consequently these utilities have to be restored somehow while fallout is still a serious danger.

g) Emergency facilities, particularly hospitals, fire departments, and police will face unusual difficulty because of the emergency. Their load is hard in peace time. In an attack, therefore, people operating these facilities cannot take cover; instead they will be on extra duty. Something must be done to reduce the radiation hazard where they need to operate.

h) Equipment for decontamination is in limited supply, in addition personnel can operate this equipment for limited periods of time (in intensely radioactive areas time available may not be enough even to get started). Hence plans must be available to put equipment and operating personnel to best use.

These are the highlights of the problem. There are many more detailed factors. In general there is an extremely complex and painful conflict to resolve. Whatever way things will be done, many lives and much property will be lost. It is very important, therefore to be prepared to do the very best that can be done both in terms of selecting the optimal combination of activities and adhering to an optimal schedule so that losses will be minimized.

## TECHNICAL BACKGROUND

Substantial research on decontamination methods has been conducted by the U. S. Naval Radiological Defense Laboratory, San Francisco, California and others, with the first experiments starting in 1948. At first the research was concerned with the removal of simulated contaminant by such obvious methods as street-sweeping and firehosing. Later on the research was concerned with the decontamination of many types of surfaces and numerous methods of removal. The total experimental effect to date is sufficient for postulating specific plans for organized decontamination of large postulated areas. There is, of course, more refined work that can be done, but this can now be defined better by highlighting the missing details after an attempt at optimizing decontamination operations under a variety of operating conditions.

Briefly, previous work can be highlighted in the following chronological order. (The list is not exhaustive.)

| Date of Report | Type of Experimental Work |
|---|---|
| 1948 | Street sweeper and firehose on roofs and pavements |
| 1948 | Handsweeping and firehose on roofs and pavements |
| 1952 | Land and vehicle decontamination |
| 1957 | Decontamination effectiveness on pavements and building surfaces |
| 1957 | Decontamination of land |
| 1958 | Evaluation of countermeasures and operational procedures |
| 1959 | Decontamination of land |
| | Dry decontamination methods |
| 1960 | Wet decontamination methods |

| Date of Report | Type of Experimental Work |
|---|---|
| 1961 | Roof washdown |
| 1962 | System plan for industrial complex |
| 1962 | System experiments on target complex containing 2-story apartment buildings |
| 1962 | Comprehensive report on up-to-date knowledge on reclamation and radiological countermeasures by Dr. C. F. Miller |

This sequence follows the usual course of a research of this importance. At first the idea of decontamination was tested on a moderate scale. Success with those experiments led to more comprehensive research. As the process progressed, decontamination systems were envisaged and after careful research was conducted to find and choose best methods of accomplishing reclamation, some tests were conducted to observe how a complete system would indeed perform.

The present work is part of an effort to postulate optimal systems and procedures to accomplish reclamation. The analysis is heavily based on Dr. C. F. Miller's publication "Fallout and Radiological Countermeasures".

## BASIC KNOWLEDGE REQUIRED FOR ANALYTICAL WORK

The information required for the formulation of operational plans is as follows:

1) Nature of post attack fallout situation, including radiation intensity, the area involved and the effect on the general public.

2) Physical methods of combating fallout, includes all countermeasure from sheltering to fallout removal.

3) Constraints within which fallout removal operations can take place and criteria for selecting best procedures.

4) Effects of environment on radiation intensity patterns

5) Effects of operational procedures on radiation patterns (e.g. ordering of processes)

6) Effects of timing and scheduling of operations

7) Resources available for the synthesis of operational facilities. This includes not only the existing facilities, but the ability of various localities for getting additional equipment

8) Priorities of some areas and facilities for decontamination with respect to other areas.

9) Existing distribution (or feasible optimal distribution) of resources

10) Effects of failure, of components essential to operations, including the failure of utilities

11) Interactions with other post attack operations

Previous work already provides substantial knowledge for items 1 and 2 and some information is available for items 3 and 4; the rest is relatively undefined.

## PURPOSE AND SCOPE OF THIS RESEARCH

The original objective of the research was to translate available basic information into operational plans for decontamination. However, after the research got underway, it was learned that very much basic information essential for operations research was still missing. Hence it became the objective to contribute to the basic methods and information needed to prepare the way for the accomplishment of the original objective. The work of this report is oriented to deal especially with items 3, 4, 5 and 6 of the preceding section. The accomplishments shown in the report are the following:

1) An example is given to show how simple techniques and available knowledge can be applied to form a skeleton plan for the decontamination of a city if the fallout situation is given. Chapter IV

2) Some criteria are given for systems optimization. Chapter V

3) Techniques for modelling systems component operations are discussed. Chapter V

4) An analytical treatment of scheduling for minimization of dosage is presented. Chapter VII

5) Environmental effects (effects of complex structures) on radiation fields is dealt with for a variety of target areas. The emphasis is on the realization of computer methods and computer programs. Examples are shown on what can be done and the programs are now available for general application. Chapter VIII

# IV. SIMPLE DECONTAMINATION SYSTEMS FOR LARGE POPULATED AREAS

## A BRIEF DESCRIPTION OF A DECONTAMINATION SYSTEM

Figure 1 represents the dominant components of a decontamination system and their interrelationships. Essentially, there are four major components:

1) Civil Defense Emergency Operating Center
2) The Decontamination Machinery
3) The Target Area
4) The Operating Personnel

In Figure 1 the attack parameters are shown as the primary input information to which the rest of the system responds. The fallout is shown as a function of the attack, the weather and the terrain. The instrumentation of the system transmits all this information to the Civil Defense Emergency Operating Center, where it is used to predict the emergency situation and to plan for it. The center is in control of public activities and over its countermeasure facilities including the decontamination operations equipment and personnel. The operating center's responsibility is to supervise reclamation operations in such a way that the process moves along efficiently and rapidly while the general public is kept in shelter. As areas become available for habitation, the operating center allows rehabilitation, taking care that the general public will not be overexposed. The reclamation and rehabilitation process is continued until the emergency is over.

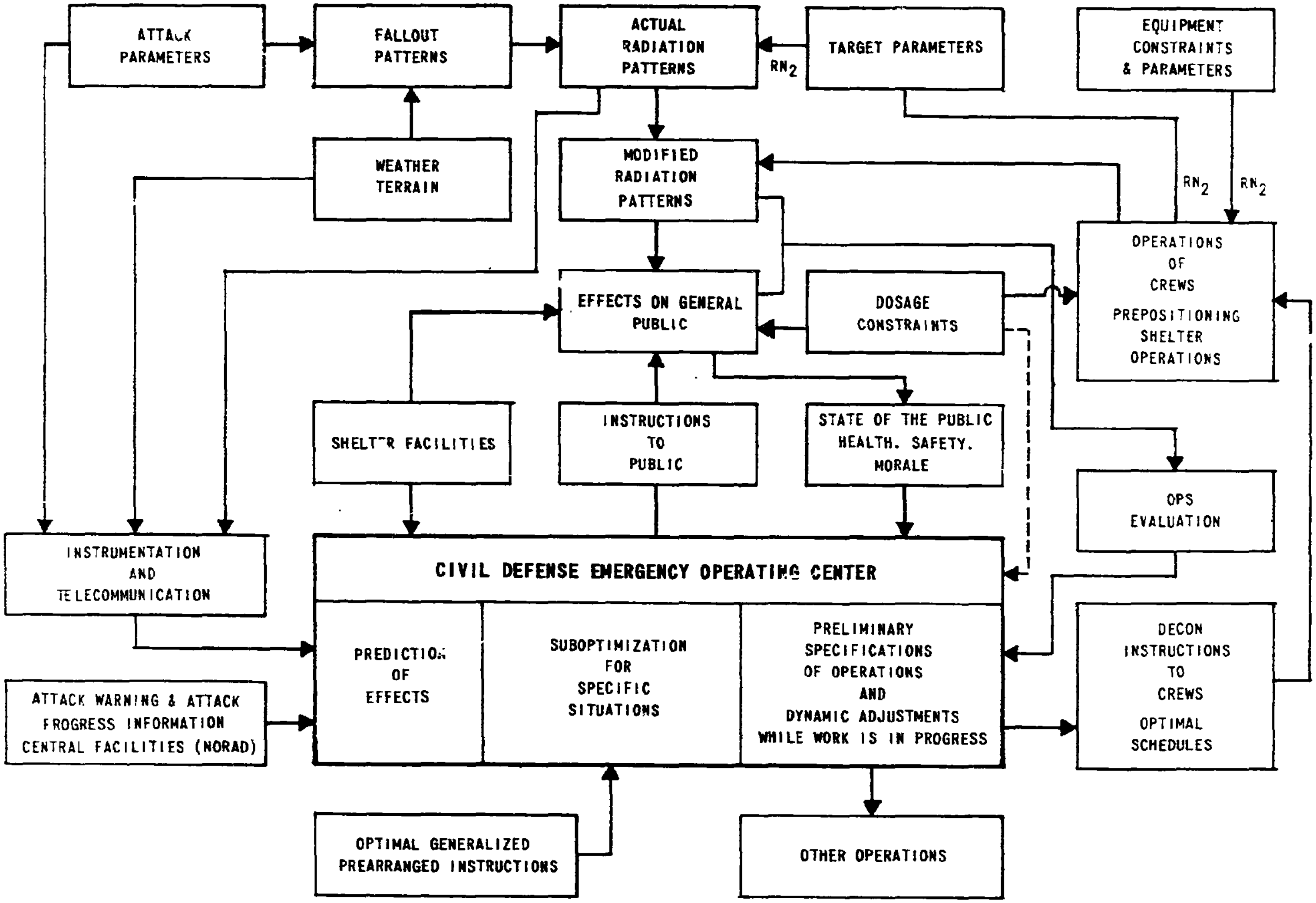


**Figure 1 SYSTEM INTERRELATIONSHIPS**

## ASSUMPTIONS FOR SIMPLIFYING THE GENERAL DECONTAMINATION PROBLEM

It is obvious that an analysis which treats the problem in all its complexity is too difficult. To gain a foothold on the problem, it is essential to simplify it until it is in a sufficiently tractable form; to solve the simple problem, and then to make consecutive adjustments after reintroducing the most important difficulties one by one. This procedure holds, in general, for any major problem which cannot be solved by available doctrinal methods.

For the purpose of this research the following assumptions were made:

1) There is no damage other than fallout. Thus the decontamination problem alone is to be studied and other aspects like debris removal and rescue work are to be considered later.

2) The radiation is uniform over small areas (of city block size). (In reality, terrain roughness, densely built up areas, and micrometeorological effects tend to negate this.)

3) There are no complications in the target area. The situation is idealized so that stalled cars, fences, trees, refuse and so on have no effect on radiation or on operations. These complications will be left for later study.

4) Operators will work until they have a permissible dose, and then stop (to be replaced by other operators). Their health and life will not be exchanged for additional achievement, except in an unusual situation.

5) All people are safely sheltered. Moreover, all people have been adequately warned so that all are indeed in shelter when attack occurs, hence rescue work will not be essential. Also once in shelter, the populace will be content to remain there until decontamination has made emergence safe.

6) Rate of work, and decontamination effectiveness as reported in the literature will be used as criteria for choosing optimal methods. Manipulation of process parameters such as water pressure, nozzle size, transport speed, etc. will not constitute part of the analysis.

7) Target structural influences on radiation will be calculated according to the examples shown in Dr. Miller's publication "Fallout and Radiological Countermeasures".

8) At first no special provision will be made for high priority facilities. All parts of a populated area will be considered equally important. The problem of special facilities will be dealt with after the general problem is well understood.

9) All people are identically influenced by the fallout, that is, nobody has a special need over any one else's, neither is anyone more or less susceptible to radiation than the "average" person.

## DECONTAMINATION METHODS

The purpose of a decontamination process is to remove, as quickly as possible, the radioactive fallout material from the surfaces on which it has settled. The removal process depends on the nature of the contaminant (whether it is wet or dry) and the nature of the surface from which it is to be removed. Dry contaminant is generated by an overland atomic explosion; wet contaminant in the form of a slurry is generated by an over-water (or under-water) burst. Therefore, for wet fallout, adhesion is a problem while for dry it is not.

Decontamination processes fall broadly into two categories:

1) Removal of surface

2) Removal of contaminant alone by
   a) Washing
   b) Sweeping and vacuuming.

The surface removal process is applicable to loose surfaces such as sod and gravel. This can be done mechanically with motor-scrapers, bulldozers, motorgraders and front-end loaders, or manually with shovels. The mechanized equipment is applicable on open areas such as parks and fields, and readily accessible lawns. The manual methods are necessary where mechanized equipment cannot be used such as lawns with cement walks and driveways in residential areas.

Wet methods apply to paved surfaces and roofs of buildings (and sometimes walls of buildings as well). These comprise firehosing and motorized street flushing. Water velocity rather than water volume is the important mechanism of contaminant removal. For wet contaminant it may be necessary to increase the work to include wetting and scrubbing as well as flushing.

Table 1 shows a list of decontamination methods suitable for some general broad classes of surface materials. This table is based on available information in the literature. It has been arranged to allow

TABLE 1

Decontamination Methods*

| Surface | Method | Process Speed ft²/min | Remnant % | Men Required | An | As | Duty Cycle % |
|---|---|---|---|---|---|---|---|
| Paved Street | Firehose | 2500 | 6.2 | 5-6 | - | - | - |
| | | 1250 | 4.3 | 5-6 | - | - | - |
| Paved Street | Sweeper | | | | | | |
| | 1 pass | 2000 | 24 | 1 | - | - | - |
| | 2 passes | 1000 | 8 | 1 | - | - | - |
| | | | concrete \| asphalt | | | | |
| Paved Street | Motorized Flusher | 10,000 | 5 \| 6 | | - | - | - |
| | | 5,000 | 2.5 \| 3.5 | | - | - | - |
| | | 2.000 | 1 \| 2 | | - | - | - |
| Sod | Hand Stripping | 20 | 10 | 4 | - | - | - |
| Sod | Sod Cutter & wheel-barrows | 35 | 3 | 7 | - | - | - |
| Sod | Sod Cutter (no removal manually) | 220 | 2 | 7 | - | - | - |
| Sod | Tractor (front end loader) | 70 | 10 | 2 | - | - | - |
| Sod | Bulldozer | 90 | 5 | 1 | | | |
| Tar & Gravel Roofs | Firehose | 100 | 11 | 6 | | | |

* This table provides figures for an initial estimate of effort required. For a detailed analysis the tables provided in Chapter 8, Reference 1, should be consulted.

spaces for all those parameters that one needs to know in order to plan a decontamination operation. Blank spaces indicate information that is not available. The tables are arranged to show the problem surface, the appropriate method for cleaning it, the speed at which the process is applied, the remnant left after application of the process, the men required per machine or per crew, the shielding factors relating to the process and the duty cycles of the process (effective time/operating time).

## THE DOSE RATE MULTIPLIER

The cumulative radiation experienced by operating personnel during decontamination and other operations should not exceed specific limits. To easily estimate the dosage accumulated by a crew, Miller has advanced the Dose Rate Multiplier concept. This is to be defined as

$$DRM(t) = \frac{1}{I(1)} \int_{t=1\,hr}^{t} I(t)\,dt$$

Thus, to calculate the dose received by a given crew member during a specific operation, it is necessary to use the formula

$$D = I(1)\left[DRM(t_2) - DRM(t_1)\right]$$

Miller bases his I(t) on the equivalent ionization rate from the decay of one atom of U239 per fission activated at zero time. The DRM achieves a steady value of 3.95 in 2.3 years. For the $t^{-1.2}$ representation,* a steady value of 5 is reached. It is shown in another section that the $t^{-1.2}$ curve is good until 5000 hours, after which it departs appreciably from the actual decay curve. Whenever calculations must account for DRM ( $t$ ) it is important to use the actual decay rate rather than $t^{-1.2}$.

Table 2 shows DRM values as a function of time. Figure 2 shows this relationship graphically. Figure 3 shows a graph of DRM*(t) where

$$DRM^*(t) = 3.95 - DRM(t)$$

* $t^{-1.2}$ is used in references 2 and 3 for example, to represent normal decay of radioactivity in fallout material.

TABLE 2

Dose Rate Multiplier

| t(hrs) | DRM | t(hrs) | DRM |
|---|---|---|---|
| 1.0 | -0- | 160 | 3.016 |
| 1.2 | 0.178 | 180 | 3.058 |
| 1.4 | 0.320 | 200 | 3.094 |
| 1.6 | 0.436 | 250 | 3.163 |
| 1.8 | 0.533 | 300 | 3.214 |
| 2.0 | 0.614 | 400 | 3.286 |
| 2.5 | 0.776 | 500 | 3.339 |
| 3 | 0.899 | 600 | 3.381 |
| 4 | 1.082 | 700 | 3.417 |
| 5 | 1.219 | 800 | 3.448 |
| 6 | 1.328 | 900 | 3.475 |
| 7 | 1.419 | 1,000 | 3.499 |
| 8 | 1.497 | 1,200 | 3,540 |
| 9 | 1.565 | 1,400 | 3,574 |
| 10 | 1.626 | 1,600 | 3,604 |
| 12 | 1.729 | 1,800 | 3,630 |
| 14 | 1.815 | 2,000 | 3,653 |
| 16 | 1.889 | 2,500 | 3,703 |
| 18 | 1.953 | 3,000 | 3,744 |
| 20 | 2.009 | 4,000 | 3,805 |
| 25 | 2.126 | 5,000 | 3,848 |
| 30 | 2.221 | 6,000 | 3.876 |
| 40 | 2.369 | 7,000 | 3.895 |
| 50 | 2.484 | 8,000 | 3.908 |
| 60 | 2.577 | 9,000 | 3.923 |
| 70 | 2.653 | 10,000 | 3.929 |
| 80 | 2.718 | 12,000 | 3.937 |
| 90 | 2.773 | 14,000 | 3.940 |
| 100 | 2.821 | 16,000 | 3.942 |
| 120 | 2.901 | 18,000 | 3.944 |
| 140 | 2.965 | 20,000 | 3.945 |

DRM*(t) is directly useful in calculating the incremental dosage for personnel who enter a radioactive area at time t and remain there. This dosage added to that received during operations and shelter constitutes total lifetime dose. For the general population it is the only dosage experienced, if they remain in shelters with high protection factors until emergence.

## THE RESIDUAL NUMBER

The residual number, RN, is a ratio of the actual dose received due to countermeasures, divided by the dose that would have been received without the countermeasures. In general, there are three major divisions in time depicting the activities of the decontamination personnel during the fallout period:

1) Shelter phase
2) Operation phase
3) Occupation phase

Miller has associated a residual number with each of these phases and labelled them $RN_1$, $RN_2$ and $RN_3$ respectively. Thus, $RN_1$ represents the actual shelter protection factor. $RN_2$ represents the total effect of structural shielding, vehicle shielding, dynamic change in radiation due to operations and so on. $RN_3$ represents the remnant fraction of fallout material remaining after operations are completed and includes also the shielding advantages of structures, living patterns and the distribution of the remaining fallout.

If we designate

$$\Delta_1 DRM = DRM(t_1)$$
$$\Delta_2 DRM = DRM(t_2) - DRM(t_1)$$
$$\Delta_3 DRM = DRM(\infty) - DRM(t_2)$$

where $t_1$ = operations start time,

$t_2$ = operations completion time

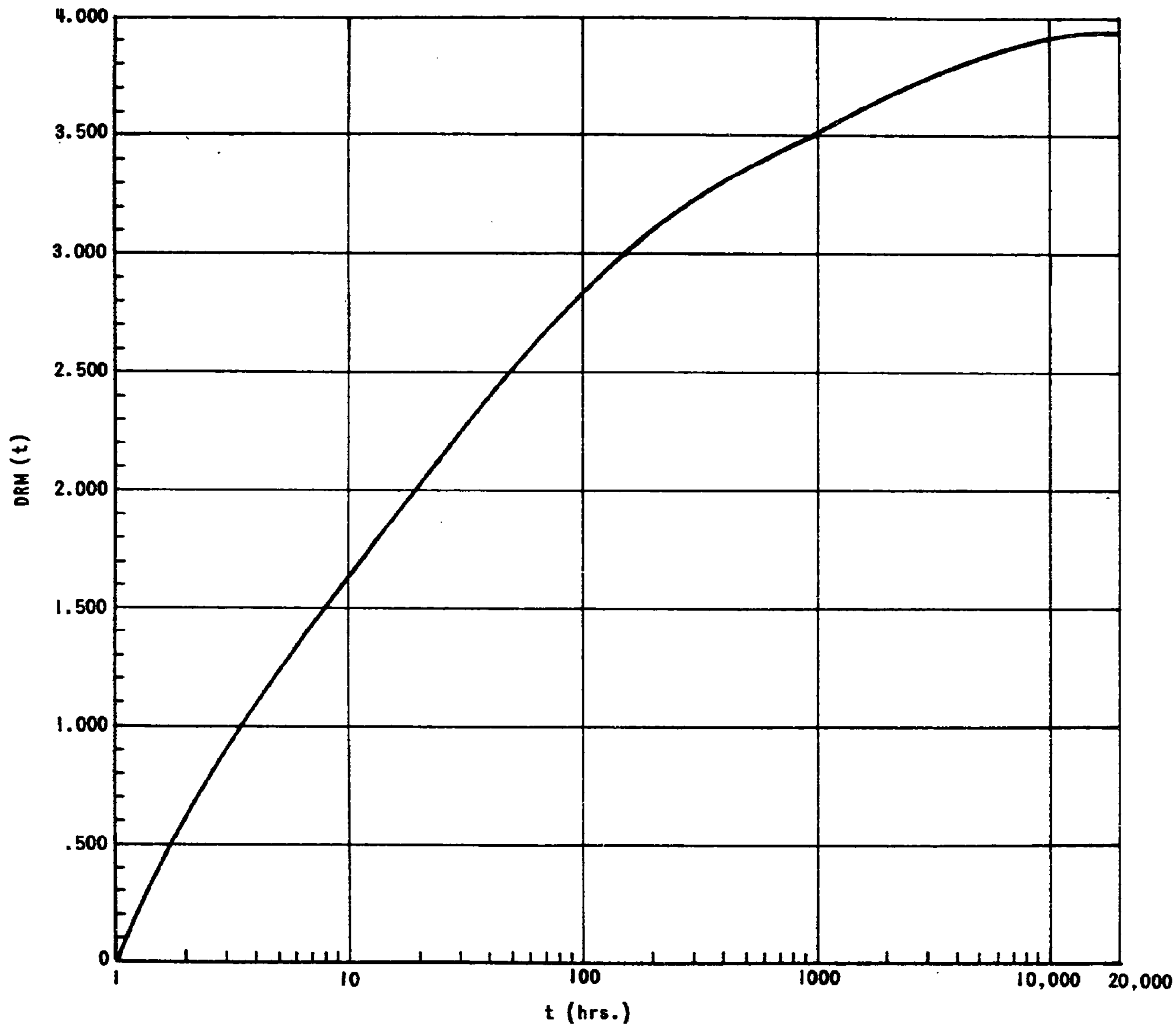


Figure 2 DOSE RATE MULTIPLIER

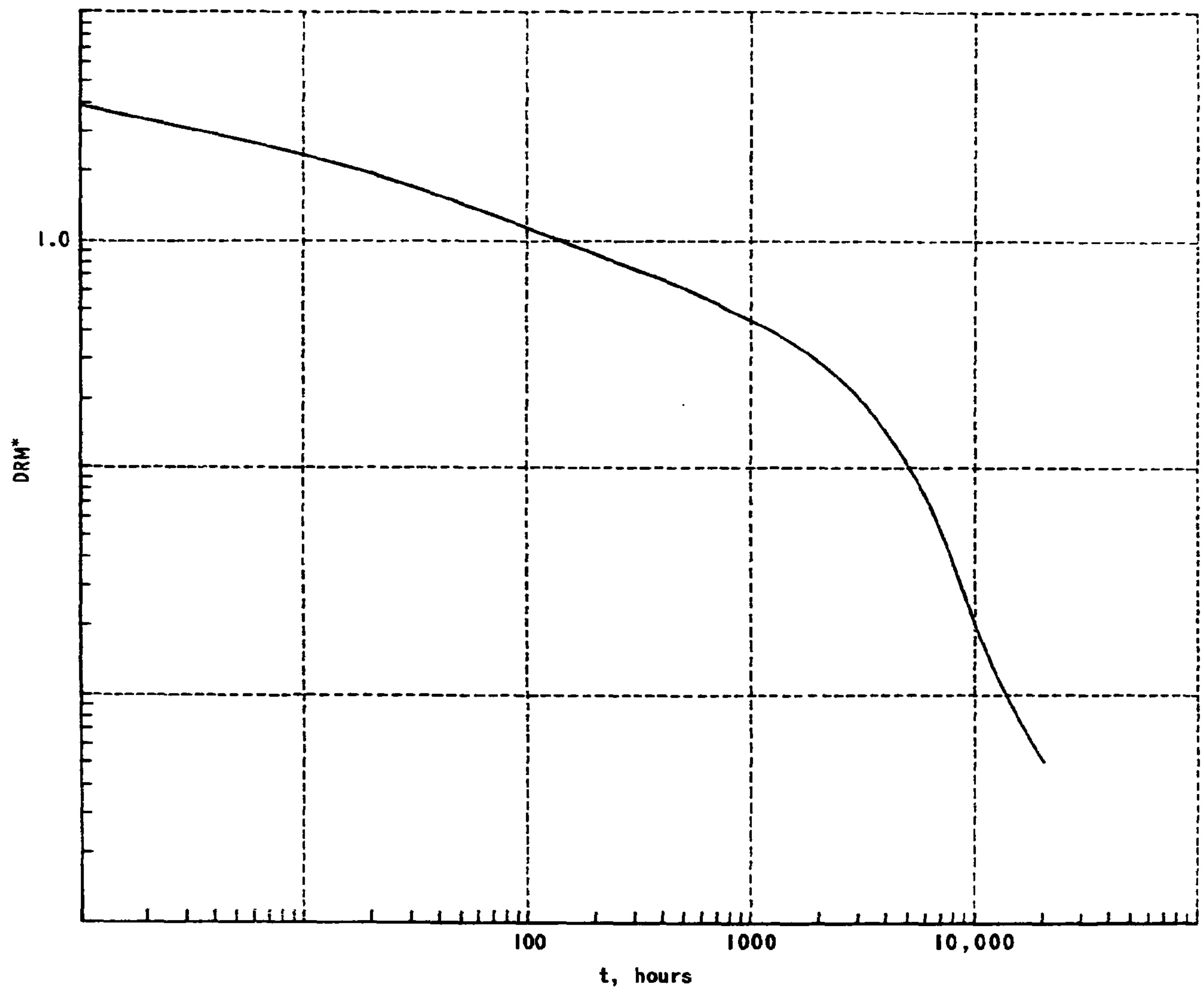


Figure 3 DRM* (t) = 3.950 - DRM (t)

then the dose received by a crew member is

$$D = I(0)\left[RN_1(\Delta_1 DRM) + RN_2(\Delta_2 DRM) + RN_3(\Delta_3 DRM)\right]$$

and for non-crew personnel it is

$$D = I(1)\left[RN_1(\Delta_1 DRM + \Delta_2 DRM) + RN_3(\Delta_3 DRM)\right]$$

## THE PLANNING DOSE

On the basis of information on biological effects on humans as indicated in the first section of this chapter, various criteria have been formulated for allowable dosage while operating in radioactive areas. There are various dose limits that have been used in studying decontamination operations in the past. They range from 30R to 75R per short term exposure to 150R to 1000R for a long term exposure. The limits recommended by Miller are 30R/day, 200R/week and 1000R/year. Compared to this, Lee used 30R/day, 230R/2 weeks and 1000R/year. Lee's limits are a little more conservative, and possibly somewhat more consistent than Miller's. Using the E R D concept* the 200R/week or 230R/2 weeks are much too high. However, if the one day recovery time constant is taken into account, these limits may be satisfactory. For this report, Miller's system will be used. However, it should be emphasized that a very good scientific basis for establishing such limits is needed, and a research program to obtain this basis is well justified. These limits are an important fundamental basis of all decontamination operations, and a change in them leads to an important change in decontamination plans. For this reason, it may be useful to let the dose limits be variable, and calculate decontamination operations as a function of risk to personnel. This procedure is more difficult, of course, and for this phase of the work it is sufficient to adhere to the limits given. In future work, however, as the decontamination picture becomes very clear, it will be very worthwhile to study the tradeoffs between personnel casualties and decontamination achievements.

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* NCRP 29 - (Equivalent Residual Dose)

## IMPLICATIONS OF CONSTRAINTS ON RE-ENTERING FALLOUT AREAS WITHOUT DECONTAMINATION

Figure 4 shows graphically the implication of the dose limits on emergence time for the general public. This graph has been obtained by using DRM* for the 1000R/year limit, DRM (1 day) for the 30R/day limit and DRM (2 weeks) for 230 R/2 weeks. Using DRM (1 week) for 200R/1 week results in a curve that falls below the combined curve for 30R/day and 1000R/year and hence it is not shown. Also shown is a smooth curve joining the 30R/day limit and 1000R/year limit; this curve is a suggestive one with the implication that emergence time should be a smooth function of initial radiation intensity. The sharp transition between the limits for 30R/day and 1000R/year indicates that personnel who adhere to them for around 1.2K R/hour are penalized more heavily than they would be for any other value. The additional smoothing line thus may be used qualitatively, using individual judgment to decide whether 30R/day and 1000R/year are good enough limits or whether other limits should be used for intermediate values of radiation. To make such decisions it is helpful to refer to basic data such as that shown in Table 3*.

From the graph it can be seen that people who find themselves in 10,000R/hour areas will have to remain in shelter for more than seven months, those in 3000R/hour areas - 75 days, and those in 1000R/hour areas - 10 days (more if the point made previously is observed). The object of decontamination is to substantially reduce this shelter time.

## OPERATIONS TIME VS. START TIME

Figure 5 is a graph from which operations time can be obtained as a function of start time, if dose limit and radiation (at one hour) are given. This graph can be used for operations planning in several different ways. If it is assumed that crews must work a minimum time to

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* Or refer to NCRP 29

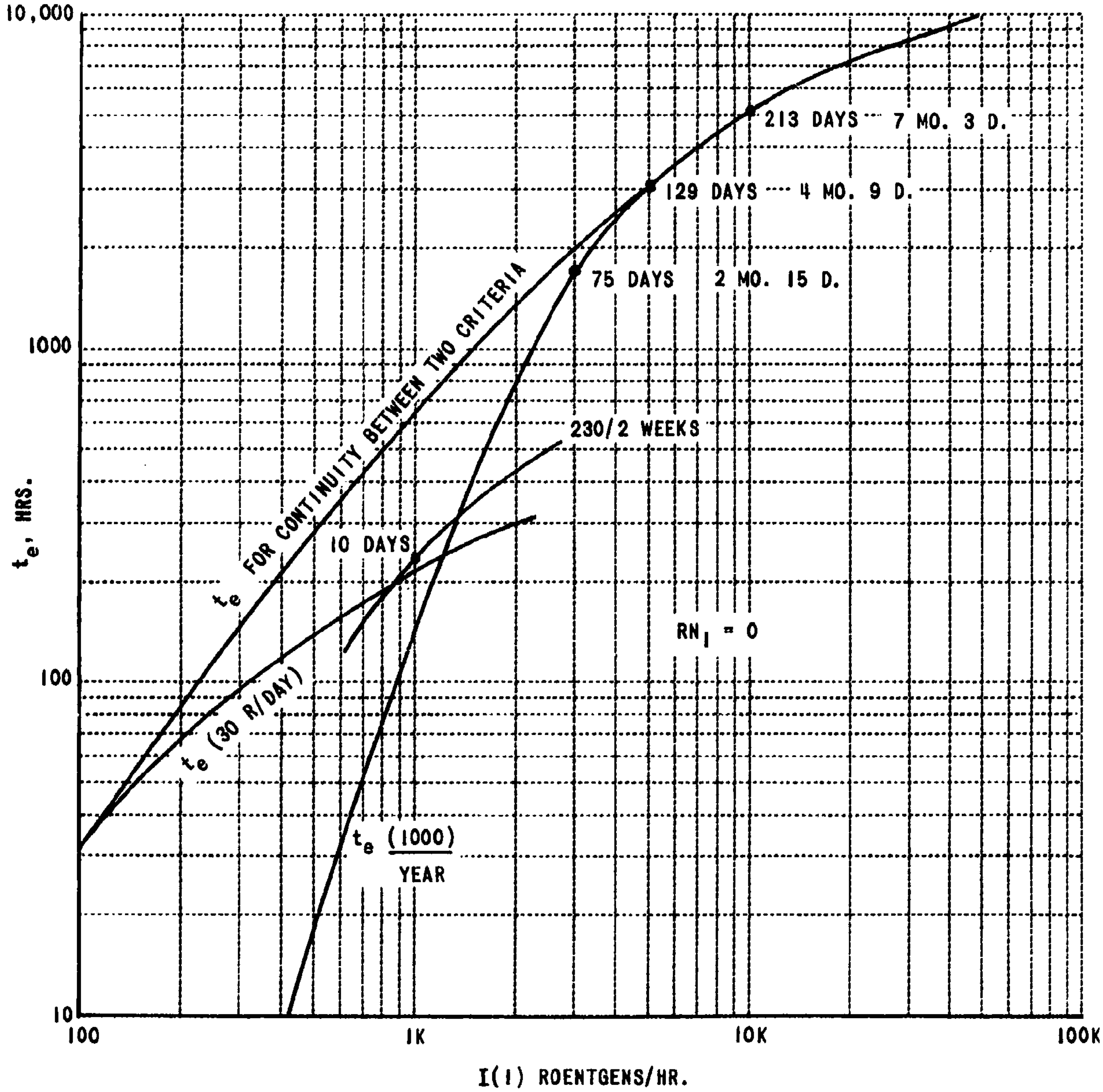


Figure 4 SHELTER STAY TIME VS. RADIATION AT 1 HOUR

TABLE 3*

Risk as a Function of Long Term Dosage

| Total Dose | 1 Day | 3 Days | 1 Week | 1Month | 3 Months | Late Effects |
|---|---|---|---|---|---|---|
| 0-75 | 0% sick | | | | | None |
| 100 | 2% sick | 0% sick | | | | None |
| 125 | 15% sick | 2% sick | 0% sick | | | None |
| 150 | 25% sick | 10% sick | 2% sick | 0% sick | | None |
| 200 | 50% sick | 25% sick | 15% sick | 2% sick | 0% sick | Some |
| 300 | 100% sick<br>20% die | 60% sick<br>5% die | 40% sick | 15% sick | 0% sick | Some |
| 450 | 50% die | 100% sick<br>25% die | 90% sick<br>15% die | 50% sick | 0-5% sick | Some |
| 650 | 95%+ die | 90% die | 100% sick<br>40% die | 80% sick<br>10% die | 5-10% sick | Some |

* From Radiological Recovery of Fixed Military Installations, USNRDL, August 1953

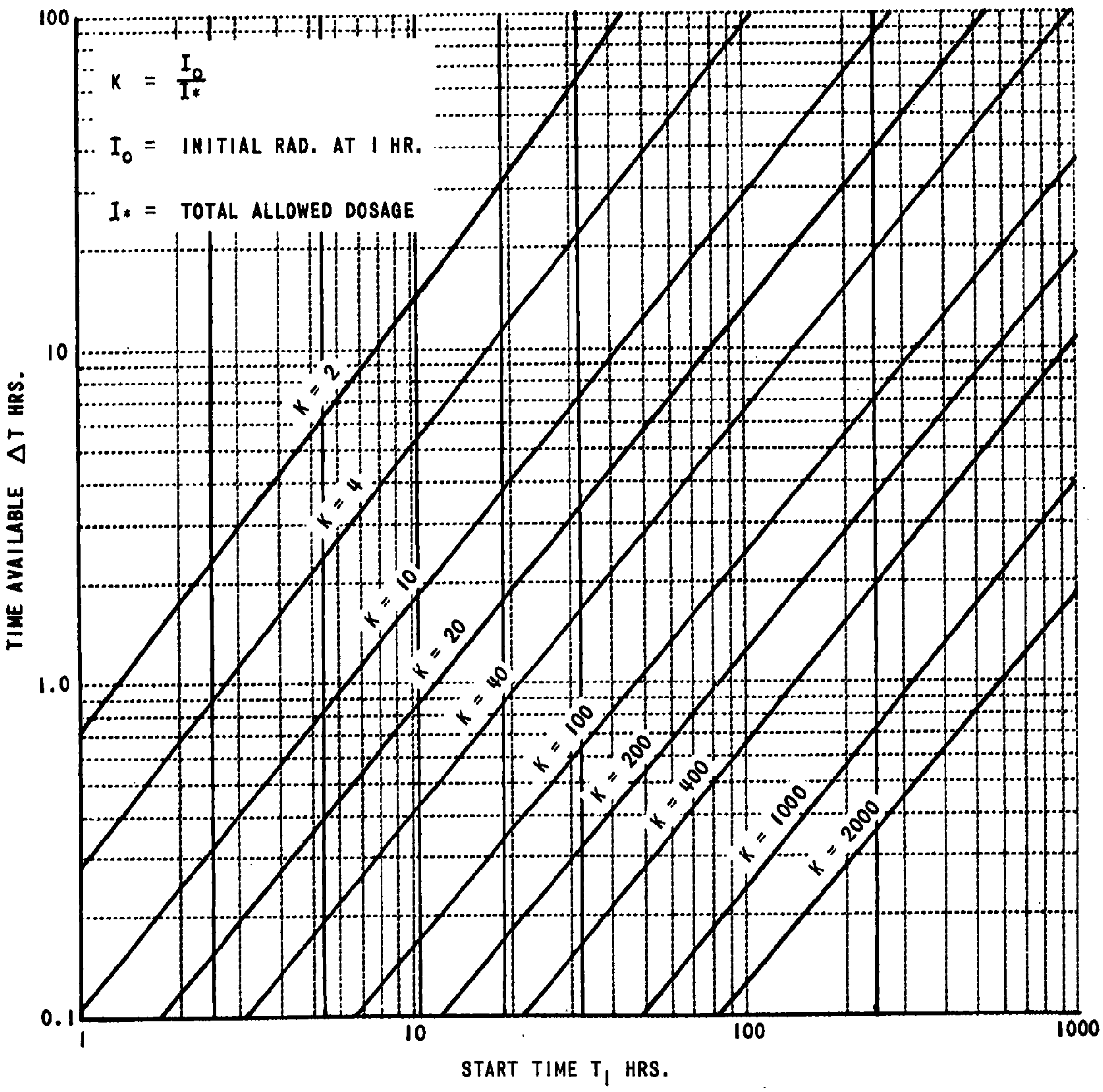


Figure 5 OPERATIONS TIME VS. START TIME

be effective, then the start time can be determined. For example, if the initial radiation (one hour) is 3000R/hour and there is a 30R limit in any given day, then K = 100. Now, if time required is 1 hour, then following this across to K = 100 and reading underneath that point yields an entry time of 47 hours after detonation. Conversely, if a need arises to go out and do something in the same area at 24 hours, then the graph tells us that 0.46 hours are available for the operation.

Another way to use this graph is to decide a given entry time and operations time, and determine from them the exposure to the operator. For example, suppose that 1 hour is required at 24 hours after attack and it is known that radiation at one hour was 3000R/hour; from the graph we read K = 45, approximately, and the dose sustained by the operator is 3000R/45 which is 75R. Such an operation may be allowed to proceed if there is enough of an emergency to warrant this risk. This graph and the preceding one are basic tools for the performance of rapid estimates for decontamination, as described later.

## SIMPLE METHODS FOR ESTIMATING CAPABILITIES

It is desirable to be ready to postulate a decontamination plan on short notice; should a nuclear attack occur, there is no time to perform detailed analysis. Many of the decisions will have to be made on the spur of the moment. For this purpose, it is useful to try out state of the art knowledge on a postulated situation and to see what comes of it. To do this, it is essential to make these additional assumptions:

1) Target shielding does not occur (studies of target effects indicate high contributions (relative to flat plane) in city complex areas for sensors placed in street centers and intersections. Hence this assumption is justifiable to an extent.)

2) Equipment shielding is insignificant. ($RN_2$ is nearly 1.0 for most equipments. Street sweepers and trucks which have $RN_2$ greater than 1 will not be used.)

3) Minimum operating time in the vicinity of a shelter is 10 minutes. Minimum operating time remote from shelter is 1 hour. This assumption provides that transport time between shelter and work need not be considered (although in some cases it may be quite important.)

4) "Once-through" decontamination at prevailing equipment rates will be applied, and will be sufficient. On the streets equipment rates will be limited somewhat by parked automobiles.*

5) People will stay in shelters for the time period that they have food available. (say two weeks). Where the stay time is in excess of this, decontamination will be applied.

6) In areas where decontamination cannot be sufficiently completed to allow people to get to emerge from shelter before shelter food stocks have run out, access routes will be cleared to shelters so that the shelters can be resupplied from the outside.

7) Mechanized operations will continue 24 hours a day until the work is done.** Manual operations requiring repeated entries by individuals and taking a long time will be done in the daytime for the endurance period of the individual (i.e. 6 hours per day on the average).

---

* In numerous cities many streets are crowded with parked automobiles, even overnight, because of inadequate off-street parking facilities.

** This implies that adequate lighting is required for night work.

Now the task ahead is to assess what work is to be done. It is far too difficult and complex to develop a specific plan for every possible kind of attack. To overcome this difficulty it is expedient to postulate an attack of moderate seriousness and to examine what must be done about it. A repetition of this process, over a few times, provides a set of conclusions from which it is possible to plan for a representative variety of attacks. On the other hand one may postulate maximum fallout over an entire populated area, and study the consequences. The extreme case is to postulate a multiple weapon attack on a populated area with blast, heat and radiation all acting at once. This last case may be an entirely hopeless one, however, so much so that one is inclined to give up the problem altogether. It is better to start with a much less serious problem, and then to apply the results to increasingly difficult situations.

Let us suppose that a given typical city has been exposed to the fallout from a megaton-size weapon explosion somewhere in the vicinity, but not close enough to cause serious structural damage in the city itself. How does one sketch a solution to this problem?

The first step is to have a map of the area with fallout contours plotted on it. Preferably the contours should be in terms of $I(1)$ , the equivalent values at one hour. Now, using Figure 4 one can determine the natural reentry time for the general population, and if need be, plot a new set of contours depicting shelter stay times. The area contained within the boundary representing 2 weeks (or any other chosen minimum time) is the area which requires decontamination. Now, the following steps are taken:

A. 1) Determine the total road and street surface that requires decontamination. An estimate can be made by counting roads along the center line of the city in an east west direction and also in the north south direction and multiplying the first by the north south dimension of the city and the second by the east west dimension. This yields total road mileage.

2) Determine house roof area that requires cleaning. Average house dimension in a sample area, multiplied by house density will provide this. If an average house is 30 x 40 feet, and the average lot (including the street) is 60 x 160 ft. then house displacement is 1/8 and roof surface is 1/8 square miles/sq. mile of land = 3,000,000 sq. feet/per square mile of land. *

3) Determine amount of sod which must be removed.
   a) on small lots
   b) in large areas

The sod removal on small lots will have to be done either manually or with small machines. That on the large open area (parks and so on) can be done with large land-moving equipment.

B. Now, from Figure 5 determine start time, for each area, assuming that a minimum of one hour per man is required for mechanized methods and 6 hours per man - day, minimum, for manual methods. **

C. From an inventory list of public works equipment, determine how much of it is suitable for decontamination, determine respective work rates and assign the machines to appropriate activities. For example all street flushers are to decontaminate streets, all fire-hoses are to be used on rooftops, and so on. Human resources should not be forgotten - those able-bodied individuals who are doing nothing else can be assigned to sod removal crews.

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* Exclusive of parks and open land.

** Firehosing will be considered a mechanized method.

From the work rates obtained in C and area estimates obtained in A the total reclamation time is available. Bearing in mind the entry constraints obtained in B a schedule of operations can be worked out for the whole area. The next section demonstrates an application of this procedure in a civil defense exercise in Erie County. Appendix I is a reproduction of the entire report submitted to Erie County Civil Defense Authorities on this exercise.

## DECONTAMINATION HIGHLIGHTS OF AN EXERCISE IN ERIE COUNTY

A situation map indicated that a 1-MT bomb had gone off northwest of Buffalo with fallout damage only, to the city proper. According to the map, about 20 square miles of populated area were initially subjected to 10,000 R/hr radiation, 50 square miles more to at least 3,000 R/hr radiation and another 70 square miles to 1,500 R/hr or more.* Using a set of curves showing what stay times were required to comply to the 30 R/day, 230 R/2 weeks and 1,000 R/year dose limits (as used by H. Lee), it was estimated that the people in the 10,000 R zone would have to stay in shelter in excess of 7 months, those in the 3000 R zone for 75 days, and only those in the 1000 R or less zone could emerge in 10 days or less. Shelters with very high protection factors are assumed, so that exposures in shelter will be negligible.

Assuming that people would be perfectly willing to remain in shelters for at least 2 weeks, it was decided to decontaminate areas where radiation at one hour, $I(1)$, was in excess of 1,500 R/hr. (Near this borderline shelter stay time was 17 1/2 days). Areas outside of this dividing line would not be decontaminated.

The decontamination plan was to decontaminate roads and streets first, to wash down roofs next (except for very high buildings) and then to remove lawns. The processes chosen were simple and available methods

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* These values are effective for one hour after weapon detonation.

namely: motorized street-flushers on the streets, firehoses on the roofs of houses and shovel and wheelbarrow for the lawns. Bulldozers and land moving equipment could of course expedite the effort.

Examination of a map yielded the estimate that there are 20 streets per mile in either direction or 40 miles per square mile in populated areas and also 10 miles per square mile in semi-rural areas. Since about half of the heavy fallout area was in semi-rural areas, this led to the estimate that 3500 miles of street needed decontamination. A record of available equipment in the area, obtained from the local CD authorities showed that 10 street flushers were available, thus each had 350 miles of streets to clean. On the basis of a very conservative estimate that each street flusher could clean 1 mile of streets an hour* (due to abandoned cars, refilling, travelling between water source and job location and changing of crews). This meant 350 hours of work at most, or two weeks and 1 day if the trucks were to work around the clock. Also, if crews were to work a minimum of 1 hour the first day for the job to be worthwhile, first start in the 1,500 R/hr zone, then work into higher radiation areas; then start time (or entry time) for this effort would be roughly 25 hours. (Start time for 3,000 R/hr is 48 hours and for 10,000 R/hr is five days; hence, the reason for working inwards.)

Street flushing is to be followed immediately with firehosing the roofs of houses, and the driveways. Assuming that each roof takes five minutes of effort, a one mile street of 200 homes takes 1000 crew minutes or one hour for 17 crews. Thus, if each street flusher is followed by 17 hose crews, the roofs would be decontaminated very soon after the streets. Firehose crews do not have to consist of firemen and firetrucks, -- all one needs is enough hoses and sufficient know how to handle them, as well as a ladder for each crew to mount up on the roofs.

---

* Speed will depend, in part, upon the amount of fallout deposited.

Lawn removal, at worst, can be done with a hand shovel and wheelbarrow. If homeowners were to get together and form work crews, -- some at their shovels, others pushing wheelbarrows, then the productivity per man is 5 sq. ft./minute or 300 sq. ft/hour.* Assuming a lot size of 10,000 square feet (usually they are smaller) this entails 33 hours of work. If the first work day were to be six hours long, this implies an entry time of five days for 1,500 R/hour, 10 days for 3,000 R/hour and 24 days for 10,000 R/hr. Thus, one week later, i.e., 12 days, 17 days and 31 days, respectively, people would be relatively free to move around in all areas. These estimates are an upper bound to the effort required, but they serve to provide the very heartening knowledge that decontamination is very feasible to those people who believe this job to be impossible. Taking into account the gains to be expected from mechanized equipment, and the advantages of self-shielding of target areas as well as that of equipment itself and optimization techniques, the time estimates can be considerably reduced.

## APPRAISAL OF THE RESULT AND FURTHER ADJUSTMENT

Now that a picture is available of the minimum that can be done, one can see some obvious methods for improving things. A street flusher proceeding at 1 mile/hour is quite slow. If arrangements can be made to have the public drive their cars off the streets before taking shelter the flusher would be able to move along more rapidly. Indeed it may be more efficient to operate the flusher at speeds of 20-50 miles/hour ** to remove only that amount which needs to be removed.

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* It is assumed that people will be rotated from shovel to wheelbarrow. The figure used here is based on 2 shovel men and 2 wheelbarrow men working as a 4 man crew.

** Ref. 1, Ch. 8, p. 18 (in draft report) indicates 20-30 mph. This is an area which requires further experimental investigation.

Another technique is to run several flushers, one after another, rather speedily if more cleanliness is required. Lawn removal may be done by faster methods than by hand shovel. If an adequate supply of front end loaders is available, together with dump trucks, lawn removal can be speeded up. In addition, some housing developments are so arranged that, if fences are removed, large land equipment would be able to clear up all the back yards in a block in very short order. Thus, for the back yards, at least, it would be better to concentrate manual effort on fence removal, and removal of all other back yard items while the bulldozers did the rest. Finally the hand shovel could be applied to the small areas which were inaccessible to the mechanized equipment.

After consideration of operations has resulted in more or less an optimal plan, further refinement can be applied by taking into consideration the $RN_2$ due to structures, to the equipment, and due to the techniques. For these refinements the techniques of the following chapters will be appropriate.

# V. MODELLING TECHNIQUES FOR SYSTEMS ANALYSIS

## THE PURPOSE OF MODELLING

A central problem in determining schedules for optimal operations is the radiation response of the operators to the varying radiation intensities encountered during operations. Various criteria have been postulated for dose limits as a function of time, usually there are two or three values. Use of these figures leads to difficulty, however; without the application of intuitive judgement, they may be misapplied. The ERD concept described in NCRP 29 together with an ERD limit of 200 R seems to be a rather consistent concept for operational use.

With the ERD limit as a constraint, it is desired to optimize system performance. Often it is easier to model the system on an analog computer, to try out schedules and methods etc. than to study the problem analytically. The analog computer is not expensive to use, yet with it, the scientist can scan numerous possible methods of problem solution much more quickly than he can do so analytically. Towards this objective, some of the concepts applicable to decontamination operations will be given in a form suitable for modelling on analog computers.

## DECONTAMINATION CRITERIA

The purpose of decontamination operations is to keep people alive, healthy, and as cheerful as possible under the circumstances. It is desirable to prevent that hopelessness and pessimism which will lead to further losses when they are not necessary. Most important, of course, is that a sufficient amount of decontamination must be accomplished to permit people to reoccupy their homes within an acceptable period of time. It must be borne in mind that an extensive shelter stay time is a source of hazard in itself inasmuch as people will run out of food, children will get sick, psychological depression will set in and so on. Thus, it is apparent that a trade-off exists between going out and trying to improve the situation, at the risk presented by exposure, and extending the stay in shelter. This trade-off is pretty hard to define, hence rather arbitrary, but realistic criteria, are required by which to make decisions concerning what to do and when to do it. For a theoretical study, an a priori decision must be made what dosage limits can be allowed for the public, based on alternate risks. (NCRP 29 makes suitable recommendations) If the most important objective is to gain time, all resources should be applied to reduce radiation to that level where these limits are complied with. The second objective should be to accommodate all the population in a fair way. Each individual should feel that he is getting a fair and square share of the benefit. It is to be hoped that a fair and square deal does not imply extinction for everyone, for if it does, another criterion must be chosen.

The following criteria, therefore, do not apply to the major part of this problem:

1) Minimize cost

2) Minimize effort

3) Minimize radiation

4) Minimize economic losses

Instead, the objectives are: (within the constraint of allowable dosage)

1) Help as many people as possible.

2) Get them out of shelter as quickly as possible.

These two criteria must be applied in combination with one another. Moreover, they are applicable for a situation where many people would have to stay in shelter unduly long periods of time without decontamination.

Where the situation is less serious it is suitable to relax the above criteria somewhat, and devote part of the effort toward the restoration of the local economy. The case of a very serious situation in which injury and death have occurred because of blast and heat will not be discussed at this stage.

The above criteria can be expressed as a minimization of the expression.

$$\sum_i T_s(i)$$

where $T_s(i)$ is the shelter stay time of the $i^{th}$ person. If it is desired to talk of groups of people $P_j$ where $P_j$ is the population in area $j$, then we seek to minimize

$$\sum_j P_j \, T_s(j)$$

where $T_s(j)$ is the shelter stay time in area $j$.

This expression can be generalized by the form

$$\sum_j P_j^{\,m} \, T_s(j)^n$$

where $m$ and $n$ are manipulable to provide a bias for extending preferred treatment of some kind to large populations and those who must endure long stay times. Heuristically, it would seem appropriate to set $m$ at 1. Putting $n$ at 2 or 3 or some larger value will tend to provide more effort for high radiation areas, and would influence more simultaneity in the emergence time for everyone. Here the trade-off is to help victims in highly radioactive areas at the expense of leaving those in less radioactive shelters for longer periods of time. For the sake of preliminary analysis it is suitable to choose $m$ and $n$ equal to 1 and also to assume that the population can quite readily remain in shelter one or two weeks, depending on the situation.

This implies minimization of the expression

$$\Sigma P_j^{\,m} (T_s(j) - T_k)^n$$

where $T_K$ is the time everyone is prepared to stay in shelter anyway. Here $m$ and $n$ are 1 as in the previous case.

After such an analysis is completed, variation of $m$ and $n$ may be performed to check qualitatively if better effects can be obtained thereby.

Other criteria which have been applied to special problems in this report are:

1) Start work as soon as it is feasible to do so in areas where stay time exceeds two weeks, and continue working until the whole area has been decontaminated, using rates of work available from the literature.

2) Given entry time and remnant, minimize radiation dose to crew. This condition applies when it is feasible to trade off entry time in order to reduce dosage to the crew.

## OPTIMAL ORDERING OF PROCESSES

For any large area, where facilities are limited, all parts of the process will operate simultaneously, although each process will operate on different areas. It is much more efficient if the various parts of the process are applied in sequence to any given area, rather than that they are applied simultaneously. This has the important advantage that one process reduces the radiation for the next, thus making it feasible for the personnel of the second process to remain on the job longer. In addition, this decoupling avoids interference between different operating machines, and also, the individual process speeds are not held back because of slowness on the part of any of the others. The following analysis shows how to choose process sequence.

Assume a fixed area. Let $Y_1$ be fraction of contaminant removed by process #1. Let $Y_2$ be fraction of contaminant removed by process #2. Let $P_1$, $P_2$ be the relative penalties attributable to using process 1, 2 and 2, 1 respectively (i. e, penalty is proportional to radiation exposure in man-roentgens).

$$P_1 = I\left[T_1 + (1-Y_1)T_2\right], \quad T_1 = \text{Time for Process 1}$$

$$P_2 = I\left[T_2 + (1-Y_2)T_1\right] \quad T_2 = \text{Time for Process 2}$$

$$\frac{P_1}{P_2} = \frac{T_1 + (1-Y_1)T_2}{T_2 + (1-Y_2)T_1}$$

Let $a = \frac{T_2}{T_1}$, $b = \frac{Y_2}{Y_1}$

$$\frac{P_1}{P_2} = \frac{1 + a(1-Y_1)}{a + (1-bY_1)} = \frac{1+a-aY_1}{1+a-bY_1}$$

$$= 1 + \frac{(b-a)Y_1}{1+a-Y_2}$$

Now since $Y_2$ ranges from 0 to 1, $1+a-Y_2$ is always positive.
Hence,

$$P_1 < P_2 \quad \text{if } b < a$$
$$P_1 = P_2 \quad \text{if } b = a$$
$$P_1 > P_2 \quad \text{if } b > a$$

The object is to minimize penalties due to process sequence. Thus, if one knows the values of a and b (these can be obtained from Table 4.) then optimal sequence can be chosen. The analysis can be extended to three or more processes.

## BIOLOGICAL EFFECTS OF RADIATION

The effects of short term radiation are summarized in Table 4.*

* Effects of Nuclear Weapons, 1957

TABLE 4

Casualties as a Function of Dosage

| Dosage Roetgens | |
|---|---|
| Up to 50 | Minor blood changes. No other effects |
| 100 | Fatigue, vomiting, nausea in 5-10% for one day |
| 150 | Fatigue, vomiting, nausea in 25% for one day |
| 200 | Fatigue, vomiting, nausea in 50% for one day |
| 300 | Fatigue, vomiting, nausea in 100% for one day; 20% deaths in 2-6 weeks; convalescence for three months |
| 450 | Fatigue, vomiting, nausea in 100% for one day; 50% deaths in one month; convalescence for six months |
| 650 | Nearly 100% deaths, survivors convalescent for six months |
| 1000 | No survivors |

This information is depicted graphically in Figure 6.

## THE EQUIVALENT RESIDUAL DOSE

The relationship between human response to short term radiation and long term radiation is not entirely clear. It is known that substantial recovery occurs after an exposure. Devaney* states that the irreparable effect of exposure is equivalent to one-tenth of the initial exposure and that this state of repair is reached in three months. Moreover, he states that half of the reparation process is accomplished in one month.

* Devaney, John F. , Operations in Fallout, OCDM-SA-61-13, June 1961. Also NCRP 29

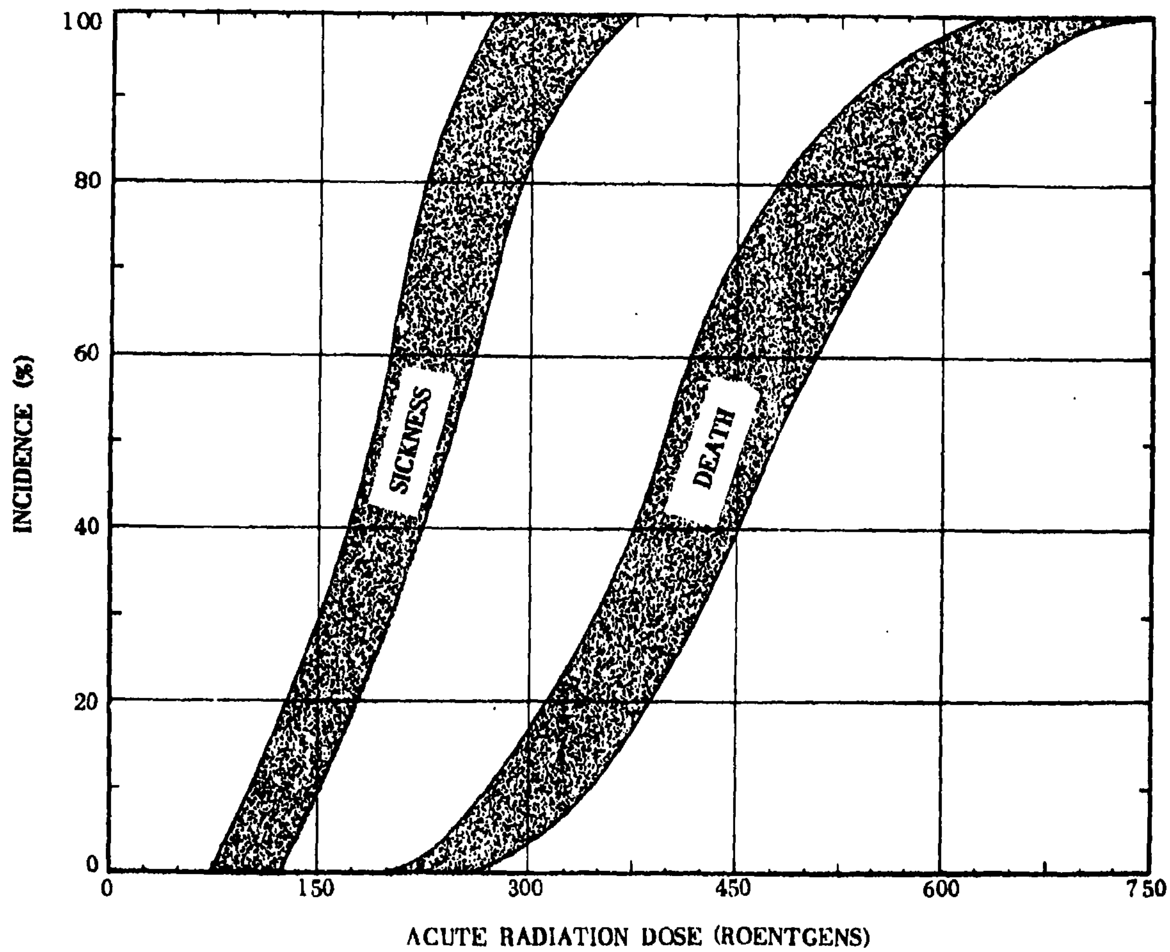


Figure 6 CASUALTIES AS A FUNCTION OF SHORT TERM DOSAGE (Ref. 3)

Considerable experimental work was done with animals, specifically mice and rats, to determine the nature of the recovery process. Much of this is reported in Claus*. This information is not very coherent; however, the following things seem to emerge:

1) The recoverable injury decreases approximately at a rate described by

$$f = e^{-\lambda t}$$

2) Recovery rate diminishes rapidly as dose increases beyond one half of $LD_{50}$. ($LD_{50}$ is the dosage which leads to 50% mortality of the population.)

3) There is a component of rapid recovery over a very short period of time (several hours to one day).

Putting 2 and 1 together suggests a recovery rate described by

$$f = e^{-(D^* - k\,LD_{50})\lambda t}$$

where k is somewhat greater than 1, possibly 1.5 or 2 and $D^*$ is the equivalent impulse dose in a mathematical sense.

Using Devaney's concept, one may state a linear equivalent recovery function to be

$$ERD(t) = \frac{D^*}{10} + \frac{9}{10} D^* e^{-\lambda t}$$

with $\lambda$ chosen such that ERD is the equivalent dosage of the remaining effect. Let this be $h(t)$, the human response to radiation. The response to time varying radiation is then

$$ERD(t) = \int_{t_0}^{t} I(\tau)\, h(t-\tau)\, d\tau$$

* Claus, W. D., Radiation Biology and Medicine, Ch. 12, Addison Wesley, 1958.

This is a linear function which is Laplace transformable, hence

$$ERD(s) = I(s)\,H(s)$$

Using the Laplace transforms of $I(t)$ and $h(t)$ separately one may obtain the transform of ERD(s) and by the inverse transform obtain ERD(t).

For the sake of this development, the transform of h( t) is

$$H(s) = \frac{1}{10s} + \frac{9}{10(s+\alpha)}$$

where $\alpha$ = .000964 to accomplish 0.45 recovery in 30 days. Here time t is measured in hours.

If we wish to take account of the 3rd item mentioned previously, this formula must take the form

$$H(s) = \frac{a}{s} + \frac{b}{s+\alpha} + \frac{c}{s+\beta}$$

where $\beta$ represents the quick recovery time (24 hours) constant and $\alpha$ the longer (1 month plus) recovery time constant. However, since little information is as yet available, this formula will not be developed further.

## THE RADIATION DECAY CURVE

The decay rate of fallout material depends on what radioactive components it is made up of, since their separate rates, which vary widely, make up the decay rate of the composition. Figure 7 shows graphically a typical decay rate for fallout resulting from an overland explosion. The solid line is actual value and the dotted line is a $t^{-1.2}$ representation.

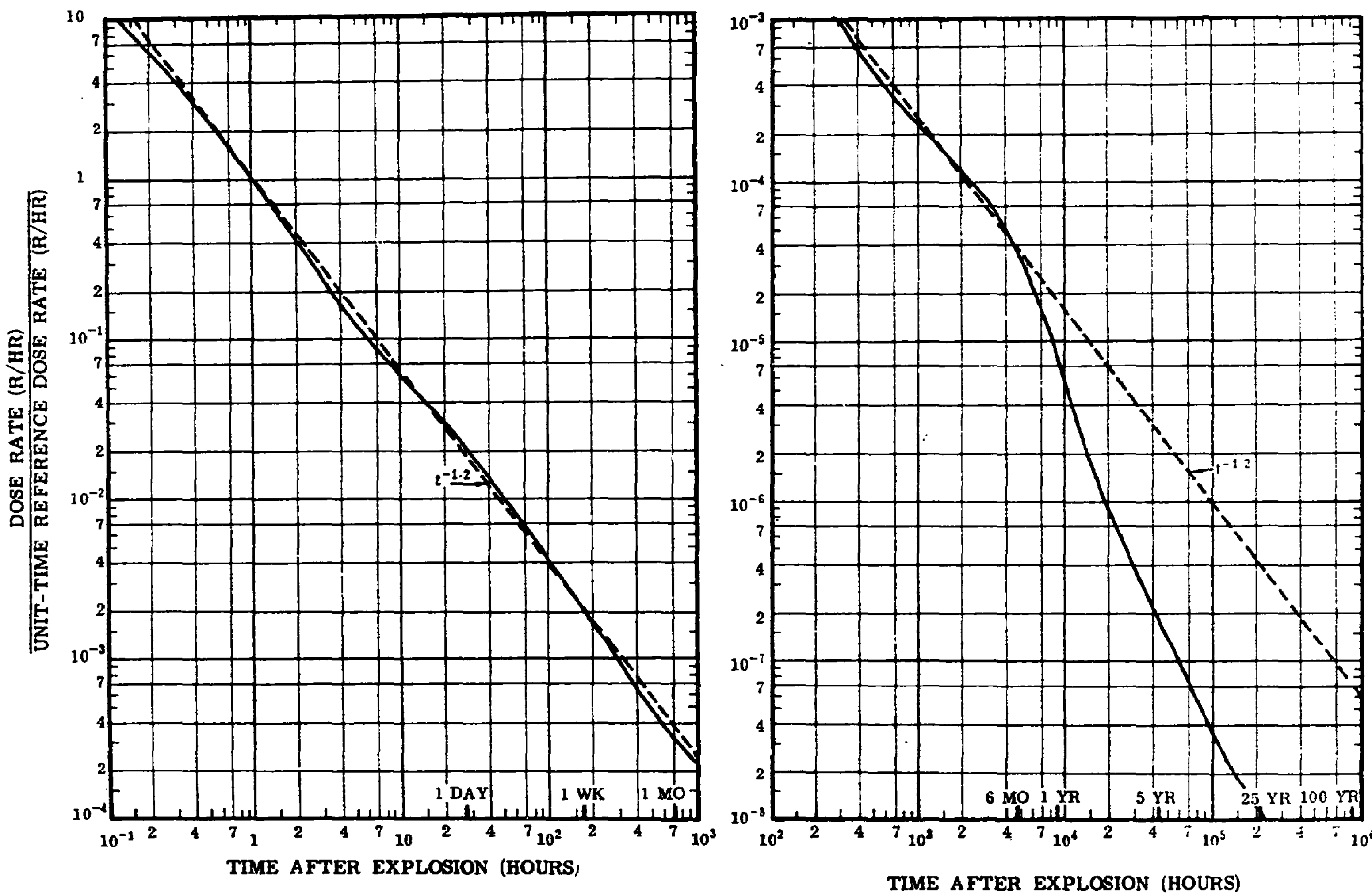


Figure 7 **RADIATION DECAY CURVE (Ref. 2)**

Here it is seen that $t^{-1.2}$ is quite representative all the way out to 5000 hours after the burst. Since the most important part of the reclamation operation will be performed within that period of time, the discrepancy after 5000 hours will not be important, except for the Dose Rate Multiplier and its implications as mentioned in a subsequent section.

It is convenient to have a rule of thumb method of estimating the dose rate at various given instants of time. There is an approximate relationship such that if the rate is unity at 1 hour after detonation, then it is 0.1 at 7 hours, 0.001 at 49 hours (i.e. 7 x 7 hours), 0.001 at 343 hours (i.e. 7 x 7 x 7 hours) and so on. In other words, if time is multiplied by seven, the radiation has decayed to one-tenth of its previous value.

Radioactivity in a fallout area builds up as shown in Figure 8.* The radioactivity increases gradually at first, as the leading edge of the fallout cloud passes over, increases most rapidly while the cloud center passes by and then gradually settles down as the trailing edge passes over. Thereafter natural decay takes place.

For computational simplicity it is useful to equate the complex radiation intensity curve with another one which starts abruptly at an equivalent fallout arrival time and then decays naturally. The area under both curves are made to be the same, thus determining the equivalent arrival time. The new curve can then be applied directly to the DRM concept to find the total exposure people are subjected to if they are in a fallout area where arrival is delayed.

## REPRESENTATION OF THE RADIATION DECAY CURVE

For the sake of being able to simulate the decay curve with an analog computer, and also for analytical work, it would be very useful to represent the $t^{-1.2}$ expression with its Laplace transform. However,

* This is true for a single weapon fallout situation.

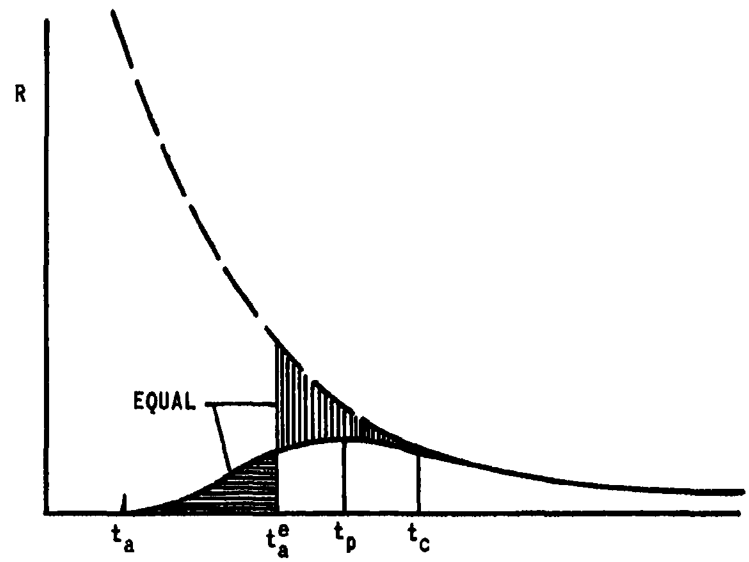


Figure 8 RADIATION BUILDUP WITH TIME (Ref. 5)

this transform is not available in readily available tables, and attempts to obtain it by performing the transformation from basic principles fail. Also, expansion into a polynomial results in a diverging series, which is also not useful. For analog computer representation, it may be adequate to represent this expression with a series of straight line segments; an expression corresponding to this may be of use analytically also, although it is tedious to handle. A possibility is to represent the decay curve with orthonormal functions, the theory of which is discussed in the next section.

## POSSIBLE REPRESENTATION OF THE DECAY CURVE WITH ORTHONORMAL FUNCTIONS

A set of functions, $\{\phi_1(t), \phi_2(t) \cdots \phi_n(t) \cdots\}$, is orthonormal over the interval (a, b) if

$$\int_a^b \phi_m(t)\,\phi_n(t)\,dt = 1 \qquad m = n$$
$$= 0 \qquad m \neq n$$

If the set is also complete, any real and continuous function f(t) can be represented in the interval (a, b) by

$$f(t) = \sum_{n=1}^{\infty} c_n\,\phi_n(t)$$

where

$$c_n = \int_a^b f(t)\,\phi_n(t)\,dt$$

Consider

$$\epsilon = \int_a^b \left[f(t) - \sum_{n=1}^{N} c_n\,\phi_n(t)\right]^2 dt$$

This expression is a minimum for the particular $C_n$ used. Any other choice of coefficients leads to a larger value of $\epsilon$ .

Note: This is not to say that one can't achieve a smaller $\epsilon$ by choosing the first N functions of a different orthonormal set. No general procedure for selecting the "best" orthonormal set exists.

For a given orthonormal set,

$$\epsilon = \sum_{n=N+1}^{\infty} C_n^2$$

We are interested in f(t) = $\frac{1}{(1+t)^{1+\alpha}}$ over the interval ( $0, \infty$ ). Possible sets of functions orthonormal over ( $0, \infty$ ) are the Laguerre functions and also the sets

$$\phi_1(t) = \sqrt{2p}\, e^{-pt}$$

$$\phi_2(t) = 2\sqrt{p}\,(2e^{-pt} - 3e^{-2pt})$$

$$\phi_3(t) = \sqrt{6p}\,(3e^{-pt} - 12e^{-2pt} + 10e^{-3pt})$$

etc.

Each choice of the parameter $p$ gives a different orthonormal set. Select the set $\phi_1(t) = \sqrt{2p}\, e^{-pt}$ etc. (The Laguerre functions are more complicated than these).

Evaluating the $C_n$ entails integrals of the following form

$$S(\alpha+1, mp) = \int_0^\infty \frac{1}{(t+1)^{\alpha+1}} e^{-mpt} dt$$

$S(x, y)$ is Schlömilch's function*, which can be expressed in terms of Whittaker's function* W

$$S(x, y) = y^{\frac{1}{2}x-1} e^{\frac{1}{2}x} W_{-\frac{1}{2}x, \frac{1}{2}-\frac{1}{2}x}(y)$$

Thus,

$$\int_0^\infty \frac{1}{(t+1)^{\alpha+1}} e^{-mpt} dt = (mp)^{\frac{\alpha-1}{2}} e^{\frac{mp}{2}} W_{-\frac{\alpha+1}{2}, -\frac{\alpha}{2}}(mp)$$

This has also led us to the Laplace transform of $\frac{1}{(t+1)^{1+\alpha}}$, which is obtained by setting m = 1 in the above.

$$\int_0^\infty \frac{1}{(t+1)^{1+\alpha}} e^{-pt} dt = p^{\frac{\alpha-1}{2}} e^{\frac{p}{2}} W_{-\frac{\alpha+1}{2}, -\frac{\alpha}{2}}(p)$$

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* Whittaker and Watson, "Modern Analysis" p. 352

Whether we are seeking the Laplace transform directly or via an approximation using orthonormal functions, we will have to work with Whittaker's function.

The Laplace transformation available by the above method is in fractional powers of $p$ and therefore not suitable for analog use. The orthonormal functions, however, promise to be much more useful.

The approach now is to evaluate Whittaker's function (which has not been done) or to start again with the original orthonormal functions and evaluate them numerically. Since Whittaker's function may have to be evaluated numerically anyway, numerical evaluation of the orthonormal set may be the most reasonable procedure.

## VI. NUMERICAL METHODS FOR ANALYSIS

### A METHOD* FOR CALCULATING THE GAMMA-RAY DOSE RATE AT ANY KNOWN DISTANCE FROM A RADIOACTIVE POINT SOURCE

A sample of radioactive material is said to have an activity of 1 curie when it disintegrates at a rate of $3.7 \times 10^{10}$ disintegrations/second.

Let a radioactive point source located at the point S have a strength of C curies, so that it decays at a rate of $3.7 \times 10^{10} \times C$ disintegrations/second. Assume that each act of disintegration results in the production of one gamma-ray photon of energy E Mev. Assume further that the radiation of these photons from the point source is emitted uniformly in all directions so that a distance d cm from the point S, the photons will be uniformly distributed over a sphere of area $4\pi d^2$ cm$^2$. Neglecting the absorption of photons in travelling the distance d from the point S to the surface of the sphere, the flux $\mathcal{U}$ at d is given by

$$\mathcal{U} = \frac{3.7 \times 10^{10} C}{4\pi d^2} \quad \text{photons/cm}^2\text{/sec} \qquad (1)$$

Since each photon has an energy of E Mev, the gamma-ray flux of energy at the distance d from the point S is $\mathcal{U} \times E$ Mev/cm$^2$ sec. Define $\mu_e$ cm$^{-1}$ as the energy-absorption coefficient of air for the specified gamma radiation of energy E. The parameter $\mu_e$ has the property that the rate of energy absorption per cm$^3$ at the distance d from the point S is given by

$$\mathcal{U} E \mu_e \quad \text{Mev/cm}^3\text{/sec.} \qquad (2)$$

*Principles of Nuclear Reactor Engineering - Samuel Glasstone pp. 539-546

Equation (2) is referred to as the dosage rate ($D_R$) at a distance d cm from a C curie point source. Since the absorption of $6.77 \times 10^4$ Mev of energy per $cm^3$ in air is equivalent to one roentgen of gamma radiation, equation (2) is usually given as

$$D_R = \frac{\mathcal{U} E \mu_e}{6.77 \times 10^4} \quad \text{roentgens/sec} \tag{3}$$

If an absorbing material (such as air) with an absorption coefficient $\mu$ $cm^{-1}$ is placed between the source and the point at which the dosage rate is being calculated then equation (3) becomes

$$D_R = \frac{\mathcal{U} E \mu_e e^{-\mu d}}{6.77 \times 10^4} \quad \text{roentgens/sec} \tag{4}$$

The energy-absorption coefficient ($\mu_e$) of air varies with the assumed energy E per photon. However, for the range of photon energies from .07 Mev to 2 Mev, $\mu_e$ for air varies only between $3 \times 10^{-5}$ $cm^{-1}$ to $3.7 \times 10^{-5}$ $cm^{-1}$. As an approximation, $\mu_e$ is assumed to have a constant value of $3.35 \times 10^{-5}$ $cm^{-1}$.

It should be emphasized that $D_R$ in equation (4) is independent of the medium exposed to the radiation and depends only on the rate of energy absorption/unit volume in <u>air</u>.

Using the results of equation (4) along with the assumption of an exponential decay for the radioactive point source, it follows that the dosage rate at a distance d and at an arbitrary time t is given by

$$D_R(d,t) = \frac{(3.7 \times 10^{10}) C_0 E \mu_e e^{-(\mu d + \lambda t)}}{6.77 \times 10^4 \times 4\pi d^2} \quad \text{roentgens/sec} \tag{5}$$

where $C_0$ = the strength of the point source in curries at time t = 0

$$\lambda = \frac{.693}{t_{1/2}}$$

$t_{\frac{1}{2}}$ = half life of the radioactive point source

It is understood that the point P is a unit volume and that $I_0 \Delta x \Delta y$ is defined as $\frac{\mathcal{U} E d^2 (3600)}{6.77 \times 10^4}$ roentgens/hr.

The mixture of radioisotope constituting the fission products in a contaminated area is so complex that the total rate of disintegration does not follow the usual exponential decay law applicable to a single species. Field tests have shown that if $R_t$ is the over-all rate of gamma-ray emission at time t, and at a particular location in a contaminated area, then the rate $R_{t+\Delta t}$ at time $t + \Delta t$ is given by $R_{t+\Delta t} = R_t \Delta t^{-1.2}$

If one makes the reasonable assumption that the dosage rate $D_1$ at time t is independent of position in a small area $A_s$ within a larger contaminated area $A_L$, it is possible to replace the area $A_L$ with a grid of radioactive point sources such that

1) The dosage rate at a distance d from each point source at one hour after detonation is given by equation (4)

2) The total dosage rate at any point P in the area $A_s$ due to all contributing point sources in $A_L$ at time t (point sources outside a circle of radius $r_o$ centered at P are considered to provide negligible contribution) is given by

$$D_1 t^{-1.2}$$

The latter assumptions form the basis of a simulation model for area decontamination studies.

## AN INVESTIGATION OF THE POINT SOURCE APPROACH IN DESCRIBING A UNIFORMLY CONTAMINATED IDEAL PLANE

An ideal plane is uniformly contaminated with radioactive fallout material. Subdivide the plane into equal $\Delta \times \Delta$ elements of area $\Delta A$. Consider an M x M matrix of areas $\Delta A$ (M assumed odd) and let $\Delta A_0$ represent the central element of area in the matrix. Let the point P be located h units above the center of $\Delta A_0$ and define $\Delta A_{ij}$ as the element of area $\Delta$ A in the $i^{th}$ row and $j^{th}$ column of the matrix.

If $\Delta x \cdot \Delta y$ is a small element of area within $\Delta A_{ij}$, then the dose rate DR(x, y, t) contribution to the point P at time t from $\Delta x \Delta y$ is given by

$$D_R(x, y, t) = \frac{I_0(t)\, e^{-\mu\sqrt{x^2+y^2+h^2}}}{x^2+y^2+h^2}\,\Delta x \Delta y \tag{6}$$

where

$I_0(t)$ = intensity/hour/unit area in roentgens/hour/unit area within the plane at time t hours

$\mu$ = linear absorption coefficient of air

Integrating over the area $\Delta A_{ij}$, the dose rate contribution DR(i, j, t) at the point P due to $\Delta A_{ij}$ is

$$D_R(i,j,t) = \iint_{\Delta A_{ij}} \frac{I_0(t)\, e^{-\mu\sqrt{x^2+y^2+h^2}}}{x^2+y^2+h^2}\, dx\, dy \tag{7}$$

If $Q_{ij}$ is a point source located at the center of $\Delta A_{ij}$ and of magnitude $DR(i,j,t) \cdot d_{ij}^2$ then it follows that the total dose rate contribution DR(t) to the point P at time t is given by

$$D_R(t) = \sum_{j=1}^{M} \sum_{i=1}^{M} D_R(i,j,t) = \sum_{j=1}^{M} \sum_{i=1}^{M} \frac{Q_{ij}}{d_{ij}^2} \tag{8}$$

where $d_{ij}$ is the distance from the center of $\Delta A_{ij}$ to the point P.

Since $Q_{ij}$ in Equation (8) involves a complicated integral, the question arises as to the existence of another form of $Q_{ij}$ which will satisfy Equation (8). Obviously, if $Q_{ij}$ is given by

$$Q_{ij} = \frac{D_R}{\sum_{j=1}^{M} \sum_{i=1}^{M} \frac{1}{d_{ij}^2}} \tag{9}$$

equation (8) will be satisfied. It should be noted that $Q_{ij}$ in equation (9) is constant and independent of i and j.

If the distribution of $Q_{ij}$'s from Equation (9) does not differ appreciably from those of the form $Q_{ij} = DR(i,j,t) \cdot d_{ij}^2$ then it would be a great simplification to describe the ideal plane in terms of a constant dose rate DR(t) rather than an intensity/hour/unit area $I_0(t)$.

Data has been generated which shows that for h = 3 feet and $\Delta$ = 1 foot the difference in the $Q_{ij}$'s is negligible -- less than 2% for all i and j's in the M x M matrix. However, when $\Delta$ is increased to 10 feet, appreciable differences occur in the $Q_{ij}$'s -- some as high as 25%. Thus, an extremely fine matrix is required in order to replace $Q_{ij} = DR(i,j,t)\, d_{ij}^2$ by the constant value

$$Q_{ij} = \sum_{j=1}^{M} \sum_{i=1}^{M} \frac{D_R(t)}{d_{ij}^2}$$

## A MODEL FOR INVESTIGATING DECONTAMINATION PROCEDURES IN AN IDEAL PLANE

An ideal plane is contaminated with radioactive fallout material. Let $I_0(t)$ be defined as the intensity/unit area in roentgens/hour/unit area at time $t$ hours in the plane. Consider any small element of area in the contaminated plane. The flux $\mathcal{U}$ at time $t$ hours in roentgens/hour at point $P$ located $d$ units from $\Delta A$ is given by

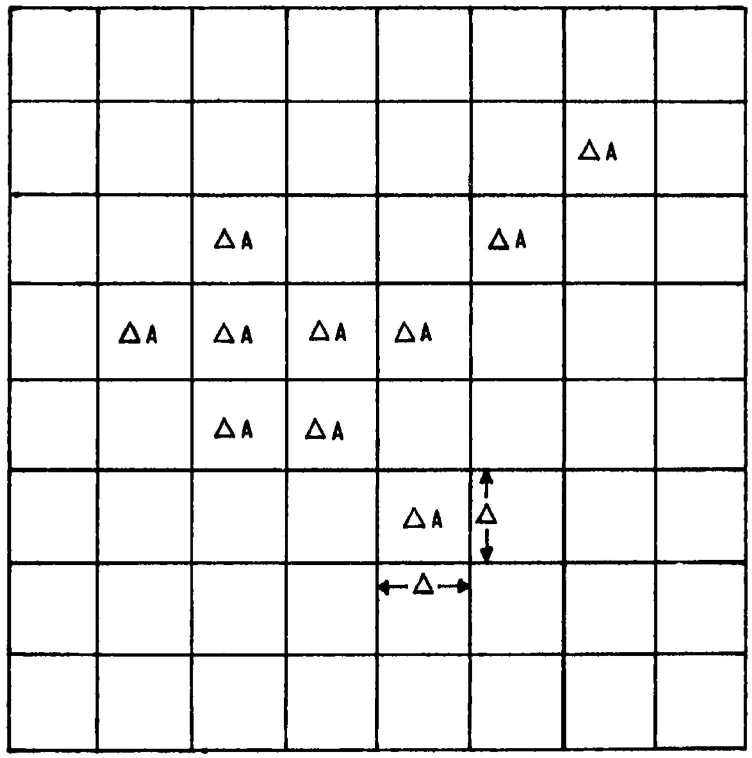
$$\mathcal{U}(t,d) = \frac{I_0(t=1)\, t^{-1.2} e^{-\mu d} \Delta A}{d^2} \qquad t \geq 1\,hr$$

where $\mu$ is the linear absorption coefficient of air and radioactive decay is assumed to follow a $t^{-1.2}$ law so that

$$I_0(t) = I_0(t=1\,hr)\, t^{-1.2} \qquad t \geq 1\,hr.$$

The ideal plane is subdivided into equal $\Delta \times \Delta$ areas $\Delta A$ as shown in Figure 9. A decontamination work crew requires $\Delta t$ hours to complete one pass over any $\Delta A$ area. At the end of the time interval $\Delta t$, the particular $\Delta A$ area cleaned out is assumed to have a fraction $F$ of the original fallout material remaining. Thus, the work crew is characterized by a work rate ( 1 pass/$\Delta A/\Delta t$ ) and an efficiency $F$ (fraction of fallout material remaining/pass) where $0 \leq F \leq 1$

Define the region to be contaminated as a finite set of $\Delta A$ areas say $\Delta A_1, \Delta A_2, - - - \Delta A_i, - - - \Delta A_M$. Assume that $\Delta A_i$ and $\Delta A_{i+1}$ are neighboring elements of area and of sufficiently




$I_o(t)$ = INTENSITY/UNIT AREA IN ROENTGENS/HOUR/UNIT AREA IN THE PLANE AT TIME $t$ HOURS

$\Delta$ = GRID SPACING

$x$ = $ft/\Delta$

Figure 9 SUBDIVISION OF IDEAL PLANE INTO $\Delta A$ AREAS

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small size so that the time required for the work crew to move from $\Delta A_i$ to $\Delta A_{i+1}$ can be neglected.

At $t = 1$ hour, the work crew enters $\Delta A_1$ and requires $\Delta t$ hours to remove a fraction $1-F$ of the fallout material in the area. The dose received by the work crew during the $\Delta t$ time interval is computed at a point $h$ units above the center of $\Delta A_1$. See the last Section for a discussion of the methodology of the dose computation. The model also computes dose values $h$ units above the center points of any finite set of $\Delta A$ areas say $\Delta A_1', \Delta A_2', ---, \Delta A_j', ---, \Delta A_N'$. At time $t = 1 + \Delta t$ hours the work crew is assigned the area $\Delta A_2$ where again a fraction $F$ of fallout material is removed from the area during the $\Delta t$ time interval. Dose computations are again calculated for the work crew and the areas $A_j'$ $j = 1, 2, ---, N$ during the $\Delta t$ time interval from $t + \Delta t$ to $t + 2\Delta t$. The process continues until all $\Delta A_i$ $i = 1, 2, ---, M$ have been decontaminated. The logical flow of the model is given in Figure 10.

The model has been programmed and checked out on the IBM-704 computer. Several runs have been made with the following assumptions:

(1) The ideal plane is subdivided into 10 feet x 10 feet elements of area so that $\Delta A = 100 \text{ ft}^2$

(2) The area requiring decontamination is assumed to be circular. Figure 11 shows the set of areas approximating this circular area.

(3) $I_o(t = 1 \text{ hour}) = 10$ roentgens/hour/unit area

(4) The set of areas for which cumulative dose values are computed is the single area $\Delta A_1$ where $\Delta A_1$ is the center of the circular decontamination pattern.

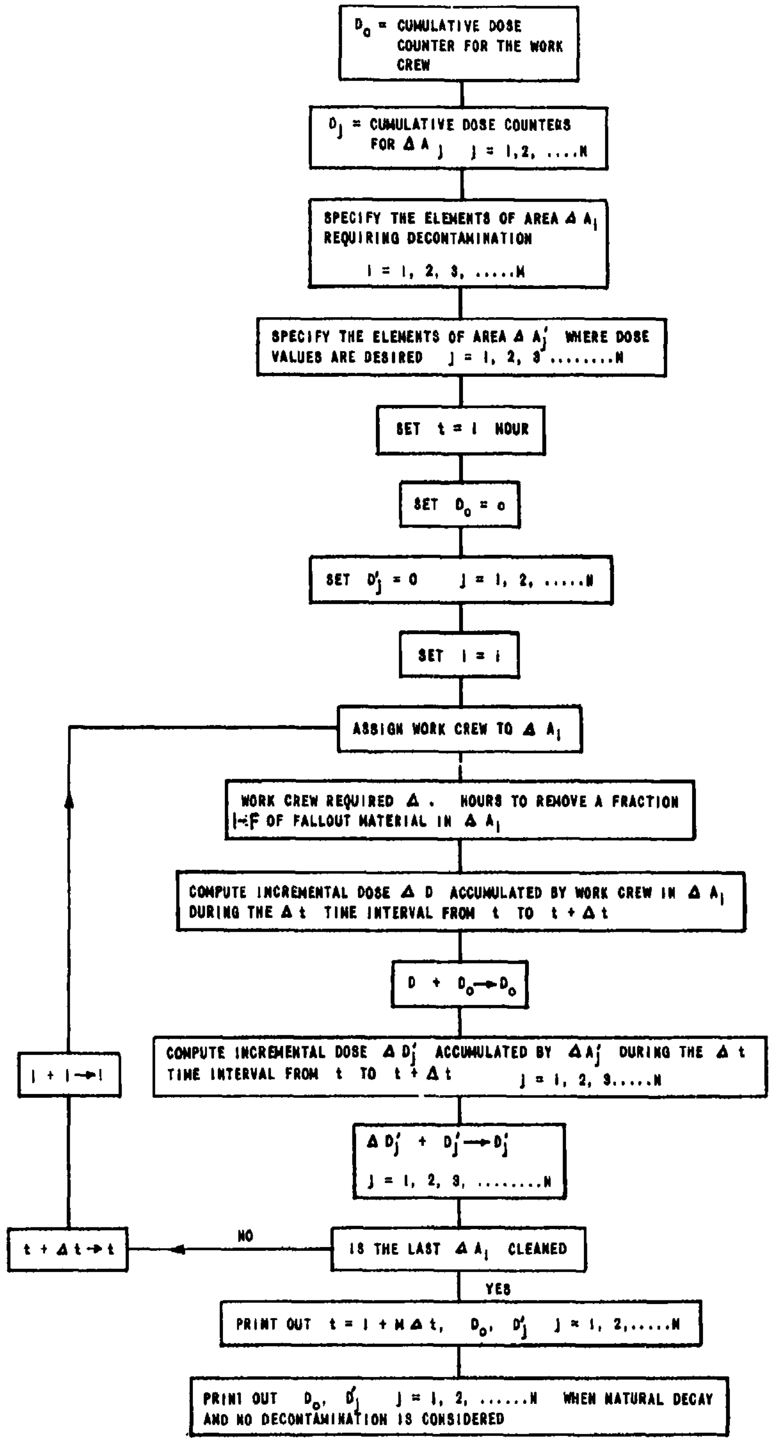


Figure 10 SIMPLIFIED LOGICAL FLOW

(5) The linear absorption coefficient of air ($\mu$) is assigned the value $.55 \times 10^{-4}$/cm.

(6) Two different decontamination work crews were considered. Work crew #1 is assigned a work rate 5000 $ft^2$/hour. (equivalent to $\Delta t$ = .02 hour) and an efficiency F = 0.1 The work rate and efficiency F of work crew #2 are 40000 $ft^2$/hour (equivalent to $\Delta t$ = .005 hour) and 0.9 respectively.

The results of this sample case are shown in Figure 12 where the dose received at a point P 3 feet above the center of the circular decontamination pattern is plotted vs. time. The dotted curve shows the variation of dose at P when no decontamination takes place and the only factor involved is natural radioactive decay. It is seen that the curve for the fast-inefficient work crew #2 deviates only slightly from the dotted decay curve. However, the slow-efficient crew #1 is very effective in reducing the dose level at P.

The model should be a valuable tool in investigating different combinations of decontamination procedures. For example, in the sample case considered suppose one fixed the size of the circular area to be decontaminated and equated the dose levels acquired by the two work crews. Then work crew #2 would be able to perform $n$ passes for a single pass of crew #1. The model could be used to investigate the dose variation with time under these assumptions. It should be pointed out that the circular decontamination pattern of the sample case is not a restriction. Any geometrical pattern for the region to be decontaminated can easily be incorporated into the model.

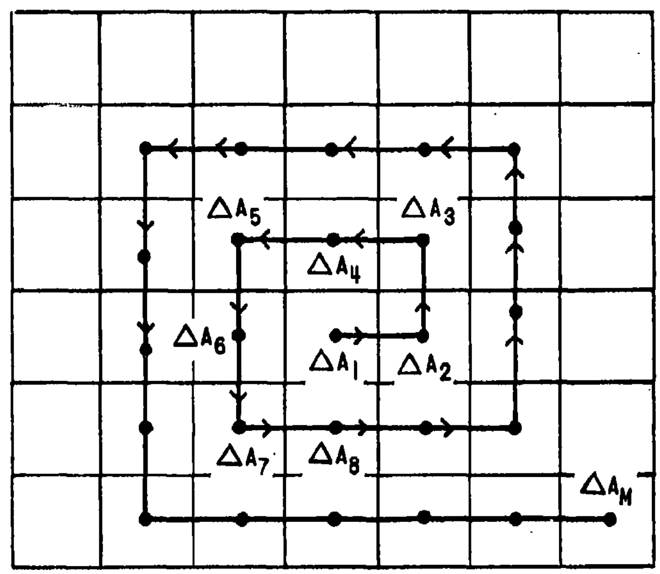


Figure 11 APPROXIMATE CIRCULAR DECONTAMINATION PATTERN

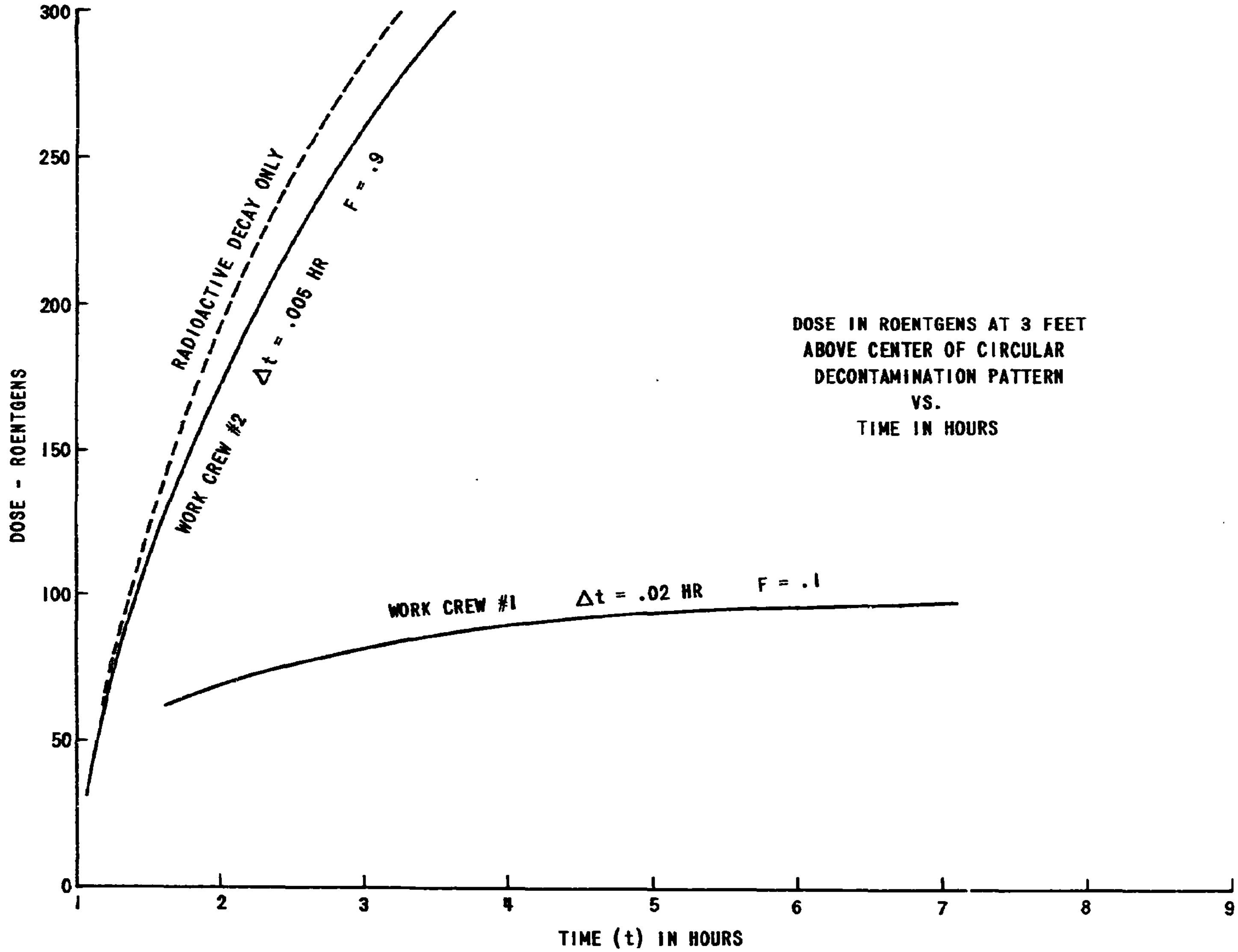


Figure 12 EFFECT OF PROCESS PARAMETER CHANGE

## MATHEMATICAL DISCUSSION OF DOSE CALCULATIONS

The ideal plane is subdivided into equal $\Delta \times \Delta$ elements of area $\Delta A$. Consider an M x M matrix of areas $\Delta A$ (M odd) specifying the central area of the matrix by $\Delta A_0$. Let $\Delta A_{ij}$ represent the element of area in the i$^{th}$ row and j$^{th}$ column of the matrix. Referring to Figure 13, let $\Delta x \Delta y$ be a small element of area within $\Delta A_{ij}$. The dose rate contribution ($\Delta$DR(x, y, t = 1 hour) in roentgens/hour at time t = 1 hour from $\Delta x \Delta y$ to a point P located $h$ units above the center point of $\Delta A_0$ is given by

$$\Delta D_R(x, y, t = 1hr) = \frac{I(t = 1hr)\, e^{-\mu\sqrt{x^2+y^2+h^2}}\, \Delta x \Delta y}{x^2 + y^2 + h^2} \qquad (10)$$

where $I_0(t=1hr)$ = assumed intensity/unit area in roentgens/hour/unit area at time t = 1 hour

$\mu$ = linear absorption coefficient of air given as $C \times 10^{-4}$/cm where C is dependent on the assumed energy level of the radiation.

The total dose rate DR(i, j, t = 1 hour) at the point P contributed by $\Delta A_{ij}$ at time t = 1 hour is obtained by integrating DR (x, y, t = 1 hour) over the area $\Delta A_{ij}$. It follows that

$$D_R(i, j, t = 1hr) = I_0(t = 1hr) \iint_{\Delta A_{ij}} \frac{e^{-\mu\sqrt{x^2+y^2+h^2}}}{x^2+y^2+h^2}\, dx\, dy \qquad (11)$$

At time $\tau >$ 1 hour, it is assumed that (1) natural decay of the radioactive fallout follows a $t^{-1.2}$ law so that the intensity/unit area $I_o(t)$ is given by $I_o(t) = I_o(t = 1 \text{ hour})\, t^{-1.2}$ (2) the fraction of fallout material remaining in an element of area $\Delta A$ exposed to $n$ passes of a decontamination crew is given by $(F)^n$ where F is the fraction of fallout remaining/pass.

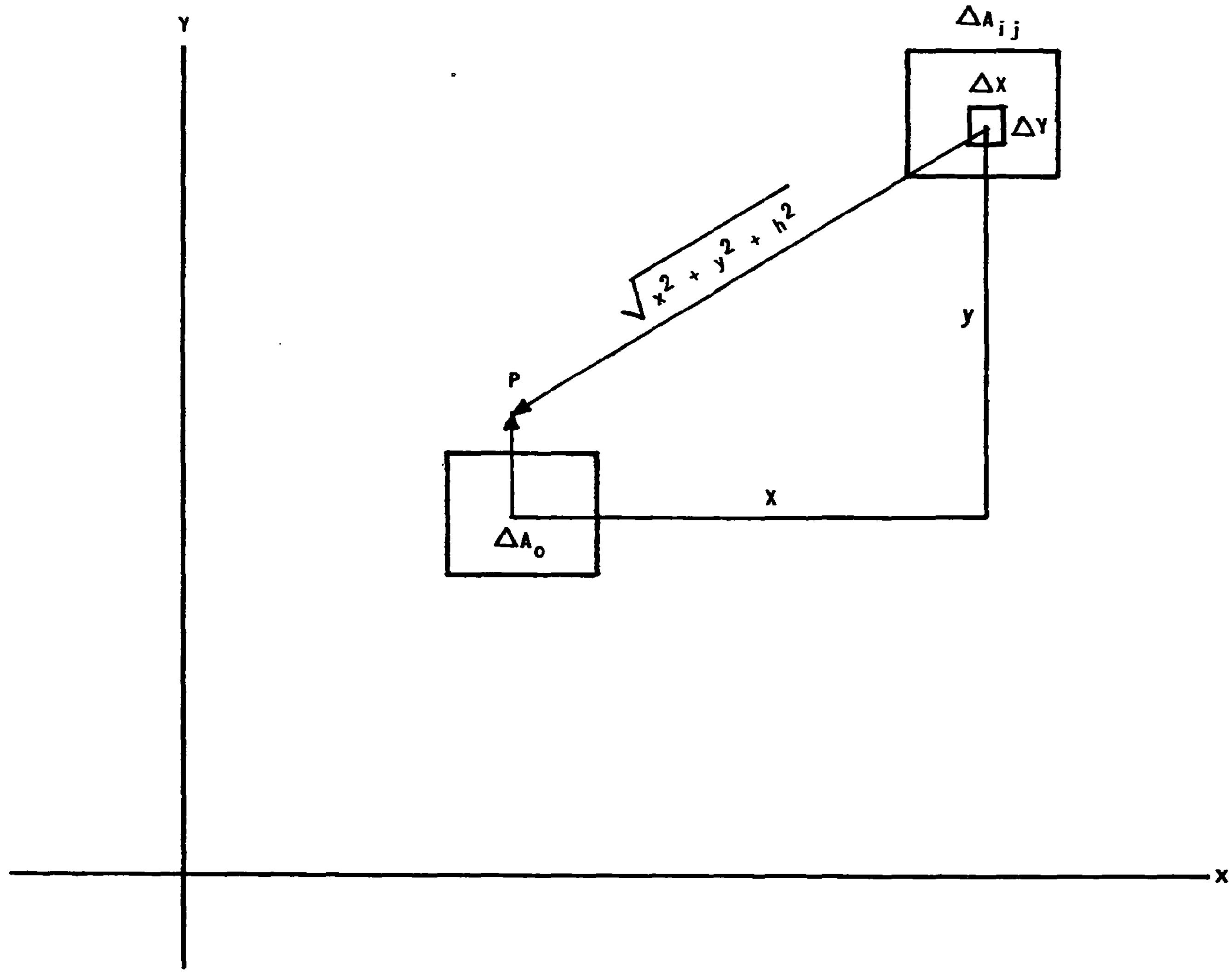


Figure 13 GEOMETRY FOR DOSE RATE CONTRIBUTION TO P

Specify an arbitrary element of area $\Delta A$ as the central area $\Delta A_0$ of the M x M matrix. Equation (11) specifies the dose rate contributions from the $\Delta A_{ij}$ areas in the matrix but at time t = 1 hour. At time t > 1 hour the dose rate contribution to P from $\Delta A_{ij}$ can be written as

$$D_R(i,j,t) = (F)^n_{ij} \, t^{-1.2} D_R(i,j,t=1\,hr) \tag{12}$$

where $F^n_{ij}$ is the fraction of fallout material "$F^n$" at time t for $\Delta A_{ij}$

From Equation (12), the total dose D(t, M) in roentgens received at the point P during the time interval from t to t + $\Delta$ t due to the $M^2$ areas $\Delta A_{ij}$ in the matrix is given by

$$D(t,M) = \Delta t \sum_{j=1}^{M} \sum_{i=1}^{M} D_R(i,j,t)$$

Finally,

$$D(t,M) = t^{-1.2} \Delta t \sum_{j=1}^{M} \sum_{i=1}^{M} (F)^n_{ij} \, D_R(i,j,t=1\,hr) \tag{13}$$

For specified values of $I_o$(t = 1 hour) and $\mu$, the model computes the M x M matrix of DR(i, j, t = 1 hour) values from Equation (11). As M increases in size, the contribution of the new DR (i, j, t = 1 hour) terms to the magnitude of D(t, M) at point P in Equation (13) decreases. In fact, given any $\epsilon > 0$ there exists an $M_o$ such that for $M > M_o$,

$$D(t,M) - D(t,M_o) < \epsilon$$

For assumed values of M = 51 and $\mu = .55 \times 10^{-4}$ the M x M matrix was computed on the computer where it was found that approximately 88% of the total dose contribution at P is accounted for. If $\mu$ is increased to 1.1 the percentage increased from 88% to about 95%.

## POINT SOURCE APPROXIMATION TO UNIFORMLY CONTAMINATED AREAS

An L x L area is assumed to be uniformly contaminated with radioactive fallout material. Define $I_o(t)$ as the intensity/unit area at time t within the area in roentgens/hour/unit area.

Referring to Figure 14 let P represent a point h units above the L x L area and offset a distance $y_0$. It can be shown that at time t the dose rate DR(t) at the point P is given by

$$D_R(t) = \int_{-\frac{L}{2}}^{\frac{L}{2}} \int_{-\frac{L}{2}}^{\frac{L}{2}} \frac{I_o t\, e^{-\mu\sqrt{x^2+(y-y_0)^2+h^2}}}{x^2+(y-y_0)^2+h^2}\, dx\, dy \quad (14)$$

where $\mu$ is the linear absorption coefficient of air.

Instead of integrating over the L x L area to determine the dose rate DR(t) at the point P, suppose one were to place a radioactive point source $Q'$ at the center of the area.

Let $Q' = I_o'(t) \cdot L^2$ where $I_o(t)$ is an intensity/unit area at time t within the L x L area such that

$$\frac{Q' e^{-\mu\sqrt{y_0^2+h^2}}}{y_0^2+h^2}$$

produces the dose rate DR(t) as given by Equation 1 at the point P.

If $I_o$ and $I_o'$ differ only slightly, then the point source method in determining dose rate calculations is a valid approximation to the integration method.

For assumed values of h = 3 feet, $I_o$ = 10 r/hr/unit area and $\mu = .55 \times 10^{-4}$/cm, Figures 15, 16 and 17 show the variation of $I_o'$ with $\sqrt{h^2+y_0^2}$ for L = 30 feet, 70 feet and 110 feet, respectively.

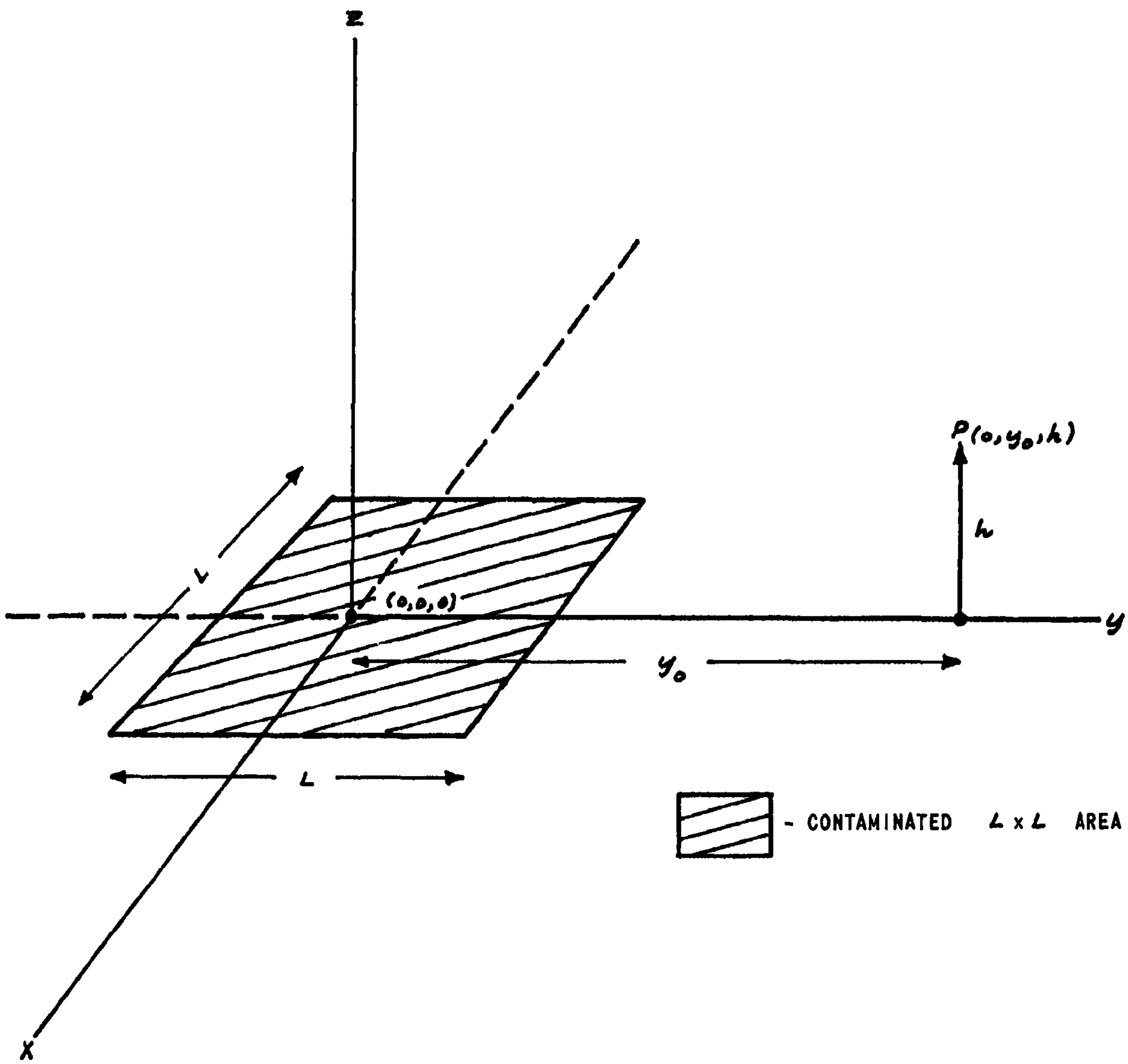


Figure 14 GEOMETRY FOR DOSE RATE COMPUTATION

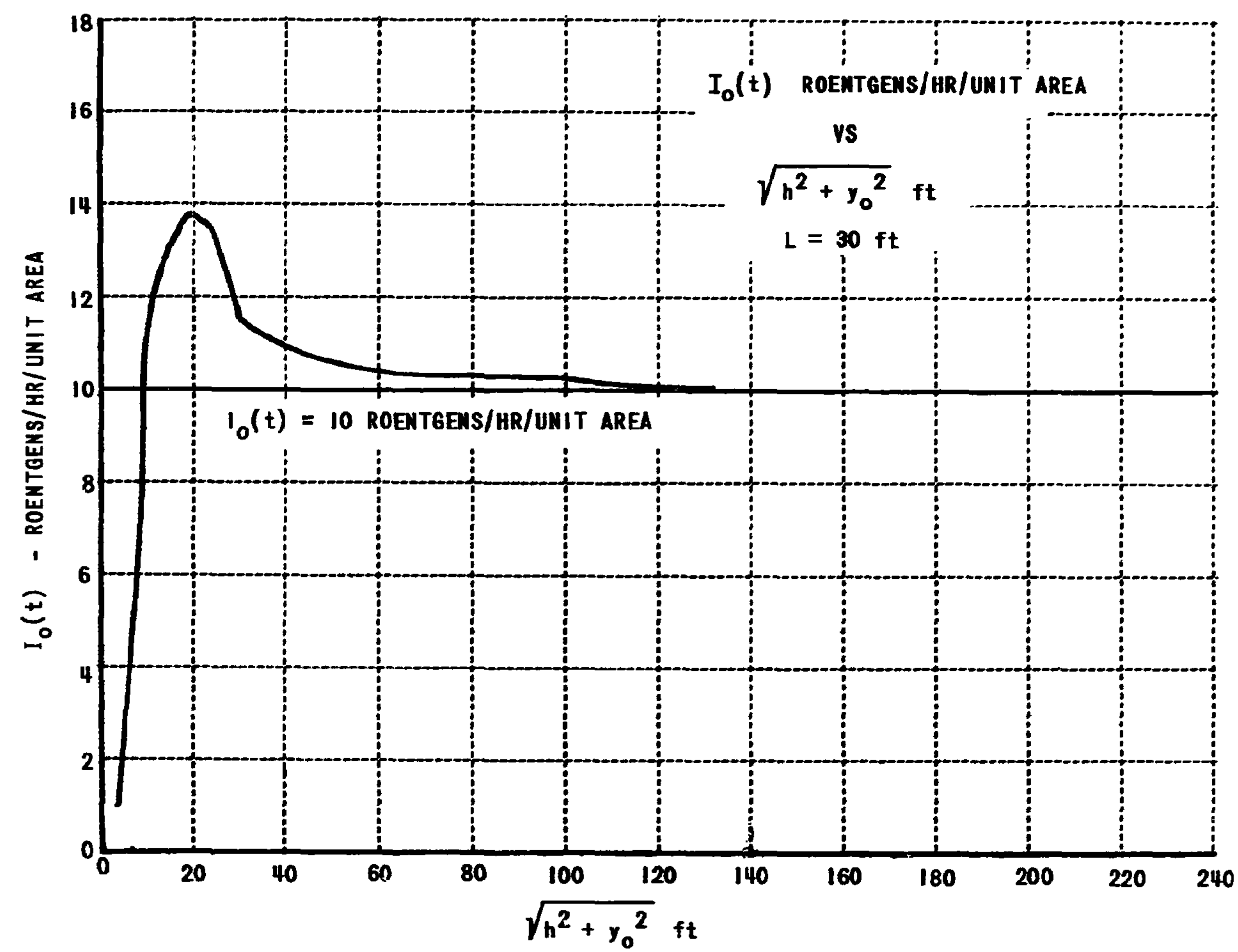


Figure 15 VARIATION OF $I_0$ WITH $\sqrt{h^2 + y_o^2}$ FOR L = 30 feet

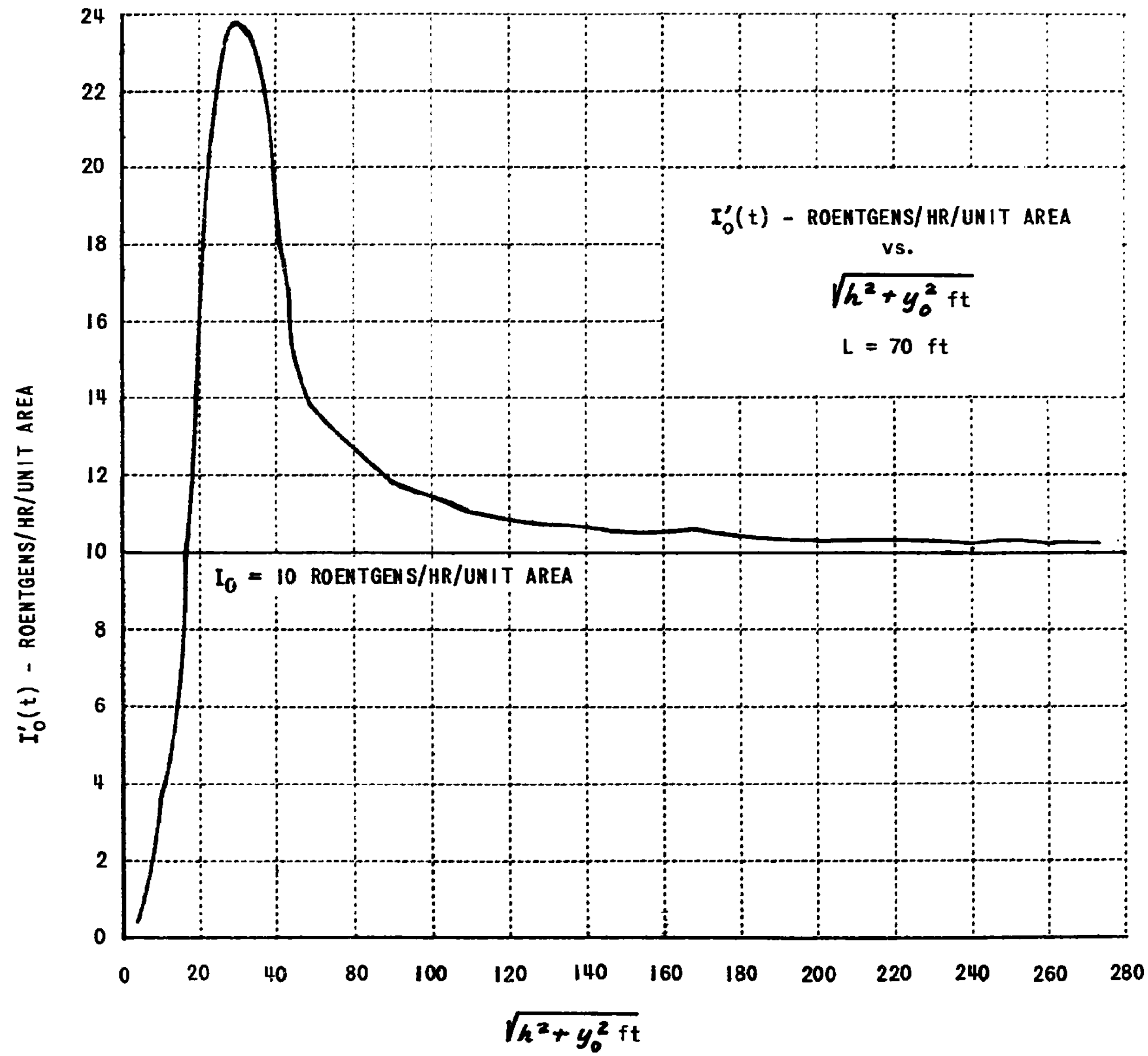


Figure 16 VARIATION OF $I'_0$ WITH $\sqrt{h^2+y_o^2}$ FOR L = 70 FEET

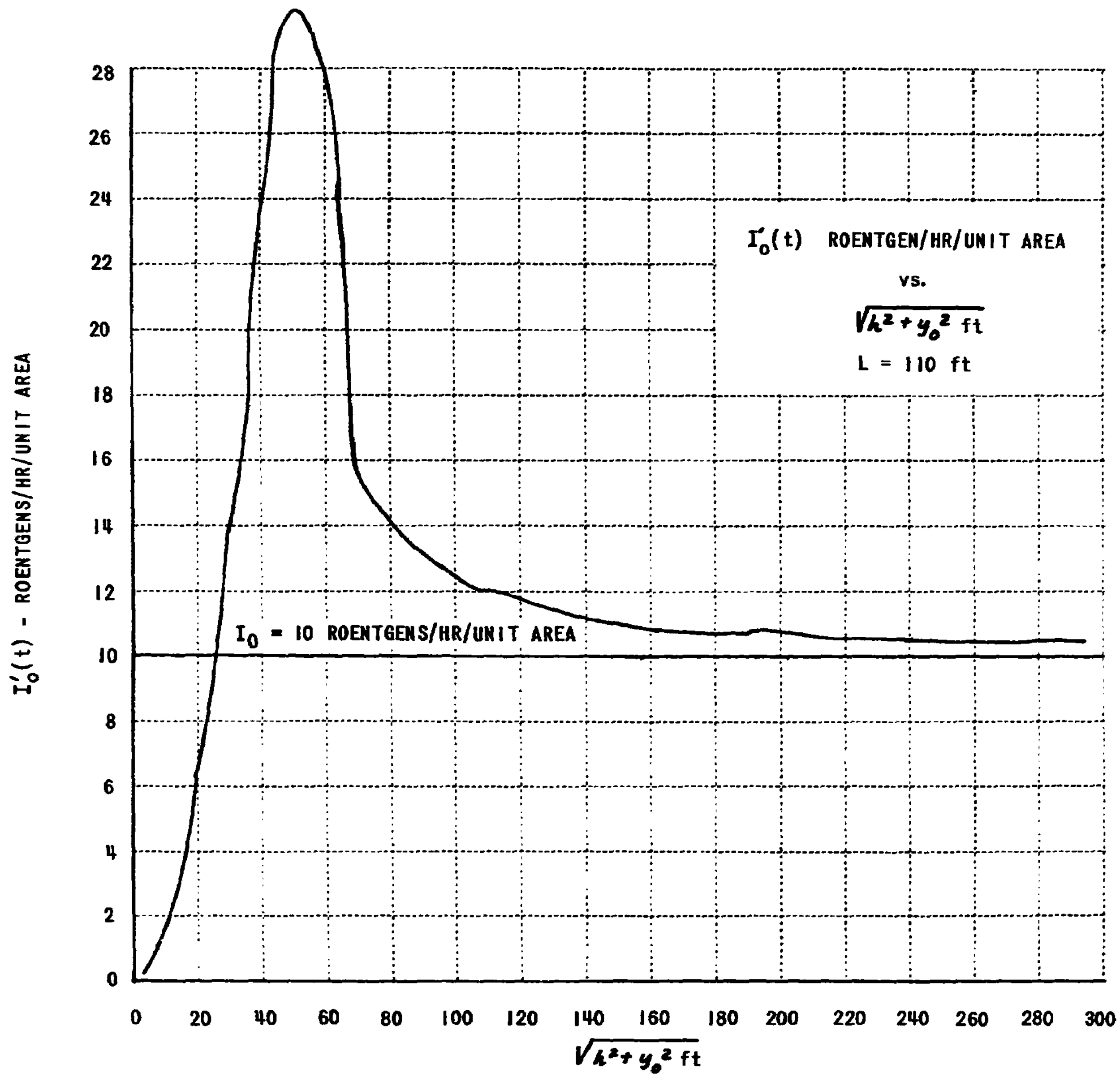


Figure 17 VARIATION OF $I_0'$ WITH $\sqrt{k^2+y_0^2}$ FOR L = 110 FEET

From the latter figures one can determine for each choice of L the distance d(L) such that whenever $\sqrt{x_0^2 + y_0^2} > d(L)$

$$\frac{I_0' - I_0}{I_0} \times 100 < P\ \%$$

Figure 18 shows the relationship between L and d(L) for P = 5%.

It follows from the above data that the validity of the point source approximation to the integration method decreases rapidly with the size of the area. At the 5% tolerance level, d(L) increased from 60 feet to 240 feet when L increased from 30 feet to 110 feet.

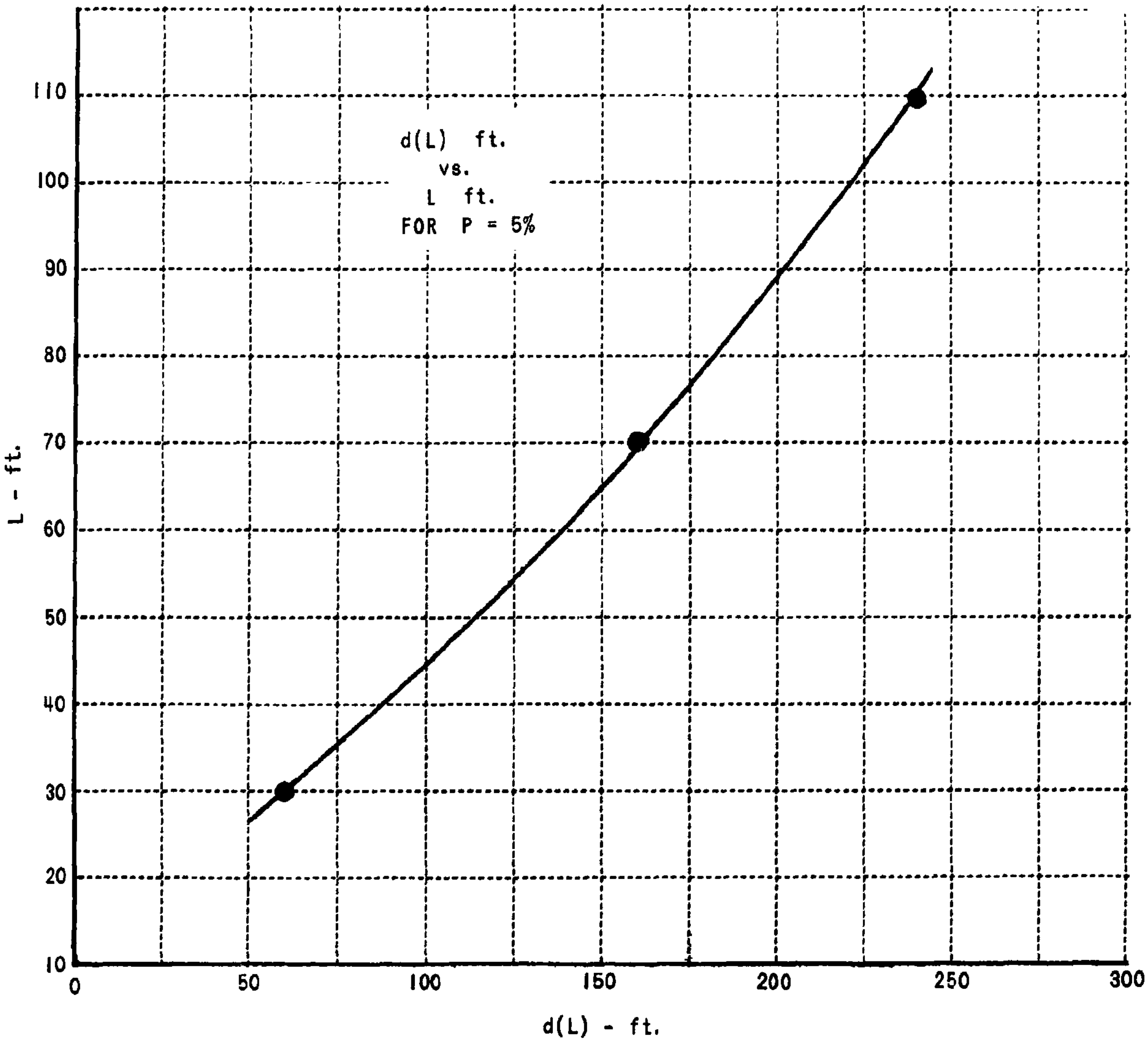


Figure 18 RELATION BETWEEN L AND d(L) FOR P=5%

# VII. ANALYTICAL EXAMINATION OF PERSONNEL SCHEDULING

## SYMBOLS USED

$t$ : Time-hours after the end of fallout $t \geq 1$.

$I(t)$ : Radiation decay function

$I(1) = 1$; $I(t)$ differentiable with $I'(t) < 0$

$R(t)$ : Dose rate at time $t$

$J(t)$ : The amount of radioactive material present at time $t$

$\Delta t$ : An interval of time, immediately following $t$ during which decontamination operations take place.

$1 - f(\Delta t)$: Fraction of radioactive material removed in the interval $t$ to $t + \Delta t$. $f(0) = 1$; $f'(\Delta t) < 0$; $f''(\Delta t) > 0$.

$D$ : Maximum allowable one-shot dose per worker

$t_r$ : Time required for worker to recover from maximum one-short dose

## GENERAL STATEMENT OF PROBLEM

Decontamination operations are to be scheduled in an area which has been subjected to radioactive fallout from a remote nuclear detonation. Find the times $t_1$, $t_2$, ---, $t_e$ and the associated decontamination periods $\Delta t_1$ $\Delta t_2$ -- $\Delta t_{e-1}$ so that certain side conditions (described in the three cases below) are satisfied. We seek and optimum schedule of the type drawn below: (Figure 19)

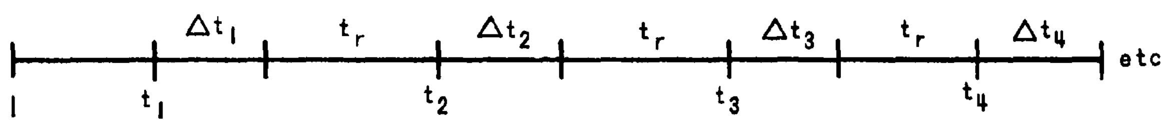


Figure 19 A SCHEDULE

Case 1

The decontamination crews, when not decontaminating, are not subject to radiation from the area being decontaminated. It is desired to reduce the dose rate from an initial level $R(1)$, to a level $R(t_e)$ by a given time, $t_e$. Under these conditions we wish to minimize the total dose to the crews and not exceed the maximum one-shot dose, D.

Case 2

The decontamination crews, when not decontaminating are subject to some of the radiation from the area being decontaminated. Definite a number $P > 1$ which is the ratio of the off-duty to on-duty protection factors. Under these conditions we wish to minimize the total dose to the crews over the period $t_1$ to $t_e$ while leaving the shelter at most $n$ times.

Case 3

Using the value P defined in Case 2, we wish to reduce the dose rate to $R(t_e)$ at time $t_e$ while minimizing the total dose to crews while leaving the shelter at most $n$ times.

## ANALYSIS OF CASE 1

The analysis begins with a consideration of the final period of decontamination which starts at $t_n$ and lasts for a length of time $\Delta t_n$ such that $t_n + \Delta t_n = t_e$, the specified time by which the dose rate must be down to $R(t_e)$. [In this analysis $R(t)$ is simply associated with $J(t)$, the amount of radioactive material present. No attempt is made to take into account the geometry of the situation, nor is any attempt made to define further how one obtains $J(t)$ from $R(t)$ or vice versa.]

Hence $R(t_e)$ determines $J(t_e)$ . Then $J(t_n)$, $R(t_n)$ and $t_n$ must satisfy the following system of equations

$$J(t_n)\, f(t_e - t_n,\, J(t_n)) = J(t_e) \tag{1}$$

$$R(t_n)\, f(t_e - t_n,\, J(t_n))\, I(1 + t_e - t_n) = R(t_e) \tag{2}$$

$$D(t_n) = R(t_n) \int_{t_n}^{t_e} f(t - t_n),\, J(t_n)\, I(1 + t - t_n)\, dt \tag{3}$$

$$D(t_n) = D \tag{4}$$

where $f(t_e - t_n, J(t_n)$ has been written to emphasize that $f(\Delta t)$ does depend on the amount of radioactive material present at the beginning of the interval.

In general, iterative methods will be required for the solution of these equations. The procedure is as follows:

a. Select a convenient trial value of $t_n$ , say $t_{n1} < t_e$

b. Solve equation (1) for $J(t_{n1})$ . Call it $J_{n1}$ . This step itself may require iteration; it will depend on the form of the function $f(\Delta t)$.

c. Substitute $J_{n1}$ and $t_{n1}$ into (2) for $J_n$ and $t_n$ respectively. Solve for $R(t_n)$

d. Compute $D(t_n)$ from equation (3). If $D(t_n) \lessgtr D$ select a different value of $t_n$ , say $t_{n2} \lessgtr t_{n1} < t_e$

e. The iteration may be stopped when for some value of $t_n$ , $D(t_n)$ is sufficiently close to but less than D.

After $R(t_n)$, $J(t_n)$ and $t_n$ have been determined, we apply the same procedure to obtain $R(t_{n-1})$, $J(t_{n-1})$ and $t_{n-1}$, using

$$t_n - t_r \text{ in place of } t_e$$

$$J(t_n - t_r) = J(t_n) \text{ in place of } J(t_e)$$

$$R(t_n - t_r) = R(t_n)/I(1 + t_n - t_r) \text{ in place of } R(t_e)$$

In a similar manner, a sequence $t_n$, $t_{n-1}$, $t_{n-2}$, - - - , $t_{n-k}$ may be obtained. The process may be terminated when for some value $k$

$$R(t_{n-k}) \geqq R(1) I(t_{n-k}) > R(t_{n-k+1})$$

Then $t_{n-k} \geqq t_1 \geq t_{n-k+1}$ and $t_1$ is determined by

$$R(1)\, I(t_1)\, f(t_{n-k+1} - t_1, J(t_1)) = R(t_{n-k+1})$$

The curve* $R(1) I(t)$ shows the radiation rate decay curve if no decontamination takes place. The goal $G_1$ in Case 1 is to reduce this rate to $R(t_e)$ at a time, $t_e$. The process starts at $G_1$ and continues upward and to the left. First $t_n$ and $R(t_n)$ are found by the iterative process described earlier. Call this point $G_2$. The point $G_3$ provides the initial conditions for determining $t_{n-1}$ and $R(t_{n-1})$. (Recall that in the final schedule which results from this process, no decontamination takes place during the $t_r$ units of time from $G_3$ to $G_2$ and that the normal decay curve is applicable there. The last decontamination period starts at $t_n$. The curve drops more rapidly during these decontamination periods). The process continues until one of the $G_i$ points lies above the $R(1) I(t)$ curve. The graphical example shows that three decontamination periods would be scheduled. The first is at $t_1$. The

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* See Figure 20

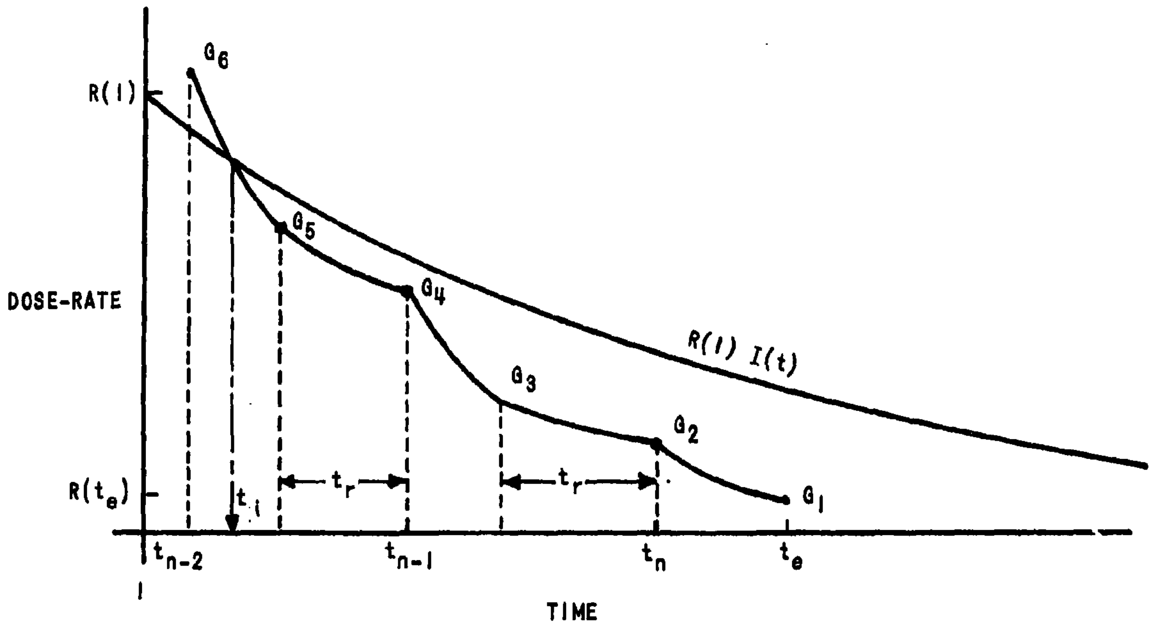


Figure 20 PROCEDURE FOR SOLUTION

second is at $t_{n-1}$ now to be designated $t_2$ . Similarly, the third period would begin at $t_n$ and can be designated $t_3$ . This schedule will have the desired properties: (1) Reduce the dose rate to $R(t_e)$ at time $t_e$. (2) Do not exceed the maximum single-exposure dose.

ANALYSIS OF CASE 2

During the j$^{th}$ period the total dose received is

$$R(1) \prod_{i=1}^{j-1} f(\Delta t_i, T(t_i)) \int_{t_j}^{t_j+\Delta t_j} f(t - t_j, T(t_j)) I(t)\, dt$$

where $R(1)$ is the initial dose rate.

Between the j$^{th}$ and $j+1$ st period (while rest and recovery is occurring) the total dose is

$$\frac{R(1)}{P} \prod_{i=1}^{j} f(\Delta t_i, T(t_i)) \int_{t_j+\Delta t_j}^{t_{j+1}} I(t)\, dt$$

The total dose is then given by

$$D_T = \frac{R(1)}{P}\left[\sum_{j=1}^{n} \prod_{i=1}^{j} f(\Delta t_i, T(t_i)) \int_{t_j+\Delta t_j}^{t_{j+1}} I(t)\, dt\right] + R(1)\left[\sum_{j=1}^{n} \prod_{i=1}^{j} f(\Delta t_{i-1}, T(t_{i-1})) \times \int_{t_j}^{t_j+\Delta t_j} f(t - t_j, T(t_j)) I(t)\, dt\right]$$

where $t_{n+1} \equiv t_e$

$\Delta t_0 = 0$

$f(0, T(t_1)) \equiv 1$

We wish to select a schedule $t_1, \Delta t_1, t_2, \Delta t_2, ---$ which minimizes the total dose to decontamination crews over the period $t_1$ to $t_e$ while leaving the shelter at most $n$ times. To accomplish this, we proceed as follows: For every fixed $t_1, t_2 \cdots t_n$ we minimize $D_T$ with respect to $\Delta t_1, \Delta t_2, \cdots \Delta t_n$ and solve the resulting equations for $\Delta t_i$ as functions of $t_i$. Then we substitute the $\Delta t_i$ as functions of the $t_i$ into $D_T$ to obtain a function of the $t_i$ only and minimize this function with respect to the $t_i$. To carry out this program, note that as a function of $t_n$ and $\Delta t_n$,

$$D_T = R(1) \prod_{i=1}^{n-1} f(\Delta t_i, J(t_i)) \left[ \frac{1}{P} f(\Delta t_n, J(t_n)) \int_{t_n+\Delta t_n}^{t_{n+1}} I(t)\,dt + \int_{t_n}^{t_n+\Delta t_n} f(t-t_n, I(t))\,dt \right]$$

$$+ \phi(t_1, t_2, \cdots t_{n-1}, \Delta t_1, \cdots \Delta t_{n-1})$$

where $\phi$ does not involve $\Delta t_n$ or $t_n$.

Setting $\frac{\partial D_T}{\partial \Delta t_n} = 0$ and simplifying, we obtain

$$\frac{1}{P} \frac{df}{d\Delta t_n} \int_{t_n+\Delta t_n}^{t_e} I(t)\,dt + \left(1 - \frac{1}{P}\right) f(\Delta t_n, J(t_n))\, I(t_n+\Delta t_n) = 0 \tag{5}$$

We also have $\frac{\partial^2 D_T}{\partial \Delta t_n^2} > 0$ if

$$\frac{1}{P} \frac{\partial^2 f}{\partial \Delta t_n^2} \int_{t_n+\Delta t_n}^{t_e} I(t)\,dt > \left(\frac{2}{P} - 1\right) \frac{\partial f}{\partial \Delta t_n} I(t_n+\Delta t_n) + \left(\frac{1}{P} - 1\right) f(\Delta t_n, J(t_n)) \frac{\partial I(t_n+\Delta t_n)}{\partial \Delta t_n} \tag{6}$$

If $I(t)$ contains $\Delta t_n$ then additional terms will appear in (5) and (6). Condition (6) provides the condition on P that ensures $\Delta t_n > 0$ From (5) we obtain $\Delta t_n$ as a function of $t_n$ . Designate this function as $g(t_n)$. If $t_n$ and $g(t_n)$ satisfy (6) and if $g\,t_n > 0$ the $\Delta t_n$ minimizes $D_T$ as a function of $\Delta t_n$. Substitute $g(t_n)$ for $\Delta t_n$ in $D_T$ and set $\frac{\partial D_T}{\partial t_n} = 0$ to obtain

$$\frac{1}{P}\frac{\partial f}{\partial t_n}\int_{t_n+g(t_n)}^{t_e} I(t)\,dt + \left[1 - \frac{1}{P}\left(1 + \frac{dg}{dt_n}\right)\right] f\left(g(t_n), J(t_n)\right) I\left(t_n + g(t_n)\right)$$

$$+ \int_{t_n}^{t_n+g(t_n)} \frac{\partial f\left(t - t_n, J(t_n)\right)}{\partial t_n} I(t)\,dt = I(t_n) \qquad (7)$$

Equation (7) involves $t_n$ as the only unknown. Solve for $t_n$ and $\Delta t_n = g(t_n)$. Now $D_T$ as a function of $\Delta t_{n-1}, t_{n-1}$ depends only on $\Delta t_{n-1}, t_{n-1}, \Delta t_n, t_n$ , the values obtained for $\Delta t_n$ and $t_n$ may be used to repeat the above procedure to determine $\Delta t_{n-1}$ and $t_{n-1}$ . These quantities depend on $J(t_{n-1})$ and $J(t_n)$. However, the relationship

$$J(t_{n-1})\, f\left(\Delta t_{n-1}, J(t_{n-1})\right) = J(t_n) \qquad (8)$$

reduces the dependence to $J(t_{n-1})$ alone. Continuing this process, $t_1$ and $\Delta t_1$ will depend only on $J(t_1)$ which is known since $R(1)$ is known. Using the analogs of (8), $J(t_2)$ , $\Delta t_2$ and $t_2$ are completely determined. Thus we obtain in sequence $J(t_1), J(t_2), \cdots, J(t_n)$ which gives finally all the $\Delta t$'s and $t$'s .

Under our assumptions about $f(t, J(t))$ and $I(t)$, $D_T$ has a unique minimum and a unique maximum. It can also be shown that, given the original assumptions, the procedure outlined is uniquely defined and satisfies $\Delta t_i \geq 0$, $t_i + \Delta t_i \leq t_{i+1}$ so that the minimum is indeed found in this way.

## ANALYSIS OF CASE 3

At the end of the first period of decontamination, we have $J(t_2) = J(t_1) f(\Delta t_1, J(t_1))$ ; at the end of the second period we have $J(t_3) = J(t_2) f(\Delta t_2, J(t_2)) = J(t_1) f(\Delta t_1, J(t_1)) f(\Delta t_2, J(t_2))$ At the end of the $j^{th}$ period

$$J(t_{j+1}) = J(t_1) \prod_{i=1}^{j} f(\Delta t_i, J(t_i))$$

Since $R(t_1)$ and $R(te)$ imply $J(t_1)$ and $J(te)$ we have

$$J(te)/J(t_1) = \prod_{i=1}^{n} f(\Delta t_i, J(t_i)) \tag{9}$$

The total dose, $D_T$, is the same as that of Case 2. Let $\lambda$ be a Lagrangian multiplier. Then

$$\psi(D_T, \lambda) = D_T + \lambda \left[ J(te)/J(t_1) - \prod_{i=1}^{n} f(\Delta t_i, J(t_i)) \right]$$

Setting $\frac{\partial \psi}{\partial \Delta t_n} = 0$ and simplifying, we obtain

$$\frac{R(1)}{P} \frac{\partial f}{\partial \Delta t_n} \int_{t_n + \Delta t_n}^{te} I(t)\, dt + R(1)\left(1 - \frac{1}{P}\right) f(\Delta t_n, J(t_n)) I(t_n + \Delta t_n) = \lambda \frac{\partial f}{\partial \Delta t_n} \tag{10}$$

From (10) we obtain $\Delta t_n$ as a function of $t_n$, $J(t_n)$ and $\lambda$, and as before, $\Delta t_i$ and $t_i$ as functions of $\lambda$, $J(t_i)$ and $t_k, \Delta t_k$ $(k = i+1, i+2, \cdots, n)$ Then the equations

$$J(t_i) f(\Delta t_i, J(t_i)) = J(t_{i+1}) \qquad i = 1, 2, 3, \cdots, n$$

$$\prod_{i=1}^{n} f(\Delta t_i, J(t_i)) = J(t_e)/J(t_1)$$

together with the known values of $J(t_1)$, $J(t_{n+1}) = J(t_e)$ suffice to determine all the $t$'s and $\Delta t$'s

## COMMENTS

1. Implicit in the total dose, $D_T$, formulation is the assumption that decontamination proceeds in such a way that reduction in dose rate, during each decontamination period, is proportional to the amount of material removed. This assumption is not essential. It may be eliminated by introducing the appropriate total dose calculation at each state. However, this leads to even more tedious algebra.

2. The cases examined are "fundamental" situations on which variation may be made. The fundamental features are the two sets of assumptions (Case 1 and Cases 2 and 3) and the unconstrained minimization criterion (Case 2) and the constrained minimization (Cases 1, 3).

3. In Cases 2 and 3, optimization over the number, $n$, of stages of decontamination proceeds most easily by trying various values of $n$.

4. Cases 2 and 3 do not incorporate the maximum one-shot dose constraints. The following comments apply, however. If all $\Delta t$'s are such that D is exceeded, the $n$ is too small to be feasible. If some, but not all, $\Delta t$'s are such that D is exceeded, then they should be reduced by increments sufficient so that D is not exceeded and the increments should be added to the earliest possible $\Delta t$'s in such a way that D is not exceeded for them. Exactly the same comments apply if

$$t_r > t_{j+1} - (t_j + \Delta t_j)$$

5. Case 1 applies, e.g., when it is desired to clean up useful area which poses no radiation problem to the population beyond it.

6. Case 2 applies, e.g., to the situation where there is no immediate urgency for use of the area and it is not feasible to remove the crews from the area for rest and recuperation, but that they can be sheltered near the area.

7. Comment 6 applies to Caue 3 except that there is some degree of urgency as expressed by $R(t_e)$ and $t_e$.

8. The case where the population is also exposed to radiation from the area is treated as in Case 3. Add terms to $D_T$ for the total dose to the population. Adopt the criterion

$$\min t_e = \sum_{i=1}^{n} t_i + \Delta t_n$$

subject to fixed dose for the crews. The Lagrangian term expresses the fixed dose for the crews. See Comment 2. Alternately, add terms to $D_T$ for the population dose, make a judicious selection of $R(t_e)$ and $t_e$ and proceed as in Case 3.

9. Assume areas $A_1, A_2, \cdots, A_m$ are to be cleaned, that they have dose rates $R^{(1)}(1)$, $R^{(2)}(1)$, $R^{m}(1)$ and that by $t_e$ they are to be reduced to $R^{(1)}(t_e), R^{(2)}(t_e), \ldots, R^{(m)}(t_e)$ while minimizing the total dose to the crews. This is essentially a combinatorial problem. Brute force with the following simplification should work. Assume that each area is to be cleaned in one stage and calculate the total dose for each ordering. Select the ordering which minimizes the total dose. It is easily shown that this ordering is still the solution if optimal schedules are adopted for each area.

## VIII. A COMPUTATIONAL ANALYSIS OF ENVIRONMENTAL SHIELDING

### INTRODUCTION

All calculations of dose rate discussed here will be given in terms of an infinite plane dose rate, $D_\infty$. The infinite plane dose rate is determined as follows: Assume that a horizontal infinite plane is uniformly covered with fallout material and has a source strength* $I_0$ per unit area with the entire plane immersed in air as the attenuating medium. The dose rate at a point three feet above the plane is found by finding the contribution to total dose rate from each elemental area, attenuating this by the standard medium (air) and integrating over the entire plane. Doing this yields a value for $D_\infty = 25\ 309 I_0$

The infinite plane dose rate can be associated with the "unit time reference dose rate" which is ordinarily specified by the fallout contours normally plotted during civil defense operations or as commonly specified by various nuclear weapons effects handbooks. Of course, the time decay of dose rate must be considered in the usual manner for these results; also, to determine total dose, the dose rate must be integrated over the time of exposure and with normal decay. Now the fallout contours present a spatial variation in dose rate corresponding to the variations in deposits of fallout material over the ground and are not a uniformly contaminated infinite plane. Computations show, however, that the dose rate three feet above a circular disc with a radius of 600 feet differs from the infinite plane dose rate by less than one percent, so that the approximation of equating $D_\infty$ to the unit-time reference dose rate is useful in most practical cases.

* The source strength can be expressed in any convenient units per unit area. If the activity of fallout material is $\rho$ per unit area, $I_0 = K\rho$, where $K$ depends on the number of energetic particles emitted per disintegration, the energy of each particle and contains a factor which converts radiation intensity to dose rate. Since dose rates are always expressed relative to a reference dose rate in this discussion, the actual units used are irrelevant.

In this target analysis, a relative dose rate is presented for each target as a ratio or percentage of the infinite plane dose rate. In this way the results have greatest generality, and can be readily applied to an actual or postulated fallout situation and have value in planning operations since they present a convenient method of gauging the effective "shielding" which a specific target complex would provide for an exposed individual.

Certain simplifying assumptions have been made for each of the five methods of computation to be discussed. Common to all of the methods are the following:

a) The ground is assumed to be a horizontal, infinite plane without the shielding effect which is normally encountered due to ground roughness.

b) All areas are plane horizontal surfaces with a uniform distribution of fallout material on them.

c) The fallout material emits gamma radiation radially outward and with equal intensity in all directions.

d) All shielding structures in the target area have a unity buildup factor.

e) Each element of contaminated surface area acts as a point source and the contribution from all point sources is additive.

Certain additional assumptions are peculiar to the particular method of computation and will be defined as required.

## METHODS OF COMPUTATION

In general, if an area (A) has a constant source strength $I_0$ per unit area due to a unform distribution of fallout material, the dose rate at a point will be given by

$$D = \int_A I_0 \; G(R) \, B(R) \, dA \qquad (1)$$

where $G(R)$ specifies the change in radiant flux with distance R and $B(R)$ is a buildup factor in the medium through which the radiation passes. If we assume each element of area to behave as a point source and have a unity buildup factor the dose rate becomes:

$$D = \int_A I_0 \; \frac{e^{-\mu R}}{R^2} \, dA \qquad (2)$$

where $\mu$ is the attenuation coefficient for gamma radiation in the medium. If the radiation passes through several $(n)$ layers of different media, the term $\mu R$ can be replaced by $\sum_{i=1}^{n} \mu_i t_i$ summed over all layers, where $\mu_i$ is the attenuation coefficient for the ith layer and $t_i$ is the path length through that layer.

The problem is now one of computing the integral (2). It cannot be solved in closed form but with certain simplifying assumptions various methods for approximating the integral have been investigated.

1. Point Source at Centroid

This method is discussed in Reference 1 (Chapter 10) and assumes that the actual area covered with uniform fallout can be replaced by an equivalent point source of strength $Q = I_0 A$ located at the centroid of the contributing area. It further assumes that $e^{-\mu R}$ can be replaced by a constant attenuation factor $A_j$ which neglects the gamma ray attenuation of air but includes that for other media. Thus, the contribution to dose rate at a point for the jth surface is

$$D_j = \frac{A_j Q_j}{d_j^2} \tag{3}$$

where $d_j$ is the distance from the point to the centroid of the area.

2. Circular Sector with Constant Attenuation

This method is also discussed in Reference 1, Chapter 10, and contains the basic assumption that any given area can be approximated by a circular sector, Again, it is assumed that the attenuation factor is a constant, $A_j$. Using these assumptions, equation (2) can be integrated exactly (see the final section of this chapter) giving

$$D_j = \frac{A_j \Theta_j I_0}{2} \log_e \left[ \frac{X_{2j}^2 + h_j^2}{X_{1j}^2 + h_j^2} \right] \tag{4}$$

for the contribution to dose rate of the jth area. In this equation $\theta_j$ is the angle subtended at the point by the projection of the jth area in the horizontal plane containing the point; $h_j$ is the height of the area above (or below) the point of interest, and $X_{1j}$, $X_{2j}$ are the minimum and maximum radii, respectively, of the jth circular sector in its horizontal projection plane.

3. Rectangular Geometry with Constant Attenuation

If we again assume that the exponential attenuation term can be replaced by a constant, $A_j$, integration over the actual rectangular (or any polygonal) area must be performed. Equation 2 becomes:

$$D_j = I_o A_j \int_{y_{1j}}^{y_{2j}} \int_{x_{1j}}^{x_{2j}} \frac{dx\,dy}{X_j^2 + y_j^2 + h_j^2} \tag{5}$$

for the contribution to dose rate from the jth area. This integral cannot be solved in closed form and is best solved numerically by machine methods.

4. Circular Sector with Attenuation

Retaining the circular sector approximation for actual areas but considering the actual variation of the attenuation factor with distance allows us to further refine the computational model. The dose rate can be expressed (see final section) as

$$D_j = I_o \theta_j \int_{z_{1j}}^{z_{2j}} \frac{e^{-z}}{z}\,dz$$

(6)

where
$$Z_{1j} = \mu \sqrt{x_{1j}^2 + h_j^2}$$
$$Z_{2j} = \mu \sqrt{x_{2j} + h_j^2}$$
$$Z = \mu r$$

Values of the integral can be determined by machine using numerical integration or by hand using tabular data for the exponential integrals. As in the second method above, $\theta_j$, $X_{1j}$, and $X_{2j}$ define the circular sector which approximates the actual contaminated jth area.

5. Rectangular Areas with Attenuation

With this method the limitation imposed above by use of circular sectors to approximate rectangular areas is removed. For a rectangular area, equation (2) would be written

$$D_j = \int_c^d \int_a^b \frac{I_o e^{-\mu \sqrt{x_j^2 + y_j^2 + h_j^2}}}{x_j^2 + y_j^2 + h_j^2} \, dx \, dy \qquad (7)$$

More complex areas could be broken up into any set of rectangular areas each of which could be expressed in the form of equation (7). This integral can best be evaluated using numerical integrations by machine methods of calculation.

Methods of computations 2, 3 and 4 have been programmed for the IBM 704. Results for specific cases are shown in the next section. The first method is simple enough for hand computations to be adequate; preliminary results of calculations showed that the small differences in dose rate and the additional complexity of method 5 as compared to method 3 did not justify preparation of an additional program. A more comprehensive method of computation is discussed in Reference 4, but the extension of work to this additional degree of complexity was not felt to be warranted or required for the present study.

## RESULTS AND DISCUSSION

This target analysis considered several different cases to illustrate the methods of computation and vary in complexity from simple idealized geometry to a complex city geometry which approximates an actual situation. Each of these cases will be defined and results discussed in detail in the ensuing paragraphs.

Circular discs - for this case the dose rate was computed using method 4 for finding the dose rate at a point three feet above the center of a circular disc. Air attenuation was assumed. Computations were made for discs of various radii in the range from 10 feet to 10,000 feet. Results are shown in Table 5.*

* Tables 5 to 12 are shown in Appendix II

Cylindrical farmhouse - method 4 was used to compute the dose rate at a point three feet above the center of the floor of a simple cylindrical structure which is located on a horizontal circular disc of radius 600 feet. Various structural parameters were varied; namely, the radius of the building was varied from 20 to 60 feet, holding the building height at 10 feet with walls and rooftop of wood, two inches thick; the height of the rooftop was varied from 10 feet to 35 feet, again using walls and rooftop of wood two inches thick and holding the building radius at 30 feet except for one case ( H = 27 feet ) where radii of 30 and 50 feet are computed; finally, wall and rooftop thicknesses of four and six inches of wood are used for various radii, holding heights at 10 feet. Results are shown in Table 6. Note that the contribution to dose rate from the rooftop and from the surrounding area are computed separately so that one must add the contributions from the two to determine total dose rate for each case.

Study of the data in Table 6 shows that increasing the height of the rooftop above the observer has a much greater effect than increasing building radius. Also, this case illustrates the value of even a small amount of shielding as compared to an individual exposed to the full radiation field with only air as the attenuating medium.

Residential area* - an idealized target area representing a typical residential area was analyzed by both method 2 and method 4. A map of the area is shown in Figure 21. For both computations, the dose rate at a point three feet above the floor at the center of the center house is found. The results (Tables 7 and 8) show a comparison between the two methods of computation; on the one hand, the simpler method in which an exponential attenuation factor is used to multiply the integral gives a total relative dose rate of 55.8%; for the other, in which the

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* This residential area is similar to the example used in Reference 1 Chapter 10, and was analyzed for use as a test case in checking out the computer programs.

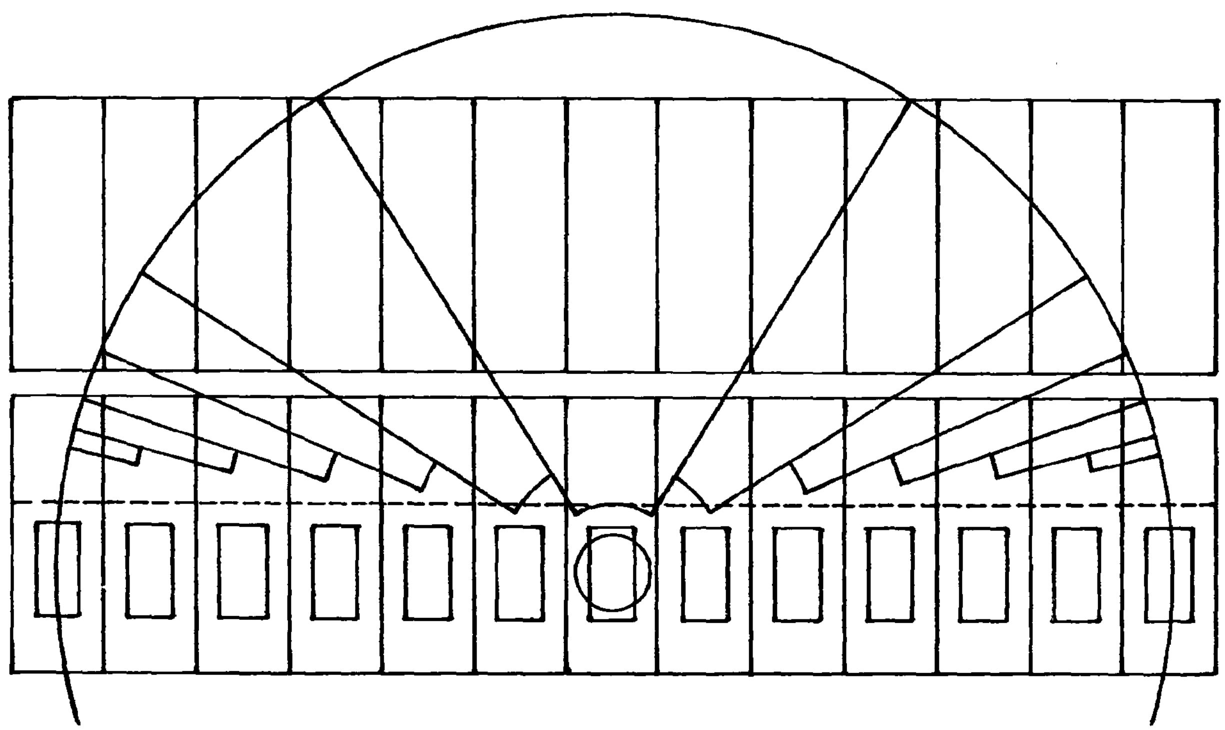

Figure 21 RESIDENTIAL AREA

exponential term enters into the integration, total relative dose rate is 50.8%. The difference between these two results is sufficiently small that use of the simpler method of computation, which is amenable to hand computations, is justifiable for use in estimating dose rates for planning purposes. Furthermore, since the simpler method will always yield higher than actual values, such estimates will be on the conservative side.

Shopping plaza - the shopping plaza case consists of a row of attached stores separated by concrete walls one foot thick. The rear wall is also one foot of concrete but the front wall was assumed to present no shielding since the display windows would have little shielding effect even if they survived the blast effects in an actual attack. Building heights were taken at 15 feet and the shielding factor for rooftops was taken as a three inch wood equivalent. Dose rate was computed at three feet above the center of the floor of the center store. A map of the shopping plaza is shown in Figure 22. The shopping plaza case was also analyzed by both methods 2 and 4. The results are shown in Tables 9 and 10. Total relative dose for the computation with "fixed attenuation" is 14.8% whereas for the computation "with attenuation" (i.e., with the exponential term retained under the integral sign) the value is 9.4%. Again the simpler method yields the more conservative estimate. It is interesting to note from these results that almost the entire dose rate is contributed by the areas immediately in front of the front window of the center store. This again illustrates the importance of shielding.

City complex - an idealized target area was analyzed representing a typical city area. Detailed maps of the downtown area were obtained from the Planning Office of the City of Buffalo, New York. From these maps, information was obtained such as street and building

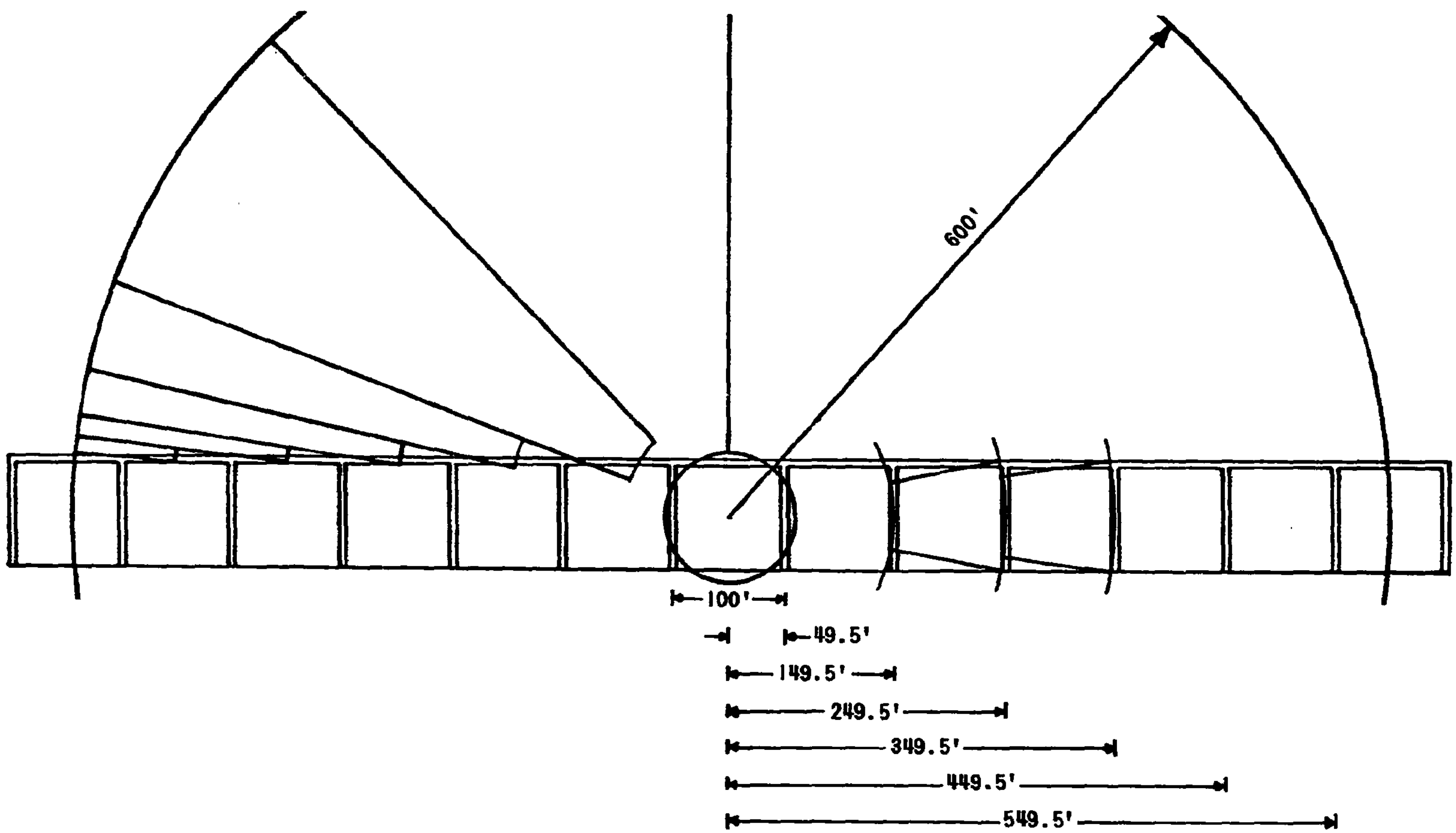


Figure 22 MAP OF SHOPPING PLAZA

dimensions, building materials, wall thicknesses and the like. Using this information, an idealized city complex was created. A four block area was considered and plan view map is shown in Figure 23. The profile views looking both north and south from the central street show the building heights, and are presented in Figure 24. The plan view shows the scheme of numbering the areas for the computations. The building material and number of stories in each building are also shown. The height of one story is taken as 12 feet. Dose rate calculations were made for five different points (floating origins) along the central street and are marked A through E. Each origin is at the center of the street, three feet above the pavement.

Computations for dose rate were made using method 3 and results are summarized in Table 11. These results are also plotted in Figure 25. In addition, the solid circles shown in this plot are those determined by subtracting from the computed dose rates 50% of the contribution to dose rate from the central street area. This is done to show how much the dose rate would be decreased by even a relatively inefficient decontamination procedure applied only to the street area. Table 12 is one of the data runs from this program given to illustrate the contributions for one of the origins (Origin A) from the individual contaminated surface areas and also showing the shielding factors used. The shielding factors (labeled "ATT.CONST." on the data runs) were determined as follows for each area: Only those slabs of attenuating material were considered which completely shielded the floating origin from the area. The thickness of the air slab for each area was determined from the distance between the origin and the closest point of the area. The horizontal slabs taken for the intermediate floors and rooftops of multi-storied buildings were taken as one foot wood equivalent regardless of the building material. By neglecting those buildings which only partially shield the origins, the computed dose rates will be on the conservative side. On the other hand, apertures such as windows, doors, etc. in buildings are neglected in the computations and these would tend to increase the dose rates.

PLAN VIEW

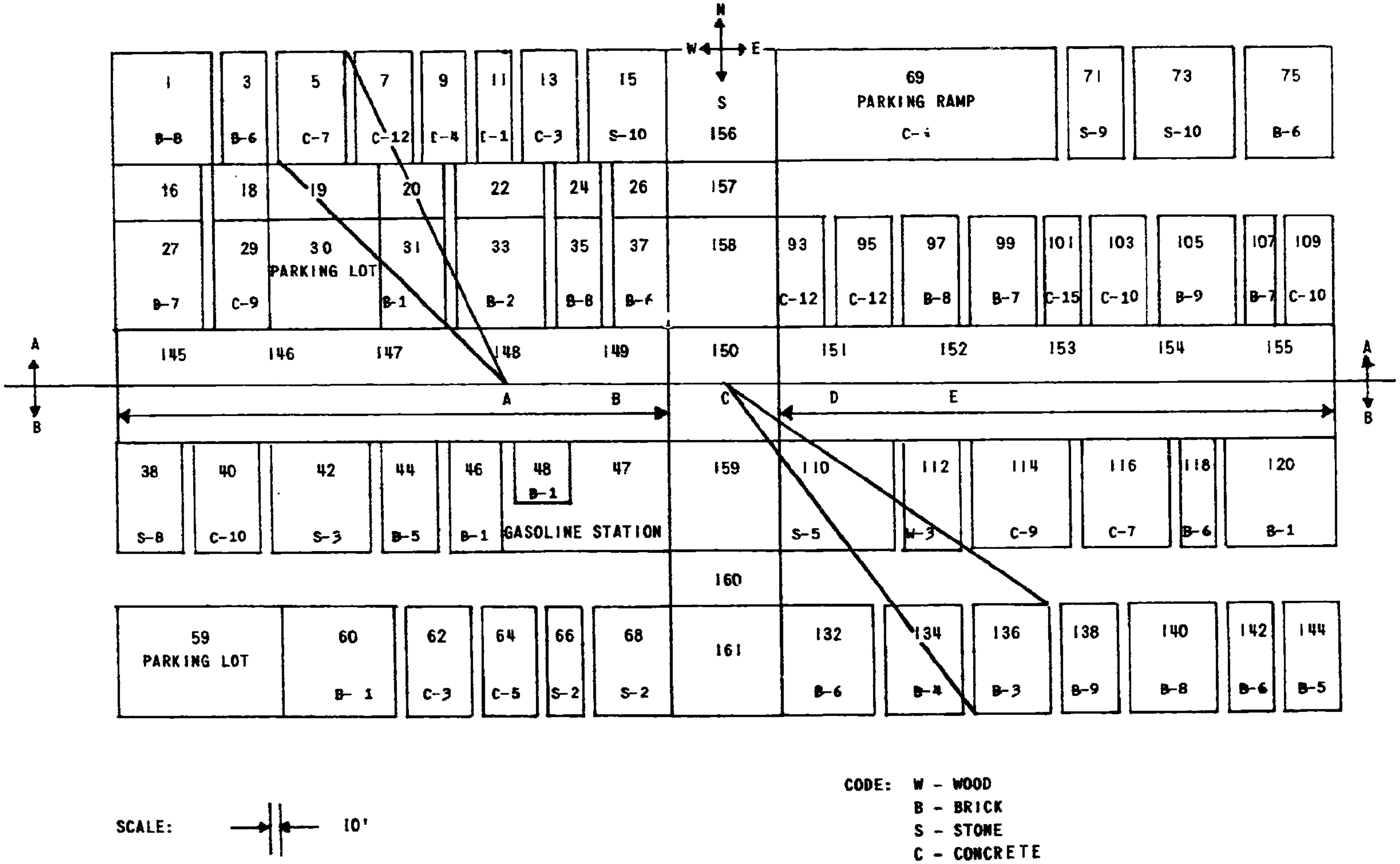


Figure 23 MAP OF CITY COMPLEX USED IN TARGET ANALYSIS PLAN VIEW

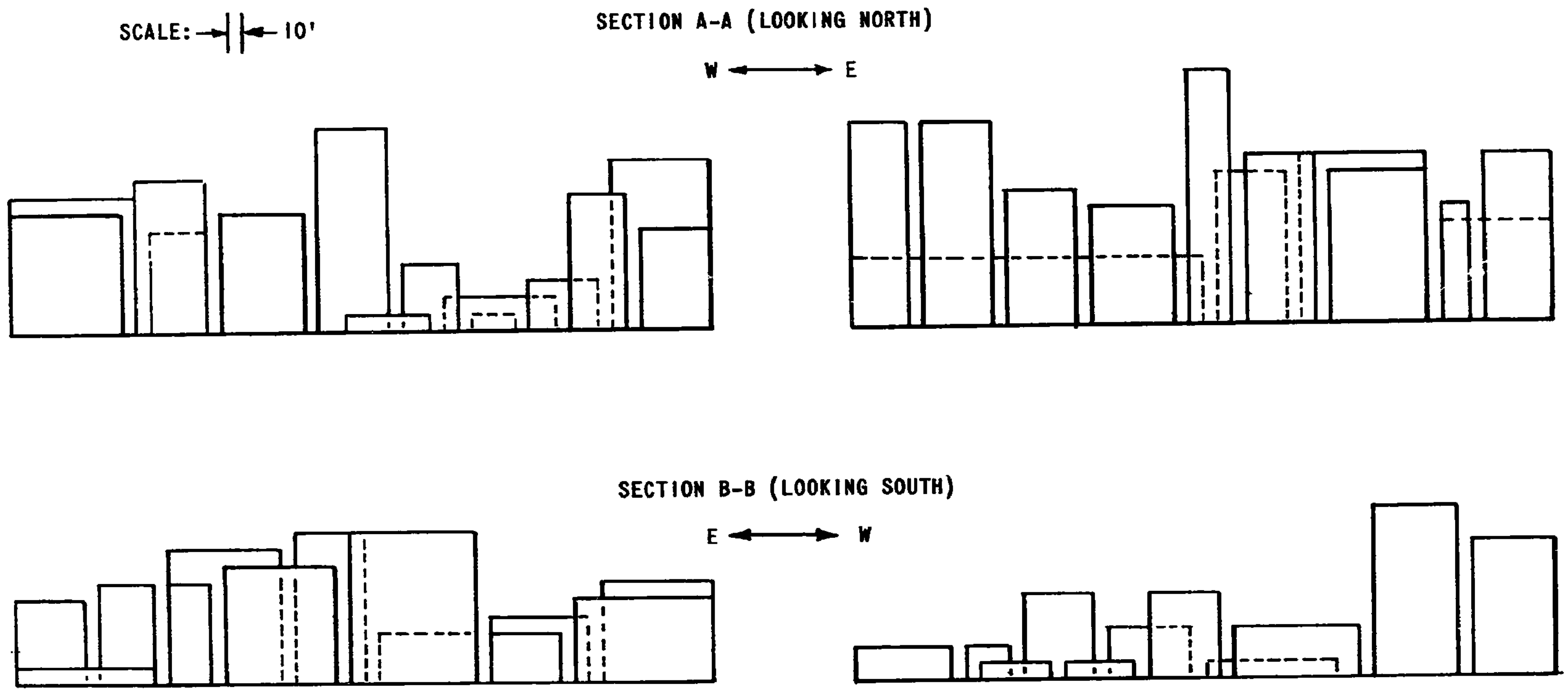


Figure 24 MAP OF CITY COMPLEX USED IN TARGET ANALYSIS PROFILE VIEW

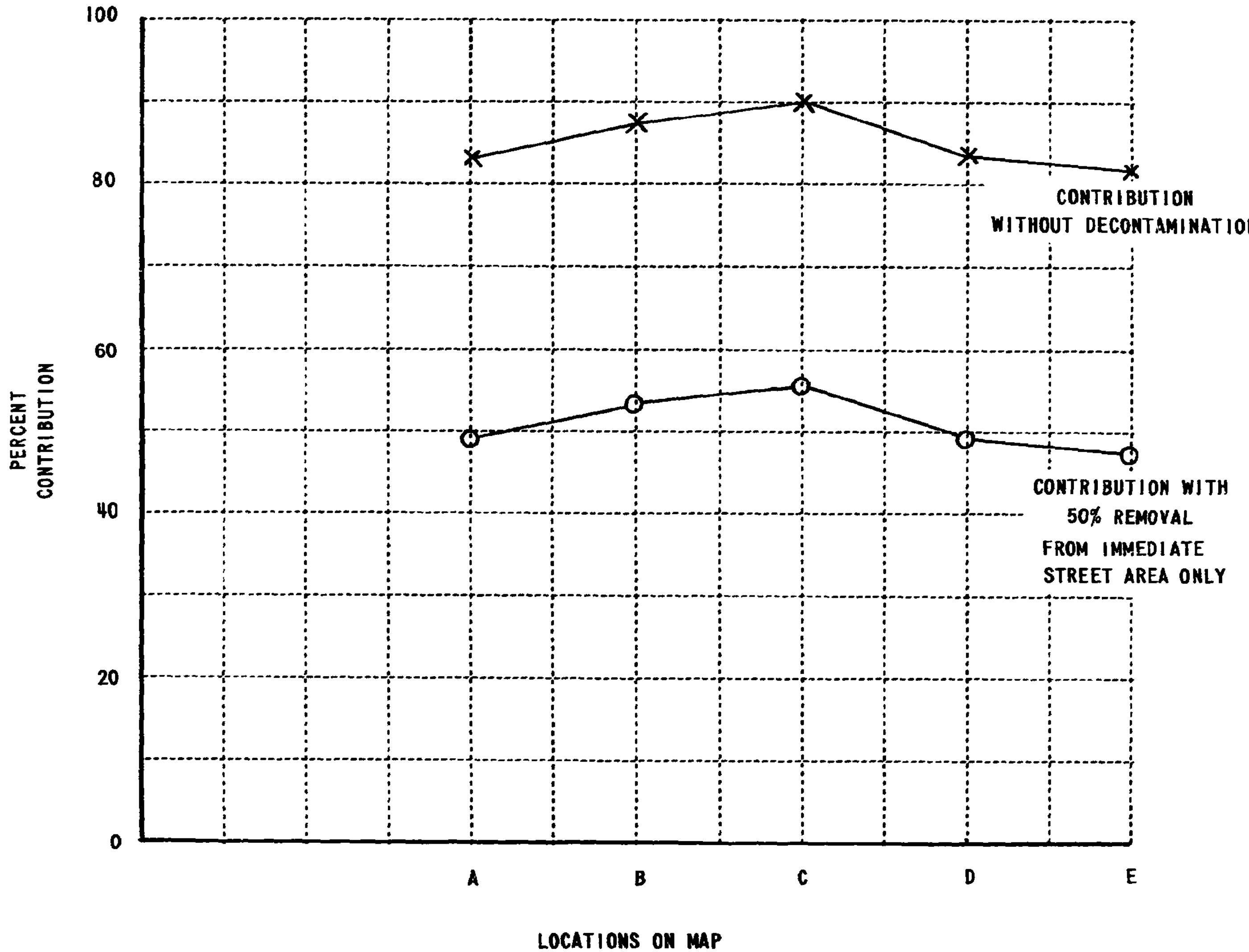


Figure 25 RELATIVE DOSE RATE ALONG CENTER OF STREET

1. Circular Sector with Constant Attenuation

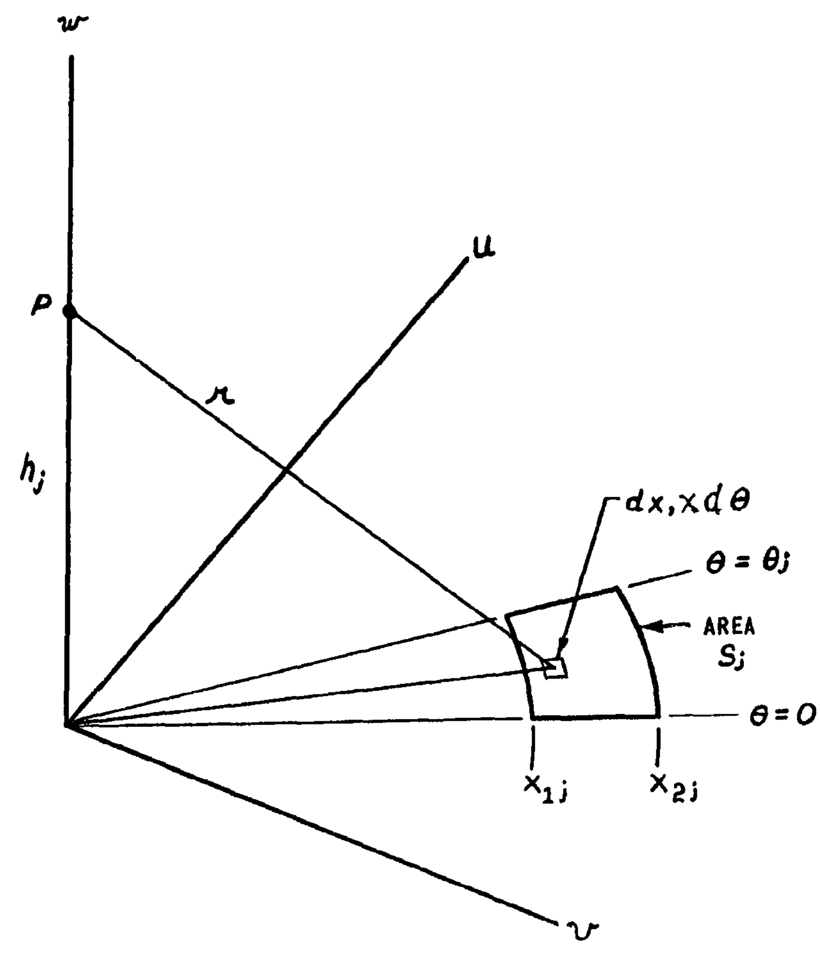


Figure 26 CIRCULAR SECTORS

Given : (1) The area, $S_j$ , defined as a circular sector in the $uv$ plane with minimum and maximum radii of $x_{1j}$, $x_{2j}$ respectively and subtending the angle $\theta_j$

(2) The point P lying along the axis to the circular sector, $S_j$ , a distance $h_j$ from the $uv$ plane.

(3) A uniform distribution of fallout material on $S_j$ such that the source strength of gamma ray flux in any direction is $I_0$ r/hr per unit area.

(4) The area $S_j$ is immersed in an isotropic homogeneous medium with total absorption coefficient $\mu$

(5) Buildup factor $\equiv$ 1

Find: The contribution to dose rate at the point P due to area $S_j$ assuming the attenuation of radiation is constant for all points on the area.

The dose rate contribution at point P will be given by:

$$D_j = \int_0^{\theta_j}\int_{x_{1j}}^{x_{2j}} \frac{I_0 e^{-\mu r} x \, dx \, d\theta}{r^2} \tag{8}$$

If the attenuation is constant over the region of integration, then $e^{-\mu r} = A_j$ = a constant and

$$D_j = I_0 A_j \int_0^{\theta_j}\int_{x_{1j}}^{x_{2j}} \frac{x \, dx \, d\theta}{r^2} \tag{9}$$

Also,

$$r^2 = x^2 + h^2$$

$$r\,dr = x\,dx \tag{10}$$

and

$$D_j = I_o A_j \int_0^{\theta_j} \int_{\sqrt{x_{1j}^2 + h_j^2}}^{\sqrt{x_{2j}^2 + h_j^2}} \frac{dr\,d\theta}{r} \tag{11}$$

Integrating,

$$D_j = I_o A_j \frac{\theta_j}{2} \log_e \left[ \frac{x_{2j}^2 + h_j^2}{x_{1j}^2 + h_j^2} \right] \tag{12}$$

2. Circular Sector with Attenuation

Given: Same as method A

Find: The contribution to dose rate at the point P due to area $S_j$ with consideration of the spatial variation of absorption.

It is now necessary to integrate 8 retaining the exponential term. Again using the transformation 10 we get,

$$D_j = \int_0^{\theta_j} \int_{\sqrt{x_{1j}^2 + h_j^2}}^{\sqrt{x_{2j}^2 + h_j^2}} \frac{I_o e^{-kr}\,dr\,d\theta}{r} \tag{13}$$

Now let
$$z = \mu r$$
$$dz = \mu dr$$
$$D_j = I_0 \int_0^{\theta_j}\int_{z_{1j}}^{z_{2j}} \frac{e^{-z}\, dz\, d\theta}{z} \qquad (14)$$

where
$$z_{1j} = \mu\sqrt{x_{1j}^2 + h_j^2}$$
$$z_{2j} = \mu\sqrt{x_{2j}^2 + h_j^2}$$

Integrating with respect to $\theta$

$$D_j = I_0 \theta_j \int_{z_{1j}}^{z_{2j}} \frac{e^{-z}\, dz}{z} \qquad (15)$$

This integral cannot be solved in closed form. The integral can be evaluated by machine using numerical methods. For hand computations the integral in equation 15 can be expressed in terms of the exponential integral:

$$E(z) = \int_z^{\infty} \frac{e^{-t}\, dt}{t} \qquad (16)$$

namely

$$\int_{z_1 j}^{z_2 j} \frac{e^{-z}\,dz}{z} = \int_{z_1 j}^{\infty} \frac{e^{-t}\,dt}{t} - \int_{z_2 j}^{\infty} \frac{e^{-t}\,dt}{t} \tag{17}$$

Values of the exponential integrals $E(z)$ are tabulated in standard tables.*

* Tables of Sine, Cosine and Exponential Integrals Works Project Administration for the City of New York, N.B.S. 1940

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APPENDIX I

STUDY OF FEASIBILITY OF DECONTAMINATION - ERIE COUNTY CIVIL DEFENSE EXERCISE "OPERATION VIGILANCE 1963"
18-19 January 1963

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Decontamination, Rehabilitation and Reclamation Members of Evacuation/ Survival Group, Consolidated Erie County Office of Civil Defense

March 1, 1963

SUMMARY

The radiation fallout pattern time history of civil defense exercise, "Operation Vigilance, 1963" is analyzed with respect to the availability of shelters for the population and the critical facilities and population areas in need of decontamination. In the southern part of the County, the natural decay of fallout will remove the need for decontamination. In the northern part, however, a general decontamination is needed to permit early re-use of large areas and large amounts of spot decontamination needed for access to and use of several critical facilities.

It was determined that decontamination was both possible and feasible. The decontamination plan consists of (1) flushing streets and roadways, (2) firehosing the roofs of structures and (3) the removal of the upper surface of ground surrounding the structures. The flushing and hosing operations could be done using available equipment, possibly supplemented by other suitably adapted apparatus. Removal of lawns or soil could be done by the dwelling or structure occupants on a regulated exposure time schedule. For the conditions existing in Operation Vigilance, 1963, in which approximately one-half of the city required decontamination treatment, the decontamination operation can be done in four to five weeks after the attack.

## INTRODUCTION

As a part of the exercise "Operation Vigilance 1963" conducted by the Consolidated Erie County Office of Civil Defense, a study was made of the problems involved in and the feasibility of decontaminating the areas affected by fallout. Since this exercise was based on the problems caused only by fallout from bombs assumed to have landed outside of Erie County, the additional complications that would have arisen in decontamination procedures in the presence of blast and fire damage were taken not to be applicable to this study.

The problem studied was to answer such questions as "what can be done to decontaminate access routes to critical facilities and to decontaminate the facilities themselves; and when can it be begun?", and "what is the feasibility of decontaminating the worst areas to advance the allowable date of reoccupancy?". To answer these questions, it was necessary to use the best available information on decontamination techniques. Data from Refs. 1 and 2 were used, with modification to compensate for difficulties that would be encountered in actual practice. Examples of such difficulties are: transporting of water from the nearest hydrant or other source; the routing of the decontamination apparatus, and allied problems required by the necessity that street flushing proceed from higher to lower elevations; the effects of abandoned vehicles in the streets; and the problems of frequently changing decontamination crews to avoid their overexposure. These complexities were assumed to result in average values of miles of street decontamination/vehicle/hour which are far less than actual vehicle velocities while flushing.

The admissible dosage for individuals is a determining factor in several respects, such as: (1) the time when a structure can be reoccupied without decontamination, (2) the completeness of decontamination needed, and (3) the levels of ambient radiation under which decontamination crews can operate for durations of practicable usefulness. This study is based on the assumption that the admissible individual dosages (in the worst cases) are 30 Roentgens in a day, 230 R in two weeks, or 1000 R during a year. These values, which are relatively high compared to the values often used in studies of community health problems, are based on Refs. 1 and 3. They must be considered to be emergency values for volunteer crews, since some individuals among the crews which receive the maximum admissible doses under these regulations will suffer immediate illness and/or permanent effects. However, examination of the results of this study and consideration of the consequences of the much greater fallout possible in heavier raids indicates that the values used are probably representative of what would be used in actual circumstances.

In performing this study, the information available from several sources was used. The fallout patterns were made available by the Radiological & Chemical Officer of the Civil Defense Office; maps, the comprehensive data on shelter locations and capacities, and the data on equipment available were provided by the Civil Defense Office Headquarters staff; and the "Operation Vigilance 1963" reports of the following services were made available and found very helpful:

| | | |
|---|---|---|
| Medical | Fire | Training |
| Welfare | Police | Northwest Zone |
| Resources and Production | Manpower | Northeast Zone |

In addition, the experience generated at Cornell Aeronautical Laboratory in performing the Office of Civil Defense Project "Radiological Target Analysis Procedures" was most helpful; and the writers wish to express appreciation for permission of the Laboratory to participate in "Operation Vigilance" and for assistance in publishing this report.

## SITUATION - OPERATION VIGILANCE 1963

At 1800 hours (6:00 pm) on 18 January 1963, a one megaton surface blast bomb was assumed to have fallen on the north end of Grand Island. A NW wind was assumed to have carried the fallout from this bomb into Erie County. A similar bomb near Erie, Pa. an hour later was also assumed but with little effect on Erie County. These bombs were assumed to have negligible blast and heat effects in Erie County.

As shown in Figure A-1, at H + 1 hour a zone of intense fallout (3000 R/hr at edge of zone and up to 10,000 R/hr or more in center) about three miles wide which, in Erie County, extended from the Niagara River between the South Grand Island Bridge and the Town of Tonawanda, across the Village of Kenmore, North East Buffalo, and Eggertsville, over the middle third of the Town of Cheektowaga and into the western half of the Village of Depew. In the surrounding area, the intensity at this time decreased steadily to 1000 R/hr along a line running from the Peace Bridge, southeastward through downtown Buffalo and Cazenovia Park, eastward through Ebenezer and the Town of West Seneca, then swinging northward through Alden and finally northwestward through the intersection of Main and Sheridan and into North Tonawanda.

At H + 49 hours, these boundaries had reduced from 3000 and 1000 R/hr to 30 and 10 R/hr respectively. At H + 2 weeks, these boundaries were 3 and 1 R/hr. In the very intense core, an oval area about three miles wide and 9 miles long in the NW/SE direction and centered at the University of Buffalo had intensities of 100 R/hr or more at H + 49 hours and 10 R/hr or more at H + 2 weeks.

## SHELTERS - COMMENTS

This exercise assumed that everyone had entered an available shelter with a radiation attenuation factor of at least 100. However, it should be pointed out that in actuality, this would not have been the case for two reasons. The first is that the hardest hit area is largely residential, having a very few large buildings. Thus, with the very small number of adequate home shelters now in existence and with most of the public shelters located in the larger buildings in the downtown and industrial areas (see Figure A-2), few of the people in the hardest hit area would have been able to reach adequate shelters. It is also pertinent to note that at 6 pm when the bomb fell, most of the population would have been at home. The second reason is that in the NW portion of Erie County, many of those persons out of doors at the time of the blast would have faced toward the blast and in most weather conditions, may have been temporarily blinded. Without assistance from others, they would not have been able to reach shelters.

The assumption is more representative of the probable case in the remainder of the County, especially where more public shelters are available, and where the fireball would have been more distant and lower on the horizon, so that intervening trees and buildings would have obscured much of the glare. However, even in this area, it is highly questionable if a sufficient number of adequate home and heighborhood shelters could have been reached in time under the present conditions of public awareness of the problem and knowledge of the location of the nearest adequate shelter. Based on estimates received from the Radiological Service combined with population estimates for the area covered by the fallout, the Medical Service report arrived at the following estimate of casualties from radiation: "Assuming that 400,000 persons living in the high fallout area were able to reach shelters with protection factors of 100, it was expected that there would be 20,000 deaths, 200,000 mild to severe cases of radiation illness and 180,000 not affected. In the event that there were people not in shelters at the time the fallout descended the degree of radiation injury would depend on the time spent outside the shelter before the person reached shelter." The limitation of shelters with factors of only 100 in a high fallout area is apparent.

These considerations are, in actuality, outside the province of this report. However, they became so startlingly clear during the conduct of this study that a comment on them was felt to be warranted here.

## NEEDS FOR DECONTAMINATION

The need for decontamination can be seen from the following data. Taking as allowable limits the criteria that an individual should not receive more than 30 R/day, 230 R in two weeks, or 1000 R in a year (or lifetime), a person with no previous exposure (i.e., having spent all of the time since the start of fallout in a perfect shelter), could at about H + 10 days safely reoccupy buildings in an area which had had 1000 R/hr at H + 1 hour. However, the corresponding times for safe reoccupation of buildings in an area having 1500 R/hr at H + 1 hour would be H + 3 weeks; for areas subjected to 3000 R/hr at H + 1 hour, the allowable entry time for permanent residence would be 2-1/2 months; and for 10,000 R/hr at H + 1 hour, the waiting period would be 7 months.

It can be seen from Figure A-1 that in the southern portion of the County it would be possible to leave the shelters and resume more or less normal occupancy in periods ranging from a few days to a few weeks. Within this period, some local decontamination would be required to allow the resumption, or continued operation, of essential services and utilities (fire, police, electricity, water, gas) and to provide access to and operation of hospitals and aid stations. In addition, there would be a desire to provide access to shelters and local fires and to permit transport and delivery of fuel oil, gasoline, and possibly some food.

Shelters are stocked for two weeks. Also, the radiation decay rate is such that there is nothing to be gained by moving a person from an inadequate shelter to an adequate one after, say, 48 hours. Therefore, in the southern part of the county there would be little urgent need for access to the shelters during the first two weeks. General decontamination will not be required in this area. Because of the large area involved, the time that would elapse before it became possible to emerge to start decontamination and the relatively short time during which general area decontamination would be needed in the southern part of the County, it is likely that in most instances the natural decay of the fallout will remove the need for such decontamination before it would be feasible to attend to it.

In the northern part of the county, however, Figure A-1 illustrates that approximately 20 sq. miles are contained in the hottest area where initial radiation appeared to be as high as 10,000 R/hr., another 50 square miles in the area affected by 3000 to 10,000 R/hr and 70 more square miles in the range 1500 to 3000 R/hr. If no decontamination were to take place in these areas, if the occupants were housed in perfect shelters (infinite radiation attenuation factors) and if the shelters could be restocked, the population might wait in the shelters for the required periods (7 months to 3 weeks) before reoccupying their homes and business in the normal way. If shelters with attenuation factors of about 100 were used, the times required before use of the shelters could be discontinued would be longer. Also, some deaths and much radiation sickness would have occurred and there would be urgent need for a large amount of evacuation (especially in the 10,000 R/hr at H + 1 area).

However, where the shelters are adequate, it is possible that, at the expense of extending the total duration of shelter occupancy somewhat, the occupants could, after a few days or weeks (depending on the situation), leave them for short periods each day. The permissible periods would depend on how much radiation they had received up to that time and the rates that would be encountered both inside and outside of the shelter in the future. Thus, with restocking and other assistance, many occupants in the most hard hit areas might continue to occupy the shelters in their area and participate in the decontamination of their own property. But, the times of occupancy would be long, for cramped quarters, and the determination of the allowable time out of the shelter would be complicated - varying from location to location and with the radiation history of each individual (especially where home shelters with varying attenuation factors are used) - so that its computation and regulation probably may be impractical.

In any event, extensive evacuation of shelter occupants in these areas at the earliest possible date may be necessary. Also, the 10,000 R/hr and 3000 R/hr areas would require extensive general area decontamination if the populations in them are to be allowed to reoccupy their buildings within a reasonable time.

In addition to the necessary general decontamination to permit early re-use of large areas, a large amount of spot decontamination would be needed in these areas. Access to and use of several facilities in this area is needed at the earliest possible date. These facilities include a major electrical power generating station, two major hospitals, a number of water intakes and storage facilities, several gas storage tanks and petroleum processing and storage areas, and several universities and colleges, in addition to numerous police and fire stations. Further, the contaminated area cuts across all of the major routes of communication between Buffalo and Niagara Falls. Finally, if the occupants of the shelters are to be evacuated or restocked, pending the completion of decontamination operations, access to the shelters is necessary.

DECONTAMINATION - TECHNIQUES AND FEASIBILITY

Decontamination techniques and equipment required have been developed and reported upon in Refs. 1-5. Experimental tests have been conducted indicating the effectiveness of various types of equipment, such as nozzles and tank pumping apparatus, and the operating procedures and conditions under which they would be used. From the results indicated in reports 1-5, decontamination could successfully be accomplished by (1) flushing of roadways; (2) washdown of roofs; and (3) removal of lawns or upper few inches of soil. It is shown in these references that effective removal of fallout type particles can be achieved on roadways and roofs by using highway flushers and/or fire hoses, provided that certain practicable flow rates and pressures are used and that the correct flushing techniques are employed. In structures where the upper one or two levels could be closed off and left vacant for six to seven months, washdown of the roof sometimes may be dispensed with.

There are roughly 40 miles of roadway per square mile in heavily populated areas and 10 miles per square mile (or less) in semi-rural areas. The hot areas are approximately evenly divided between both types of areas. Thus, there are 3500 miles of roadway to be flushed. Considering traffic difficulties (abandoned cars on the roadway), loading of water, travel between work and water supply (fire hydrants), changing of crews in a safe place, a water flusher equipped with the required nozzles and apparatus is expected to clean one mile of roadway each hour. If we have 10 flushers in the area, this implies that there are 350 hours of work for each of them (or two weeks working around the clock). If the rate of flushing achieved is faster, then less effort will be required. Now, if the minimum useful period of a crew to work is one hour, operations could begin one day (24 hours) after attack in the area where radiation is 1500 R/hour* and could progress inwards into the hot areas. Start times are two days or later for the 3000 R/hour* area and 5 days for the 10,000 R/hour* zones. By working inwards toward the hottest zone, these start times can be complied with. A report from the Resources and Production Service** indicates that it would be impractical to use any of the vehicles in the Transportation Service (such as tank trucks, tractors, etc.) for a period of

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* Radiation at one hour I (1).

** A technical group associated with Erie County Civil Defense.

H to H + 7 days.* From H + 7 to H + 28, it is possible to decontaminate this equipment so that by the end of that period all resources would be available. The number of vehicles are much greater than the ten vehicles assumed in the above analysis but further investigation is needed to determine the number equipped with suitable apparatus for the task.

Fire-house crews could perform roof-washdown immediately after the road-flushers. They would, of course, be limited by the same work time limit (one hour at the start) as the road-flusher crews. If a fire-hose crew spends 5 minutes on each roof washdown, then 17 crews are required to follow each road flusher or 170 crews each hour.** The flushing crews may consist of members chosen from the public, supervised by one member from the fire department so that fire-department personnel will be available for the entire operation.

Whereas decontamination of roadways and roofs require somewhat special equipment and experienced manpower to at least direct the operation, the decontamination of the ground around each dwelling or structure could be done by each individual occupant. The operation would consist of removing the top few inches of lawn or soil and depositing it at the back or remote part of the yard and covering it with about a foot of dirt. The bare essentials for equipment would be shovels and wheelbarrows.

For the sake of efficiency, residents might form teams so that some work the shovels and others the barrows. It is estimated that each man can remove five square feet of sod per minute or 300 square feet per hour. If each lot contains 10,000 square feet, then 33 hours of labor are required. This work may be divided into 5-1/2 days of 6 hours each. The entry time for a 6-hour shift is 5 days for the 1500 R/hr zone, 10 days for the 3000 R/hr zone, and 24 days in the 10,000 R/hr zone. Therefore, by the end of 4 or 5 weeks after impact enough general decontamination can have taken place to allow people to resume normal activities. Direction would have to be provided to each occupant or worker for the allowable time or frequency he should be able to remain out of the shelter depending on the radiation history. The task of decontamination of ground areas could be done more efficiently if earth moving equipment and operating manpower were available and the area was accessible to this type of equipment. Narrow strips or small areas cannot accommodate the large machine equipment or spacing between dwelling may restrict the machines from access to rear areas. There are, however, many types and sizes of machines of the garden tractor variety that could be used in small areas.

* An assumption for this experiment.

** Based on 50 ft lots, thus 100 houses/mile each side of street - or 200 houses/mile on both sides of street.

Instead of removing and depositing radioactive ground in back areas, it may be more feasible in some cases to dispose of the ground similar to a snow removal operation. A further study of all the types and sizes of available equipment that could be adapted to the task is necessary.

Some areas like hospitals and utilities need to be decontaminated very early. If the utilities can be operated without extensive human supervision, it would be best to defer decontamination for at least 48 hours in the 3000 R/hr area and 5 days in the 10,000 R/hr area, i.e., until it is possible to work a crew at least an hour. Fortunately, many of these structures are massive and portions of them constitute fallout shelters. Therefore, in many instances, an operating crew will be available on the premises to perform brief tasks of maintenance and adjustment as soon as the radiation level permits some egress. Emergency decontamination around hospitals and critical tasks at utilities might proceed as soon as a 10-minute opportunity is available, i.e., 11 hours after attack for the 3000 R/hr area and 28 hours in the 10,000 R/hr area. It is important that personnel who will perform the work are prepared to be very efficient because at 10 minutes per man, many men will be needed. The eventual decontamination around hospitals in the "hot" area should endeavor to remove contaminant up to a distance of 300 ft. Cleanup should be quite meticulous near the building, but does not need to be quite so careful farther away. Furthermore, roof washdown will be required unless it is feasible to vacate the upper two or three floors of the hospital. Until the decontamination has been completed, patients will have to be well sheltered.

## INFLUENCE OF WEATHER

The foregoing analysis was performed using data applicable to fair weather with temperatures above freezing. The exercise being considered here took place in January and Western New York encounters several months of freezing weather each year.

From the nature of the operations involved, it appears that if a snow cover existed at the time of fallout and was not deeply covered by additional snow before decontamination began, techniques for removal of the snow from streets, roofs and yards would suffice. In this case, the snow (or at least the top few inches of it) would have to be removed to a remote area, not just plowed to the side. Clearly, a brief thaw or a heavy snowfall before decontamination could begin would seriously complicate matters, as would situations of drifting snow. In extreme cases, any general decontamination would have to be deferred until Spring.

In the event of cold weather without a snow cover, an even less hopeful situation would exist. Tests with street sweepers and vacuum cleaners have shown less favorable results (Ref. 1), providing less complete and less efficient removal. However, in cold dry weather, such methods would have to be used to the extent possible. Streets, sidewalks and paved areas could be swept or vacuumed, flat lawns might be vacuumed. At present, there appears to be no practicable method for treating large areas of roofs or rough ground during such weather.

One favorable aspect of weather is the effect of rain. A heavy shower, subsequent to the initial fallout, would wash most of the particles containing radioactive materials off sloping roofs and crowned roads. Some of the material would be washed into sewers, other portions into gutters. Subsequent decontamination efforts would be simplified appreciably.

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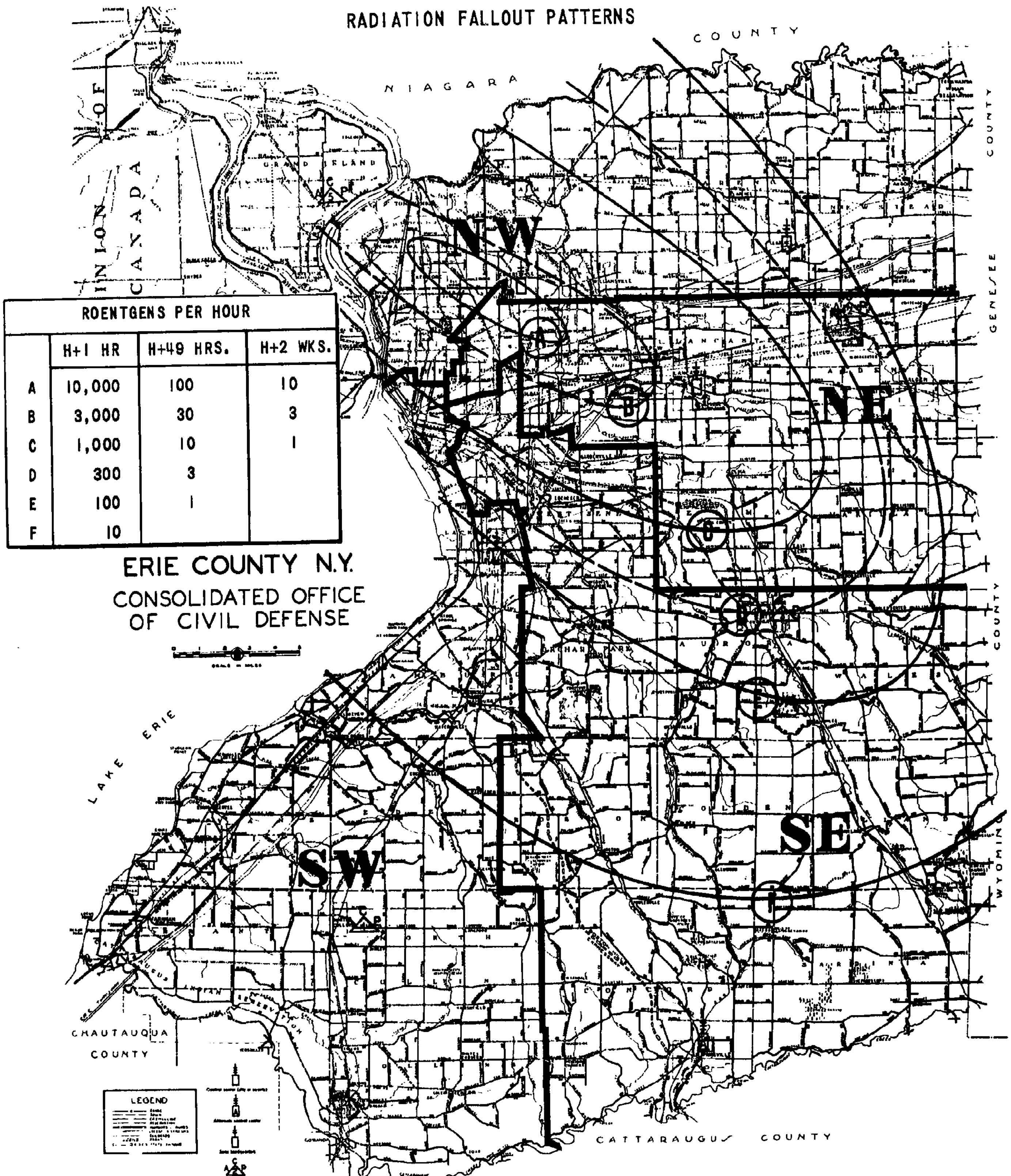



| | ROENTGENS PER HOUR | | |
|---|---|---|---|
| | H+1 HR | H+49 HRS. | H+2 WKS. |
| A | 10,000 | 100 | 10 |
| B | 3,000 | 30 | 3 |
| C | 1,000 | 10 | 1 |
| D | 300 | 3 | |
| E | 100 | 1 | |
| F | 10 | | |

1960 CENSUS (TOTAL 1,064,688)

City of Buffalo 532,759

City of Lackawanna 29,564

City of Tonawanda 21,561

VILLAGES

| | | | |
|---|---|---|---|
| Alden | 2,042 | Blasdell | 3,909 |
| Williamsville | 6,316 | Hamburg | 9,145 |
| East Aurora | 6,791 | Depew (part) | 6,221 |
| Farnham | 422 | Lancaster | 12,254 |
| Depew (part) | 7,359 | Akron | 2,841 |
| Sloan | 5,803 | North Collins | 1,574 |
| Gowanda (part) | 1,079 | Orchard Park | 3,278 |
| Springville | 3,852 | Kenmore | 21,261 |
| Angola | 2,499 | | |

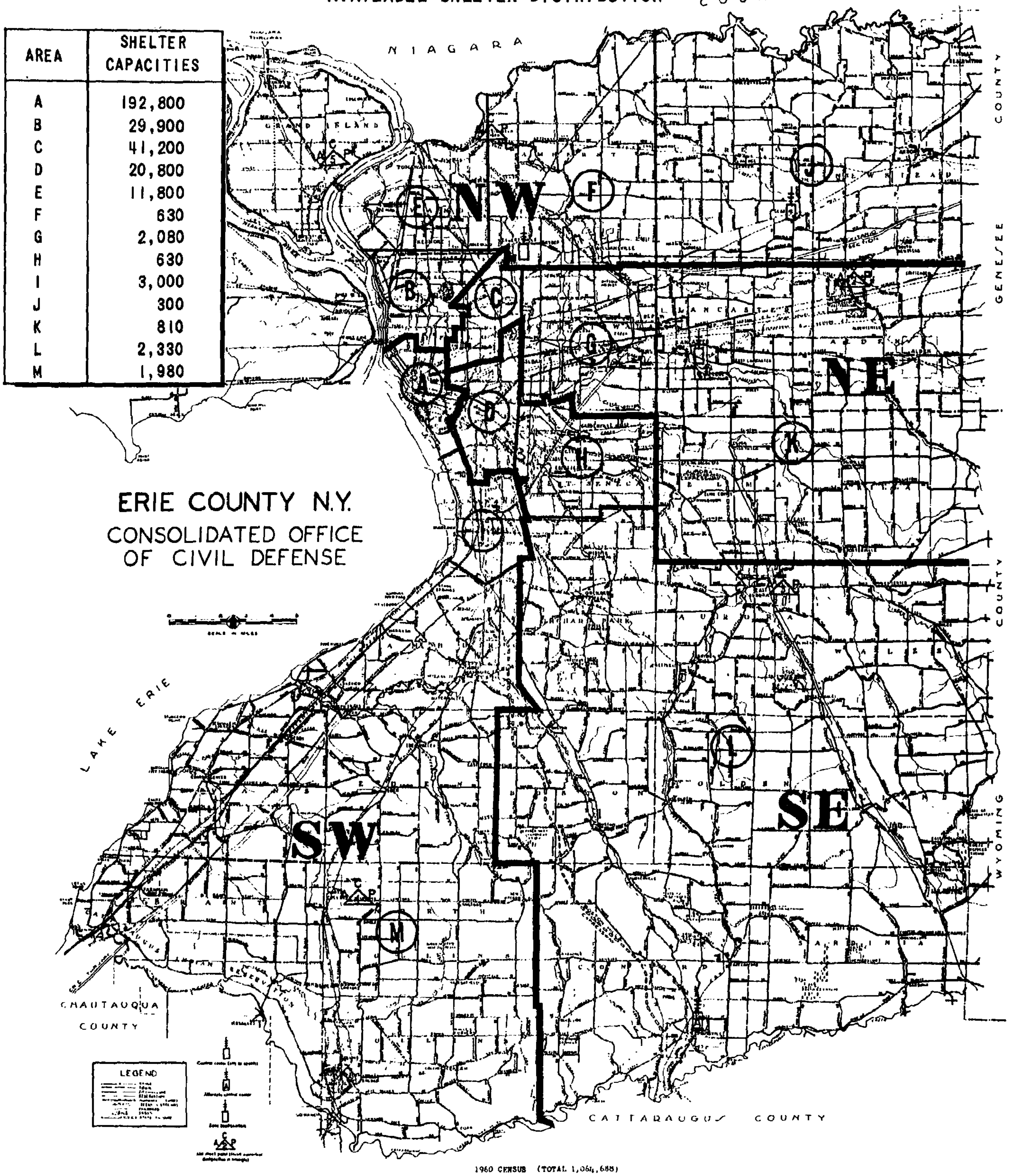
TOWNS

| | | | | | |
|---|---|---|---|---|---|
| Alden | 7,615 | Collins | 6,984 | Lancaster | 25,605 |
| Amherst | 62,937 | Concord | 6,452 | Marilla | 2,252 |
| Aurora | 12,888 | Eden | 6,630 | Newstead | 5,825 |
| Boston | 5,106 | Elma | 7,468 | North Collins | 3,805 |
| Brant | 2,290 | Evans | 12,078 | Orchard Park | 15,876 |
| Cheektowaga | 84,056 | Grand Island | 9,607 | Sardinia | 2,145 |
| Clarence | 13,267 | Hamburg | 41,288 | Tonawanda | 105,032 |
| Colden | 2,384 | Holland | 2,304 | Wales | 1,910 |
| | | | | West Seneca | 33,644 |

Figure la

## AVAILABLE SHELTER DISTRIBUTION

| AREA | SHELTER CAPACITIES |
|---|---|
| A | 192,800 |
| B | 29,900 |
| C | 41,200 |
| D | 20,800 |
| E | 11,800 |
| F | 630 |
| G | 2,080 |
| H | 630 |
| I | 3,000 |
| J | 300 |
| K | 810 |
| L | 2,330 |
| M | 1,980 |




1960 CENSUS (TOTAL 1,064,688)

City of Buffalo 532,759 — City of Lackawanna 29,564 — City of Tonawanda 21,561

**VILLAGES**

| | | | |
|---|---|---|---|
| Alden | 2,042 | Blasdell | 3,909 |
| Williamsville | 6,316 | Hamburg | 9,145 |
| East Aurora | 6,791 | Depew (part) | 6,221 |
| Farnham | 422 | Lancaster | 12,254 |
| Depew (part) | 7,359 | Akron | 2,841 |
| Sloan | 5,803 | North Collins | 1,574 |
| Gowanda (part) | 1,079 | Orchard Park | 3,278 |
| Springville | 3,852 | Kenmore | 21,261 |
| Angola | 2,499 | | |

**TOWNS**

| | | | | | |
|---|---|---|---|---|---|
| Alden | 7,615 | Collins | 6,984 | Lancaster | 25,605 |
| Amherst | 62,337 | Concord | 6,452 | Marilla | 2,252 |
| Aurora | 12,830 | Eden | 6,630 | Newstead | 5,825 |
| Boston | 5,106 | Elma | 7,468 | North Collins | 3,805 |
| Brant | 2,290 | Evans | 12,078 | Orchard Park | 15,876 |
| Cheektowaga | 84,056 | Grand Island | 9,607 | Sardinia | 2,145 |
| Clarence | 13,267 | Hamburg | 41,288 | Tonawanda | 105,032 |
| Colden | 2,384 | Holland | 2,304 | Wales | 1,710 |
| | | | | West Seneca | 33,644 |

Figure 2a

# APPENDIX II

## Digital Computer Results for Target Area Shielding Analysis

(These data illustrate the methods of computation and are discussed in Chapter VIII)

## Table 5
## CIRCULAR DISCS

SECTOR GEOMETRY METHOD WITH ATTENUATION

PROJECT RADTAP (W/A=E12-110) —— J.RINALDO,DEPT. 4707

RELATIVE DOSAGE COMPUTATIONS —— DOSE RATES FROM CIRCULAR DISCS OF VARIOUS RADII

CIRCULAR SECTOR METHOD WITH ATTENUATION

LOCATION OF COORDINATE ORIGIN IS THREE FEET ABOVE CENTER OF CIRCULAR DISC AIR ATTENUATION

PARAMETERS ——

D SUB INFINITY = 2.5309E 01 NUMBER OF AREAS = 28

INTEGRATIONS VIA ADAMS-MOULTON VARIABLE INCREMENT METHOD

| AREA NO. | AREA IDENTIFICATION | H(FT) | R ONE (FT) | R TWO (FT) | THETA (RAD) | DOSE | PERCENTAGE OF D INF |
|---|---|---|---|---|---|---|---|
| 1 | CIRCULAR DISC OF RADIUS R2 | 3.000 | 0. | 10.000 | 6.28368 | 7.67939E 00 | 30.3425 |
| 2 | | 3.000 | 0. | 20.000 | 6.28368 | 1.14488E 01 | 45.2362 |
| 3 | | 3.000 | 0. | 30.000 | 6.28368 | 1.39380E 01 | 55.0714 |
| 4 | | 3.000 | 0. | 40.000 | 6.28368 | 1.55323E 01 | 61.3706 |
| 5 | | 3.000 | 0. | 50.000 | 6.28368 | 1.67315E 01 | 66.1090 |
| 6 | | 3.000 | 0. | 60.000 | 6.28368 | 1.76799E 01 | 69.8562 |
| 7 | | 3.000 | 0. | 70.000 | 6.28368 | 1.84558E 01 | 72.9221 |
| 8 | | 3.000 | 0. | 80.000 | 6.28368 | 1.91061E 01 | 75.4914 |
| 9 | | 3.000 | 0. | 90.000 | 6.28368 | 1.96606E 01 | 77.6822 |
| 10 | | 3.000 | 0. | 100.000 | 6.28368 | 2.01403E 01 | 79.5775 |
| 11 | | 3.000 | 0. | 120.000 | 6.28368 | 2.09301E 01 | 82.6984 |
| 12 | | 3.000 | 0. | 140.000 | 6.28368 | 2.15543E 01 | 85.1646 |
| 13 | | 3.000 | 0. | 160.000 | 6.28368 | 2.20598E 01 | 87.1617 |
| 14 | | 3.000 | 0. | 180.000 | 6.28368 | 2.24763E 01 | 88.8077 |
| 15 | | 3.000 | 0. | 200.000 | 6.28368 | 2.28247E 01 | 90.1840 |
| 16 | | 3.000 | 0. | 250.000 | 6.28368 | 2.34822E 01 | 92.7820 |
| 17 | | 3.000 | 0. | 300.000 | 6.28368 | 2.39357E 01 | 94.5740 |
| 18 | | 3.000 | 0. | 350.000 | 6.28368 | 2.42595E 01 | 95.8531 |
| 19 | | 3.000 | 0. | 400.000 | 6.28368 | 2.44962E 01 | 96.7884 |
| 20 | | 3.000 | 0. | 450.000 | 6.28368 | 2.46723E 01 | 97.4844 |
| 21 | | 3.000 | 0. | 500.000 | 6.28368 | 2.48055E 01 | 98.0104 |
| 22 | | 3.000 | 0. | 550.000 | 6.28368 | 2.49071E 01 | 98.4122 |
| 23 | | 3.000 | 0. | 600.000 | 6.28368 | 2.49855E 01 | 98.7219 |
| 24 | | 3.000 | 0. | 700.000 | 6.28368 | 2.50940E 01 | 99.1506 |
| 25 | | 3.000 | 0. | 800.000 | 6.28368 | 2.51610E 01 | 99.4154 |
| 26 | | 3.000 | 0. | 900.000 | 6.28368 | 2.52031E 01 | 99.5814 |
| 27 | | 3.000 | 0. | 1000.000 | 6.28368 | 2.52299E 01 | 99.6875 |
| 28 | | 3.000 | 0. | 10000.000 | 6.28368 | 2.52807E 01 | 99.8883 |

Table 6

**CYLINDRICAL FARM HOUSE**

SECTOR GEOMETRY METHOD WITH ATTENUATION

PROJECT RADTAP (W/A=E12-110) —— J.RINALDO,DEPT. 4707
RELATIVE DOSAGE COMPUTATIONS —— DOSE RATE CALCULATIONS FOR CYLINDRICAL FARMHOUSE ON CIRCULAR DISC
COMPUTED FOR VARIATIONS IN PARAMETERS
LOCATION OF COORDINATE ORIGIN IS CENTER OF FARMHOUSE THREE FEET ABOVE FLOOR

PARAMETERS ——
D SUB INFINITY = 2.5309E 01 NUMBER OF AREAS = 42
INTEGRATIONS VIA ADAMS-MOULTON VARIABLE INCREMENT METHOD

| AREA NO. | AREA IDENTIFICATION | H(FT) | R ONE (FT) | R TWO (FT) | THETA (RAD) | DOSE | PERCENTAGE OF D INF |
|---|---|---|---|---|---|---|---|
| 1 | ROOFTOP (VARIOUS RADII) 2 INCH WOOD | 7.000 | 0. | 20.000 | 6.28368 | 6.20707E 00 | 24.5252 |
| 2 | OUTSIDE AREA | 3.000 | 20.000 | 600.000 | 6.28368 | 1.07361E 01 | 42.4203 |
| 3 | ROOFTOP 2 INCH WOOD WALLS | 7.000 | 0. | 30.000 | 6.28368 | 8.00011E 00 | 31.6097 |
| 4 | OUTSIDE AREA | 3.000 | 30.000 | 600.000 | 6.28368 | 9.24328E 00 | 36.5217 |
| 5 | ROOFTOP 2 INCH WOOD WALLS | 7.000 | 0. | 40.000 | 6.28368 | 9.20432E 00 | 36.3678 |
| 6 | OUTSIDE AREA | 3.000 | 40.000 | 600.000 | 6.28368 | 8.09833E 00 | 31.9978 |
| 7 | ROOFTOP 2 INCH WOOD WALLS | 7.000 | 0. | 50.000 | 6.28368 | 1.02473E 01 | 40.4886 |
| 8 | OUTSIDE AREA | 3.000 | 50.000 | 600.000 | 6.28368 | 7.18428E 00 | 28.3863 |
| 9 | ROOFTOP 2 INCH WOOD WALLS | 7.000 | 0. | 60.000 | 6.28368 | 1.09332E 01 | 43.1988 |
| 10 | OUTSIDE AREA | 3.000 | 60.000 | 600.000 | 6.28368 | 6.43207E 00 | 25.4141 |
| 11 | ROOFTOP (VARIOUS HEIGHTS) 2 IN. WOOD | 12.000 | 0. | 30.000 | 6.28368 | 5.43444E 00 | 21.4723 |
| 12 | OUTSIDE AREA | 3.000 | 30.000 | 600.000 | 6.28368 | 9.24328E 00 | 36.5217 |
| 13 | ROOFTOP 2 INCH WOOD WALLS | 17.000 | 0. | 30.000 | 6.28368 | 3.86252E 00 | 15.2614 |
| 14 | OUTSIDE AREA | 3.000 | 30.000 | 600.000 | 6.28368 | 9.24328E 00 | 36.5217 |
| 15 | ROOFTOP 2 INCH WOOD WALLS | 22.000 | 0. | 30.000 | 6.28368 | 2.84340E 00 | 11.2347 |
| 16 | OUTSIDE AREA | 3.000 | 30.000 | 600.000 | 6.28368 | 9.24328E 00 | 36.5217 |
| 17 | ROOFTOP 2 INCH WOOD WALLS | 22.000 | 0. | 50.000 | 6.28368 | 4.75320E 00 | 18.7807 |
| 18 | OUTSIDE AREA | 3.000 | 50.000 | 600.000 | 6.28368 | 7.18428E 00 | 28.3863 |
| 19 | ROOFTOP 2 INCH WOOD WALLS | 27.000 | 0. | 30.000 | 6.28368 | 2.15156E 00 | 8.5012 |
| 20 | OUTSIDE AREA | 3.000 | 30.000 | 600.000 | 6.28368 | 9.24328E 00 | 36.5217 |
| 21 | ROOFTOP 2 INCH WOOD WALLS | 32.000 | 0. | 30.000 | 6.28368 | 1.66633E 00 | 6.5839 |
| 22 | OUTSIDE AREA | 3.000 | 30.000 | 600.000 | 6.28368 | 9.24328E 00 | 36.5217 |
| 23 | ROOFTOP (VARIOUS WALLS) 4 INCH WOOD | 7.000 | 0. | 20.000 | 6.28368 | 5.76350E 00 | 22.6516 |
| 24 | OUTSIDE AREA | 3.000 | 20.000 | 600.000 | 6.28368 | 9.02095E 00 | 35.6432 |
| 25 | ROOFTOP 4 INCH WOOD WALLS | 7.000 | 0. | 30.000 | 6.28368 | 7.33687E 00 | 28.9971 |
| 26 | OUTSIDE AREA | 3.000 | 30.000 | 600.000 | 6.28368 | 7.94227E 00 | 31.3812 |
| 27 | ROOFTOP 4 INCH WOOD WALLS | 7.000 | 0. | 40.000 | 6.28368 | 8.43700E 00 | 33.3360 |
| 28 | OUTSIDE AREA | 3.000 | 40.000 | 600.000 | 6.28368 | 7.06446E 00 | 27.9126 |
| 29 | ROOFTOP 4 INCH WOOD WALLS | 7.000 | 0. | 50.000 | 6.28368 | 9.14349E 00 | 36.1274 |
| 30 | OUTSIDE AREA | 3.000 | 50.000 | 600.000 | 6.28368 | 6.33624E 00 | 25.0355 |
| 31 | ROOFTOP 4 INCH WOOD WALLS | 7.000 | 0. | 60.000 | 6.28368 | 9.64701E 00 | 38.1169 |
| 32 | OUTSIDE AREA | 3.000 | 60.000 | 600.000 | 6.28368 | 5.72114E 00 | 22.6051 |
| 33 | ROOFTOP 6 INCH WOOD WALLS | 7.000 | 0. | 20.000 | 6.28368 | 5.39159E 00 | 21.3031 |
| 34 | OUTSIDE AREA | 3.000 | 20.000 | 600.000 | 6.28368 | 7.77022E 00 | 30.7014 |
| 35 | ROOFTOP 6 INCH WOOD WALLS | 7.000 | 0. | 30.000 | 6.28368 | 6.74102E 00 | 26.6349 |
| 36 | OUTSIDE AREA | 3.000 | 30.000 | 600.000 | 6.28368 | 6.94184E 00 | 27.4284 |
| 37 | ROOFTOP 6 INCH WOOD WALLS | 7.000 | 0. | 40.000 | 6.28368 | 7.64335E 00 | 30.2001 |
| 38 | OUTSIDE AREA | 3.000 | 40.000 | 600.000 | 6.28368 | 6.24021E 00 | 24.6561 |
| 39 | ROOFTOP 6 INCH WOOD WALLS | 7.000 | 0. | 50.000 | 6.28368 | 8.19174E 00 | 32.3669 |
| 40 | OUTSIDE AREA | 3.000 | 50.000 | 600.000 | 6.28368 | 5.64300E 00 | 22.2964 |
| 41 | ROOFTOP 6 INCH WOOD WALLS | 7.000 | 0. | 60.000 | 6.28368 | 8.56159E 00 | 33.8283 |
| 42 | OUTSIDE AREA | 3.000 | 60.000 | 600.000 | 6.28368 | 5.12815E 00 | 20.2622 |

TOTAL RELATIVE DOSE = 3.0509E 02
=1205.444 PER CENT OF BACKGROUND RADIATION

## Table 7
### RESIDENTIAL AREA FIXED ATTENUATION

PROJECT RADTAP (M/A=E12-110) --- J.RINALDO,DEPT. 470/
RELATIVE DOSAGE COMPUTATIONS --- TEST CASE - RESIDENTIAL AREA (HAND CHECK) ---RUN 8B
PROJECT RADTAP E12-110 J. D. RINALDO
LOCATION OF COORDINATE ORIGIN IS CENTER OF CENTER HOUSE 3 FEET ABOVE FLOOR
PARAMETERS ---
SUB INFINITY = 2.5309E 01 NUMBER OF AREAS = 48

| AREA NO. | AREA IDENTIFICATION | H(FT) | R ONE (FT) | R TWO (FT) | THETA (RAD) | WALL THICKNESS(IN) | A SUB J | DOSE |
|---|---|---|---|---|---|---|---|---|
| 1 | CENTER ROOF | 12.000 | 0.000 | 20.000 | 6.28400 | 2.0000 | 7.600E-01 | 3.17297E 00 |
| 2 | ROOF 1 LEFT | 12.000 | 37.500 | 62.500 | 1.00000 | 6.0000 | 4.400E-01 | 2.11280E-01 |
| 3 | ROOF 1 RIGHT | 12.000 | 37.500 | 62.500 | 1.00000 | 6.0000 | 4.400E-01 | 2.11280E-01 |
| 4 | ROOF 2 LEFT | 12.000 | 87.500 | 112.500 | 0.50000 | 10.0000 | 2.600E-01 | 3.21951E-02 |
| 5 | ROOF 2 RIGHT | 12.000 | 87.500 | 112.500 | 0.50000 | 10.0000 | 2.600E-01 | 3.21951E-02 |
| 6 | ROOF 3 LEFT | 12.000 | 137.500 | 162.500 | 0.33300 | 14.0000 | 1.500E-01 | 8.29067E-03 |
| 7 | ROOF 3 RIGHT | 12.000 | 137.500 | 162.500 | 0.33300 | 14.0000 | 1.500E-01 | 8.29067E-03 |
| 8 | ROOF 4 LEFT | 12.000 | 187.500 | 212.500 | 0.25000 | 18.0000 | 8.600E-02 | 2.68129E-03 |
| 9 | ROOF 4 RIGHT | 12.000 | 187.500 | 212.500 | 0.25000 | 18.0000 | 8.600E-02 | 2.68129E-03 |
| 10 | ROOF 5 LEFT | 12.000 | 237.500 | 262.500 | 0.20000 | 22.0000 | 5.000E-02 | 9.98524E-04 |
| 11 | ROOF 5 RIGHT | 12.000 | 237.500 | 262.500 | 0.20000 | 22.0000 | 5.000E-02 | 9.98524E-04 |
| 12 | ROOF 6 LEFT | 12.000 | 287.500 | 312.500 | 0.16670 | 26.0000 | 2.900E-02 | 4.02446E-04 |
| 13 | ROOF 6 RIGHT | 12.000 | 287.500 | 312.500 | 0.16670 | 26.0000 | 2.900E-02 | 4.02446E-04 |
| 14 | CENTER YARD - LAWN | 3.000 | 20.000 | 37.500 | 6.28400 | 2.0000 | 7.600E-01 | 2.96424E 00 |
| 15 | SIDE YARD 1-2 LEFT | 3.000 | 62.500 | 87.500 | 0.66660 | 6.0000 | 4.400E-01 | 9.85234E-02 |
| 16 | SIDE YARD 1-2 RIGHT | 3.000 | 62.500 | 87.500 | 0.66660 | 6.0000 | 4.400E-01 | 9.85234E-02 |
| 17 | SIDE YARD 2-3 LEFT | 3.000 | -112.500 | 137.500 | 0.40000 | 10.0000 | 2.600E-01 | 2.08575E-02 |
| 18 | SIDE YARD 2-3 RIGHT | 3.000 | 112.500 | 137.500 | 0.40000 | 10.0000 | 2.600E-01 | 2.08575E-02 |
| 19 | SIDE YARD 3-4 LEFT | 3.000 | 162.500 | 187.500 | 0.28600 | 14.0000 | 1.500E-01 | 6.13721E-03 |
| 20 | SIDE YARD 3-4 RIGHT | 3.000 | 162.500 | 187.500 | 0.28600 | 14.0000 | 1.500E-01 | 6.13721E-03 |
| 21 | SIDE YARD 4-5 LEFT | 3.000 | 212.500 | 237.500 | 0.22200 | 18.0000 | 8.600E-02 | 2.12314E-03 |
| 22 | SIDE YARD -5 RIGHT | 3.000 | 212.500 | 237.500 | 0.22200 | 18.0000 | 8.600E-02 | 2.12314E-03 |
| 23 | SIDE YARD 5-6 LEFT | 3.000 | 262.500 | 287.500 | 0.18200 | 22.0000 | 5.000E-02 | 8.27744E-04 |
| 24 | SIDE YARD 5-6 RIGHT | 3.000 | 262.500 | 287.500 | 0.18200 | 22.0000 | 5.000E-02 | 8.27744E-04 |
| 25 | BACK YARD CENTER L | 3.000 | 37.500 | 300.000 | 0.98400 | 2.0000 | 7.600E-01 | 1.55274E 00 |
| 26 | BACK YARD CENTER R | 3.000 | 37.500 | 300.000 | 0.98400 | 2.0000 | 7.600E-01 | 1.55274E 00 |
| 27 | FRONT YARD CENTER L | 3.000 | 37.500 | 300.000 | 0.98400 | 2.0000 | 7.600E-01 | 1.55274E 00 |
| 28 | FRONT YARD CENTER R | 3.000 | 37.500 | 300.000 | 0.98400 | 2.0000 | 7.600E-01 | 1.55274E 00 |
| 29 | BACK YARD B LEFT | 3.000 | 59.600 | 300.000 | 0.31000 | 6.0000 | 4.400E-01 | 2.20274E-01 |
| 30 | BACK YARD B RIGHT | 3.000 | 59.600 | 300.000 | 0.31000 | 6.0000 | 4.400E-01 | 2.20274E-01 |
| 31 | FRONT YARD B LEFT | 3.000 | 59.600 | 300.000 | 0.31000 | 6.0000 | 4.400E-01 | 2.20274E-01 |
| 32 | FRONT YARD B RIGHT | 3.000 | 59.600 | 300.000 | 0.31000 | 6.0000 | 4.400E-01 | 2.20274E-01 |
| 33 | BACK YARD C LEFT | 3.000 | 110.200 | 300.000 | 0.09800 | 10.0000 | 2.600E-01 | 2.55097E-02 |
| 34 | BACK YARD C RIGHT | 3.000 | 110.200 | 300.000 | 0.09800 | 10.0000 | 2.600E-01 | 2.55097E-02 |
| 35 | FRONT YARD C LEFT | 3.000 | 110.200 | 300.000 | 0.09800 | 10.0000 | 2.600E-01 | 2.55097E-02 |
| 36 | FRONT YARD C RIGHT | 3.000 | 110.200 | 300.000 | 0.09800 | 10.0000 | 2.600E-01 | 2.55097E-02 |
| 37 | BACK YARD D LEFT | 3.000 | 160.100 | 300.000 | 0.05600 | 14.0000 | 1.500E-01 | 5.27401E-03 |
| 38 | BACK YARD D RIGHT | 3.000 | 160.100 | 300.000 | 0.05600 | 14.0000 | 1.500E-01 | 5.27401E-03 |
| 39 | FRONT YARD D LEFT | 3.000 | 160.100 | 300.000 | 0.05600 | 14.0000 | 1.500E-01 | 5.27401E-03 |
| 40 | FRONT YARD D RIGHT | 3.000 | 160.100 | 300.000 | 0.05600 | 14.0000 | 1.500E-01 | 5.27401E-03 |
| 41 | BACK YARD E LEFT | 3.000 | 220.200 | 300.000 | 0.03800 | 18.0000 | 8.600E-02 | 1.01048E-03 |
| 42 | BACK YARD E RIGHT | 3.000 | 220.200 | 300.000 | 0.03800 | 18.0000 | 8.600E-02 | 1.01048E-03 |
| 43 | FRONT YARD E LEFT | 3.000 | 220.200 | 300.000 | 0.03800 | 18.0000 | 8.600E-02 | 1.01048E-03 |
| 44 | FRONT YARD E RIGHT | 3.000 | 220.200 | 300.000 | 0.03800 | 18.0000 | 8.600E-02 | 1.01048E-03 |
| 45 | BACK YARD F LEFT | 3.000 | 275.700 | 300.000 | 0.00800 | 22.0000 | 5.000E-02 | 3.37840E-05 |
| 46 | BACK YARD F RIGHT | 3.000 | 275.700 | 300.000 | 0.00800 | 22.0000 | 5.000E-02 | 3.37840E-05 |
| 47 | FRONT YARD F LEFT | 3.000 | 275.700 | 300.000 | 0.00800 | 22.0000 | 5.000E-02 | 3.37840E-05 |
| 48 | FRONT YARD F RIGHT | 3.000 | 275.700 | 300.000 | 0.00800 | 22.0000 | 5.000E-01 | 3.37840E-04 |

TOTAL RELATIVE DOSE = 1.4126E 01
= 55.815 PER CENT OF BACKGROUND RADIATION

## Table 8
## RESIDENTIAL AREA WITH ATTENUATION

DUTTON GEOMETRY METHOD WITH ATTENUATION

PROJECT RADTAP (L7A-E12-110) --- J.H. ALDO, DEPT. 4707
RELATIVE DOSAGE COMPUTATIONS --- RESIDENTIAL AREA (RELATIVE TO INFINITE PLANE)
2 INCH WOODEN WALLS, ROOFS 15 FEBRUARY 1965
LOCATION OF COORDINATE ORIGIN IS CENTER OF CENTER HOUSE 3 FEET ABOVE FLOOR.

PARAMETERS ---
D SUB INFINITY = 2.5309E 01 NUMBER OF AREAS = 48
INTEGRATIONS VIA ADAMS-MOULTON VARIABLE INCREMENT METHOD

| AREA NO. | AREA IDENTIFICATION | H(FT) | R ONE (FT) | R TWO (FT) | THETA (RAD) | DOSE | PERCENTAGE OF D INF |
|---|---|---|---|---|---|---|---|
| 1 | CENTER ROOF | 12.000 | 0.000 | 25.000 | 6.28400 | 3.72564E 00 | 14.7562 |
| 2 | ROOF 1 LEFT | 12.000 | 37.500 | 62.500 | 1.00000 | 3.42245E-01 | 1.3522 |
| 3 | ROOF 1 RIGHT | 12.000 | 37.500 | 62.500 | 1.00000 | 3.42245E-01 | 1.3522 |
| 4 | ROOF 2 LEFT | 12.000 | 87.500 | 112.500 | 0.50000 | 5.69200E-02 | 0.2249 |
| 5 | ROOF 2 RIGHT | 12.000 | 87.500 | 112.500 | 0.50000 | 5.69200E-02 | 0.2249 |
| 6 | ROOF 3 LEFT | 12.000 | 137.500 | 162.500 | 0.33300 | 1.67112E-02 | 0.0660 |
| 7 | ROOF 3 RIGHT | 12.000 | 137.500 | 162.500 | 0.33300 | 1.67112E-02 | 0.0660 |
| 8 | ROOF 4 LEFT | 12.000 | 187.500 | 212.500 | 0.25000 | 6.22605E-03 | 0.0246 |
| 9 | ROOF 4 RIGHT | 12.000 | 187.500 | 212.500 | 0.25000 | 6.22605E-03 | 0.0246 |
| 10 | ROOF 5 LEFT | 12.000 | 237.500 | 262.500 | 0.20000 | 2.63622E-03 | 0.0104 |
| 11 | ROOF 5 RIGHT | 12.000 | 237.500 | 262.500 | 0.20000 | 2.63622E-03 | 0.0104 |
| 12 | ROOF 6 LEFT | 12.000 | 287.500 | 312.500 | 0.16670 | 1.21375E-03 | 0.0048 |
| 13 | ROOF 6 RIGHT | 12.000 | 287.500 | 312.500 | 0.16670 | 1.21375E-03 | 0.0048 |
| 14 | CENTER YARD - LAWN | 3.000 | 25.000 | 37.500 | 6.28400 | 2.37670E 00 | 9.3906 |
| 15 | SIDE YARD 1-2 LEFT | 3.000 | 62.500 | 87.500 | 0.66666 | 1.05099E-01 | 0.4153 |
| 16 | SIDE YARD 1-2 RIGHT | 3.000 | 62.500 | 87.500 | 0.66666 | 1.05099E-01 | 0.4153 |
| 17 | SIDE YARD 2-3 LEFT | 3.000 | 112.500 | 137.500 | 0.40000 | 2.94914E-02 | 0.1165 |
| 18 | SIDE YARD 2-3 RIGHT | 3.000 | 112.500 | 137.500 | 0.40000 | 2.94914E-02 | 0.1165 |
| 19 | SIDE YARD 3-4 LEFT | 3.000 | 162.500 | 187.500 | 0.28600 | 1.17520E-02 | 0.0464 |
| 20 | SIDE YARD 3-4 RIGHT | 3.000 | 162.500 | 187.500 | 0.28600 | 1.17520E-02 | 0.0464 |
| 21 | SIDE YARD 4-5 LEFT | 3.000 | 212.500 | 237.500 | 0.22200 | 5.53765E-03 | 0.0219 |
| 22 | SIDE YARD 4-5 RIGHT | 3.000 | 212.500 | 237.500 | 0.22200 | 5.53765E-03 | 0.0219 |
| 23 | SIDE YARD 5-6 LEFT | 3.000 | 262.500 | 287.500 | 0.18200 | 2.89943E-03 | 0.0115 |
| 24 | SIDE YARD 5-6 RIGHT | 3.000 | 262.500 | 287.500 | 0.18200 | 2.89943E-03 | 0.0115 |
| 25 | BACK YARD CENTER L | 3.000 | 37.500 | 300.000 | 0.98400 | 1.14485E 00 | 4.5234 |
| 26 | BACK YARD CENTER R | 3.000 | 37.500 | 300.000 | 0.98400 | 1.14485E 00 | 4.5234 |
| 27 | FRONT YARD CENTER L | 3.000 | 37.500 | 300.000 | 0.98400 | 1.14485E 00 | 4.5234 |
| 28 | FRONT YARD CENTER R | 3.000 | 37.500 | 300.000 | 0.98400 | 1.14485E 00 | 4.5234 |
| 29 | BACK YARD B LEFT | 3.000 | 59.600 | 300.000 | 0.31000 | 2.11634E-01 | 0.8362 |
| 30 | BACK YARD B RIGHT | 3.000 | 59.600 | 300.000 | 0.31000 | 2.11634E-01 | 0.8362 |
| 31 | FRONT YARD B LEFT | 3.000 | 59.600 | 300.000 | 0.31000 | 2.11634E-01 | 0.8362 |
| 32 | FRONT YARD B RIGHT | 3.000 | 59.600 | 300.000 | 0.31000 | 2.11634E-01 | 0.8362 |
| 33 | BACK YARD C LEFT | 3.000 | 110.200 | 300.000 | 0.09800 | 3.21677E-02 | 0.1271 |
| 34 | BACK YARD C RIGHT | 3.000 | 110.200 | 300.000 | 0.09800 | 3.21677E-02 | 0.1271 |
| 35 | FRONT YARD C LEFT | 3.000 | 110.200 | 300.000 | 0.09800 | 3.21677E-02 | 0.1271 |
| 36 | FRONT YARD C RIGHT | 3.000 | 110.200 | 300.000 | 0.09800 | 3.21677E-02 | 0.1271 |
| 37 | BACK YARD D LEFT | 3.000 | 160.100 | 300.000 | 0.05600 | 9.17224E-03 | 0.0362 |
| 38 | BACK YARD D RIGHT | 3.000 | 160.100 | 300.000 | 0.05600 | 9.18250E-03 | 0.0363 |
| 39 | FRONT YARD D LEFT | 3.000 | 160.100 | 300.000 | 0.05600 | 9.18250E-03 | 0.0363 |
| 40 | FRONT YARD D RIGHT | 3.000 | 160.100 | 300.000 | 0.05600 | 9.18250E-03 | 0.0363 |
| 41 | BACK YARD E LEFT | 3.000 | 220.200 | 300.000 | 0.03600 | 2.45428E-03 | 0.0097 |
| 42 | BACK YARD E RIGHT | 3.000 | 220.200 | 300.000 | 0.03600 | 2.45428E-03 | 0.0097 |
| 43 | FRONT YARD E LEFT | 3.000 | 220.200 | 300.000 | 0.03600 | 2.45428E-03 | 0.0097 |
| 44 | FRONT YARD E RIGHT | 3.000 | 220.200 | 300.000 | 0.03600 | 2.45428E-03 | 0.0097 |
| 45 | BACK YARD F LEFT | 3.000 | 275.700 | 300.000 | 0.00800 | 1.14931E-04 | 0.0005 |
| 46 | BACK YARD F RIGHT | 3.000 | 275.700 | 300.000 | 0.00800 | 1.14931E-04 | 0.0005 |
| 47 | FRONT YARD F LEFT | 3.000 | 275.700 | 300.000 | 0.00800 | 1.14931E-04 | 0.0005 |
| 48 | FRONT YARD F RIGHT | 3.000 | 275.700 | 300.000 | 0.00800 | 1.14931E-04 | 0.0005 |

TOTAL RELATIVE DOSE = 1.2869E 01
= 50.849 PER CENT OF BACKGROUND RADIATION

## Table 9

### SHOPPING PLAZA WITH FIXED ATTENUATION

PROJECT RADTAP (W/A=E12-11C) --- J.RINALDO,DEPT. 4707
RELATIVE DOSAGE COMPUTATIOUS --- DOSE RATE CALCULATIONS FOR SHOPPING PLAZA FIXED ATTENUATION)
RADTAP PROJECT E12-110 22 JAN 63 J. RINALDO CONCRETE STRUCTURE
LOCATION OF COORDINATE ORIGIN IS CENTER OF CENTER STORE

PARAMETERS ---
D SUB INFINITY = 2.5309E 01 NUMBER OF AREAS = 37

| AREA NO. | AREA IDENTIFICATION | H(FT) | R ONE (FT) | R TWO (FT) | THETA (RAD) | WALL THICK-NESS(IN) | A SUB J | DOSE |
|---|---|---|---|---|---|---|---|---|
| 1 | CENTER ROOFTOP | 12.000 | 0. | 56.419 | 6.28369 | 12.0000 | 1.220E-03 | 1.2085[illegible] |
| 2 | ROOFTOP FOR HOUSE 1 RIGHT | 12.000 | 56.419 | 149.500 | 1.00500 | 24.0000 | 1.490E-06 | 1.43093E-04 |
| 3 | ROOFTOP FOR HOUSE 1 LEFT | 12.000 | 56.419 | 149.500 | 1.00500 | 24.0000 | 1.490E-06 | 1.43093E-04 |
| 4 | ROOFTOP FOR HOUSE 2 RIGHT | 12.000 | 149.500 | 249.500 | 0.50130 | 36.0000 | 1.800E-09 | 4.60290E-10 |
| 5 | ROOFTOP FOR HOUSE 2 LEFT | 12.000 | 149.500 | 249.500 | 0.50130 | 36.0000 | 1.800E-09 | 4.60290E-10 |
| 6 | ROOFTOP FOR HOUSE 3 RIGHT | 12.000 | 249.500 | 349.500 | 0.33390 | 48.0000 | 2.210E-12 | 2.48294E-13 |
| 7 | ROOFTOP FOR HOUSE 3 LEFT | 12.000 | 249.500 | 349.500 | 0.33390 | 48.0000 | 2.210E-12 | 2.48294E-13 |
| 8 | ROOFTOP FOR HOUSE 4 RIGHT | 12.000 | 349.500 | 449.500 | 0.25030 | 60.0000 | 2.690E-15 | 1.69269E-16 |
| 9 | ROOFTOP FOR HOUSE 4 LEFT | 12.000 | 349.500 | 449.500 | 0.25030 | 60.0000 | 2.690E-15 | 1.69269E-16 |
| 10 | ROOFTOP FOR HOUSE 5 RIGHT | 12.000 | 449.500 | 549.500 | 0.20020 | 72.0000 | 3.250E-18 | 1.30621E-19 |
| 11 | ROOFTOP FOR HOUSE 5 LEFT | 12.000 | 449.500 | 549.500 | 0.20020 | 72.0000 | 3.250E-18 | 1.30621E-19 |
| 12 | ROOFTOP FOR HOUSE 6 RIGHT | 12.000 | 549.500 | 600.000 | 0.16680 | 90.0000 | 3.970E-21 | 5.81954E-22 |
| 13 | ROOFTOP FOR HOUSE 6 LEFT | 12.000 | 549.500 | 600.000 | 0.16680 | 90.0000 | 3.970E-21 | 5.81954E-22 |
| 14 | BACK LOT 1 RIGHT | 3.000 | 56.419 | 600.000 | 0.79050 | 12.0000 | 1.220E-03 | 2.27964E-03 |
| 15 | BACK LOT 1 LEFT | 3.000 | 56.419 | 600.000 | 0.79050 | 12.0000 | 1.220E-03 | 2.27964E-03 |
| 16 | BACK LOT 2 RIGHT | 3.000 | 95.987 | 600.000 | 0.46300 | 24.0000 | 1.490E-06 | 1.26401E-06 |
| 17 | BACK LOT 2 LEFT | 3.000 | 95.987 | 600.000 | 0.46300 | 24.0000 | 1.490E-06 | 1.26401E-06 |
| 18 | BACK LOT 3 RIGHT | 3.000 | 197.472 | 600.000 | 0.12200 | 36.0000 | 1.800E-09 | 2.44026E-10 |
| 19 | BACK LOT 3 LEFT | 3.000 | 197.472 | 600.000 | 0.12200 | 36.0000 | 1.800E-09 | 2.44026E-10 |
| 20 | BACK LOT 4 RIGHT | 3.000 | 300.842 | 600.000 | 0.05600 | 48.0000 | 2.250E-12 | 9.69727E-14 |
| 21 | BACK LOT 4 LEFT | 3.000 | 300.842 | 600.000 | 0.05600 | 48.0000 | 2.250E-12 | 9.69727E-14 |
| 22 | BACK LOT 5 RIGHT | 3.000 | 404.204 | 600.000 | 0.03000 | 60.0000 | 2.690E-15 | 3.19761E-17 |
| 23 | BACK LOT 5 LEFT | 3.000 | 404.204 | 600.000 | 0.03000 | 60.0000 | 2.690E-15 | 3.19761E-17 |
| 24 | BACK LOT 6 RIGHT | 3.000 | 506.072 | 600.000 | 0.02000 | 72.0000 | 3.250E-18 | 1.10660E-20 |
| 25 | BACK LOT 6 LEFT | 3.000 | 506.072 | 600.000 | 0.02000 | 72.0000 | 3.250E-18 | 1.10660E-20 |
| 26 | FRONT LOT 1 RIGHT | 3.000 | 56.419 | 600.000 | 0.79050 | 0. | 1.000E 00 | 1.86774E 00 |
| 27 | FRONT LOT 1 LEFT | 3.000 | 56.419 | 600.000 | 0.79050 | 0. | 1.000E 00 | 1.86774E 00 |
| 28 | FRONT LOT 2 RIGHT | 3.000 | 95.987 | 600.000 | 0.46300 | 12.0000 | 1.220E-03 | 1.03495E-03 |
| 29 | FRONT LOT 2 LEFT | 3.000 | 95.987 | 600.000 | 0.46300 | 12.0000 | 1.220E-03 | 1.03495E-03 |
| 30 | FRONT LOT 3 RIGHT | 3.000 | 197.472 | 600.000 | 0.12200 | 24.0000 | 1.490E-06 | 2.01999E-07 |
| 31 | FRONT LOT 3 LEFT | 3.000 | 197.472 | 600.000 | 0.12200 | 24.0000 | 1.490E-06 | 2.01999E-07 |
| 32 | FRONT LOT 4 RIGHT | 3.000 | 300.842 | 600.000 | 0.05600 | 36.0000 | 1.800E-09 | 6.95930E-11 |
| 33 | FRONT LOT 4 LEFT | 3.000 | 300.842 | 600.000 | 0.05600 | 36.0000 | 1.800E-09 | 6.95930E-11 |
| 34 | FRONT LOT 5 RIGHT | 3.000 | 404.204 | 600.000 | 0.03000 | 48.0000 | 2.210E-12 | 2.61852E-14 |
| 35 | FRONT LOT 5 LEFT | 3.000 | 404.204 | 600.000 | 0.03000 | 48.0000 | 2.210E-12 | 2.61852E-14 |
| 36 | FRONT LEFT 6 RIGHT | 3.000 | 506.072 | 600.000 | 0.02000 | 60.0000 | 2.690E-15 | 9.15921E-18 |
| 37 | FRONT LOT 6 LEFT | 3.000 | 506.072 | 600.000 | 0.02000 | 60.0000 | 2.690E-15 | 9.15921E-18 |

TOTAL RELATIVE DOSE = 3.7541E 00
= 14.833 PER CENT OF BACKGROUND RADIATION

## Table 10

### SHOPPING PLAZA WITH ATTENUATION

SECTOR GEOMETRY METHOD WITH ATTENUATION

PROJECT RADTAP (W/A=E12-110) --- J.R. ALDO, DEPT. 4707
RELATIVE DOSAGE COMPUTATIONS --- DOSE RATE CALCULATIONS FOR SHOPPING PLAZA (WITH ATTENUATION)
RADTAP PROJECT E12-110 22 JAN 63 J. RINALDO CONCRETE STRUCTURE

LOCATION OF COORDINATE ORIGIN IS CENTER OF CENTER STORE

PARAMETERS ---
D SUB INFINITY = 2.5309E 01 NUMBER OF AREAS = 37
INTEGRATIONS VIA ADAMS-MOULTON VARIABLE INCREMENT METHOD

| AREA NO. | AREA IDENTIFICATION | H(FT) | R ONE (FT) | R TWO (FT) | THETA (RAD) | DOSE | PERCENTAGE OF D INF |
|---|---|---|---|---|---|---|---|
| 1 | CENTER ROOFTOP | 12.000 | 0. | 56.419 | 0.28366 | 4.57618E-01 | 1.6081 |
| 2 | ROOFTOP FOR HOUSE 1 RIGHT | 12.000 | 56.419 | 149.500 | 1.00500 | 2.85693E-05 | 0.0001 |
| 3 | ROOFTOP FOR HOUSE 1 LEFT | 12.000 | 56.419 | 149.500 | 1.00500 | 2.85693E-05 | 0.0001 |
| 4 | ROOFTOP FOR HOUSE 2 RIGHT | 12.000 | 149.500 | 249.500 | 0.50130 | 9.86255E-15 | 0.0000 |
| 5 | ROOFTOP FOR HOUSE 2 LEFT | 12.000 | 149.500 | 249.500 | 0.50130 | 9.86255E-15 | 0.0000 |
| 6 | ROOFTOP FOR HOUSE 3 RIGHT | 12.000 | 249.500 | 349.500 | 0.33390 | 2.95337E-24 | 0.0000 |
| 7 | ROOFTOP FOR HOUSE 3 LEFT | 12.000 | 249.500 | 349.500 | 0.33390 | 2.95337E-24 | 0.0000 |
| 8 | ROOFTOP FOR HOUSE 4 RIGHT | 12.000 | 349.500 | 449.500 | 0.25030 | 1.18497E-33 | 0.0000 |
| 9 | ROOFTOP FOR HOUSE 4 LEFT | 12.000 | 349.500 | 449.500 | 0.25030 | 1.18497E-33 | 0.0000 |
| 10 | ROOFTOP FOR HOUSE 5 RIGHT | 12.000 | 449.500 | 549.500 | 0.20020 | 0. | 0. |
| 11 | ROOFTOP FOR HOUSE 5 LEFT | 12.000 | 449.500 | 549.500 | 0.20020 | 0. | 0. |
| 12 | ROOFTOP FOR HOUSE 6 RIGHT | 12.000 | 549.500 | 600.000 | 0.16660 | 0. | 0. |
| 13 | ROOFTOP FOR HOUSE 6 LEFT | 12.000 | 549.500 | 600.000 | 0.16660 | 0. | 0. |
| 14 | BACK LOT 1 RIGHT | 3.000 | 56.419 | 600.000 | 0.79050 | 6.85113E-05 | 0.0003 |
| 15 | BACK LOT 1 LEFT | 3.000 | 56.419 | 600.000 | 0.79050 | 6.85113E-05 | 0.0003 |
| 16 | BACK LOT 2 RIGHT | 3.000 | 95.987 | 600.000 | 0.46300 | 2.63592E-06 | 0.0000 |
| 17 | BACK LOT 2 LEFT | 3.000 | 95.987 | 600.000 | 0.46300 | 2.63592E-06 | 0.0000 |
| 18 | BACK LOT 3 RIGHT | 3.000 | 197.472 | 600.000 | 0.12200 | 3.99113E-12 | 0.0000 |
| 19 | BACK LOT 3 LEFT | 3.000 | 197.472 | 600.000 | 0.12200 | 3.99113E-12 | 0.0000 |
| 20 | BACK LOT 4 RIGHT | 3.000 | 300.842 | 600.000 | 0.05600 | 1.02126E-15 | 0.0000 |
| 21 | BACK LOT 4 LEFT | 3.000 | 300.842 | 600.000 | 0.05600 | 1.02126E-15 | 0.0000 |
| 22 | BACK LOT 5 RIGHT | 3.000 | 404.204 | 600.000 | 0.03000 | 2.88616E-19 | 0.0000 |
| 23 | BACK LOT 5 LEFT | 3.000 | 404.204 | 600.000 | 0.03000 | 2.88616E-19 | 0.0000 |
| 24 | BACK LOT 6 RIGHT | 3.000 | 506.072 | 600.000 | 0.02000 | 7.84067E-23 | 0.0000 |
| 25 | BACK LOT 6 LEFT | 3.000 | 506.072 | 600.000 | 0.02000 | 7.84067E-23 | 0.0000 |
| 26 | FRONT LOT 1 RIGHT | 3.000 | 56.419 | 600.000 | 0.79050 | 9.58816E-01 | 3.7884 |
| 27 | FRONT LOT 1 LEFT | 3.000 | 56.419 | 600.000 | 0.79050 | 9.58816E-01 | 3.7884 |
| 28 | FRONT LOT 2 RIGHT | 3.000 | 95.987 | 600.000 | 0.46300 | 4.37554E-05 | 0.0002 |
| 29 | FRONT LOT 2 LEFT | 3.000 | 95.987 | 600.000 | 0.46300 | 4.37554E-05 | 0.0002 |
| 30 | FRONT LOT 3 RIGHT | 3.000 | 197.472 | 600.000 | 0.12200 | 4.76358E-09 | 0.0000 |
| 31 | FRONT LOT 3 LEFT | 3.000 | 197.472 | 600.000 | 0.12200 | 4.76358E-09 | 0.0000 |
| 32 | FRONT LOT 4 RIGHT | 3.000 | 300.842 | 600.000 | 0.05600 | 1.09447E-12 | 0.0000 |
| 33 | FRONT LOT 4 LEFT | 3.000 | 300.842 | 600.000 | 0.05600 | 1.09447E-12 | 0.0000 |
| 34 | FRONT LOT 5 RIGHT | 3.000 | 404.204 | 600.000 | 0.03000 | 2.91356E-16 | 0.0000 |
| 35 | FRONT LOT 5 LEFT | 3.000 | 404.204 | 600.000 | 0.03000 | 2.91356E-16 | 0.0000 |
| 36 | FRONT LEFT 6 RIGHT | 3.000 | 506.072 | 600.000 | 0.02000 | 7.62103E-20 | 0.0000 |
| 37 | FRONT LOT 6 LEFT | 3.000 | 506.072 | 600.000 | 0.02000 | 7.62103E-20 | 0.0000 |

TOTAL RELATIVE DOSE = 2.3756E 00
= 9.366 PER CENT OF BACKGROUND RADIATION

TABLE 11

Relative Dose Rate Along Center of Street

| Origin | Contribution No Decontamination | Contribution 50% Remnant |
|---|---|---|
| A | 83.4 % | 49.4 % |
| B | 87.6 % | 53.6 % |
| C | 90.0 % | 56.0 % |
| D | 83.4 % | 49.4 % |
| E | 81.7 % | 47.7 % |

Table 12

TYPICAL DATA RUN FOR CITY COMPLEX

RECTANGULAR GEOMETRY METHOD WITH FLOATING ORIGIN AND FIXED ATTENUATION

PROJECT RADTAP (W/A=E12-110) —— J.RINALDO, DEPT.470

RELATIVE DOSAGE COMPUTATIONS —— 161 AREAS —— CITY COMPLEX TARGET AREA ——

INTEGRATIONS ON X VIA SIMPSON RULE
Y VIA ADAMS-MOULTON VARAIBLE INCREMENT METHOD

PARAMETERS —— D SUB INFINITY = 2.5309E 01
NUMBER OF AREAS = 161

SAVED INPUT DATA APPEARS IN FILE 1 OF BINARY TAPE 5

ATTENUATION COEFFICIENTS

| CODE | MEDIUM | MU(/FT) |
|---|---|---|
| ER | EFFECTIVE AIR | 2.0960E-02 |
| AR | AIR | 3.3833E-03 |
| CN | CONCRETE | 6.7056E 00 |
| BR | BRICK | 5.3547E 00 |
| ST | STONE | 6.0537E 00 |
| WD | WOOD | 2.3520E-01 |

LIST OF AREAS PROCESSED

| AREA | IDENTIFICATION | ALT. | K | X(K) | Y(K) | K | X(K) | Y(K) | K | X(K) | Y(K) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | BUILDING 1 8 STORY BRICK | 96.0 | 1 | 0. | 600.0 | 3 | 90.0 | 500.0 | | | |
| | | | 2 | 0. | 500.0 | 4 | 90.0 | 600.0 | | | |
| 2 | ALLEY BETWEEN BUILDINGS 1 AND 3 | 0. | 1 | 90.0 | 600.0 | 3 | 100.0 | 500.0 | | | |
| | | | 2 | 90.0 | 500.0 | 4 | 100.0 | 600.0 | | | |
| 3 | BUILDING 3 6 STORY BRICK | 72.0 | 1 | 100.0 | 600.0 | 3 | 140.0 | 500.0 | | | |
| | | | 2 | 100.0 | 500.0 | 4 | 140.0 | 600.0 | | | |
| 4 | ALLEY BETWEEN BUILDING 3 AND 5 | 0. | 1 | 140.0 | 600.0 | 3 | 150.0 | 500.0 | | | |
| | | | 2 | 140.0 | 500.0 | 4 | 150.0 | 600.0 | | | |
| 5 | BUILDING 5 7 STORY CONCRETE | 84.0 | 1 | 150.0 | 600.0 | 3 | 210.0 | 500.0 | | | |
| | | | 2 | 150.0 | 500.0 | 4 | 210.0 | 600.0 | | | |
| 6 | ALLEY BETWEEN BUILDING 5 AND 7 | 0. | 1 | 210.0 | 600.0 | 3 | 220.0 | 500.0 | | | |
| | | | 2 | 210.0 | 500.0 | 4 | 220.0 | 600.0 | | | |
| 7 | BUILDING 7 12 STORY CONCRETE | 144.0 | 1 | 220.0 | 600.0 | 3 | 270.0 | 500.0 | | | |
| | | | 2 | 220.0 | 500.0 | 4 | 270.0 | 600.0 | | | |
| 8 | ALLEY BETWEEN BUILDINGS 7 AND 9 | 0. | 1 | 270.0 | 600.0 | 3 | 280.0 | 500.0 | | | |
| | | | 2 | 270.0 | 500.0 | 4 | 280.0 | 600.0 | | | |
| 9 | BUILDING 9 4 STORY BRICK | 48.0 | 1 | 280.0 | 600.0 | 3 | 320.0 | 500.0 | | | |
| | | | 2 | 280.0 | 500.0 | 4 | 320.0 | 600.0 | | | |
| 10 | ALLEY BETWEEN BUILDINGS 9 AND 11 | 0. | 1 | 320.0 | 600.0 | 3 | 330.0 | 500.0 | | | |
| | | | 2 | 320.0 | 500.0 | 4 | 330.0 | 600.0 | | | |
| 11 | BUILDING 11 1 STORY BRICK | 12.0 | 1 | 330.0 | 600.0 | 3 | 360.0 | 500.0 | | | |
| | | | 2 | 330.0 | 500.0 | 4 | 360.0 | 600.0 | | | |
| 12 | ALLEY BETWEEN BUILDINGS 11 AND 13 | 0. | 1 | 360.0 | 600.0 | 3 | 370.0 | 500.0 | | | |

Table 12 (Cont.)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 2 | 360.0 | 500.0 | 4 | 370.0 | 600.0 |
| 13. | BUILDING 13 3 STORY CONCRETE | 36.0 | 1 | 370.0 | 600.0 | 3 | 420.0 | 500.0 |
| | | | 2 | 370.0 | 500.0 | 4 | 420.0 | 600.0 |
| 14 | ALLEY BETWEEN BUILDINGS 13 AND 15 | 0. | 1 | 420.0 | 600.0 | 3 | 430.0 | 500.0 |
| | | | 2 | 420.0 | 500.0 | 4 | 430.0 | 600.0 |
| 15 | BUILDING 15 10 STORY STONE | 120.0 | 1 | 430.0 | 600.0 | 3 | 500.0 | 500.0 |
| | | | 2 | 430.0 | 500.0 | 4 | 500.0 | 600.0 |
| 16 | STREET AREA BEHIND BUILDING 27 | 0. | 1 | 0. | 500.0 | 3 | 80.0 | 450.0 |
| | | | 2 | 0. | 450.0 | 4 | 80.0 | 500.0 |
| 17 | STREET AREA BEHIND ALLEY 28 | 0. | 1 | 80.0 | 500.0 | 3 | 90.0 | 450.0 |
| | | | 2 | 80.0 | 450.0 | 4 | 90.0 | 500.0 |
| 18 | STREET AREA BEHIND BUILDING 29 | 0. | 1 | 90.0 | 500.0 | 3 | 140.0 | 450.0 |
| | | | 2 | 90.0 | 450.0 | 4 | 140.0 | 500.0 |
| 19 | STREET AREA BEHIND PARKING LOT 30 | 0. | 1 | 140.0 | 500.0 | 3 | 240.0 | 450.0 |
| | | | 2 | 140.0 | 450.0 | 4 | 240.0 | 500.0 |
| 20 | STREET AREA BEHIND BUILDING 31 | 0. | 1 | 240.0 | 500.0 | 3 | 300.0 | 450.0 |
| | | | 2 | 240.0 | 450.0 | 4 | 300.0 | 500.0 |
| 21 | STREET AREA BEHIND ALLEY 32 | 0. | 1 | 300.0 | 500.0 | 3 | 310.0 | 450.0 |
| | | | 2 | 300.0 | 450.0 | 4 | 310.0 | 500.0 |
| 22 | STREET AREA BEHIND BUILDING 33 | 0. | 1 | 310.0 | 500.0 | 3 | 390.0 | 450.0 |
| | | | 2 | 310.0 | 450.0 | 4 | 390.0 | 500.0 |
| 23 | STREET AREA BEHIND ALLEY 34 | 0. | 1 | 390.0 | 500.0 | 3 | 400.0 | 450.0 |
| | | | 2 | 390.0 | 450.0 | 4 | 400.0 | 500.0 |
| 24 | STREET AREA BEHIND BUILDING 35 | 0. | 1 | 400.0 | 500.0 | 3 | 440.0 | 450.0 |
| | | | 2 | 400.0 | 450.0 | 4 | 440.0 | 500.0 |
| 25 | STREET AREA BEHIND ALLEY 36 | 0. | 1 | 440.0 | 500.0 | 3 | 450.0 | 450.0 |
| | | | 2 | 440.0 | 450.0 | 4 | 450.0 | 500.0 |
| 26 | STREET AREA BEHIND BUILDING 37 | 0. | 1 | 450.0 | 500.0 | 3 | 500.0 | 450.0 |
| | | | 2 | 450.0 | 450.0 | 4 | 500.0 | 500.0 |
| 27 | BUILDING 27 7 STORY BRICK | 84.0 | 1 | 0. | 450.0 | 3 | 80.0 | 350.0 |
| | | | 2 | 0. | 350.0 | 4 | 80.0 | 450.0 |
| 28 | ALLEY BETWEEN BUILDINGS 27 AND 29 | 0. | 1 | 80.0 | 450.0 | 3 | 90.0 | 350.0 |
| | | | 2 | 80.0 | 350.0 | 4 | 90.0 | 450.0 |
| 29 | BUILDING 29 9 STORY CONCRETE | 108.0 | 1 | 90.0 | 450.0 | 3 | 140.0 | 350.0 |
| | | | 2 | 90.0 | 350.0 | 4 | 140.0 | 450.0 |
| 30 | PARKING LOT 30 | 0. | 1 | 140.0 | 450.0 | 3 | 240.0 | 350.0 |
| | | | 2 | 140.0 | 350.0 | 4 | 240.0 | 450.0 |
| 31 | BUILDING 31 1 STORY BRICK | 12.0 | 1 | 240.0 | 450.0 | 3 | 300.0 | 350.0 |
| | | | 2 | 240.0 | 350.0 | 4 | 300.0 | 450.0 |
| 32 | ALLEY BETWEEN BUILDINGS 31 AND 33 | 0. | 1 | 300.0 | 450.0 | 3 | 310.0 | 350.0 |
| | | | 2 | 300.0 | 350.0 | 4 | 310.0 | 450.0 |
| 33 | BUILDING 33 2 STORY BRICK | 24.0 | 1 | 310.0 | 450.0 | 3 | 390.0 | 350.0 |
| | | | 2 | 310.0 | 350.0 | 4 | 390.0 | 450.0 |
| 34 | ALLEY BETWEEN BUILDINGS 33 AND 35 | 0. | 1 | 390.0 | 450.0 | 3 | 400.0 | 350.0 |
| | | | 2 | 390.0 | 350.0 | 4 | 400.0 | 450.0 |
| 35 | BUILDING 35 8 STORY BRICK | 96.0 | 1 | 400.0 | 450.0 | 3 | 440.0 | 350.0 |
| | | | 2 | 400.0 | 350.0 | 4 | 440.0 | 450.0 |
| 36 | ALLEY BETWEEN BUILDINGS 35 AND 37 | 0. | 1 | 440.0 | 450.0 | 3 | 450.0 | 350.0 |
| | | | 2 | 440.0 | 350.0 | 4 | 450.0 | 450.0 |
| 37 | BUILDING 37 6 STORY BRICK | 72.0 | 1 | 450.0 | 450.0 | 3 | 500.0 | 350.0 |
| | | | 2 | 450.0 | 350.0 | 4 | 500.0 | 450.0 |
| 38 | BUILDING 38 8 STORY STONE | 96.0 | 1 | 0. | 250.0 | 3 | 60.0 | 150.0 |
| | | | 2 | 0. | 150.0 | 4 | 60.0 | 250.0 |
| 39 | ALLEY BETWEEN BUILDINGS 38 AND 40 | 0. | 1 | 60.0 | 250.0 | 3 | 70.0 | 150.0 |
| | | | 2 | 60.0 | 150.0 | 4 | 70.0 | 250.0 |
| 40 | BUILDING 40 10 STORY CONCRETE | 120.0 | 1 | 70.0 | 250.0 | 3 | 130.0 | 150.0 |
| | | | 2 | 70.0 | 150.0 | 4 | 130.0 | 250.0 |
| 41 | ALLEY BETWEEN BUILDINGS 40 AND 42 | 0. | 1 | 130.0 | 250.0 | 3 | 140.0 | 150.0 |
| | | | 2 | 130.0 | 150.0 | 4 | 140.0 | 250.0 |
| 42 | BUILDING 42 3 STORY STONE | 36.0 | 1 | 140.0 | 250.0 | 3 | 230.0 | 150.0 |
| | | | 2 | 140.0 | 150.0 | 4 | 230.0 | 250.0 |
| 43 | ALLEY BETWEEN BUILDINGS 42 AND 44 | 0. | 1 | 230.0 | 250.0 | 3 | 240.0 | 150.0 |
| | | | 2 | 230.0 | 150.0 | 4 | 240.0 | 250.0 |
| 44 | BUILDING 44 5 STORY BRICK | 60.0 | 1 | 240.0 | 250.0 | 3 | 290.0 | 150.0 |
| | | | 2 | 240.0 | 150.0 | 4 | 290.0 | 250.0 |
| 45 | ALLEY BETWEEN BUILDINGS 44 AND 46 | 0. | 1 | 290.0 | 250.0 | 3 | 300.0 | 150.0 |

Table 12 (Cont.)

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2 | 290.0 | 150.0 | 4 | 500.0 | 250.0 | | | |
| 46 | BUILDING 46 1 STORY BRICK | 12.0 | 1 | 300.0 | 250.0 | 3 | 350.0 | 150.0 | | | |
| | | | 2 | 300.0 | 150.0 | 4 | 350.0 | 250.0 | | | |
| 47 | GASOLINE STATION | 0. | 1 | 350.0 | 250.0 | 4 | 500.0 | 250.0 | 7 | 360.0 | 400.0 |
| | | | 2 | 350.0 | 150.0 | 5 | 410.0 | 250.0 | 8 | 360.0 | 250.0 |
| | | | 3 | 500.0 | 150.0 | 6 | 410.0 | 200.0 | | | |
| 48 | GARAGE IN GAS STATION 1 STORY BRICK | 12.0 | 1 | 360.0 | 250.0 | 3 | 410.0 | 200.0 | | | |
| | | | 2 | 360.0 | 200.0 | 4 | 410.0 | 250.0 | | | |
| 49 | STREET AREA BEHIND BUILDING 38 | 0. | 1 | 0. | 150.0 | 3 | 60.0 | 100.0 | | | |
| | | | 2 | 0. | 100.0 | 4 | 60.0 | 150.0 | | | |
| 50 | STREET AREA BEHIND ALLEY 39 | 0. | 1 | 60.0 | 150.0 | 3 | 70.0 | 100.0 | | | |
| | | | 2 | 60.0 | 100.0 | 4 | 70.0 | 150.0 | | | |
| 51 | STREET AREA BEHIND BUILDING 40 | 0. | 1 | 70.0 | 150.0 | 3 | 130.0 | 100.0 | | | |
| | | | 2 | 70.0 | 100.0 | 4 | 130.0 | 150.0 | | | |
| 52 | STREET AREA BEHIND ALLEY 41 | 0. | 1 | 130.0 | 150.0 | 3 | 140.0 | 100.0 | | | |
| | | | 2 | 130.0 | 100.0 | 4 | 140.0 | 150.0 | | | |
| 53 | STREET AREA BEHIND BUILDING 42 | 0. | 1 | 140.0 | 150.0 | 3 | 230.0 | 100.0 | | | |
| | | | 2 | 140.0 | 100.0 | 4 | 230.0 | 150.0 | | | |
| 54 | STREET AREA BEHIND ALLEY 43 | 0. | 1 | 230.0 | 150.0 | 3 | 240.0 | 100.0 | | | |
| | | | 2 | 230.0 | 100.0 | 4 | 240.0 | 150.0 | | | |
| 55 | STREET AREA BEHIND BUILDING 44 | 0. | 1 | 240.0 | 150.0 | 3 | 290.0 | 100.0 | | | |
| | | | 2 | 240.0 | 100.0 | 4 | 290.0 | 150.0 | | | |
| 56 | STREET AREA BEHIND ALLEY 45 | 0. | 1 | 290.0 | 150.0 | 3 | 300.0 | 100.0 | | | |
| | | | 2 | 290.0 | 100.0 | 4 | 300.0 | 150.0 | | | |
| 57 | STREET AREA BEHIND BUILDING 46 | 0. | 1 | 300.0 | 150.0 | 3 | 350.0 | 100.0 | | | |
| | | | 2 | 300.0 | 100.0 | 4 | 350.0 | 150.0 | | | |
| 58 | STREET AREA BEHIND GASOLINE STATION | 0. | 1 | 350.0 | 150.0 | 3 | 500.0 | 100.0 | | | |
| | | | 2 | 350.0 | 100.0 | 4 | 500.0 | 150.0 | | | |
| 59 | PARKING LOT 59 | 0. | 1 | 0. | 100.0 | 3 | 150.0 | 0. | | | |
| | | | 2 | 0. | 0. | 4 | 150.0 | 100.0 | | | |
| 60 | BUILDING 60 1 STORY BRICK | 12.0 | 1 | 150.0 | 100.0 | 3 | 250.0 | 0. | | | |
| | | | 2 | 150.0 | 0. | 4 | 250.0 | 100.0 | | | |
| 61 | ALLEY BETWEEN BUILDINGS 60 AND 62 | 0. | 1 | 250.0 | 100.0 | 3 | 260.0 | 0. | | | |
| | | | 2 | 250.0 | 0. | 4 | 260.0 | 100.0 | | | |
| 62 | BUILDING 62 3 STORY CONCRETE | 36.0 | 1 | 260.0 | 100.0 | 3 | 320.0 | 0. | | | |
| | | | 2 | 260.0 | 0. | 4 | 320.0 | 100.0 | | | |
| 63 | ALLEY BETWEEN BUILDINGS 62 AND 64 | 0. | 1 | 320.0 | 100.0 | 3 | 330.0 | 0. | | | |
| | | | 2 | 320.0 | 0. | 4 | 330.0 | 100.0 | | | |
| 64 | BUILDING 64 5 STORY CONCRETE | 60.0 | 1 | 330.0 | 100.0 | 3 | 380.0 | 0. | | | |
| | | | 2 | 330.0 | 0. | 4 | 380.0 | 100.0 | | | |
| 65 | ALLEY BETWEEN BUILDINGS 64 AND 66 | 0. | 1 | 380.0 | 100.0 | 3 | 390.0 | 0. | | | |
| | | | 2 | 380.0 | 0. | 4 | 390.0 | 100.0 | | | |
| 66 | BUILDING 66 2 STORY STONE | 24.0 | 1 | 390.0 | 100.0 | 3 | 420.0 | 0. | | | |
| | | | 2 | 390.0 | 0. | 4 | 420.0 | 100.0 | | | |
| 67 | ALLEY BETWEEN BUILDINGS 66 AND 68 | 0. | 1 | 420.0 | 100.0 | 3 | 430.0 | 0. | | | |
| | | | 2 | 420.0 | 0. | 4 | 430.0 | 100.0 | | | |
| 68 | BUILDING 68 2 STORY STONE | 24.0 | 1 | 430.0 | 100.0 | 3 | 500.0 | 0. | | | |
| | | | 2 | 430.0 | 0. | 4 | 500.0 | 100.0 | | | |
| 69 | PARKING RAMP 4 STORY CONCRETE | 48.0 | 1 | 600.0 | 600.0 | 3 | 850.0 | 500.0 | | | |
| | | | 2 | 600.0 | 500.0 | 4 | 850.0 | 600.0 | | | |
| 70 | ALLEY BETWEEN RAMP AND BUILDING 71 | 0. | 1 | 850.0 | 600.0 | 3 | 860.0 | 500.0 | | | |
| | | | 2 | 850.0 | 500.0 | 4 | 860.0 | 600.0 | | | |
| 71 | BUILDING 71 9 STORY STONE | 108.0 | 1 | 860.0 | 600.0 | 3 | 910.0 | 500.0 | | | |
| | | | 2 | 860.0 | 500.0 | 4 | 910.0 | 600.0 | | | |
| 72 | ALLEY BETWEEN BUILDINGS 71 AND 73 | 0. | 1 | 910.0 | 600.0 | 3 | 920.0 | 500.0 | | | |
| | | | 2 | 910.0 | 500.0 | 4 | 920.0 | 600.0 | | | |
| 73 | BUILDING 73 10 STORY STONE | 120.0 | 1 | 920.0 | 600.0 | 3 | 1010.0 | 500.0 | | | |
| | | | 2 | 920.0 | 500.0 | 4 | 1010.0 | 600.0 | | | |
| 74 | ALLEY BETWEEN BUILDINGS 73 AND 75 | 0. | 1 | 1010.0 | 600.0 | 3 | 1020.0 | 500.0 | | | |
| | | | 2 | 1010.0 | 500.0 | 4 | 1020.0 | 600.0 | | | |
| 75 | BUILDING 75 6 STORY BRICK | 72.0 | 1 | 1020.0 | 600.0 | 3 | 1100.0 | 500.0 | | | |
| | | | 2 | 1020.0 | 500.0 | 4 | 1100.0 | 600.0 | | | |
| 76 | STREET AREA BEHIND BUILDING 93 | 0. | 1 | 600.0 | 500.0 | 3 | 640.0 | 450.0 | | | |
| | | | 2 | 600.0 | 450.0 | 4 | 640.0 | 500.0 | | | |
| 77 | STREET AREA BEHIND ALLEY 94 | 0. | 1 | 640.0 | 500.0 | 3 | 650.0 | 450.0 | | | |
| | | | 2 | 640.0 | 450.0 | 4 | 650.0 | 500.0 | | | |

Table 12 (Cont.)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 78 | STREET AREA BEHIND BUILDING 95 | 0. | 1 | 650.0 | 500.0 | 3 | 700.0 | 450.0 |
| | | | 2 | 650.0 | 450.0 | 4 | 700.0 | 500.0 |
| 79 | STREET AREA BEHIND ALLEY 96 | 0. | 1 | 700.0 | 500.0 | 3 | 710.0 | 450.0 |
| | | | 2 | 700.0 | 450.0 | 4 | 710.0 | 500.0 |
| 80 | STREET AREA BEHIND BUILDING 97 | 0. | 1 | 710.0 | 500.0 | 3 | 760.0 | 450.0 |
| | | | 2 | 710.0 | 450.0 | 4 | 760.0 | 500.0 |
| 81 | STREET AREA BEHIND ALLEY 98 | 0. | 1 | 760.0 | 500.0 | 3 | 770.0 | 450.0 |
| | | | 2 | 760.0 | 450.0 | 4 | 770.0 | 500.0 |
| 82 | STREET AREA BEHIND BUILDING 99 | 0. | 1 | 770.0 | 500.0 | 3 | 830.0 | 450.0 |
| | | | 2 | 770.0 | 450.0 | 4 | 830.0 | 500.0 |
| 83 | STREET AREA BEHIND ALLEY 100 | 0. | 1 | 830.0 | 500.0 | 3 | 840.0 | 450.0 |
| | | | 2 | 830.0 | 450.0 | 4 | 840.0 | 500.0 |
| 84 | STREET AREA BEHIND BUILDING 101 | 0. | 1 | 840.0 | 500.0 | 3 | 870.0 | 450.0 |
| | | | 2 | 840.0 | 450.0 | 4 | 870.0 | 500.0 |
| 85 | STREET AREA BEHIND ALLEY 102 | 0. | 1 | 870.0 | 500.0 | 3 | 880.0 | 450.0 |
| | | | 2 | 870.0 | 450.0 | 4 | 880.0 | 500.0 |
| 86 | STREET AREA BEHIND BUILDING 103 | 0. | 1 | 880.0 | 500.0 | 3 | 930.0 | 450.0 |
| | | | 2 | 880.0 | 450.0 | 4 | 930.0 | 500.0 |
| 87 | STREET AREA BEHIND ALLEY 104 | 0. | 1 | 930.0 | 500.0 | 3 | 940.0 | 450.0 |
| | | | 2 | 930.0 | 450.0 | 4 | 940.0 | 500.0 |
| 88 | STREET AREA BEHIND BUILDING 105 | 0. | 1 | 940.0 | 500.0 | 3 | 1010.0 | 450.0 |
| | | | 2 | 940.0 | 450.0 | 4 | 1010.0 | 500.0 |
| 89 | STREET AREA BEHIND ALLEY 106 | 0. | 1 | 1010.0 | 500.0 | 3 | 1020.0 | 450.0 |
| | | | 2 | 1010.0 | 450.0 | 4 | 1020.0 | 500.0 |
| 90 | STREET AREA BEHIND BUILDING 107 | 0. | 1 | 1020.0 | 500.0 | 3 | 1040.0 | 450.0 |
| | | | 2 | 1020.0 | 450.0 | 4 | 1040.0 | 500.0 |
| 91 | STREET AREA BEHIND ALLEY 108 | 0. | 1 | 1040.0 | 500.0 | 3 | 1050.0 | 450.0 |
| | | | 2 | 1040.0 | 450.0 | 4 | 1050.0 | 500.0 |
| 92 | STREET AREA BEHIND BUILDING 109 | 0. | 1 | 1050.0 | 500.0 | 3 | 1100.0 | 450.0 |
| | | | 2 | 1050.0 | 450.0 | 4 | 1100.0 | 500.0 |
| 93 | BUILDING 93 12 STORY CONCRETE | 144.0 | 1 | 600.0 | 450.0 | 3 | 640.0 | 350.0 |
| | | | 2 | 600.0 | 350.0 | 4 | 640.0 | 450.0 |
| 94 | ALLEY BETWEEN BUILDINGS 93 AND 95 | 0. | 1 | 640.0 | 450.0 | 3 | 650.0 | 350.0 |
| | | | 2 | 640.0 | 350.0 | 4 | 650.0 | 450.0 |
| 95 | BUILDING 95 12 STORY CONCRETE | 144.0 | 1 | 650.0 | 450.0 | 3 | 700.0 | 350.0 |
| | | | 2 | 650.0 | 350.0 | 4 | 700.0 | 450.0 |
| 96 | ALLEY BETWEEN BUILDINGS 95 AND 97 | 0. | 1 | 700.0 | 450.0 | 3 | 710.0 | 350.0 |
| | | | 2 | 700.0 | 350.0 | 4 | 710.0 | 450.0 |
| 97 | BUILDING 97 6 STORY BRICK | 96.0 | 1 | 710.0 | 450.0 | 3 | 760.0 | 350.0 |
| | | | 2 | 710.0 | 350.0 | 4 | 760.0 | 450.0 |
| 98 | ALLEY BETWEEN BUILDINGS 97 AND 99 | 0. | 1 | 760.0 | 450.0 | 3 | 770.0 | 350.0 |
| | | | 2 | 760.0 | 350.0 | 4 | 770.0 | 450.0 |
| 99 | BUILDING 99 7 STORY BRICK | 64.0 | 1 | 770.0 | 450.0 | 3 | 830.0 | 350.0 |
| | | | 2 | 770.0 | 350.0 | 4 | 830.0 | 450.0 |
| 100 | ALLEY BETWEEN BUILDINGS 99 A ND 101 | 0. | 1 | 830.0 | 450.0 | 3 | 840.0 | 350.0 |
| | | | 2 | 830.0 | 350.0 | 4 | 840.0 | 450.0 |
| 101 | BUILDING 101 15 STORY CONCRETE | 180.0 | 1 | 840.0 | 450.0 | 3 | 870.0 | 350.0 |
| | | | 2 | 840.0 | 350.0 | 4 | 870.0 | 450.0 |
| 102 | ALLEY BETWEEN BUILDINGS 101 AND 103 | 0. | 1 | 870.0 | 450.0 | 3 | 880.0 | 350.0 |
| | | | 2 | 870.0 | 350.0 | 4 | 880.0 | 450.0 |
| 103 | BUILDING 103 10 STORY CONCRETE | 120.0 | 1 | 880.0 | 450.0 | 3 | 930.0 | 350.0 |
| | | | 2 | 880.0 | 350.0 | 4 | 930.0 | 450.0 |
| 104 | ALLEY BETWEEN BUILDINGS 103 AND 105 | 0. | 1 | 930.0 | 450.0 | 3 | 940.0 | 350.0 |
| | | | 2 | 930.0 | 350.0 | 4 | 940.0 | 450.0 |
| 105 | BUILDING 105 9 STORY BRICK | 108.0 | 1 | 940.0 | 450.0 | 3 | 1010.0 | 350.0 |
| | | | 2 | 940.0 | 350.0 | 4 | 1010.0 | 450.0 |
| 106 | ALLEY BETWEEN BUILDINGS 105 AND 107 | 0. | 1 | 1010.0 | 450.0 | 3 | 1020.0 | 350.0 |
| | | | 2 | 1010.0 | 350.0 | 4 | 1020.0 | 450.0 |
| 107 | BUILDING 107 7 STORY BRICK | 64.0 | 1 | 1020.0 | 450.0 | 3 | 1040.0 | 350.0 |
| | | | 2 | 1020.0 | 350.0 | 4 | 1040.0 | 450.0 |
| 108 | ALLEY BETWEEN BUILDINGS 107 AND 109 | 0. | 1 | 1040.0 | 450.0 | 3 | 1050.0 | 350.0 |
| | | | 2 | 1040.0 | 350.0 | 4 | 1050.0 | 450.0 |
| 109 | BUILDING 109 10 STORY CONCRETE | 120.0 | 1 | 1050.0 | 450.0 | 3 | 1100.0 | 350.0 |
| | | | 2 | 1050.0 | 350.0 | 4 | 1100.0 | 450.0 |
| 110 | BUILDING 110 5 STORY STONE | 60.0 | 1 | 600.0 | 250.0 | 3 | 700.0 | 150.0 |
| | | | 2 | 600.0 | 150.0 | 4 | 700.0 | 250.0 |

Table 12 (Cont.)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 111 | ALLEY BETWEEN BUILDINGS 110 AND 112 | 0. | 1 | 700.0 | 250.0 | 3 | 710.0 | 150.0 |
| | | | 2 | 700.0 | 150.0 | 4 | 710.0 | 250.0 |
| 112 | BUILDING 112 3 STORY WOOD | 36.0 | 1 | 710.0 | 250.0 | 3 | 760.0 | 150.0 |
| | | | 2 | 710.0 | 150.0 | 4 | 760.0 | 250.0 |
| 113 | ALLEY BETWEEN BUILDINGS 112 AND 114 | 0. | 1 | 760.0 | 250.0 | 3 | 770.0 | 150.0 |
| | | | 2 | 760.0 | 150.0 | 4 | 770.0 | 250.0 |
| 114 | BUILDING 114 9 STORY CONCRETE | 108.0 | 1 | 770.0 | 250.0 | 3 | 860.0 | 150.0 |
| | | | 2 | 770.0 | 150.0 | 4 | 860.0 | 250.0 |
| 115 | ALLEY BETWEEN BUILDINGS 114 AND 116 | 0. | 1 | 860.0 | 250.0 | 3 | 870.0 | 150.0 |
| | | | 2 | 860.0 | 150.0 | 4 | 870.0 | 250.0 |
| 116 | BUILDING 116 7 STORY CONCRETE | 84.0 | 1 | 870.0 | 250.0 | 3 | 950.0 | 150.0 |
| | | | 2 | 870.0 | 150.0 | 4 | 950.0 | 250.0 |
| 117 | ALLEY BETWEEN BUILDINGS 116 AND 118 | 0. | 1 | 950.0 | 250.0 | 3 | 960.0 | 150.0 |
| | | | 2 | 950.0 | 150.0 | 4 | 960.0 | 250.0 |
| 118 | BUILDING 118 6 STORY BRICK | 72.0 | 1 | 960.0 | 250.0 | 3 | 990.0 | 150.0 |
| | | | 2 | 960.0 | 150.0 | 4 | 990.0 | 250.0 |
| 119 | ALLEY BETWEEN BUILDINGS 118 AND 120 | 0. | 1 | 990.0 | 250.0 | 3 | 1000.0 | 150.0 |
| | | | 2 | 990.0 | 150.0 | 4 | 1000.0 | 250.0 |
| 120 | BUILDING 120 1 STORY BRICK | 12.0 | 1 | 1000.0 | 250.0 | 3 | 1100.0 | 150.0 |
| | | | 2 | 1000.0 | 150.0 | 4 | 1100.0 | 250.0 |
| 121 | STREET AREA BEHIND BUILDING 110 | 0. | 1 | 600.0 | 150.0 | 3 | 700.0 | 100.0 |
| | | | 2 | 600.0 | 100.0 | 4 | 700.0 | 150.0 |
| 122 | STREET AREA BEHIND ALLEY 111 | 0. | 1 | 700.0 | 150.0 | 3 | 710.0 | 100.0 |
| | | | 2 | 700.0 | 100.0 | 4 | 710.0 | 150.0 |
| 123 | STREET AREA BEHIND BUILDING 112 | 0. | 1 | 710.0 | 150.0 | 3 | 760.0 | 100.0 |
| | | | 2 | 710.0 | 100.0 | 4 | 760.0 | 150.0 |
| 124 | STREET AREA BEHIND ALLEY 113 | 0. | 1 | 760.0 | 150.0 | 3 | 770.0 | 100.0 |
| | | | 2 | 760.0 | 100.0 | 4 | 770.0 | 150.0 |
| 125 | STREET AREA BEHIND BUILDING 114 | 0. | 1 | 770.0 | 150.0 | 3 | 860.0 | 100.0 |
| | | | 2 | 770.0 | 100.0 | 4 | 860.0 | 150.0 |
| 126 | STREET AREA BEHIND ALLEY 115 | 0. | 1 | 860.0 | 150.0 | 3 | 870.0 | 100.0 |
| | | | 2 | 860.0 | 100.0 | 4 | 870.0 | 150.0 |
| 127 | STREET AREA BEHIND BUILDING 116 | 0. | 1 | 870.0 | 150.0 | 3 | 950.0 | 100.0 |
| | | | 2 | 870.0 | 100.0 | 4 | 950.0 | 150.0 |
| 128 | STREET AREA BEHIND ALLEY 117 | 0. | 1 | 950.0 | 150.0 | 3 | 960.0 | 100.0 |
| | | | 2 | 950.0 | 100.0 | 4 | 960.0 | 150.0 |
| 129 | STREET AREA BEHIND BUILDING 118 | 0. | 1 | 960.0 | 150.0 | 3 | 990.0 | 100.0 |
| | | | 2 | 960.0 | 100.0 | 4 | 990.0 | 150.0 |
| 130 | STREET AREA BEHIND ALLEY 119 | 0. | 1 | 990.0 | 150.0 | 3 | 1000.0 | 100.0 |
| | | | 2 | 990.0 | 100.0 | 4 | 1000.0 | 150.0 |
| 131 | STREET AREA BEHIND BUILDING 120 | 0. | 1 | 1000.0 | 150.0 | 3 | 1100.0 | 100.0 |
| | | | 2 | 1000.0 | 100.0 | 4 | 1100.0 | 150.0 |
| 132 | BUILDING 132 6 STORY BRICK | 72.0 | 1 | 600.0 | 100.0 | 3 | 680.0 | 0. |
| | | | 2 | 600.0 | 0. | 4 | 680.0 | 100.0 |
| 133 | ALLEY BETWEEN BUILDINGS 132 AND 134 | 0. | 1 | 680.0 | 100.0 | 3 | 690.0 | 0. |
| | | | 2 | 680.0 | 0. | 4 | 690.0 | 100.0 |
| 134 | BUILDING 134 4 STORY BRICK | 48.0 | 1 | 690.0 | 100.0 | 3 | 760.0 | 0. |
| | | | 2 | 690.0 | 0. | 4 | 760.0 | 100.0 |
| 135 | ALLEY BETWEEN BUILDINGS 134 AND 136 | 0. | 1 | 760.0 | 100.0 | 3 | 770.0 | 0. |
| | | | 2 | 760.0 | 0. | 4 | 770.0 | 100.0 |
| 136 | BUILDING 136 3 STORY BRICK | 36.0 | 1 | 770.0 | 100.0 | 3 | 840.0 | 0. |
| | | | 2 | 770.0 | 0. | 4 | 840.0 | 100.0 |
| 137 | ALLEY BETWEEN BUILDINGS 136 AND 138 | 0. | 1 | 840.0 | 100.0 | 3 | 850.0 | 0. |
| | | | 2 | 840.0 | 0. | 4 | 850.0 | 100.0 |
| 138 | BUILDING 138 9 STORY BRICK | 108.0 | 1 | 850.0 | 100.0 | 3 | 900.0 | 0. |
| | | | 2 | 850.0 | 0. | 4 | 900.0 | 100.0 |
| 139 | ALLEY BETWEEN BUILDINGS 138 AND 140 | 0. | 1 | 900.0 | 100.0 | 3 | 910.0 | 0. |
| | | | 2 | 900.0 | 0. | 4 | 910.0 | 100.0 |
| 140 | BUILDING 140 8 STORY BRICK | 96.0 | 1 | 910.0 | 100.0 | 3 | 990.0 | 0. |
| | | | 2 | 910.0 | 0. | 4 | 990.0 | 100.0 |
| 141 | ALLEY BETWEEN BUILDINGS 140 AND 142 | 0. | 1 | 990.0 | 100.0 | 3 | 1000.0 | 0. |
| | | | 2 | 990.0 | 0. | 4 | 1000.0 | 100.0 |
| 142 | BUILDING 142 6 STORY BRICK | 72.0 | 1 | 1000.0 | 100.0 | 3 | 1040.0 | 0. |
| | | | 2 | 1000.0 | 0. | 4 | 1040.0 | 100.0 |
| 143 | ALLEY BETWEEN BUILDINGS 142 AND 144 | 0. | 1 | 1040.0 | 100.0 | 3 | 1050.0 | 0. |
| | | | 2 | 1040.0 | 0. | 4 | 1050.0 | 100.0 |

Table 12 (Cont.)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 144 | BUILDING 144 5 STORY BRICK | 60.0 | 1 | 1050.0 | 100.0 | 3 | 1100.0 | 0. |
| | | | 2 | 1050.0 | 0. | 4 | 1100.0 | 100.0 |
| 145 | STREET AREA | 0. | 1 | 0. | 350.0 | 3 | 100.0 | 250.0 |
| | | | 2 | 0. | 250.0 | 4 | 100.0 | 350.0 |
| 146 | STREET AREA | 0. | 1 | 100.0 | 350.0 | 3 | 200.0 | 250.0 |
| | | | 2 | 100.0 | 250.0 | 4 | 200.0 | 350.0 |
| 147 | STREET AREA | 0. | 1 | 200.0 | 350.0 | 3 | 300.0 | 250.0 |
| | | | 2 | 200.0 | 250.0 | 4 | 300.0 | 350.0 |
| 148 | STREET AREA | 0. | 1 | 300.0 | 350.0 | 3 | 400.0 | 250.0 |
| | | | 2 | 300.0 | 250.0 | 4 | 400.0 | 350.0 |
| 149 | STREET AREA | 0. | 1 | 400.0 | 350.0 | 3 | 500.0 | 250.0 |
| | | | 2 | 400.0 | 250.0 | 4 | 500.0 | 350.0 |
| 150 | STREET AREA | 0. | 1 | 500.0 | 350.0 | 3 | 600.0 | 250.0 |
| | | | 2 | 500.0 | 250.0 | 4 | 600.0 | 350.0 |
| 151 | STREET AREA | 0. | 1 | 600.0 | 350.0 | 3 | 700.0 | 250.0 |
| | | | 2 | 600.0 | 250.0 | 4 | 700.0 | 350.0 |
| 152 | STREET AREA | 0. | 1 | 700.0 | 350.0 | 3 | 800.0 | 250.0 |
| | | | 2 | 700.0 | 250.0 | 4 | 800.0 | 350.0 |
| 153 | STREET AREA | 0. | 1 | 800.0 | 350.0 | 3 | 900.0 | 250.0 |
| | | | 2 | 800.0 | 250.0 | 4 | 900.0 | 350.0 |
| 154 | STREET AREA | 0. | 1 | 900.0 | 350.0 | 3 | 1000.0 | 250.0 |
| | | | 2 | 900.0 | 250.0 | 4 | 1000.0 | 350.0 |
| 155 | STREET AREA | 0. | 1 | 1000.0 | 350.0 | 3 | 1100.0 | 250.0 |
| | | | 2 | 1000.0 | 250.0 | 4 | 1100.0 | 350.0 |
| 156 | STREET AREA | 0. | 1 | 500.0 | 600.0 | 3 | 600.0 | 500.0 |
| | | | 2 | 500.0 | 500.0 | 4 | 600.0 | 600.0 |
| 157 | STREET AREA | 0. | 1 | 500.0 | 500.0 | 3 | 600.0 | 450.0 |
| | | | 2 | 500.0 | 450.0 | 4 | 600.0 | 500.0 |
| 158 | STREET AREA | 0. | 1 | 500.0 | 450.0 | 3 | 600.0 | 350.0 |
| | | | 2 | 500.0 | 350.0 | 4 | 600.0 | 450.0 |
| 159 | STREET AREA | 0. | 1 | 500.0 | 250.0 | 3 | 600.0 | 150.0 |
| | | | 2 | 500.0 | 150.0 | 4 | 600.0 | 250.0 |
| 160 | STREET AREA | 0. | 1 | 500.0 | 150.0 | 3 | 600.0 | 100.0 |
| | | | 2 | 500.0 | 100.0 | 4 | 600.0 | 150.0 |
| 161 | STREET AREA | 0. | 1 | 500.0 | 100.0 | 3 | 600.0 | 0. |
| | | | 2 | 500.0 | 0. | 4 | 600.0 | 100.0 |

Table 12 (Cont.)

ORIGIN ---- ORIGIN A 200 FT. WEST OF INTRSCTN. X = 350.0
Y = 300.0
H = 3.0

(NOTE-DIMENSIONS IN FEET UNLESS OTHERWISE INDICATED)

RESULTS OF COMPUTATIONS

| AREA | ATT. CONST. | DOSE | DOSE/DINF | J | CODE | LAYER TYPE | THICKNESS | SLANT |
|---|---|---|---|---|---|---|---|---|
| 1 | 4.8873E-04 | 2.5187E-05 | 0.0001 | | | | | |
| | | | | 1 | AR | VERTICAL | 340.0000 | 353.4007 |
| | | | | 2 | BR | VERTICAL | 1.0000 | 1.0394 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 3.6662 |
| 2 | 7.5605E-06 | 5.5676E-08 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 320.0000 | 320.0140 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0001 |
| 3 | 5.2443E-04 | 1.6428E-05 | 0.0001 | | | | | |
| | | | | 1 | AR | VERTICAL | 297.0000 | 305.2910 |
| | | | | 2 | BR | VERTICAL | 1.0000 | 1.0279 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 4.3202 |
| 4 | 8.5675E-05 | 7.7344E-08 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 283.0000 | 283.0159 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0001 |
| 5 | 1.6140E-04 | 9.3543E-06 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 256.0000 | 271.8301 |
| | | | | 2 | CN | VERTICAL | 1.0000 | 1.0536 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 3.1755 |
| 6 | 2.2182E-10 | 2.6205E-12 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 239.0000 | 239.0189 |
| | | | | 2 | BR | VERTICAL | 4.0000 | 4.0003 |
| 7 | 7.6127E-05 | 3.8565E-06 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 257.0000 | 307.1628 |
| | | | | 2 | CN | VERTICAL | 1.0000 | 1.1952 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 1.8259 |
| 8 | 1.0888E-05 | 1.5416E-07 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 212.0000 | 212.0212 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0002 |
| 9 | 9.7515E-07 | 5.6132E-08 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 203.0000 | 207.9647 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0489 |
| | | | | 31 | WD | HORIZONTAL | 2.0000 | 9.2082 |
| 10 | 1.1262E-05 | 1.7323E-07 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 202.0000 | 202.0225 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0002 |
| 11 | 2.7900E-10 | 1.2981E-11 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 203.0000 | 203.2054 |
| | | | | 2 | BR | VERTICAL | 3.0000 | 3.0030 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 22.2447 |

Table 12 (Cont.)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 12 | 1.1319E-05 | 1.7533E-07 | 0.0000 | 1 | AR | VERTICAL | 200.5000 | 200.5225 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0002 |
| 13 | 2.5106E-09 | 1.8468E-10 | 0.0000 | 1 | AR | VERTICAL | 205.0000 | 207.7446 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0268 |
| | | | | 3 | CN | VERTICAL | 1.0000 | 1.0134 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 6.1724 |
| 14 | 2.4292E-10 | 3.4392E-12 | 0.0000 | 1 | AR | VERTICAL | 212.0000 | 212.0212 |
| | | | | 2 | BR | VERTICAL | 4.0000 | 4.0004 |
| 15 | 2.3957E-04 | 1.7772E-05 | 0.0001 | 1 | AR | VERTICAL | 248.0000 | 282.2215 |
| | | | | 2 | ST | VERTICAL | 1.0000 | 1.1380 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 2.0951 |
| 16 | 3.5152E-01 | 1.0431E-02 | 0.0412 | 1 | AR | VERTICAL | 309.0000 | 309.0146 |
| 17 | 8.0892E-06 | 3.7449E-08 | 0.0000 | 1 | AR | VERTICAL | 300.0000 | 300.0150 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0001 |
| 18 | 9.3226E-06 | 2.5446E-07 | 0.0000 | 1 | AR | VERTICAL | 258.0000 | 258.0174 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0001 |
| 19 | 1.1886E-05 | 1.0013E-06 | 0.0000 | 1 | AR | VERTICAL | 186.0000 | 186.0242 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0003 |
| 20 | 1.3060E-05 | 9.9830E-07 | 0.0000 | 1 | AR | VERTICAL | 158.0000 | 158.0284 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0004 |
| 21 | 1.3192E-05 | 1.9183E-07 | 0.0000 | 1 | AR | VERTICAL | 155.0000 | 155.0289 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0004 |
| 22 | 1.3415E-05 | 1.6435E-06 | 0.0000 | 1 | AR | VERTICAL | 150.0000 | 150.0300 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0004 |
| 23 | 1.3192E-05 | 1.9183E-07 | 0.0000 | 1 | AR | VERTICAL | 155.0000 | 155.0289 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0004 |
| 24 | 1.3016E-05 | 6.9268E-07 | 0.0000 | 1 | AR | VERTICAL | 159.0000 | 159.0286 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0004 |
| 25 | 2.7504E-10 | 3.2720E-12 | 0.0000 | 1 | AR | VERTICAL | 175.0000 | 175.0257 |
| | | | | 2 | BR | VERTICAL | 4.0000 | 4.0006 |
| 26 | 1.2128E-05 | 6.1724E-07 | 0.0000 | 1 | AR | VERTICAL | 180.0000 | 180.0249 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0003 |
| 27 | 5.9738E-04 | 3.9791E-05 | 0.0002 | 1 | AR | VERTICAL | 286.0000 | 296.1836 |
| | | | | 2 | BR | VERTICAL | 1.0000 | 1.0426 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 3.5344 |

Table 12 (Cont.)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 28 | 4.0794E-01 | 4.7216E-03 | 0.0187 | 1 | AR | VERTICAL | 265.0000 | 265.0170 |
| 29 | 1.4966E-04 | 9.1524E-06 | 0.0000 | 1 | AR | VERTICAL | 216.0000 | 240.1963 |
| | | | | 2 | CN | VERTICAL | 1.0000 | 1.1120 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 2.2862 |
| 30 | 6.6623E-01 | 1.8240E-01 | 0.7207 | 1 | AR | VERTICAL | 120.0000 | 120.0370 |
| 31 | 5.4962E-04 | 2.0352E-04 | 0.0008 | 1 | AR | VERTICAL | 72.0000 | 72.5809 |
| | | | | 2 | BR | VERTICAL | 1.0000 | 1.0081 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 7.9201 |
| 32 | 8.0239E-01 | 7.3385E-02 | 0.2900 | 1 | AR | VERTICAL | 65.0000 | 65.0713 |
| 33 | 1.3374E-03 | 1.1473E-03 | 0.0045 | 1 | AR | VERTICAL | 55.0000 | 59.6541 |
| | | | | 2 | BR | VERTICAL | 1.0000 | 1.0646 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 2.5824 |
| 34 | 8.0239E-01 | 7.3385E-02 | 0.2900 | 1 | AR | VERTICAL | 65.0000 | 65.0713 |
| 35 | 5.6267E-05 | 9.1129E-06 | 0.0000 | 1 | AR | VERTICAL | 115.0000 | 190.0042 |
| | | | | 2 | BR | VERTICAL | 1.0000 | 1.6522 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 1.2562 |
| 36 | 7.0327E-01 | 3.6050E-02 | 0.1424 | 1 | AR | VERTICAL | 104.0000 | 104.0441 |
| 37 | 7.0519E-04 | 1.0987E-04 | 0.0004 | 1 | AR | VERTICAL | 130.0000 | 152.7641 |
| | | | | 2 | BR | VERTICAL | 1.0000 | 1.1751 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 1.9041 |
| 38 | 2.6863E-04 | 1.2433E-05 | 0.0000 | 1 | AR | VERTICAL | 306.0000 | 323.0145 |
| | | | | 2 | ST | VERTICAL | 1.0000 | 1.0487 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 3.3185 |
| 39 | 3.8384E-01 | 3.9073E-03 | 0.0154 | 1 | AR | VERTICAL | 283.0000 | 283.0157 |
| 40 | 1.1900E-04 | 7.7352E-06 | 0.0000 | 1 | AR | VERTICAL | 255.0000 | 287.2504 |
| | | | | 2 | CN | VERTICAL | 1.0000 | 1.1265 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 2.1722 |
| 41 | 4.8313E-01 | 7.9848E-03 | 0.0315 | 1 | AR | VERTICAL | 215.0000 | 215.0208 |
| 42 | 4.6691E-04 | 1.0552E-04 | 0.0004 | 1 | AR | VERTICAL | 134.0000 | 138.2499 |
| | | | | 2 | ST | VERTICAL | 1.0000 | 1.0317 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 4.0643 |
| 43 | 6.6623E-01 | 2.7394E-02 | 0.1082 | 1 | AR | VERTICAL | 120.0000 | 120.0370 |
| 44 | 5.9559E-04 | 1.4146E-04 | 0.0006 | | | | | |

Table 12 (Cont.)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 1 | AR | VERTICAL | 95.0000 | 117.6092 |
| | | | | 2 | BR | VERTICAL | 1.0000 | 1.2360 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 1.6963 |
| 45 | 7.8363E-01 | 6.3997E-02 | 0.2529 | | | | | |
| | | | | 1 | AR | VERTICAL | 72.0000 | 72.0646 |
| 46 | 9.6465E-04 | 5.2273E-04 | 0.0021 | | | | | |
| | | | | 1 | AR | VERTICAL | 51.0000 | 51.8196 |
| | | | | 2 | BR | VERTICAL | 1.0000 | 1.0161 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 5.6446 |
| 47 | 8.4411E-01 | 6.3007E-01 | 2.4895 | | | | | |
| | | | | 1 | AR | VERTICAL | 50.0000 | 50.0899 |
| 48 | 9.4358E-04 | 3.3856E-04 | 0.0013 | | | | | |
| | | | | 1 | AR | VERTICAL | 51.0000 | 51.7863 |
| | | | | 2 | BR | VERTICAL | 1.0000 | 1.0155 |
| | | | | 31 | WD | HORIZONTAL | 1.0003 | 5.7532 |
| 49 | 1.8305E-06 | 3.8678E-08 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 326.0000 | 326.0136 |
| | | | | 2 | ST | VERTICAL | 2.0000 | 2.0001 |
| 50 | 4.2125E-11 | 1.7580E-13 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 317.0000 | 317.0141 |
| | | | | 2 | ST | VERTICAL | 2.0000 | 2.0001 |
| | | | | 3 | BR | VERTICAL | 2.0000 | 2.0001 |
| 51 | 4.9868E-11 | 1.5074E-12 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 267.0000 | 267.0169 |
| | | | | 2 | ST | VERTICAL | 2.0000 | 2.0001 |
| | | | | 3 | BR | VERTICAL | 2.0000 | 2.0001 |
| 52 | 5.1231E-11 | 3.1160E-13 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 259.0000 | 259.0175 |
| | | | | 2 | ST | VERTICAL | 2.0000 | 2.0001 |
| | | | | 3 | BR | VERTICAL | 2.0000 | 2.0001 |
| 53 | 1.1648E-05 | 8.5664E-07 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 192.0000 | 192.0234 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0002 |
| 54 | 2.6599E-10 | 2.8544E-12 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 185.0000 | 185.0241 |
| | | | | 2 | BR | VERTICAL | 4.0000 | 4.0005 |
| 55 | 1.2929E-05 | 8.0590E-07 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 161.0000 | 161.0278 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0003 |
| 56 | 1.3104E-05 | 1.8466E-07 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 157.0000 | 157.0283 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0004 |
| 57 | 1.3415E-05 | 1.0157E-06 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 150.0000 | 150.0300 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0004 |
| 58 | 6.0194E-01 | 1.1574E-01 | 0.4573 | | | | | |
| | | | | 1 | AR | VERTICAL | 150.0000 | 150.0300 |
| 59 | 6.5966E-06 | 6.8823E-07 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 282.0000 | 282.0159 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0001 |

Table 12 (Cont.)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 60 | 1.4029E-10 | 1.5701E-11 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 225.0000 | 225.1822 |
| | | | | 2 | BR | VERTICAL | 3.0000 | 3.0024 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 24.8653 |
| 61 | 1.0634E-05 | 1.4287E-07 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 219.0000 | 219.0205 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0002 |
| 62 | 1.3160E-07 | 1.1315E-08 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 205.0000 | 207.7112 |
| | | | | 2 | CN | VERTICAL | 1.0000 | 1.0132 |
| | | | | 2 | BR | VERTICAL | 1.0000 | 1.0132 |
| | | | | 31 | WD | HORIZONTAL | 2.0000 | 12.4189 |
| 63 | 1.1262E-05 | 1.7323E-07 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 202.0000 | 202.0225 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0002 |
| 64 | 2.0395E-01 | 1.4957E-02 | 0.0591 | | | | | |
| | | | | 1 | AR | VERTICAL | 208.0000 | 216.2825 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 3.6485 |
| 65 | 1.1262E-05 | 1.7145E-07 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 202.0000 | 202.0222 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0002 |
| 66 | 2.3238E-05 | 1.0214E-06 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 204.0000 | 205.0784 |
| | | | | 2 | BR | VERTICAL | 1.0000 | 1.0053 |
| | | | | 31 | WD | HORIZONTAL | 2.0000 | 19.5275 |
| 67 | 1.0962E-05 | 1.5520E-07 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 210.0000 | 210.0210 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0002 |
| 68 | 2.0595E-09 | 1.8093E-10 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 216.0000 | 217.0240 |
| | | | | 2 | ST | VERTICAL | 1.0000 | 1.0047 |
| | | | | 3 | BR | VERTICAL | 2.0000 | 2.0095 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 10.3061 |
| 69 | 9.0[illegible]47E-30 | 1.0687E-30 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 326.0000 | 329.2045 |
| | | | | 2 | CN | VERTICAL | 1.0000 | 1.0098 |
| | | | | 3 | BR | VERTICAL | 2.0000 | 2.0197 |
| | | | | 31 | CN | HORIZONTAL | 1.0000 | 7.1845 |
| 70 | 5.3819E-12 | 1.5811E-14 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 540.0000 | 540.0084 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0000 |
| | | | | 3 | CN | VERTICAL | 2.0000 | 2.0000 |
| 71 | 5.4746E-16 | 7.1042E-18 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 557.0000 | 567.1392 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0364 |
| | | | | 3 | CN | VERTICAL | 2.0000 | 2.0364 |
| | | | | 4 | ST | VERTICAL | 1.0000 | 1.0182 |
| | | | | 31 | WD | HORIZONTAL | 2.0000 | 10.6245 |
| 72 | [illegible].4684E-12 | 1.0917E-14 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 595.0000 | 595.0076 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0000 |
| | | | | 3 | CN | VERTICAL | 2.0000 | 2.0000 |
| 76 | 8.3109E-06 | 1.5020E-07 | 0.0000 | | | | | |

Table 12 (Cont.)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 1 | AR | VERTICAL | 292.0000 | 292.0155 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0001 |
| 77 | 7.4338E-06 | 2.9490E-08 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 325.0000 | 325.0137 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0001 |
| 78 | 7.1624E-06 | 1.2297E-07 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 336.0000 | 336.0134 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0001 |
| 79 | 9.2128E-12 | 2.7439E-14 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 381.0000 | 381.0118 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0001 |
| | | | | 3 | CN | VERTICAL | 2.0000 | 2.0001 |
| 80 | 8.9368E-12 | 1.1681E-13 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 390.0000 | 390.0115 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0001 |
| | | | | 3 | CN | VERTICAL | 2.0000 | 2.0001 |
| 81 | 1.1419E-17 | 2.6261E-20 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 437.0000 | 437.0103 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0000 |
| | | | | 3 | CN | VERTICAL | 4.0000 | 4.0001 |
| 82 | 1.1040E-17 | 1.3290E-19 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 447.0000 | 447.0101 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0000 |
| | | | | 3 | CN | VERTICAL | 4.0000 | 4.0001 |
| 83 | 4.0776E-13 | 7.1550E-16 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 504.0000 | 504.0090 |
| | | | | 2 | CN | VERTICAL | 4.0000 | 4.0001 |
| 84 | 8.8623E-18 | 4.3441E-20 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 512.0000 | 512.0088 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0000 |
| | | | | 3 | CN | VERTICAL | 4.0000 | 4.0001 |
| 85 | 8.0619E-18 | 1.2280E-20 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 540.0000 | 540.0083 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0000 |
| | | | | 3 | CN | VERTICAL | 4.0000 | 4.0001 |
| 86 | 7.8203E-18 | 5.3935E-20 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 549.0000 | 549.0081 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0000 |
| | | | | 3 | CN | VERTICAL | 4.0000 | 4.0001 |
| 93 | 9.3125E-05 | 3.3727E-06 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 293.0000 | 334.8237 |
| | | | | 2 | CN | VERTICAL | 1.0000 | 1.1427 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 2.0663 |
| 94 | 3.6982E-01 | 3.5398E-03 | 0.0140 | | | | | |
| | | | | 1 | AR | VERTICAL | 294.0000 | 294.0153 |
| 95 | 1.0107E-04 | 3.4755E-06 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 335.0000 | 369.2499 |
| | | | | 2 | CN | VERTICAL | 1.0000 | 1.1022 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 2.3775 |
| 96 | 3.0188E-01 | 2.0626E-03 | 0.0061 | | | | | |
| | | | | 1 | AR | VERTICAL | 354.0000 | 354.0127 |

Table 12 (Cont.)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 97 | 4.1566E-04 | 1.1612E-05 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 375.0000 | 367.0816 |
| | | | | 2 | BR | VERTICAL | 1.0000 | 1.0322 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 4.0340 |
| 98 | 2.4809E-01 | 1.2663E-03 | 0.0050 | | | | | |
| | | | | 1 | AR | VERTICAL | 412.0000 | 412.0109 |
| 99 | 2.7915E-04 | 7.1366E-06 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 430.0000 | 437.8139 |
| | | | | 2 | BR | VERTICAL | 1.0000 | 1.0182 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 5.3167 |
| 100 | 1.9380E-01 | 7.3555E-04 | 0.0029 | | | | | |
| | | | | 1 | AR | VERTICAL | 485.0000 | 485.0094 |
| 101 | 6.1212E-05 | 5.7725E-07 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 523.0000 | 555.7446 |
| | | | | 2 | CN | VERTICAL | 1.0000 | 1.0626 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 2.9570 |
| 102 | 1.6984E-01 | 5.5363E-04 | 0.0022 | | | | | |
| | | | | 1 | AR | VERTICAL | 524.0000 | 524.0086 |
| 103 | 5.2422E-05 | 7.3694E-07 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 547.0000 | 560.0550 |
| | | | | 2 | CN | VERTICAL | 1.0000 | 1.0239 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 4.6586 |
| 104 | 1.3958E-01 | 3.6910E-04 | 0.0015 | | | | | |
| | | | | 1 | AR | VERTICAL | 582.0000 | 582.0077 |
| 105 | 1.4284E-04 | 2.2682E-06 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 602.0000 | 611.3920 |
| | | | | 2 | BR | VERTICAL | 1.0000 | 1.0156 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 5.7272 |
| 110 | 2.7757E-04 | 2.5402E-05 | 0.0001 | | | | | |
| | | | | 1 | AR | VERTICAL | 262.0000 | 268.4681 |
| | | | | 2 | ST | VERTICAL | 1.0000 | 1.0247 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 4.5832 |
| 111 | 3.0086E-01 | 2.0556E-03 | 0.0081 | | | | | |
| | | | | 1 | AR | VERTICAL | 355.0000 | 355.0128 |
| 112 | 1.7128E-02 | 5.0127E-04 | 0.0020 | | | | | |
| | | | | 1 | AR | VERTICAL | 362.0000 | 363.4891 |
| | | | | 2 | WD | VERTICAL | 1.0000 | 1.0041 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 11.0591 |
| 113 | 2.4642E-01 | 1.2577E-03 | 0.0050 | | | | | |
| | | | | 1 | AR | VERTICAL | 414.0000 | 414.0109 |
| 114 | 8.2580E-05 | 2.9341E-06 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 435.0000 | 448.2034 |
| | | | | 2 | CN | VERTICAL | 1.0000 | 1.0304 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 4.1505 |
| 115 | 1.7688E-01 | 5.9831E-04 | 0.0024 | | | | | |
| | | | | 1 | AR | VERTICAL | 512.0000 | 512.0088 |
| 116 | 3.9654E-05 | 8.9827E-07 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 530.0000 | 536.3332 |
| | | | | 2 | CN | VERTICAL | 1.0000 | 1.0119 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 6.5264 |

Table 12 (Cont.)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 121 | 3.7486E-01 | 1.4674E-02 | 0.0580 | 1 | AR | VERTICAL | 290.0000 | 290.0153 |
| 122 | 1.5199E-06 | 4.5268E-09 | 0.0000 | 1 | AR | VERTICAL | 381.0000 | 381.0118 |
| | | | | 2 | ST | VERTICAL | 2.0000 | 2.0001 |
| 123 | 1.4744E-06 | 1.9272E-08 | 0.0000 | 1 | AR | VERTICAL | 390.0000 | 390.0115 |
| | | | | 2 | ST | VERTICAL | 2.0000 | 2.0001 |
| 124 | 1.2577E-06 | 2.8923E-09 | 0.0000 | 1 | AR | VERTICAL | 437.0000 | 437.0103 |
| | | | | 2 | ST | VERTICAL | 2.0000 | 2.0000 |
| 125 | 1.2159E-06 | 2.0800E-08 | 0.0000 | 1 | AR | VERTICAL | 447.0000 | 447.0101 |
| | | | | 2 | ST | VERTICAL | 2.0000 | 2.0000 |
| 126 | 5.7175E-07 | 9.0152E-10 | 0.0000 | 1 | AR | VERTICAL | 531.0000 | 531.0085 |
| | | | | 2 | ST | VERTICAL | 2.0000 | 2.0000 |
| | | | | 3 | WD | VERTICAL | 2.0000 | 2.0000 |
| 127 | 5.4901E-07 | 5.9728E-09 | 0.0000 | 1 | AR | VERTICAL | 543.0000 | 543.0083 |
| | | | | 2 | ST | VERTICAL | 2.0000 | 2.0000 |
| | | | | 3 | WD | VERTICAL | 2.0000 | 2.0000 |
| 132 | 4.3979E-04 | 2.1855E-05 | 0.0001 | 1 | AR | VERTICAL | 328.0000 | 335.5311 |
| | | | | 2 | BR | VERTICAL | 1.0000 | 1.0233 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 4.7465 |
| 133 | 2.7182E-01 | 1.4549E-03 | 0.0057 | 1 | AR | VERTICAL | 385.0000 | 385.0116 |
| 134 | 1.4879E-04 | 4.7568E-06 | 0.0000 | 1 | AR | VERTICAL | 396.0000 | 398.5685 |
| | | | | 2 | BR | VERTICAL | 1.0000 | 1.0065 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 8.8227 |
| 135 | 2.1378E-01 | 8.5024E-04 | 0.0034 | 1 | AR | VERTICAL | 456.0000 | 456.0099 |
| 136 | 3.4685E-05 | 8.3944E-07 | 0.0000 | 1 | AR | VERTICAL | 465.0000 | 466.1685 |
| | | | | 2 | BR | VERTICAL | 1.0000 | 1.0025 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 14.1320 |
| 137 | 1.6643E-01 | 5.0486E-04 | 0.0020 | 1 | AR | VERTICAL | 530.0000 | 530.0085 |
| 138 | 8.2773E-10 | 1.1068E-11 | 0.0000 | 1 | AR | VERTICAL | 549.0000 | 559.3384 |
| | | | | 2 | BR | VERTICAL | 1.0000 | 1.0188 |
| | | | | 3 | ST | VERTICAL | 2.0000 | 2.0377 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 5.2253 |
| 139 | 7.6238E-07 | 1.9190E-09 | 0.0000 | 1 | AR | VERTICAL | 585.0000 | 565.0077 |
| | | | | 2 | ST | VERTICAL | 2.0000 | 2.0000 |
| 140 | 5.6381E-10 | 1.0127E-11 | 0.0000 | 1 | AR | VERTICAL | 603.0000 | 610.3301 |
| | | | | 2 | ST | VERTICAL | 2.0000 | 2.0345 |

Table 12 (Cont.)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 3 | ER | VERTICAL | 1.0000 | 1.0122 |
| | | | | 31 | WD | HORIZONTAL | 1.0000 | 6.4717 |
| 145 | 4.2918E-01 | 4.5149E-02 | 0.1784 | | | | | |
| | | | | 1 | AR | VERTICAL | 250.0000 | 250.0180 |
| 146 | 6.0194E-01 | 1.4499E-01 | 0.5729 | | | | | |
| | | | | 1 | AR | VERTICAL | 150.0000 | 150.0300 |
| 147 | 8.4411E-01 | 9.3877E-01 | 5.7093 | | | | | |
| | | | | 1 | AR | VERTICAL | 50.0000 | 50.0899 |
| 148 | 9.5906E-01 | 1.7239E 01 | 68.1141 | | | | | |
| | | | | 31 | ER | HORIZONTAL | 3.0000 | 3.0000 |
| 149 | 8.4411E-01 | 9.3877E-01 | 5.7093 | | | | | |
| | | | | 1 | AR | VERTICAL | 50.0000 | 50.0899 |
| 150 | 6.0194E-01 | 1.4499E-01 | 0.5729 | | | | | |
| | | | | 1 | AR | VERTICAL | 150.0000 | 150.0300 |
| 151 | 4.2918E-01 | 4.5149E-02 | 0.1784 | | | | | |
| | | | | 1 | AR | VERTICAL | 250.0000 | 250.0180 |
| 152 | 3.0599E-01 | 1.7994E-02 | 0.0711 | | | | | |
| | | | | 1 | AR | VERTICAL | 350.0000 | 350.0128 |
| 153 | 2.1816E-01 | 8.1870E-03 | 0.0323 | | | | | |
| | | | | 1 | AR | VERTICAL | 450.0000 | 450.0100 |
| 154 | 1.5554E-01 | 4.0471E-03 | 0.0160 | | | | | |
| | | | | 1 | AR | VERTICAL | 550.0000 | 550.0082 |
| 155 | 1.1090E-01 | 2.1179E-03 | 0.0084 | | | | | |
| | | | | 1 | AR | VERTICAL | 650.0000 | 650.0069 |
| 156 | 9.5455E-06 | 6.8319E-07 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 251.0000 | 251.0181 |
| | | | | 2 | BR | VERTICAL | 2.0000 | 2.0001 |
| 157 | 2.4292E-10 | 1.6294E-11 | 0.0000 | | | | | |
| | | | | 1 | AR | VERTICAL | 212.0000 | 212.0212 |
| | | | | 2 | BR | VERTICAL | 4.0000 | 4.0004 |
| 158 | 5.8192E-01 | 1.1182E-01 | 0.4418 | | | | | |
| | | | | 1 | AR | VERTICAL | 160.0000 | 160.0288 |
| 159 | 5.8192E-01 | 1.1182E-01 | 0.4418 | | | | | |
| | | | | 1 | AR | VERTICAL | 160.0000 | 160.0288 |
| 160 | 4.8805E-01 | 3.2736E-02 | 0.1293 | | | | | |
| | | | | 1 | AR | VERTICAL | 212.0000 | 212.0212 |
| 161 | 4.2773E-01 | 3.9575E-02 | 0.1564 | | | | | |
| | | | | 1 | AR | VERTICAL | 251.0000 | 251.0181 |

TOTAL RELATIVE DOSE = 2.1103E 01
= 83.361 PER CENT OF BACKGROUND RADIATION