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An Assessment of Radiation Doses from Incandescent Gas Mantles that Contain Thorium

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HEALTH AND SAFETY RESEARCH DIVISION
OAK RIDGE NATIONAL LABORATORY

Prepared for the
U.S. Nuclear Regulatory Commission
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Division of Risk Analysis
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ABSTRACT

Potential radiation dose equivalents were estimated for individuals and the population of the United States from annual distribution, use, and disposal of 25 million thorium-containing incandescent gas mantles. Under exposure scenarios developed from the best available information, total dose equivalents (sums of annual external dose equivalents and 50-year dose commitments from intakes during the year of radionuclides) to individuals were estimated to range from 0.01 pSv (1 prem) to 0.2 mSv (20 mrem) to total body, 0.02 pSv to 0.5 mSv to bone, and 0.01 pSv to 0.5 mSv to lungs. Collective dose commitments were estimated to range from 6 to 70 person-Sv (600-7000 person-rem), 20 to 400 bone-Sv, and 20 to 700 lung-Sv. Only ranges of potential dose commitments could be estimated because of uncertainties regarding nuclide behavior in mantles and some aspects of the personal behavior of some exposed persons. The uncertainties are discussed.

SUMMARY

Incandescent gas mantles contain between 50 and 500 mg of thorium, which is a naturally occurring radioactive material consisting of 11 radionuclides. Because mantles are widely distributed and used, they are potential sources of radiation exposure to the public. This report presents estimates of radiation dose equivalents that might be received by individuals and the population of the United States from annual distribution, use, and disposal of 25 million incandescent mantles.

Persons who might be exposed to the mantles were divided into functionally related groups. Exposure scenarios for a representative individual from each group were constructed from information supplied by mantle manufacturers, distributors, and users and from a previous study of methods used to transport and distribute consumer products. Scenarios were constructed for groups of persons involved in transport, distribution, use, and disposal of mantles. In addition, consideration was given to persons who could be exposed to mantles incidentally and accidentally during transport, distribution, disposal, and unusual circumstances.

The resulting scenarios were then used to calculate doses to individuals. Individual doses were summed to obtain population doses.

The dose calculations were complicated by uncertainties regarding the radionuclide composition in new mantles, the behavior of the nuclides during mantle operation, the rate of ^{220}Rn diffusion from the mantles, and the behavior of mantle changers. Each topic is discussed, but, without factual characterization, only ranges of potential doses could be estimated.

The following table is a brief summary of total doses (sums of dose equivalents from external exposure and 50-year dose commitments from internal exposures that occur during one year) associated with annual transport, distribution, use, and disposal of 25 million mantles and with unusual events. Section 5 of this report contains a detailed summary of the dose estimates. Average individual doses to workers

Summary of total dose estimates from annual transport, distribution, use, and disposal of 25 million incandescent gas mantles and from unusual events

Affected persons	Number of persons, thousands	Doses to total body		Doses to bone		Doses to lungs	
		Individual, Sv	Population person-Sv	Individual, Sv	Population, bone-Sv	Individual, Sv	Population, lung-Sv
Workers	300	2E-6	6E-1	4E-6	1	2E-6	5E-1
Users	26,148	1E-6	4E+1	7E-6	2E+2	2E-5	5E+2
General public	210,000	1E-8	3	1E-8	3	1E-8	2
All persons	210,000	2E-7	4E+1	9E-7	2E+2	2E-6	5E+2
Unusual events:							
Drinking contaminated water	1,000	4E-11	4E-5	3E-10	3E-4	2E-14	2E-8
Ingesting a mantle	[a]	1E-3	[a]	7E-3	[a]	4E-7	[a]

[a] Value was not estimated.

(transport and distribution) were estimated to be 2 μSv to total body and lungs, and 4 μSv to bone. Average doses to mantle users were estimated to be 1 μSv to total body, 7 μSv to bone, and 20 μSv to lungs. Average doses to other members of the general public were estimated to be 0.01 μSv to total body, bone, and lungs. Overall average individual doses were estimated to be 0.2 μSv to total body, 0.9 μSv to bone, and 2 μSv to lungs.

An individual drinking contaminated water that runs from a campground at which broken mantles were discarded into a reservoir could receive 0.04 nSv to total body, 0.3 nSv to bone, and 0.00002 nSv to lungs. Ingestion of an entire mantle could result in doses (50-year dose commitments) of 1 mSv to total body, 7 mSv to bone, and 0.0004 mSv to lungs.

Corresponding overall population doses were estimated to be 40 person-Sv (to total body), 200 bone-Sv, and 500 lung-Sv. Essentially all of the population doses were attributable to use of mantles by campers, indoor and outdoor residential light users, and recreational vehicle users.

As noted throughout this report, all of the dose estimates for individuals and population groups span a range of values. In general, the highest dose values are twice the average values given in this brief summary. Section 5 gives the ranges and compares them to doses from environmental sources of radiation.

1. INTRODUCTION

Gas lamps have been used as sources of light since the late 1700s. Although largely replaced by the electric light bulb, gas lamps are still used in portable, remote, decorative, and emergency lighting applications. The primary source of light in a modern gas lamp is a device which was developed in the 1800s. It is called the Welsbach, or incandescent, gas mantle and consists essentially of a mesh bag that is impregnated with compounds of thorium and other metals (Griggs, 1973; Cullen and Paschoa, 1978). Placement of such a mantle in or near the flame of an operating lamp allows the mantle to be heated to a temperature at which the contained thorium will incandesce (i.e., glow brightly).

Because thorium, a naturally occurring radioactive material, is classified as "source material," its use is regulated by the U.S. Nuclear Regulatory Commission (NRC). Current (1980) regulations require that manufacture and import of thorium-containing incandescent mantles be licensed, but place no restrictions on receipt, possession, use, transfer, and acquisition of mantles (i.e., these actions are exempt from regulation and requirements for a license) *(Code of Federal Regulations*, 1980a).

This report contains our latest estimates of radiation dose equivalents that might be received by the population of the United States during unrestricted transport, distribution, use, and disposal of incandescent mantles that contain thorium. As such, it updates, refines, and corrects our preliminary dose equivalent estimates (O'Donnell, 1976 and 1978) and complements another recently published mantle study (Buckley et al., 1980).

Information concerning manufacture, transport, and distribution of mantles was obtained by a survey of domestic mantle manufacturers, by informal conversions with transport companies and mantle distributors, and from available literature. (To preserve confidentiality, only published information is referenced in this report.) This information and that gleaned from conversations with mantle users were used to construct representative scenarios (sets of exposure conditions) for

transport, distribution, use, and disposal of the mantles. The resultant sets of conditions were the bases for calculating radiation doses to exposed persons.

Section 2 contains a description of incandescent mantles, an explanation of their operation, a listing of their uses, and an estimate of their annual consumption by type of use. Section 3 contains a discussion of the strategy and methods used to estimate radiation doses to man. Section 4 contains estimates of radiation dose equivalents to persons from exposures that may occur during transport, distribution, use, and disposal of the mantles. Section 5 contains a detailed summary and discussion of the dose estimates.

Sections 3 and 4 contain specifications of the assumptions and exposure conditions used to make the dose estimates. This is done in recognition of the fact that we selected for use in this assessment a small, representative (neither worst nor best) sample of the infinitely large number of possible scenarios.

In compliance with the official policy of the Oak Ridge National Laboratory, this report uses the International System of Units (SI). The relationship between the new SI units and the previously used units for the radiation quantities found in this report are given in Table 1. For convenience, the numerical values of prefix symbols used in this report are given in Table 2.

2. PRODUCT INFORMATION

Information obtained from domestic manufacturers and distributors of incandescent mantles and from import estimates* indicate that on the order of 25 million mantles are distributed annually throughout the United States. (Recent import estimates show a decreasing trend in the number of mantles imported each year.) These mantles are used in a variety of gas- and kerosene-fired lighting devices. Most mantles are used in portable (e.g., camping) lanterns (~85%); the remainder, in

*Import estimates may be found in annual editions of the *Minerals Yearbook*, published by the U.S. Bureau of Mines, and in the March issues of the *Engineering and Mining Journal*.

Table 1. Relationship between some SI units and previously used units

Quantity	SI unit and symbol	Previous unit and symbol	Conversion factor
Activity	becquerel, Bq	curie, Ci	1 Bq = 2.7×10^{-11} Ci
Dose equivalent	sievert, Sv	rem, rem	1 Sv = 100 rem
Exposure	none, C/kg	roentgen, R	1 C/kg = 3900 R

Table 2. Values of prefix symbols used in this report

Prefix	Value	Prefix	Value
p	10^{-12}	m	10^{-3}
n	10^{-9}	k	10^{3}
μ	10^{-6}		

residential and commercial outdoor gas lights (~8%), residential indoor gas and kerosene lamps (~5%), and lights installed in recreational vehicles (~2%). Regulations recently promulgated by the U. S. Department of Energy (*Code of Federal Regulations*, 1980b) will prevent increased use of outdoor gas lights and, in fact, have been instrumental in reducing the number of such lights by ~1.5 million units below the number in service during 1978 (*Federal Register*, 1979).

The function of an incandescent mantle is to produce a bright light during operation of the lighting device in which the mantle is installed. To function, the mantle must be heated to a temperature at which the contained thorium will incandesce. This is achieved by placing the mantle over, in, or near the gas (or kerosene) flame that burns during operation of the lighting device. Such placement allows the flame to heat the thorium to 1600-2100 K, a temperature range in which thorium will incandesce and, thus, give off the desired light.

All incandescent mantles are essentially bags fashioned from a thorium-impregnated, webbed fabric (usually rayon). They are made in a variety of designs and sizes, each intended to fit into one of the various lighting devices that are available. Common designs are "soft" mantles for "inverted" installation and "hard" mantles for either "upright" or "inverted" installation.* Most mantles, when flattened, consist of two layers of fabric that are between 4- and 11-cm long and 2- and 7-cm wide. They may contain between 50 and 500 mg of thorium in nitrate, hydroxide, or oxide form plus a few milligrams of cerium,

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*A "soft" mantle is a flexible bag having its open end either equipped with a drawstring for tying it directly to the burner assembly, or affixed to a holder that attaches to the burner assembly. "Soft" mantles are typified by those used in camping lanterns.

A "hard" mantle is a bag that is preshaped by attachment to a rigid support frame that either attaches to or sits over the burner assembly. "Hard" mantles are typified by those used in kerosene lamps.

In "inverted" installation, a mantle attaches to and hangs below a burner assembly that directs its flame downward, into the mantle.

In "upright" installation, a mantle attaches to or sets over a burner assembly that directs its flame upward, into the mantle.

aluminum, and, possibly, other metal compounds (Griggs, 1973; Cullen and Paschoa, 1978). The most common mantle design used in the United States is the "soft" design used in portable (camping) lanterns. This design is nominally 8-cm long and 6-cm wide and is reported to contain as much as 250 mg of thorium. We analyzed an old (∿20-y old) pack of two such mantles and found it to contain ∿300 mg of thorium and to have a total (beta particle plus photon) exposure rate of ∿4 nC/kg·s (1 mR/h) at the surface of the bag. The photon contribution to the exposure rate was estimated to be ∿0.4 nC/kg·s.

Mantles are manufactured by soaking a webbed fabric in a solution containing water-soluble nitrates of thorium and the other metals. When saturated, the fabric is removed from the solution and dried. In some cases, the fabric is treated to convert the soluble nitrates into insoluble compounds (most likely into hydroxides), and then is rinsed and dried. The fabric is then coated with lacquer, dried, cut, and fashioned into mantles. Some hard mantles are preburned at the factory (Cullen and Paschoa, 1978). This procedure volatilizes the fabric bag and the lacquer coating, leaving a fragile shell of thorium and other metal compounds.

Finished mantles are packaged and distributed as ordinary consumer products. Hard mantles are normally boxed singly; one or two soft mantles are usually sealed in a plastic pack. In both cases, a box or a pack may be placed in a carton containing a new lighting device, or may be combined with other boxes or packs in a carton containing replacement mantles. Section 4.1 contains descriptions of typical packaging configurations for new lighting devices and for replacement mantles.

Except for mantles to be installed in outdoor lighting devices, which are normally purchased and installed by utility companies, most mantles and new lighting devices are purchased from retail stores and installed in the lighting devices by persons who use the mantles and devices. All mantles are installed manually in the appropriate device, which may accommodate between one and four mantles. Once installed, the mantles are preburned to shape and condition them for use. As noted above, this procedure converts the mantles into thin, fragile, conical

or spheroidal shells of thoria (thorium dioxide, ThO_2) plus other unvolatilized metal oxides. This form is retained throughout the useful life of the mantles, which depends on the manner and the environment in which the lighting device containing the mantles is used. Generally, use in stable environments (e.g., those free from mechanical abuse by shocks, vibrations, and drafts) will yield longer useful lives. Manufacturers estimate that mantles used in stable environments (e.g., in fixed outdoor and indoor residential lights) remain intact typically for six to eight months. In less stable environments (e.g., moveable indoor lights), mantles may last between one and three months. In portable devices (e.g., camping lanterns), which are subject to frequent movement and to transportation stresses, a useful life of 50 burning hours is typical.

Disposal of broken mantles is a function of when the user becomes aware of the fact that the mantle is broken and the urgency to replace it. Many camping mantles will be replaced at campsites. In this case, the broken mantles most likely will be discarded on the ground at the campsite. Replacement of mantles in the home will usually result in the broken residue being discarded as domestic solid waste. In this case, some of the powdery residue will most likely fall to the floor before being swept up and discarded. Replacement of mantles used in other outdoor lighting applications will be similar to replacement of camping mantles, except that the broken mantles will be discarded on the ground at the location of the light. Replacement of recreational vehicle lights will substitute the vehicle for the home, but the procedure will be similar.

3. ASSESSMENT STRATEGY

The purpose of this study was to estimate potential radiation dose equivalents to individuals and the population of the United States from incandescent mantles. To do this, average dose equivalents (hereafter simply called doses) to total body, bone, and lungs were calculated with the aid of the CONDOS methodology and computer code (O'Donnell et al., 1981) for annual transport, distribution, use, and disposal of 25 million mantles. As prescribed by the methodology, the population

was divided into functionally related groups of persons. Each group was represented by a typical individual who was assumed to be exposed to the mantles under a set of exposure events. Each event was described by a set of exposure conditions prepared from the information described in Sects. 1 and 2. The computer code and the exposure conditions were used to: (1) calculate external, internal, and total doses to individual group members; (2) sum individual doses to give group population doses; and (3) sum group doses to give overall population doses. The possible effects on the dose calculations of several processes which could influence the radionuclide content of the mantles and the release of radionuclides from the mantles were also considered, and are discussed below.

3.1 POPULATION GROUPS CONSIDERED

The population groups considered are described in Sect. 4. They include persons who could be exposed: (1) during bulk transport of mantles (e.g., truck drivers, truck terminal workers, parcel handlers, and persons along truck routes); (2) during distribution of mantles (e.g., warehouse workers, truck drivers, retail sales and stock clerks, retail store customers, persons along truck routes, and utility company employees); (3) during use of mantles (e.g., campers and their families, residents of homes near outdoor residential lights, users of indoor residential lamps, and recreational vehicle users); (4) during and after disposal of broken mantles (e.g., solid waste collection workers and persons residing near incinerators); and (5) during unusual events (e.g., drinking water from a contaminated reservoir and ingesting a mantle).

3.2 DOSIMETRIC CONSIDERATIONS

This report gives estimations of dose equivalents to the total body, bone, and lungs of individuals or groups of persons who may be exposed during one year to radionuclides contained in or released from incandescent gas mantles. The dose equivalents are expressed as external, internal, or total doses. These expressions have the following meanings:

1. External doses are received from exposures to photons emitted by radionuclides contained in or on sources (e.g., gas mantles, air, and ground) external to the bodies of exposed persons. The external doses given in this report are either those from specific external exposure events or the sums of doses received by the designated persons from all external exposure events in which the persons were assumed to participate during one year.
2. Internal doses are received from exposures to all radiations (photons and alpha and beta particles) emitted by radionuclides taken into the bodies of exposed individuals. The internal doses given in this report are 50-y dose commitments (the sums of doses that will be received over the 50 years succeeding the intakes) from inhalation and ingestion of radionuclides. They are either doses from specific internal exposure events or the sums of doses received by the designated persons from all intakes of radionuclides during one year.
3. Total doses, as given in this report, are the sums of external and internal doses from specific exposure events or from all exposure events in which the designated persons were assumed to participate during one year.

We attempted to specify throughout this report the dose expressions used. All doses associated with transport and distribution of mantles are external doses, except those to utility installers, which include both external and internal doses. Doses associated with mantle use generally include both external and internal doses. Most doses associated with mantle disposal and the unusual events are internal doses, but a few (e.g., those to solid waste collectors) are external doses.

All doses were calculated using the CONDOS II computer code (O'Donnell et al., 1981). CONDOS II calculates external doses from direct exposures to physical objects (e.g., gas mantles and contaminated

ground) and immersion in contaminated air, and internal doses from inhalation and ingestion of radionuclides released from mantles. In all cases, the dose calculations were based on the input data described in Sect. 4 and Appendix A.

CONDOS II solves standard source geometry equations to calculate doses from physical objects. Dose-rate conversion factors (Kocher, 1980) are used to calculate doses from immersion in contaminated air. All organ doses from external exposures are based on factors derived from estimates by Poston and Snyder (1974) of absorbed dose rates in the organs for monoenergetic photons emitted by radionuclides dispersed uniformly in a semi-infinite air space. All radionuclide decay data used in the external (and the internal) dose calculations are taken from Kocher (1977).

CONDOS II uses a breathing rate of 0.9 m^3/h and organ-specific 50-y dose-conversion factors from Dunning et al. (1979) to calculate internal doses from inhalation of radionuclides. Ingestion doses are calculated using input-specified quantities of ingested radionuclides and organ-specific 50-y dose-conversion factors from Dunning et al. (1979). All internal dose-conversion factors are based on a quality factor of ten for alpha particles. Table 3 is a listing of the radionuclides in the thorium decay chain and their radioactive half-lives, specific activities, and immersion, inhalation, and ingestion dose-conversion factors for total body, bone, and lungs. (The inhalation and ingestion dose-conversion factors for endosteal bone cells are approximately two to three times higher than those for bone, which were used in this assessment.)

The inhalation dose-conversion factors are derived (Dunning et al., 1979) using the International Commission on Radiological Protection (ICRP) task group lung model (Morrow et al., 1966) and parameters from ICRP Publication 19 (ICRP, 1972). Retention of radionuclides in organs other than the respiratory tract is modeled by linear combinations of up to five decaying exponential functions. The factors used in this assessment correspond to those for particles having activity median aerodynamic diameters of 1.0 μm and solubility

Table 3. Radioactive half-lives, specific activities, and dose-conversion factors for the radionuclides in the thorium decay chain

Nuclide	Radioactive half-life (s)	Specific activity (Bq/kg)	Dose-conversion factors								
			Immersion (Sv/y per Bq/cubic cm)			Inhalation (Sv/Bq)[a]			Ingestion (Sv/Bq)[a]		
			Total body	Bone	Lungs	Total body	Bone	Lungs	Total body	Bone	Lungs
Th-232	4.43E17[b]	4.06E06	2.66E-04	4.16E-04	1.82E-04	2.2E-05	2.42E-04	6.24E-05	4.1E-07	4.9E-06	3.05E-11
Ra-228	1.81E08	1.01E16	5.51E-11	8.32E-12	4.54E-12	1.5E-06	4.1E-06	7.0E-07	1.2E-06	3.0E-06	6.51E-10
Ac-228	2.20E04	8.31E19	1.38	1.58	1.30	1.43E-09	8.24E-09	3.5E-08	7.4E-11	3.86E-10	7.00E-12
Th-228	6.03E07	3.04E16	3.00E-03	4.89E-03	2.51E-03	3.8E-06	1.9E-05	9.86E-05	7.30E-08	8.9E-07	1.70E-11
Ra-224	3.16E05	5.89E18	1.52E-02	2.18E-02	1.36E-02	3.8E-08	4.1E-08	1.2E-06	2.61E-08	5.4E-08	2.49E-11
Rn-220	5.56E01	3.42E22	8.16E-04	9.76E-04	7.62E-04	4.43E-12	2.01E-12	3.00E-10	3.14E-12	3.65E-11	2.29E-14
Po-216	1.50E-01	1.29E25	0.0	0.0	0.0	4.73E-14	1.36E-13	2.54E-12	8.38-E15	9.86E-14	6.19E-17
Pb-212	3.83E04	5.15E19	2.22E-01	3.32E-01	1.96E-01	5.08E-09	1.76E-08	2.49E-07	1.12E-09	1.25E-08	1.44E-11
Bi-212	3.63E03	5.43E20	2.81E-01	3.11E-01	2.64E-01	6.00E-10	2.17E-10	3.78E-08	2.43E-11	3.38E-11	3.49E-12
Tl-208	1.84E02	1.09E22	5.46	5.76	5.16	6.11E-13	2.78E-13	1.94E-11	8.54E-13	2.76E-13	6.95E-13
Po-212	3.05E-07	6.46E30	0.0	0.0	0.0	5.86E-20	1.45E-29	4.11E-18	2.66E-22	2.40E-40	0.0

[a]Inhalation and ingestion dose-conversion factors are 50-year dose commitments.

[b]Read as 4.43×10^{17}.

classifications (Y or W) which have the highest lung dose-conversion factors.

The ingestion dose-conversion factors are derived (Dunning et al., 1979) using a four-segment catenary model of the gastrointestinal (GI) tract (Bernard, 1968) with mean transit times suggested by Eve (1966). Retention of radionuclides in organs other than the GI tract are modeled using the above-mentioned linear combinations of decaying exponential functions.

3.3 PROCESSES AFFECTING THE RADIONUCLIDE CONTENT OF THORIUM

The thorium used to manufacture incandescent gas mantles (thorium nitrate, called mantle-grade thorium) is prepared from ores of naturally occurring thorium which contains 11 radionuclides in secular, radioactive equilibrium (see Table 4). However, the various chemical and physical processes to which the thorium is subjected during mantle manufacture and use can significantly alter this equilibrium condition. Disequilibrium can cause significant variations in the dose estimates, depending on the type of exposure, the degree of variation, and the radionuclides affected.

The most important processes include: (1) selective removal of some or all of the radionuclides, except those of thorium, during chemical preparation of mantle-grade thorium and the solutions used to impregnate the fabric bags with thorium; (2) diffusion of ^{220}Rn, an inert gas, from the mantles; and (3) vaporization of some or all of the radionuclides, except those of thorium, during mantle operation. The degree to which these processes affect the radionuclide content of mantles and the release of radionuclides from the mantles are, at best, imprecisely known. Therefore, certain assumptions, which are stated in Sect. 3.3.1, were used in this assessment to account for these processes. The possible effects of these processes on decay chain equilibrium are discussed in Sects. 3.3.2, 3.3.3, and 3.3.4; possible effects on the dose estimates are discussed in Sect. 3.3.5.

Table 4. Radioactivities of the radionuclides in natural and depleted[a] thorium relative to the activity of Th-232

Radionuclide	Natural thorium	Age of thorium after depletion							
		0	1 day	7 days	6 months	1 year	5 years	10 years	20 years
Th-232	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Ra-228	1.0	0.0	0.0003	0.002	0.06	0.11	0.45	0.70	0.91
Ac-228	1.0	0.0	0.0002	0.002	0.06	0.11	0.45	0.70	0.91
Th-228	1.0	1.0	1.0	0.99	0.84	0.72	0.42	0.59	0.87
Ra-224	1.0	0.0	0.17	0.73	0.84	0.72	0.42	0.59	0.87
Rn-220	1.0	0.0	0.17	0.73	0.84	0.72	0.42	0.59	0.87
Po-216	1.0	0.0	0.17	0.73	0.84	0.72	0.42	0.59	0.87
Pb-212	1.0	0.0	0.09	0.70	0.84	0.72	0.42	0.59	0.87
Bi-212	1.0	0.0	0.08	0.69	0.84	0.72	0.42	0.59	0.87
Tl-208	0.36	0.0	0.03	0.25	0.30	0.26	0.15	0.21	0.31
Po-212	0.64	0.0	0.05	0.44	0.54	0.46	0.27	0.38	0.56

[a]Depleted thorium is defined as natural thorium that has had all but the two thorium nuclides removed at time zero.

3.3.1 Assumptions Used

As shown in Table 4, chemical removal of some or all of the radionuclides, except those of thorium, can significantly perturb the decay chain composition. Detailed consideration of all possible perturbations would be too time consuming and not overly instructive. Therefore, to show the effects of such perturbations, we calculated doses for mantles that were assumed to contain either natural thorium (to obtain maximum doses under the conditions used) or six-month-old, depleted thorium (to obtain more likely doses).

Because insufficient data were available to calculate the diffusion rate of ^{220}Rn from mantles, we assumed that 25% of the ^{220}Rn produced in mantles escapes from them (see Sect. 3.3.3). In effect, two assumptions were made: (1) that 25% of the ^{220}Rn which escapes from the solid thorium reaches the interparticle void space, and (2) that all of the escaping ^{220}Rn diffuses immediately from the mantles.

To bracket the possible effects of selective nuclide vaporization during mantle use, we calculated doses for the two most likely cases: (1) vaporization only of ^{220}Rn and its progeny, and (2) vaporization of all but the two thorium nuclides. For the first case, all of the ^{220}Rn and its progeny were assumed to leave the mantles immediately. Once the mantles are extinguished, the ^{220}Rn and its progeny will rebuild to their equilibrium values within 4.5 days. For the second case, all but the thorium nuclides were assumed to leave the mantles immediately upon ignition. This produces completely depleted thorium which is analogous to chemically depleted thorium.

3.3.2 Chemical Removal of Radionuclides

Chemical preparation of mantle-grade thorium has been reported to remove all but the two thorium radionuclides (Buckley et al., 1980). Preparation of impregnating solutions could have a similar effect, but this is doubtful and is ignored in the subsequent discussion. It takes approximately 100 years following complete depletion for the thorium decay chain to reestablish equilibrium (Table 4). The ^{228}Ra and ^{228}Ac activities rebuild slowly; the progeny of ^{228}Th rebuild rapidly and

then decrease over the next five years as the ^{228}Th decays. After five years, the ^{228}Th and its progeny rebuild slowly to their equilibrium activities.

3.3.3 Diffusion of ^{220}Rn from Mantles

Radon-220 almost certainly diffuses from mantles, but the rate of diffusion is unknown. This diffusion rate can be estimated with the aid of an equation developed by Culot and Schaiger (1973), if several parameters can be specified. [See Tennery et al. (1978) for a discussion of the equation and its requisite parameters for estimating ^{220}Rn diffusion from thorium.] Attempts to apply this equation to ^{220}Rn diffusion from mantles revealed three important, unknown parameters: (1) the fraction of the total mantle volume which is not occupied by solid particles; (2) the effective diffusion coefficient of ^{220}Rn in the interparticle void space; and (3) the emanation factor, or the fraction of ^{220}Rn which escapes from the solid particles and reaches the interparticle void space. [Emanation factors for ^{220}Rn have not been measured, but Tennery et al. (1978) report values for ^{222}Rn that range from about 0.01 to 0.23.] The effect of ^{220}Rn diffusion on the thorium decay chain composition is simply to reduce the values given in Table 4 for ^{220}Rn and its progeny by the fraction of ^{220}Rn that escapes. For example, our assumed emanation factor of 0.25 results in relative activities of ^{220}Rn and its progeny that are 75% of those given in Table 4. It should be noted that, unless appropriate barriers intervene, the ^{220}Rn that diffuses from the mantles will provide a steady flux of ^{220}Rn into the air around the mantle. This ^{220}Rn will decay and introduce its progeny into the air space. The resulting contaminated air will be a potential source for exposure by immersion in and inhalation of the contaminated air.

3.3.4 Volatilization of Radionuclides

During operation, incandescent mantles reach temperatures that are high enough to volatilize some and possibly all of the nuclides, except those of thorium, that are contained in the mantles. The existence of

this process was noted by Griggs (1973) and is supported by our calculations of evaporation rates for the nuclides found in mantles. Based on available vapor pressure data (Ackermann and Thorn, 1965; Dushman, 1962; and Honig, 1962) and our evaporation rate calculations,* we concluded that during mantle operation: (1) ^{220}Rn and its progeny will vaporize rapidly regardless of their chemical forms; (2) thorium will not vaporize, especially if it is in the expected oxide form; and (3) the actinium and the two radium nuclides may or may not vaporize, depending on the temperatures actually reached and the chemical form of the nuclides. The uncertainty in the third conclusion is due largely to a lack of vapor pressure data on radium and actinium compounds and to the unknown chemical form of these elements in the mantles.

Vaporization of all but the two thorium nuclides during mantle operation will perturb the decay chain exactly as was described in Sect. 3.3.2 for chemical depletion during preparation of mantle-grade thorium. For the purpose of dose calculations, major differences between chemical depletion and vaporization are that vaporization will recur every time a mantle is used and that the vaporized nuclides will, in the absence of barriers, enter the surrounding air in a pulse and subsequently can contribute to doses via inhalation of and immersion in the radioactively contaminated air. Once a pulse discharge to an air space (e.g., a room) has occurred, the subsequent airborne concentration of nuclides can diminish rapidly, depending on the rate of air exchange between the room and the large volume of surrounding air.

Vaporization of ^{220}Rn and its progeny during mantle operation will act like diffusion of ^{220}Rn from mantles, but will remove all the ^{220}Rn and its progeny from the decay chain. Unlike diffusion, which is a continuing effect, the effects of vaporization are short-term because the ^{220}Rn and its progeny will reattain radioactive equilibrium within

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*The evaporation rate can be calculated from $E\ (g/s) = A \times G$, where A is the total surface area of the sample in cm^2 and $G\ (g/cm^2 \cdot s) = (P/17.14) \times (M/T)^{0.5}$, where P is the vapor pressure of the element in millimeters of mercury, M is the molecular weight of the gaseous species, and T is the temperature in K (Winkler, 1971). Dushman (1962) gives alternate evaporation rate equations that yield results almost identical to those given by the above equation.

a few days, as noted above. Both vaporization and diffusion will produce airborne concentrations of ^{220}Rn and its progeny. The major difference for dose calculations is that vaporization introduces a pulse of ^{220}Rn and its progeny into the air space, while diffusion introduces a steady flux of only ^{220}Rn which decays to produce an equilibrium concentration of ^{220}Rn and its progeny in the air space.

3.3.5 Possible Effects on Dose Estimates

To discuss possible effects of the above processes on radiation doses, it is convenient to divide the thorium decay chain into three groups of nuclides: (1) ^{232}Th and ^{228}Th; (2) ^{228}Ra, ^{228}Ac, and ^{224}Ra; and (3) ^{220}Rn and progeny. The relative contributions of these groups to the total dose from natural thorium are as follows:

Exposure mode	Organ	Percent of dose from natural thorium		
		Group 1	Group 2	Group 3
External	All	0.2	39	61
Internal				
Inhalation	Total body	94	6	0.02
	Bone	98	2	0.01
	Lungs	99	1	0.2
Ingestion	Total body	29	71	0.07
	Bone	66	34	0.1
	Lungs	6	91	2

Using the relative contributions of the nuclide groups and the thorium compositions in Table 4, we find that complete depletion (to Group 1) would: (1) reduce external exposures by a factor of 500 initially, by factors of 2 to 2.5 over the first five years, and by factors gradually approaching unity after five years; (2) have very little effect on inhalation doses for situations in which airborne mantle particulates become airborne; and (3) reduce initial ingestion doses significantly, followed by a gradual buildup to initial values as the Group 2 nuclides rebuild.

Radon-220 diffusion (Group 3) is a steady, long-term process that produces steady-state effects. It would: (1) reduce significantly external doses from mantles, depending on the fraction of ^{220}Rn that escapes from the source (e.g., if 25% escapes, the dose reduction would be 25% of 61%, or 15%, a factor of 1.2), and produce very low doses from immersion in air containing the escaped ^{220}Rn and its subsequently produced progeny; (2) produce relatively small, but potentially important inhalation doses; and (3) not significantly affect ingestion doses.

Vaporization occurs only during operation of the mantles. It is characterized by an initial, pulse-type release of Group 3 and, possibly, Group 2 nuclides. This is followed by a steady, but very small release of newly formed nuclides. If only Group 3 nuclides vaporize, the effects would be similar to those for ^{220}Rn diffusion with 100% escape. Vaporization of Group 2 and 3 nuclides would: (1) reduce external doses as described above for complete depletion; (2) produce doses from inhalation of vaporized nuclides that are between 5 and 300 times higher, depending on the affected organ, than those from vaporization of only Group 3 nuclides; and (3) reduce ingestion doses as described for complete depletion.

4. DOSE ESTIMATES

Radiation doses were estimated for transport, distribution, use, and disposal of 25 million incandescent mantles during one year. In this section, we summarize the dose estimates and discuss the more important exposure conditions used to make the calculations. Appendix A contains detailed tabulations of the exposure conditions. Appendix B contains corresponding tabulations of the dose estimates.

4.1 TRANSPORT OF MANTLES

The transport and distribution schemes used in this study were constructed from information supplied by mantle manufacturers and distributors, transportation and parcel delivery companies, and a summary of procedures and exposure conditions for transport and distribution of

consumer products (Etnier and O'Donnell, 1979). We attempted to construct relatively simple schemes that encompass a wide range of exposure conditions. For bulk transport of lighting devices containing mantles and cartons of mantles, we considered the following scenarios: (1) transport from three suppliers to 30 large retail store warehouses of 86,400 lighting devices (e.g., lanterns) containing 129,600 mantles via direct, long-distance (over-the-road) truck and 6.2 million replacement mantles via a regional truck system (see Fig. 1 and Table A.1); (2) transport from three suppliers to 300 wholesalers of 360,000 lighting devices containing 540,000 mantles via a regional truck system and 15.6 million replacement mantles via a parcel delivery system (see Fig. 2 and Table A.2); and (3) transport from three suppliers to 999 utility companies of 3.0 million replacement mantles via a parcel delivery system (see Fig. 3 and Table A.3).

In all cases, local pickup drivers were assumed to carry shipments to local terminals (except for over-the-road trucking which was assumed to bypass all terminals). At the local truck or parcel terminals, shipments were assumed to be unloaded, handled, and loaded onto regional delivery trucks. The trucks were assumed to travel 400 km (250 miles) to regional terminals where shipments were assumed to be handled and loaded onto other regional delivery trucks. This process was assumed to occur three times per shipment. At the final terminals, the shipments were assumed to be loaded onto local or regional delivery trucks that deliver them to the appropriate destinations.

Table 5 is a summary of annual external radiation doses to the total bodies of individuals and the various groups involved in the three scenarios for transporting mantles that contain natural thorium. Doses to bone may be estimated by multiplying the given doses by a factor of 1.1; doses to lungs by 0.95. Multiplication by 0.55 will give doses for mantles containing six-month-old thorium. Details of the dose calculations are given in Tables B.1-B.3. For these calculations, we assumed that the mantle packaging effectively prevents escape of ^{220}Rn. Therefore, all doses are from external exposures to arrays of lighting devices and cartons of mantles.

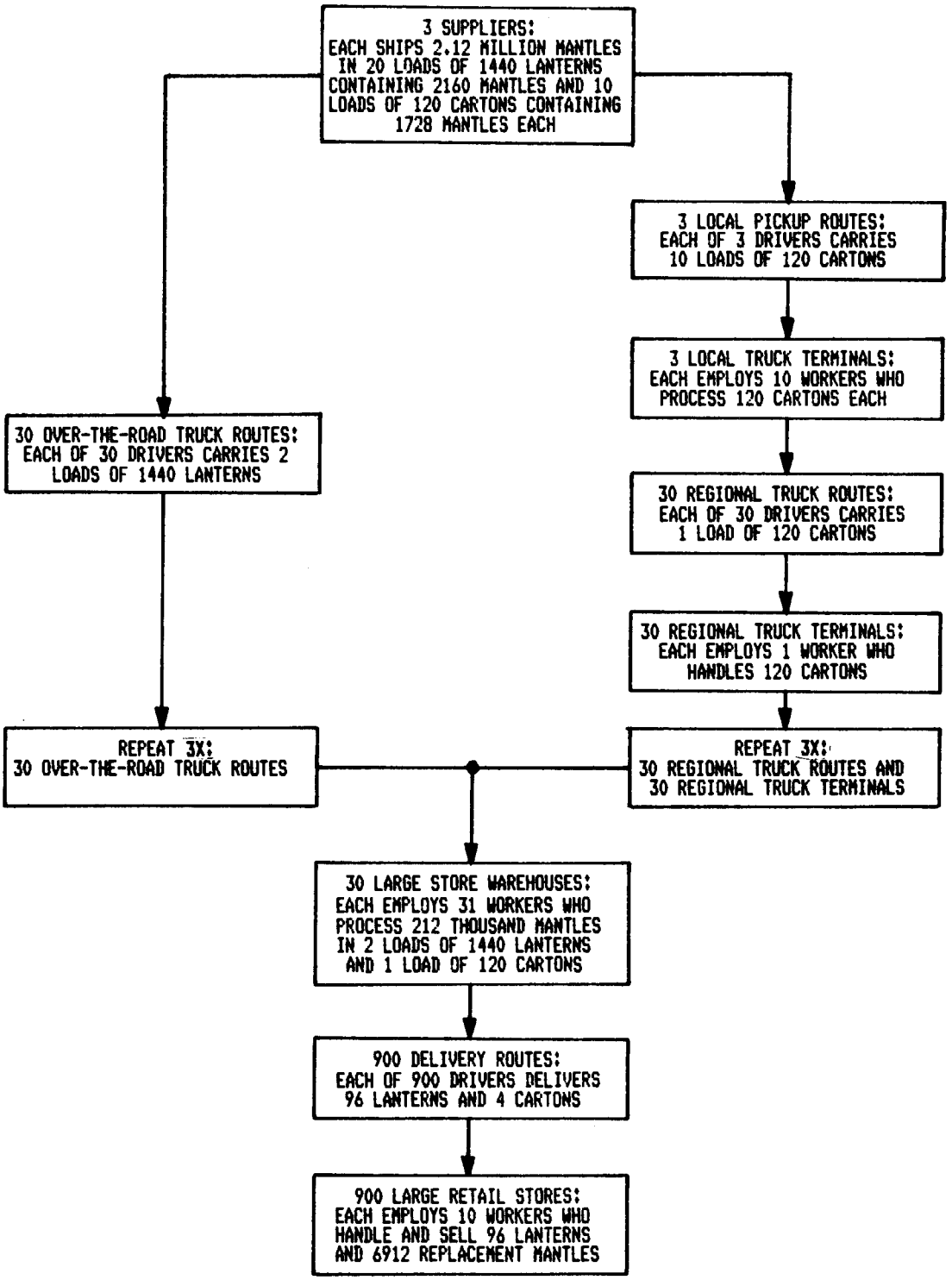

Fig. 1. Flow diagram for transport and distribution of mantles via large retail stores.

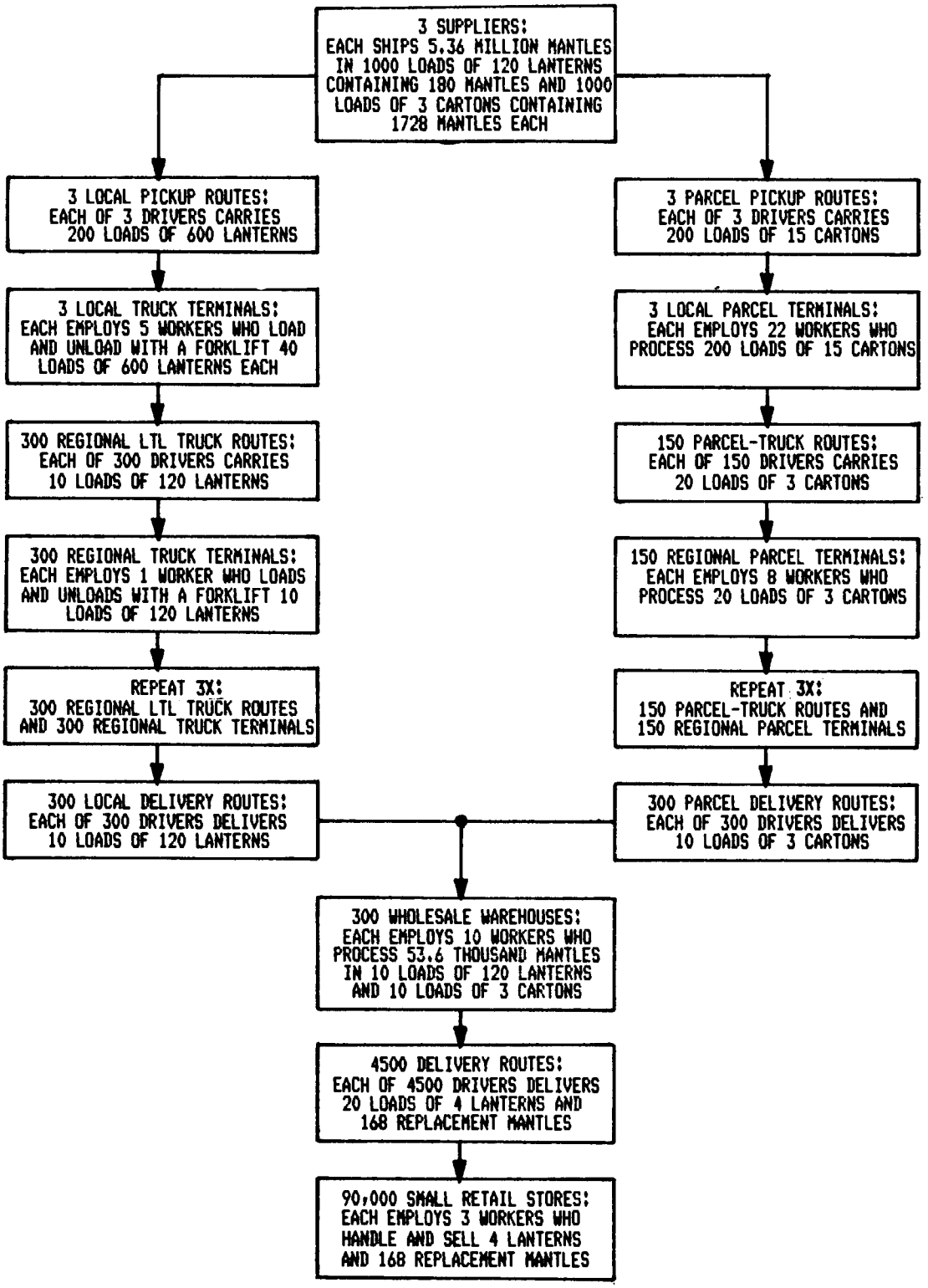

Fig. 2. Flow diagram for transport and distrbution of mantles via small retail stores.

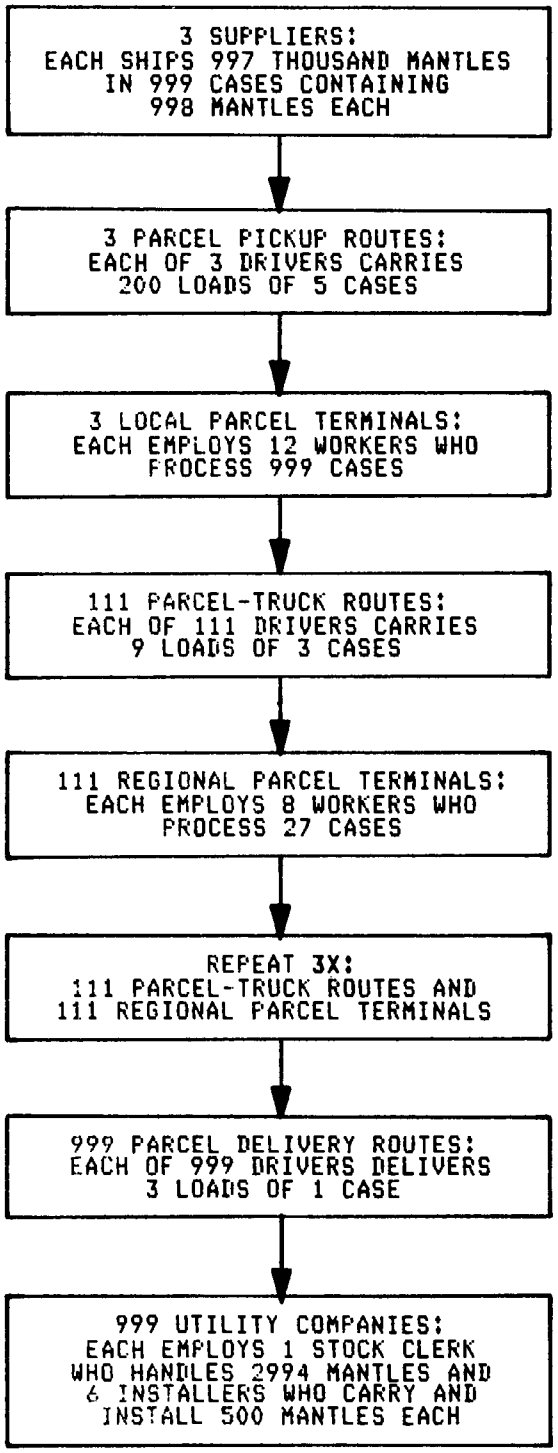

Fig. 3. Flow diagram for transport and distrbution of mantles via utility companies.

Table 5. Summary of annual total-body doses due to annual transport of 25 million mantles that contain natural thorium

Population group	Individual doses, Sv			Number of persons	Population doses, person-Sv
	Average	Lowest	Highest		
Truck drivers	2E-6	2E-7	2E-4	3,504	7E-3
Truck terminal workers	3E-7	3E-8	3E-6	1,035	3E-4
Parcel terminal workers	2E-7	3E-8	3E-5	6,366	2E-3
Public on truck routes	5E-12	3E-14	4E-9	210E6	1E-3

Three parcel pickup drivers who were each assumed to handle and transport during the year 200 shipments of cartons that contained 1728 mantles each (25,920 mantles per shipment) were found to receive the highest annual individual doses, 200 μSv (20 mrem). Other drivers were found to receive between 0.2 and 80 μSv (0.02 and 8 mrem); the average dose to all truck drivers was found to be 2 μSv (0.2 mrem). Doses to truck terminal workers averaged 0.3 μSv and ranged between 0.03 and 30 μSv. The population dose to all truck drivers and terminal workers was found to be 0.009 person-Sv (0.9 person-rem). If the mantles contained six-month-old thorium, the resulting doses would be 55% of those given above.

To estimate doses to members of the public on truck routes, we combined the dose estimates for the three transport modes and took the exposed population to be 210 million persons. Overlapping of truck routes justifies this procedure. The highest individual dose, 0.004 μSv (0.4 μrem), was obtained by summing the highest individual doses from each of the three transport schemes. The lowest individual dose was 0.03 pSv. The average individual dose was 5 pSv (0.5 nrem), and was obtained by dividing the total public population dose, 0.001 person-Sv (0.1 person-rem), by 210 million persons.

The total population dose for all transport was approximately 0.01 person-Sv (1 person-rem). This was obtained by summing doses to all truck drivers, terminal workers, and persons along truck routes.

4.2 DISTRIBUTION OF MANTLES

The distribution scheme used in this study complements the transportation scheme. We considered (1) distribution from 30 warehouses to 900 large retail stores and sale in the stores of 86,400 lighting devices containing 129,600 mantles and 6.2 million replacement mantles (see Fig. 1 and Table A.4); (2) distribution from 300 wholesalers to 90,000 small retail stores and sale in the stores of 360,000 lighting devices containing 540,000 mantles and 15.6 million replacement mantles (see Fig. 2 and Table A.5); and (3) distribution and installation of 3.0 million replacement mantles by 999 utility companies (see Fig. 3 and Table A.6).

In the first two cases, warehouse workers were assumed to handle and work near mantles awaiting distribution and to load local or regional delivery trucks that transport the mantles to the stores. Store workers were assumed to receive, handle, and sell mantles from floor displays. Store customers were assumed to be exposed to the displays. In the third case, a stock clerk was assumed to dispense mantles to employees who transport them to customers' outdoor lights and then install them in place of broken mantles.

Table 6 is a summary of radiation doses to the total bodies of individuals and the various groups of persons involved in the three distribution schemes. Details of the dose calculations are given in Tables B.4-B.6. All doses, except those to utility installers, are annual external doses because no escape of radionuclides was assumed from packaged mantles. Utility installers' doses are total doses (internal plus external) from working during the year with packaged, unpackaged, and broken mantles. Doses from six-month-old thorium and doses to bone and lungs, except those to mantle installers, can be estimated by using the factors given in the transport section.

Stock handlers in large retail store warehouses were found to receive the highest annual individual doses, 100 μSv (10 mrem). Each of the 300 handlers was assumed to handle 288 lighting devices and 12 cartons of mantles and to work near an average of 720 lighting devices and 60 cartons throughout the year. Other warehouse workers were estimated to receive annual doses between 0.3 and 6 μSv (0.03 and 0.6 mrem); the average dose to warehouse workers was estimated to be 10 μSv (1 mrem). Annual doses to truck drivers averaged 2 μSv and ranged between 0.03 and 1 μSv. Doses to retail store workers averaged 2 μSv and ranged between 0.03 and 4 μSv. Utility company stock clerks could receive 10 μSv/y.

Utility company installers are a special case of distribution workers because they could inhale or ingest radionuclides while replacing mantles. To estimate potential radiation doses from replacing mantles, we devised the following scenario:

Table 6. Summary of total-body doses due to distribution of 25 million mantles that contain natural thorium

Population group	Individual doses, Sv			Number of persons	Population doses, person-Sv
	Average	Lowest	Highest		
Warehouse workers	1E-5	3E-7	1E-4	3,930	4E-2
Truck drivers	1E-6	2E-7	1E-6	5,400	6E-3
Store workers	2E-6	3E-8	6E-6	275E3	6E-1
Store customers	2E-8	5E-9	1E-8	210E6	3
Utility stock clerks	1E-5	1E-5	1E-5	999	1E-2
Utility installers[a]	4E-5	1E-9	4E-5	5,994	2E-1
Public on truck routes	3E-13	4E-14	3E-12	210E6	6E-5

[a]Doses to utility installers are total doses.

I. Exposures to Two New Mantles

A. Direct Exposure: The installer was 90 cm from two mantles containing a total of 0.5 g of thorium which was depleted in ^{220}Rn and progeny because of ^{220}Rn diffusion (25%) from the thorium.

B. Airborne Exposures: 25% of the ^{220}Rn escaped into a hemispherical air space with a volume of 7 m^3 and an air exchange rate of either 1000 vol/h (an outdoor replacement in a 3-km/h breeze) or 1 vol/h (an indoor replacement).

II. Exposures to Two Old Mantles

A. Direct Exposure: As above.

B. Airborne Exposures

(1) As above.

(2) The installer blew broken mantles from the light, thus dispersing into the air space 1% of the old mantles as respirable particles.

C. Ingestion Exposures: While handling the mantles, 5% (25 mg) of the thorium adhered to the installers' hands. Subsequent washing left only 1% (0.25 mg) of the adhered material, which was ultimately ingested.

Table 7 lists total doses to the three most affected organs from exposures under the above scenario for the two limiting cases: (1) both old and new mantles contain natural thorium from which only ^{220}Rn and progeny escape, and (2) new mantles contain six-month-old thorium and old mantles contain six-month-old thorium from which all but the two thorium nuclides vaporized during use 7 days before the change. For outdoor changes, total-body doses could range from 0.00004 to 2 μSv; bone doses, from 0.00004 to 10 μSv; and lung doses, from 0.0001 to 0.4 μSv. For indoor changes, total-body doses could range from 0.0008 to 7 μSv, bone doses, from 0.003 to 60 μSv; and lung doses,

Table 7. Summary of potential total doses (Sv) from changing two mantles

Organ	Exposure condition[a]	Outdoor changes		Indoor changes	
		Natural thorium	6-month thorium	Natural thorium	6-month thorium
Total body	1	1E-10	4E-11	2E-9	8E-10
	2	2E-6	5E-7	2E-6	5E-7
	3	2E-6	5E-7	7E-6	5E-6
Bone	1	1E-10	4E-11	5E-9	3E-9
	2	9E-6	6E-6	9E-6	6E-6
	3	1E-5	6E-6	6E-5	5E-5
Lungs	1	2E-10	1E-10	8E-8	4E-8
	2	1E-9	2E-10	8E-8	4E-8
	3	4E-7	3E-7	3E-5	3E-5

[a]Condition 1: Includes external exposure to mantles and immersion in and inhalation of nuclides from diffusion of Rn-220 from mantles.

Condition 2: Includes condition 1 plus ingestion of old (broken) mantle residues.

Condition 3: Includes condition 2 plus immersion in and inhalation of blown mantle parts (e.g., from blowing broken mantle residues).

from 0.04 to 30 μSv. The lower doses are due to direct exposures to the mantles and immersion in and ingestion of airborne nuclides resulting from diffusion of ^{220}Rn from the mantles. The higher doses are due mainly to ingestion of mantle parts and, to a lesser extent, to inhalation of airborne mantle particles.

Each of the 5994 utility company installers was assumed to replace 500 mantles per year in outdoor lights. Thus, an installer's doses could range between 0.01 and 400 μSv (0.001 and 40 mrem) to total body, 0.01 and 2000 μSv (0.001 and 200 mrem) to bone, and 0.03 and 90 μSv (0.003 and 9 mrem) to lungs. It is, however, doubtful that these professional installers would in all cases blow broken mantle parts and ingest material. In the latter case, subsequent work activities and hand washing would most likely remove much of the adhered thorium. Therefore, we artibrarily chose doses to installers to be 10% of the higher values given above. This yielded doses of 40 μSv (4 mrem) to total body, 200 μSv (20 mrem) to bone, and 9 μSv (0.9 mrem) to lungs. These doses make insignificant the 0.2 μSv received while carrying and transporting mantles in trucks (see Table B.6).

Store customers were estimated to receive between 0.005 and 0.01 μSv (0.5 and 1 μrem) to total body. Persons along truck routes were treated as were those involved in transport (Sect. 4.1). Again, potential doses to these persons appear to be quite low. (It should be noted that some individuals could be exposed under combinations of public and work exposures. In most cases, one exposure will dominate and, thus, failure to add doses from all possible exposures of an individual will not significantly affect the total dose to the individual.) The population dose to the general public due to distribution of 25 million mantles per year was estimated to be about 3 person-Sv (300 person-rem).

The total population dose from annual distribution of 25 million mantles was estimated to be 4 person-Sv (400 person-rem). All exposed distribution workers and members of the general public were included in this estimate.

4.3 USE OF MANTLES

Radiation doses were estimated for use of 20.25 million mantles in camping lanterns, 1.25 million in indoor residential lamps, 3.0 million in outdoor gaslights, and 0.5 million in recreational vehicle lights. The scenarios (exposure conditions) used to calculate the dose were constructed from private conversations with a variety of persons who use or are familiar with the use of incandescent mantles in the various lighting devices. The doses given in this section, unless otherwise indicated, are total doses (Sect. 3.2).

4.3.1 Camping Lanterns

Persons who use incandescent mantles in camping lanterns may be exposed to them under a multitude of conditions. Consideration of all possible conditions is impossible. Our approach was to construct representative scenarios for a two-day camping trip, mantle storage in the home between camping trips, replacement of broken mantles, and exposure to contaminated ground at campsites. These scenarios were used to estimate radiation doses to campers who use two double-mantled lanterns and four replacement mantles. The resulting individual doses are very likely maximums for the scenarios because few campers would use more than two lanterns. Doses to persons using fewer mantles can be scaled down in direct proportion to the number of mantles used. For example, if one double-mantled lantern and two replacement mantles were used, the resulting individual doses would be about half those given in the following discussion.

It will become obvious in the following discussion that the uncertainties discussed in Sect. 3 regarding the behavior of the nuclides in the thorium decay chain complicated the assessment and led to order-of-magnitude variations in some of the dose estimates. Other important uncertainties include the personal habits of mantle changers and the effectiveness of barriers to ^{220}Rn dispersion in homes. We attempted to bracket the possible effects of the uncertainties, but could not specify typical effects. In fact, typical effects may not exist because, depending on specific conditions, the processes, personal

habits, and effectiveness of the barriers could have a wide range of values and, thus, could produce a wide range of effects.

The camping scenario included purchase of mantles, loading, and unloading of camping vehicle, travel to and from campsites, lantern ignition, and use of lanterns at the campsite. Table A.7 contains details of the exposure conditions used to represent the camping activities.

Doses were calculated for mantles containing either natural or six-month-old thorium. We also considered vaporization of all but the two thorium nuclides and of only ^{220}Rn and progeny. Detailed estimates are presented in Appendix B of external, internal, and total doses to total body (Table B.7), bone (Table B.8), and lungs (Table B.9). Note that appropriate air exchange rates were used for exposures in vehicles, tents, and outdoors.

Table 8 is a summary of potential total doses to a principal camper and other campers from use of four new and used mantles in two lanterns and four new replacement mantles during a two-day camping trip. (A principal camper is one who participates in all the events in Tables A.7 and B.7-B.9 except numbers 4 and 19. An other camper is one who participates in all events but numbers 1, 2, 3, 7, 12, 17, 18, and 20.) A principal camper using new lantern mantles could receive total doses between 0.008 and 0.4 μSv (0.8 and 40 μrem) to total body, 0.02 and 1 μSv to bone, and 0.3 and 0.6 μSv to lungs. The lower doses are from six-month-old thorium that releases only ^{220}Rn and progeny during operation. The higher doses are from natural thorium that releases all but the thorium nuclides. In this case, ~90% of the total body and bone doses, and ~80% of the lung dose were due to inhalation of nuclides that vaporized during the first ignition of new mantles (event 7). A principal camper using used lantern mantles could receive total doses between 0.004 and 0.01 μSv to total body, 0.006 and 0.02 μSv to bone, and 0.1 and 0.3 μSv to lungs.

Total doses to other campers using new lantern mantles were found to range between 0.007 and 0.04 μSv (0.7 and 4 μrem) to total body, 0.01 and 0.09 μSv to bone, and 0.1 and 0.2 μSv to lungs. Again, most

Table 8. Summary of potential total radiation doses (Sv) during a representative two-day camping trip for different radionuclide compositions and behaviors

Type of camper	Organ	Condition of lantern mantles	Natural thorium, vaporization of:		6-month-old thorium, vaporization of:	
			All but thorium	Rn-220 + progeny	All but thorium	Rn-220 + progeny
Principal	Total body	New	4E-7	2E-8	3E-8	8E-9
		Used	6E-9	1E-8	4E-9	7E-9
	Bone	New	1E-6	3E-8	7E-8	2E-8
		Used	7E-9	2E-8	6E-9	1E-8
	Lungs	New	6E-7	3E-7	4E-7	3E-7
		Used	1E-7	3E-7	1E-7	2E-7
Other	Total body	New	4E-8	2E-8	7E-9	8E-9
		Used	6E-9	2E-8	4E-9	8E-9
	Bone	New	9E-8	2E-8	1E-8	1E-8
		Used	7E-9	2E-8	5E-9	1E-8
	Lungs	New	1E-7	2E-7	1E-7	2E-7
		Used	4E-8	2E-7	4E-8	2E-7

of the higher doses to total body (~80%) and bone (~90%) are attributable to the initial burn of new mantles. Most of the lung doses are due to airborne ^{220}Rn and progeny from diffusion of ^{220}Rn into the camping vehicle (events 4 and 19) and the tent (events 10 and 15). In this case, vaporization only of ^{220}Rn and progeny produces the higher doses. This is attributable to the rapid rebuilding of that part of the decay chain when the ^{224}Ra precursor of ^{220}Rn remains in the mantles. Other campers using used lantern mantles could receive between 0.004 and 0.02 μSv to total body, 0.005 and 0.02 μSv to bone, and 0.04 and 0.2 μSv to lungs. For other campers, doses from external exposures, especially those experienced while traveling in the camping vehicle, become significant contributors to the total doses.

Campers also replace broken mantles with new ones. Tables 7 and 9 contain estimates of potential doses from this activity.

Another potential exposure pathway for campers is mantles that have been broken and discarded at campsites. To estimate doses from this exposure pathway, we assumed a 4000-m^2 (1-acre) campground at which two mantles are discarded per week. After one year of such discard, enough thorium could be discarded at the campground to produce an average ground-surface contamination of 0.006 g/m^3. Dose rates in tissue at 90 cm above the center of such a campground would be 0.02 nSv/h for natural thorium and 0.009 nSv/h for six-month-old thorium. Assuming the annual-average, ground-contamination level at all campsites to be 0.006 g/m^3, campers could receive during a two-day camping trip (38 h at 90 cm from the center of the campground) average external doses between 0.003 and 0.006 μSv (0.3 and 0.6 μrem) to total body, 0.003 and 0.007 μSv to bone, and 0.003 and 0.005 μSv to lungs. Doses from inhalation of airborne ^{220}Rn and progeny would be negligible in comparison with the doses from direct exposure to the ground contamination.

Campers also store mantles in their homes when not camping. In this circumstance, any ^{220}Rn that diffuses from the mantles can enter the home air and produce doses via inhalation of the ^{220}Rn and its progeny. If four unpackaged mantles are stored in a home having a ventilation rate of 1 vol/h, if 25% of newly formed ^{220}Rn enters the

Table 9. Ranges of potential total doses (Sv) to various campers

Exposure pathway	One-time campers		Avid campers	
	Principal	Others	Principal	Others
Total Body				
Camping activities				
From mantles	4E-9 to 4E-7	4E-9 to 4E-8	2E-7 to 2E-6	1E-7 to 1E-6
From ground	3E-9 to 6E-9	3E-9 to 6E-9	7E-8 to 1E-7	7E-8 to 1E-7
Changing mantles	0 to 4E-6		3E-10 to 6E-5	
Storing mantles	1E-8 to 7E-7	1E-8 to 7E-7	4E-8 to 2E-6	4E-8 to 2E-6
Combined[a]	2E-8 to 4E-6	2E-8 to 7E-7	3E-7 to 6E-5	2E-7 to 4E-6
Bone				
Camping activities				
From mantles	6E-9 to 1E-6	5E-9 to 9E-8	4E-7 to 4E-6	1E-7 to 6E-7
From ground	3E-9 to 6E-9	3E-9 to 6E-9	8E-8 to 2E-7	8E-8 to 2E-7
Changing mantles	0 to 3E-5		3E-10 to 5E-4	
Storing mantles	4E-8 to 2E-6	4E-8 to 2E-6	1E-7 to 8E-6	1E-7 to 8E-6
Combined[a]	4E-8 to 3E-5	4E-8 to 2E-6	6E-7 to 5E-4	3E-7 to 8E-6
Lungs				
Camping activities				
From mantles	1E-7 to 6E-7	4E-8 to 2E-7	4E-6 to 8E-6	1E-6 to 6E-6
From ground	3E-9 to 5E-9	3E-9 to 5E-9	7E-8 to 1E-7	7E-8 to 1E-7
Changing mantles	0 to 2E-5		8E-10 to 2E-4	
Storing mantles	5E-7 to 3E-5	5E-7 to 3E-5	2E-6 to 1E-4	2E-6 to 1E-4
Combined[a]	6E-7 to 5E-5	5E-7 to 3E-5	6E-6 to 4E-4	3E-6 to 1E-4

[a]Columns may not add to give combined values because the latter were obtained by summing values within the indicated event ranges.

air and disperses rapidly throughout the home, and if the campers are at home 50% of the time (4380 h/y), they could receive annual total doses of 2-3 μSv (0.2-0.3 mrem) to total body, 6-9 μSv to bone, and ~100 μSv to lungs. The lower doses are from undisturbed six-month-old thorium, the higher from natural thorium. If the mantles have been burned and all but the thorium nuclides have vaporized, total body and bone doses would be approximately one half those given; lung doses, about one third. Vaporization of ^{220}Rn and progeny has little effect on the doses.

Another process is important in estimating doses in the home from ^{220}Rn diffusion. Consider that unpackaged mantles are usually installed in lanterns. The globe and any other packaging could act as a barrier to ^{220}Rn escape. This could reduce doses significantly. Our calculations indicate that, if the air confined in a lantern's globe exchanges with the same rate as the room air, radioactive decay would limit the quantity of ^{220}Rn that escapes from the lantern to the home air to ~5% of the quantity escaping from the mantles. The progeny of the ^{220}Rn that decays in the lantern would most likely deposit inside the lantern. This could reduce doses during home storage to 0.05-0.08 μSv (5-8 μrem) to total body, 0.1-0.2 μSv to bone, and 2-3 μSv to lungs.

The number of ways that the preceding exposure pathways and their resultant doses can be combined and manipulated are indeed legion. Moreover, any choice is subject to uncertainty. It is possible, however, to bracket potential doses to individuals by considering infrequent (one-time) and frequent (avid) campers. One-time campers were assumed to make one 2-day camping trip per year with one single-mantled lantern and one replacement mantle. Avid campers were assumed to make the equivalent of 26 two-day camping trips per year with two double-mantled lanterns and four replacement mantles. Lowest and highest doses to these campers were estimated by adding the respective lowest and highest doses previously found for each of the exposure pathways. All doses were scaled to account for the number of mantles involved. For home storage, the lower doses included those from direct exposures to stored mantles and those associated with dispersion in the home air of 5% of the ^{220}Rn escaping (25% of that produced) from

mantles containing six-month-old thorium from which all but the two thorium nuclides had vaporized. The higher doses included those from direct exposures and those associated with dispersion of all ^{220}Rn escaping from mantles containing natural thorium from which only ^{220}Rn and progeny had vaporized. For mantle replacement, a principal one-time camper was assumed to change no mantles as a minimum; one, as a maximum. An avid principal camper was assumed to change 16 mantles – four changes of two mantles in both lanterns – during the year. (This is required by the 50-h useful life of camping mantles.) Variations in the doses were the result of having assumed neither blown mantle particles nor ingestion (lower values) and all of the given exposure pathways, including indoor and outdoor changes, for mantle replacement (higher values).

Table 9 contains the results of applying the above assumptions. A principal one-time camper could receive total doses between 0.02 and 4 μSv (0.002 and 0.4 mrem) to total body, 0.04 and 30 μSv to bone, 0.6 and 50 μSv to lungs. Other one-time campers could receive between 0.02 and 0.7 μSv to total body, 0.04 and 2 μSv to bone, and 0.5 and 30 μSv to lungs. Principal avid campers could receive between 0.3 and 60 μSv (0.03 and 6 mrem) to total body, 0.6 and 500 μSv to bone, and 6 and 400 μSv to lungs. Other avid campers could receive between 0.2 and 4 μSv to total body, 0.3 and 8 μSv to bone, and 3 and 100 μSv to lungs.

To estimate population doses, we multiplied the lower and higher doses in Table 9 for each of the four camper types by the number of campers of that type (one principal and two others) and divided by the number of mantles to which each was exposed (two for one-time campers and 20 for avid campers). The resulting person-Sv per mantle values were then averaged and multiplied by the number of mantles used for camping, 20.25 million. This resulted in collective dose estimates of 16 person-Sv (1600 person-rem), 110 bone-Sv, and 230 lung-Sv.

In the above calculations, six persons were assumed to use 22 mantles per year. If this is taken as typical of the national average, ∿6 million campers would be required to use 20.25 million mantles per year. This number is slightly lower than our earlier estimate of ∿7 million campers (O'Donnell, 1978), which was based on an old

survey of campground usage. When divided into the collective doses, this number allows us to estimate average individual total doses from one year of mantle use to be 3 μSv to total body, 20 μSv to bone, and 40 μSv to lungs.

4.3.2 Indoor Residential Lamps

Indoor lamps containing incandescent mantles have functional applications (e.g., in rural cabins and cottages) and decorative applications (e.g., in permanent homes). No data are available concerning the relative magnitudes of the two uses. For this assessment, we assume that 75% of the lamps are used functionally in vacation cottages, and 25% decoratively in permanent residences.

When used in decorative lamps, which we assumed are not burned, mantles will behave like camping mantles stored in the home. Since most lamps have open chimneys or vents, no barriers exist to retard ^{220}Rn dispersion into the home air. Total radiation doses from two mantles in lamps will approximate those from storage in the home of two camping mantles that release 25% of their ^{220}Rn content. Individuals could receive ~1 μSv (0.1 mrem) to total body, 3-4 μSv to bone, and approximately 50-70 μSv to lungs.

Mantles used in functional lamps will be ignited. Thus, the potential exists for vaporization of the nuclides into the home air. Radiation doses associated with this type of exposure are dependent on the timing and duration of exposures with respect to the mantle burning schedule. To obtain typical individual doses, we assumed a cottage containing two mantles to be occupied by three persons for 12 h/d, 52 d/y (26 weekends). One occupant was assumed to change two mantles that undergo initial ignition during the year. To obtain a maximum individual dose, we assumed daily occupancy, and replacement and ignition of four new mantles.

Maximum individual total doses could range between 6 and 40 μSv (0.6 and 4 mrem) to total body, 10 and 200 μSv to bone, and 300 and 500 μSv to lungs. The higher doses to total body and bone, as usual, were attributable largely to vaporization of all but the thorium nuclides and to mantle replacement; the lower, to ^{220}Rn diffusion.

Radon diffusion was the major contributor to lung doses. A typical individual who changes no mantles could receive between 0.2 and 10 μSv to total body, 5 and 30 μSv to bone, and 70 and 100 μSv to lungs. One who changes two mantles could receive between 2 and 20 μSv to total body, 5 and 100 μSv to bone, and 70 and 100 μSv to lungs.

For use of two mantles per residence and occupancy by three persons, use of 1.25 million mantles could expose ∿470 thousand persons in 160 thousand permanent residences and ∿1.4 million persons in 470 thousand cottages. The resulting population doses (total) could be between 3 and 20 person-Sv (300 and 2000 person-rem), 8 and 80 bone-Sv, and 100 and 200 lung-Sv.

4.3.3 Outdoor Gaslights

Outdoor gaslights are usually located several meters from residences. For a light containing two mantles located at an average distance of 18 m from exposed persons and swept by a 3-km/h breeze, the annual individual doses were calculated to range between 2 and 3 nSv (0.2 and 0.3 μrem) to total body, 2 and 4 nSv to bone, and 2 and 3 nSv to lungs. Essentially all of the doses were attributable to direct, external exposures to the mantles contained in the gaslight.

Approximately 1.5 million gaslights would be required to house 3.0 million mantles. If an average of 12 persons were exposed to each light for one year, the population doses could range between 0.03 and 0.06 person-Sv (3 and 6 person-rem), 0.03 and 0.07 bone-Sv, and 0.03 and 0.06 lung-Sv.

4.3.4 Recreational Vehicles

Exposures from use of mantles in recreational vehicles (RVs) are similar to those from use of indoor lamps in cottages. Although RVs are generally smaller than cottages, they usually have a higher air exchange rate. Thus, the potentially greater airborne concentrations of radionuclides in the smaller volume will be largely offset by the faster rate of removal. On this basis, we assume doses to RV users are similar to those for users in cottages. The maximum RV user, however,

would not occupy the vehicle every day. Thus, we use only the typical doses from the cottage exposure scenarios.

Persons who use, but do not change, mantles in RVs could receive between 2 and 10 μSv to total body, 5 and 30 μSv to bone, and 70 and 100 μSv to lungs. Persons who also change mantles could receive between 2 and 20 μSv to total body, 5 and 100 μSv to bone, and 70 and 100 μSv to lungs. Use of 0.5 million mantles in 250 thousand RVs (two mantles per vehicle) with an average of three occupants each could result in population doses between 1 and 10 person-Sv, 4 and 40 bone-Sv, and 60 and 80 lung-Sv.

4.4 DISPOSAL OF MANTLES

Broken mantles are commonly discarded as conventional, domestic, solid waste, and as litter at replacement sites. Disposal as litter was discussed in Sect. 4.3.1 and potential doses from this exposure pathway were added to campers' doses. The scenario used in Sect. 4.3.1 could account for disposal of between 5 and 15 million mantles. For the needs of this section, we assumed that 10 million mantles are so discarded. The remaining 15 million were assumed discarded as domestic solid waste.

Domestic solid waste is collected in sizeable packages and is transported in large trucks to landfills and incinerators. Collection workers and members of the public on collection routes could be exposed to the discarded mantles. Generally, these persons would be exposed to very few mantles over very short time periods, and the mantles would be well shielded by the large bulk of waste in which they would be imbedded. Therefore, doses to these persons should be very low. Doses to collection workers certainly should be less than the 0.2 μSv received by utility installers while transporting new mantles (see Table B.6). Doses to the public would be negligible when added to the other doses they could receive from distribution and use of mantles. On these bases, we chose not to assess in detail potential doses from waste collection.

Approximately 90% of all domestic solid waste is buried in landfills. The potential for exposure to radionuclides escaping from buried mantles is very small. The small concentrations of thorium that would be present in a landfill, the layers of cover material and the bulk of co-buried waste, the relative immobility of the buried nuclides, and the short lifetime of all but the thorium nuclides all combine to make slight the possibility that buried nuclides would reach man. [Buckley et al. (1980) discussed this problem and reached essentially the same conclusion.] In addition, any doses that might result from such exposures would most likely produce lower doses than those given in Sect. 4.5.1 for leaching of littered mantle parts into a reservoir.

The remaining 10% of discarded mantles (1.5 million in this case) could be incinerated. Exactly which radionuclides might be discharged by an incinerator is unknown. The two thorium nuclides should not vaporize, but could become airborne because of the turbulence in an incinerator. The group 2 nuclides (see Sect. 3) could, but should not, vaporize at the operating temperatures of most incinerators. They could, of course, become airborne because of turbulence. The ^{220}Rn and progeny will vaporize.

To assess the potential impacts of incineration, we assumed one incinerator to process 5% of the mantles scheduled for incineration (75,000 mantles containing 19 kg of thorium). We also assumed that 1% of the thorium escaped capture by the emission control system and the slag and, thus, was emitted from the incinerator stack. Individual and population doses from this scenario were calculated with the AIRDOS-II computer code (Moore, 1977). Exposure pathways evaluated were inhalation of airborne radionuclides and external exposure by nuclides deposited on the ground. A uniform distribution of one million persons within an 80-km radius of the incinerator and broadly based average meteorological conditions (U.S. Atomic Energy Commission, 1974) were also assumed.

The highest individual doses were obtained for an improbable person who remained for the entire year at 1 km from the stack. This person could receive 0.01 μSv (0.001 mrem) to total body, 0.10 μSv to bone, and 0.06 μSv to lungs. The average individual, who was also

assumed to be exposed for the full year, was estimated to receive 0.003 nSv (0.3 nrem) to total body, 0.03 nSv to bone, and 0.01 nSv to lungs. Total population doses from 20 incinerators were estimated to be 0.0006 person-Sv (0.06 person-rem), 0.005 bone-Sv, and 0.003 lung-Sv. Most of the doses were due to the 50-year dose commitments from inhalation of the two thorium nuclides and the subsequent buildup of their progeny. In this case, doses from natural and six-month-old thorium were essentially the same.

4.5 UNUSUAL EVENTS

4.5.1 Leaching to a Reservoir

To estimate doses that might result from leaching of thorium from discarded mantles, we assumed the campground described in Sect. 4.3.1 to be located on a reservoir (or a stream that feeds it) that supplies water to one million persons. If the average daily water consumption per household is ~1 m^3 (U.S. Department of Housing and Urban Development, 1975) and the average household consists of three persons, the minimum reservior capacity must be ~10,000,000 m^3 to assure a 30-day supply of water. If 1% of the thorium discarded per year at the campground (0.26 g = 0.01 × 104 mantles × 0.25 g/mantle) enters the reservoir, the average equilibrium concentration of thorium in the water would be 0.026 μg/m^3. A person consuming 370 l of such water per year (~0.001 m^3/d) (U.S. Nuclear Regulatory Commission, 1976) would ingest ~0.01 μg of thorium per year. The resultant internal doses, depending on the age of the thorium, could be 0.02-0.07 nSv (0.002-0.007 μrem) to total body, 0.2-0.3 nSv to bone, and 0.005-0.03 pSv to lungs. Collective doses to one million such persons could be 0.02-0.07 person-mSv (2-7 person-mrem), 0.2-0.3 bone-mSv, and 0.005-0.03 lung-mSv.

4.5.2 Ingestion of a Mantle

If a person ingests a mantle (0.25 g of thorium), that person could receive 50-y dose commitments of 0.6-2.0 mSv (0.06-0.2 rem) to total body, 6-9 mSv to bone, and 0.0001-0.0008 mSv to lungs. When compared with other individual doses, these would be among the highest.

However, it is extremely unlikely that any member of the general public would ingest a significant portion of a mantle.

5. SUMMARY AND DISCUSSION OF DOSE ESTIMATES

The various radiation dose estimates given in Sect. 4 are summarized in Tables 10-12. These tables contain average, lowest, and highest individual and population doses for the various groups of persons considered. Annual total doses associated with transport, distribution, use, and disposal of 25 million incandescent gas mantles are given for total body (Table 10), bone (Table 11), and lungs (Table 12). The unusual events considered are also included in the tables.

Workers who transport or distribute mantles could receive between 0.01 and 200 μSv (0.001 and 20 mrem) to total body, bone, and lungs. Average individual doses to ∿300 thousand workers were estimated to be 2 μSv to total body and lungs, and 4 μSv to bone. The highest individual doses were calculated for three parcel pickup drivers and 300 stock handlers in wholesale warehouses. Utility installers, under the worst assumptions, could receive the highest bone and lung doses among the worker group.

Mantle users could receive between 0.002 and 60 μSv (0.0002 and 6 mrem) to total body, 0.002 and 500 μSv to bone and lungs. Average individual doses to the ∿26 million users were estimated to be 1 μSv to total body, 7 μSv to bone, and 20 μSv to lungs. Highest doses to all user groups, except outdoor residential light users, were attributable to inhalation and ingestion of broken mantle parts and inhalation of ^{220}Rn and progeny during mantle changes, and to inhalation of ^{220}Rn and progeny from diffusion of ^{220}Rn into home or vehicle air. Both the mantle changing and the diffusion scenarios contain certain assumptions that give wide ranges of possible doses and, therefore, should be verified.

Members of the general public could receive between 0.01 pSv and 0.01 μSv to total body, 0.02 pSv and 0.1 μSv to bone, and 0.01 pSv and 0.06 μSv to lungs. The average member of the general public was estimated to receive from all sources of exposure (shopping, being on truck

Table 10. Summary of total doses to total body from annual transport, distribution, use, and disposal of 25 million incandescent gas mantles and from unusual events

Affected persons	Number of persons, thousands	Individual doses, Sv			Population doses, person-Sv		
		Average	Lowest	Highest	Average	Lowest	Highest
Workers:							
Transport	11	6E-7	2E-8	2E-4	7E-3	5E-3	9E-3
Distribution	289	2E-6	2E-8	1E-4	6E-1	4E-1	9E-1
All workers[a]	300	2E-6	2E-8	2E-4	6E-1	4E-1	9E-1
Users							
Campers and families	5,523	3E-6	2E-8	6E-5	2E+1	3E-1	3E+1
Indoor residential	1,875	7E-6	1E-6	4E-5	1E+1	3	2E+1
Outdoor residential	18,000	3E-9	2E-9	3E-9	5E-2	3E-2	6E-2
Recreational vehicle	750	9E-6	2E-6	2E-5	7	1	1E+1
All users[a]	26,148	1E-6	2E-9	6E-5	4E+1	4	7E+1
General public:							
Store customers	210,000	1E-8	3E-9	1E-8	3	2	3
On truck routes	210,000	4E-12	1E-14	4E-9	9E-4	6E-4	1E-3
Near incinerators	20,000	3E-11	3E-12	1E-8	6E-4	6E-4	7E-4
All public[a]	210,000	1E-8	1E-14	1E-8	3	2	3
All persons[a]	210,000	2E-7	1E-14	2E-4	4E+1	6	7E+1
Unusual events:							
Drinking contaminated water	1,000	4E-11	2E-11	7E-11	4E-5	2E-5	7E-5
Ingesting a mantle	*b*	1E-3	6E-4	2E-3	*b*	*b*	*b*

[a]"All" totals may differ from column sums due to rounding or to inclusion of some persons in more than one group.

[b]Value was not estimated.

Table 11. Summary of total doses to bone from annual transport, distribution, use, and disposal of 25 million incandescent gas mantles and from unusual events

Affected persons	Number of persons, thousands	Individual doses, Sv			Population doses, person-Sv		
		Average	Lowest	Highest	Average	Lowest	Highest
Workers:							
Transport	11	7E-7	2E-8	2E-4	8E-3	6E-3	1E-4
Distribution	289	4E-6	2E-8	2E-4	1	4E-1	2
All workers[a]	300	4E-6	2E-8	2E-4	1	4E-1	2
Users							
Campers and families	5,523	2E-5	4E-8	5E-4	1E+2	6E-1	2E+2
Indoor residential	1,875	2E-5	3E-6	2E-4	4E+1	8	8E+1
Outdoor residential	18,000	3E-9	2E-9	4E-9	5E-2	3E-2	7E-2
Recreational vehicle	750	3E-5	5E-6	9E-5	2E+1	4	4E+1
All users[a]	26,148	7E-6	2E-9	5E-4	2E+2	1E+1	3E+2
General public:							
Store customers	210,000	1E-8	3E-9	1E-8	3	2	4
On truck routes	210,000	5E-12	2E-14	5E-9	5E-4	7E-4	1E-3
Near incinerators	20,000	3E-10	3E-11	1E-7	5E-3	5E-3	5E-3
All public[a]	210,000	1E-8	2E-14	1E-7	3	2	4
All persons[a]	210,000	9E-7	2E-14	5E-4	2E+2	2E+1	3E+2
Unusual events:							
Drinking contaminated water	1,000	3E-10	2E-10	3E-10	3E-4	2E-4	3E-4
Ingesting a mantle	*b*	7E-3	6E-3	9E-3	*b*	*b*	*b*

[a]"All" totals may differ from column sums due to rounding or to inclusion of some persons in more than one group.

[b]Value was not estimated.

Table 12. Summary of total doses to lungs from annual transport, distribution, use, and disposal of 25 million incandescent gas mantles and from unusual events

Affected persons	Number of persons, thousands	Individual doses, Sv			Population doses, person-Sv		
		Average	Lowest	Highest	Average	Lowest	Highest
Workers							
Transport	11	6E-7	1E-8	2E-4	7E-3	5E-3	9E-3
Distribution	289	2E-6	2E-8	1E-4	5E-1	3E-1	7E-1
All workers[a]	300	2E-6	1E-8	2E-4	5E-1	3E-1	7E-1
Users							
Campers and families	5,523	4E-5	5E-7	4E-4	2E+2	7	5E+2
Indoor residential	1,875	8E-5	5E-5	5E-4	2E+2	1E+2	2E+2
Outdoor residential	18,000	2E-9	2E-9	3E-9	4E-2	3E-2	6E-2
Recreational vehicle	750	9E-5	8E-5	1E-4	7E+1	6E+1	8E+1
All users[a]	26,148	2E-5	2E-9	5E-4	5E+2	2E+2	7E+2
General public							
Store customers	210,000	1E-8	3E-9	1E-8	2	2	3
On truck routes	210,000	4E-12	1E-14	4E-9	8E-4	6E-4	1E-3
Near incinerators	20,000	2E-10	1E-11	6E-8	3E-3	3E-3	3E-3
All public[a]	210,000	1E-8	1E-14	6E-8	2	2	3
All persons[a]	210,000	2E-6	1E-14	5E-4	5E+2	2E+2	7E+2
Unusual events							
Drinking contaminated water	1,000	2E-14	3E-15	3E-14	2E-8	3E-9	3E-8
Ingesting a mantle	*b*	4E-7	1E-7	8E-7	*b*	*b*	*b*

[a]"All" totals may differ from column sums due to rounding or to inclusion of some persons in more than one group.

[b]Value was not estimated.

routes, and living near an incinerator) 0.01 μSv to total body, bone, and lungs. The highest individual doses were calculated for an improbable individual who was assumed to reside for an entire year at 1 km (0.6 mile) from an incinerator.

Combining all affected persons, we found individual doses to range between 0.01 pSv and 200 μSv to total body, 0.02 pSv and 500 μSv to bone, and 0.01 pSv and 500 μSv to lungs. The average doses to an individual in the United States were estimated to be 0.2 μSv to total body, 0.9 μSv to bone, and 2 μSv to lungs.

Total population doses associated with transport, distribution, use, and disposal of 25 million mantles per year were estimated to be between 6 and 70 person-Sv (600 and 7000 person-rem) for total body, 20 and 300 bone-Sv, and 200 and 700 lung-Sv. Average population doses were 40 person-Sv, 200 bone-Sv, and 500 lung-Sv. Almost all of the population doses are attributable to use of mantles.

To put the various doses associated with mantles into perspective, consider that the average individual dose (total body) in the United States from environmental sources of radiation is ~1000 μSv/y (National Academy of Sciences, 1972). This corresponds to a population dose of ~210,000 person-Sv/y (for a population of 210 million persons). Using these values, the maximum total individual dose (200 μSv) associated with mantles is ~20% of the environmental dose; the average individual dose (0.2 μSv) is only ~0.02%. Similarly, the maximum population dose from mantles (70 person-Sv) is ~0.03% of the environmentally derived population dose; the average population dose is ~0.02%.

Medically related doses to the population of the United States are ~700 μSv/y to the average individual and ~150,000 person-Sv/y to the population (National Academy of Sciences, 1972). These doses are also much higher than those associated with gas mantles.

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APPENDIX A

DETAILED TABULATIONS OF EXPOSURE CONDITIONS

DETAILED TABULATIONS OF EXPOSURE CONDITIONS

The following definitions will be useful for interpreting the headings of Tables A.1-A-6:

TIME	duration (h/y) of exposure,
AIR:	
CONC	airborne concentration (g/cm^3) of radionuclides,
RADIUS	radius (cm) of the air space,
AMT ING	mass (g) of ingested radionulides,
SOURCE:	
DESCRIPTION	source description,
G	source geometry index number (1 indicates a point source; 11 indicates a cylindrical source),
M	source material index number (14–16 = composite materials used to represent cartons and arrays of gas mantles),
MASS	mass of thorium in the source (in g if G = 1; g/cm^3 if G = 11),
LENGTH	length (cm) of a cylindrical source,
RADIUS	radius (cm) of a cylindrical source,
DISTANCE	distance (cm) between source and exposed persons,
ABSORBER:	
DESCRIPTION	absorber description,
M	absorbing material index number (1 = aluminum, 10 = celluloe, 11 = pyrex, and 13 = air), and
THICK	thickness (cm) of the absorber.

TABLE A.1. EXPOSURE CONDITIONS FOR TRANSPORT OF TRANSPORT OF MANTLES FROM 3 SUPPLIERS TO 30 LARGE RETAIL STORE WAREHOUSES

		AIR:			SOURCE:							ABSORBER:		
	TIME (H/Y)	CONC (G /CM**3)	RADIUS (CM)	AMT ING (G)	DESCRIPTION	G, NO	M, NO	MASS (G)	LENGTH (CM)	RADIUS (CM)	DISTANC (CM)	DESCRIPTION	M, NO	THICK (CM)
					TRUCK DRIVERS									
OVER THE ROAD (9.0000E 01 MEMBERS)														
DRIVING	1.0E 01	0.0	0.0	0.0	1440 LANTERN	11	14	7.1E-06	9.1E 02	1.6E 02	1.4E 02	TRUCK PARTS	1	5.0E-01
*					*							AIR	13	1.4E 02
LOCAL PICKUP (3.0000E 00 MEMBERS)														
DRIVING	5.0E 00	0.0	0.0	0.0	120 CARTONS	11	15	6.8E-03	2.7E 02	9.5E 01	6.0E 01	TRUCK PARTS	1	5.0E-01
*					*							AIR	13	6.0E 01
REGIONAL DELIVERY (9.0000E 01 MEMBERS)														
DRIVING	5.0E 00	0.0	0.0	0.0	120 CARTONS	11	15	6.8E-03	2.7E 02	9.5E 01	1.4E 02	TRUCK PARTS	1	5.0E-01
*					*							AIR	13	1.4E 02
LOCAL DELIVERY (3.0000E 01 MEMBERS)														
DRIVING	5.0E-01	0.0	0.0	0.0	120 CARTONS	11	15	6.8E-03	2.7E 02	9.5E 01	1.4E 02	TRUCK PARTS	1	5.0E-01
*					*							AIR	13	1.4E 02
HANDLE CARGO	2.0E 00	0.0	0.0	0.0	1 CARTON	11	15	1.4E-02	2.4E 01	2.1E 01	3.0E 01	AIR	13	3.0E 01
NEAR CARGO	5.0E-01	0.0	0.0	0.0	60 CARTONS	11	15	6.8E-03	1.3E 02	9.5E 01	9.0E 01	AIR	13	9.0E 01
AT DOCK	1.5E 00	0.0	0.0	0.0	60 CARTONS	11	15	6.8E-03	1.3E 02	9.5E 01	3.0E 02	AIR	13	3.0E 02
					TERMINAL WORKERS									
CARGO HANDLERS (1.2000E 02 MEMBERS)														
HANDLE CARGO	6.8E-02	0.0	0.0	0.0	60 CARTONS	11	15	6.8E-03	1.3E 02	9.5E 01	1.2E 02	AIR	13	1.2E 02
NEAR CARGO	1.0E 00	0.0	0.0	0.0	60 CARTONS	11	15	6.8E-03	1.3E 02	9.5E 01	3.0E 02	AIR	13	3.0E 02
					GENERAL PUBLIC, AVG.									
ON REG. PICKUP RTES. (4.3125E 06 MEMBERS)														
LANTERN PICKUPS	2.0E-02	0.0	0.0	0.0	1440 LANTERN	11	14	7.1E-06	2.3E 02	3.3E 02	1.8E 04	TRAILER WALL	1	1.8E-01
*					*							AIR	13	1.8E 04
MANTLE PICKUPS	1.0E-02	0.0	0.0	0.0	120 CARTONS	11	15	6.8E-03	1.2E 02	1.4E 02	1.8E 04	TRAILER WALL	1	1.8E-01
*					*							AIR	13	1.8E 04

TABLE A.1. (CONTINUED)

	TIME (H/Y)	AIR: CONC (G /CM**3)	AIR: RADIUS (CM)	AMT ING (G)	SOURCE: DESCRIPTION	SOURCE: G, NO	SOURCE: M, NO	SOURCE: MASS (G)	SOURCE: LENGTH (CM)	SOURCE: RADIUS (CM)	SOURCE: DISTANC (CM)	ABSORBER: DESCRIPTION	ABSORBER: M, NO	ABSORBER: THICK (CM)
ON LOC. PICKUP RTES. (1.7250E 05 MEMBERS)														
MANTLE DELIVERIES	1.0E-01	0.0	0.0	0.0	120 CARTONS	11	15	6.8E-03	1.2E 02	1.4E 02	1.8E 04	TRAILER WALL	1	1.8E-01
*					*							AIR	13	1.8E 04
ON REG. TRUCK RTES. (1.4400E 05 MEMBERS)														
LANTERN DELIVERIES	9.0E-03	0.0	0.0	0.0	1440 LANTERN	11	14	7.1E-06	2.3E 02	3.3E 02	1.8E 04	TRAILER WALL	1	1.8E-01
*					*							AIR	13	1.8E 04
MANTLE DELIVERIES	4.5E-03	0.0	0.0	0.0	120 CARTONS	11	15	6.8E-03	1.2E 02	1.4E 02	1.8E 04	TRAILER WALL	1	1.8E-01
*					*							AIR	13	1.8E 04
ON LOC. DELIVERY RTS (1.7250E 06 MEMBERS)														
MANTLE DELIVERIES	1.0E-02	0.0	0.0	0.0	120 CARTONS	11	15	6.8E-03	1.2E 02	1.4E 02	1.8E 04	TRAILER WALL	1	1.8E-01
*					*							AIR	13	1.8E 04
					GENERAL PUBLIC, MAX.									
ON REG. PICKUP RTES. (1.0000E 00 MEMBERS)														
MANTLE PICKUPS	2.0E-03	0.0	0.0	0.0	120 CARTONS	11	15	6.8E-03	1.2E 02	1.4E 02	3.1E 03	TRAILER WALL	1	1.8E-01
*					*							AIR	13	3.0E 03
LANTERN PICKUPS	4.0E-03	0.0	0.0	0.0	1440 LANTERN	11	14	7.1E-06	2.3E 02	3.3E 02	3.1E 03	TRAILER WALL	1	1.8E-01
*					*							AIR	13	3.0E 03
ON LOC. PICKUP RTES. (1.0000E 00 MEMBERS)														
MANTLE DELIVERIES	2.0E-02	0.0	0.0	0.0	120 CARTONS	11	15	6.8E-03	1.2E 02	1.4E 02	3.1E 03	TRAILER WALL	1	1.8E-01
*					*							AIR	13	3.0E 03
ON REG. TRUCK RTES. (1.0000E 00 MEMBERS)														
LANTERN DELIVERIES	1.8E-03	0.0	0.0	0.0	1440 LANTERN	11	14	7.1E-06	2.3E 02	3.3E 02	3.1E 03	TRAILER WALL	1	1.8E-01
*					*							AIR	13	3.0E 03
MANTLE DELIVERIES	9.1E-04	0.0	0.0	0.0	120 CARTONS	11	15	6.8E-03	1.2E 02	1.4E 02	3.1E 03	TRAILER WALL	1	1.8E-01
*					*							AIR	13	3.0E 03
ON LOC. DELIVERY RTS (1.0000E 00 MEMBERS)														
MANTLE DELIVERIES	2.0E-03	0.0	0.0	0.0	120 CARTONS	11	15	6.8E-03	1.2E 02	1.4E 02	3.1E 03	TRAILER WALL	1	1.8E-01
*					*							AIR	13	3.0E 03

TABLE A.2. EXPOSURE CONDITIONS FOR TRANSPORT OF MANTLES FROM 3 SUPPLIERS TO 300 WHOLESALE WAREHOUSES

		AIR:			SOURCE:							ABSORBER:		
	TIME (H/Y)	CONC (G /CM**3)	RADIUS (CM)	AMT ING (G)	DESCRIPTION	G, NO	M, NO	MASS (G)	LENGTH (CM)	RADIUS (CM)	DISTANC (CM)	DESCRIPTION	M, NO	THICK (CM)
					TRUCK DRIVERS									
LOCAL PICKUP-LANTERN (3.0000E 00 MEMBERS)														
DRIVING	1.0E 02	0.0	0.0	0.0	600 LANTERNS	11	14	7.1E-06	3.8E 02	1.6E 02	1.4E 02	TRUCK PARTS	1	5.0E-01
*					*							AIR	13	1.4E 02
REGIONAL-LANTERNS (9.0000E 02 MEMBERS)														
DRIVING	5.0E 01	0.0	0.0	0.0	120 LANTERNS	11	14	2.1E-05	1.0E 02	8.2E 01	1.4E 02	TRUCK PARTS	1	5.0E-01
*					*							AIR	13	1.4E 02
DELIVERY-LANTERNS (3.0000E 02 MEMBERS)														
DRIVING	1.0E 01	0.0	0.0	0.0	120 LANTERNS	11	14	2.1E-05	1.0E 02	8.2E 01	1.4E 02	TRUCK PARTS	1	5.0E-01
*					*							AIR	13	1.4E 02
HANDLE CARGO	1.0E 01	0.0	0.0	0.0	1 LANTERN	1	1	3.8E-01	0.0	0.0	5.0E 01	PYREX GLOBE	11	1.6E-01
*					*							AIR	13	5.0E 01
NEAR CARGO	2.5E 00	0.0	0.0	0.0	1 PALLET	11	14	7.1E-06	1.0E 02	8.2E 01	9.0E 01	AIR	13	9.0E 01
AT DOCK	7.5E 00	0.0	0.0	0.0	1 PALLET	11	14	7.1E-06	1.0E 02	8.2E 01	3.0E 02	AIR	13	3.0E 02
PARCEL PICKUP-MANTLE (3.0000E 00 MEMBERS)														
HANDLE CARGO	2.5E 01	0.0	0.0	0.0	1 CARTON	11	15	1.4E-02	2.4E 01	2.1E 01	3.0E 01	AIR	13	3.0E 01
DRIVING	2.0E 02	0.0	0.0	0.0	15 CARTONS	11	15	6.8E-03	4.0E 01	8.7E 01	3.0E 02	AIR	13	3.0E 02
AWAY FROM TRUCK	4.0E 02	0.0	0.0	0.0	15 CARTONS	11	15	6.8E-03	4.0E 01	8.7E 01	1.5E 03	AIR	13	1.5E 03
REGIONAL PARCEL-MANT (4.5000E 02 MEMBERS)														
DRIVING	1.0E 02	0.0	0.0	0.0	3 CARTONS	11	15	4.1E-02	2.4E 01	2.1E 01	1.0E 03	TRUCK PARTS	1	5.0E-01
*					*							AIR	13	1.0E 03
PARCEL DELIVERY-MANT (3.0000E 02 MEMBERS)														
DRIVING	1.0E 01	0.0	0.0	0.0	3 CARTONS	11	15	4.1E-02	2.4E 01	2.1E 01	3.0E 02	AIR	13	3.0E 02
HANDLE CARTONS	2.5E-01	0.0	0.0	0.0	1 CARTON	11	15	1.4E-02	2.4E 01	2.1E 01	3.0E 01	AIR	13	3.0E 01
NEAR CARGO	5.0E 00	0.0	0.0	0.0	1 CARTON	11	15	1.4E-02	2.4E 01	2.1E 01	9.0E 01	AIR	13	9.0E 01

TABLE A.2. (CONTINUED)

	AIR:				SOURCE:							ABSORBER:		
	TIME (H/Y)	CONC (G /CM**3)	RADIUS (CM)	AMT ING (G)	DESCRIPTION	G, NO	M, NO	MASS (G)	LENGTH (CM)	RADIUS (CM)	DISTANC (CM)	DESCRIPTION	M, NO	THICK (CM)
					TRUCK TERM. WORKERS									
LOC TERM WORKERS-LAN (1.5000E 01 MEMBERS)														
UNLOAD-FORKLIFT	1.0E 01	0.0	0.0	0.0	1 PALLET	11	14	7.1E-06	1.0E 02	8.2E 01	1.2E 02	AIR	13	1.2E 02
NEAR CARGO	4.0E 02	0.0	0.0	0.0	300 LANTERNS	11	14	7.1E-06	1.9E 02	1.6E 02	3.1E 02	AIR	13	3.1E 02
LOAD-FORKLIFT	1.0E 01	0.0	0.0	0.0	1 PALLET	11	14	7.1E-06	1.0E 02	8.2E 01	1.2E 02	AIR	13	1.2E 02
REG TERM WORKERS-LAN (9.0000E 02 MEMBERS)														
LOAD&UNLOAD-FORKLIFT	5.0E-01	0.0	0.0	0.0	1 PALLET	11	14	7.1E-06	1.0E 02	8.2E 01	1.2E 02	AIR	13	1.2E 02
NEAR CARGO	2.0E 01	0.0	0.0	0.0	1 PALLET	11	14	7.1E-06	1.0E 02	8.2E 01	3.1E 02	AIR	13	3.1E 02
					PARCEL TERM. WORKERS									
LOC UNLOADERS-MANTLE (3.0000E 00 MEMBERS)														
HANDLE CARGO	3.0E 00	0.0	0.0	0.0	1 CARTON	11	15	1.4E-02	2.4E 01	2.1E 01	3.0E 01	AIR	13	3.0E 01
NEAR CARGO	1.0E 02	0.0	0.0	0.0	15 CARTONS	11	15	6.8E-03	4.0E 01	8.7E 01	6.0E 02	AIR	13	6.0E 02
LOC PROCESSERS-MANTL (3.0000E 00 MEMBERS)														
HANDLE CARGO	3.0E 00	0.0	0.0	0.0	1 CARTON	11	15	1.4E-02	2.4E 01	2.1E 01	3.0E 01	AIR	13	3.0E 01
NEAR CARTONS	2.0E 02	0.0	0.0	0.0	1 CARTON	11	15	1.4E-02	2.4E 01	2.1E 01	6.0E 02	AIR	13	6.0E 02
LOC SORTERS-MANTLES (3.0000E 01 MEMBERS)														
SORT CARTONS	3.0E-01	0.0	0.0	0.0	1 CARTON	11	15	1.4E-02	2.4E 01	2.1E 01	9.0E 01	AIR	13	9.0E 01
NEAR CARTONS	2.5E 01	0.0	0.0	0.0	1 CARTON	11	15	1.4E-02	2.4E 01	2.1E 01	6.0E 02	AIR	13	6.0E 02
LOC LOADERS-MANTLES (3.0000E 01 MEMBERS)														
HANDLE CARGO	4.0E-01	0.0	0.0	0.0	1 CARTON	11	15	1.4E-02	2.4E 01	2.1E 01	3.0E 01	AIR	13	3.0E 01
NEAR CARGO	2.5E 01	0.0	0.0	0.0	3 CARTONS	11	15	4.1E-02	2.4E 01	2.1E 01	6.0E 02	AIR	13	6.0E 02
REG UNLOADERS-MANTLE (9.0000E 02 MEMBERS)														
HANDLE CARGO	3.0E-02	0.0	0.0	0.0	1 CARTON	11	15	1.4E-02	2.4E 01	2.1E 01	3.0E 01	AIR	13	3.0E 01
NEAR CARGO	5.0E 00	0.0	0.0	0.0	3 CARTONS	11	15	4.1E-02	2.4E 01	2.1E 01	6.0E 02	AIR	13	6.0E 02

TABLE A.2. (CONTINUED)

		AIR:			SOURCE:							ABSORBER:		
	TIME (H/Y)	CONC (G /CM**3)	RADIUS (CM)	AMT ING (G)	DESCRIPTION	G, NO	M, NO	MASS (G)	LENGTH (CM)	RADIUS (CM)	DISTANC (CM)	DESCRIPTION	M, NO	THICK (CM)
REG PROCESSERS-MANTL (9.0000E 02 MEMBERS)														
HANDLE CARGO	3.0E-02	0.0	0.0	0.0	1 CARTON	11	15	1.4E-02	2.4E 01	2.1E 01	3.0E 01	AIR	13	3.0E 01
NEAR CARGO	1.0E 01	0.0	0.0	0.0	1 CARTON	11	15	1.4E-02	2.4E 01	2.1E 01	6.0E 02	AIR	13	6.0E 02
REG SORTERS-MANTLES (9.0000E 02 MEMBERS)														
SORT CARGO	3.0E-02	0.0	0.0	0.0	1 CARTON	11	15	1.4E-02	2.4E 01	2.1E 01	9.0E 01	AIR	13	9.0E 01
NEAR CARGO	1.3E 01	0.0	0.0	0.0	1 CARTON	11	15	1.4E-02	2.4E 01	2.1E 01	6.0E 02	AIR	13	6.0E 02
REG LOADERS-MANTLES (9.0000E 02 MEMBERS)														
LOAD CARTONS	4.0E-02	0.0	0.0	0.0	1 CARTON	11	15	1.4E-02	2.4E 01	2.1E 01	3.0E 01	AIR	13	3.0E 01
NEAR CARGO	1.3E 01	0.0	0.0	0.0	3 CARTONS	11	15	4.1E-02	2.4E 01	2.1E 01	6.0E 02	AIR	13	6.0E 02
					GENERAL PUBLIC, AVG.									
ON LOC PICKUP RT-LAN (1.7250E 05 MEMBERS)														
LANTERN PICKUPS	2.0E 00	0.0	0.0	0.0	600 LANTERNS	11	14	7.1E-06	2.3E 02	2.1E 02	1.8E 04	TRAILER WALL	1	1.8E-01
*					*							AIR	13	1.8E 04
ON LOC PICKUP RT-MAN (4.6335E 05 MEMBERS)														
MANTLE PICKUPS	3.3E 00	0.0	0.0	0.0	15 CARTONS	11	15	6.8E-03	1.7E 02	4.2E 01	1.8E 04	TRAILER WALL	1	1.8E-01
*					*							AIR	13	1.8E 04
ON REG DEL RT-LAN (8.6250E 07 MEMBERS)														
LANTERN DELIVERIES	1.0E-01	0.0	0.0	0.0	120 LANTERNS	11	14	7.1E-06	4.3E 02	7.7E 01	1.8E 04	TRAILER WALL	1	1.8E-01
*					*							AIR	13	1.8E 04
ON REG TRUCK RT-LAN (1.4400E 06 MEMBERS)														
LANTERN DELIVERIES	4.5E-02	0.0	0.0	0.0	120 LANTERNS	11	14	7.1E-06	4.3E 02	7.7E 01	1.8E 04	TRAILER WALL	1	1.8E-01
*					*							AIR	13	1.8E 04
ON PAR DEL RT-MAN (4.3125E 07 MEMBERS)														
MANTLE DELIVERIES	2.0E-01	0.0	0.0	0.0	15 CARTONS	11	15	6.8E-03	1.7E 02	4.2E 01	1.8E 04	TRAILER WALL	1	1.8E-01
*					*							AIR	13	1.8E 04

TABLE A.2. (CONTINUED)

	TIME (H/Y)	AIR: CONC (G /CM**3)	AIR: RADIUS (CM)	AMT ING (G)	SOURCE: DESCRIPTION	SOURCE: G, NO	SOURCE: M, NO	SOURCE: MASS (G)	SOURCE: LENGTH (CM)	SOURCE: RADIUS (CM)	SOURCE: DISTANC (CM)	ABSORBER: DESCRIPTION	ABSORBER: M, NO	ABSORBER: THICK (CM)
ON PAR TRUCK RT-MAN (7.2000E 05 MEMBERS) MANTLE DELIVERIES	9.1E-02	0.0	0.0	0.0	15 CARTONS	11	15	6.8E-03	1.7E 02	4.2E 01	1.8E 04	TRAILER WALL	1	1.8E-01
*					*							AIR	13	1.8E 04
ON LOC DEL RT-LAN (1.7250E 07 MEMBERS) LANTERN DELIVERIES	1.0E-01	0.0	0.0	0.0	120 LANTERNS	11	14	7.1E-06	4.3E 02	7.7E 01	1.8E 04	TRAILER WALL	1	1.8E-01
*					*							AIR	13	1.8E 04
ON LOC DEL RT-MAN (4.6350E 07 MEMBERS) MANTLE DELIVERIES	1.7E-01	0.0	0.0	0.0	3 CARTONS	11	15	4.1E-02	2.4E 01	2.1E 01	1.8E 04	TRAILER WALL	1	1.8E-01
*					*							AIR	13	1.8E 04
					GENERAL PUBLIC, MAX.									
ON LOC PICKUP RT-LAN (1.0000E 00 MEMBERS) LANTERN PICKUPS	4.0E-01	0.0	0.0	0.0	600 LANTERNS	11	14	7.1E-06	2.3E 02	2.1E 02	3.1E 03	TRAILER WALL	1	1.8E-01
*					*							AIR	13	3.0E 03
ON LOC PICKUP RT-MAN (1.0000E 00 MEMBERS) MANTLE PICKUPS	6.7E-01	0.0	0.0	0.0	15 CARTONS	11	15	6.8E-03	1.7E 02	4.2E 01	3.1E 03	TRAILER WALL	1	1.8E-01
*					*							AIR	13	3.0E 03
ON REG DEL RT-LAN (1.0000E 00 MEMBERS) LANTERN DELIVERIES	2.0E-02	0.0	0.0	0.0	120 LANTERNS	11	14	7.1E-06	4.3E 02	7.7E 01	3.1E 03	TRAILER WALL	1	1.8E-01
*					*							AIR	13	3.0E 03
ON REG TRUCK RT-LAN (1.0000E 00 MEMBERS) LANTERN DELIVERIES	9.0E-03	0.0	0.0	0.0	120 LANTERNS	11	14	7.1E-06	4.3E 02	7.7E 01	3.1E 03	TRAILER WALL	1	1.8E-01
*					*							AIR	13	3.0E 03
ON PAR DEL RT-MAN (1.0000E 00 MEMBERS) MANTLE DELIVERIES	4.0E-02	0.0	0.0	0.0	15 CARTONS	11	15	6.8E-03	1.7E 02	4.2E 01	3.1E 03	TRAILER WALL	1	1.8E-01
*					*							AIR	13	3.0E 03

TABLE A.2. (CONTINUED)

		AIR:			SOURCE:							ABSORBER:		
	TIME (H/Y)	CONC (G /CM**3)	RADIUS (CM)	AMT ING (G)	DESCRIPTION	G, NO	M, NO	MASS (G)	LENGTH (CM)	RADIUS (CM)	DISTANC (CM)	DESCRIPTION	M, NO	THICK (CM)
ON PAR TRUCK RT-MAN (1.0000E 00 MEMBERS)														
MANTLE DELIVERIES	1.8E-02	0.0	0.0	0.0	15 CARTONS	11	15	6.8E-03	1.7E 02	4.2E 01	3.1E 03	TRAILER WALL	1	1.8E-01
*					*							AIR	13	3.0E 03
ON LOC DEL RT-LAN (1.0000E 00 MEMBERS)														
LANTERN DELIVERIES	2.0E-02	0.0	0.0	0.0	120 LANTERNS	11	14	7.1E-06	4.3E 02	7.7E 01	3.1E 03	TRAILER WALL	1	1.8E-01
*					*							AIR	13	3.0E 03
ON LOC DEL RT-MAN (1.0000E 00 MEMBERS)														
MANTLE DELIVERIES	3.3E-02	0.0	0.0	0.0	3 CARTONS	11	15	4.1E-02	2.4E 01	2.1E 01	3.1E 03	TRAILER WALL	1	1.8E-01
*					*							AIR	13	3.0E 03

TABLE A.3. EXPOSURE CONDITIONS FOR TRANSPORT OF MANTLES FROM 3 SUPPLIERS TO 999 LOCAL UTILITY COMPANIES

		AIR:			SOURCE:							ABSORBER:		
	TIME (H/Y)	CONC (G /CM**3)	RADIUS (CM)	AMT ING (G)	DESCRIPTION	G, NO	M, NO	MASS (G)	LENGTH (CM)	RADIUS (CM)	DISTANC (CM)	DESCRIPTION	M, NO	THICK (CM)
					TRUCK DRIVERS									
PARCEL PICKUP (3.0000E 00 MEMBERS)														
HANDLE CARGO	8.3E 00	0.0	0.0	0.0	1 CARTON	11	16	2.0E-02	2.3E 01	1.3E 01	3.0E 01	AIR	13	3.0E 01
DRIVING	2.0E 02	0.0	0.0	0.0	5 CARTONS	11	16	1.0E-01	2.3E 01	1.3E 01	3.0E 02	AIR	13	3.0E 02
AWAY FROM TRUCK	4.0E 02	0.0	0.0	0.0	5 CARTONS	11	16	1.0E-01	2.3E 01	1.3E 01	1.5E 03	AIR	13	1.5E 03
REGIONAL PARCEL (3.3300E 02 MEMBERS)														
DRIVING	4.5E 01	0.0	0.0	0.0	3 CARTONS	11	16	6.0E-02	2.3E 01	1.3E 01	1.0E 03	TRUCK PARTS	1	5.0E-01
*					*							AIR	13	1.0E 03
LOC PARCEL DEL-MAN (9.9900E 02 MEMBERS)														
DRIVING	3.0E 00	0.0	0.0	0.0	1 CARTON	11	16	2.0E-02	2.3E 01	1.3E 01	3.0E 02	AIR	13	3.0E 02
HANDLE CARTONS	2.5E-02	0.0	0.0	0.0	1 CARTON	11	16	2.0E-02	2.3E 01	1.3E 01	3.0E 01	AIR	13	3.0E 01
NEAR CARGO	1.5E 00	0.0	0.0	0.0	1 CARTON	11	16	2.0E-02	2.3E 01	1.3E 01	9.0E 01	AIR	13	9.0E 01
					PARCEL TERM. WORKERS									
LOC UNLOADERS-MANTLE (3.0000E 00 MEMBERS)														
HANDLE CARGO	1.0E 00	0.0	0.0	0.0	1 CARTON	11	16	2.0E-02	2.3E 01	1.3E 01	3.0E 01	AIR	13	3.0E 01
NEAR CARGO	1.0E 02	0.0	0.0	0.0	5 CARTONS	11	16	1.0E-01	2.3E 01	1.3E 01	6.0E 02	AIR	13	6.0E 02
LOC PROCESSERS-MANTL (3.0000E 00 MEMBERS)														
HANDLE CARGO	1.0E 00	0.0	0.0	0.0	1 CARTON	11	16	2.0E-02	2.3E 01	1.3E 01	3.0E 01	AIR	13	3.0E 01
NEAR CARTONS	2.0E 02	0.0	0.0	0.0	1 CARTON	11	16	2.0E-02	2.3E 01	1.3E 01	6.0E 02	AIR	13	6.0E 02
LOC SORTERS-MANTLES (1.5000E 01 MEMBERS)														
SORT CARTONS	2.0E-01	0.0	0.0	0.0	1 CARTON	11	16	2.0E-02	2.3E 01	1.3E 01	9.0E 01	AIR	13	9.0E 01
NEAR CARTONS	5.0E 01	0.0	0.0	0.0	1 CARTON	11	16	2.0E-02	2.3E 01	1.3E 01	6.0E 02	AIR	13	6.0E 02

TABLE A.3. (CONTINUED)

	TIME (H/Y)	AIR: CONC (G /CM**3)	AIR: RADIUS (CM)	AMT ING (G)	SOURCE: DESCRIPTION	G, M, NO NO	MASS (G)	LENGTH (CM)	RADIUS (CM)	DISTANC (CM)	ABSORBER: DESCRIPTION	M, NO	THICK (CM)
LOC LOADERS-MANTLES (1.5000E 01 MEMBERS)													
HANDLE CARGO	2.7E-01	0.0	0.0	0.0	1 CARTON	11 16	2.0E-02	2.3E 01	1.3E 01	3.0E 01	AIR	13	3.0E 01
NEAR CARGO	5.0E 01	0.0	0.0	0.0	5 CARTONS	11 16	1.0E-01	2.3E 01	1.3E 01	6.0E 02	AIR	13	6.0E 02
REG UNLOADERS-MANTLE (3.3300E 02 MEMBERS)													
HANDLE CARGO	2.7E-02	0.0	0.0	0.0	1 CARTON	11 16	2.0E-02	2.3E 01	1.3E 01	3.0E 01	AIR	13	3.0E 01
NEAR CARGO	4.5E 00	0.0	0.0	0.0	3 CARTONS	11 16	6.0E-02	2.3E 01	1.3E 01	6.0E 02	AIR	13	6.0E 02
REG PROCESSERS-MANTL (3.3300E 02 MEMBERS)													
HANDLE CARGO	2.7E-02	0.0	0.0	0.0	1 CARTON	11 16	2.0E-02	2.3E 01	1.3E 01	3.0E 01	AIR	13	3.0E 01
NEAR CARGO	9.0E 00	0.0	0.0	0.0	1 CARTON	11 16	2.0E-02	2.3E 01	1.3E 01	6.0E 02	AIR	13	6.0E 02
REG SORTERS-MANTLES (9.9900E 02 MEMBERS)													
SORT CARGO	9.0E-03	0.0	0.0	0.0	1 CARTON	11 16	2.0E-02	2.3E 01	1.3E 01	9.0E 01	AIR	13	9.0E 01
NEAR CARGO	3.8E 00	0.0	0.0	0.0	1 CARTON	11 16	2.0E-02	2.3E 01	1.3E 01	6.0E 02	AIR	13	6.0E 02
REG LOADERS-MANTLES (9.9900E 02 MEMBERS)													
LOAD CARTONS	1.2E-02	0.0	0.0	0.0	1 CARTON	11 16	2.0E-02	2.3E 01	1.3E 01	3.0E 01	AIR	13	3.0E 01
NEAR CARGO	3.8E 00	0.0	0.0	0.0	3 CARTONS	11 16	6.0E-02	2.3E 01	1.3E 01	6.0E 02	AIR	13	6.0E 02
					GENERAL PUBLIC, AVG.								
ON LOCAL PICKUP RT (4.6335E 05 MEMBERS)													
MANTLE DELIVERIES	3.3E 00	0.0	0.0	0.0	5 CARTONS	11 16	1.0E-01	2.3E 01	1.3E 01	1.8E 04	TRAILER WALL	1	1.8E-01
*					*						AIR	13	1.8E 04
ON REG DELIVERY RT (3.1912E 07 MEMBERS)													
MANTLE DELIVERIES	9.0E-02	0.0	0.0	0.0	3 CARTONS	11 16	6.0E-02	2.3E 01	1.3E 01	1.8E 04	TRAILER WALL	1	1.8E-01
*					*						AIR	13	1.8E 04

TABLE A.3. (CONTINUED)

	AIR:				SOURCE:								ABSORBER:		
	TIME (H/Y)	CONC (G /CM**3)	RADIUS (CM)	AMT ING (G)	DESCRIPTION	G, NO	M, NO	MASS (G)	LENGTH (CM)	RADIUS (CM)	DISTANC (CM)	DESCRIPTION	M, NO	THICK (CM)
ON REGIONAL TRUCK RT (5.3280E 05 MEMBERS)														
MANTLE DELIVERIES	4.1E-02	0.0	0.0	0.0	3 CARTONS	11	16	6.0E-02	2.3E 01	1.3E 01	1.8E 04	TRAILER WALL	1	1.8E-01
*					*							AIR	13	1.8E 04
ON LOCAL DELIVERY RT (1.5430E 08 MEMBERS)														
MANTLE DELIVERIES	5.0E-02	0.0	0.0	0.0	1 CARTON	11	16	2.0E-02	2.3E 01	1.3E 01	1.8E 04	TRAILER WALL	1	1.8E-01
*					*							AIR	13	1.8E 04
					GENERAL PUBLIC, MAX.									
ON LOCAL PICKUP RT (1.0000E 00 MEMBERS)														
MANTLE DELIVERIES	6.7E-01	0.0	0.0	0.0	5 CARTONS	11	16	1.0E-01	2.3E 01	1.3E 01	3.1E 03	TRAILER WALL	1	1.8E-01
*					*							AIR	13	3.0E 03
ON REG DELIVERY RT (1.0000E 00 MEMBERS)														
MANTLE DELIVERIES	1.8E-02	0.0	0.0	0.0	3 CARTONS	11	16	6.0E-02	2.3E 01	1.3E 01	3.1E 03	TRAILER WALL	1	1.8E-01
*					*							AIR	13	3.0E 03
ON REGIONAL TRUCK RT (1.0000E 00 MEMBERS)														
MANTLE DELIVERIES	8.2E-03	0.0	0.0	0.0	3 CARTONS	11	16	6.0E-02	2.3E 01	1.3E 01	3.1E 03	TRAILER WALL	1	1.8E-01
*					*							AIR	13	3.0E 03
ON LOCAL DELIVERY RT (1.0000E 00 MEMBERS)														
MANTLE DELIVERIES	1.0E-02	0.0	0.0	0.0	1 CARTON	11	16	2.0E-02	2.3E 01	1.3E 01	3.1E 03	TRAILER WALL	1	1.8E-01
*					*							AIR	13	3.0E 03

TABLE A.4. EXPOSURE CONDITIONS FOR DISTRIBUTION OF MANTLES BY 30 LARGE RETAIL STORE WAREHOUSES AND 900 LARGE RETAIL STORES

		AIR:			SOURCE:						ABSORBER:		
	TIME (H/Y)	CONC (G /CM**3)	RADIUS (CM)	AMT ING (G)	DESCRIPTION	G, M, NO NO	MASS (G)	LENGTH (CM)	RADIUS (CM)	DISTANC (CM)	DESCRIPTION	M, NO	THICK (CM)
					WAREHOUSE WORKERS								
FORKLIFT OPERATOR (3.0000E 01 MEMBERS)													
UNLOAD LANTERNS	6.0E 00	0.0	0.0	0.0	40 LANTERNS	11 14	7.1E-06	1.0E 02	8.2E 01	1.2E 02	AIR	13	1.2E 02
UNLOAD MANTLES	1.7E-01	0.0	0.0	0.0	60 LANTERNS	11 15	6.8E-03	1.4E 02	9.5E 01	1.2E 02	AIR	13	1.2E 02
UNLOADERS (3.0000E 02 MEMBERS)													
NEAR TRUCKS-LANTERNS	1.0E 01	0.0	0.0	0.0	720 LANTERNS	11 14	7.1E-06	4.6E 02	1.6E 02	6.0E 02	MISCELANEOUS	1	5.0E-01
*					*						AIR	13	6.0E 02
NEAR TRUCKS-MANTLES	5.0E 00	0.0	0.0	0.0	60 CARTONS	11 15	6.8E-03	1.4E 02	9.5E 01	6.0E 02	MISCELANEOUS	1	5.0E-01
*					*						AIR	13	6.0E 02
STOCK HANDLERS (3.0000E 02 MEMBERS)													
HANDLE LANTERNS	1.2E 00	0.0	0.0	0.0	1 LANTERN	1 1	3.8E-01	0.0	0.0	3.0E 01	AIR	13	3.0E 01
HANDLE MANTLES	5.0E-02	0.0	0.0	0.0	1 CARTON	11 15	6.8E-03	2.4E 01	2.1E 01	3.0E 01	AIR	13	3.0E 01
NEAR STORED LANTERNS	2.5E 02	0.0	0.0	0.0	720 LANTERNS	11 14	7.1E-06	9.1E 02	8.2E 01	6.0E 02	AIR	13	6.0E 02
NEAR STORED MANTLES	2.5E 02	0.0	0.0	0.0	60 CARTONS	11 15	6.8E-03	1.4E 02	9.5E 01	6.0E 02	AIR	13	6.0E 02
LOADERS (3.0000E 02 MEMBERS)													
HANDLE LANTERNS	2.4E 00	0.0	0.0	0.0	1 LANTERN	1 1	3.8E-01	0.0	0.0	3.0E 01	AIR	13	3.0E 01
HANDLE MANTLES	1.0E-01	0.0	0.0	0.0	1 CARTON	11 15	6.8E-03	2.4E 01	2.1E 01	3.0E 01	AIR	13	3.0E 01
NEAR LANTERN LOAD	6.0E 00	0.0	0.0	0.0	24 LANTERNS	11 14	7.1E-06	5.1E 01	8.2E 01	3.0E 02	AIR	13	3.0E 02
NEAR MANTLE LOAD	6.0E 00	0.0	0.0	0.0	1 CARTON	11 15	6.8E-03	2.4E 01	2.1E 01	3.0E 02	AIR	13	3.0E 02
NEAR OTHERS LANTERNS	5.4E 01	0.0	0.0	0.0	24 LANTERNS	11 14	7.1E-06	5.1E 01	8.2E 01	1.0E 03	AIR	13	1.0E 03
NEAR OTHERS MANTLES	5.4E 01	0.0	0.0	0.0	1 CARTON	11 15	6.8E-03	2.4E 01	2.1E 01	1.0E 03	AIR	13	1.0E 03

TABLE A.4. (CONTINUED)

	TIME (H/Y)	AIR: CONC (G /CM**3)	AIR: RADIUS (CM)	AMT ING (G)	SOURCE: DESCRIPTION	SOURCE: G, M, NO NO	SOURCE: MASS (G)	SOURCE: LENGTH (CM)	SOURCE: RADIUS (CM)	SOURCE: DISTANC (CM)	ABSORBER: DESCRIPTION	ABSORBER: M, NO	ABSORBER: THICK (CM)
					TRUCK DRIVERS								
DELIVERY DRIVERS (9.0000E 02 MEMBERS)													
DRIVING LANTERNS	5.0E 00	0.0	0.0	0.0	48 LANTERNS	11 14	7.1E-06	1.0E 02	8.2E 01	8.0E 02	TRUCK	1	1.0E 01
*					*						AIR	13	7.9E 02
DRIVING MANTLES	1.0E 01	0.0	0.0	0.0	1 CARTON	11 15	6.8E-03	2.4E 01	2.1E 01	8.0E 02	TRUCK	1	1.0E 01
*					*						AIR	13	7.9E 02
HANDLING LANTERNS	8.0E-01	0.0	0.0	0.0	1 LANTERN	1 1	3.8E-01	0.0	0.0	3.0E 01	AIR	13	3.0E 01
UNLOADING MANTLES	3.3E-02	0.0	0.0	0.0	1 CARTON	11 15	6.8E-03	2.4E 01	2.1E 01	3.0E 01	AIR	13	3.0E 01
NEAR LANTERNS	2.0E 00	0.0	0.0	0.0	24 LANTERNS	11 14	7.1E-06	5.1E 01	8.2E 01	3.0E 02	AIR	13	3.0E 02
NEAR MANTLES	4.0E 00	0.0	0.0	0.0	1 CARTON	11 15	6.8E-03	2.4E 01	2.1E 01	3.0E 02	AIR	13	3.0E 02
					LARGE STORE WORKERS								
STOCK CLERKS (1.8000E 03 MEMBERS)													
CHECK LANTERNS	1.7E-01	0.0	0.0	0.0	48 LANTERNS	11 14	7.1E-06	1.0E 02	8.2E 01	9.0E 01	AIR	13	9.0E 01
CHECK MANTLES	6.7E-02	0.0	0.0	0.0	1 CARTON	11 15	6.8E-03	2.4E 01	2.1E 01	9.0E 01	AIR	13	9.0E 01
HANDLE LANTERNS	1.6E 00	0.0	0.0	0.0	1 LANTERN	1 1	3.8E-01	0.0	0.0	3.0E 01	AIR	13	3.0E 01
HANDLE MANTLES	6.7E-02	0.0	0.0	0.0	1 CARTON	11 15	6.8E-03	2.4E 01	2.1E 01	3.0E 01	AIR	13	3.0E 01
NEAR LANTERNS	1.0E 03	0.0	0.0	0.0	24 LANTERNS	11 14	7.1E-06	5.1E 01	8.2E 01	6.0E 02	AIR	13	6.0E 02
NEAR MANTLES	1.0E 03	0.0	0.0	0.0	1 CARTON	11 15	6.8E-03	2.4E 01	2.1E 01	6.0E 02	AIR	13	6.0E 02
SALES CLERKS (1.8000E 03 MEMBERS)													
HANDLE LANTERNS	8.0E 00	0.0	0.0	0.0	1 LANTERN	1 1	3.8E-01	0.0	0.0	3.0E 01	AIR	13	3.0E 01
HANDLE MANTLES	2.4E 00	0.0	0.0	0.0	1 PACKAGE	11 16	1.4E-02	1.5E 01	3.0E 00	3.0E 01	AIR	13	3.0E 01
HANDLE PACKS	2.9E 01	0.0	0.0	0.0	1 PACK	1 1	5.0E-01	0.0	0.0	3.0E 01	AIR	13	3.0E 01
NEAR DISPLAY	1.0E 03	0.0	0.0	0.0	12 LANTERNS	1 1	4.5E 00	0.0	0.0	6.0E 02	AIR	13	6.0E 02
*					1/2 PACKAGE	11 16	6.8E-03	7.6E 00	3.0E 00	6.0E 02	AIR	13	6.0E 02
NEAR STORED	1.0E 03	0.0	0.0	0.0	12 LANTERNS	1 1	4.5E 00	0.0	0.0	6.0E 02	WOOD	10	1.3E 00
*					*						AIR	13	6.0E 02
*					1/2 CARTON	11 15	6.8E-03	1.2E 01	2.1E 01	6.0E 02	WOOD	10	1.3E 00
*					*						AIR	13	6.0E 02
OTHER CLERKS (1.8000E 03 MEMBERS)													
NEAR DISPLAY	1.0E 03	0.0	0.0	0.0	12 LANTERNS	1 1	4.5E 00	0.0	0.0	1.5E 03	AIR	13	1.5E 03
*					1/2 PACKAGE	11 16	6.8E-03	7.6E 00	3.0E 00	1.5E 03	AIR	13	1.5E 03
NEAR STORED	1.0E 03	0.0	0.0	0.0	12 LANTERNS	1 1	4.5E 00	0.0	0.0	1.5E 03	WOOD	10	1.3E 00
*					*						AIR	13	1.5E 03
*					1/2 CARTON	11 15	6.8E-03	1.2E 01	2.1E 01	1.5E 03	WOOD	10	1.3E 00
*					*						AIR	13	1.5E 03

TABLE A.4. (CONTINUED)

	AIR:				SOURCE:							ABSORBER:		
	TIME (H/Y)	CONC (G /CM**3)	RADIUS (CM)	AMT ING (G)	DESCRIPTION	G, NO	M, NO	MASS (G)	LENGTH (CM)	RADIUS (CM)	DISTANC (CM)	DESCRIPTION	M, NO	THICK (CM)
					GENERAL PUBLIC, AVG.									
STORE CUSTOMERS (9.0000E 07 MEMBERS)														
NEAR DISPLAY	3.0E 00	0.0	0.0	0.0	12 LANTERNS	1	1	4.5E 00	0.0	0.0	6.0E 02	AIR	13	6.0E 02
*					1/2 PACKAGE	11	16	6.8E-03	7.6E 00	3.0E 00	6.0E 02	AIR	13	6.0E 02
NEAR STORED	9.0E 00	0.0	0.0	0.0	12 LANTERNS	1	1	4.5E 00	0.0	0.0	1.5E 03	WOOD	10	1.3E 00
*					*							AIR	13	1.5E 03
*					1/2 CARTON	11	15	6.8E-03	1.2E 01	2.1E 01	1.5E 03	WOOD	10	1.3E 00
*					*							AIR	13	1.5E 03
ON RURAL TRUCK RTES. (1.0350E 07 MEMBERS)														
LANTERN DELIVERIES	2.0E-02	0.0	0.0	0.0	48 LANTERNS	11	14	7.1E-06	1.0E 02	8.2E 01	1.8E 04	TRUCK, ETC.	1	1.0E 00
*					*							AIR	13	1.8E 04
MANTLE DELIVERIES	1.0E-02	0.0	0.0	0.0	1 CARTON	11	15	6.8E-03	2.4E 01	2.1E 01	1.8E 04	TRUCK, ETC.	1	1.0E 00
*					*							AIR	13	1.8E 04
ON LOCAL DELIVERY RT (1.3900E 08 MEMBERS)														
LANTERN DELIVERIES	3.3E-02	0.0	0.0	0.0	48 LANTERNS	11	14	7.1E-06	1.0E 02	8.2E 01	1.8E 04	TRUCK, ETC.	1	1.0E 00
*					*							AIR	13	1.8E 04
MANTLE DELIVERIES	1.7E-02	0.0	0.0	0.0	1 CARTON	11	15	6.8E-03	2.4E 01	2.1E 01	1.8E 04	TRUCK, ETC.	1	1.0E 00
*					*							AIR	13	1.8E 04
					GENERAL PUBLIC, MAX.									
ON RURAL TRUCK RTES. (1.0000E 00 MEMBERS)														
LANTERN DELIVERIES	4.0E-03	0.0	0.0	0.0	48 LANTERNS	11	14	7.1E-06	1.0E 02	8.2E 01	3.1E 03	TRUCK, ETC.	1	1.0E 00
*					*							AIR	13	3.0E 03
MANTLE DELIVERIES	2.0E-03	0.0	0.0	0.0	1 CARTON	11	15	6.8E-03	2.4E 01	2.1E 01	3.1E 03	TRUCK, ETC.	1	1.0E 00
*					*							AIR	13	3.0E 03
ON LOCAL DELIVERY RT (1.0000E 00 MEMBERS)														
LANTERN DELIVERIES	6.7E-03	0.0	0.0	0.0	48 LANTERNS	11	14	7.1E-06	1.0E 02	8.2E 01	3.1E 03	TRUCK, ETC.	1	1.0E 00
*					*							AIR	13	3.0E 03
MANTLE DELIVERIES	3.3E-03	0.0	0.0	0.0	1 CARTON	11	15	6.8E-03	2.4E 01	2.1E 01	3.1E 03	TRUCK, ETC.	1	1.0E 00
*					*							AIR	13	3.0E 03

TABLE A.5. EXPOSURE CONDITIONS FOR DISTRIBUTION OF MANTLES BY 300 WHOLESALERS AND 90,000 SMALL RETAIL STORES

	AIR:				SOURCE:							ABSORBER:		
	TIME (H/Y)	CONC (G /CM**3)	RADIUS (CM)	AMT ING (G)	DESCRIPTION	G, NO	M, NO	MASS (G)	LENGTH (CM)	RADIUS (CM)	DISTANC (CM)	DESCRIPTION	M, NO	THICK (CM)
					WAREHOUSE WORKERS									
RECEIVERS														
(3.0000E 02 MEMBERS)														
HANDLE LANTERNS	1.0E 00	0.0	0.0	0.0	1 LANTERN	1	1	3.8E-01	0.0	0.0	3.0E 01	AIR	13	3.0E 01
NEAR LANTERNS	1.0E 01	0.0	0.0	0.0	60 LANTERNS	1	1	2.3E 01	0.0	0.0	3.0E 02	AIR	13	3.0E 02
HANDLE MANTLES	2.5E-02	0.0	0.0	0.0	1 CARTON	11	14	6.8E-03	2.4E 01	2.1E 01	3.0E 01	AIR	13	3.0E 01
NEAR MANTLES	1.0E 01	0.0	0.0	0.0	1 CARTON	11	14	6.8E-03	2.4E 01	2.1E 01	3.0E 02	AIR	13	3.0E 02
FORK-LIFT OPERATOR														
(3.0000E 02 MEMBERS)														
MOVE LANTERNS	2.5E 00	0.0	0.0	0.0	40 LANTERNS	11	15	7.1E-06	1.0E 02	8.2E 01	1.2E 02	AIR	13	1.2E 02
MOVE MANTLES	8.3E-01	0.0	0.0	0.0	3 CARTONS	11	14	2.0E-02	2.4E 01	2.1E 01	1.2E 02	AIR	13	1.2E 02
STOCK HANDLERS														
(1.5000E 03 MEMBERS)														
HANDLE LANTERNS	1.0E 00	0.0	0.0	0.0	1 LANTERN	1	1	3.8E-01	0.0	0.0	3.0E 01	AIR	13	3.0E 01
NEAR LANTERNS	2.5E 02	0.0	0.0	0.0	40 LANTERNS	11	15	7.1E-06	1.0E 02	8.2E 01	6.0E 02	AIR	13	6.0E 02
HANDLE MANTLES	1.8E 00	0.0	0.0	0.0	24 MANTLES	11	16	1.4E-02	1.5E 01	3.0E 00	3.0E 01	AIR	13	3.0E 01
NEAR MANTLES	2.5E 02	0.0	0.0	0.0	1 CARTON	11	14	6.8E-03	2.4E 01	2.1E 01	3.0E 02	AIR	13	3.0E 02
MOVE SHIPMENT	5.0E 00	0.0	0.0	0.0	4 LANTERNS	1	1	1.5E 00	0.0	0.0	1.2E 02	AIR	13	1.2E 02
*					168 MANTLES	11	16	1.4E-04	1.5E 01	8.0E 00	1.2E 02	AIR	13	1.2E 02
LOADERS														
(9.0000E 02 MEMBERS)														
HANDLE LANTERNS	3.3E-01	0.0	0.0	0.0	1 LANTERN	1	1	3.8E-01	0.0	0.0	3.0E 01	AIR	13	3.0E 01
HANDLE MANTLES	3.3E-01	0.0	0.0	0.0	168 MANTLES	11	16	1.4E-02	1.5E 01	8.0E 00	3.0E 01	AIR	13	3.0E 01
NEAR SHIPMENT	1.0E 02	0.0	0.0	0.0	4 LANTERNS	1	1	1.5E 00	0.0	0.0	3.0E 02	AIR	13	3.0E 02
*					168 MANTLES	11	16	1.4E-02	1.5E 01	8.0E 00	3.0E 02	AIR	13	3.0E 02
					TRUCK DRIVERS									
DELIVERY														
(4.5000E 03 MEMBERS)														
DRIVING	1.0E 02	0.0	0.0	0.0	4 LANTERNS	1	1	1.5E 00	0.0	0.0	1.8E 02	AIR	13	1.8E 02
*					168 MANTLES	11	16	1.4E-02	1.5E 01	8.0E 00	1.8E 02	AIR	13	1.8E 02
UNLOADING LANTERNS	6.7E-02	0.0	0.0	0.0	1 LANTERN	1	1	3.8E-01	0.0	0.0	3.0E 01	AIR	13	3.0E 01
UNLOADING MANTLES	1.7E-02	0.0	0.0	0.0	168 MANTLES	11	16	1.4E-02	1.5E 01	8.0E 00	3.0E 01	AIR	13	3.0E 01
NEAR SHIPMENT	5.0E 00	0.0	0.0	0.0	4 LANTERNS	1	1	1.5E 00	0.0	0.0	3.0E 02	AIR	13	3.0E 02
*					168 MANTLES	11	16	1.4E-02	1.5E 01	8.0E 00	3.0E 02	AIR	13	3.0E 02

TABLE A.5. (CONTINUED)

		AIR:			SOURCE:							ABSORBER:		
	TIME (H/Y)	CONC (G /CM**3)	RADIUS (CM)	AMT ING (G)	DESCRIPTION	G, NO	M, NO	MASS (G)	LENGTH (CM)	RADIUS (CM)	DISTANC (CM)	DESCRIPTION	M, NO	THICK (CM)
					SMALL STORE WORKERS									
STOCK CLERKS														
(9.0000E 04 MEMBERS)														
HANDLE LANTERNS	3.3E-01	0.0	0.0	0.0	1 LANTERN	1	1	3.8E-01	0.0	0.0	3.0E 01	AIR	13	3.0E 01
HANDLE MANTLES	8.3E-02	0.0	0.0	0.0	168 MANTLES	11	16	1.4E-02	1.5E 01	8.0E 00	3.0E 01	AIR	13	3.0E 01
SALES CLERKS														
(1.8000E 05 MEMBERS)														
HANDLE LANTERNS	1.7E-01	0.0	0.0	0.0	1 LANTERN	1	1	3.8E-01	0.0	0.0	3.0E 01	AIR	13	3.0E 01
HANDLE PACKAGES OF M	5.8E-02	0.0	0.0	0.0	24 MANTLES	11	16	1.4E-02	1.5E 01	3.0E 00	3.0E 01	AIR	13	3.0E 01
HANDLE PACKS OF 2 M	7.0E-01	0.0	0.0	0.0	2 MANTLES	1	1	5.0E-01	0.0	0.0	3.0E 01	AIR	13	3.0E 01
NEAR DISPLAY	1.0E 03	0.0	0.0	0.0	2 LANTERNS	1	1	7.5E-01	0.0	0.0	3.0E 02	AIR	13	3.0E 02
*					84 MANTLES	11	16	1.4E-02	1.5E 01	5.7E 00	3.0E 02	AIR	13	3.0E 02
OTHER ACTIVITIES	1.0E 03	0.0	0.0	0.0	2 LANTERNS	1	1	7.5E-01	0.0	0.0	6.0E 02	AIR	13	6.0E 02
*					84 MANTLES	11	16	1.4E-02	1.5E 01	5.7E 00	6.0E 02	AIR	13	6.0E 02
					GENERAL PUBLIC, AVG.									
STORE CUSTOMERS														
(2.1000E 08 MEMBERS)														
NEAR DISPLAY	3.0E 00	0.0	0.0	0.0	2 LANTERNS	1	1	7.5E-01	0.0	0.0	3.0E 02	AIR	13	3.0E 02
*					84 MANTLES	11	16	1.4E-02	1.5E 01	5.7E 00	3.0E 02	AIR	13	3.0E 02
IN STORE	9.0E 00	0.0	0.0	0.0	2 LANTERNS	1	1	7.5E-01	0.0	0.0	6.0E 02	AIR	13	6.0E 02
*					84 MANTLES	11	16	1.4E-02	1.5E 01	5.7E 00	6.0E 02	AIR	13	6.0E 02
ON RURAL PART OF RTS														
(3.3000E 07 MEMBERS)														
NEAR TRUCK ROUTES	2.0E-01	0.0	0.0	0.0	4 LANTERNS	1	1	1.5E 00	0.0	0.0	1.8E 04	TRUCK SIDE	1	1.0E 00
*					*							AIR	13	1.8E 04
*					168 MANTLES	11	16	1.4E-02	1.5E 01	8.0E 00	1.8E 04	TRUCK SIDE	1	1.0E 00
*					*							AIR	13	1.8E 04
ON CITY PART OF RTES														
(1.7700E 08 MEMBERS)														
NEAR TRUCK ROUTES	3.3E-01	0.0	0.0	0.0	4 LANTERNS	1	1	1.5E 00	0.0	0.0	1.8E 04	TRUCK SIDE	1	1.0E 00
*					*							AIR	13	1.8E 04
*					168 MANTLES	11	16	1.4E-02	1.5E 01	8.0E 00	1.8E 04	TRUCK SIDE	1	1.0E 00
*					*							AIR	13	1.8E 04

TABLE A.5. (CONTINUED)

		AIR:			SOURCE:							ABSORBER:		
	TIME (H/Y)	CONC (G /CM**3)	RADIUS (CM)	AMT ING (G)	DESCRIPTION	G, NO	M, NO	MASS (G)	LENGTH (CM)	RADIUS (CM)	DISTANC (CM)	DESCRIPTION	M, NO	THICK (CM)
					GENERAL PUBLIC, MAX.									
ON RURAL PART OF RTS (1.0000E 00 MEMBERS)														
NEAR TRUCK ROUTES	4.0E-02	0.0	0.0	0.0	4 LANTERNS	1	1	1.5E 00	0.0	0.0	3.1E 03	TRUCK SIDE	1	1.0E 00
*					*							AIR	13	3.0E 03
*					168 MANTLES	11	16	1.4E-02	1.5E 01	8.0E 00	3.1E 03	TRUCK SIDE	1	1.0E 00
*					*							AIR	13	3.0E 03
ON CITY PART OF RTES (1.0000E 00 MEMBERS)														
NEAR TRUCK ROUTES	6.7E-02	0.0	0.0	0.0	4 LANTERNS	1	1	1.5E 00	0.0	0.0	3.1E 03	TRUCK SIDE	1	1.0E 00
*					*							AIR	13	3.0E 03
*					168 MANTLES	11	16	1.4E-02	1.5E 01	8.0E 00	3.1E 03	TRUCK SIDE	1	1.0E 00
*					*							AIR	13	3.0E 03

TABLE A.6. EXPOSURE CONDITIONS (LESS THOSE FOR MANTLE INSTALLATION) FOR DISTRIBUTION OF MANTLES BY 999 UTILITY COMPANIES

		AIR:			SOURCE:							ABSORBER:		
	TIME (H/Y)	CONC (G /CM**3)	RADIUS (CM)	AMT ING (G)	DESCRIPTION	G, NO	M, NO	MASS (G)	LENGTH (CM)	RADIUS (CM)	DISTANC (CM)	DESCRIPTION	M, NO	THICK (CM)
					UTILITY WORKERS									
STOCK CLERKS (9.9900E 02 MEMBERS)														
IN STOCK ROOM	2.0E 03	0.0	0.0	0.0	449 MANTLES	11	14	2.0E-02	1.2E 01	1.3E 01	6.0E 02	AIR	13	6.0E 02
DISPENSE MANTLES	4.2E 00	0.0	0.0	0.0	1 MANTLE	1	1	2.5E-01	0.0	0.0	3.0E 01	AIR	13	3.0E 01
*					499 MANTLES	11	14	2.0E-02	1.2E 01	1.3E 01	3.0E 01	AIR	13	3.0E 01
CARRY MANTLES	1.3E 01	0.0	0.0	0.0	2 MANTLES	1	1	5.0E-01	0.0	0.0	3.0E 01	AIR	13	3.0E 01
INSTALLERS (5.9940E 03 MEMBERS)														
CARRY MANTLES	2.1E 00	0.0	0.0	0.0	2 MANTLES	1	1	5.0E-01	0.0	0.0	3.0E 01	AIR	13	3.0E 01
DRIVING	1.0E 03	0.0	0.0	0.0	2 MANTLES	1	1	5.0E-01	0.0	0.0	1.8E 02	AIR	13	1.8E 02
					GENERAL PUBLIC, AVG.									
ON INSTALLER ROUTES (1.5000E 08 MEMBERS)														
ON ROUTES	4.2E 00	0.0	0.0	0.0	2 MANTLES	1	1	5.0E-01	0.0	0.0	1.8E 04	TRUCK SIDE	1	1.0E 00
*					*							AIR	13	1.8E 04
					GENERAL PUBLIC, MAX.									
ON INSTALLER ROUTES (1.0000E 00 MEMBERS)														
ON ROUTES	8.3E-01	0.0	0.0	0.0	2 MANTLES	1	1	5.0E-01	0.0	0.0	3.1E 03	TRUCK SIDE	1	1.0E 00
*					*							AIR	13	3.0E 03

TABLE A.7. EXPOSURE CONDITIONS FOR A TYPICAL TWO-DAY CAMPING TRIP

Event	Purchase 4 mantles	Load car	Travel to camp in front seat	Travel to camp in rear seat	Unload car	Set up camp	Ignite 2 lanterns at camp
Duration of exposure, h	1	8.33E-3	1.5	1.5	8.33E-3	2	1.67E-2
Site	Car	Outdoors	Car	Car	Campsite	Campsite	Campsite
Effective volume, cm**3			5.66E+6	5.66E+6		1.60E+9	1.48E+7
Effective radius, cm			140	140		900	150
Effective air exchange rate, volumes/day			1440	1440		4.22E+3	2.54E+4
Source 1	4 mantles	2 lanterns	2 lanterns	2 lanterns	2 lanterns	2 lanterns	2 lanterns
Mass of Th-232, g	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Composition indices	1	1	1	1	1	1	1
Distance from exposed person, cm	90	90	180	90	90	300 and 600	90 and 600
Shield 1	None	Pyrex globe	Pyrex globe	Pyrex globe	Pyrex globe	Pyrex globe	Pyrex globe
Density, g/cm**3		2.2	2.2	2.2	2.2	2.2	2.2
Thickness, cm		0.159	0.159	0.159	0.159	0.159	0.159
Shield 2	None	None	Seats, etc.	Seats, etc.	None	None	None
Density, g/cm**3			1.4	1.4			
Thickness, cm			30.0	8.26			
Effective concentration in air, g/cm**3	0	0	1.77E-7	1.77E-7	0	6.25E-10	6.74E-8
Air composition indices			5	5		5	2 or 5
Source 2	None	4 mantles	4 mantles	4 mantles	4 mantles	4 mantles	4 mantles
Mass of Th-232, g		1.0	1.0	1.0	1.0	1.0	1.0
Composition indices		1	1	1	1	1	1
Distance from exposed person, cm		90	180	90	90	300	600
Shield 1		Box	Box, seats	Box, seats	Box	Box	Box
Density, g/cm**3		1.4	1.4	1.4	1.4	1.4	1.4
Thickness, cm		0.635	30.6	8.90	0.635	0.635	0.635

TABLE A.7. (CONTINUED)

Event	Under light of burning lanterns	In tent with lit lantern	In tent with doused lantern	At site
Duration of exposure, h	3	0.5	7.5	12.5
Site	Campsite	Tent	Tent	Campsite
Effective volume, cm**3	6.87E+8	2.04E+7	2.04E+7	1.60E+9
Effective radius, cm	600	200	200	900
Effective air exchange rate, volumes/day	6.33E+3	1.44E+3	1.44E+3	4.22E+3
Source 1	2 lanterns	2 lanterns	2 lanterns	2 lanterns
Mass of Th-232, g	1.0	1.0	1.0	1.0
Composition indices	4 or 3	4 or 3	1	1
Distance from exposed person, cm	300	90 and 600	90 and 600	600
Shield 1	Pyrex globe	Pyrex globe	Pyrex globe	Pyrex globe
Density, g/cm**3	2.2	2.2	2.2	2.2
Thickness, cm	0.159	0.159	0.159	0.159
Shield 2	None	None	None	None
Density, g/cm**3				
Thickness, cm				
Effective concentration in air, g/cm**3	1.46E-9	2.45E-8	2.45E-8	6.25E-10
Air composition indices	2 or 5	2 or 5	2 or 5	5
Source 2	4 mantles	4 mantles	4 mantles	4 mantles
Mass of Th-232,g	1.0	1.0	1.0	1.0
Composition indices	1	1	1	1
Distance from exposed person, cm	300	600	600	600
Shield 1	Box	Box	Box	Box
Density, g/cm**3	1.4	1.4	1.4	1.4
Thickness, cm	0.635	0.635	0.635	0.635

Nuclide composition indices:

1. All are present.
2. All are present except Th-232 and Th-228.
3. All are present except Rn-220 + daughters.
4. Only Th-232 and Th-228 are present.
5. Only Rn-220 + daughters are present.

If two entries are given, the first refers to cases with volitilization of all nuclides but those of thorium; the second refers to cases with volitilization of only Rn-220 plus daughters.

Two entries for the exposure distance indicates substantially different placement of each mantle with respect to the exposed person. A distance is given for each mantle.

APPENDIX B

DETAILED TABULATIONS OF RADIATION DOSES

TABLE B.1. TOTAL-BODY RADIATION DOSES DUE TO TRANSPORT OF MANTLES FROM 3 SUPPLIERS TO 30 LARGE RETAIL STORE WAREHOUSES

	INDIVIDUAL DOSE EQUIVALENT, SV			POPULATION DOSE EQUIVALENT, PERSON-SV
	EXTERNAL	INTERNAL	TOTAL	
	TRUCK DRIVERS			
OVER THE ROAD (9.000E 01 MEMBERS)				
DRIVING	2.84E-07	0.0	2.84E-07	2.56E-05
DOSE TO OVER THE ROAD	2.84E-07	0.0	2.84E-07	2.56E-05
LOCAL PICKUP (3.000E 00 MEMBERS)				
DRIVING	7.51E-05	0.0	7.51E-05	2.25E-04
DOSE TO LOCAL PICKUP	7.51E-05	0.0	7.51E-05	2.25E-04
REGIONAL DELIVERY (9.000E 01 MEMBERS)				
DRIVING	2.84E-05	0.0	2.84E-05	2.55E-03
DOSE TO REGIONAL DELIVERY	2.84E-05	0.0	2.84E-05	2.55E-03
LOCAL DELIVERY (3.000E 01 MEMBERS)				
DRIVING	2.84E-06	0.0	2.84E-06	8.51E-05
HANDLE CARGO	5.69E-06	0.0	5.69E-06	1.71E-04
NEAR CARGO	4.45E-06	0.0	4.45E-06	1.34E-04
AT DOCK	2.20E-06	0.0	2.20E-06	6.60E-05
DOSE TO LOCAL DELIVERY	1.52E-05	0.0	1.52E-05	4.55E-04
SUMMARY OF DOSES FOR TRUCK DRIVERS		: LOWEST	2.84E-07	
		HIGHEST	7.51E-05	
		TOTAL		3.26E-03
	TERMINAL WORKERS			
CARGO HANDLERS (1.200E 02 MEMBERS)				
HANDLE CARGO	4.20E-07	0.0	4.20E-07	5.03E-05
NEAR CARGO	1.47E-06	0.0	1.47E-06	1.76E-04
DOSE TO CARGO HANDLERS	1.89E-06	0.0	1.89E-06	2.26E-04
SUMMARY OF DOSES FOR TERMINAL WORKERS		: LOWEST	1.89E-06	
		HIGHEST	1.89E-06	
		TOTAL		2.26E-04
	GENERAL PUBLIC, AVG.			
ON REG. PICKUP RTES. (4.313E 06 MEMBERS)				
LANTERN PICKUPS	1.51E-13	0.0	1.51E-13	6.50E-07
MANTLE PICKUPS	6.68E-12	0.0	6.68E-12	2.88E-05
DOSE TO ON REG. PICKUP RTES.	6.83E-12	0.0	6.83E-12	2.95E-05

TABLE B.1. (CONTINUED)

	INDIVIDUAL DOSE EQUIVALENT, SV			POPULATION DOSE EQUIVALENT, PERSON-SV
	EXTERNAL	INTERNAL	TOTAL	
ON LOC. PICKUP RTES. (1.725E 05 MEMBERS)				
MANTLE DELIVERIES	6.68E-11	0.0	6.68E-11	1.15E-05
DOSE TO ON LOC. PICKUP RTES.	6.68E-11	0.0	6.68E-11	1.15E-05
ON REG. TRUCK RTES. (1.440E 05 MEMBERS)				
LANTERN DELIVERIES	6.79E-14	0.0	6.79E-14	9.77E-09
MANTLE DELIVERIES	3.01E-12	0.0	3.01E-12	4.33E-07
DOSE TO ON REG. TRUCK RTES.	3.07E-12	0.0	3.07E-12	4.43E-07
ON LOC. DELIVERY RTS (1.725E 06 MEMBERS)				
MANTLE DELIVERIES	6.68E-12	0.0	6.68E-12	1.15E-05
DOSE TO ON LOC. DELIVERY RTS	6.68E-12	0.0	6.68E-12	1.15E-05
SUMMARY OF DOSES FOR GENERAL PUBLIC, AVG.:		LOWEST	3.07E-12	
		HIGHEST	6.68E-11	
		TOTAL		5.29E-05
	GENERAL PUBLIC, MAX.			
ON REG. PICKUP RTES. (1.000E 00 MEMBERS)				
MANTLE PICKUPS	7.38E-11	0.0	7.38E-11	0.0
LANTERN PICKUPS	1.62E-12	0.0	1.62E-12	0.0
DOSE TO ON REG. PICKUP RTES.	7.54E-11	0.0	7.54E-11	0.0
ON LOC. PICKUP RTES. (1.000E 00 MEMBERS)				
MANTLE DELIVERIES	7.38E-10	0.0	7.38E-10	0.0
DOSE TO ON LOC. PICKUP RTES.	7.38E-10	0.0	7.38E-10	0.0
ON REG. TRUCK RTES. (1.000E 00 MEMBERS)				
LANTERN DELIVERIES	7.29E-13	0.0	7.29E-13	0.0
MANTLE DELIVERIES	3.36E-11	0.0	3.36E-11	0.0
DOSE TO ON REG. TRUCK RTES.	3.43E-11	0.0	3.43E-11	0.0
ON LOC. DELIVERY RTS (1.000E 00 MEMBERS)				
MANTLE DELIVERIES	7.38E-11	0.0	7.38E-11	0.0
DOSE TO ON LOC. DELIVERY RTS	7.38E-11	0.0	7.38E-11	0.0
SUMMARY OF DOSES FOR GENERAL PUBLIC, MAX.:		LOWEST	3.43E-11	
		HIGHEST	7.38E-10	
		TOTAL		0.0
SUMMARY OF DOSES FOR TRANS TO CHAIN WHSES:		LOWEST	3.07E-12	
		HIGHEST	7.51E-05	
		TOTAL		3.54E-03

TABLE B.2. TOTAL-BODY RADIATION DOSES DUE TO TRANSPORT OF MANTLES FROM 3 SUPPLIERS TO 300 WHOLESALE WAREHOUSES

	INDIVIDUAL DOSE EQUIVALENT, SV			POPULATION DOSE EQUIVALENT, PERSON-SV
	EXTERNAL	INTERNAL	TOTAL	
	TRUCK DRIVERS			
LOCAL PICKUP-LANTERN (3.000E 00 MEMBERS)				
DRIVING	2.39E-06	0.0	2.39E-06	7.16E-06
DOSE TO LOCAL PICKUP-LANTERN	2.39E-06	0.0	2.39E-06	7.16E-06
REGIONAL-LANTERNS (9.000E 02 MEMBERS)				
DRIVING	6.48E-07	0.0	6.48E-07	5.83E-04
DOSE TO REGIONAL-LANTERNS	6.48E-07	0.0	6.48E-07	5.83E-04
DELIVERY-LANTERNS (3.000E 02 MEMBERS)				
DRIVING	1.30E-07	0.0	1.30E-07	3.89E-05
HANDLE CARGO	1.75E-08	0.0	1.75E-08	5.26E-06
NEAR CARGO	2.12E-08	0.0	2.12E-08	6.36E-06
AT DOCK	9.40E-09	0.0	9.40E-09	2.82E-06
DOSE TO DELIVERY-LANTERNS	1.78E-07	0.0	1.78E-07	5.33E-05
PARCEL PICKUP-MANTLE (3.000E 00 MEMBERS)				
HANDLE CARGO	7.11E-05	0.0	7.11E-05	2.13E-04
DRIVING	1.23E-04	0.0	1.23E-04	3.68E-04
AWAY FROM TRUCK	1.08E-05	0.0	1.08E-05	3.23E-05
DOSE TO PARCEL PICKUP-MANTLE	2.05E-04	0.0	2.05E-04	6.14E-04
REGIONAL PARCEL-MANT (4.500E 02 MEMBERS)				
DRIVING	1.27E-06	0.0	1.27E-06	5.73E-04
DOSE TO REGIONAL PARCEL-MANT	1.27E-06	0.0	1.27E-06	5.73E-04
PARCEL DELIVERY-MANT (3.000E 02 MEMBERS)				
DRIVING	1.42E-06	0.0	1.42E-06	4.26E-04
HANDLE CARTONS	7.11E-07	0.0	7.11E-07	2.13E-04
NEAR CARGO	2.28E-06	0.0	2.28E-06	6.83E-04
DOSE TO PARCEL DELIVERY-MANT	4.41E-06	0.0	4.41E-06	1.32E-03
SUMMARY OF DOSES FOR TRUCK DRIVERS		: LOWEST	1.78E-07	
		HIGHEST	2.05E-04	
		TOTAL		3.15E-03
	TRUCK TERM. WORKERS			
LOC TERM WORKERS-LAN (1.500E 01 MEMBERS)				
UNLOAD-FORKLIFT	5.77E-08	0.0	5.77E-08	8.65E-07
NEAR CARGO	2.58E-06	0.0	2.58E-06	3.87E-05
LOAD-FORKLIFT	5.77E-08	0.0	5.77E-08	8.65E-07
DOSE TO LOC TERM WORKERS-LAN	2.70E-06	0.0	2.70E-06	4.04E-05

TABLE B.2. (CONTINUED)

	INDIVIDUAL DOSE EQUIVALENT, SV			POPULATION DOSE EQUIVALENT, PERSON-SV
	EXTERNAL	INTERNAL	TOTAL	
REG TERM WORKERS-LAN (9.000E 02 MEMBERS)				
LOAD&UNLOAD-FORKLIFT	2.83E-09	0.0	2.83E-09	2.54E-06
NEAR CARGO	2.43E-08	0.0	2.43E-08	2.19E-05
DOSE TO REG TERM WORKERS-LAN	2.72E-08	0.0	2.72E-08	2.45E-05
SUMMARY OF DOSES FOR TRUCK TERM. WORKERS :		LOWEST	2.72E-08	
		HIGHEST	2.70E-06	
		TOTAL		6.49E-05
	PARCEL TERM. WORKERS			
LOC UNLOADERS-MANTLE (3.000E 00 MEMBERS)				
HANDLE CARGO	8.53E-06	0.0	8.53E-06	2.56E-05
NEAR CARGO	1.65E-05	0.0	1.65E-05	4.96E-05
DOSE TO LOC UNLOADERS-MANTLE	2.51E-05	0.0	2.51E-05	7.52E-05
LOC PROCESSERS-MANTL (3.000E 00 MEMBERS)				
HANDLE CARGO	8.53E-06	0.0	8.53E-06	2.56E-05
NEAR CARTONS	2.44E-06	0.0	2.44E-06	7.32E-06
DOSE TO LOC PROCESSERS-MANTL	1.10E-05	0.0	1.10E-05	3.29E-05
LOC SORTERS-MANTLES (3.000E 01 MEMBERS)				
SORT CARTONS	1.37E-07	0.0	1.37E-07	4.10E-06
NEAR CARTONS	3.05E-07	0.0	3.05E-07	9.14E-06
DOSE TO LOC SORTERS-MANTLES	4.41E-07	0.0	4.41E-07	1.32E-05
LOC LOADERS-MANTLES (3.000E 01 MEMBERS)				
HANDLE CARGO	1.14E-06	0.0	1.14E-06	3.41E-05
NEAR CARGO	9.12E-07	0.0	9.12E-07	2.74E-05
DOSE TO LOC LOADERS-MANTLES	2.05E-06	0.0	2.05E-06	6.15E-05
REG UNLOADERS-MANTLE (9.000E 02 MEMBERS)				
HANDLE CARGO	8.53E-08	0.0	8.53E-08	7.68E-05
NEAR CARGO	1.82E-07	0.0	1.82E-07	1.64E-04
DOSE TO REG UNLOADERS-MANTLE	2.68E-07	0.0	2.68E-07	2.41E-04
REG PROCESSERS-MANTL (9.000E 02 MEMBERS)				
HANDLE CARGO	8.53E-08	0.0	8.53E-08	7.68E-05
NEAR CARGO	1.22E-07	0.0	1.22E-07	1.10E-04
DOSE TO REG PROCESSERS-MANTL	2.07E-07	0.0	2.07E-07	1.87E-04
REG SORTERS-MANTLES (9.000E 02 MEMBERS)				
SORT CARGO	1.37E-08	0.0	1.37E-08	1.23E-05
NEAR CARGO	1.52E-07	0.0	1.52E-07	1.37E-04
DOSE TO REG SORTERS-MANTLES	1.66E-07	0.0	1.66E-07	1.49E-04

TABLE B.2. (CONTINUED)

	INDIVIDUAL DOSE EQUIVALENT, SV			POPULATION DOSE EQUIVALENT, PERSON-SV
	EXTERNAL	INTERNAL	TOTAL	
REG LOADERS-MANTLES (9.000E 02 MEMBERS)				
LOAD CARTONS	1.13E-07	0.0	1.13E-07	1.02E-04
NEAR CARGO	4.56E-07	0.0	4.56E-07	4.10E-04
DOSE TO REG LOADERS-MANTLES	5.70E-07	0.0	5.70E-07	5.13E-04
SUMMARY OF DOSES FOR PARCEL TERM. WORKERS:		LOWEST	1.66E-07	
		HIGHEST	2.51E-05	
		TOTAL		1.27E-03
	GENERAL PUBLIC, AVG.			
ON LOC PICKUP RT-LAN (1.725E 05 MEMBERS)				
LANTERN PICKUPS	6.32E-12	0.0	6.32E-12	1.09E-06
DOSE TO ON LOC PICKUP RT-LAN	6.32E-12	0.0	6.32E-12	1.09E-06
ON LOC PICKUP RT-MAN (4.634E 05 MEMBERS)				
MANTLE PICKUPS	2.40E-10	0.0	2.40E-10	1.11E-04
DOSE TO ON LOC PICKUP RT-MAN	2.40E-10	0.0	2.40E-10	1.11E-04
ON REG DEL RT-LAN (8.625E 07 MEMBERS)				
LANTERN DELIVERIES	6.06E-14	0.0	6.06E-14	5.23E-06
DOSE TO ON REG DEL RT-LAN	6.06E-14	0.0	6.06E-14	5.23E-06
ON REG TRUCK RT-LAN (1.440E 06 MEMBERS)				
LANTERN DELIVERIES	2.73E-14	0.0	2.73E-14	3.93E-08
DOSE TO ON REG TRUCK RT-LAN	2.73E-14	0.0	2.73E-14	3.93E-08
ON PAR DEL RT-MAN (4.312E 07 MEMBERS)				
MANTLE DELIVERIES	1.44E-11	0.0	1.44E-11	6.21E-04
DOSE TO ON PAR DEL RT-MAN	1.44E-11	0.0	1.44E-11	6.21E-04
ON PAR TRUCK RT-MAN (7.200E 05 MEMBERS)				
MANTLE DELIVERIES	6.56E-12	0.0	6.56E-12	4.72E-06
DOSE TO ON PAR TRUCK RT-MAN	6.56E-12	0.0	6.56E-12	4.72E-06
ON LOC DEL RT-LAN (1.725E 07 MEMBERS)				
LANTERN DELIVERIES	6.06E-14	0.0	6.06E-14	1.05E-06
DOSE TO ON LOC DEL RT-LAN	6.06E-14	0.0	6.06E-14	1.05E-06
ON LOC DEL RT-MAN (4.635E 07 MEMBERS)				
MANTLE DELIVERIES	3.91E-12	0.0	3.91E-12	1.81E-04
DOSE TO ON LOC DEL RT-MAN	3.91E-12	0.0	3.91E-12	1.81E-04

TABLE B.2. (CONTINUED)

	INDIVIDUAL DOSE EQUIVALENT, SV			POPULATION DOSE EQUIVALENT, PERSON-SV
	EXTERNAL	INTERNAL	TOTAL	
SUMMARY OF DOSES FOR GENERAL PUBLIC, AVG.:		LOWEST	2.73E-14	
		HIGHEST	2.40E-10	
		TOTAL		9.26E-04
	GENERAL PUBLIC, MAX.			
ON LOC PICKUP RT-LAN (1.000E 00 MEMBERS) LANTERN PICKUPS	6.81E-11	0.0	6.81E-11	0.0
DOSE TO ON LOC PICKUP RT-LAN	6.81E-11	0.0	6.81E-11	0.0
ON LOC PICKUP RT-MAN (1.000E 00 MEMBERS) MANTLE PICKUPS	2.62E-09	0.0	2.62E-09	0.0
DOSE TO ON LOC PICKUP RT-MAN	2.62E-09	0.0	2.62E-09	0.0
ON REG DEL RT-LAN (1.000E 00 MEMBERS) LANTERN DELIVERIES	6.26E-13	0.0	6.26E-13	0.0
DOSE TO ON REG DEL RT-LAN	6.26E-13	0.0	6.26E-13	0.0
ON REG TRUCK RT-LAN (1.000E 00 MEMBERS) LANTERN DELIVERIES	2.82E-13	0.0	2.82E-13	0.0
DOSE TO ON REG TRUCK RT-LAN	2.82E-13	0.0	2.82E-13	0.0
ON PAR DEL RT-MAN (1.000E 00 MEMBERS) MANTLE DELIVERIES	1.57E-10	0.0	1.57E-10	0.0
DOSE TO ON PAR DEL RT-MAN	1.57E-10	0.0	1.57E-10	0.0
ON PAR TRUCK RT-MAN (1.000E 00 MEMBERS) MANTLE DELIVERIES	7.08E-11	0.0	7.08E-11	0.0
DOSE TO ON PAR TRUCK RT-MAN	7.08E-11	0.0	7.08E-11	0.0
ON LOC DEL RT-LAN (1.000E 00 MEMBERS) LANTERN DELIVERIES	6.26E-13	0.0	6.26E-13	0.0
DOSE TO ON LOC DEL RT-LAN	6.26E-13	0.0	6.26E-13	0.0
ON LOC DEL RT-MAN (1.000E 00 MEMBERS) MANTLE DELIVERIES	4.40E-11	0.0	4.40E-11	0.0
DOSE TO ON LOC DEL RT-MAN	4.40E-11	0.0	4.40E-11	0.0
SUMMARY OF DOSES FOR GENERAL PUBLIC, MAX.:		LOWEST	2.82E-13	
		HIGHEST	2.62E-09	
		TOTAL		0.0
SUMMARY OF DOSES FOR TRANS TO WHOLESALERS:		LOWEST	2.73E-14	
		HIGHEST	2.05E-04	
		TOTAL		5.42E-03

TABLE B.3. TOTAL-BODY RADIATION DOSES DUE TO TRANSPORT OF MANTLES FROM 3 SUPPLIERS TO 999 LOCAL UTILITY COMPANIES

	INDIVIDUAL DOSE EQUIVALENT, SV			POPULATION DOSE EQUIVALENT, PERSON-SV
	EXTERNAL	INTERNAL	TOTAL	
	TRUCK DRIVERS			
PARCEL PICKUP (3.000E 00 MEMBERS)				
HANDLE CARGO	1.43E-05	0.0	1.43E-05	4.28E-05
DRIVING	2.60E-05	0.0	2.60E-05	7.81E-05
AWAY FROM TRUCK	2.13E-06	0.0	2.13E-06	6.38E-06
DOSE TO PARCEL PICKUP	4.24E-05	0.0	4.24E-05	1.27E-04
REGIONAL PARCEL (3.330E 02 MEMBERS)				
DRIVING	3.15E-07	0.0	3.15E-07	1.05E-04
DOSE TO REGIONAL PARCEL	3.15E-07	0.0	3.15E-07	1.05E-04
LOC PARCEL DEL-MAN (9.990E 02 MEMBERS)				
DRIVING	7.81E-08	0.0	7.81E-08	7.80E-05
HANDLE CARTONS	4.28E-08	0.0	4.28E-08	4.28E-05
NEAR CARGO	3.80E-07	0.0	3.80E-07	3.79E-04
DOSE TO LOC PARCEL DEL-MAN	5.01E-07	0.0	5.01E-07	5.00E-04
SUMMARY OF DOSES FOR TRUCK DRIVERS		: LOWEST	3.15E-07	
		HIGHEST	4.24E-05	
		TOTAL		7.32E-04
	PARCEL TERM. WORKERS			
LOC UNLOADERS-MANTLE (3.000E 00 MEMBERS)				
HANDLE CARGO	1.72E-06	0.0	1.72E-06	5.16E-06
NEAR CARGO	3.34E-06	0.0	3.34E-06	1.00E-05
DOSE TO LOC UNLOADERS-MANTLE	5.06E-06	0.0	5.06E-06	1.52E-05
LOC PROCESSERS-MANTL (3.000E 00 MEMBERS)				
HANDLE CARGO	1.72E-06	0.0	1.72E-06	5.16E-06
NEAR CARTONS	1.34E-06	0.0	1.34E-06	4.01E-06
DOSE TO LOC PROCESSERS-MANTL	3.06E-06	0.0	3.06E-06	9.17E-06
LOC SORTERS-MANTLES (1.500E 01 MEMBERS)				
SORT CARTONS	5.06E-08	0.0	5.06E-08	7.60E-07
NEAR CARTONS	3.34E-07	0.0	3.34E-07	5.01E-06
DOSE TO LOC SORTERS-MANTLES	3.85E-07	0.0	3.85E-07	5.77E-06
LOC LOADERS-MANTLES (1.500E 01 MEMBERS)				
HANDLE CARGO	4.58E-07	0.0	4.58E-07	6.86E-06
NEAR CARGO	1.67E-06	0.0	1.67E-06	2.51E-05
DOSE TO LOC LOADERS-MANTLES	2.13E-06	0.0	2.13E-06	3.19E-05

TABLE B.3. (CONTINUED)

	INDIVIDUAL DOSE EQUIVALENT, SV			POPULATION DOSE EQUIVALENT, PERSON-SV
	EXTERNAL	INTERNAL	TOTAL	
REG UNLOADERS-MANTLE (3.330E 02 MEMBERS)				
HANDLE CARGO	4.64E-08	0.0	4.64E-08	1.55E-05
NEAR CARGO	9.03E-08	0.0	9.03E-08	3.01E-05
DOSE TO REG UNLOADERS-MANTLE	1.37E-07	0.0	1.37E-07	4.55E-05
REG PROCESSERS-MANTL (3.330E 02 MEMBERS)				
HANDLE CARGO	4.64E-08	0.0	4.64E-08	1.55E-05
NEAR CARGO	6.01E-08	0.0	6.01E-08	2.00E-05
DOSE TO REG PROCESSERS-MANTL	1.07E-07	0.0	1.07E-07	3.55E-05
REG SORTERS-MANTLES (9.990E 02 MEMBERS)				
SORT CARGO	2.28E-09	0.0	2.28E-09	2.28E-06
NEAR CARGO	2.51E-08	0.0	2.51E-08	2.50E-05
DOSE TO REG SORTERS-MANTLES	2.73E-08	0.0	2.73E-08	2.73E-05
REG LOADERS-MANTLES (9.990E 02 MEMBERS)				
LOAD CARTONS	2.06E-08	0.0	2.06E-08	2.06E-05
NEAR CARGO	7.53E-08	0.0	7.53E-08	7.52E-05
DOSE TO REG LOADERS-MANTLES	9.59E-08	0.0	9.59E-08	9.58E-05
SUMMARY OF DOSES FOR PARCEL TERM. WORKERS:		LOWEST	2.73E-08	
		HIGHEST	5.06E-06	
		TOTAL		2.66E-04
	GENERAL PUBLIC, AVG.			
ON LOCAL PICKUP RT (4.634E 05 MEMBERS)				
MANTLE DELIVERIES	7.14E-11	0.0	7.14E-11	3.31E-05
DOSE TO ON LOCAL PICKUP RT	7.14E-11	0.0	7.14E-11	3.31E-05
ON REG DELIVERY RT (3.191E 07 MEMBERS)				
MANTLE DELIVERIES	1.16E-12	0.0	1.16E-12	3.70E-05
DOSE TO ON REG DELIVERY RT	1.16E-12	0.0	1.16E-12	3.70E-05
ON REGIONAL TRUCK RT (5.328E 05 MEMBERS)				
MANTLE DELIVERIES	5.28E-13	0.0	5.28E-13	2.82E-07
DOSE TO ON REGIONAL TRUCK RT	5.28E-13	0.0	5.28E-13	2.82E-07
ON LOCAL DELIVERY RT (1.543E 08 MEMBERS)				
MANTLE DELIVERIES	2.14E-13	0.0	2.14E-13	3.31E-05
DOSE TO ON LOCAL DELIVERY RT	2.14E-13	0.0	2.14E-13	3.31E-05
SUMMARY OF DOSES FOR GENERAL PUBLIC, AVG.:		LOWEST	2.14E-13	
		HIGHEST	7.14E-11	
		TOTAL		1.03E-04

TABLE B.3. (CONTINUED)

	INDIVIDUAL DOSE EQUIVALENT, SV			POPULATION DOSE EQUIVALENT, PERSON-SV
	EXTERNAL	INTERNAL	TOTAL	
	GENERAL PUBLIC, MAX.			
ON LOCAL PICKUP RT (1.000E 00 MEMBERS)				
MANTLE DELIVERIES	8.14E-10	0.0	8.14E-10	0.0
DOSE TO ON LOCAL PICKUP RT	8.14E-10	0.0	8.14E-10	0.0
ON REG DELIVERY RT (1.000E 00 MEMBERS)				
MANTLE DELIVERIES	1.32E-11	0.0	1.32E-11	0.0
DOSE TO ON REG DELIVERY RT	1.32E-11	0.0	1.32E-11	0.0
ON REGIONAL TRUCK RT (1.000E 00 MEMBERS)				
MANTLE DELIVERIES	6.01E-12	0.0	6.01E-12	0.0
DOSE TO ON REGIONAL TRUCK RT	6.01E-12	0.0	6.01E-12	0.0
ON LOCAL DELIVERY RT (1.000E 00 MEMBERS)				
MANTLE DELIVERIES	2.44E-12	0.0	2.44E-12	0.0
DOSE TO ON LOCAL DELIVERY RT	2.44E-12	0.0	2.44E-12	0.0
SUMMARY OF DOSES FOR GENERAL PUBLIC, MAX.:		LOWEST	2.44E-12	
		HIGHEST	8.14E-10	
		TOTAL		0.0
SUMMARY OF DOSES FOR TRANS TO UTILITIES :		LOWEST	2.14E-13	
		HIGHEST	4.24E-05	
		TOTAL		1.10E-03

TABLE B.4. TOTAL-BODY RADIATION DOSES DUE TO DISTRIBUTION OF MANTLES BY 30 LARGE RETAIL STORE WAREHOUSES AND 900 LARGE RETAIL STORES

	INDIVIDUAL DOSE EQUIVALENT, SV			POPULATION DOSE EQUIVALENT, PERSON-SV
	EXTERNAL	INTERNAL	TOTAL	
	WAREHOUSE WORKERS			
FORKLIFT OPERATOR (3.000E 01 MEMBERS)				
UNLOAD LANTERNS	3.39E-08	0.0	3.39E-08	1.02E-06
UNLOAD MANTLES	1.03E-06	0.0	1.03E-06	3.09E-05
DOSE TO FORKLIFT OPERATOR	1.06E-06	0.0	1.06E-06	3.19E-05
UNLOADERS (3.000E 02 MEMBERS)				
NEAR TRUCKS-LANTERNS	2.83E-08	0.0	2.83E-08	8.50E-06
NEAR TRUCKS-MANTLES	2.05E-06	0.0	2.05E-06	6.16E-04
DOSE TO UNLOADERS	2.08E-06	0.0	2.08E-06	6.24E-04
STOCK HANDLERS (3.000E 02 MEMBERS)				
HANDLE LANTERNS	6.06E-09	0.0	6.06E-09	1.82E-06
HANDLE MANTLES	7.09E-08	0.0	7.09E-08	2.13E-05
NEAR STORED LANTERNS	2.10E-07	0.0	2.10E-07	6.30E-05
NEAR STORED MANTLES	1.06E-04	0.0	1.06E-04	3.19E-02
DOSE TO STOCK HANDLERS	1.06E-04	0.0	1.06E-04	3.19E-02
LOADERS (3.000E 02 MEMBERS)				
HANDLE LANTERNS	1.21E-08	0.0	1.21E-08	3.64E-06
HANDLE MANTLES	1.42E-07	0.0	1.42E-07	4.25E-05
NEAR LANTERN LOAD	4.50E-09	0.0	4.50E-09	1.35E-06
NEAR MANTLE LOAD	1.42E-07	0.0	1.42E-07	4.26E-05
NEAR OTHERS LANTERNS	4.05E-09	0.0	4.05E-09	1.21E-06
NEAR OTHERS MANTLES	1.18E-07	0.0	1.18E-07	3.55E-05
DOSE TO LOADERS	4.23E-07	0.0	4.23E-07	1.27E-04
SUMMARY OF DOSES FOR WAREHOUSE WORKERS		: LOWEST	4.23E-07	
		HIGHEST	1.06E-04	
		TOTAL		3.27E-02
	TRUCK DRIVERS			
DELIVERY DRIVERS (9.000E 02 MEMBERS)				
DRIVING LANTERNS	5.19E-10	0.0	5.19E-10	4.67E-07
DRIVING MANTLES	1.74E-08	0.0	1.74E-08	1.56E-05
HANDLING LANTERNS	4.04E-09	0.0	4.04E-09	3.64E-06
UNLOADING MANTLES	4.68E-08	0.0	4.68E-08	4.21E-05
NEAR LANTERNS	1.50E-09	0.0	1.50E-09	1.35E-06
NEAR MANTLES	9.46E-08	0.0	9.46E-08	8.52E-05
DOSE TO DELIVERY DRIVERS	1.65E-07	0.0	1.65E-07	1.48E-04
SUMMARY OF DOSES FOR TRUCK DRIVERS		: LOWEST	1.65E-07	
		HIGHEST	1.65E-07	
		TOTAL		1.48E-04

TABLE B.4. (CONTINUED)

	INDIVIDUAL DOSE EQUIVALENT, SV			POPULATION DOSE EQUIVALENT, PERSON-SV
	EXTERNAL	INTERNAL	TOTAL	
	LARGE STORE WORKERS			
STOCK CLERKS (1.800E 03 MEMBERS)				
CHECK LANTERNS	1.42E-09	0.0	1.42E-09	2.55E-06
CHECK MANTLES	1.52E-08	0.0	1.52E-08	2.74E-05
HANDLE LANTERNS	8.09E-09	0.0	8.09E-09	1.46E-05
HANDLE MANTLES	9.50E-08	0.0	9.50E-08	1.71E-04
NEAR LANTERNS	2.03E-07	0.0	2.03E-07	3.66E-04
NEAR MANTLES	6.08E-06	0.0	6.08E-06	1.09E-02
DOSE TO STOCK CLERKS	6.40E-06	0.0	6.40E-06	1.15E-02
SALES CLERKS (1.800E 03 MEMBERS)				
HANDLE LANTERNS	4.04E-08	0.0	4.04E-08	7.28E-05
HANDLE MANTLES	1.23E-07	0.0	1.23E-07	2.21E-04
HANDLE PACKS	1.95E-07	0.0	1.95E-07	3.50E-04
NEAR DISPLAY	1.91E-07	0.0	1.91E-07	3.44E-04
NEAR STORED	3.27E-06	0.0	3.27E-06	5.89E-03
DOSE TO SALES CLERKS	3.82E-06	0.0	3.82E-06	6.88E-03
OTHER CLERKS (1.800E 03 MEMBERS)				
NEAR DISPLAY	2.97E-08	0.0	2.97E-08	5.34E-05
NEAR STORED	5.15E-07	0.0	5.15E-07	9.27E-04
DOSE TO OTHER CLERKS	5.45E-07	0.0	5.45E-07	9.81E-04
SUMMARY OF DOSES FOR LARGE STORE WORKERS :		LOWEST	5.45E-07	
		HIGHEST	6.40E-06	
		TOTAL		1.94E-02
	GENERAL PUBLIC, AVG.			
STORE CUSTOMERS (9.000E 07 MEMBERS)				
NEAR DISPLAY	5.73E-10	0.0	5.73E-10	5.16E-02
NEAR STORED	4.64E-09	0.0	4.64E-09	4.17E-01
DOSE TO STORE CUSTOMERS	5.21E-09	0.0	5.21E-09	4.69E-01
ON RURAL TRUCK RTES. (1.035E 07 MEMBERS)				
LANTERN DELIVERIES	4.80E-15	0.0	4.80E-15	4.97E-08
MANTLE DELIVERIES	3.69E-14	0.0	3.69E-14	3.82E-07
DOSE TO ON RURAL TRUCK RTES.	4.17E-14	0.0	4.17E-14	4.32E-07
ON LOCAL DELIVERY RT (1.390E 08 MEMBERS)				
LANTERN DELIVERIES	7.99E-15	0.0	7.99E-15	1.11E-06
MANTLE DELIVERIES	6.16E-14	0.0	6.16E-14	8.57E-06
DOSE TO ON LOCAL DELIVERY RT	6.96E-14	0.0	6.96E-14	9.68E-06
SUMMARY OF DOSES FOR GENERAL PUBLIC, AVG.:		LOWEST	4.17E-14	
		HIGHEST	5.21E-09	
		TOTAL		4.69E-01

TABLE B.4. (CONTINUED)

	INDIVIDUAL DOSE EQUIVALENT, SV			POPULATION DOSE EQUIVALENT, PERSON-SV
	EXTERNAL	INTERNAL	TOTAL	
	GENERAL PUBLIC, MAX.			
ON RURAL TRUCK RTES. (1.000E 00 MEMBERS)				
LANTERN DELIVERIES	5.35E-14	0.0	5.35E-14	0.0
MANTLE DELIVERIES	4.20E-13	0.0	4.20E-13	0.0
DOSE TO ON RURAL TRUCK RTES.	4.74E-13	0.0	4.74E-13	0.0
ON LOCAL DELIVERY RT (1.000E 00 MEMBERS)				
LANTERN DELIVERIES	8.92E-14	0.0	8.92E-14	0.0
MANTLE DELIVERIES	6.99E-13	0.0	6.99E-13	0.0
DOSE TO ON LOCAL DELIVERY RT	7.89E-13	0.0	7.89E-13	0.0
SUMMARY OF DOSES FOR GENERAL PUBLIC, MAX.:		LOWEST	4.74E-13	
		HIGHEST	7.89E-13	
		TOTAL		0.0
SUMMARY OF DOSES FOR LARGE STORE DISTRIBU:		LOWEST	4.17E-14	
		HIGHEST	1.06E-04	
		TOTAL		5.21E-01

TABLE B.5. TOTAL-BODY RADIATION DOSES DUE TO DISTRIBUTION OF MANTLES BY 300 WHOLESALERS AND 90,000 SMALL RETAIL STORES

	INDIVIDUAL DOSE EQUIVALENT, SV			POPULATION DOSE EQUIVALENT, PERSON-SV
	EXTERNAL	INTERNAL	TOTAL	
	WAREHOUSE WORKERS			
RECEIVERS (3.000E 02 MEMBERS)				
HANDLE LANTERNS	5.05E-09	0.0	5.05E-09	1.52E-06
NEAR LANTERNS	2.96E-08	0.0	2.96E-08	8.88E-06
HANDLE MANTLES	3.54E-08	0.0	3.54E-08	1.06E-05
NEAR MANTLES	2.37E-07	0.0	2.37E-07	7.10E-05
DOSE TO RECEIVERS	3.07E-07	0.0	3.07E-07	9.20E-05
FORK-LIFT OPERATOR (3.000E 02 MEMBERS)				
MOVE LANTERNS	1.41E-08	0.0	1.41E-08	4.24E-06
MOVE MANTLES	3.36E-07	0.0	3.36E-07	1.01E-04
DOSE TO FORK-LIFT OPERATOR	3.50E-07	0.0	3.50E-07	1.05E-04
STOCK HANDLERS (1.500E 03 MEMBERS)				
HANDLE LANTERNS	5.05E-09	0.0	5.05E-09	7.58E-06
NEAR LANTERNS	8.83E-08	0.0	8.83E-08	1.33E-04
HANDLE MANTLES	9.20E-08	0.0	9.20E-08	1.38E-04
NEAR MANTLES	5.92E-06	0.0	5.92E-06	8.87E-03
MOVE SHIPMENT	7.64E-09	0.0	7.64E-09	1.15E-05
DOSE TO STOCK HANDLERS	6.11E-06	0.0	6.11E-06	9.16E-03
LOADERS (9.000E 02 MEMBERS)				
HANDLE LANTERNS	1.67E-09	0.0	1.67E-09	1.50E-06
HANDLE MANTLES	1.15E-07	0.0	1.15E-07	1.03E-04
NEAR SHIPMENT	4.90E-07	0.0	4.90E-07	4.41E-04
DOSE TO LOADERS	6.07E-07	0.0	6.07E-07	5.46E-04
SUMMARY OF DOSES FOR WAREHOUSE WORKERS		: LOWEST	3.07E-07	
		HIGHEST	6.11E-06	
		TOTAL		9.91E-03
	TRUCK DRIVERS			
DELIVERY (4.500E 03 MEMBERS)				
DRIVING	1.33E-06	0.0	1.33E-06	5.98E-03
UNLOADING LANTERNS	3.37E-10	0.0	3.37E-10	1.52E-06
UNLOADING MANTLES	5.82E-09	0.0	5.82E-09	2.62E-05
NEAR SHIPMENT	2.45E-08	0.0	2.45E-08	1.10E-04
DOSE TO DELIVERY	1.36E-06	0.0	1.36E-06	6.11E-03
SUMMARY OF DOSES FOR TRUCK DRIVERS		: LOWEST	1.36E-06	
		HIGHEST	1.36E-06	
		TOTAL		6.11E-03

TABLE B.5. (CONTINUED)

	INDIVIDUAL DOSE EQUIVALENT, SV			POPULATION DOSE EQUIVALENT, PERSON-SV
	EXTERNAL	INTERNAL	TOTAL	
	SMALL STORE WORKERS			
STOCK CLERKS (9.000E 04 MEMBERS)				
HANDLE LANTERNS	1.68E-09	0.0	1.68E-09	1.51E-04
HANDLE MANTLES	2.90E-08	0.0	2.90E-08	2.61E-03
DOSE TO STOCK CLERKS	3.07E-08	0.0	3.07E-08	2.76E-03
SALES CLERKS (1.800E 05 MEMBERS)				
HANDLE LANTERNS	8.44E-10	0.0	8.44E-10	1.52E-04
HANDLE PACKAGES OF M	2.98E-09	0.0	2.98E-09	5.37E-04
HANDLE PACKS OF 2 M	4.72E-09	0.0	4.72E-09	8.49E-04
NEAR DISPLAY	2.46E-06	0.0	2.46E-06	4.42E-01
OTHER ACTIVITIES	6.22E-07	0.0	6.22E-07	1.12E-01
DOSE TO SALES CLERKS	3.09E-06	0.0	3.09E-06	5.56E-01
SUMMARY OF DOSES FOR SMALL STORE WORKERS :		LOWEST	3.07E-08	
		HIGHEST	3.09E-06	
		TOTAL		5.58E-01
	GENERAL PUBLIC, AVG.			
STORE CUSTOMERS (2.100E 08 MEMBERS)				
NEAR DISPLAY	7.37E-09	0.0	7.37E-09	1.55E 00
IN STORE	5.60E-09	0.0	5.60E-09	1.18E 00
DOSE TO STORE CUSTOMERS	1.30E-08	0.0	1.30E-08	2.72E 00
ON RURAL PART OF RTS (3.300E 07 MEMBERS)				
NEAR TRUCK ROUTES	1.49E-13	0.0	1.49E-13	4.91E-06
DOSE TO ON RURAL PART OF RTS	1.49E-13	0.0	1.49E-13	4.91E-06
ON CITY PART OF RTES (1.770E 08 MEMBERS)				
NEAR TRUCK ROUTES	2.48E-13	0.0	2.48E-13	4.38E-05
DOSE TO ON CITY PART OF RTES	2.48E-13	0.0	2.48E-13	4.38E-05
SUMMARY OF DOSES FOR GENERAL PUBLIC, AVG.:		LOWEST	1.49E-13	
		HIGHEST	1.30E-08	
		TOTAL		2.72E 00
	GENERAL PUBLIC, MAX.			
ON RURAL PART OF RTS (1.000E 00 MEMBERS)				
NEAR TRUCK ROUTES	1.70E-12	0.0	1.70E-12	0.0
DOSE TO ON RURAL PART OF RTS	1.70E-12	0.0	1.70E-12	0.0

TABLE B.5. (CONTINUED)

	INDIVIDUAL DOSE EQUIVALENT, SV			POPULATION DOSE EQUIVALENT, PERSON-SV
	EXTERNAL	INTERNAL	TOTAL	
ON CITY PART OF RTES (1.000E 00 MEMBERS) NEAR TRUCK ROUTES	2.83E-12	0.0	2.83E-12	0.0
DOSE TO ON CITY PART OF RTES	2.83E-12	0.0	2.83E-12	0.0
SUMMARY OF DOSES FOR GENERAL PUBLIC, MAX.:		LOWEST	1.70E-12	
		HIGHEST	2.83E-12	
		TOTAL		0.0
SUMMARY OF DOSES FOR SMALL STORE DISTRIBU:		LOWEST	1.49E-13	
		HIGHEST	6.11E-06	
		TOTAL		3.30E 00

TABLE B.6. TOTAL-BODY RADIATION DOSES DUE TO DISTRIBUTION OF MANTLES BY 999 UTILITY COMPANIES (LESS DOSES FROM INSTALLATION)

	INDIVIDUAL DOSE EQUIVALENT, SV			POPULATION DOSE EQUIVALENT, PERSON-SV
	EXTERNAL	INTERNAL	TOTAL	
	UTILITY WORKERS			
STOCK CLERKS (9.990E 02 MEMBERS)				
IN STOCK ROOM	7.32E-06	0.0	7.32E-06	7.31E-03
DISPENSE MANTLES	4.46E-06	0.0	4.46E-06	4.46E-03
CARRY MANTLES	8.42E-08	0.0	8.42E-08	8.41E-05
DOSE TO STOCK CLERKS	1.19E-05	0.0	1.19E-05	1.19E-02
INSTALLERS (5.994E 03 MEMBERS)				
CARRY MANTLES	1.40E-08	0.0	1.40E-08	8.40E-05
DRIVING	1.84E-07	0.0	1.84E-07	1.10E-03
DOSE TO INSTALLERS	1.98E-07	0.0	1.98E-07	1.19E-03
SUMMARY OF DOSES FOR UTILITY WORKERS		: LOWEST	1.98E-07	
		HIGHEST	1.19E-05	
		TOTAL		1.30E-02
	GENERAL PUBLIC, AVG.			
ON INSTALLER ROUTES (1.500E 08 MEMBERS)				
ON ROUTES	3.91E-14	0.0	3.91E-14	5.86E-06
DOSE TO ON INSTALLER ROUTES	3.91E-14	0.0	3.91E-14	5.86E-06
SUMMARY OF DOSES FOR GENERAL PUBLIC, AVG.:		LOWEST	3.91E-14	
		HIGHEST	3.91E-14	
		TOTAL		5.86E-06
	GENERAL PUBLIC, MAX.			
ON INSTALLER ROUTES (1.000E 00 MEMBERS)				
ON ROUTES	4.49E-13	0.0	4.49E-13	0.0
DOSE TO ON INSTALLER ROUTES	4.49E-13	0.0	4.49E-13	0.0
SUMMARY OF DOSES FOR GENERAL PUBLIC, MAX.:		LOWEST	4.49E-13	
		HIGHEST	4.49E-13	
		TOTAL		0.0
SUMMARY OF DOSES FOR UTILITY DISTRIBUTION:		LOWEST	3.91E-14	
		HIGHEST	1.19E-05	
		TOTAL		1.30E-02

TABLE B.7. EVENT-SPECIFIC RADIATION DOSES (SV) TO TOTAL BODY DURING A TWO-DAY CAMPING TRIP UNDER SEVERAL ASSUMPTIONS REGARDING THE COMPOSITION AND BEHAVIOR OF THE RADIONUCLIDES IN GAS MANTLES

Event	Natural thorium that releases while burning:						6-month-old thorium that releases while burning:					
	All but thorium nuclides			Only Rn-220 plus daughters			All but thorium nuclides			Only Rn-220 plus daughters		
Number and name	External	Internal	Total	External	Internal	Total	External	Internal	Total	External	Internal	Total
1 Purchase	1.5E-09	0.0E+00	1.5E-09	1.5E-09	0.0E+00	1.5E-09	8.1E-10	0.0E+00	8.1E-10	8.1E-10	0.0E+00	8.1E-10
2 Load car	2.2E-11	0.0E+00	2.2E-11	2.2E-11	0.0E+00	2.2E-11	1.1E-11	0.0E+00	1.1E-11	1.1E-11	0.0E+00	1.1E-11
Travel to camp:												
3 In front seat	3.2E-10	9.5E-10	1.3E-09	3.2E-10	9.5E-10	1.3E-09	1.7E-10	8.0E-10	9.7E-10	1.7E-10	8.0E-10	9.7E-10
4 In rear seat	2.9E-09	9.5E-10	3.8E-09	2.9E-09	9.5E-10	3.8E-09	1.5E-09	8.0E-10	2.3E-09	1.5E-09	8.0E-10	2.3E-09
5 Unload car	2.2E-11	0.0E+00	2.2E-11	2.2E-11	0.0E+00	2.2E-11	1.1E-11	0.0E+00	1.1E-11	1.1E-11	0.0E+00	1.1E-11
6 Set up camp	3.9E-10	1.4E-12	3.9E-10	3.9E-10	1.4E-12	3.9E-10	2.0E-10	8.0E-13	2.0E-10	2.0E-10	8.0E-13	2.0E-10
7 Ignite 2 lanterns	1.2E-11	3.4E-07	3.4E-07	1.2E-11	9.2E-10	9.3E-10	5.9E-12	2.7E-08	2.7E-08	5.9E-12	7.8E-10	7.8E-10
8 Under light	3.8E-10	2.9E-08	2.9E-08	5.3E-10	9.2E-11	6.3E-10	2.1E-10	2.4E-09	2.6E-09	2.2E-10	7.8E-11	2.9E-10
In tent:												
9 Lantern burning	1.5E-11	2.1E-10	2.3E-10	1.6E-10	1.7E-10	3.3E-10	8.5E-12	1.8E-10	1.9E-10	1.8E-11	1.4E-10	2.0E-10
10 Lantern out	2.4E-10	2.0E-11	2.6E-10	2.8E-09	6.7E-10	3.4E-09	1.3E-10	1.7E-11	1.5E-10	5.9E-10	5.6E-10	1.1E-09
11 At site	1.9E-10	4.2E-13	1.9E-10	3.0E-10	4.1E-12	3.1E-10	1.0E-10	3.5E-13	1.0E-10	1.4E-10	3.4E-12	1.4E-10
12 Ignite 2 lanterns	9.0E-13	1.3E-09	1.3E-09	9.7E-12	6.7E-10	6.8E-10	6.0E-13	1.1E-09	1.1E-09	4.3E-12	5.6E-10	5.7E-10
13 Under light	3.8E-10	1.3E-10	5.2E-10	5.3E-10	7.0E-11	6.0E-10	2.1E-10	1.1E-10	3.2E-10	2.2E-10	5.9E-11	2.8E-10
In tent:												
14 Lantern burning	1.5E-11	2.1E-10	2.3E-10	1.6E-10	1.7E-10	3.3E-10	8.5E-12	1.8E-10	1.9E-10	1.8E-11	1.4E-10	1.6E-10
15 Lantern out	2.4E-10	2.0E-11	2.6E-10	2.8E-09	6.7E-10	3.4E-09	1.3E-10	1.7E-11	1.5E-10	5.9E-10	5.6E-10	1.1E-09
16 At site	1.9E-10	4.2E-13	1.9E-10	3.0E-10	4.1E-12	3.1E-10	1.0E-10	3.5E-13	1.0E-10	1.4E-10	3.4E-12	1.4E-10
17 Load car	1.2E-11	0.0E+00	1.2E-11	2.1E-11	0.0E+00	2.1E-11	6.7E-12	0.0E+00	6.7E-12	1.0E-11	0.0E+00	1.0E-11
Travel home:												
18 In front seat	1.8E-10	1.4E-10	3.2E-10	2.9E-10	9.5E-10	1.2E-09	1.0E-10	1.2E-10	2.2E-10	1.5E-10	8.0E-10	9.5E-10
19 In rear seat	1.6E-09	1.4E-10	1.7E-09	2.7E-09	9.5E-10	3.6E-09	9.0E-10	1.2E-10	1.0E-09	1.3E-09	8.0E-10	2.1E-09
20 Unload car	1.2E-11	0.0E+00	1.2E-11	2.1E-11	0.0E+00	2.1E-11	6.7E-12	0.0E+00	6.7E-12	1.0E-11	0.0E+00	1.0E-11

TABLE B.8. EVENT-SPECIFIC RADIATION DOSES (SV) TO BONE DURING A TWO-DAY CAMPING TRIP UNDER SEVERAL ASSUMPTIONS REGARDING THE COMPOSITION AND BEHAVIOR OF THE RADIONUCLIDES IN GAS MANTLES

Event	Natural thorium that releases while burning:						6-month-old thorium that releases while burning:					
	All but thorium nuclides			Only Rn-220 plus daughters			All but thorium nuclides			Only Rn-220 plus daughters		
Number and name	External	Internal	Total	External	Internal	Total	External	Internal	Total	External	Internal	Total
1 Purchase	1.7E-09	0.0E+00	1.7E-09	1.7E-09	0.0E+00	1.7E-09	9.1E-10	0.0E+00	9.1E-10	9.1E-10	0.0E+00	9.1E-10
2 Load car	2.5E-11	0.0E+00	2.5E-11	2.5E-11	0.0E+00	2.5E-11	1.3E-11	0.0E+00	1.3E-11	1.3E-11	0.0E+00	1.3E-11
Travel to camp:												
3 In front seat	3.6E-10	2.0E-09	2.4E-09	3.6E-10	2.0E-09	2.4E-09	2.0E-10	1.7E-09	1.9E-09	2.0E-10	1.7E-09	1.9E-09
4 In rear seat	3.3E-09	2.0E-09	5.3E-09	3.3E-09	2.0E-09	5.3E-09	1.7E-09	1.7E-09	3.4E-09	1.7E-09	1.7E-09	3.4E-09
5 Unload car	2.5E-11	0.0E+00	2.5E-11	2.5E-11	0.0E+00	2.5E-11	1.3E-11	0.0E+00	1.3E-11	1.3E-11	0.0E+00	1.3E-11
6 Set up camp	4.4E-10	1.8E-12	4.4E-10	4.4E-10	1.8E-12	4.4E-10	2.3E-10	3.6E-13	2.3E-10	2.3E-10	3.6E-13	2.3E-10
7 Ignite 2 lanterns	1.4E-11	8.9E-07	8.9E-07	1.3E-11	2.9E-09	2.9E-09	6.8E-12	6.2E-08	6.2E-08	6.7E-12	2.4E-09	2.4E-09
8 Under light	4.3E-10	7.7E-08	7.7E-08	6.1E-10	2.6E-10	8.7E-10	2.3E-10	5.4E-09	5.6E-09	2.5E-10	2.2E-10	4.7E-10
In tent:												
9 Lantern burning	1.8E-11	2.5E-10	2.7E-10	1.8E-10	3.6E-10	5.4E-10	9.8E-12	2.2E-10	2.3E-10	2.1E-11	3.0E-10	3.2E-10
10 Lantern out	2.8E-10	4.2E-11	3.2E-10	3.2E-09	1.4E-09	4.6E-09	1.5E-10	3.7E-11	1.9E-10	6.8E-10	1.2E-09	1.9E-09
11 At site	2.1E-10	5.6E-13	2.1E-10	3.4E-10	5.5E-12	3.5E-10	1.1E-10	4.7E-13	1.1E-10	1.6E-10	4.7E-12	1.7E-10
12 Ignite 2 lanterns	1.0E-12	1.7E-09	1.7E-09	1.1E-11	2.1E-09	2.1E-09	6.9E-13	1.5E-09	1.5E-09	4.9E-12	1.8E-09	1.8E-09
13 Under light	4.3E-10	1.7E-10	6.0E-10	6.1E-10	2.0E-10	8.0E-10	2.3E-10	1.4E-10	3.8E-10	2.5E-10	1.6E-10	4.1E-10
In tent:												
14 Lantern burning	1.8E-11	2.5E-10	2.7E-10	1.8E-10	3.6E-10	5.4E-10	9.8E-12	2.2E-10	2.3E-10	2.1E-11	3.0E-10	3.2E-10
15 Lantern out	2.8E-10	4.2E-11	3.2E-10	3.2E-09	1.4E-09	4.6E-09	1.5E-10	3.7E-11	1.9E-10	6.8E-10	1.2E-09	1.9E-09
16 At site	2.1E-10	5.6E-13	2.1E-10	3.4E-10	5.5E-12	3.5E-10	1.1E-10	4.7E-13	1.1E-10	1.6E-10	4.7E-12	1.7E-10
17 Load car	1.4E-11	0.0E+00	1.4E-11	2.3E-11	0.0E+00	2.3E-11	7.6E-12	0.0E+00	7.6E-12	1.1E-11	0.0E+00	1.1E-11
Travel home:												
18 In front seat	2.0E-10	3.0E-10	5.0E-10	3.3E-10	2.0E-09	2.3E-09	1.2E-10	2.5E-10	3.7E-10	1.7E-10	1.7E-09	1.9E-09
19 In rear seat	1.8E-09	3.0E-10	2.1E-09	3.0E-09	2.0E-09	5.1E-09	1.0E-09	2.5E-10	1.3E-09	1.5E-09	1.7E-09	3.2E-09
20 Unload car	1.4E-11	0.0E+00	1.4E-11	2.3E-11	0.0E+00	2.3E-11	7.6E-12	0.0E+00	7.6E-12	1.1E-11	0.0E+00	1.1E-11

TABLE B.9. EVENT-SPECIFIC RADIATION DOSES (SV) TO LUNGS DURING A TWO-DAY CAMPING TRIP UNDER SEVERAL ASSUMPTIONS REGARDING THE COMPOSITION AND BEHAVIOR OF THE RADIONUCLIDES IN GAS MANTLES

Event	Natural thorium that releases while burning:						6-month-old thorium that releases while burning:					
	All but thorium nuclides			Only Rn-220 plus daughters			All but thorium nuclides			Only Rn-220 plus daughters		
Number and name	External	Internal	Total	External	Internal	Total	External	Internal	Total	External	Internal	Total
1 Purchase	1.4E-09	0.0E+00	1.4E-09	1.4E-09	0.0E+00	1.4E-09	7.6E-10	0.0E+00	7.6E-10	7.6E-10	0.0E+00	7.6E-10
2 Load car	2.1E-11	0.0E+00	2.1E-11	2.1E-11	0.0E+00	2.1E-11	1.1E-11	0.0E+00	1.1E-11	1.1E-11	0.0E+00	1.1E-11
Travel to camp:												
3 In front seat	3.0E-10	5.4E-08	5.5E-08	3.0E-10	5.4E-08	5.5E-08	1.7E-10	4.6E-08	4.6E-08	1.7E-10	4.6E-08	4.6E-08
4 In rear seat	2.7E-09	5.4E-08	5.7E-08	2.7E-09	5.4E-08	5.7E-08	1.4E-09	4.6E-08	4.7E-08	1.4E-09	4.6E-08	4.7E-08
5 Unload car	2.1E-11	0.0E+00	2.1E-11	2.1E-11	0.0E+00	2.1E-11	1.1E-11	0.0E+00	1.1E-11	1.1E-11	0.0E+00	1.1E-11
6 Set up camp	3.7E-10	8.4E-11	4.5E-10	3.7E-10	8.4E-11	4.5E-10	1.9E-10	5.4E-11	2.5E-10	1.9E-10	5.4E-11	2.5E-10
7 Ignite 2 lanterns	1.1E-11	4.7E-07	4.7E-07	1.1E-11	4.6E-08	4.6E-08	5.6E-12	2.7E-07	2.7E-07	5.6E-12	3.9E-08	3.9E-08
8 Under light	3.6E-10	4.1E-08	4.1E-08	5.0E-10	4.8E-09	5.3E-09	1.9E-10	2.4E-08	2.4E-08	2.0E-10	4.1E-09	4.2E-09
In tent:												
9 Lantern burning	1.4E-11	6.4E-09	6.4E-09	1.5E-10	9.8E-09	1.0E-08	8.0E-12	5.4E-09	5.4E-09	1.7E-11	8.3E-09	8.3E-09
10 Lantern out	2.3E-10	1.2E-09	1.4E-09	2.6E-09	3.8E-08	4.1E-08	1.2E-10	9.4E-10	1.1E-09	5.5E-10	3.2E-08	3.3E-08
11 At site	1.7E-10	2.6E-11	2.0E-10	2.8E-10	2.5E-10	5.4E-10	9.6E-11	2.2E-11	1.2E-10	1.3E-10	2.1E-10	3.5E-10
12 Ignite 2 lanterns	8.4E-13	4.1E-08	4.1E-08	9.1E-12	3.4E-08	3.4E-08	5.7E-13	3.5E-08	3.5E-08	4.1E-12	2.8E-08	2.8E-08
13 Under light	3.6E-10	4.1E-09	4.5E-09	5.0E-10	3.7E-09	4.2E-09	1.9E-10	3.5E-09	3.6E-09	2.0E-10	3.1E-09	3.3E-09
In tent:												
14 Lantern burning	1.4E-11	6.4E-09	6.4E-09	1.5E-10	9.8E-09	1.0E-08	8.0E-12	5.4E-09	5.4E-09	1.7E-11	8.3E-09	8.3E-09
15 Lantern out	2.3E-10	1.2E-09	1.4E-09	2.6E-09	3.8E-08	4.1E-08	1.2E-10	9.4E-10	1.1E-09	5.5E-10	3.2E-08	3.3E-08
16 At site	1.7E-10	2.6E-11	2.0E-10	2.8E-10	2.5E-10	5.4E-10	9.6E-11	2.2E-11	1.2E-10	1.3E-10	2.1E-10	3.5E-10
17 Load car	1.1E-11	0.0E+00	1.1E-11	1.9E-11	0.0E+00	1.9E-11	6.3E-12	0.0E+00	6.3E-12	9.4E-12	0.0E+00	9.4E-12
Travel home:												
18 In front seat	1.7E-10	8.2E-09	8.4E-09	2.8E-10	5.4E-08	5.5E-08	9.8E-11	6.9E-09	7.0E-09	1.5E-10	4.6E-08	4.6E-08
19 In rear seat	1.5E-09	8.2E-09	9.7E-09	2.5E-09	5.4E-08	5.7E-08	8.5E-10	6.9E-09	7.7E-09	1.3E-09	4.6E-08	4.7E-08
20 Unload car	1.1E-11	0.0E+00	1.1E-11	1.9E-11	0.0E+00	1.9E-11	6.4E-12	0.0E+00	6.4E-12	9.6E-12	0.0E+00	9.6E-12

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