ORAU Team **Dose Reconstruction Project for NIOSH** Pinellas Plant – Occupational Environmental Dose	Document Number: ORAUT-TKBS-0029-4 Effective Date: 04/05/2005 Revision No.: 00 Controlled Copy No.: _____ Page 1 of 29
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RECORD OF ISSUE/REVISIONS

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Draft	12/09/2004	00-A	New technical basis document for Pinellas Plant – Occupational Environmental Dose. Initiated by Mark D. Notich.
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ACRONYMS AND ABBREVIATIONS

AEC	U.S. Atomic Energy Commission
Bq	becquerel
Ci	curie
DOE	U.S. Department of Energy
g	gram
JFD	joint frequency distribution
keV	kilovolt-electron, 1,000 electron volts
L	liter
m	meter
MEE	maximally exposed employee
ml	milliliter
mrem	millirem
pCi	picocurie
RTG	radioisotopic thermoelectric generator
Sv	sievert
TBD	technical basis document
U.S.C.	United States Code
yr	year
µCi	microcurie

4.0 OCCUPATIONAL ENVIRONMENTAL DOSE

4.1 INTRODUCTION

Technical Basis Documents (TBDs) and Site Profile Documents are general working documents that provide guidance concerning the preparation of dose reconstructions at particular sites or categories of sites. They will be revised in the event additional relevant information is obtained about the affected site(s). These documents may be used to assist the National Institute for Occupational Safety and Health in the completion of the individual work required for each dose reconstruction.

In this document the word "facility" is used as a general term for an area, building, or group of buildings that served a specific purpose at a site. It does not necessarily connote an "atomic weapons employer facility" or a "Department of Energy facility" as defined in the Energy Employees Occupational Illness Compensation Program Act of 2000 (42 U.S.C. Sections 7384l(5) and (12)).

This TBD provides historical environmental dose information for the Pinellas Plant workers about onsite exposure to the plant's radiological releases to air and ambient conditions. The information is based on the available literature on the site, which consists primarily of environmental monitoring reports and site environmental reports published between 1971 and 1995. No records could be found to demonstrate that environmental dose monitoring was conducted on the site, such as with environmental thermoluminescent dosimeters. Because of the apparent lack of an environmental dosimetry program that focused on monitoring workers, the environmental doses in this TBD have been estimated using an appropriate computer model and claimant-favorable assumptions.

4.1.1 Employee Monitoring

An external dosimetry program was started in 1957 to monitor individual personnel working in the production areas for the neutron generators. From 1960 to 1973, the U.S. Atomic Energy Commission (AEC) annual exposure summary reports showed that Pinellas had 27.5% of its workers wearing dosimetry. In the 1980s, approximately 10% to 14% of workers were monitored for radiation dose. This percentage range appears to be representative of the entire history of monitoring at the Pinellas Plant (no documentation was found that shows all employees were monitored during any given period). Only employees that performed activities that could have caused them to obtain doses greater than radiation protection guidelines were monitored. A smaller percentage of employees were monitored for internal exposures. Therefore, a majority of employees could have received environmental doses that were not monitored because they did not wear external dosimetry or were not monitored for internal dose.

4.1.2 Detection and Measurement of Airborne Effluents

4.1.2.1 Stack Emissions

Because of the differing physical and radiological properties of airborne effluents (tritium gas, tritium oxide, and krypton gas), the systems necessary to detect and measure them have different requirements. Air samples were drawn through Kanne type ionization chambers connected to pico ammeters to analyze tritium gas and krypton gas (minimum detection limit of 6.4E-6 µCi/ml) (IT/ Radiological Sciences Laboratory, 1986). To analyze tritium oxide, water vapor in the sample stream was condensed by a refrigeration device and the liquid counted by liquid scintillation spectrometry. Stack effluents were continuously sampled and recorded and water vapor condensate was continuously collected and analyzed daily (AEC, 1972). In later years, silica gel columns were used to collect the tritium oxide which was then desorbed from the silica columns and counted on the liquid

scintillation counters. Plutonium was analyzed with resin separation, chemical separation and electroplating with counting performed with alpha spectrometry. C-14 was analyzed with liquid scintillation.

4.1.2.2 Retention Pond Emissions

From 1957 through 1973, drain lines containing liquid industrial effluent were directed to an on-site acid neutralization facility and from there to the 3,250,000 gallon north-east retention pond (AEC, 1974). From 1974 to December 1, 1982, the industrial effluent was combined with the sanitary waste effluent in the 2,600,000 gallon west lake where the wastewater was aerated and pumped to a nine-acre spray irrigation field. A drain system collected water from the irrigation field and sent it to the east retention basin for subsequent release to a county drainage ditch located off-site. Beginning on December 1, 1982, all sanitary and industrial liquid discharges were sent to the Pinellas County publicly owned treatment works although storm water continued to be diverted to the retention pond where trace quantities of tritium remained (DOE, 1983b). Liquid samples were taken from the north-east retention pond where the pond discharges to the drainage ditch. Tritium was the only radionuclide discharged through this pathway. Tritium results prior to 1983 were referenced to the standards set forth in the Rules of the Florida State Board of Health, Chapter 170J-1, Control of Radiation Hazards, and in the AEC Manual Chapter 0524, Standards for Radiation Protection (AEC, 1973). Sampling results were recorded in the annual environmental reports in terms of µCi/ml. After 1982, all samples were analyzed in accordance with the latest edition of Standard Methods for the Examination of Water and Wastewater, published by the American Public Health Association, American Water Works Association, and Water Pollution Control Federation (DOE, 1983b).

4.1.3 Mode of Exposure to Airborne Effluents

Most of the radioactivity released to the atmosphere from the stacks was due to tritium and ^{85}Kr. Tritium emits very low energy beta particles, and ^{85}Kr emits high-energy beta particles. The exposure pathways for these radionuclides are briefly explained below.

Tritium was the primary radionuclide used at the Pinellas Plant. While it can exist in all compounds that contain normal hydrogen, two of the more common forms are (1) tritium gas, and (2) tritium oxide in either the liquid or the vapor state. With a physical half-life of 12.3 yr, tritium emits low-energy beta particles and decays to ^{3}He. The emitted beta particles have a maximum energy of 18.6 keV and an average energy of 5.7 keV. The emitted beta particles, because of their very low energy, lack penetrability and result in no radiation dose from external exposure. Therefore, tritium only contributes to internal dose (DOE, 1995a). The specific activity of isotopically pure tritium is 9,620 Ci/g (IT/Radiological Sciences Laboratory, 1986).

In comparison to tritium gas, tritium oxide (which readily exchanges with the body's water) is greater than 10,000 times more biologically reactive. However, because the body readily excretes water, tritium oxide has a biological half-life of 4 to 18 days. *Biological half-life* is the time it takes for half of the tritium to be eliminated from the body through both excretion and radioactive decay (DOE, 1995a).

Krypton-85, which exists only in the gaseous state, has a specific activity of 393 Ci/g and a half-life of 10.7 yr. Its most common decay (99.57%) is by beta particle emission with maximum energy of 687 keV and an average energy of 251 keV. Its alternative decay scheme (0.43%) is by beta particle emission (maximum energy of 173 keV) followed by gamma ray emission (energy of 514 keV) (IT/Radiological Sciences Laboratory, 1986).

Small quantities of ^{14}C labeled solvents were used in a laboratory testing operation in Building 100 from 1979 to 1983. Because ^{14}C emits a low-energy beta particle, radiation doses result primarily from internal deposition (DOE, 1983a).

The tritium oxide released to the retention pond would naturally evaporate into the atmosphere at the same rate as the water and become a possible internal source of exposure to a worker working adjacent to the retention pond. The retention pond is located a short distance away from other Pinellas Plant facilities and there was no known reason why any workers would be near the retention pond except to conduct monitoring of the pond.

4.1.4 Exhaust Stacks and Releases

Exhaust stacks were the primary source for gaseous radiological release to the environment. Table 4.1.4-1 lists the stacks along with their locations, dimensions, and nature of releases. Figure 4.1.4-1 shows the location of the emission points at the Pinellas Plant.

By 1992, approximately 82% of the total releases had occurred during the first 4 yr of operation, 1957 through 1960. Table 4.1.4-2 lists the radionuclide releases from Pinellas Plant exhaust stacks (AEC, 1972; 1973; 1974; ERDA, 1975; 1976; 1977; DOE, 1978; 1979; 1980; 1981; 1982; 1983b; 1984; 1985; 1986; 1987; 1988; 1989; 1990; 1991; 1992; 1993; 1994; 1995b).

As indicated in Table 4.1.4-1, mainly tritium gas and tritium oxide, and to a relatively lesser degree ^{85}Kr, comprised the radiological contents of the exhausts from the Pinellas Plant stacks. Pinellas began using ^{85}Kr for leak detection in 1963 (Burkhart, 1990). Relatively small contributions of ^{14}C to the overall air releases were reported for 1979 to 1983, as indicated in Table 4.1.4-2.

Table 4.1.4-1 Exhaust Stacks, Their Dimensions, and Their Radionuclide Releases

Name	Location	Height, m (ft)	Diameter, m (ft)	Nature of Exhaust
Building 100 Main Stack (East Main Stack)	East of Building 100	30.48 (100) 21.34 (70)[1]	2.44 (8)[7]	Tritium gas, tritium oxide, and krypton-85 gas.
Building 100 Laboratory Stack (West Main Stack)	West of Building 100	30.48(100)	1.52 (5)[7]	Tritium gas and tritium oxide. During 1979 through 1983, also C-14.
Building 800 Stack (Accelerator Facility Stack)	Building 800	6.4 (21)[2] 6.4 (21)[3][7] 9.1 (30)[4]	 0.25 x 0.33[3][7] (10/12 x 13/12) 0.51 (1.67)[5]	Tritium gas and tritium oxide.
Building 200 Stack	Building 200	17.7 (~ 58)[6]	0.30 (1)[4]	Tritium gas and tritium oxide.

(1) In July 1981, the stack was reduced to this height to provide more stability in the event of hurricane force winds (DOE, 1982).
(2) The first release from this stack occurred in 1980 (DOE, 1982).
(3) In October 1981, modifications were made that resulted in changes in the volume of air exhausted and in the configuration of the exhaust stack (DOE, 1982, DOE, 1984, and DOE, 1989).
(4) DOE, 1991.
(5) State of Florida, 1994.
(6) Discharge from the Building 200 exhaust stack appeared in literature for 1989 for the first time (DOE, 1990).
(7) DOE, 1984; DOE, 1989.

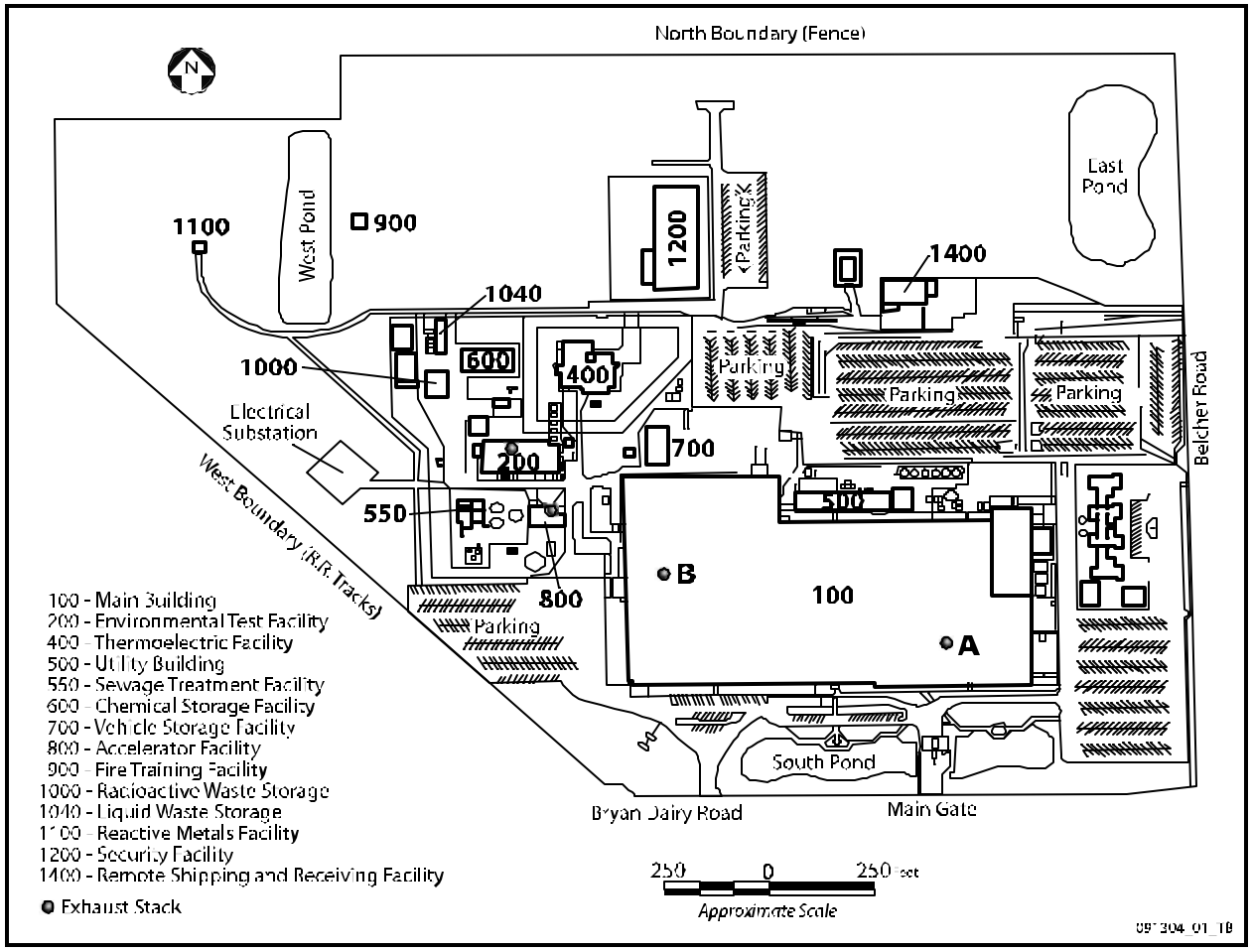

Figure 4.1.4-1 Location of Exhaust Stacks

Table 4.1.4-2 Radionuclides Released From Pinellas Plant Stacks

Year	Tritium Gas (Ci/yr)	Tritium Oxide (Ci/yr)	Krypton-85 (Ci/yr)	Carbon-14 (Ci/yr)[1]	Additional Information
1957	6660	140	NR[2]	NR	See Note 1.
1958	31920	580	NR	NR	
1959	41070	1330	NR	NR	
1960	6265	435	NR	NR	
1961	504	306	NR	NR	
1962	611	249	NR	NR	
1963	179	103	4	NR	In 1963, Kr-85 began to be used for leak detection in Building 100 (Burkhart, 1990) and presumably exhausted through the Building 100 Main Stack (East Main Stack).
1964	233	57	47	NR	
1965	50	100	153	NR	
1966	325	385	49	NR	
1967	1994	213	70	NR	
1968	1586	215	202	NR	
1969	3275	297	55	NR	

Year	Tritium Gas (Ci/yr)	Tritium Oxide (Ci/yr)	Krypton-85 (Ci/yr)	Carbon-14 (Ci/yr)(1)	Additional Information
1970	587	465	44	NR	
1971	694	374	12	NR	Building 100 Main Stack and Building 100 Laboratory Stack.
1972	111	222	15	NR	Building 100 Main Stack and Building 100 Laboratory Stack.
1973	74	318	1	NR	
1974	155	202	4	NR	
1975	154	165	1	NR	
1976	101	176	20	NR	ERDA, 1977, p. 3-1 & p. 4-2
1977	129	161	28	NR	
1978	132	156	5	NR	
1979	128	206	5	1.E-04	The reported C-14 discharges (1979 – 1983) are from the Building 100 Laboratory Stack.
1980	140	209	2	2.E-04	Releases from Bldg. 800 began to be reported in this year.
1981	222	195	4	9.E-05	DOE, 1982, pp. 3-1 - 3-2, provides the following information: Main stack height was reduced from 30.5 m (100 ft) to 21.3 m (70 ft) after June 30, 1981, to provide improved stability in the event of hurricane force winds.
1982	227	257	8	4.E-05	
1983	259	152	11	1.E-05	
1984	96	206	1.97	NR	
1985	111	149	5.31	NR	
1986	33	161	4.6	NR	
1987	68	138	38	NR	
1988	132.2	124.1	30	NR	
1989	43.7	60	12.9	NR	For the first time, discharges from the Building 200 exhaust stack began to appear.
1990	61.6	60.5	10.1	NR	DOE, 1991, pages 32, 53, 65
1991	23	88	4	NR	In 1991 two minor point sources (chemical hoods) exhausted tritium gas and tritium oxide through two roof openings. These were roof opening #378 (Chemistry Laboratory) and roof opening #413 (Environmental Laboratory).
1992	8	32	10	NR	Emissions were only from the two main stacks (undetectable amounts from Buildings 800 and 200 exhaust stacks).
1993	Total gas and oxide: 12		19	NR	
1994	Total gas and oxide: 25		13	NR	See Note 2.

(1) From Building 100 main stack.
(2) NR = No recorded release. For the first six years of operation, no Kr-85 was used at the site (Burkhart, 1990). For C-14, no documentation was found regarding its use or release other than for those years for which values are given.
Note 1: By 1992, approximately 82% of all stack releases had occurred during the first 4 years of the plant operation, 1957-1960.
Note 2: The releases for 1994 were: 13.6 Curies of tritium gas, 11.4 Curies of tritium oxide, and 13 Curies of Kr-85, respectively (Weaver, 1995).

4.1.5 Tritium Releases from the North-east Retention Pond

The tritium concentration in the liquid contained in the north-east retention pond and discharged to the drainage ditch was reported in environmental monitoring reports from 1971 through 1994. Table 4.1.5-1 summarizes the annual maximum and average concentration of tritium in the retention pond. Since no data is known for the years prior to 1971, the highest concentration for the subsequent years was assigned to 1957-1970. Note that the data in Table 4.1.5-1 are reflective of results as measured at the discharge point to the drainage ditch. The actual quantity of tritium sent to the retention pond from Pinellas Plant manufacturing processes is not known.

Table 4.1.5-1 Tritium Concentrations in the North-east Retention Pond

Year*	Maximum Concentration in the Water (µCi/ml)	Average Concentration in the Water (µCi/ml)	Minimum Detection Level (µCi/ml)	Discharge Volume (liters of water)	Total Curies sent to Retention Basin
1957	5.5E-4	4.6E-5	1.0E-5	NR	NR
1958	5.5E-4	4.6E-5	1.0E-5	NR	NR
1959	5.5E-4	4.6E-5	1.0E-5	NR	NR
1960	5.5E-4	4.6E-5	1.0E-5	NR	NR
1961	5.5E-4	4.6E-5	1.0E-5	NR	NR
1962	5.5E-4	4.6E-5	1.0E-5	NR	NR
1963	5.5E-4	4.6E-5	1.0E-5	NR	NR
1964	5.5E-4	4.6E-5	1.0E-5	NR	NR
1965	5.5E-4	4.6E-5	1.0E-5	NR	NR
1966	5.5E-4	4.6E-5	1.0E-5	NR	NR
1967	5.5E-4	4.6E-5	1.0E-5	NR	NR
1968	5.5E-4	4.6E-5	1.0E-5	NR	NR
1969	5.5E-4	4.6E-5	1.0E-5	NR	NR
1970	5.5E-4	4.6E-5	1.0E-5	NR	NR
1971	5.5E-4	4.6E-5	1.0E-5	NR	NR
1972	1.5E-4	4.7E-5	1.0E-6	1.32E8	5.6
1973	3.0E-5	8.6E-6	1.0E-6	NR	NR
1974	2.6E-5	9.2E-6	1.0E-6	NR	NR
1975	9.8E-6	6.4E-6	1.3E-7	1.23E8	0.79
1976	6.7E-6	4.1E-6	1.6E-7	3.9E7	0.16
1977	6.7E-6	5.0E-6	1.4E-7	1.90E8	0.95
1978	5.2E-6	4.1E-6	1.4E-7	1.27E8	0.54
1979	1.1E-5	3.6E-6	1.4E-7	8.72E7	0.31
1980	8.7E-6	6.0E-6	1.4E-7	9.05E7	0.54
1981	1.4E-5	1.3E-5	1.6E-7	4.69E7	0.60
1982	1.2E-5	6.7E-6	1.7E-7	1.09E7	0.73
1983	5.0E-6	1.4E-6	3.0E-7	2.74E8	0.37
1984	4.8E-6	8.7E-7	1.7E-7	1.73E8	0.15
1985	3.2E-6	8.9E-7	8.5E-8	NR	NR
1986	2.1E-6	9.0E-7	5.5E-7	NR	NR
1987	1.05E-6	5.6E-7	7.8E-7	NR	NR
1988	1.3E-6	4.4E-7	6.3E-7	NR	NR
1989	2.8E-6	4.9E-7	5.1E-7	NR	NR
1990	5.1E-7	NR	NR	NR	NR
1991	4.8E-7	NR	NR	NR	NR

Year*	Maximum Concentration in the Water (µCi/ml)	Average Concentration in the Water (µCi/ml)	Minimum Detection Level (µCi/ml)	Discharge Volume (liters of water)	Total Curies sent to Retention Basin
1992	2.9E-7	BDL	4.5E-7	NR	NR
1993	NR	BDL	4.8E-7	NR	NR
1994	NR	BDL	4.3E-7	NR	NR

AEC, 1972; 1973; 1974; ERDA, 1975; 1976; 1977; DOE, 1978; 1979; 1980; 1981; 1982; 1983b; 1984; 1985; 1986; 1987; 1988; 1989; 1990; 1991; 1992; 1993; 1994; 1995b
NR = Not reported
BDL = Below Detection Limit
* No environmental reports were available from 1957 through 1970. The maximum values reported (1971) are therefore assumed to be applicable to these prior years.

The amount of tritium measured in the north-east retention basin for all years was less than one percent of the concentration guide for tritium in water as set forth in ERDA Manual Chapter 0524.

Beginning in 1986, results from tritium analyses in water from the west and south ponds were reported. The reported values were of the same order of magnitude as the results from the north-east retention pond.

4.2 INTAKES FROM ONSITE ATMOSPHERIC RADIATION CONCENTRATIONS

Literature surveys revealed very little occupational environmental dose information. No information could be found for the first 15 years of plant operation (1957 to 1971) other than the number of curies released to the environment. For the remaining years (1972 to 1994), the dose to a maximally exposed individual (member of the public) was estimated using a computational model by the Pinellas Plant. Depending on the year calculated, the member of the public could be at the plant boundary or at a greater distance outside the plant boundary. Because of the distance from the general plant work environment and the fact that calculations included dose from ingestion, the dose to the maximally exposed member of the public could not be taken to be representative of the environmental dose to a worker within the plant boundary.

In this section, the maximum annual intakes due to emissions from stacks and the north-east retention pond are estimated.

While greater than 95% of the activity released during the history of the Pinellas Plant were from tritium and therefore potentially contributed to intake, the small amount of ^{14}C emitted could also have contributed to a worker's intake.

4.2.1 Maximum Onsite Intake Determination

The intake at any location is directly proportional to the dry-air deposition concentration at that location. Therefore, using the computer model, the meteorological data, and the assumptions made (as described in Appendix A), the intake at the location of maximum dry-air deposition concentration within the plant site boundary was determined as the maximum intake within the plant site boundary for the corresponding exhaust stack and for a unit release of each effluent from that stack. The releases, by radionuclide, for each stack are shown in Table A-4a and Table A-4b.

Using the data in Table A-4a and Table A-4b, Table 4.2.4-1 summarizes the calculated intake by the MEE in Becquerel per year.

Table 4.2.4-1 Number of Becquerels of Each Radionuclide Inhaled Each Year by a MEE from Stack Emissions

Year	Total Annual Inhalation for each radionuclide by a MEE from Stack Emissions (Bq)[a]		
	H-3 gas	H-3 oxide	C-14
1957	1.51E+04	3.15E+02	NR
1958	7.21E+04	1.31E+03	NR
1959	9.28E+04	2.99E+03	NR
1960	1.42E+04	9.79E+02	NR
1961	1.14E+03	6.89E+02	NR
1962	1.38E+03	5.60E+02	NR
1963	4.05E+02	2.32E+02	NR
1964	5.27E+02	1.28E+02	NR
1965	1.13E+02	2.25E+02	NR
1966	7.35E+02	8.66E+02	NR
1967	4.51E+03	4.79E+02	NR
1968	3.58E+03	4.84E+02	NR
1969	7.40E+03	6.68E+02	NR
1970	1.33E+03	1.05E+03	NR
1971	1.57E+03	8.42E+02	NR
1972	2.51E+02	5.00E+02	NR
1973	1.67E+02	7.16E+02	NR
1974	3.50E+02	4.55E+02	NR
1975	3.48E+02	3.71E+02	NR
1976	2.28E+02	3.96E+02	NR
1977	2.92E+02	3.62E+02	NR
1978	2.98E+02	3.51E+02	NR
1979	2.89E+02	4.64E+02	2.25E-04
1980	5.53E+02	7.38E+02	4.50E-04
1981[b]	2.19E+02	2.65E+02	5.05E-05
1981[b]	3.88E+02	4.17E+02	5.05E-05
1982	1.37E+03	1.55E+03	9.00E-05
1983	1.75E+03	7.87E+02	2.25E-05
1984	5.12E+02	1.24E+03	NR
1985	1.81E+03	9.30E+02	NR
1986	2.35E+02	9.68E+02	NR
1987	3.24E+02	8.05E+02	NR
1988	1.01E+03	4.54E+02	NR
1989	3.18E+02	3.83E+02	NR
1990	4.84E+02	4.25E+02	NR
1991	1.52E+02	3.51E+02	NR
1992	3.98E+01	1.79E+02	NR
1993[c]	0.00E+00	6.81E+01	NR
1994	9.89E+01	8.44E+01	NR

a. NR = no release recorded; calculation of maximum total annual intakes based on the estimated intakes associated with the release of 1 Ci of each radionuclide from the 21-m-high main stack and the 30-m-high laboratory stack.

b. 1981 was broken into two halves: January through June, and July through December because of the change in stack height.

c. For 1993, it was assumed that tritium released was all in oxide form.

4.2.2 Determination of the Maximum Onsite Intake due to Emissions from the North-east Retention Pond

An approach similar to that described in Section 4.2.1 for calculating the intake by a MEE from stack emissions was performed for a MEE located near the north-east retention pond. The following assumptions were made:

1. Zero plume rise was assumed for the releases from each exhaust stack to minimize the altitudinal distance the plume would rise, thereby maximizing how much of the plume remained onsite.

2. All of the tritium in the pond evaporated and was inhaled by the MEE who was located 100 meters west of the northeast retention pond. This location was chosen because it was modeled to be the location where ground-level concentrations would be highest based on meteorological data described in Section A-1 of Appendix A.

3. It was assumed that the worker was outdoors for 10 hours/workday, 5 days/week, and 52 weeks/yr for a total of 2,600 hours/yr.

4. The breathing rate of the MEE was assumed to be 11.5 cubic meters per day, 260 days per year.

5. The combination of two available 5-yr JFDs as meteorological data (for 1960 to 1964 and 1969 to 1973) was assumed to be applicable to the entire period from 1957 to 1994. This is a reasonable assumption as, on average, the meteorological data do not change considerably.

Based on the maximum activity detected in the north-east retention pond (5.6 Ci in 1972), the intake of tritium for a MEE near the pond would be 2,027.2 Bq per year.

4.3 EXTERNAL DOSE

External doses to workers from environmental sources could have occurred at the Pinellas Plant. In this section, the annual environmental external dose to a maximally exposed employee (MEE) within the plant boundary is estimated for the years 1957 to 1994. The external dose estimations were based on Pinellas Plant emissions to which a worker could have been exposed while outdoors.

The computer model used for the estimation of intakes (Appendix A) was also used for estimation of external dose.

4.3.1 External Dose from Stack Emissions

The external dose from the stack emissions would be much less than internal dose because the primary environmental release at Pinellas was tritium which does not contribute to external dose. The external dose was calculated in a similar manner as the internal intake. A dose per unit curie was determined that could be multiplied by the total curies released to obtain mrem per year. Table 4.3.1-1 shows the annual external dose associated with stack emissions to a MEE. Note that from 1957 through 1962, there were no external doses due to stack emissions because neither ^{14}C nor ^{85}Kr was emitted during these years.

Table 4.3.1-1 Total Annual External Dose to a MEE Due to Stack Emissions[a]

Year	Total Releases from Building 100 Stacks (Ci)		Total Annual External Dose (Sv)	Total Annual External Dose (mrem)
	Kr-85	C-14		
1957	NR	NR	NR	NR
1958	NR	NR	NR	NR
1959	NR	NR	NR	NR
1960	NR	NR	NR	NR
1961	NR	NR	NR	NR
1962	NR	NR	NR	NR
1963	4	NR	6.8E-24	6.8E-19
1964	47	NR	7.99E-23	7.99E-18
1965	153	NR	2.6E-22	2.6E-17
1966	49	NR	8.33E-23	8.33E-18
1967	70	NR	1.19E-22	1.19E-17
1968	202	NR	3.43E-22	3.43E-17
1969	55	NR	9.35E-23	9.35E-18
1970	44	NR	7.48E-23	7.48E-18
1971	12	NR	2.04E-23	2.04E-18
1972	15	NR	2.55E-23	2.55E-18
1973	1.36	NR	2.31E-24	2.31E-19
1974	4	NR	6.8E-24	6.8E-19
1975	1	NR	1.7E-24	1.7E-19
1976	20	NR	3.4E-23	3.4E-18
1977	28	NR	4.76E-23	4.76E-18
1978	5	NR	8.5E-24	8.50E-19
1979	5	1.00E-04	1.83E-18	1.83E-13
1980	2	2.00E-04	3.66E-18	3.66E-13
1981	4	9.00E-05	8.24E-19	8.24E-14
1982	8	4.00E-05	7.32E-19	7.32E-14
1983	11	1.00E-05	1.83E-19	1.83E-14
1984	1.97	NR	1.07E-23	1.07E-18
1985	5.31	NR	2.89E-23	2.89E-18
1986	4.6	NR	2.51E-23	2.51E-18
1987	38	NR	2.07E-22	2.07E-17
1988	30	NR	1.64E-22	1.64E-17
1989	12.9	NR	7.03E-23	7.03E-18
1990	10.1	NR	5.50E-23	5.50E-18
1991	4	NR	2.18E-23	2.18E-18
1992	10	NR	5.45E-23	5.45E-18
1993	19	NR	1.04E-22	1.04E-17
1994	13	NR	7.09E-23	7.09E-18

a. NR = no release recorded; calculation of maximum total annual doses based on the estimated doses associated with the release of 1 Ci of each radionuclide from the laboratory stacks.

The external dose associated with emissions from the north-east pond is zero, since the only emission was tritium.

4.3.2 Plutonium Releases to Air – Onsite Monitoring

In 1975, a facility became operational at the Pinellas Plant that used sealed plutonium capsules (thimble-size containers), as heat sources in the manufacture of radioisotopic thermoelectric generators (RTGs). The supplied sources were triply encapsulated in metal before shipment to the site. While no releases of ^{238}Pu and ^{239}Pu were anticipated, a preoperational, comprehensive onsite and offsite environmental survey was conducted (ERDA 1975). The results of the survey showed concentrations corresponding to global fallout levels.

The results from four continuous onsite perimeter air samplers were analyzed beginning with those from November 1975, the month in which the first plutonium heat sources were received by the site. Table 4.3.2-1 lists the concentrations of ^{238}Pu and ^{239}Pu in air at the site perimeter sample stations in four directions (ERDA, 1976).

Table 4.3.2-1 Perimeter Plutonium Air Samples[a]

Year	Sample Station, Isotope, Average Concentration in Air with 2 Standard Deviations (2s), and Minimum Detection LIevel (MDL)[b] [The values in the table are to be multiplied by 10^{-18} µCi/ml]									
	North		East		South		West		Average	
	Pu-238 Avg. (2s) [MDL]	Pu-239 Avg. (2s) [MDL]	Pu-238 Avg. (2s) [MDL]	Pu-239 Avg. (2s) [MDL]	Pu-238 Avg. (2s) [MDL]	Pu-239 Avg. (2s) [MDL	Pu-238 Avg. (2s) [MDL]	Pu-239 Avg. (2s) [MDL]	Pu-238 [MDL]	Pu-239
1975									<2.9 (3.3)[c] [0.9 – 4.1]	<2.6 (2.1)[c]
1976	<0.9 (1.0) [0.3 – 1.2]	4.7 (3.6)	<1.4 (2.0) [0.3 – 1.2]	3.2 (1.9)	0.8 (0.6) [0.3 – 1.2]	4.9 (3.1)	0.9 (0.5) [0.3 – 1.2]	3.4 (1.0)	<1.0	4.1
1977	<1.1(0.5) [0.7 – 1.8]	17.8 (8.2) [0.7 – 0.8]	<1.1 (0.7) [0.7 – 2.2]	15.1 (5.7) [0.7 – 0.9]	<2.1 (1.0) [0.5 – 2.7]	14.5 (7.4) [0.5 – 1.0]	<1.8 (0.5) [1.4 – 2.4]	22.7 (6.1)	<1.5	17.5
1978	<1.3 (0.6) [0.8 – 1.9]	25.5 (23.4) [0.6 – 2.0]	<2.4 (1.3) [1.4 – 4.2]	31.0 (34.0) [1.0 – 4.2]	<1.7 (1.0) [0.5 – 2.6]	18.5 (12.3) [0.5 – 1.8]	<1.3 (0.5) [0.7 – 2.0]	26.5 (20.1)	<1.7	25.4
1979	<1.2 [1.2]	<1.2	<0.5 [0.5]	1.9	<0.6 [0.6]	1.7	0.4 [0.2]	5.0	<0.7	<2.5
1980	0.2 [0.19 – 0.25]	0.2 [0.09 –0. 26]	<0.25 [0.19 – 0.25]	<0.14 [0.09 – 0.26]	<0.19 [0.19 – 0.25]	0.31 [0.09 – 0.26]	<0.22 [0.19 – 0.25]	<0.26 [0.09 – 0.26]	<0.22	<0.23
1981	<0.7 [0.2 – 0.7]	11.0	<0.4 [0.2 – 0.7]	10.7	<0.4 [0.2 – 0.7]	6.4	<0.2 [0.2 – 0.7]	9.2	<0.4	9.3
1982	<1.1 (0.9) [0.4 – 1.6]	<1.0 (0.5)	<0.6 (0.1) [0.4 – 1.6]	0.8 (0.3)	<0.6 (0.2) [0.4 – 1.6]	<0.6 (0.2)	<0.7 (0.2) [0.4 – 1.6]	0.8 (0.5)	<0.8	<0.8
1983	<1.3 (0.6) [0.5 – 1.9]	<1.3 (0.6)	<1.4 (0.3) [0.5 – 1.9]	<1.4 (0.3)	<1.2 (0.5) [0.5 – 1.9]	<1.2 (0.5)	<0.8 (0.3) [0.5 – 1.9]	<0.8 (0.3)	<1.2	<1.2
1984	<MDL [0.5 – 2.4]	<MDL	<MDL [0.5 – 2.4]	<MDL	<MDL [0.5 – 2.4]	<MDL	<MDL [0.5 – 2.4]	<MDL	<MDL	<MDL
1985	<MDL [0.59 – 2.7]	<MDL	<MDL [0.59 – 2.7]	<MDL	<MDL [0.59 – 2.7]	<MDL	<MDL [0.59 – 2.7]	<MDL	<MDL	<MDL
1986	<MDL [0.41 – 3.7]	<MDL	<MDL [0.41 – 3.7]	<MDL	<MDL [0.41 – 3.7]	<MDL	<MDL [0.41 – 3.7]	<MDL	<MDL	<MDL
1987	<MDL [0.17 – 5.5]	<MDL	<MDL [0.17 – 5.5]	<MDL	<MDL [0.17 – 5.5]	<MDL	<MDL [0.17 – 5.5]	<MDL	<MDL	<MDL
1988	<MDL [3.4 – 52]	<MDL	<MDL [3.4 – 52]	<MDL	<MDL [3.4 – 52]	<MDL	<MDL [3.4 – 52]	<MDL	<MDL	<MDL
1989	<MDL [1.1 – 65]	<MDL	<MDL [1.1 – 65]	<MDL	<MDL [1.1 – 65]	<MDL	<MDL [1.1 – 65]	<MDL	<MDL	<MDL
1990	<MDL [1.1 – 65]	<MDL	<MDL [1.1 – 65]	<MDL	<MDL [1.1 – 65]	<MDL	<MDL [1.1 – 65]	<MDL	<MDL	<MDL

a. Sources: (ERDA, 1976; 1977); (DOE, 1978; 1979; 1980; 1981; 1982; 1983b; 1984; 1985; 1986; 1987; 1988; 1989; 1990; 1991).
b. Results showing less than the minimum detection level were assigned this value when computing averages.
c. Combined results for the last two months of the year with 2 standard deviations in parentheses .

DOE (1991) states:

> *It should be noted that Plutonium-239 is present in the environment as a result of past atmospheric nuclear weapons testing. Plutonium was utilized in Building 400 as a sealed source, and has never been detected in the building effluent monitoring system. The Building 400 RTG production process, which utilized triply encapsulated plutonium, has been discontinued, and all plutonium has been removed from the Pinellas Plant site.*

All plutonium heat sources were removed from the site by February 1991. All plutonium-related manufacturing operations ceased in 1991 (DOE, 1995a). Because no ^{238}Pu or ^{239}Pu has been shown to be released at the Pinellas Plant, no external environmental exposures due to these radionuclides have occurred.

4.3.3 Ambient Natural Environmental Dose

No site-specific background radiation studies were found in the documentation for the Pinellas Plant. The population of the United States is expected to receive 77 mrem/yr. National Council on Radiation Protection and Measurements Report 93 states that this total external radiation accounts for 36 mrem/yr from rocks and soil, 40 mrem/yr from cosmic radiation, and 1 mrem/yr from weapons testing (NCRP, 1987).

4.4 UNCERTAINTY

There are many sources of uncertainty involved in calculation of doses from building effluents. The sources of uncertainty range from the amount of effluent released, to the amount of dispersion, to the location and behavior of the receptor. Each individual uncertainty is reflected in some degree in the uncertainty in the resultant dose calculation.

Uncertainty in Amount of Effluent Release: The amount of effluent released directly affects the amount of dose for a given receptor. Assuming all other parameters remain constant, the resultant dose is proportional to the amount of effluent.

Uncertainty in Amount of Dispersion: The amount of dispersion is dependent on many factors including the release height above ground, the height of the surrounding buildings, the distance from the release location to the receptor, and the local meteorological parameters such as wind speed, frequency of wind direction, and frequency of atmospheric stability. The release height affects the ground-level concentrations: The higher the release height, the lower the ground-level concentration at a given location. The distance between the release location and the receptor affects the amount of dispersion. For an elevated release, the ground-level concentration rises for distances close to the release point (distances prior to the effluent plume touches the ground) and then decreases. To minimize the uncertainties, 10 yr of meteorological data was used in the dose calculations. Because the effluent release heights varied during plant operation, three different stack heights were used: 30 m, 21 m, and 6.4 m.

Uncertainty in Location and Behavior of the Receptor: The location of the receptor was determined by selecting the distance and direction that would result in the maximum onsite concentration. In addition, it was assumed that the receptor was in an unshielded condition (outdoors) for 10 hours/day, 5 days/week, and 52 weeks/yr. It was also assumed that the receptor was breathing 50% of the daily rate during working hours. Furthermore, it was assumed that the same worker received the maximum dose from all three stack sources, which would mean the worker was in three different locations at one time.

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GLOSSARY

background radiation

Background radiation is the radiation received that is not associated with a worker's occupation. This includes cosmic, terrestrial, and manmade sources.

becquerel

The derived International System unit of radioactivity equal to 1 disintegration/second.

beta radiation

Radiation consisting of charged particles of very small mass (i.e., the electron) emitted spontaneously from the nuclei of certain radioactive elements. Most (if not all) of the direct fission products emit beta radiation. The beta particle is physically identical to an electron moving at high velocity.

dosimetry

The science of assessing absorbed dose, dose equivalent, effective dose equivalent, etc., from external and/or internal sources of radiation.

exposure

As used in the technical sense, exposure refers to a measure expressed in roentgens (R) of the ionization produced by photon radiation (i.e., gamma and X-rays) in air.

gamma rays

Electromagnetic radiation (photons) originating in atomic nuclei and accompanying many nuclear reactions (e.g., fission, radioactive decay, and neutron capture). Gamma rays are physically identical to X-rays of high energy, the only essential difference being that X-rays do not originate in the nucleus.

neutron

A basic particle that is electrically neutral and has nearly the same mass as the hydrogen atom.

radiation

Alpha, beta, neutron, and photon radiation.

radioactivity

The spontaneous emission of radiation, generally alpha or beta particles, gamma rays, and neutrons from unstable nuclei.

radioisotopic thermoelectric generator

A radioisotope thermoelectric generator (RTG) is a very simple electrical generator that obtains its power from passive radioactive decay. Such a generator uses the fact that radioactive materials (such as ^{238,239}Pu) generate heat as they decay. The heat used is converted into electricity by an array of thermocouples.

rem

A unit of dose equivalent equal to the product of the number of rad absorbed and a quality factor. The sievert (Sv) is the International System unit correlating to rem and equals 100 rem.

thermoluminescent dosimeter (TLD)

A holder containing solid chips of material that when heated release the stored energy as light. The measurement of this light provides a measurement of absorbed dose.

APPENDIX A

This appendix provides information on the computer model invoked, the meteorological data used, and the assumptions made in estimating the intake by, and the external dose to, a maximally exposed employee (MEE) at the Pinellas Plant. It summarizes the data for determining the location of a MEE in relation to each stack.

Tables A-4a and A-4b summarize plant emissions in relation to the buildings and stacks. This information was used in the computer code GENII to determine intakes and external exposure for a unit curie.

4.4.1 A-1 Computer Model and Meteorological Data

The GENII Version II computer program was used to estimate the annual intake by, and the annual external dose to, the MEE at the Pinellas Plant (Napier et al., 2002). The meteorological data were obtained from two 5-year joint frequency distribution (JFD) files that are available as attachments to the GENII, Version II, program. The two 5-year JFD files were combined to form a 10-year dataset.

Discharges for the Building 800 and Building 200 stacks were combined into one hypothetical stack. The following general steps in the annual onsite dose estimation process were repeated for the three analyzed exhaust stacks:

1. For a release of 1 Ci of tritium gas from a particular stack, the air concentration was calculated as a function of direction and distance from the source. It should be noted that the concentration distribution would be the same for any other radioisotope involved. A matrix of concentration by direction and distance, constructed from these results, was examined to determine the location with maximum concentration within the Pinellas Plant site boundary.

2. Considering the proportionality of intake, or external dose, to air concentration for each pathway (air inhalation, air immersion, and ground surface), the intake and external dose at the location of maximum concentration (maximum intake or external dose) were determined for 1 Ci (a unit source) of each radioisotope released from the stack for each pathway.

   Krypton-85 and ^{14}C do not deposit on the ground and, while tritium can deposit on the ground, the dose conversion factor for tritium is zero. In other words, because of its low-energy emission of beta radiation, tritium is not considered an external radiation source.

3. Because intake, or external dose, at a location is directly proportional to the total radionuclides released, the total intakes, or total external doses by radionuclide and by pathway were obtained by multiplying the results obtained in Step 2 by the corresponding annual releases from the source (emission stack).

4. For each year of operations, the total annual maximum intake, or external dose, corresponding to the radionuclides released from the stack was determined as the sum of all intakes, or all external doses obtained in Step 3.

5. The above steps were repeated for the other two exhaust stacks to estimate maximum intake, or external dose, from them.

6. The total intake by, or the total external dose to, the MEE was calculated by summing the values obtained in Steps 4 and 5 for the three stacks for each radionuclide.

4.4.2 A-2 Calculation Assumptions

The determination of the intake by, or external dose to, the MEE included the following claimant-favorable assumptions:

1. Zero plume rise was assumed for the releases from each exhaust stack to minimize the altitudinal distance the plume would rise, thereby maximizing how much of the plume remained onsite.

2. The midpoint between the Building 100 main stack (Stack A in Figure 4.1.4-1) and the Building 100 laboratory stack (Stack B in Figure 4.1.4-1) was assumed to be the location of a single hypothetical stack for 1957 through June of 1981. This is a reasonable assumption because both stacks had the same height (30.4 m) during this period and the annual releases of tritium gas and the annual releases of tritium oxide from both stacks were known for 1957 to 1981.

3. For the years after June 1981 when the Building 100 Main Stack was shortened from 30.48 m to 21.34 m, it was assumed for computer modeling that both stacks in Building 100 were located at the midpoint between them with emissions at the respective heights.

4. The combination of two available 5-yr JFDs as meteorological data (for 1960 to 1964 and 1969 to 1973) was assumed to be applicable to the entire period from 1957 to 1994. This is a reasonable assumption as, on average, the meteorological data do not change considerably.

5. The intake by an MEE is the sum of the maximum intakes from releases from all stacks, despite the fact that, for each stack, the location of the MEE is different from that for another stack.

6. It was assumed that the worker was outdoors for 10 hours/workday, 5 days/week, and 52 weeks/yr for a total of 2,600 hours/yr.

7. The breathing rate of the MEE was assumed to be 11.5 cubic meters per day, 260 days per year.

8. The intake calculated was due to air inhalation of tritium gas, tritium oxide, and ^{14}C. The external dose calculated was due to exposure to ^{85}Kr and ^{14}C. Nothing was planted, grown, or produced on the Pinellas Plant soil to be consumed to create an ingestion dose.

9. In case of conflicting reports on some annual releases, the maximum values were chosen.

4.4.3 A-3 Air Deposition Concentration within the Plant Boundary

Using a unit source (1 Ci/yr of tritium gas), a distribution of dry-air deposition concentration within the boundary of the plant and in 16 directions was estimated using GENII results, as indicated in Table A-1 for a 30-m-high stack, Table A-2 for a 21-m-high stack, and Table A-3 for a 6.4-m-high stack in Building 800.

The shaded areas in Tables A-1 and A-2 reflect the locations outside the Pinellas Plant boundary in relation to a stack (source) assumed to have been at the midpoint between the two stacks in Building 100. The accuracy of the plant boundaries in these two tables depends on the step size (100 m) used to perform the computations and construct the tables.

The distance from the source and the direction of the point of maximum dry-air deposition concentration was determined from each of the tables mentioned above by visual examination. For the 30-m-high stack, the maximum dry-air deposition concentration was estimated to be

7.53×10^{-4} Bq/m^3 at 300 m east of the source. For the 21-m-high stack, the maximum dry air deposition concentration was estimated to be 2.42×10^{-3} Bq/m^3 at 300 m west of the source. For the 6.4-m-high stack, the maximum dry-air deposition concentration was estimated to be 4.60×10^{-2} Bq/m^3 at 100 m west of the Building 800 stack. The **bold** type in Tables A-1, A-2, and A-3 indicates the maximum air concentration values.

Table A-1 Concentration of Tritium in Air (Bq/m3) as a Function of Distance and Direction to Source (30-m-high-stack case)[a]

Direction	Deg.	Distance from the Source (the midpoint between the two stacks in Building 100), m										Plant boundary to source, m
		1.00E+02	2.00E+02	3.00E+02	4.00E+02	5.00E+02	6.00E+02	7.00E+02	8.00E+02	9.00E+02	1.00E+03	
NNE	22.5	3.00E-05	2.22E-04	3.52E-04	3.98E-04	3.93E-04	3.66E-04	3.32E-04	3.00E-04	2.70E-04	2.44E-04	4.42E+02
NE	45	3.7E-05	2.58E-04	3.63E-04	3.81E-04	3.64E-04	3.34E-04	3.03E-04	2.74E-04	2.48E-04	2.26E-04	3.75E+02
ENE	67.5	4.71E-05	3.40E-04	4.80E-04	4.97E-04	4.66E-04	4.21E-04	3.75E-04	3.35E-04	3.00E-04	2.69E-04	2.92E+02
E	90	6.4E-05	4.98E-04	**7.53E-04**	8.20E-04	7.92E-04	7.28E-04	6.57E-04	5.89E-04	5.29E-04	4.77E-04	2.67E+02
ESE	112.5	1.66E-05	1.38E-04	2.68E-04	3.57E-04	3.89E-04	3.88E-04	3.72E-04	3.50E-04	3.27E-04	3.04E-04	3.00E+02
SE	135	1.9E-05	1.28E-04	2.55E-04	3.52E-04	3.96E-04	4.04E-04	3.95E-04	3.79E-04	3.59E-04	3.39E-04	1.97E+02
SSE	157.5	1.81E-05	1.30E-04	2.50E-04	3.36E-04	3.71E-04	3.74E-04	3.62E-04	3.45E-04	3.26E-04	3.06E-04	1.50E+02
S	180	3.53E-05	2.29E-04	4.10E-04	5.37E-04	5.91E-04	5.96E-04	5.79E-04	5.52E-04	5.21E-04	4.91E-04	1.42E+02
SSW	202.5	3.42E-05	2.15E-04	3.88E-04	5.09E-04	5.56E-04	5.58E-04	5.38E-04	5.09E-04	4.78E-04	4.47E-04	1.50E+02
SW	225	3.14E-05	2.32E-04	4.42E-04	5.88E-04	6.47E-04	6.51E-04	6.31E-04	6.01E-04	5.68E-04	5.35E-04	1.75E+02
WSW	247.5	2.66E-05	2.70E-04	5.44E-04	7.31E-04	8.10E-04	8.22E-04	8.02E-04	7.70E-04	7.32E-04	6.94E-04	1.92E+02
W	270	4.50E-05	3.97E-04	7.50E-04	9.73E-04	1.06E-03	1.07E-03	1.04E-03	9.92E-04	9.43E-04	8.94E-04	2.50E+02
WNW	292.5	4.12E-05	2.95E-04	4.93E-04	6.07E-04	6.46E-04	6.41E-04	6.17E-04	5.86E-04	5.53E-04	5.21E-04	5.25E+02
NW	315	3.68E-05	2.76E-04	4.57E-04	5.47E-04	5.68E-04	5.52E-04	5.21E-04	4.85E-04	4.51E-04	4.18E-04	4.83E+02
NNW	337.5	3.39E-05	2.74E-04	4.47E-04	5.29E-04	5.44E-04	5.25E-04	4.93E-04	4.58E-04	4.24E-04	3.92E-04	4.42E+02
N	360	4.32E-05	2.89E-04	4.83E-04	5.85E-04	6.05E-04	5.82E-04	5.42E-04	4.98E-04	4.56E-04	4.18E-04	4.08E+02

a. The shaded areas reflect the locations outside the Pinellas Plant boundary in relation to a stack (source) assumed to have been at the midpoint between the two stacks in Building 100.

Table A-2 Concentration of Tritium in Air (Bq/m3) as a Function of Distance and Direction to Source (21-m-high-stack case)[a]

Direction		Distance from source (the midpoint between the two main stacks), m										Plant boundary to source, m
	Deg.	1.00E+02	2.00E+02	3.00E+02	4.00E+02	5.00E+02	6.00E+02	7.00E+02	8.00E+02	9.00E+02	1.00E+03	
NNE	22.5	2.55E-04	7.68E-04	9.07E-04	8.31E-04	7.14E-04	6.08E-04	5.21E-04	4.51E-04	3.95E-04	3.49E-04	4.42E+02
NE	45	3.11E-04	7.85E-04	8.47E-04	7.62E-04	6.57E-04	5.64E-04	4.88E-04	4.26E-04	3.75E-04	3.33E-04	3.75E+02
ENE	67.5	4.03E-04	1.03E-03	1.09E-03	9.49E-04	8.00E-04	6.75E-04	5.75E-04	4.96E-04	4.33E-04	3.82E-04	2.92E+02
E	90	5.72E-04	1.63E-03	1.84E-03	1.65E-03	1.41E-03	1.19E-03	1.02E-03	8.77E-04	7.65E-04	6.74E-04	2.67E+02
ESE	112.5	1.50E-04	6.04E-04	8.88E-04	9.09E-04	8.41E-04	7.56E-04	6.76E-04	6.04E-04	5.42E-04	4.88E-04	3.00E+02
SE	135	1.48E-04	5.79E-04	9.02E-04	9.58E-04	9.14E-04	8.43E-04	7.70E-04	7.02E-04	6.41E-04	5.88E-04	1.97E+02
SSE	157.5	1.46E-04	5.66E-04	8.45E-04	8.82E-04	8.32E-04	7.62E-04	6.92E-04	6.28E-04	5.72E-04	5.23E-04	1.50E+02
S	180	2.74E-04	9.24E-04	1.35E-03	1.41E-03	1.33E-03	1.22E-03	1.11E-03	1.01E-03	9.13E-04	8.33E-04	1.42E+02
SSW	202.5	2.57E-04	8.75E-04	1.27E-03	1.31E-03	1.23E-03	1.11E-03	1.00E-03	9.02E-04	8.15E-04	7.39E-04	1.50E+02
SW	225	2.60E-04	9.97E-04	1.48E-03	1.54E-03	1.45E-03	1.33E-03	1.21E-03	1.10E-03	1.00E-03	9.18E-04	1.75E+02
WSW	247.5	2.72E-04	1.23E-03	1.84E-03	1.95E-03	1.86E-03	1.73E-03	1.58E-03	1.45E-03	1.33E-03	1.22E-03	1.92E+02
W	270	4.16E-04	1.68E-03	**2.42E-03**	2.52E-03	2.40E-03	2.22E-03	2.04E-03	1.88E-03	1.73E-03	1.59E-03	2.50E+02
WNW	292.5	3.47E-04	1.09E-03	1.48E-03	1.51E-03	1.41E-03	1.29E-03	1.18E-03	1.07E-03	9.80E-04	9.00E-04	5.25E+02
NW	315	3.16E-04	1.01E-03	1.31E-03	1.28E-03	1.17E-03	1.04E-03	9.27E-04	8.29E-04	7.47E-04	6.78E-04	4.83E+02
NNW	337.5	3.12E-04	9.85E-04	1.25E-03	1.22E-03	1.10E-03	9.77E-04	8.67E-04	7.73E-04	6.92E-04	6.24E-04	4.42E+02
N	360	3.43E-04	1.07E-03	1.39E-03	1.34E-03	1.19E-03	1.04E-03	9.06E-04	7.95E-04	7.03E-04	6.27E-04	4.08E+02

a. The shaded areas reflect the locations outside the Pinellas Plant boundary in relation to a stack (source) assumed to have been at the midpoint between the two stacks in Building 100.

Table A-3 Concentration of Tritium in Air (Bq/m^3) as a Function of Distance and Direction to Source (6.4-m-high-stack case)

Direction	Deg.	Distance from source (the stack in Building 800), m									
		1.000E+02	**2.000E+02**	**3.000E+02**	**4.000E+02**	**5.000E+02**	**6.000E+02**	**7.000E+02**	**8.000E+02**	**9.000E+02**	**1.000E+03**
NNE	22.5	1.328E-02	7.106E-03	4.263E-03	2.862E-03	2.062E-03	1.559E-03	1.223E-03	9.862E-04	8.134E-04	6.832E-04
NE	45	1.231E-02	6.819E-03	4.100E-03	2.735E-03	1.957E-03	1.473E-03	1.150E-03	9.248E-04	7.609E-04	6.379E-04
ENE	67.5	1.490E-02	7.778E-03	4.587E-03	3.034E-03	2.162E-03	1.623E-03	1.265E-03	1.016E-03	8.350E-04	6.994E-04
E	90	2.611E-02	1.367E-02	8.043E-03	5.321E-03	3.795E-03	2.850E-03	2.224E-03	1.787E-03	1.469E-03	1.232E-03
ESE	112.5	1.589E-02	1.003E-02	6.269E-03	4.260E-03	3.081E-03	2.334E-03	1.831E-03	1.477E-03	1.218E-03	1.023E-03
SE	135	1.747E-02	1.229E-02	8.208E-03	5.807E-03	4.309E-03	3.319E-03	2.634E-03	2.143E-03	1.778E-03	1.500E-03
SSE	157.5	1.586E-02	1.091E-02	7.224E-03	5.088E-03	3.764E-03	2.895E-03	2.295E-03	1.865E-03	1.547E-03	1.304E-03
S	180	2.542E-02	1.734E-02	1.138E-02	7.972E-03	5.879E-03	4.511E-03	3.571E-03	2.899E-03	2.403E-03	2.026E-03
SSW	202.5	2.329E-02	1.530E-02	9.852E-03	6.827E-03	5.002E-03	3.822E-03	3.018E-03	2.445E-03	2.023E-03	1.704E-03
SW	225	2.767E-02	1.916E-02	1.270E-02	8.939E-03	6.609E-03	5.079E-03	4.025E-03	3.270E-03	2.711E-03	2.286E-03
WSW	247.5	3.563E-02	2.556E-02	1.711E-02	1.208E-02	8.944E-03	6.877E-03	5.452E-03	4.429E-03	3.673E-03	3.097E-03
W	270	**4.599E-02**	3.346E-02	2.280E-02	1.629E-02	1.215E-02	9.387E-03	7.466E-03	6.081E-03	5.051E-03	4.265E-03
WNW	292.5	2.702E-02	1.889E-02	1.279E-02	9.146E-03	6.833E-03	5.287E-03	4.210E-03	3.433E-03	2.854E-03	2.411E-03
NW	315	2.204E-02	1.411E-02	9.259E-03	6.535E-03	4.851E-03	3.740E-03	2.972E-03	2.419E-03	2.008E-03	1.696E-03
NNW	337.5	2.076E-02	1.288E-02	8.144E-03	5.591E-03	4.073E-03	3.101E-03	2.442E-03	1.975E-03	1.632E-03	1.373E-03
N	360	2.231E-02	1.282E-02	7.861E-03	5.328E-03	3.858E-03	2.927E-03	2.300E-03	1.858E-03	1.534E-03	1.290E-03

Table A-4a Annual Releases, for 1957 to June 1981[a]

Year	Total releases from Bldg. 100 30-m stacks (Ci)			Total releases from Bldg. 800 6.4-m stack (Ci)		
	H-3 gas	H-3 oxide	Kr-85	C-14	H-3-gas	H-3 oxide
1957	6,660	140	NR	NR	NR	NR
1958	31,920	580	NR	NR	NR	NR
1959	41,070	1330	NR	NR	NR	NR
1960	6,265	435	NR	NR	NR	NR
1961	504	306	NR	NR	NR	NR
1962	611	249	NR	NR	NR	NR
1963	179	103	4	NR	NR	NR
1964	233	57	47	NR	NR	NR
1965	50	100	153	NR	NR	NR
1966	325	385	49	NR	NR	NR
1967	1,994	213	70	NR	NR	NR
1968	1,586	215	202	NR	NR	NR
1969	3,275	297	55	NR	NR	NR
1970	587	465	44	NR	NR	NR
1971	694	374	12	NR	NR	NR
1972	111	222	15	NR	NR	NR
1973	74	318	1.36	NR	NR	NR
1974	155	202	4	NR	NR	NR
1975	154	165	1	NR	NR	NR
1976	101	176	20	NR	NR	NR
1977	129	161	28	NR	NR	NR
1978	132	156	5	NR	NR	NR
1979	128	206	5	1.0E-04	NR	NR
1980	138.26	207.03	2	2.0E-04	1.74E+00	1.97E+00
1981[b]	108.03	93.57	3.28	4.5E-05	1.41E+00	2.32E+00

a. NR = no release recorded.
b. January through June 1981

Table A-4b Annual Releases for July 1981 to 1994[a]

Year	Releases from the 21-m-high main stack			Releases from the 30-m-high lab stack			Releases from the 6.4-m-high stack (Bldg. 800)	
	H-3 gas (Ci)	H-3 oxide (Ci)	Kr-85 (Ci)	H-3 gas (Ci)	H-3 oxide (Ci)	C-14 (Ci)	H-3 gas (Ci)	H-3 oxide (Ci)
1981[b]	66	59.39	0.36	44.855	37.68	4.5E-05	1.41	2.32
1982	150.7	131.19	8	75.07	123.71	4.0E-05	0.75	2.33
1983	219.8	71.61	11	39.19	80.1	1.0E-05	0.48	0.64
1984	53.25	116.67	1.97	42.55	87.8	NR	0.21	1.42
1985	68	92	5.31	34	56	NR	9	1
1986	21	113	4.6	12	48	NR	0.4	0.3
1987	32.2	97	38	35.5	41.3	NR	0.07	0.07
1988	85.7	31.8	30	45.8	92.2	NR	2.03	0.12
1989	34.4	46.9	12.9	9	13	NR	0.347	0.1
1990	53	56.9	10.1	8	3.6	NR	0.586	0.038
1991	12.7	28.9	4	10	59	NR	0.26621	0.0626
1992	4.3	20.7	10	3.8	10.9	NR	NR	0.033849
1993[c]	NR	6.08	19	NR	5.47	NR	NR	0.0851
1994	13.6	9.32	13	NR	2.08	NR	NR	0.0887

a. NR = no release recorded.
b. July 1981 through December 1981.
c. For 1993, it was assumed that tritium released was all in oxide form.