DOE/ID/12228

cy 1

Incineration of Hazardous and Low-Level Radioactive Waste by a Small Generator

Final Report
October 1984

Prepared for:
U.S. Department of Energy
Assistant Secretary for Conservation and Renewable Energy
Office of Energy from Municipal Waste
Under DOE Contract AC01-77CS20099

Printed in the United States of America

Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
NTIS Price Codes: Printed Copy A09
Microfiche A01

DOE/ID/12228

INCINERATION OF HAZARDOUS AND LOW-LEVEL RADIOACTIVE WASTE BY A SMALL GENERATOR

Final Report
Published October 1984

Prepared by
Carla C. (Greenup) Dwight
Arizona State University
Tempe, Arizona 85287

Published by
EG&G Idaho, Inc.
Idaho Falls, Idaho 83415

Prepared for:
U.S. Department of Energy
Assistant Secretary for Conservation and
Renewable Energy
Office of Energy from Municipal Waste
Washington DC 20585

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

INCINERATION OF HAZARDOUS AND LOW-LEVEL RADIOACTIVE WASTE BY A SMALL GENERATOR

INTRODUCTION

Increasing transportation costs and decreasing land availability for burial sites prompted Arizona State University (ASU) to consider the potential for incineration as a means to dispose of hazardous and low-level radioactive waste. The university was issued a federal grant from the Department of Energy (administered through EG&G Idaho, Inc.) in 1981 to research the feasibility of a small generator incinerating low-level radioactive waste in a pathological incinerator. The research included various aspects of environmental impact, public relations, cost versus benefit and licensing procedures. Three years of work resulted in a license amendment authorizing ASU to incinerate certain hazardous and low-level radioactive waste.

The project consisted of four main tasks. They were:

1) Determine the requirements to obtain an amendment to ASU's broad radioactive material users license from the Arizona Radiation Regulatory Agency (ARRA) which would permit incineration,
2) Determine the need to interface with other national, state or local agencies,
3) Utilize ASU's existing pathological incinerator for disposal of hazardous and low-level radioactive waste and devise an appropriate monitoring system, and
4) Compare the licensing procedures of the other twenty-five Agreement States to those of Arizona.

TASK #1

The ARRA follows the same guidelines for incineration as the Nuclear Regulatory Commission (NRC). The requirements are listed on the following page and the supporting documentation from ASU which was submitted to the ARRA in the license amendment request follows.

NRC Incineration Guidelines
For Medical/Academic Licensees

1. Submit the characteristics of the incinerator such as height of the stack, height of and distance to buildings in the surrounding areas, rated airflow of the incinerator in cubic feet per hour or similar units and its proximity to any air intake ducts.

2. State specifically the isotopes and the maximum amount of each isotope that you wish to incinerate per burn. For the combination of isotopes listed, submit calculations to demonstrate that the following conditions have been met:

   A. The gaseous effluent from the incinerator stack should not exceed the limits specified for air in Appendix B, Table II, 10 CFR Part 20 when averaged over a 24 hour period.

   B. In order to be in compliance with the ALARA philosophy stated in section 20.1(c), 10 CFR Part 20, the gaseous effluent from the incinerator stack should be a fraction (approximately 10%) of the limits specified for air in Appendix B, Table II, 10 CFR Part 20, when averaged over a period of one year.

If more than one isotope is involved, your calculations must follow the "sum of ratios" method in the "Note" at the end of the Appendix B, 10 CFR Part 20.

3. State the maximum number of burns to be performed in any one week and the maximum number of burns per year.

4. A. Describe your method for measuring or estimating the concentration of radioactive material remaining in the ash residue. Unless you present scientific evidence to the contrary, you must use the most conservative assumption.

   B. Submit your procedures for collection, handling and disposal of the ash residue, including radiation safety precautions to be observed.

5. Describe procedures to be followed to minimize exposure to personnel during all phases of the operation, including instruction given to personnel handling the combustibles and the ash.

6. Submit evidence (e.g., copies of outgoing and incoming letters) to show that all state and local jurisdiction have been notified of your plans to incinerate radioactive waste and have no objections to them.

INCINERATOR CHARACTERISTICS

The incinerator is located on ASU property at Price Road and First Street in Tempe. It was installed adjacent to the Lab Animal Care Facility (LACF) in December 1980, when the LACF was also built. It was to be used for pathological waste generated by ASU labs.

The specifications are as follows:

CONSUMAT Model #C-75P

Dual Chamber - Controlled Air

175 lb/hr (75 cu ft/hr) Capacity

2 Chambers, 3 Burners (natural gas)

Lower: 2 burners 250,000 Btu/hr
operating temp. 1500°F

Upper: 1 burner 700,000 Btu/hr
operating temp. 1800°F

Forced Air Supply:

Lower: 500 cfm

Upper: 500 cfm

Total flow: = 1000 cfm = 4.7×10^5 ml/sec

Stack Ht.: 2.7m (9 ft)

Total Ht.: 6.4m (21 ft)

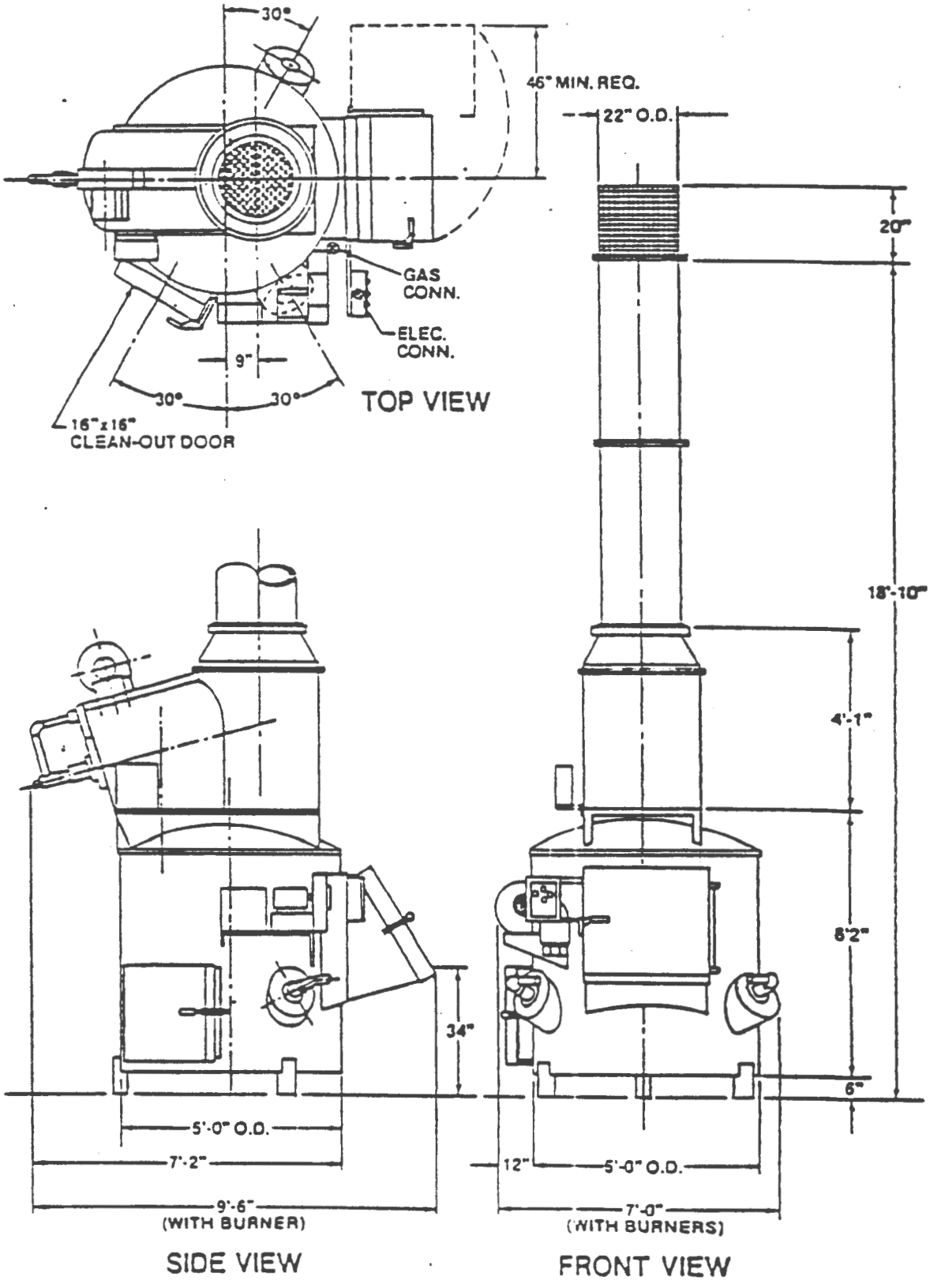
The original cost of the incinerator was approximately $25,000.00. An automatic loading devise and a liquid injection system may be added for an additional estimated installed cost of $22,000.00 and $4,500.00, respectively.

GENERAL DESCRIPTION[13]

"The CONSUMAT incinerator is a compact, factory assembled incinerator that employs IIA (Incinerator Institute of America) recommended velocity profiles in a novel arrangement, that meets or exceeds all Environmental Protection Agency (EPA) standards for particulate matter and noxious gas emissions, when maintained and operated in a responsible manner.

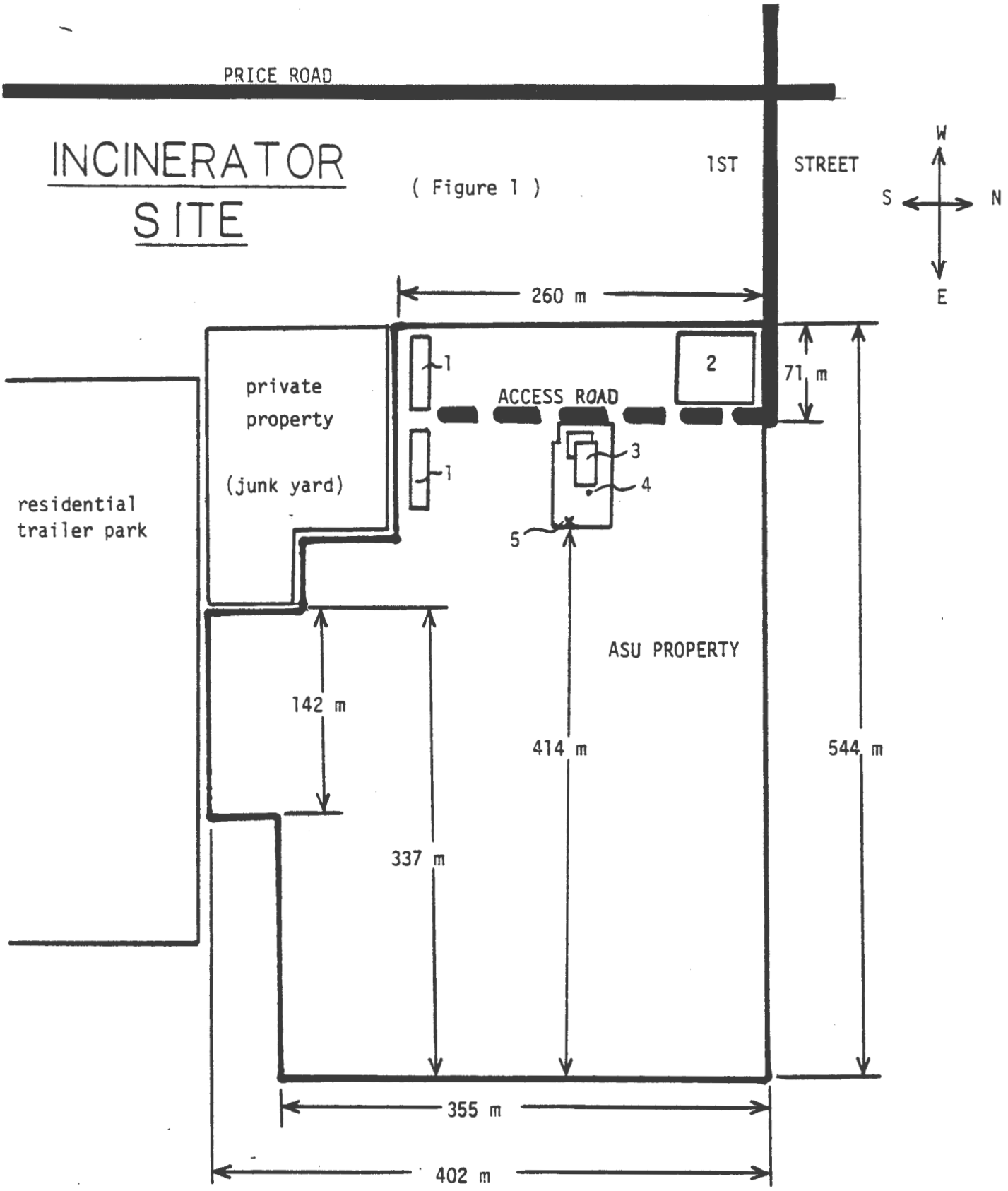
The grateless lower chamber, or distillation chamber, volatilizes, or partially oxidizes the waste. In the upper chamber, the gases that are generated in the lower chamber are fully combusted. As a result, the CONSUMAT incinerator can consume from Type 0 to Type 6 wastes, when properly set up for each, without emitting smoke, odor of fly ash. This is accomplished without the use of water scrubbers or electrostatic precipitators."

MODEL C-75P


30°
46" MIN. REQ.
22" O.D.
20"
GAS CONN.
ELEC. CONN.
9"
30°
30°
TOP VIEW
16"x16" CLEAN-OUT DOOR
18'-10"
4'-1"
8'2"
6"
34"
5'-0" O.D.
7'-2"
9'-6" (WITH BURNER)
SIDE VIEW
12"
5'-0" O.D.
7'-0" (WITH BURNERS)
FRONT VIEW

INCINERATOR SITE

(Figure 1)



1. ASU surplus warehouses
2. ASU site security residence
3. ASU Lab Animal Care Facility
4. Current incinerator location
5. Future incinerator location

Most of the radioactive waste generated by ASU labs falls into the category of Type 4 waste, defined as waste consisting of not more than 85% moisture and 5% incombustible solids. A breakdown of ASU's waste is shown below.

Waste	% of Total Volume
• animal remains and animal bedding radioactive 5% non-radioactive 95%	50
• liquid scintillation fluid in 20 ml vials-- primarily toluene glass 70% plastic 30%	20
• dry waste (paper, gloves, disposable lab equipment)	20
• absorbed liquid in one gallon plastic jars filled with wood chips-- primarily organic solvents	10

The license amendment currently authorizes incineration of the isotopes listed in Table #1. The isotopes are categorized according to abundancy, maximum permissible concentration and half life to simplify disposal. Isotopes in the same category are placed in the same waste receptacle in each lab. Category 5 wastes are stored in a warehouse for decay on the ASU campus before incineration (see Table #2).

From the warehouse, the waste is taken to the incinerator in the ASU Radiation Protection Office van. When the incinerator has been pre-heated for at least 45 minutes the waste is manually loaded by two people wearing protective clothing (long pants and sleeves, gloves and a hardhat with a plastic face shield). No more than 200 full liquid scintillation vials are loaded at once. Each load burns for at least 15 minutes before the next is loaded. Information such as weather conditions, operating temperatures, contents, volume, weight, activity and stack observations, plus survey results (discussed later in this paper) are recorded for each burn.

Table #1 WASTE CATEGORIES

Category	Isotope	% Total Waste *
1	H-3 C-14	83.8
2	Na-22 Cl-36 Sr-90 I-129	4.7
3	Ca-45 Mn-54 Eu-154 Eu-155	1.0
4	Ni-63 Zn-65 Pm-147 Sm-151	6.5
5	Na-24 K-42 P-33 Rb-86 S-35 I-125	3.7

TOTAL ACTIVITY: 174,487 μCi

% NON-BURNABLE: 0.3

* Sealed Sources Not Included

Table #2 DECAY IN STORAGE

Isotope	Half Life	Decay Period (10 Half Lives)
Na-22 K-42	15 h 12 h	6 days
P-32 P-33 Rb-86	14 d 24 d 19 d	8 mos.
*S-35 I-125	88 d 60 d	1.5 yrs.

*Because of the longer half life of S-35, it will be stored with I-125 waste for only 6 half lives in 1.5 yrs.

An estimate of 335 fifty-five gallon drums, based on previous shipping and inventory records, (see Table #3) was predicted for the amount of waste to be generated by 1985, five years since the last shipment. The incinerator is operated once a week to accomodate the radioactive waste. (The LACF may operate the incinerator an additional one or two times weekly, but strictly for non-radioactive waste.) Each burn lasts between eight to ten hours, which includes the five hour burn-down time after the last load is complete. Non-radioactive waste, mostly animals and bedding, is burned with the radioactive material. Before the license was amended to permit radioactive burning, only non-radioactive representative waste, primarily exempt quantities of C-14 and H-3 ($\leq$0.05 μCi/gm), was burned. The non-radioactive burns have been conducted since December, 1981.

TABLE # 3 PREVIOUS SHIPPING AND INVENTORY DATA

DATE SHIPPED	NO. DRUMS SHIPPED	NO. MONTHS WASTE COLLECTED	DRUMS/ MONTH	COST/DRUM FOR SHIPPING	TOTAL COST/SHIPMENT	INCREASE IN COST/DRUM SINCE PREVIOUS SHIMPMENT
6/25/74	3	-----	----	no records	no records	no records
1/15/75	7	7	1	no records	no records	no records
12/17/75	10	11	.9	25.00	250.00	----------
7/15/76	15	7	2.1	28.00	420.00	1.3 x
4/28/77	17	9	1.9	36.00	612.00	1.6 x
1/13/78	21	9	2.3	45.50	955.00	1.5 x
2/07/79	38	13	2.9	73.90	2802.10	1.9 x
6/23/80	57	16	3.6	106.67	6080.03	1.6 x
9/30/82	82 *	26	3.2	600.00	28200.00	5.6 x

* Amount in storage; 6/23/80 was date of last shipment

Calculations to demonstrate compliance with the NRC guidelines for effluent concentrations were performed for the isotopes listed in Table #1. The NRC requires that the stack top concentration not exceed the maximum permissible concentration (MPC) values for air given in Appendix B, Table II, 10 CFR Part 20 (hereafter referred to only as MPC) when averaged over a 24 hour period, and not exceed 10% of the MPC limits when averaged over one year.

The following formula was used to calculate the maximum activity which could be burned and stay within the suggested limits.

$$\text{Activity} = \text{MPC} \times \text{Dilution Factor}$$

$$Q(\mu Ci/sec) = \chi(\mu Ci/ml)\ E(ml/sec)$$

The results are shown in Table #4 on the following page.

As Table #4 indicates, the allowable amount is much larger than the actual inventory, except in the case of Sr-90. However, the ARRA recommended an additional approach for the licensing criterion which would take into account atmospheric dispersion. So calculations were made to determine the maximum amount of activity which could be burned without exceeding 10% of the MPC at the point where the maximum ground level concentration occurred based on the maximum average windspeed and on intermediate stability category. The dilution factor was not averaged-- instead, only the actual burning time was used. Methods from D.B. Turner's Workbook of Atmospheric Dispersion Estimates (Reference #2) were used in the calculations.

The maximum ground level concentration was calculated as a function of effective stack height and meteorological stability. Figure 3-9, page 12, gives the distance to the point of maximum concentration, χ_{max}, on the ordinate and the relative maximum concentration, $(\chi u/Q)_{max}$, on the abscissa as a function of effective stack height and stability class.

(The effective stack height calculation is given on page 13).

Table #4 NRC SUGGESTED MAXIMUM BURNABLE ACTIVITIES

Isotope	ASU Inventory (μCi)	X MPC * (μCi/ml)	(μCi/burn) normalized to 24 hrs. $E=4.06\times10^{10}$ml/burn	Q (μCi/yr.) using 10% MPC $E=1.48\times10^{13}$ml/yr.
H-3	118,240	2×10^{-7}	8120	2,960,000
C-14	27,743	1×10^{-7}	4060	1,480,000
Na-22	250	3×10^{-10}	12	4,440
Cl-36	90	8×10^{-10}	32	11,800
Sr-90	8000	3×10^{-11}	1	444
I-129	0	2×10^{-11}	0.8	296
Ca-45	1,692	1×10^{-9}	40	14,800
Mn-54	0	1×10^{-9}	40	14,800
Eu-154	0	1×10^{-10}	4	1,480
Eu-155	0	1×10^{-9}	40	14,800
Ni-63	1,976	2×10^{-9}	81	29,600
Zn-65	0	2×10^{-9}	81	29,600
Pm-147	25	2×10^{-9}	81	29,600
Sm-151	9,470	2×10^{-9}	81	29,600
Na-24	0	5×10^{-9}	203	74,000
K-42	0	4×10^{-9}	162	59,200
P-32	6,500/0.05 +	2×10^{-9}	81	29,600
P-33	0	1×10^{-10}	4	1,480
Rb-86	0	2×10^{-9}	81	29,600
S-35	0	9×10^{-9}	365	133,000
I-125	1.5/0.003+	8×10^{-11}	3	1,180

*Most conservative MPC value, (either soluble or insoluble).

+Amount left after decay procedure.

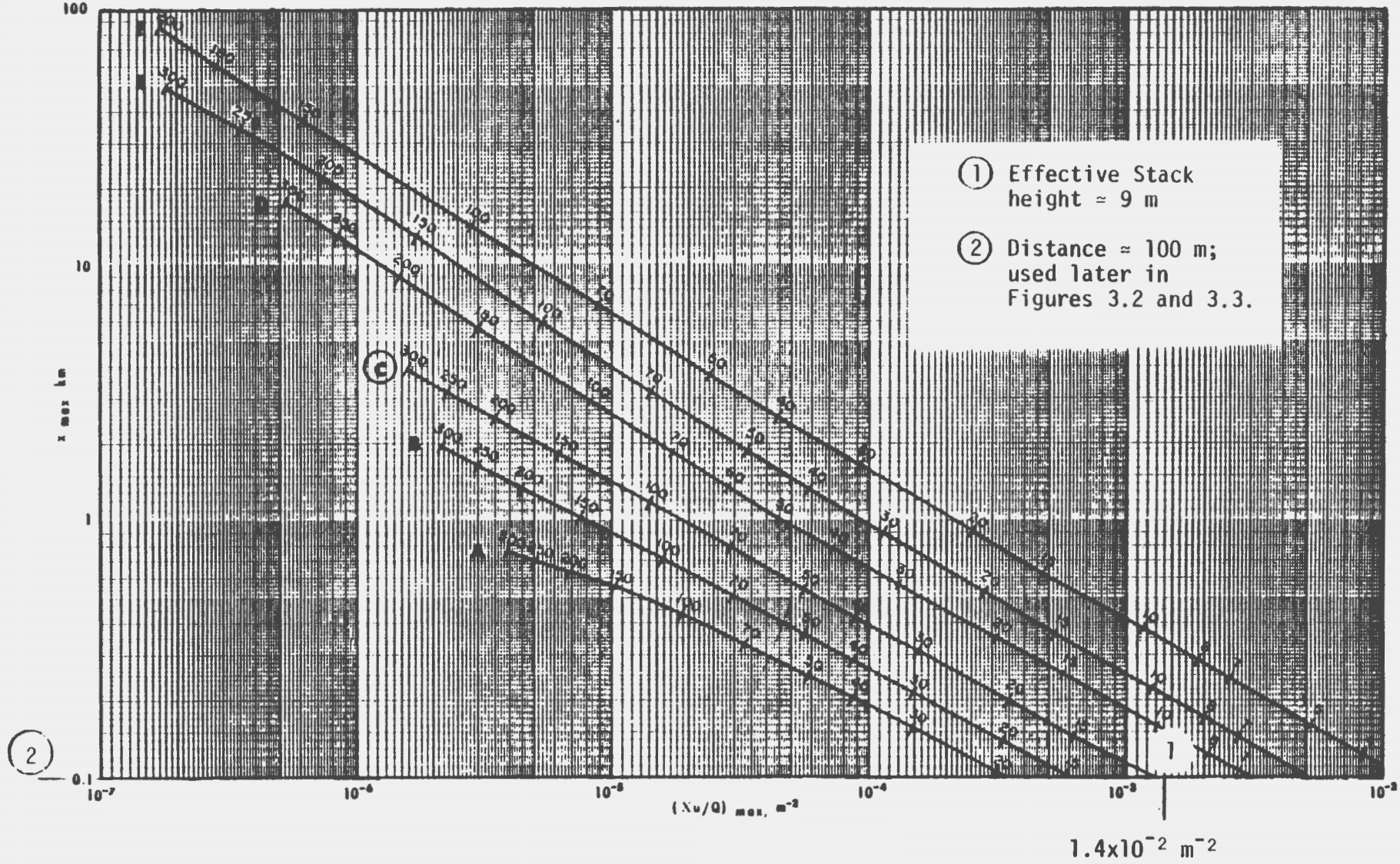


Figure 3-9. Distance of maximum concentration and maximum $\chi u/Q$ as a function of stability (curves) and effective height (meters) of emission (numbers).

CALCULATION OF EFFECTIVE STACK HEIGHT

$H_{release} = h_{stack} + \Delta H_{effluent}$

$\Delta H_{effluent} = V_s\, d/\bar{u}\, [1.5 + 2.68 \times 10^{-3}\, p((T_s - T_a)/T_s)\, d]$ *

*Workbook of Atmospheric Dispersion Estimates, by D. B. Turner, Environmental Science Services Adm., EPA, 1970, pg. 31.

where:
- V_s ~ stack gas exit velocity (m/s)
- d ~ inside stack diameter (m)
- $\bar{u}$ ~ mean windspeed (m/s)
- p ~ atmospheric pressure (mb)
- T_s ~ stack gas temp (°K)
- T_a ~ air temp (°K)
- 2.68×10^{-3} ~ constant ($mb^{-1}\ m^{-1}$)

FOR ASU INCINERATOR:

h_{stack} (total ht.) = 21(ft.)(.3048 m/ft) = 6.4 (m)

V_s = 7.68 (m/s)

d = 1.5(ft.)(.3048 m/ft) = .4572 (m)

$\bar{u}$ = 3.4 (m/s)

p = 760 mm Hg = 1013 (mb)

T_s = 1800°F = °K = (°F-32)5/9 + 273 = 1256°K

T_a = 90°F = 305°K

$\Delta H_{effluent} = (7.68)(.4572)/(3.4)[1.5 + 2.68 \times 10^{-3}(1013)((1256-305)/1256)(.4572)]$

$\Delta H_{effluent}$ = 2.5(m) = 8(ft)

$H_{release} = 6.4 + 2.5 = 8.9(m) = 27(ft)$

To comply with the criterion previously mentioned, the maximum ground level concentration was set to 10% MPC. The relative maximum ground level concentration was read from the abscissa of Figure 3-9 by using stability category C and an effective stack height of approximately 9 meters. The maximum activity which could be burned was calculated using the following relation.

$$\text{max. ground level conc.} = \text{max. relative conc.} \times \frac{\text{max. activity}}{\text{average windspeed}}$$

$$\chi_{max}(\mu Ci/ml) = (\chi u/Q)_{max}(m^{-2}) \frac{Q(\mu Ci/sec)}{u(m/sec)}$$

where: χ_{max} = 10% MPC

$(\chi u/Q)_{max} = 1.4 \times 10^{-2}\ m^{-2}$

(taken from Figure 3-9)

$u = 3.4$ m/sec

Rearranging the terms to solve for Q yields:

$$Q(\mu Ci/sec) = \frac{[(3.4\ m/sec)(10\%\ MPC\ \mu Ci/ml)]}{1.4 \times 10^{-2}(m^{-2})} (1 \times 10^{6}\ ml/m^{3})$$

$$Q(\mu Ci/sec) = (10\%\ MPC)(2.43 \times 10^{8})$$

The results for Q are given in Table #5 on the following page.

Notice that the "Q" values from Table #4, the NRC guideline averaging method, are more restrictive than those of Table #5, the method which accounts for atomspheric dispersion. All of the isotopes in the ASU inventory could easily be burned in one year without exceeding the Table #4 limits, except Sr-90. ASU will not burn more than the amount specified in Table #4 to be conservative. A maximum of 400 μCi of Sr-90 will be burned in one year.

Table #5 MAXIMUM BURNABLE ACTIVITIES
BASED ON DISPERSION ESTIMATES

Isotope	X_{max} (μCi/ml) 10% MPC	Q (μCi/burn) for 8.5 hr. burn	Q (μCi/yr.) for 50 burns/yr.
H-3	2×10^{-8}	149,000	7,430,000
C-14	1×10^{-8}	74,300	3,720,000
Na-22	3×10^{-11}	223	11,100
Cl-36	8×10^{-11}	595	29,700
Sr-90	3×10^{-12}	22	1,110
I-129	2×10^{-12}	15	7,430
Ca-45	1×10^{-10}	743	37,200
Mn-54	1×10^{-10}	743	37,200
Eu-154	1×10^{-11}	74	3,720
Eu-155	1×10^{-10}	743	3,720
Ni-63	2×10^{-10}	1,490	74,300
Zn-65	2×10^{-10}	1,490	74,300
Pm-147	2×10^{-10}	1,490	74,300
Sm-151	2×10^{-10}	1,490	74,300
Na-24	5×10^{-10}	3,720	186,000
K-42	4×10^{-10}	2,970	149,000
P-32	2×10^{-10}	1,490	74,300
P-33	1×10^{-11}	74	3,720
Rb-86	2×10^{-10}	1,490	74,300
S-35	9×10^{-10}	6,690	334,000
I-125	8×10^{-12}	59	2,970

The NRC guidelines require that a sum of ratios calculation be made when more than one isotope is burned simultaneously.

$$\frac{C_A}{MPC_A} + \frac{C_B}{MPC_B} + \frac{C_C}{MPC_C} + \ldots \leq 1$$

Table #6 below gives the sum of ratios for each isotope computed by assuming the entire ASU inventory is burned in one year.

Table #6 SUM OF RATIOS

Isotope	Inventory (μCi)	Concentration at 100 m (μCi/ml)	Ratio
H-3	118,240	3.2×10^{-11}	0.0016
C-14	27,743	7.5×10^{-12}	0.0008
Na-22	250	6.8×10^{-14}	0.0023
Cl-36	90	2.4×10^{-14}	0.0003
Sr-90	1,000	2.7×10^{-13}	0.0900
Ca-45	1,692	4.5×10^{-13}	0.0045
Ni-63	1,976	5.3×10^{-13}	0.0027
Pm-147	25	6.7×10^{-15}	0
Sm-151	9,470	2.5×10^{-12}	0.0127
P-32	0.05	1.3×10^{-17}	0
I-125	0.003	8.1×10^{-19}	0
		Sum:	0.1149

Another area of concern by the ARRA were dose estimates for the personnel and surrounding public. Various annual dose estimates were calculated by the method prescribed in the NRC Regulatory Guide 1.109, Appendix C -- Reference #10.

Dose = inhalation rate x concentration x inhalation dose factor

$D_{ia} = R_a \chi_i DFA_i$

where:

D_{ia} (mrem/yr) ~ annual dose to whole body of an individual in the age group "a" due to the inhalation of radionuclide "i"; (These calculated values are given in Tables 7.1 and 7.2.)

DFA_i (mrem/pCi) ~ inhalation dose factor; (These were taken from Tables C.1 and C.3 in Reference #10. The values are included in Tables 7.1 and 7.2.)

R_a(ml/yr) ~ annual air intake; (These were taken from ICRP, Report of the Task Group on Reference Man, page 346-- Reference #4.)

χ_i(pCi/ml) ~ concentration of radionuclides at the area of interest; (See pages 21 through 25 for the calculations and results.)

The doses given in Tables 7.1 and 7.2 represent the maximum doses which would result from each isotope if the full amount of activity given in Table #5 was burned in one year. The actual ASU inventory (see Table #4) represents only 1.4% of the calculated permissible burnable activity. The total dose estimates, calculated by assuming the actual ASU inventory is burned in one year, are given in Table #7.3.

Table #7.1 ADULT DOSE ESTIMATES

Isotope	DFA (mrem/pCi)	D(mrem/yr.) + Stack	200 m	300 m
H-3	1.3×10^{-7}	6.2×10^{-6}	1.2×10^{-6}	6.4×10^{-7}
C-14	4.3×10^{-7}	1.0×10^{-5}	2.0×10^{-6}	1.1×10^{-6}
Na-22	1.3×10^{-5}	9.4×10^{-7}	1.8×10^{-7}	9.6×10^{-8}
*Cl-36	5.8×10^{-3}	1.1×10^{-3}	2.2×10^{-4}	1.2×10^{-4}
Sr-90	1.2×10^{-2}	8.6×10^{-5}	1.6×10^{-5}	8.6×10^{-6}
I-129	5.5×10^{-3}	2.6×10^{-5}	5.2×10^{-6}	2.8×10^{-6}
*Ca-45	3.4×10^{-4}	8.2×10^{-5}	1.6×10^{-5}	8.6×10^{-6}
Mn-54	1.8×10^{-4}	4.3×10^{-5}	8.4×10^{-6}	4.5×10^{-6}
Eu-154	7.4×10^{-4}	1.8×10^{-5}	3.4×10^{-6}	1.8×10^{-6}
Eu-155	1.0×10^{-4}	2.4×10^{-5}	4.6×10^{-6}	2.5×10^{-6}
Ni-63	5.4×10^{-5}	2.6×10^{-5}	5.0×10^{-6}	2.7×10^{-6}
Zn-65	1.1×10^{-4}	5.3×10^{-5}	1.0×10^{-5}	5.4×10^{-6}
Pm-147	8.4×10^{-5}	4.0×10^{-5}	7.8×10^{-6}	4.2×10^{-6}
Sm-151	8.6×10^{-5}	4.1×10^{-5}	8.0×10^{-6}	4.3×10^{-6}
Na-24	1.7×10^{-6}	2.0×10^{-6}	3.9×10^{-7}	2.1×10^{-7}
* K-42	1.7×10^{-5}	1.6×10^{-5}	3.2×10^{-6}	1.7×10^{-6}
P-32	1.7×10^{-4}	8.2×10^{-5}	1.6×10^{-5}	8.6×10^{-6}
* P-33	1.7×10^{-5}	4.1×10^{-7}	7.9×10^{-8}	4.3×10^{-8}
Rb-86	1.7×10^{-5}	8.2×10^{-8}	1.6×10^{-8}	8.6×10^{-9}
* S-35	1.7×10^{-5}	3.7×10^{-5}	7.1×10^{-6}	3.8×10^{-6}
* I-125	1.7×10^{-5}	3.3×10^{-7}	6.3×10^{-8}	3.4×10^{-8}

* DFA values were not given in Reference #10, so estimates were used based on the average of each category.

+ See Table 7.2.

Table #7.2 CHILD DOSE ESTIMATES

Isotope	DFA (mrem/pCi)	D(rem/yr.) + Stack	200 m	300 m
H-3	2.0×10^{-7}	2.2×10^{-5}	1.2×10^{-6}	6.5×10^{-7}
C-14	1.7×10^{-6}	9.4×10^{-5}	5.2×10^{-6}	2.7×10^{-6}
Na-22	4.4×10^{-5}	7.3×10^{-6}	4.0×10^{-7}	2.2×10^{-7}
*Cl-36	1.7×10^{-2}	7.5×10^{-3}	4.1×10^{-4}	2.2×10^{-4}
Sr-90	4.4×10^{-3}	7.3×10^{-5}	4.0×10^{-6}	2.2×10^{-6}
I-129	2.1×10^{-2}	2.3×10^{-4}	1.3×10^{-5}	7.0×10^{-6}
*Ca-45	1.0×10^{-3}	5.5×10^{-4}	3.0×10^{-5}	1.6×10^{-5}
*Mn-54	5.4×10^{-4}	3.0×10^{-4}	1.7×10^{-5}	9.2×10^{-6}
*Eu-154	2.2×10^{-3}	1.2×10^{-4}	6.6×10^{-6}	3.6×10^{-6}
Eu-155	1.7×10^{-3}	9.4×10^{-4}	5.2×10^{-5}	2.8×10^{-5}
*Ni-63	1.6×10^{-4}	1.8×10^{-4}	9.9×10^{-6}	5.3×10^{-6}
*Zn-65	3.3×10^{-4}	3.6×10^{-4}	2.0×10^{-5}	1.1×10^{-5}
*Pm-147	2.5×10^{-4}	2.8×10^{-4}	1.5×10^{-5}	8.1×10^{-6}
*Sm-151	2.6×10^{-4}	2.9×10^{-4}	1.6×10^{-5}	8.6×10^{-6}
*Na-24	5.1×10^{-6}	1.4×10^{-5}	7.7×10^{-7}	4.2×10^{-7}
* K-42	5.1×10^{-5}	1.1×10^{-4}	6.1×10^{-6}	3.3×10^{-6}
* P-32	5.1×10^{-4}	5.6×10^{-4}	3.1×10^{-5}	1.7×10^{-5}
* P-33	5.1×10^{-5}	2.8×10^{-6}	1.5×10^{-7}	8.1×10^{-8}
*Rb-86	5.1×10^{-5}	5.6×10^{-7}	3.1×10^{-8}	1.7×10^{-8}
* S-35	5.1×10^{-5}	2.5×10^{-4}	1.4×10^{-5}	7.6×10^{-6}
* I-125	5.1×10^{-5}	2.2×10^{-6}	1.2×10^{-7}	6.5×10^{-8}

* DFA values were not given in Reference #10, so estimates were used based on the ratios of the given adult and child values.

+ R = 8.4×10^{6}ml/yr. Adult 24 hr./day exposure
R = 5.5×10^{6}ml/yr. Child 24 hr./day exposure
R = 2.4×10^{6}ml/yr. Adult 40 hr./week exposure

For the dose calculations at 200 m and 300 m, the 24 hr./day intake was used. Dose estimates were made at the stack for an adult occupational exposure and also for a child 24 hr./day exposure to determine the dose estimate to the animals at the LACF.

Table #7.3 ACTUAL TOTAL DOSE

Location		Dose (mrem/yr)
Adult	Stack	9.9×10^{-5}
	200 m	1.8×10^{-5}
	300 m	1.0×10^{-5}
Child	Stack	1.6×10^{-4}
	200 m	8.9×10^{-6}
	300 m	4.9×10^{-6}

The ground level concentration for the points of interest, 200 m and 300 m, (See Figures 1 and 2 on pages 6 and 22, respectively) were determined by using Pasquill's model for Gaussian distribution, (from D.B. Turner's Workbook of Atmospheric Dispersion Estimates -- Reference #2).

$$\chi = \frac{Q}{\pi \sigma_y \sigma_z u} \exp[-1/2(H/\sigma_z)^2]$$

Eqn. 3-3 from Reference #2.

Where:

χ (μCi/ml) ~ concentration

Q (μCi/burn) ~ emmission rate based on 10% MPC at maximum ground level concentration-- Table 5 values.

σ_y, σ_z ~ horizontal and vertical standard deviations, respectively-- determined from Figures 3.2 and 3.3 on pages 23 and 24 respectively.

u ~ average windspeed = 3.4 m/sec

H ~ effective stack height = 8.9 m

The simplified formulas for the concentration at 200 m and 300 m, respectively are:

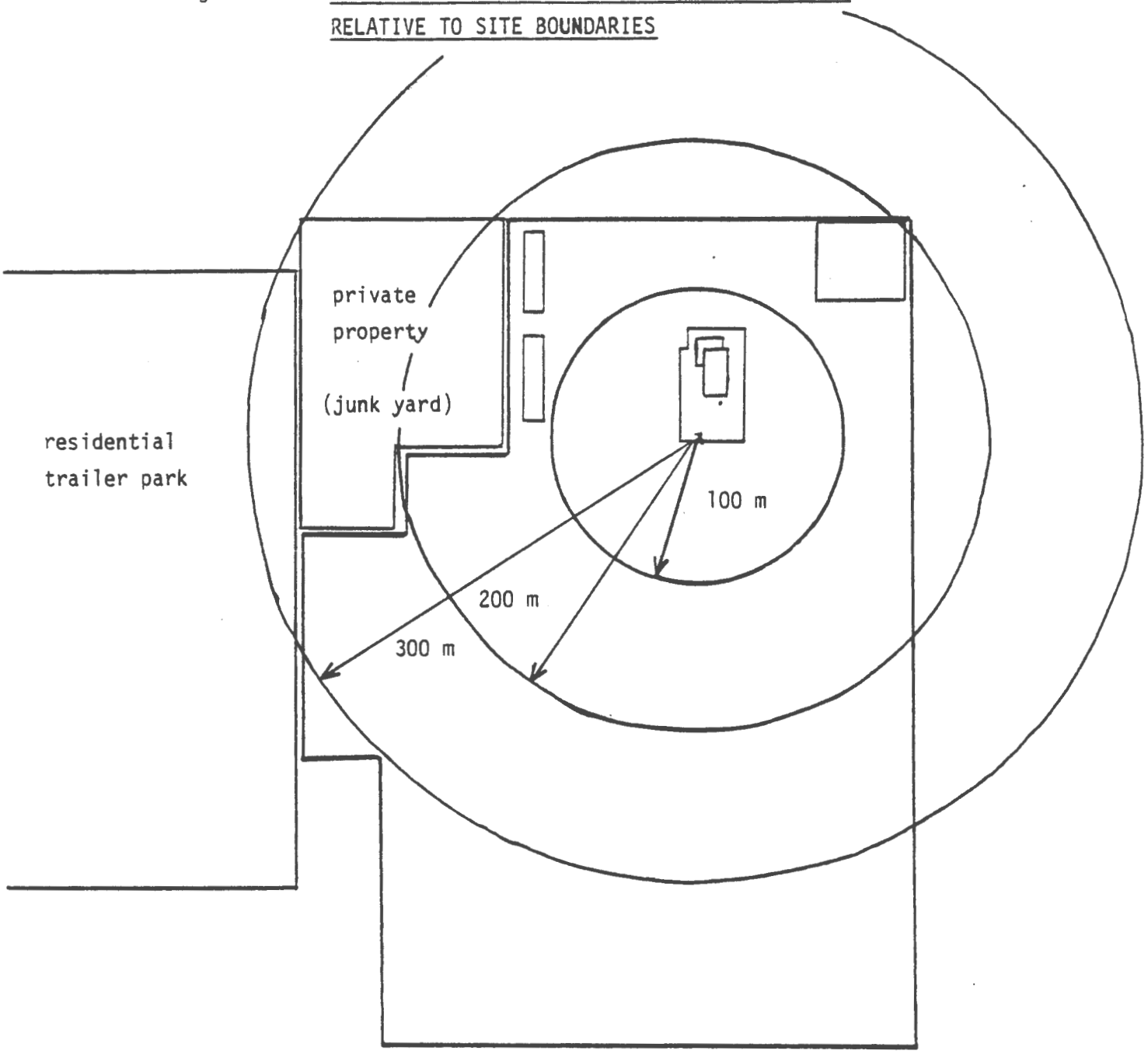
$$\chi = Q(\mu Ci/burn)\ (7.44 \times 10^{-15})$$

$$\chi = Q(\mu Ci/burn)\ (3.9 \times 10^{-15})$$

(Use Q values from Table #5)

Table #8, on page 25, contains the results.

Figure 2 MAXIMUM GROUND LEVEL CONCENTRATION LOCATION RELATIVE TO SITE BOUNDARIES



Maximun ground-level concentration occurs at 100 m.

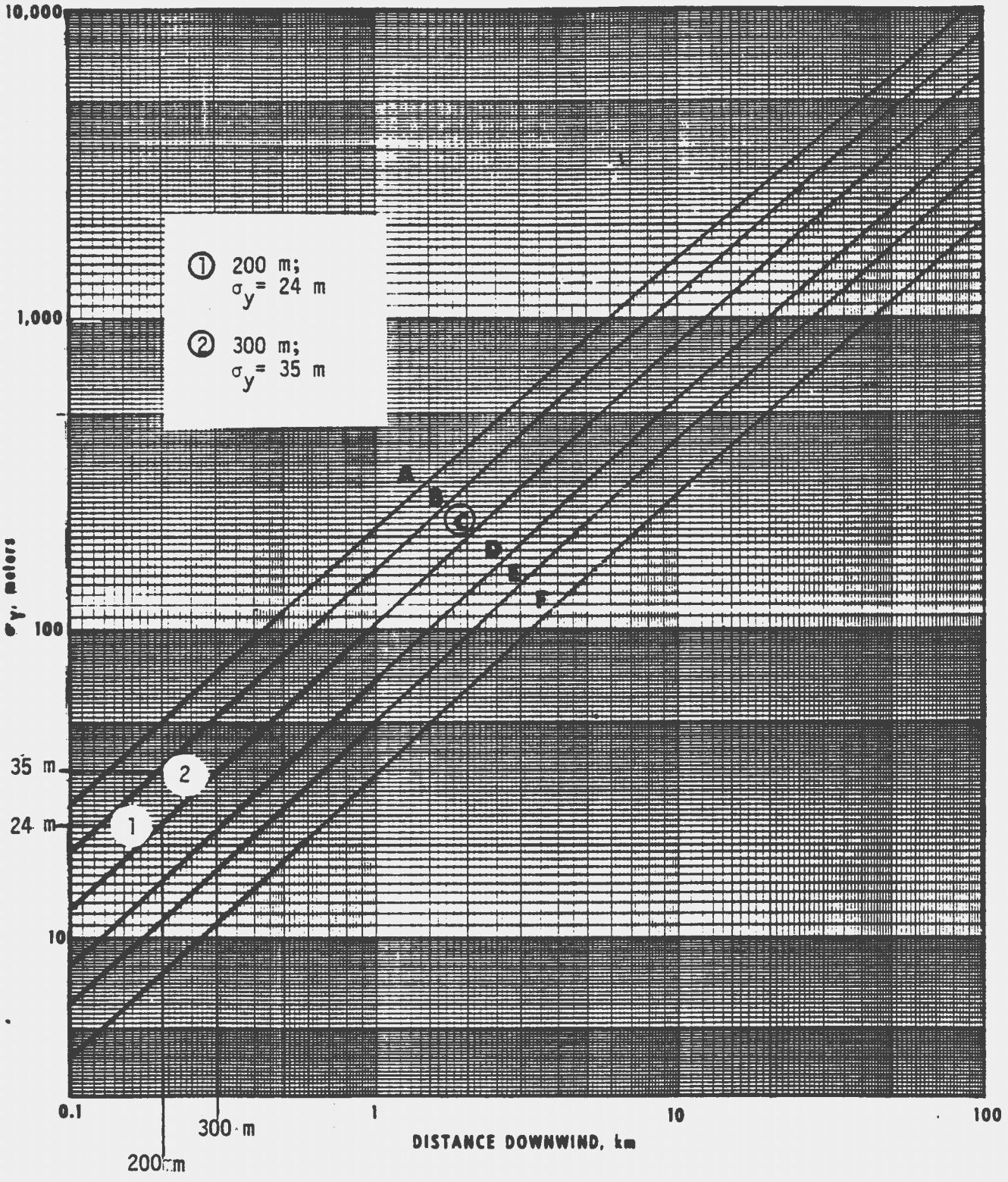


Figure 3-2. Horizontal dispersion coefficient as a function of downwind distance from the source.

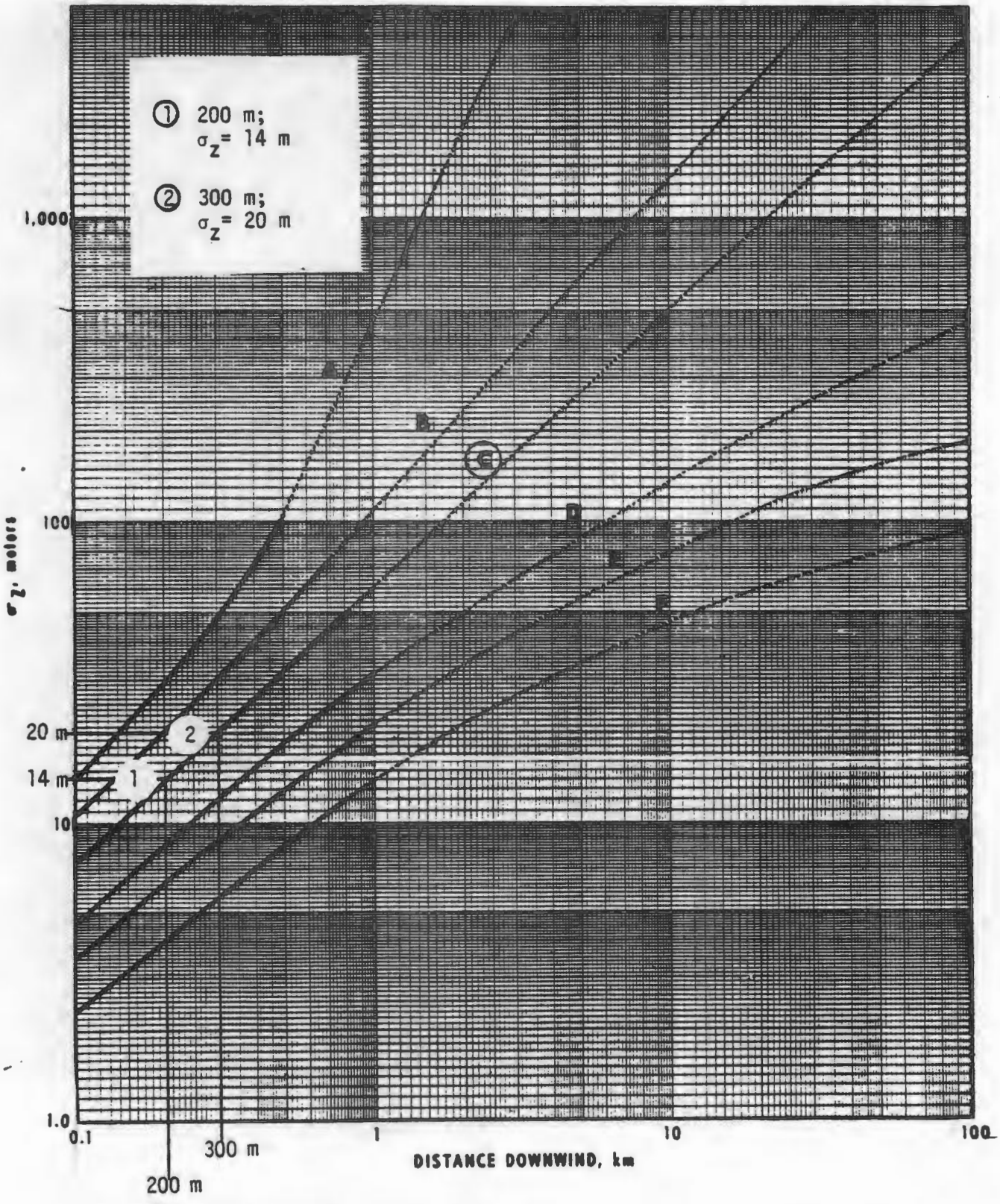


Figure 3-3. Vertical dispersion coefficient as a function of downwind distance from the source.

Estimates

Table #8 CALCULATED CONCENTRATIONS AT VARIOUS POINTS

Isotope	Stack (10% MPC)	χ (pCi/ml) 200 m	300 m
H-3	$2x10^{-5}$	$1.11x10^{-6}$	$5.90x10^{-7}$
C-14	$1x10^{-5}$	$5.53x10^{-7}$	$2.94x10^{-7}$
Na-22	$3x10^{-8}$	$1.66x10^{-9}$	$8.83x10^{-10}$
Cl-36	$8x10^{-8}$	$4.43x10^{-9}$	$2.36x10^{-9}$
Sr-90	$3x10^{-9}$	$1.64x10^{-10}$	$8.71x10^{-11}$
I-129	$2x10^{-9}$	$1.12x10^{-10}$	$5.94x10^{-11}$
Ca-45	$1x10^{-7}$	$5.53x10^{-9}$	$2.94x10^{-9}$
Mn-54	$1x10^{-7}$	$5.53x10^{-9}$	$2.94x10^{-9}$
Eu-154	$1x10^{-8}$	$5.51x10^{-10}$	$2.90x10^{-10}$
Eu-155	$1x10^{-7}$	$5.53x10^{-9}$	$2.94x10^{-9}$
Ni-63	$2x10^{-7}$	$1.11x10^{-8}$	$5.90x10^{-9}$
Zn-65	$2x10^{-7}$	$1.11x10^{-8}$	$5.90x10^{-9}$
Pm-147	$2x10^{-7}$	$1.11x10^{-8}$	$5.90x10^{-9}$
Sm-151	$2x10^{-7}$	$1.11x10^{-8}$	$5.90x10^{-9}$
Na-24	$5x10^{-7}$	$2.77x10^{-8}$	$1.47x10^{-8}$
K-42	$4x10^{-7}$	$2.21x10^{-8}$	$1.18x10^{-8}$
P-32	$2x10^{-7}$	$1.11x10^{-8}$	$5.90x10^{-9}$
P-33	$1x10^{-8}$	$5.51x10^{-10}$	$2.93x10^{-10}$
Rb-86	$2x10^{-9}$	$1.12x10^{-10}$	$5.94x10^{-11}$
S-35	$9x10^{-7}$	$4.98x10^{-8}$	$2.65x10^{-8}$
I-125	$8x10^{-9}$	$4.39x10^{-10}$	$2.34x10^{-10}$

Although there is no current ASU inventory of the following isotopes, the calculations described thus far in this paper were done for each and will be submitted to the ARRA for incineration approval. Those isotopes are: Mg-28, K-40, Ca-47, Fe-55, Co-57, Fe-59, Co-60, Cu-64, $Tc-99^{m}$, I-131 and Cs-137.

Ash Handling Procedure

After the incinerator has cooled sufficiently the health physics technician, under the supervision of the Radiation Protection Officer, surveys the ash removal door with a low-level survey meter. If the reading is not above background level, he opens the door and surveys the ashes and melted glass with the low-level pancake probe. If the reading is not above background, he lightly sprays the remains with water to reduce dust during removal-- being very careful not to spray the refractory so as to avoid possible damage. The technician, wearing protective clothing, including a dust mask, then breaks-up the glass and shovels the remains into a 30 gallon steel drum and disposes of the ash as ordinary trash. If the survey meter reading is above background level, the waste is re-burned for another day. If the results are the same following the re-burn, the waste is removed into a metal drum and shipped for burial along with any other non-burnable radioactive material at ASU.

Monitoring Procedures

Air samples are taken about once every month with a portable low volume air sampler at various points within the site boundary. The filter is analyzed by gamma spectroscopy and liquid scintillation. The same is done with wipe samples.

Soil samples will be taken and analyzed every year for comparison to samples taken before radioactive burning commenced.

It is hoped that eventually a TLD monitoring program can be utilized. TLD's would be placed in protective containers around the site and analyzed periodically for change in the activity level.

TASK #2

The final NRC guideline for incineration concerns the interaction with state and local jurisdictions. Before the license amendment could be approved, the ARRA required that all operating requirements of the Arizona Department of Health Services (ADHS) be met and that the mayors of the cities surrounding the incinerator be notified. The Bureau of

Air Quality Control (AQC), a division of ADHS, serves the same purpose in Arizona as the Environmental Protection Agency (EPA).

AQC required that the stack emissions not exceed EPA limits for particulates or vinyl chlorides. EPA Test Method 106 from Appendix B in 40 CFR Part 61 was required for the vinyl chlorides, but because of the manufacturer's specifications and other incinerator operations, a test for particulate emissions was not required. Inadequate equipment and procedures caused two unsuccessful vinyl chloride test attempts. However, from the third test it was proved there were no vinyl chlorides in the effluent, so AQC approved an operating permit.

It was recently learned that as of March 16, 1984 a new AQC regulation governing incinerator operations will take effect. The regulation voids incinerators which burn less than 20 tons per year or produce less than 40 tons per year of SO_2 particulates. Therefore, the operating permit for the ASU incinerator does not have to be renewed each year.

The mayors of Mesa, Tempe and the Tribal President of the Salt River Pima Reservation were notified of the plans to incinerate hazardous and low-level radioactive waste. ASU expected at least a request for a public hearing on the matter, but only a letter of acknowledgement from each was received.

TASK #3

Pursuant to the statements, conditions and procedures discussed in Task #'s 1 and 2 of this paper, a license amendment permitting disposal by incineration was issued to ASU by the ARRA on Feb. 10, 1984. The pathological incinerator, installed at the LACF and pre-set for Type 4 waste, needed no mechanical alterations to accomodate hazardous or low-level radioactive material.

The original task list of the project included designing and installing a liquid waste injection system to the incinerator. The liquid waste, primarily toluene, would serve as a fuel additive. However, due to excessive cost and the additional waste management procedures it would require, the task was deleted. The cost to design the system was estimated at $4,500.00. Additional waste management procedures would include either emptying the liquid scintillation vials or crushing them and separating the glass.

Monies have been requested to fund moving the incinerator approximately 30 yards from the building and installing an automatic loading device. The estimated cost is $23,000.00. Safety is the primary objective of the proposal. The funds have not yet been delegated.

The main problem encountered in the incinerator operation is occasional incomplete combustion and, subsequently, black smoke. The problem is caused from either a mal-functioning burner ignitor or an excess of toluene in the load, (the high Btu content requires more oxygen in the upper chamber than is present). Monthly maintenance and a carefully monitored feed rate help remedy the problem.

TASK #4

Each of the 25 other Agreement States were contacted-- first to determine their licensing requirements and secondly to obtain the number and contacts of state-licensed incinerators. Table #9 summarizes the replies. Unfortunately, the contacts have not been made to determine more specific requirements and procedures on the problems encountered.

Table #9 AGREEMENT STATE STUDY

State	Response 1=least detailed level 4=most detailed level Level	Comments	# of Licensed Incinerators
Alabama	3	same as in 10 CFR 20	no response
Arkansas	4	own written regs., plus info sheet which includes calculation examples	1
California	3		2
Colorado	2	NRC guideline sheet	1
Florida	4	own written regs., plus info on commercial incinerator service	2
Georgia	2		2
Idaho	3		2
Kansas	3		no response
Kentucky	1	no response	2
Louisiana	4	allow incineration without license for H-3, C-14, I-125 ($\leq$0.05 μCi/gm.)	3
Maryland	1	no response	2
Mississippi	4	own handbook - basically same guidelines as NRC, 10 CFR 20	2
Nebraska	3		2
Nevada	3		0
New Hampshire	3		0
New Mexico	1	no response	0
New York	1	no response	no response
North Carolina	3		3
North Dakota	2		NRC 2
Oregon	3		NRC 3
Rhode Island	4	very detailed hazardous waste incineration guidelines	0
South Carolina	1	no guidelines considered	0
Tennessee	2		no response
Texas	4	own handbook - basically same guidelines as NRC, 10 CFR 20	2
Washington	3		1

CONCLUSION

The statements, procedures, calculations and results presented here represent only a summary of all the work involved towards licensing the incinerator. Obtaining the license amendment required over three years of correspondence and cooperation between ASU, ARRA, ADHS, DOE, city mayors and others. Experience and a look at the licensing requirements of other Agreement States exemplify the need for more detailed, specific guidelines. Perseverance however pays off, as this project has demonstrated that incineration of hazardous and low-level radioactive waste at ASU is a viable, cost effective alternative to shallow land burial.

REFERENCES

1. Bureau of Radiological Health, Radiological Health Handbook, U.S. Dept. of Health, Education, and Welfare, Maryland, 1970.

2. D. Bruce Turner, Workbook Of Atmospheric Dispersion Estimates, Environmental Protection Agency, North Carolina, 1970, pgs. 5-45.

3. D. Bush, R.S. Hundal, "The Fate Of Radioactive Materials Burnt In An Industrial Institutional Incineration", Health Physics Journal, Pergamon Press, New York, May 1973, pg. 564-568.

4. ICRP, Report Of The Task Group On Reference Man, Pergamon Press, New York, 1975, pg. 346.

5. L.R. Cooley, M.R. McCampbell, J.D. Thompson, Current Practice Of Incineration Of Low-Level Institutional Radioactive Waste, U.S. Dept. of Energy - EG&G Idaho, National Technical Information Service, U.S., Feb. 1981.

6. M. Eisenbud, "The Status Of Radioactive Waste Management: Needs For Reassessment", Health Physics Journal, Pergamon Press, New York, April 1981, pgs. 429-432.

7. N.W. Crouch, J.E. Watson, Jr., "Radionuclide Emissions From Incineration Of Institutional Low-Level Radioactive Wastes", Health Physics Journal, Pergamon Press, New York, June 1982, pgs. 871-873.

8. Purdue University, Radioactive Waste Incineration; National Low-Level Radioactive Waste Management Program, National Technical Information Service, U.S., Nov. 1982.

9. R. Landolt, "Evaluation Of A Small Inexpensive Incinerator For Institutional Radioactive Waste", Health Physics Journal, Pergamon Press, New York, June 1983, pgs. 671-675.

10. U.S. NRC, Regulatory Guide 1.109; Calculation Of Annual Doses To Man From Routine Releases Of Reactor Effluents For The Purpose Of Evaluating Compliance With 10 CFR Part 50, Appendix I, March, 1976.

11. United States Nuclear Regulatory Commission, Rules And Regulations, Title 10, Chapter 1, Code of Federal Regulations, Part 20, Appendix B, Table II, Column 1, Aug. 1, 1980.

12. Roche-Farmer, Study Of Alternative Methods For The Management Of Liquid Scintillation Counting Wastes, U.S. NRC, Feb. 1980.

13. Consumat Model C75-P Pathological Destructor Operators Manual, Nov. 6, 1980. (The diagram on the cover, the General Description on page 4, and the incinerator illustration on page 5 of this paper were all taken from the Consumat Manual.)

SUPPLEMENT TO MARCH 1984 REPORT

Isotope	Reference MPC	T 1/2	Table #1 Waste Category	Table #2 Decay Time	Table #4 Q uCi/burn	Table #4 Q uCi/yr	Table #5 Q uCi/burn	Table #5 Q uCi/yr	Table #6 Sum of Ratio
Mg-28	$1x10^{-10}$	21 h	5	6 d	4	1,480	74	3,720	0
K-40	$1x10^{-10}$	$1.3x10^{9}$y	2		4	1,480	74	3,720	0
Ca-47	$6x10^{-9}$	4.5 d	5	8 m	244	88,800	4,461	223,074	0
Fe-55	$3x10^{-8}$	2.6 y	3		1,218	444,000	22,307	1,115,370	0
Co-57	$6x10^{-9}$	270 d	3		244	88,800	4,461	223,074	0
Fe-59	$2x10^{-9}$	46 d	5	1.5 y	81	29,600	1,487	74,358	0
Co-60	$3x10^{-10}$	5.3 y	2		12	4,440	223	11,153	0
Cu-64	$4x10^{-8}$	12.8 h	5	8 m	1,624	592,000	29,743	1,487,160	0
$Tc-99^{m}$	$5x10^{-7}$	6 h	5	6 d	20,300	7,400,000	371,790	18,589,500	0
I-131	$1x10^{-10}$	8 d	5	8 m	4	1,480	74	3,717	0
Cs-137	$5x10^{-10}$	30 y	2		20	7,400	372	18,590	0

Table #7.1 ADULT DOSE ESTIMATES

SUPPLEMENT (cont.)

Isotope	DFA (mrem/pCi)	+ Stack	D(mrem/yr.) 200 m	300 m
Mg-28	*1.7×10^{-5}	4.1×10^{-5}	7.9×10^{-8}	4.1×10^{-8}
K-40	*5.8×10^{-3}	1.4×10^{-2}	2.7×10^{-5}	1.4×10^{-5}
Ca-47	*1.7×10^{-5}	2.4×10^{-3}	4.6×10^{-6}	2.4×10^{-6}
Fe-55	3.4×10^{-5}	2.5×10^{-2}	4.8×10^{-5}	2.5×10^{-5}
Co-57	4.6×10^{-5}	6.6×10^{-3}	1.3×10^{-5}	6.8×10^{-6}
Fe-59	3.5×10^{-3}	1.7×10^{-1}	3.3×10^{-4}	1.7×10^{-4}
Co-60	7.5×10^{-4}	5.4×10^{-3}	1.0×10^{-5}	5.2×10^{-6}
Cu-64	6.1×10^{-6}	5.9×10^{-3}	1.1×10^{-5}	5.8×10^{-6}
$Tc\text{-}99^{m}$	5.2×10^{-7}	6.2×10^{-3}	1.2×10^{-5}	6.3×10^{-6}
I-131	1.5×10^{-3}	3.6×10^{-3}	6.9×10^{-6}	3.6×10^{-6}
Cs-137	5.4×10^{-5}	6.5×10^{-4}	1.3×10^{-6}	6.8×10^{-7}

Table #7.2 CHILD DOSE ESTIMATES

Isotope	DFA (mrem/pCi)	+ Stack	D(mrem/yr.) 200 m	300 m
Mg-28	*5.1×10^{-5}	2.8×10^{-4}	1.5×10^{-7}	8.1×10^{-8}
K-40	*1.7×10^{-2}	9.4×10^{-2}	5.2×10^{-5}	2.7×10^{-5}
Ca-47	*5.1×10^{-5}	1.7×10^{-2}	9.4×10^{-6}	4.9×10^{-6}
Fe-55	*1.0×10^{-4}	1.7×10^{-1}	9.4×10^{-5}	4.9×10^{-5}
Co-57	*1.4×10^{-4}	4.6×10^{-2}	2.5×10^{-5}	1.3×10^{-5}
Fe-59	*5.1×10^{-5}	5.6×10^{-3}	3.1×10^{-6}	1.6×10^{-6}
Co-60	1.9×10^{-3}	3.1×10^{-2}	1.7×10^{-5}	9.0×10^{-6}
Cu-64	*5.1×10^{-5}	1.1×10^{-1}	6.1×10^{-5}	3.2×10^{-5}
$Tc\text{-}99^{m}$	*5.1×10^{-5}	1.4×10^{-0}	7.7×10^{-4}	4.1×10^{-4}
I-131	4.2×10^{-3}	2.3×10^{-2}	1.3×10^{-5}	6.7×10^{-6}
Cs-137	2.4×10^{-4}	6.6×10^{-3}	3.6×10^{-6}	1.9×10^{-6}

* See notes from original report

\+

Table #7.3 ACTUAL TOTAL DOSE

SUPPLEMENT (cont.)

Location		Dose (mrem/yr)
Adult	Stack	0
	200 m	0
	300 m	0
Child	Stack	0
	200 m	0
	300 m	0

Table #8 CALCULATED CONCENTRATIONS AT VARIOUS POINTS

Isotope	Stack (10% MPC)	χ (pCi/ml) 200 m	300 m
Mg-28	1×10^{-6}	5.5×10^{-10}	2.9×10^{-10}
K-40	1×10^{-6}	5.5×10^{-10}	2.9×10^{-10}
Ca-47	6×10^{-5}	3.3×10^{-8}	1.8×10^{-8}
Fe-55	3×10^{-4}	1.7×10^{-7}	8.8×10^{-8}
Co-57	6×10^{-5}	3.3×10^{-8}	1.8×10^{-8}
Fe-59	2×10^{-5}	1.1×10^{-8}	5.8×10^{-9}
Co-60	3×10^{-6}	1.7×10^{-9}	8.7×10^{-10}
Cu-64	4×10^{-4}	2.2×10^{-7}	1.2×10^{-7}
$Tc\text{-}99^{m}$	5×10^{-3}	2.8×10^{-6}	1.5×10^{-6}
I-131	1×10^{-6}	5.5×10^{-10}	2.9×10^{-10}
Cs-137	5×10^{-6}	2.8×10^{-9}	1.5×10^{-9}

Appendix A

Arizona Radiation Regulatory Agency Requirements

INFORMATION TO BE SUBMITTED WHEN REQUESTING AMENDMENT TO DISPOSE OF RADIOACTIVE WASTE BY DECAY-IN-STORAGE METHOD

This is in reference to your request for information concerning authorization to dispose of radioactive waste via decay-in-storage. In order to approve such an amendment request, we need the following information:

1. Please submit a diagram of the area where the waste will be decayed-in-storage. Show the type, location, and thickness of shielding that you will have available in this area on your diagram. Your storage area should be large enough to handle an accumulation of used Tc-99m generators as well as other solid waste.

   Identify adjacent unrestricted areas located across the walls from the storage area and show that adequate steps have been taken to assure that radiation levels do not exceed the limits specified in 10 CFR 20.105 (enclosed).

2. Describe your security measures for the decay-in-storage area.

3. Confirm that radiation levels in this area will be surveyed and recorded at least weekly.

4. Describe your procedures for monitoring the waste to assure that it has decayed to background levels prior to disposal. As a minimum, your description should include these points:

   a. Monitor the waste in a low background area.

   b. Monitor with a low level GM type survey meter as appropriate for contamination surveys. Use the most sensitive scale.

   c. Remove all shielding prior to monitoring.

   d. Maintain records of these surveys as required under 10 CFR 20.

5. Note that decay-in-storage may not be a practical method of disposal for Tc-99m generators. These generators may contain long-lived radioisotopic contaminants. If you intend to dispose of generators by this method, you should include procedures for segregating the generator columns so that they can be monitored separately.

Be certain to submit your amendment request in duplicate. Unless your institution is fee exempt, your request should be accompanied by the appropriate amendment fee. Refer to 10 CFR 170.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
Office of Public Affairs
Washington, D.C. 20555

No. 80-182
Tel. 301/492-7715

FOR IMMEDIATE RELEASE
(Wednesday, October 8, 1980)

NRC CONSIDERS CHANGES TO REGULATIONS ON DISPOSAL OF RADIOACTIVE WASTES RESULTING FROM MEDICAL RESEARCH

The Nuclear Regulatory Commission is considering changing its regulations to eliminate the requirement that licensed biomedical research laboratories and hospitals send animal carcasses and vials containing tracer amounts of certain radioactive materials to radioactive waste burial grounds. Under the amended regulations, licensees would be able to dispose of these materials without regard to their radioactivity.

The licensed materials covered by the changes would be:

1) 0.05 microcuries or less of hydrogen-3 or carbon-14, per gram of liquid scintillation media, and

2) 0.05 microcuries or less of hydrogen-3 or carbon-14, per gram of animal tissue averaged over the weight of the entire animal.

Tracer amounts of hydrogen-3 and carbon-14 are added to chemical compounds or experimental drugs to study the drugs' behavior in research animals. After the drug containing radioactive material is administered to an animal, a sample from the animal's urine, blood or body tissue is combined with an organic solvent--such as toluene--in a small vial to make a "liquid scintillation medium." The vial is placed in a "liquid scintillation counter," which measures the amount of radioactivity in the sample. The radioactivity amount can be used to derive the needed information on the behavior of the drug. The vials are used once and then are ready for disposal.

Research laboratories and hospitals throughout the country are using between 84 and 159 million vials per year, which represents 200 to 400 thousand gallons of liquid scintillation media. Disposal of this waste in radioactive waste burial grounds requires approximately 400 thousand cubic feet of storage space at a cost of over $13 million per year.

Animals are also used for the development and testing of new drugs. Virtually every chemical compound that is considered for use as a human or veterinary drug is first tagged with a hydrogen-3 or carbon-14 tracer and injected into research animals to study how the compound behaves. The animal carcasses containing tracer quantities of hydrogen-3 and carbon-14 require about 80 thousand cubic feet of space in radioactive waste burial grounds at a cost of about $3 million per year.

Liquid scintillation media and animal carcasses containing tracer quantities of hydrogen-3 and carbon-14 together constitute the largest volume of radioactive medical waste. Liquid scintillation media make up approximately 43 percent of the total volume of radioactive waste in burial grounds that is not related to nuclear power generation and its supporting fuel cycle. Animal carcasses constitute about 9 percent of the non-nuclear-power-related radioactive waste in burial grounds.

Because the amount of hydrogen-3 and carbon-14 that could be released to the environment as a result of this rulemaking is very small, and because calculations indicate the dose to any exposed individual is likely to be much less than 1 millirem per year, the Commission believes that the changes to the regulations would have little adverse impact on the environment from a radiological health standpoint. The proposed rule changes would conserve waste burial capacity that is already in short supply.

The amendments would also raise the limit for the amount of hydrogen-3 and carbon-14 that may be released to sanitary sewerage systems. Under present NRC regulations, a licensee may release a total of 1 curie of all radioactive materials in this manner. Raising the limit for hydrogen-3 to 5 curies per year and for carbon-14 to 1 curie per year, as would be permitted by the proposed revisions to the regulations, would be a negligible addition to the amount of radioactivity already present in the natural environment.

Interested persons are invited to submit written comments on the proposed amendments, which are to Part 20 of the Commission's regulations, to the Secretary, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Docketing and Service Branch, by November 24, 1980 (45 days after publication in the Federal Register on October 8, 1980).

#

(6A)

STATE OF ARIZONA

RADIATION REGULATORY AGENCY

925 S. 52nd Street, Suite 2 • Tempe, AZ 85281

Phone: (602) 255-4845

January 26, 1981

TO ALL MEDICAL AND ACADEMIC LICENSEES

There are a number of steps licensees engaged in nuclear medicine practice and biomedical research can take under NRC rules to substantially reduce, and in some cases eliminate, the need to send radioactive waste to commercial low-level waste disposal facilities. By taking advantage of these alternatives and following good waste management practices, licensees can often reduce the risk of having their programs impacted through further curtailment of commercial waste disposal facilities. Some of the more important steps that can be taken are to:

1. Segregate radioactive waste from non-radioactive waste to reduce unnecessary volume. This simply requires a little time and discipline in the laboratory.

2. Hold waste with short-lived radionuclides in storage for decay to background levels, then dispose of it in the ordinary trash. This procedure requires a license amendment. (See Enclosure 1 for information to be submitted with the amendment request).

3. Release certain materials into the sanitary sewage system in accordance with Article 4, Regulation R12-1-418.

Judicious use of these three steps can substantially reduce the volume of waste shipped to burial grounds. Some nuclear medicine laboratories using only short-lived radionuclides can eliminate waste shipments.

Waste from biomedical research is generally somewhat more difficult to manage. Two of the most common problems are disposal of liquid scintillation counting waste (LSCW) and animal carcasses. The most frequently used radioisotopes in both are tritium and carbon-14. LSCW presents a particularly troublesome problem due to the flammability and toxicity of the solvents. Disposal of LSCW has been given special consideration by the ARRA. The staff has investigated alternatives to managing these wastes and the results have been published in Nuclear Regulatory publication NUREG-0656.

Consideration should be given to disposal by incineration for LSCW and laboratory animals containing small amounts of tritium and carbon-14. This method requires a license amendment; Regulation R12-1-420 contains the provisions for incineration. Enclosure 2 identifies the information to be submitted with an amendment request for incineration.

There are other provisions in the regulations that cover waste disposal. We have mentioned only the few that are most easily and commonly used. Other regulatory provisions include:

1. Disposal by burial in soil in accordance with R12-1-419 (A proposed rule change is under consideration to delete this provision. It will likely be replaced by a provision which requires specific approval by license amendment for burial).

2. Release as effluents to unrestricted areas pursuant to Regulation R12-1-407. In keeping with the ALARA concept, this method should normally be used only for released incident to the procedures involved.

We suggest that you review and consider alternatives to commercial land burial for the management of your low-level radioactive waste. Implementation of some of these alternatives may require an amendment to your license. Amendment requests should be submitted to the ARRA.

Sincerely,

Darrell Warren

Darrell Warren, Health Physicist
Radioactive Materials

DW:jr

Enclosures:

1. Information to be Submitted When Requesting Amendment to Dispose of Radioactive Waste by Decay-in-Storage.

2. Information Required for ARRA Approval of Treatment or Disposal by Incineration.

Enclosure 1

Information to be Submitted When Requesting Amendment to Dispose of Radioactive Waste by Decay-In-Storage Method

This is in reference to your request for information concerning authorization to dispose of radioactive waste via decay-in-storage. In order to approve such an amendment request, we need the following information:

1. Please submit a diagram of the area where the waste will be decayed-in-storage. Show the type, location, and thickness of shielding that you will have available in this area on your diagram. Your storage area should be large enough to handle an accumulation of used Tc-99m generators as well as other solid waste.

   Identify adjacent unrestricted areas located across the walls from the storage area and show that adequate steps have been taken to assure that radiation levels do not exceed the limits specified in Regulation R12-1-406.

2. Describe your security measures for the decay-in-storage area.

3. Confirm that radiation levels in this area will be surveyed and recorded at least weekly.

4. Describe your procedures for monitoring the waste to assure that it has decayed to background levels prior to disposal. As a minimum, your description should include these points:

   a. Monitor the waste in a low background area.

   b. Monitor with a low level GM type survey meter as appropriate for contamination surveys. Use the most sensitive scale.

   c. Remove all shielding prior to monitoring.

   d. Maintain records of these surveys as required under Article 4.

5. Note that decay-in-storage may not be a practical method of disposal for Tc-99m generators. These generators may contain long-lived radioisotopic contaminants. If you intend to dispose of generators by this method, you should include procedures for segregating the generator columns so that they may be monitored separately.

Be certain to submit your amendment request in duplicate.

Enclosure 2

INFORMATION REQUIRED FOR ARRA APPROVAL OF TREATMENT OR DISPOSAL BY INCINERATION

1. State specifically the isotopes you wish to incinerate. For each isotope listed, you should submit calculations demonstrating that air concentrations of the effluents at the stack are in accordance with the requirements of Regulation R12-1-407.

2. Submit the characteristics of the incinerator, such as height of the stack, height of and distance to buildings in the surrounding areas, rated airflow of the incinerator in cubic feet per hour or similar units and its proximity to any air intake ducts.

3. The gaseous effluent from the incinerator stack should not exceed the limits specified for air in Appendix A, Table II, Article 4, when averaged over a twenty-four (24) hour period.

4. In order to be in compliance with the ALARA philosophy stated in Regulation R12-1-401.B., the gaseous effluent from the incenerator stack should be a fraction (approximately 10%) of the limits specified for air in Appendix A, Table II, Article 4, when averaged over a one-year period.

5. Describe the method of measurement or estimation of the concentration of radioactive material appearing in ash residue.

6. Describe the procedures for handling and disposing of ash from the incinerator.

7. Describe procedures to be followed to prevent overexposure of personnel during all phases of the operation, including instruction given to personnel handling.

8. Submit evidence that all State and local regulations concerning incineration of radioactive material have been met by your institution.

9. State the maximum number of burns to be performed in any one week and the maximum number of burns per year.

(1)

INFORMATION REQUIRED FOR COMMISSION APPROVAL OF TREATMENT OR DISPOSAL BY INCINERATION

Revised October 3, 1979

1. State specifically the isotopes you wish to incinerate. For each isotope listed, you should submit calculations demonstrating that air concentrations of the effluents at the stack are in accordance with the requirements of Section 20.106 of 10 CFR Part 20.

2. Submit the characteristics of the incinerator such as height of the stack, height of and distance to buildings in the surrounding areas, rated airflow of the incinerator in cubic feet per hour or similar units and its proximity to any air intake ducts.

3. The gaseous effluent from the incinerator stack should not exceed the limits specified for air in Appendix B, Table II, 10 CFR Part 20, when averaged over a twenty-four (24) hour period.

4. In order to be in compliance with the ALARA philosophy stated in Section 20.1(c) of 10 CFR Part 20, the gaseous effluent from the incinerator stack should be a fraction (approximately 10 percent) of the limits specified for air in Appendix B, Table II, 10 CFR Part 20, when averaged over a one year period.

5. Describe the method of measurement or estimation of the concentration of radioactive material appearing in the ash residue.

6. Describe the procedures for handling and disposing of ash from the incinerator.

7. Describe procedures to be followed to prevent overexposure of personnel during all phases of the operation, including instruction given to personnel handling the combustibles and the ash.

8. Submit evidence that all state and local regulations concerning incineration of radioactive material have been met by your institution.

9. State the maximum number of burns to be performed in any one week and the maximum number of burns per year.

Enclosure 3

(8)

File Copy

ARIZONA STATE
UNIVERSITY

TEMPE ARIZONA 85281

UNIVERSITY RADIATION SAFETY OFFICE
c/o COLLEGE OF ENGINEERING (D-102) (602) 965-6140

May 20, 1981

TO: Mr. Charles Tedford, Director, Arizona Radiation Regulatory Agency

FROM: Ronald H. Alvarado, Ph.D., Chairman, Radiation Safety Committee
Richard F. Brown, Radiation Safety Officer

SUBJECT: Revision of ASU's Radioactive Materials License 7-37.

I. It is requested that subject license be amended to provide for the disposal of radioactive material (RAM) by incineration and burial in accordance with the provisions of ARRA Rules and Regulations, Title 12, R12-1-417; R12-1-419; and R12-1-420.

II. Pertinent information to be considered in this request follows:

A. Incinerator:

1. Manufactured by CONSUMAT, gasfired, pathological destructor.

2. Performance data.

a. Capacity: 75 cu. ft. or 175 lb/hr.

b. Approximately weight: 11,300 lbs.

c. Lower Chamber: 12 gauge H.R. steel lined with 1" mineral wool insulation and 3" high strength 2600° F cast refractory.

d. Charging Door: 24"x24" free opening slant type. Lined same as lower chamber with asbestos gasket at sealing surface.

e. Ash Removal Door: 16"x12" free opening swing type lined same as charging door.

f. Upper Chamber: 12 gauge lined with 1½" mineral wool insulation and 4½" insulation and 4½" insulating 2800° F cast refractory.

g. Stack 2-4' sections lined with 2" insulating refractory.

h. Spark Arrestor: #2 mesh. Free area equals 4 times breaching area.

i. Burners: Manufactured by Eclipse. Upper chamber. 700,000 BTU/kr forced air.

j. Forced Air Supply: Upper and lower chambers approximately 500 CFM each powered by a ½ HP motor driving Dayton Blower No. 1C791.

3. Location: Approximately 40 acre site off Price Road at ASU's Laboratory Animal Care Facility. This facility is near the center of the site. See appendix-A (map of area).

B. Burial: All ash residual from the incinerator will be analyzed for radioactivity. We do NOT expect the ashes to exceed background activity. If the results of analysis does indicate mixed by-product activity it will then be buried on the Price Road site in an area designated by ASU and in compliance with R12-1-419.

C. RAM to be disposed of through incineration or burial:

1. RAM's with atomic numbers between 1 and 82.

2. Only RAM's with very low specific activity will be incinerated. (Low specific activity as used in this amendment request means the effluent from incineration will not exceed the limits specified in article R12-1-407 (B).)

3. Material to be incinerated will consist of LSC vials and LSC fluid; animal carcasses; routine laboratory supplies (gloves, absorbent papers, towels, pippettes, "empty" shipping containers, etc.);

4. Liquids which have been absorbed by diatomaceous earth.

5. There will be NO incineration of heavy metals or alpha emitters.

D. Meteorological Characteristics: Daily data will be obtained from the Climatology Laboratory on campus. ~~Temperature, wind direction and speed, barometer, humidity and rain fall will be recorded prior to incineration.~~ Poor weather conditions will dictate NO incineration.

E. Geological Characteristics: N.A.

F. Topographical Characteristics: N.A.

G. Procedures to be observed to minimize the risk of unexpected or hazardous exposures: ~~Air samples before, during and after each burn will be conducted by the RSO staff to determine the activity of RAM from the effluent at the stack.~~ Any indication of an increase in activity will result in the immediate shut down of the incinerator. Corrective action will be taken to resolve the situation.

H. Equipment to be utilized to insure safe operating conditions: in addition to the equipment listed on our application for ARRA License #7-37, we have acquired or will acquire the following:

1. Ludlum model 3 portable survey meter with probes Models, 44-9 (B-G); 44-6 thin wall gm; 43-5 alpha scintillator.

2. High Volume Air Sampler Model 809V RADECO, Inc.

3. Staplex Co. Air Sampler (Low Volume) for measurement of particulates.

4. National DRAEGER toxic gas monitor with 140 gas and vapor tubes.

5. Photodosimetry service for area and personnel.

I. Estimate of volume vs estimate of specific activity of material to be incinerated.

1. Volume and activity of shipment to Richland, Washington 6-23-80 (Covers previous six months accumulation)
Volume: 427.5 cu. ft. (12.08 m^3)
Activity (mCi): 131.56 mCi
Materials: Mixed by-product material consisting primarly of ~~H-3, C-14, S-35, Ca-137, Na-22, Cl-36, P-32, I-125, Sr-90~~ NOTE: the following radioisotopes were shipped but would not be incinerated. U-238, Pb-210, Bi-210, Po-210, Am-241, Ra-226, Cf-252.

2. RAM presently on hand in waste storage awaiting disposal. (7-1-80; 5-1-81).
Volume: 230 cu. ft.
Activity: 208 mCi
Materials: Mixed by-products material. (Approximately same as #1 above.)

3. Although the specific activity will probably remain constant per unit volume, it is anticipated that the volume will increase over the future as it has in the past.

J. Physical description of incineration site - Note enclosure. (Exhibit 2).

III. EXHIBIT:

A. A re-print of an article in the HPS Journal (Vol. 40, No. 4) is enclosed for information.

B. Map of area.

Submitted by:

Ronald H. Alvarado

Ronald H. Alvarado, Ph.D.
Chairman, Radiation Safety Committee

Richard F. Brown

Richard F. Brown
Radiation Safety Officer

Carla

(10)

STATE OF ARIZONA
RADIATION REGULATORY AGENCY

925 S. 52nd Street, Suite 2 • Tempe, AZ 85281
Phone: (602) 255-4845

July 20, 1981

Mr. Richard F. Brown
Radiation Safety Officer
College of Engineering
Arizona State University
Tempe, AZ 85281

Dear Dick:

We have reviewed your application to dispose of radioactive material by incinceration. Based on our analysis and a review by the N.R.C., it is felt that additional information is needed before an amendment can be granted.

1. It is required that air concentrations of radioactive materials in unrestricted areas, as a result of incinerator operation, not exceed the limits specified in R12-1-407. These may be met at the stack or at the property boundary. Please determine which and submit appropriate calculations to demonstrate compliance.

2. Note that different concentration limits are specified for each isotope, and for soluble and insoluble forms. To demonstrate your anticipated compliance, you will need to provide calculations for each isotope incinerated. You will also need to document your choice of other than the most restrictive limit.

3. Specific parameters to define "poor weather conditions" are required.

4. A specific procedure for analysis of the ash must be developed. This must state type of equipment to be used and activity levels used as cutoff points.

5. We understand that the incineration project is research in nature with many changes in procedures and possible modifications of equipment anticipated. In order to comply with Article 10, you will need to formulate initial procedures and update these as changes occur. These procedures should cover all phases of the operations.

6. The last paragraph of the second column of page 430 of the article "The Status of Radioactive Waste Management: Needs for Reassessment" (Health Physics Vol 40, Pages 429-437) suggests that public exposure should be limited to 10% of the limits given in R12-1-407. Since you have submitted this as part of your application, how will you apply these restrictions in your program?

Upon receipt of the above information, we will continue to review your application and issue your amendment as soon as possible.

Sincerely,

Darrell Warren

Darrell Warren, Health Physicist
Radioactive Materials

RB:DW:jr

Carla

(11)

1. We have chosen to demonstrate our anticipated compliance with the limits specified in R12-1-407 at the nearest site boundary by using the Gaussian effluent dispersion model. The theoretical basis for the model has been published extensively and I'm sure you are familiar with it. As used herein the average effluent concentration X at the site boundary normalized by the source strength Q is given by

$$\frac{\chi}{Q} = \frac{1}{\pi \bar{u} \sigma_y(x) \sigma_z(x)} \exp\left[\frac{-h^2}{2\sigma_z^2(x)}\right] \frac{sec}{m^3}$$

where:

X= downwind distance to site boundary

$\bar{u}$ = mean wind velocity

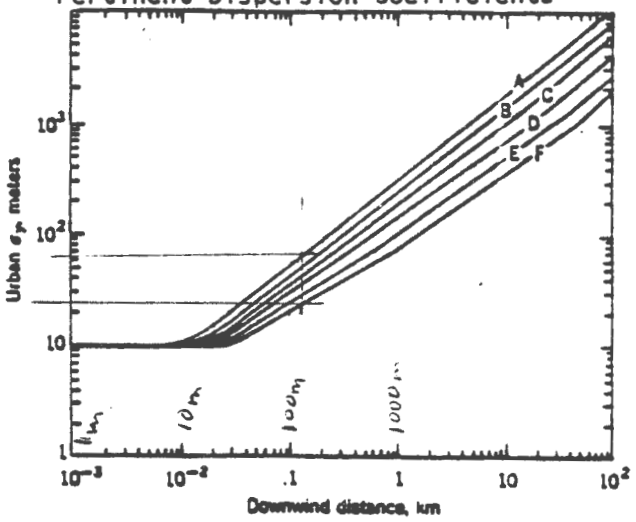
$\sigma_y(x), \sigma_z(x)$ = horizontal and vertical plume standard deviation for existing atmospheric stability classification

h= effective release height

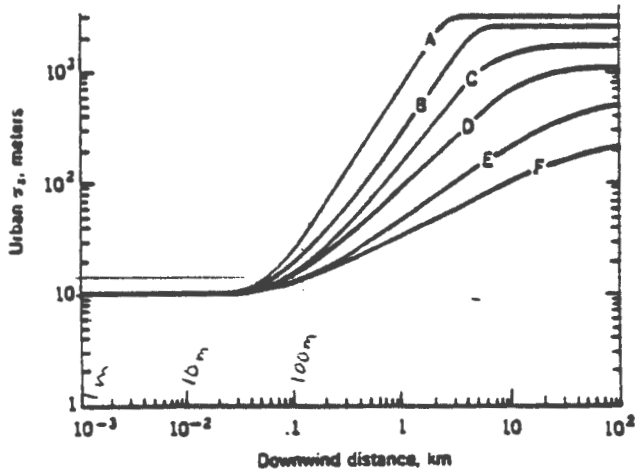
For purposes of conservatism it will be assumed that during the course of an eight hour burn (Incinerator design burn time) there is an average wind velocity of [redacted] in the direction of the nearest site boundary ([redacted] approximately [redacted]). σ_y and σ_z are taken from Bowne Bo(74) in which coefficients for distances ranging as low as 1m are tabulated. "h" is taken to be approximately 8m based on stack height and the velocity of stack emmissions.
As suggested in "The Status of Radioactive Waste Management: Needs for Reassessment" (Health Physics vol 40 pp 429-437). We will limit X, the concentration at the nearest site boundary, to 10% of the limits specified in R12-1-407 and we will also normalize the effluent source strength Q to our 8 hr burn time and calculate the maximum activity which maybe incinerated while insuring that our self-imposed limits are maintained with a significant factor of safety. Calculations of the maximum activity which may be burned while not exceeding our limits are tabulated for each isotope which would normally be disposed of through the Radiation Safety Office, limits have been calculated for an eight hour burn time under meteorological stability classifications A&F which reflect the highest and lowest degrees of effluent dispersion. Also shown in Table I is the total waste shipped from ASU in July 1980. This represents one year's generation of waste and our current inventory is comparable to these values.

FIGURE 1

Pertinent Dispersion Coefficients



1(a)Urban horizontal dispersion coefficient as a function of distance from the source.



1(b)Urban vertical dispersion coefficientas a function of downwind distance from the source.

* Dispersion coefficients from N.E. Bowne "Diffusion Rates", Journal of the Air Pollution Control Association 9-74

TABLE I

Maximum releases of radionuclides from stack

ISOTOPE	X μCi/ml	Q(A) mCi	Q(F) mCi	1980 Disposal mCi
H-3	2(-8)	8330	542	32.602
C-14	1(-8)	4165	277	16.031
Na-22	6(-10)	249.9	16.3	1.28
P-32	2(-10)	83.3	5.42	12.0
S-35	9(-10)	374.9	24.4	0.01
Cl-36	1(-9)	416.5	27.1	0.125
Co-60	1(-9)	416.5	27.1	0.043
Sr-90	3(-12)	1.25	0.08	0.016
I-125	8(-12)	3.33	0.22	61.25
Te-127m	5(-10)	20.8	13.6	0.002
I-131	1(-11)	4.17	0.271	0.005
Cs-137	2(-10)	83.3	5.42	4.5

at 120 m away

X= 10% of limits prescribed in R12-1-407

Q= Maximum activity which may be released in an 8-hr. period under the limits of X above and the specified meteorological stability category.

We also feel that an estimation of the mean yearly concentration of all radio nuclides at the site boundary would be useful to you in your decision regarding our license amendment. The Gaussian dispersion model used previously can be modified to express a prolonged dispersion rate as below

$$\frac{\bar{\chi}}{Q} = \sum_{ij} \frac{(f_D)_{ij}}{\pi u_i \sigma_{yj} \sigma_{zj}} \exp\left[\frac{-h^2}{2\sigma_{zj}^2}\right] \frac{\text{sec}}{m^3}$$

where $(f_D)_{ij}$ is the frequency with which the wind blows toward a direction D with wind speed i and stability class j.

Since the long term wind patterns at the facility do not differ significantly from those at the National Weather Service station at Sky Harbor International Airport the annual wind rose from that facility is used to estimate the mean concentration at several locations around the perimeter of the incinerator site. As before estimations are given for stability classifications A and F. Q is the value of the source strength and is given as equivalent to the present inventory of radioactive waste at ASU normalized over one years time.

Incinerator Site

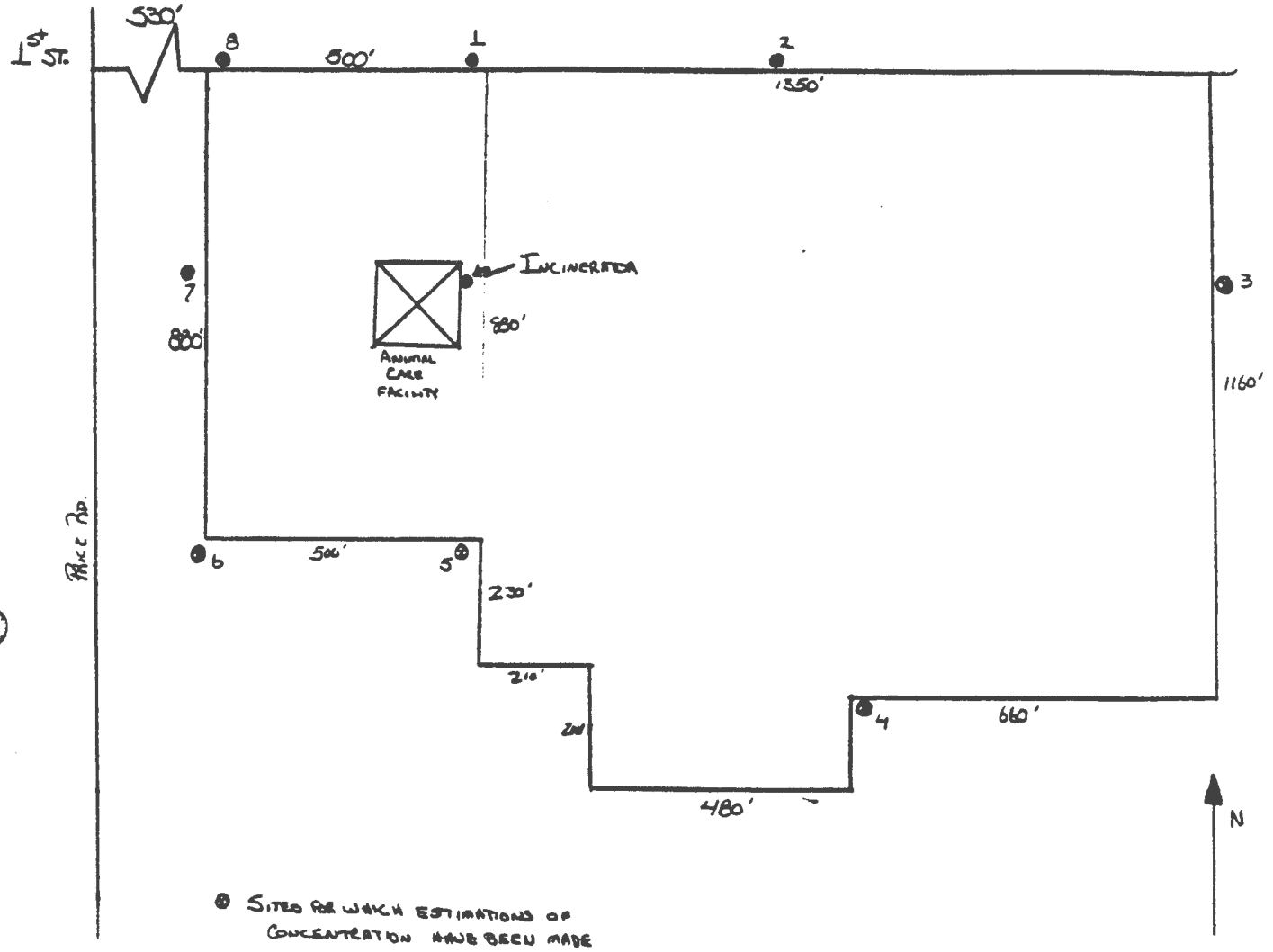


TABLE II

Estimate of Mean Yearly Concentration at Site Boundary

Wind Vector	Frequency	Wind Speed	Dist. to Site Bndry	Concentration Ci/ml	
				X(A)	X(F)
N	6.3%	3.17m/s	125 m	9.29(-15)	1.10(-13)
NE	9.5	3.53	175	1.26(-14)	1.17(-13)
E	19.3	4.34	425	2.05(-15)	8.50(-14)
SE	14.5	3.53	320	3.78(-15)	8.97(-14)
S	3.8	3.03	125	5.86(-15)	6.93(-14)
SW	5.3	3.35	200	4.13(-15)	5.05(-14)
W	28.05	4.34	150	3.75(-14)	8.98(-13)
NW	15.8	3.35	175	2.20(-14)	6.45(-13)
CALM					

It is also important to note that the values given in Tables I and II are based on unrealistically conservative assumptions. Several of these assumptions are listed below:

Our Assumptions	Realistic Assumptions
1. All activity released through stack emmissions	Significant percentage of activity remains in ash
2. No decay-in-storage before incineration	Significant decay especially of I-125 and P-32
3. Wind blows toward nearest site boundary (North 125m)	Wind vector most often toward West (150m), or East (425m)
4. Extremely unstable meteorological conditions for dispersion	Slightly favorable conditions
5. Neglect high volume flow rate out of stack(taken as point source)	High volume flow rate (1000 cfm) considered - lower volume concentration of activity.

2. Our response to item 1 has included an analysis based on different concentration limits for each isotope. In al cases we have demonstrated compliance with the most restrictive limit.

3. Poor weather conditions will include:

   1. Likely precipitation anticipated by,
      a)National Weather Service prediction
      b)60% or greater cloud cover

   2. Prolonged atmospheric inversion which would result in insufficient dispersion of stack effluent.

   3. Other conditions deemed pertinent by the ARRA

4. Our proposed ash analysis procedure is as follows

   1. Allow sufficient time for ash to cool
   2. Survey outside of charging door and ash-removal door with portable detector prior to opening.
   3. Open ash-removal door slowly while surveying with portable detector.
   4. Wet down ash prior to removal to minimize airborne radioactive particles.
   5. Remove ash to fiberboard containers.
   6. Analyze ash in portable Germanium detection system interfaced with multichannel analyzer to determine proper method of final disposal (On-site burial, shipment,etc.)

Air samples will be collected at the stack and at site boundaries with a Staplex filtration system and samples will be analyzed by liquid scintillation ~~spectrometry~~.

5. Personnel Dosimetry will be provided to all persons involved with the incineration of radioactive materials. Wipe surveys will be performed before and after each burn to insure that the incinerator and its surroundingsare not contaminated. Additionally, dosimetry will be provided to any resident of the nearby residential park who so desires. The ARRA will be notified of any changes in either operational or experimental procedure.

6. The suggestion that public exposure be limited to 10% of the limits specified in R12-1-407 ("The Status of Radioactive Waste Management..." Health Physics vol.40 pp429-437) has been incorporated into the calculations made in item 1.

28

Carla

ARIZONA
RADIATION REGULATORY AGENCY

Bruce Babbitt
Governor
Charles F. Tedford
Director

925 South 52nd Street, Suite #2 • Tempe, Arizona 85281 • (602) 255-4845

April 19, 1982

Ronald H. Alvarado, Ph.D.
Chairman Radiation Safety Committee
Richard F. Brown, RSO
College of Engineering
Arizona State University
Tempe, Arizona 85281

Gentlemen:

We are currently processing your request for amendment of your radioactive material license #7-37. Before further action can be taken on your request, we need the following additional information:

1. After careful consideration, we have determined that your demonstration of compliance with limits specified in R12-1-407 at the nearest site boundary is not acceptable for this application. Please submit calculations demonstrating compliance with the emission limits at the incinerator stack.

2. Your calculations were based on an incinerator design burn time of eight hours. However, information developed during the onsite inspection and specifications given in the Operator's Manual indicate a maximum and variable design burn time of five hours. Please determine the actual burn time and profile that will be utilized and submit recalculations accordingly.

3. In calculating the average ground level concentration (χ) using the Gaussian effluent dispersion model, you used an effective release height of 8 meters. Based on the information that you have provided us, we were unable to duplicate this figure. Please provide additional information on this point.

4. On the first page of your response to our letter of July 20, 1982, the 6th line of the 3rd paragraph, you refer to a significant factor of safety. It is not clear to us whether this safety factor refers to the effectiveness of your self-imposed limits to meet the limits specified in R12-1-407 or your commitment to limit the concentration to no more than 10% of those limits. Please clarify this point and give us an estimate of the safety factor and its basis.

5. Please give a projection of quantities of radioactive contaminated waste to be incinerated for the next five (5) years.

6. In Table 1 on the third page of your response to our July 20, 1981 letter, in the second column you specify X in terms of curies per milliliter. This is normally given in terms of curies per cubic meter or microcuries per milliliter. Please review this table and confirm or correct. You should add to this table realistic estimates of percentages of radioisotopes incinerated which will be emitted through the stack and which will be retained in ash, based on previously published research.

7. In Table 2, you give distances to site boundaries for each wind factor direction shown. Please clarify as to whether these are minimum distances, maximum distances, or actual measured distances in each case. Also, in this table, please specify whether the concentration figures given are at ground level or are maxima, and determine whether the point of maximum ground level concentrations occur within or outside the boundary.

8. The assumptions given on the page following Table 2 needs some clarification. According to a note given in the Journal Health Physics, Volume 24, No. 5, May, 1972, page 564 entitled "The Fate of Radioactive Materials Burnt in an Industrial Incinerator", essentially 100% of tritium, Carbon-14, and iodines will be released through the stack. Sulphur-35 and Tellurium-127m will be approximately evenly divided while the majority of the other isotopes will remain in the ash. Please review the available literature and reconsider your assumptions. With respect to assumptions 4 and 5, please provide additional information and clarify your meaning.

9. On your proposed ash analysis procedure, the analysis should be sufficient to quantify with reasonable accuracy, the amount of radioactive material remaining in the ash so that the amount which will be released via the stack can be quantified. We will need fairly detailed procedures specifying equipment and estimating for: lower limits of detection; confidence limits; sample error; and overall error in order to adequately judge your procedure. The same considerations will apply to your proposed air sampling system.

10. With respect to personnel dosimetry, please specify the type of dosimetry to be provided and the procedures and criteria to be used to ensure that all who may require personnel dosimetry are given same. Additionally, with respect to dosimetry to be provided to nearby residents, please give the procedures that will be used for receiving such requests. Finally, please provide calculations of individual and collective dosages which would accrue to personnel and surrounding residence.

11. Please confirm that all other necessary permits for the operation of this incinerator have been obtained and provide copies of same. Also provide copies of your procedure for notifying the cities of Tempe and Mesa and the Salt River Indian Reservation authorities when burns of radioactive material are to be made.

12. In order to comply with current standards, an application for waste disposal of this type must include a cost-benefit analysis of incineration versus other types of waste disposal and, in addition, a separate cost-benefit analysis related to the operation of this site, as opposed to operation of the incinerator at another location.

13. You have indicated an intent to institute stack monitoring using a system which appears to be based on EPA method 5. Please provide a complete description of this system and how it would operate. Also address a question of placing filters in the stack and what criteria you might use to determine whether or not such filters are necessary or would be of advantage. This may be part of your cost versus benefit analysis.

14. You should develop, establish and operate a system of environmental sampling to confirm calculated deposition and ground level concentrations as a function of location and MET regime for the radionuclides to be released. This is particularly important with respect to the Japanese truck farm located on the university approximately one mile (SW) from the incinerator site. Preoperational environmental sampling should also be considered.

15. When considering your projections of future radioactive material incineration and projected doses to the population and surrounding areas, you should also consider area growth factors and specific age sex factors.

16. Please consider and establish emergency operating procedures evaluating the type of emergencies which could occur and the appropriate response to each.

17. In addition to assuring compliance with the Agency's rules and regulations, as found in Article 4, please review the following federal regulations to ensure compliance with them. Title 10, Code of Federal Regulations, Parts 20.104B; 20.105B1-B2; 20.106.C.2. (I. through IV); 20.106.C.3.; C.6, D and E.

Upon receipt of the above requested information, we will continue to review your request and issue the amendment as soon as possible.

Sincerely,

Richard L. Blanton

Richard Blanton, Health Physicist
Radioactive Materials

RB:jr

(28A)

April 22, 1982

MEMORANDUM

TO: Dick Blanton, HP, ARRA

FROM: Richard F. Brown, Radiation Protection Officer

SUBJECT: Submission of letter to all Agreement States; notification of

1. I have prepared and sent a letter (copy enclosed) to all agreement states as required by my DOE grant.

2. As replys arrive, I will send you a copy for your files.

NOTE: I have received your letter of 4-18-82 requesting additional information concerning our application for incineration ammendment. I would like to come to your office with Scott to diesuss a couple of points prior to preparing a reply. Please call and let me know a convient time for Scott and I to come over.

Enclosure

(35)

ARIZONA STATE
UNIVERSITY TEMPE, ARIZONA 85281

UNIVERSITY RADIATION SAFETY OFFICE
c/o COLLEGE OF ENGINEERING (D-102) (602) 965-6140

July 19, 1982

Richard Blanton
Health Physicist
Radioactive Materials
Arizona Radiation Regulatory Agency
925 S. 52nd St., Suite 2
Tempe AZ 85281

Dear Mr. Blanton,

Enclosed is our response to your request for additional information concerning our request for an amendment which would allow disposal of low-level radioactive waste by incineration to our license # 7-37. If you have any further questions, we would be happy to meet with you to discuss the amendment.

Thank you for your consideration.

Sincerely,

Richard F. Brown

Richard F. Brown
Radiation Protection Officer

1. To demonstrate compliance with the limits specified in R12-1-407 at the incinerator stack we will again limit χ, the concentration at release to 10% of the limits previously specified. As before we have calculated the maximum activity which may be incinerated while maintaining these limits. Our results are presented in Table 1.

TABLE 1

Maximum Releases Of Radionuclides From Stack

Isotope	χ_1 (uCi/ml)	χ_2 (uCi/ml)	Q(uCi)	Percent Released
H-3	$2(10^{-7})$	$2(10^{-8})$	1159.2	~100
C-14	$1(10^{-7})$	$1(10^{-8})$	579.0	~100
Na-22	$6(10^{-9})$	$6(10^{-10})$	34.7	
P-32	$2(10^{-9})$	$2(10^{-10})$	11.58	5-10
S-35	$9(10^{-9})$	$9(10^{-10})$	52.11	50
Cl-36	$1(10^{-8})$	$1(10^{-9})$	57.90	
Co-60	$1(10^{-8})$	$1(10^{-9})$	57.90	0
Sr-90	$3(10^{11})$	$3(10^{-12})$	1.737	
I-125	$8(10^{11})$	$8(10^{-12})$	0.463	~100
Te-127m	$5(10^{-9})$	$5(10^{-10})$	28.95	
I-131	$1(10^{10})$	$1(10^{-11})$	0.579	~100
Cs-137	$2(10^{10})$	$2(10^{-11})$	1.159	80-100

χ_1 = limits prescribed in R12-1-407

χ_2 = 10% of limits prescribed in R12-1-407

Q = Maximum activity which may be incinerated in an 8 hour period under the limits of χ

2. Calculations were submitted for an eight hour burn time because it was originally thought that this was the incinerator's design burn time. It has since been discovered that the design burn time is five hours, however we still feel that our calculations using the eight hour burn time provide the best estimate of our releases because the five hour timer is reactivated after every charge. Therefore, for most burns the incinerator will be in operation for at least eight hours or longer. Additionally, the Nuclear Regulatory Commission has approved several license amendments based on calculations performed for a 24 hour burn time whether or not the incinerator is in operation for that period of time.

3. Our use of eight meters as our effective release height was based on a very conservative estimate of stack height along with effluent velocity. A more accurate calculation (below) yields an effective release height of 9.51m.

$$H_{release} = H_{stack} + \Delta H_{effluent}$$

$$= H_{stack} + \frac{V_s d}{u}\left[1.5 + 2.68(10^{-3})p\,\frac{T_s - T_a}{T_s}\,d\right]$$

$$= 6.71\text{m} + \frac{(7.68\text{m/s})\left(\frac{20\text{in}}{39.7\text{in}}\,\text{m}\right)}{3.92\text{m/s}}\left[1.5 + 2.68(10^{-3})(1013\text{mb})\right] \times \left[\frac{1273 - 20}{1273}\right]\frac{20}{39.7}$$

$\therefore\ H_{release} = 9.51$ m.

$u \sim$ wind speed affecting plume

4. The "Factor of Safety" which you refer to is based on the ability of our self imposed limits to allow us to maintain an effluent concentration far below the agencies R12-1-407 limits. Therefore, if we maintain our self imposed limits we will always have a factor of safety of at least one order of magnitude.

5. During the next five years the Radiation Protection Office plans to incinerate an average of approximately 100-125 mCi per year allowing for decay. This should build to a maximum of approximately 150 mCi during the fifth year. All radionuclides received for disposal with half lives of less than 60 days will be stored for decay before incinerating to further demonstrate our commitment to the ALARA philosophy.

6. Due to a typographical error the character "μ" was omitted for Table 1 in our response. χ should be specified in terms of micro curies (uCi) per milliliter.

7. The distances given in Table 2 were estimated from the site map on the next page. The concentration figures presented are at ground level. Concentration at maxima for the specified directions are given in Table 2.

TABLE 2

$\chi_f(10^{-3})pCi/m^3$

ISOTOPE	Q1	NORTH	NE	E	SE	S	SW	W	NW
H-3	32.602	2.125	2.21	1.48	1.78	1.344	1.14	6.16	3.88
C-14	16.031	1.04	1.086	.726	.873	.659	.558	3.02	1.903
Na-22	1.28	.083	.0866	.0579	.0696	.0526	.0445	.241	.152
P-32	12.0	.78	.81	.544	.654	.495	.419	2.27	1.43
S-35	0.01	.00065	.0068	.00045	.00054	.000412	.00035	.00139	.00119
Cl-36	0.125	.00812	.00848	.00566	.00681	.00515	.00276	.0236	.0149
Co-60	0.043	.00279	.00291	.00195	.00234	.00177	.00150	.00811	.0051
Sr-90	0.016	.00104	.00109	.000726	.000873	.000659	.000558	.00302	.0019
I-125	61.25	3.98	4.16	2.776	3.34	2.52	2.14	11.57	7.28
Te-127m	0.002	.00013	.00036	.0000907	.000109	.0000824	.0000698	.000378	.000238
I-131	0.005	.000325	.000339	.000227	.0042	.000206	.000174	.000945	.000595
Cs-137	4.5	.292	.305	0.204	.245	.185	.157	.049	.534

9. Ash Analysis Procedure

1) Pull samples from several radial distances from centerline.

2) Disolve samples in nitric acid solution.

3) Pull through fritted filter and neutralize to pH of 6.5-70.

4) Pipet 1.0 ml into scintillation vial.

5) Add scintillation flour and count in Beckman 100-C liquid scintillation counter.

10. Film badges will be provided to all ASU Radiation Protection office representatives working at the site. Additionally film badges will be provided for all lab technicians employed at the ASU Laboratory Animal Care Facility who will be working in close proximity to the incinerator. We will also provide dosimetry to several residents of the mobile home park which is near the site. Representatives of the park who would like to participate will be asked to volunteer through the park's Homeowner's Association. We will also provide dosimetry at several locations at the park. Estimates of the inhalation dose which would be received at the site boundaries are tabulated below.

DOSE ESTIMATES AT SITE BOUNDARIES

Direction	Distance (m)	Inhalation Dose (mrem/yr)		
		Adult	Teen	Child
North	125	$1.69(10^{-3})$	$1.31(10^{-3})$	$5.61(10^{-4})$
Northeast	175	$1.77(10^{-3}$	$1.26(10^{-3})$	$5.89(10^{-4})$
East	425	$1.17(10^{-3})$	$8.42(10^{-4})$	$3.94(10^{-4})$
Southeast	320	$1.41(10^{-3})$	$1.10(10^{-3})$	$4.75(10^{-4})$
South	125	$1.07(10^{-3})$	$8.29(10^{-4})$	$3.52(10^{-4})$
Southwest	200	$9.01(10^{-4})$	$7.03(10^{-4})$	$3.03(10^{-4})$
West	150	$4.9(10^{-3})$	$3.65(10^{-3})$	$1.64(10^{-3})$
Northwest	175	$3.09(10^{-3})$	$2.39(10^{-3})$	$1.03(10^{-3})$

11. See enclosures. Copies of permits received from Arizona Department of Health Services will be forwarded to your office as soon as we receive them.

12. The table below shows a simplified cost-benefit analysis for operation of the ASU incinerator at the Laboratory Animal Care Facility vs. shipping waste to a low level waste disposal site.

Incinerate Waste		Ship Waste	
Pick up waste and transport to incinerator	0.7 hrs	Pick up waste & transport to RSO warehouse	0.5
Incinerate Waste	1.0 hr	Put liners into drum	0.1
Clean Incinerator and dispose of ashes	0.5 hr	Fill drum with waste	0.5
		Seal and ship waste	0.1
Total per barrel	2.2 hr		1.2
Cost per barrel	$22		$12

Incinerate Waste		Ship Waste	
		Drum	17.50
		Liner	2.00
		Absorbent	6.00
		Shipping	200.00
Supplies per drum	Neg.		225.50
Capital	0		0
Equipment			
Misc	Miscellaneous expenses will be approximately equal for both methods of disposal.		

Expenses

Incinerator already installed and paid for through University Lab Animal Care Program.

Therefore, we have a net difference in cost of approximately 215.00 per barrel of waste disposed. If we assume an average of 75 barrels of waste shipped from the ASU campus per year, the net cost difference would be approximately $16,200 per year.

13. Our stack monitoring will be done with a simple air sampling system. The cost of instituting a system based on the EPA method five sampling train would be prohibitive and no significant results could be expected. Regarding the question of placing filters in the stack: This incinerator has been rated at a particulate output of 0.03 grains per dry standard cubic foot (EPA maximum is 0.08 g/ft^3). Therefore the quality filters necessary to reduce the particulate output would represent a significant expenditure with little or no real advantage.

16. The Radiation Protection Office will, in the unlikely event of an emergency, follow the guidelines established in the University Radiation Safety Manual.

17. We envision no potential operations of the incinerator which will involve the regulations you have cited.

APPENDIX A

DOSE RATE DATA

NORTH

ISOTOPE	DFA ADULT	DFA TEEN	DFA CHILD	Xi	Xi DFA ADULT	Xi DFA TEEN	Xi DFA CHILD
H-3	1.34E-7	1.06E-6	2.03E-7	2.12E-2	2.84E-9	2.25E-8	4.30E-9
C-14	4.27E-7	5.66E-6	1.69E-6	1.04E-2	4.44E-9	5.89E-8	1.76E-8
Na-22	1.30E-5	1.76E-5	4.42E-5	0.08E-2	1.04E-8	1.408E-8	3.54E-8
P-32	6.27E-6	6.27E-6	6.27E-6	0.78E-2	4.89E-8	4.89E-8	4.89E-8
Co-60	1.85E-6	2.06E-7	5.07E-7	0.00279E-2	5.16E-11	5.79E-12	1.41E-5
Sr-90	7.62E-4	9.04E-5	2.70E-4	0.00104E-7	7.92E-9	9.4E-10	2.81E-9
Te-127m	1.96E-7	1.96E-7	1.96E-7	.00013E-2	2.55E-13	2.55E-13	2.55E-13
I-131	2.56E-6	3.52E-6	9.47E-6	.000325E-2	8.32E-12	1.14E-11	3.08E-11
Cs-137	5.36E-5	3.79E-5	3.38E-5	.292E-2	1.57E-7	1.11E-7	9.87E-8
				Total	2.32E-7	2.563E-7	2.0776E-7
				Dose Rate	1.69E-3 mrem/yr	1.31E-3 mrem/yr	5.61E-4 mrem/yr

NORTHEAST

ISOTOPE	DFA ADULT	DFA TEEN	DFA CHILD	Xi	Xi DFA ADULT	Xi DFA TEEN	Xi DFA CHILD
H-3	1.34E-7	1.06E-6	2.03E-7	2.21E-2	2.96E-9	2.34E-9	4.49E-9
C-14	4.27E-7	5.66E-6	1.69E-6	1.086E-2	4.64E-9	6.15E-8	1.84E-8
Na-22	1.30E-5	1.76E-5	4.42E-5	0.0866E-2	1.13E-8	1.52E-8	3.83E-8
P-32	6.27E-6	6.27E-6	6.27E-6	.81E-2	5.08E-8	5.08E-8	5.08E-8
Co-60	1.85E-6	2.06E-7	5.07E-7	2.91E-5	5.38E-11	6.0E-12	14.75E-11
Sr-90	7.62E-4	9.04E-5	2.7E-4	1.09E-5	8.3E-9	9.85E-10	2.94E-9
Te-127m	1.96E-7	1.96E-7	1.96E-7	1.36E-6	2.66E-13	2.66E-13	2.66E-13
I-131	2.56E-6	3.52E-6	9.47E-6	3.39E-6	8.57E-12	1.18E-11	3.17E-11
Cs-137	5.36E-5	3.79E-5	3.38E-5	3.05E-3	1.64E-7	1.16E-7	1.03E-7
				Total	2.42E-7	2.468E-7	2.18E-7
				Dose Rate	1.767E-3	1.26E-3	5.189E-4

EAST

ISOTOPE	DFA ADULT	DFA TEEN	DFA CHILD	Xi	Xi DFA ADULT	Xi DFA TEEN	Xi DFA CHILD
H-3	1.34E-7	1.06E-6	2.03E-7	1.48E-2	1.98E-9	1.57E-9	3.00E-9
C-14	4.27E-7	5.66E-6	1.69E-6	7.26E-3	3.10E-9	4.11E-8	1.23E-8
Na-22	1.30E-5	1.76E-5	4.42E-5	5.79E-4	7.53E-9	1.02E-8	2.56E-8
P-32	6.27E-6	6.27E-6	6.27E-6	5.44E-3	3.41E-8	3.41E-8	3.41E-8
Co-60	1.85E-6	2.06E-7	5.07E-7	1.95E-5	3.63E-11	4.02E-12	9.89E-12
Sr-90	7.62E-4	9.04E-5	2.7E-4	7.26E-6	5.53E-9	6.56E-10	1.96E-9
Te-127m	1.8E-7	1.96E-7	1.96E-7	9.07E-7	1.78E-13	1.78E-13	1.78E-13
I-131	2.56E-6	3.52E-6	9.47E-6	2.27E-6	5.81E-12	7.99E-12	2.15E-11
Cs-137	5.36E-5	3.79E-5	3.38E-5	2.04E-3	1.09E-7	7.73E-8	6.90E-8
				Total	1.61E-7	1.65E-7	1.46E-7
				Dose Rate	1.17E-3	8.42E-4	3.94E-4

SOUTHEAST

ISOTOPE	DFA ADULT	DFA TEEN	DFA CHILD	Xi	Xi DFA ADULT	Xi DFA TEEN	Xi DFA CHILD
H-3	1.34E-7	1.06E-6	2.03E-7	1.78E-2	2.38E-9	1.89E-8	3.61E-9
C-14	4.27E-7	5.66E-6	1.69E-6	8.73E-3	3.73E-9	4.94E-8	1.47E-8
Na-22	1.30E-5	1.76E-5	4.42E-5	6.96E-4	9.05E-9	1.22E-8	3.08E-8
P-32	6.27E-6	6.27E-6	6.27E-6	6.54E-3	4.10E-8	4.10E-8	4.10E-8
Co-60	1.85E-6	2.06E-7	5.07E-7	2.34E-5	4.33E-11	4.82E-12	1.19E-11
Sr-90	7.62E-4	9.04E-5	2.7E-4	8.73E-6	6.65E-9	7.89E-10	2.36E-9
Te-127m	1.96E-7	1.96E-7	1.96E-7	1.09E-6	2.14E-13	2.14E-15	2.14E-13
I-131	2.56E-6	3.52E-6	9.47E-6	4.2E-5	1.08E-10	1.48E-10	3.98E-10
Cs-137	5.36E-5	3.79E-5	3.38E-5	2.45E-3	1.31E-7	9.29E-8	8.28E-8
				Total	1.94E-7	2.15E-7	1.76E-7
				Dose Rate	1.41E-3	1.10E-3	4.75E-4

SOUTH

ISOTOPE	DFA ADULT	DFA TEEN	DFA CHILD	Xi	Xi DFA ADULT	Xi DFA TEEN	Xi DFA CHILD
H-3	1.34E-7	1.06E-6	2.03E-7	1.344E-2	1.80E-9	1.42E-8	2.73E-9
C-14	4.27E-7	5.66E-6	1.69E-6	6.59E-3	2.81E-9	3.73E-8	1.11E-8
Na-22	1.30E-5	1.76E-5	4.42E-5	5.26E-4	6.84E-9	9.26E-9	2.32E-8
P-32	6.27E-6	6.27E-6	6.27E-6	4.95E-3	3.10E-8	3.10E-8	3.10E-8
Co-60	1.85E-6	2.06E-7	5.07E-7	1.77E-5	3.27E-11	3.65E-12	8.97E-12
Sr-90	7.62E-4	9.04E-5	7.76E-4	6.59E-6	5.02E-9	5.96E-10	1.78E-9
Te-127m	1.96E-7	1.96E-7	1.96E-7	8.24E-7	1.61E-13	1.61E-13	1.61E-13
I-131	2.56E-6	3.52E-6	9.47E-6	2.06E-6	5.27E-12	7.25E-12	1.95E-11
Cs-137	5.36E-5	3.79E-5	3.38E-5	1.85E-3	9.92E-8	7.01E-8	6.25E-8
				Total	1.47E-7	1.62E-7	1.32E-7
				Dose Rate	1.07E-3	8.29E-4	3.57E-4

SOUTHWEST

ISOTOPE	DFA ADULT	DFA TEEN	DFA CHILD	Xi	Xi DFA ADULT	Xi DFA TEEN	Xi DFA CHILD
H-3	1.34E-7	1.06E-6	2.03E-7	1.14E-2	1.53E-9	1.21E-8	2.31E-9
C-14	4.27E-7	5.66E-6	1.69E-6	5.58E-3	2.38E-9	3.16E-8	9.43E-9
Na-22	1.30E-5	1.76E-5	4.42E-5	4.45E-4	4.78E-9	7.83E-9	1.97E-8
P-32	6.27E-6	6.27E-6	6.27E-6	4.19E-3	2.63E-8	2.63E-8	2.63E-8
Co-60	1.85E-6	2.06E-7	5.07E-7	1.5E-5	2.77E-11	3.09E-12	7.6E-12
Sr-90	7.62E-4	9.04E-5	2.70E-4	5.58E-6	4.25E-9	5.04E-10	1.51E-9
Te-127m	1.96E-7	1.96E-7	1.96E-7	6.98E-7	1.37E-13	1.37E-13	1.37E-13
I-131	2.56E-6	3.52E-6	9.47E-6	1.74E-6	4.45E-12	6.12E-12	1.65E-11
Cs-137	5.36E-5	3.79E-5	3.38E-5	1.57E-3	8.42E-8	5.95E-8	5.31E-8
				Total	1.23E-7	1.378E-11	1.12E-7
				Dose Rate	9.01E-4	7.03E-4	3.03E-4

WEST

ISOTOPE	DFA ADULT	DFA TEEN	DFA CHILD	Xi	Xi DFA ADULT	Xi DFA TEEN	Xi DFA CHILD
H-3	1.34E-7	1.06E-6	2.03E-7	6.16E-2	8.25E-9	6.53E-8	1.25E-8
C-14	4.27E-7	5.66E-6	1.69E-6	3.02E-2	1.29E-8	1.71E-7	5.10E-8
Na-22	1.30E-5	1.76E-5	4.42E-5	2.41E-3	3.13E-8	4.24E-8	1.07E-7
P-32	6.27E-6	6.27E-6	6.27E-6	2.27E-2	1.42E-7	1.42E-7	1.42E-7
Co-60	1.85E-6	2.06E-7	5.07E-7	8.11E-5	1.50E-10	1.67E-11	4.11E-11
Sr-90	7.62E-4	9.04E-5	2.70E-4	3.02E-5	2.30E-8	2.73E-9	8.15E-9
Te-127m	1.96E-7	1.96E-7	1.96E-7	3.78E-6	7.41E-13	7.41E-13	7.41E-13
I-131	2.56E-6	3.52E-6	9.47E-6	9.45E-6	2.42E-11	3.33E-11	8.95E-11
Cs-137	5.36E-5	3.79E-5	3.38E-5	8.49E-3	4.55E-7	3.22E-7	7.87E-7
				Total	6.73E-7	7.15E-7	6.08E-7
				Dose Rate	4.91E-3	3.65E-3	1.64E-3

NORTHWEST

ISOTOPE	DFA ADULT	DFA TEEN	DFA CHILD	Xi	Xi DFA ADULT	Xi DFA TEEN	Xi DFA CHILD
H-3	1.34E-7	1.06E-6	2.03E-7	3.88E-2	5.20E-9	4.11E-8	7.88E-9
C-14	4.27E-7	5.66E-6	1.69E-6	1.903E-2	8.12E-9	1.08E-7	3.22E-8
Na-22	1.30E-5	1.76E-5	4.42E-5	1.52E-3	1.98E-8	2.68E-8	6.72E-8
P-32	6.27E-6	6.27E-6	6.27E-6	1.43E-2	8.97E-8	8.97E-8	8.97E-8
Co-60	1.85E-6	7.06E-7	5.07E-7	5.1E-5	9.44E-11	1.05E-11	2.59E-11
Sr-90	7.62E-4	9.04E-5	2.7E-4	1.9E-5	1.45E-8	1.72E-9	5.13E-9
Te-127m	1.96E-7	1.96E-7	1.96E-7	2.38E-6	4.66E-13	4.66E-13	4.66E-13
I-131	2.56E-6	3.52E-6	9.47E-6	5.95E-6	1.52E-11	2.09E-11	5.63E-11
Cs-137	5.36E-5	3.79E-5	3.38E-5	5.34E-3	2.86E-7	2.02E-7	1.80E-7
				Total	4.23E-7	4.69E-7	3.82E-7
				Dose Rate	3.09E-3	2.39E-3	1.03E-3

APPENDIX B

NOTIFICATION OF ADJOINING COMMUNITIES

ARIZONA STATE
UNIVERSITY TEMPE, ARIZONA 85281

UNIVERSITY RADIATION SAFETY OFFICE
c/o COLLEGE OF ENGINEERING (D-102) (602) 965-6140

July 20, 1982

NOTE Original copies sent to:

The Honorable Don Strauch
Mayor of Mesa

The Honorable Harry E. Mitchell
Mayor of Tempe

The Honorable Herschel Andrews
Salt River Pima Tribal President

This letter is to advise you of the intentions of ASU to incinerate "Low-Level Radioactive Waste" (LLRAW) at the pathological incinerator located on ASU property near Price Rd. and First Ave. in Tempe.

I have been given the responsibility of coordinating this project. The proceeding papagraphs contain a brief explanation and some background information concerning this project. I welcome any comments and questions you may have and would enjoy meeting with you and any interested governmental parties to discuss the issue.

We first began the project about one year ago by burning representative non-radioactive waste of the same nature as the LLRAW generated by various ASU laboratories. This was done to monitor stack effluent and determine whether or not the results were within Air Quality Control Board (AQCB) limitations. We expect to complete the initial testing and receive AQCB approval within the next two weeks.

We submitted a request to Arizona Radiation Regulatory Agency (ARRA) in May of 1981 for an amendment to our Radiation Material License which would allow us to dispose of LLRAW by incineration. The ARRA cannot act officially on our request until we receive approval from the AQCB. However, they (ARRA) have been following the project closely inasmuchas ASU is the first in Arizona to request such authorization.

You may rest assured that we are going to meet all standards of the AQCB and ARRA and will make every possible effort to set our own standards at least a magnitude below those prescribed.

Again, let me extend my invitation for you to meet with me and discuss any questions or comments you may have.

Very sincerely yours,

Richard F. Brown

Richard F. Brown
Radiation Protection Officer

Appendix B

License Amendment Request

(62)

ARIZONA STATE
UNIVERSITY TEMPE, ARIZONA 85287

UNIVERSITY RADIATION PROTECTION
MCALLISTER OFFICE COMPLEX 130-B (602) 965-6140/6190

July 18, 1983

Arizona Radiation Regulatory Agency
925 S. 52nd Street, Suite 2
Tempe, AZ 85281

Gentlemen:

Enclosed you will find an updated report and summary of information previously submitted regarding our request for a license amendment to incinerate hazardous and low-level radioactive waste.

Please contact us if you have any questions or further requirements concerning an amendment.

Thank you.

Sincerely,

Carla Greenup
Student Research

Richard F. Brown
Radiation Protection Officer

Enclosure

CCG/jls

INCINERATION OF HAZARDOUS AND LOW-LEVEL RADIOACTIVE WASTE AT ARIZONA STATE UNIVERSITY

LICENSE AMENDMENT REQUEST

July 1983

Carla Greenup . . . . . .Student Researcher

Richard Brown . . . . . .Radiation Protection Officer

Assisted by

Scott Miller . . . . . .preliminary research

Ronald Daggett . . . . . .computer inventory program

Thomas Hjellming . . . . . .technical assistance

Robert Krouch . . . . . .vinyl chloride analysis

Ken Evans . . . . . .weather reports

Work sponsored in part by the Department of Energy, Grant #DE-FG06-81ID12228 administered through EG&G Idaho, Inc.

TABLE OF CONTENTS

Table of Contents Cont.

ABSTRACT

This report is a summary of the information required by the Arizona Radiation Regulatory Agency to obtain a license amendment which would permit incineration of hazardous and low-level radioactive waste in a small (175 lb/hr.), pathological incinerator. We intend to incinerate approximately 21 isotopes per year, totaling no more than 220,000 μCi of activity. This amount constitutes 99.8% of the expendable low-level radioactive waste on campus. Volume and weight reductions, from 90-20/1 and 90-6/1, respectively, will result in substantial savings of money and storage space to the University. Calculations for concentrations and doses are included in the report, along with waste management and monitoring procedures, and public relations correspondence.

INCINERATOR CHARACTERISTICS

The incinerator is located on ASU property at Price Road and 1st Street in Tempe. It was installed adjacent to the Lab Animal Care Facility (LACF) in Dec., 1980, when the LACF was also built. It was to be used for pathological waste generated by ASU labs.

The specifications are as follows:

CONSUMAT Model # C-75P

Dual Chamber - Controlled Air

175 lb/hr (75 cu ft/hr) Capacity

2 Chambers, 3 Burners (natural gas)

Lower: 2 burners 250,000 Btu/hr
operating temp. 1500°F

Upper: 1 burner 700,000 Btu/hr
operating temp. 1800°F

Stack Ht.: 2.7 m (9 ft)

Total Ht.: 6.4 m (21 ft)

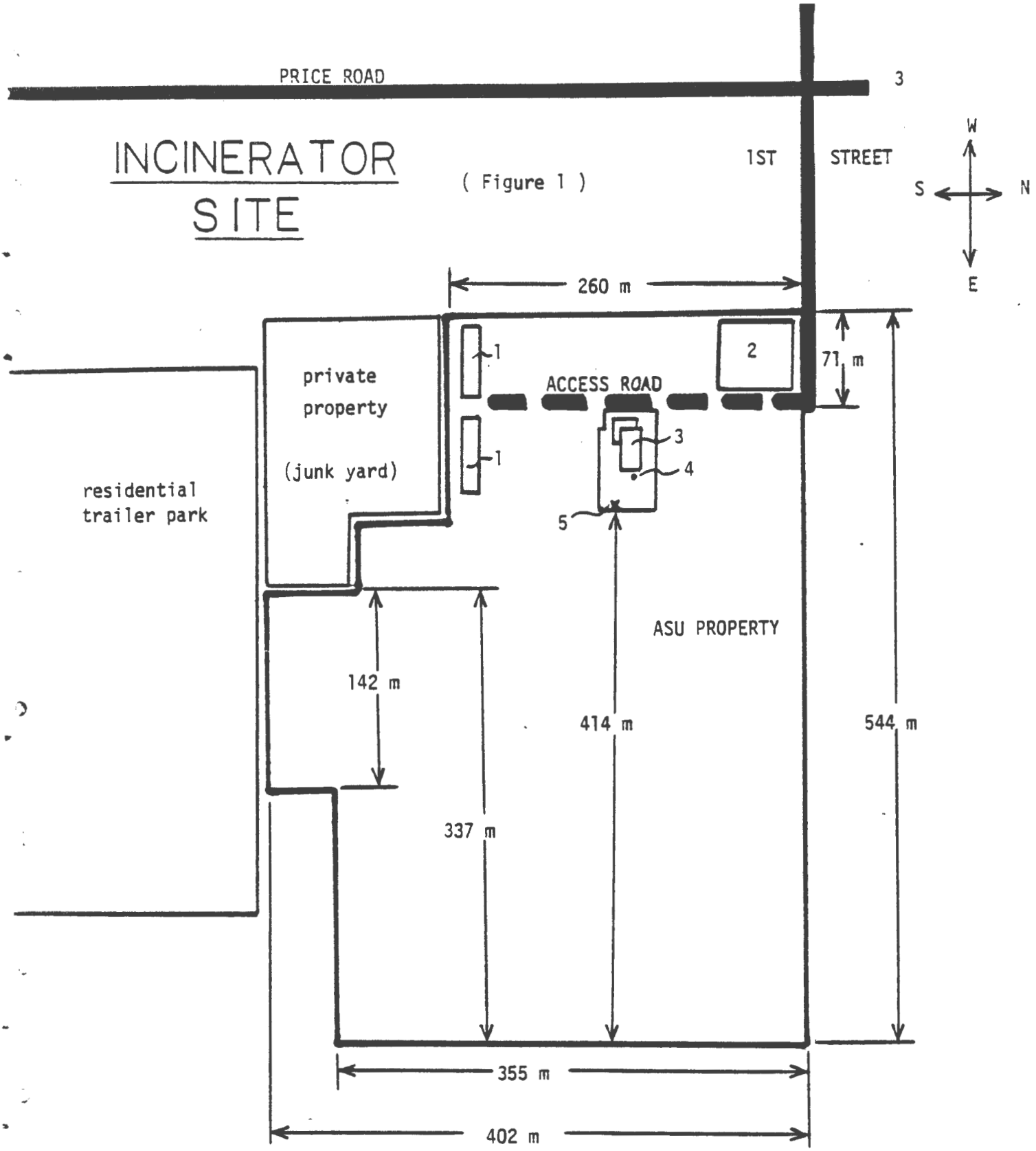
Inside Diameter of Stack: 0.4572 m (1.5 ft)

Emission Rate: 7.68 m/sec 1.26×10^6 ml/sec

See Appendix K for further specifications and a diagram of the incinerator.

INCINERATOR SITE

(Figure 1)



1. ASU surplus warehouses
2. ASU site security residence
3. ASU Lab Animal Care Facility
4. Current incinerator location
5. Future incinerator location

WASTE ANALYSIS

Table 1, below, lists a current inventory of isotopes used at ASU.

Table 1 ISOTOPE INVENTORY

TOTAL WASTE (%)		CATEGORY	ISOTOPE	INVENTORY (uCi)	
99.8 Will incinerate	7.7	1	H-3	153,190	
			C-14	40,000	
	3.8	2	Na-22	498	
			Cl-36	193	
			Sr-90	8,500	
			I-129	0.75	
	2.5	3	Ca-45	6,003	
			Mn-54	0	
			Eu-154	0	
			Eu-155	0	
	4.6	4	Ni-63	989	
			Zn-65	0	
			Pm-147	1,000	
			Sm-151	9,522	AFTER DECAY*
	11.9	5	Na-24	0	0
			K-42	0	0
			P-32	19,640	20
			P-33	0	0
			Rb-86	0	0
			S-35	10,000	157
			I-125	380	0.38
0.2 Will not incinerate		6	Po-210	100	
			Ra-226	2	
			Th-230	9	
			U-233	9	
			Pu-239	100	
			Am-241	100	
			Cm-244	100	
			TOTAL	250,155.75	211,993.13

*See next page for decay in storage procedure

Each category of waste in Table 1 denotes a separate waste receptacle within each lab for the various isotopes. This separation scheme was devised to simplify the disposal of each group.

All waste receptacles are picked up from the labs by the health physics technician and stored in a warehouse on campus until disposal.

Categories 1-4 may be incinerated immediately . Category 5 waste is stored for decay (see Table #2) and then incinerated accordingly. Category 6 waste will not be incinerated. It is stored in the warehouse until shipped to a low-level waste repository.

Procedure For Decay In Storage

The short-lived isotopes of category 5 waste (from Table 1) will be stored for decay of 10 half-lives (except S-35*), and then incinerated accordingly.

Table 2 DECAY IN STORAGE

ISOTOPE	HALF-LIFE	TIME FOR 10 HALF-LIVES	QUANTITY AFTER DECAY (uCi)
Na-22	15h	6 days	0
K-42	12.4h		0
P-32	14.3d	8 mos.	20
P-33	24.4d		0
Rb-86	18.6d		0
*S-35	88d	1.5 yrs.	157
I-125	60.2d		0.38

*Because of the longer half-life of S-35, it will be stored with I-125 waste for only 6 half-lives in 1.5 years.

Table 3 contains data from an analysis of previous shipping records.

Table 3 PREVIOUS SHIPMENT DATA
(as of 9/82)

DATE SHIPPED	NO. DRUMS SHIPPED	NO. MONTHS WASTE COLLECTED	DRUMS/ MONTH	COST/DRUM FOR SHIPPING	TOTAL COST/SHIPMENT	INCREASE IN COST/DRUM SINCE PREVIOUS SHIMPMENT
6/25/74	3	-----	----	no records	no records	no records
1/15/75	7	7	1	no records	no records	no records
12/17/75	10	11	.9	25.00	250.00	----------
7/15/76	15	7	2.1	28.00	420.00	1.3 x
4/28/77	17	9	1.9	36.00	612.00	1.6 x
1/13/78	21	9	2.3	45.50	955.00	1.5 x
2/07/79	38	13	2.9	73.90	2802.10	1.9 x
6/23/80	57	16	3.6	106.67	6080.03	1.6 x
9/30/82	47 82 *	26	3.2	600.00	28200.00	5.6 x

*82 drums was the amount collected since the last shipment; 47 was the amount still in storage.

There are approximately 40 drums of waste collected per year. This number is expected to increase by 3.6 drums per year based on previous shipping data. (See Appendix B - Cost Analysis report)

The amount of waste collected in the next 5 years will be approximately 286 drums plus the 47 in storage since the last shipment for a total of 333 drums.

Assuming an even distribution of activity to volume, we can assume 99.8% of the volume may be incinerated.

Burning Rate

This amount of waste, 332 drums, may be incinerated at a rate of approximately 1.5 drums per week, operating 48 weeks per year.

The 1.5 drums of waste will be selected for burning according to isotope and volume.

The waste is manually fed to the incinerator over a period of 3.5 hours, and then the incinerator burns for five hours after the last load.

CONCENTRATION COMPLIANCE

The NRC incineration guidelines (Appendix A) require that a licensee comply to the MPC's in air given in 10 CFR 20 Appendix B Table II.

The guidelines suggest limiting the stack top concentration to the MPC values when averaged over a 24 hour period.

To comply with the ALARA philosophy, they suggest limiting the stack top concentration to 10% of the MPC averaged over one year.

To determine the amount of activity which may be burned without exceeding the suggested limits, the following calculations were made:

$Q(\mu Ci/sec) = \chi(\mu Ci/mL)/E(sec/mL)$ where

Q~quantity

χ~MPC from 10 CFR 20 Table II, Appendix B

E~inverse emission rate (or dilution factor)

E is calculated as follows:

$[V_S(m/sec)\ A(m^2)\ 1000(L/m^3)\ 1000(mL/L) = mL/sec]^{-1}$ where

V_S~stack velocity

A~stack area = πr^2

r~inside stack radius

Therefore $E = [(7.68)(3.14)(.2286)^2(1000)(1000)]^{-1}$

$$\boxed{E = 1.26 \times 10^{-6}\ sec/mL}$$

The calculations of Q based on averaging * the release time to 24 hours and one year are shown in Table 4 (following page).

* 86400 sec/24 hours $E = [1.09 \times 10^{11} \text{ (mL/24 hrs.)}]^{-1}$

3.15 x 10^7 sec/yr. $E = [3.97 \times 10^{13} \text{ (mL/yr.)}]^{-1}$

When the release times are averaged, the values for Q are very large. We could easily burn a full years inventory at ASU in one year following these guidelines. However, several other incinerators have been licensed using more conservative criterion. (See Appendix C for other studies.)

In order to be conservative, we shall calculate the maximum Q which may be burned and not exceed 10% of the MPC in 10 CFR 20 without using the allowable averaging. These calculations are based on an emission rate of 8.5 hours per burn and 48 burns per year.

30600 sec/burn $E = [3.86 \times 10^{10} \text{ (mL/burn)}]^{-1}$

1.47 x 10^6 sec/yr. $E = [1.85 \times 10^{12} \text{ (mL/year)}]^{-1}$

The results are shown in Table 5 (pg.10)

The last column in Table 5 shows the percent of the MPC from 10 CFR 20 at the stack when Q is assumed to be the total ASU inventory which would be burned in one year. As seen from those figures, most of the isotopes exceed the 10% limit. Therefore the 10% criterion is too conservative. These results agree with the study conducted by the University of North Carolina (see Appendix C-3).

The above mentioned study stresses the importance of considering atmospheric dispersion when assessing radionuclide emissions.

Maximum ground-level concentrations can be calculated from Figure 3.9 (Appendix D) in D. B. Turner's Workbook of Atmospheric Dispersion Estimates (Reference 2) as a function of effective stack height and meteorological stability.

The effective stack height is a function of windspeed.

Table 6 (page 11) shows the frequency and average windspeed in 8 directions. (See Appendix E).

Table 4 NRC SUGGESTED MAX. Q

ISOTOPE	MPC ^{X} (µCi/mL)	(uCi/burn)	^{Q} (µCi/yr)
H-3	$2x10^{-7}$	13700	$4.32x10^{10}$
C-14	$1x10^{-7}$	6860	$2.16x10^{10}$
Na-22	$3x10^{-10}$	21	$6.62x10^{7}$
Cl-36	$8x10^{-10}$	55	$1.73x10^{8}$
Sr-90	$3x10^{-11}$	2	$6.31x10^{6}$
I-129	$2x10^{-11}$	1.4	$4.42x10^{6}$
Ca-45	$1x10^{-9}$	69	$2.18x10^{8}$
Mn-54	$1x10^{-9}$	69	$2.18x10^{8}$
Eu-154	$1x10^{-10}$	6.9	$2.18x10^{7}$
Eu-155	$1x10^{-9}$	69	$2.18x10^{8}$
Ni-63	$2x10^{-9}$	137	$4.32x10^{8}$
Zn-65	$2x10^{-9}$	137	$4.32x10^{8}$
Pm-147	$2x10^{-9}$	137	$4.32x10^{8}$
Sm-151	$2x10^{-9}$	137	$4.32x10^{8}$
Na-24	$5x10^{-9}$	343	$1.08x10^{9}$
P-32	$2x10^{-9}$	137	$4.32x10^{8}$
P-33	$1x10^{-10}$	6.9	$2.18x10^{7}$
S-35	$9x10^{-9}$	617	$1.95x10^{9}$
K-42	$4x10^{-9}$	274	$8.64x10^{8}$
Rb-86	$2x10^{-9}$	137	$4.32x10^{8}$
I-125	$8x10^{-11}$	5.5	$1.73x10^{7}$

Table 5 "CONSERVATIVE" MAX. Q AT STACK

ISOTOPE	χ (μCi/mL) 10% MPC	Q (μCi/burn)	μCi/yr	ASU (μCi) INVENTORY	% MPC
H-3	2×10^{-8}	52.0	2490	153,190	66
C-14	1×10^{-8}	26.0	1240	40,000	74
Na-22	3×10^{-11}	0.08	3.7	500	308
Cl-36	8×10^{-11}	0.21	10	200	46
Sr-90	3×10^{-12}	0.008	0.4	8,500	52417
I-129	2×10^{-12}	0.005	0.25	0.75	7
Ca-45	1×10^{-10}	0.26	12	6,000	1110
Mn-54	1×10^{-10}	0.26	12	0	0
Eu-154	1×10^{-11}	0.03	1.2	0	0
Eu-155	1×10^{-10}	0.26	12	0	0
Ni-63	2×10^{-10}	0.52	25	1,000	93
Zn-65	2×10^{-10}	0.52	25	0	0
Pm-147	2×10^{-10}	0.52	25	1,000	93
Sm-151	2×10^{-10}	0.52	25	9,600	888
Na-24	5×10^{-10}	1.3	62	0	0
P-32	2×10^{-10}	0.52	25	20	2
P-33	1×10^{-11}	0.03	1.2	0	0
* S-35	9×10^{-10}	2.3	112	157	3
K-42	4×10^{-10}	1.0	50	0	0
Rb-86	2×10^{-10}	0.52	25	0	0
I-125	8×10^{-12}	0.02	1	0.38	0.9

*Amount left after decay

Table 6 WIND DATA

WIND DIRECTION	FREQUENCY (%)	AVG. SPEED (m/sec)
N	4.6	2.8
NE	13.8	3.1
E	27.0	2.8
SE	13.9	3.0
S	5.8	2.8
SW	13.8	3.2
W	14.4	3.4
NW	6.7	2.8

To be conservative, we used the maximum average windspeed of 3.4 (m/sec) to calculate the effective stack height, of 8.9 (m). (See Appendix F for calculations.)

The maximum ground-level concentration occurs at some intermediate stability category. Based on the average windspeed, stability category C is used for the maximum ground-level concentration calculations.

Figure 3-9 gives the distance (m) to the point of maximum ground-level concentration and the relative maximum concentration, as a function of effective stack height and stability class.

The maximum ground-level concentration can be calculated as follows:

$$\chi_{max} = (\chi^u/Q_{max})_{max} Q/u$$

where: χ_{max} - maximum ground-level concentration (μCi/mL)

$(\chi^u/Q_{max})_{max}$ - relative max. concentration (m^{-2})

Q - stack emission rate (μCi/sec)

u - wind velocity (m/sec)

Therefore:

$$(\chi^u/Q)_{max} = 1.4 \times 10^{-2}\ (m^{-2})$$

$$\chi_{max} = 1.4 \times 10^{-2}(m^{-2})[Q(\mu Ci/sec)/3.4(m/sec)][1 \times 10^{-6}(m^3/mL)]$$

By setting χ_{max} equal to 10% of the MPC in 10 CFR 20 for each isotope and using the maximum average windspeed, the maximum Q which can be burned in one year without exceeding 10% MPC at the point of maximum ground-level concentration* can be determined.

$$Q(\mu Ci/sec) = [3.4(m/sec)[10\%\ MPC\ (\mu Ci/mL)]/1.4 \times 10^{-2}(m^{-2})]\ 1x10^6(mL/m^3)$$

Q is then normalized to 8.5 hrs/burn and 48 burns/yr.

The results are shown in Table 7 (next page).

*The point of maximum ground-level concentration for an effective stack height of 8.9 (m) occurs at approximately 100 (m).

For the various average windspeeds shown in Table 6, the effective stack height varies from 8.9 (m) to 9.5 (m). From Figure 3-9 it is not possible to distinguish the difference in effective stack heights. Therefore, we shall assume the maximum ground-level concentration occurs at 100 (m) from the stack for each direction.

The last column in Table 7 shows the percent of MPC at maximum ground level when Q is assumed to be the total ASU inventory which would be burned in one year. The concentration for this amount is shown in column 5. As seen from those figures, all of the concentrations, except Sr-90, are well below the upper bound of 10% MPC.

Table 7 MAX. Q AT MAX. GROUND LEVEL

ISOTOPE	Q (uCi/burn)	Q (uCi/yr.)	ASU (uCi) INVENTORY	ACTUAL MAX. GROUND LEVEL CONC. (uCi/mL)	% MPC
H-3	149,000	7,130,000	153,190	4×10^{-10}	0.2
C-14	74,300	3,570,000	40,000	1×10^{-10}	0.1
Na-22	223	10,700	500	1.5×10^{-12}	0.5
Cl-36	595	28,500	200	2.1×10^{-13}	0.07
Sr-90	22	1,070	8,500	2.4×10^{-11}	79.0
I-129	15	713	0.75	2×10^{-15}	0.01
Ca-45	743	35,700	6,000	1.7×10^{-11}	1.7
Mn-54	743	35,700	0	0	0
Eu-154	74	3,570	0	0	0
Eu-155	743	35,700	0	0	0
Ni-63	1,490	71,300	1,000	2×10^{-12}	0.1
Zn-65	1,490	71,300	0	0	0
Pm-147	1,490	71,300	1,000	2×10^{-12}	0.1
Sm-151	1,490	71,300	9,600	2.6×10^{-11}	1.3
Na-24	3,720	178,000	0	0	0
P-32	1,490	71,300	20	6×10^{-14}	0.003
P-33	74	3,570	0	0	0
S-35	6,690	321,000	157	4.5×10^{-13}	0.005
K-42	2,970	143,000	0	0	0
Rb-86	1,490	71,300	0	0	0
I-125	60	2,850	0.38	8×10^{-16}	0.001

All of the data used in this analysis have been the most conservative estimates. For example, the total ASU activity inventory used for the annual concentration calculations was 250,155 µCi. The actual activity ordered last year was only 150,465 µCi.

This analysis proves that all of the isotopes at ASU which will be incinerated, except Sr-90, can easily be done so without exceeding 10% of the MPC from 10 CFR 20 at the point of maximum ground-level concentration, which is approximately 100 m from the stack in all directions. Because of the large inventory of Sr-90, 90% of the Sr-90 waste will be shipped. We shall limit the amount burned in one year to 1000 µCi.

Sum of Ratios

Since there will be a mixture of isotopes being incinerated, the "sum of ratios" method, from the note to Appendix B in 10 CFR 20, is calculated below and the results are shown in Table 8.

$$\frac{C_A}{MPC_A} + \frac{C_B}{MPC_B} + \frac{C_C}{MPC_C} \quad \ldots \leq 1$$

where:

The radionuclides A, B and C are present in concentration C_A, C_B and C_C, respectively.

Table 8 SUM OF RATIOS

CATEGORY	CALCULATION & RESULT	
H-3 C-14	$\frac{4\times10^{-10}}{2\times10^{-7}} + \frac{1\times10^{-10}}{1\times10^{-7}} = 0.003$	<1
Ca-45 Mn-54 Eu-154 Eu-155	$\frac{1.7\times10^{-11}}{1\times10^{-9}} + 0 + 0 + 0 = 0.017$	<1
Ni-63 Zn-65 Pm-147 Sm-151	$\frac{2\times10^{-12} + 0 + 2\times10^{-12} + 2.6\times10^{-11}}{2\times10^{-9}} = 0.015$	<1
Na-22 Cl-36 Sr-90 I-129	$\frac{1.5\times10^{-12}}{3\times10^{-10}} + \frac{2.1\times10^{-13}}{8\times10^{-10}} + \frac{2.4\times10^{-11}}{3\times10^{-11}} + \frac{2\times10^{-15}}{2\times10^{-11}} = 0.796$	<1
Na-24 P-32 P-33 S-35 K-42 Rb-86 I-125	$0 + \frac{6\times10^{-14}}{2\times10^{-9}} + 0 + \frac{4.5\times10^{-13}}{9\times10^{-9}} + 0 + 0 + \frac{8\times10^{-16}}{8\times10^{-11}} = 0.00009$	<1

DOSE ANALYSIS

Estimates of the annual dose can be calculated using the following equation*:

$$D_{ia} = R_a \chi_i DFA_{ia}$$

where:

D_{ia} - annual dose to the whole body of an individual in the age group "a" due to the inhalation of radionuclide "i". (mrem/yr.)

DFA_{ia} - inhalation dose factor (mrem/pCi). (Tables C-1 thru C-3; see Appendix G).

R_a - annual air intake (mL/yr). (See Appendix H for values.)

χ_i - concentration (pCi/mL)

*From NCR Regulatory Guide 1.109, Appendix C. (See AppendiX G).

The areas to be concerned about dose are at the stack, where occupational exposures may occur, and the residential areas near the site. The closest residence to the stack, the site security officer's trailer, is approximately 200(m)away. The next point of concern is a single residence and a trailer park approximately 300(m)away. (See Figure 2 on page 18).

The ground-level concentration for these distances can be determined by using Pasquill's model for Gaussian distribution (see Appendix D and Reference 2).

$$\chi = \frac{Q}{\pi\sigma_y\sigma_z u} \exp[-1/2(H/\sigma_z)^2]$$

(Eqn. 3-3 in Reference 2)

where:

χ - concentration (μCi/mL)

Q - emission rate (based on 10% MPC) (μCi/burn) = Table 7 values

σ_y, σ_z - horizontal and vertical standard deviations, respectively. (determined from Figure 3-2, 3 in Reference 2)

u - windspeed = 3.4(m/sec)

H - effective stack height = 8.9(m)

For 200(m) with maximum average windspeed (stability class C):

σ_y = 24(m)

σ_z = 14(m)

χ = Q(uCi/burn) 7.44×10^{-15}

For 300(m):

σ_y = 35(m)

σ_z = 20(m)

χ = Q(uCi/burn) 3.96×10^{-15}

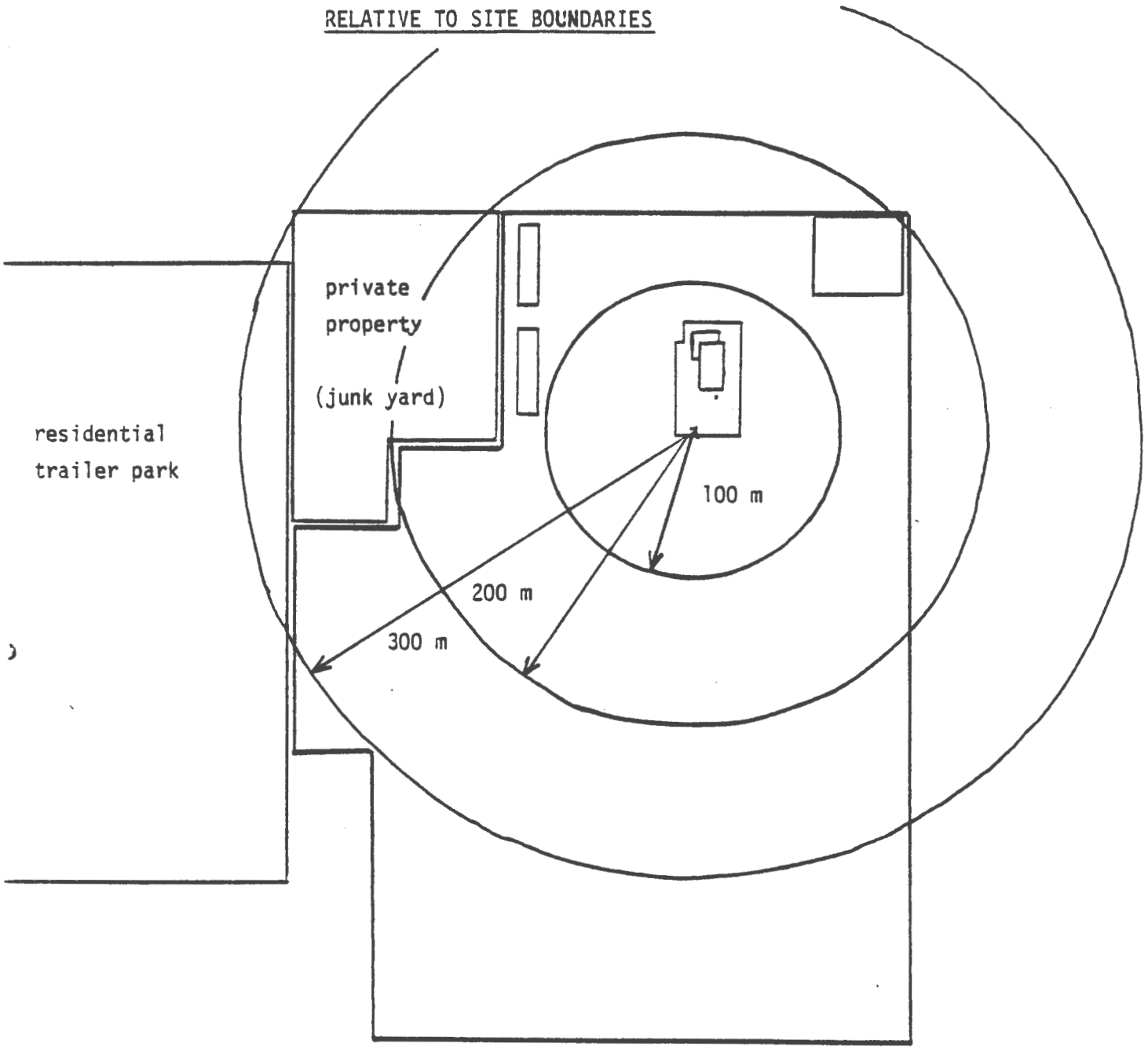
The results are shown in Table 9.

Dose estimates for adults, teens and children at the areas of interest (at the stack, 200 and 300(m) away) are shown in Tables 10.1-3, (pages 20,21).

The DFA conversion factor was not available for the isotopes not shown in Table 10.

However, since we are not going to exceed 10% of the MPC in air for any isotope, neither are we going to exceed the maximum permissible concentration in air for exposure, which is used to determine the maximum allowable dose, (Reference 1 and Appendix I).

Figure 2 MAXIMUM GROUND LEVEL CONCENTRATION LOCATION RELATIVE TO SITE BOUNDARIES



Maximun ground-level concentration occurs at 100 m.

Table 9 CONC. AT 200, 300(m)

ISOTOPE	χ (uCi/mL) at 200(m)	χ (uCi/mL) at 300(m)
H-3	2.4×10^{-11}	1.3×10^{-11}
C-14	6.2×10^{-12}	3.3×10^{-12}
Na-22	7.8×10^{-14}	4.1×10^{-14}
Cl-36	3.1×10^{-14}	1.7×10^{-14}
Sr-90	1.7×10^{-13}	8.8×10^{-14}
I-129	1.2×10^{-16}	6.2×10^{-17}
Ca-45	9.3×10^{-13}	4.9×10^{-13}
Mn-54	0	0
Eu-154	0	0
Eu-155	0	0
Ni-63	1.6×10^{-13}	8.3×10^{-14}
Zn-65	0	0
Pm-147	1.6×10^{-13}	1.6×10^{-13}
Sm-151	1.5×10^{-12}	7.9×10^{-13}
Na-24	0	0
P-32	3.1×10^{-15}	1.7×10^{-15}
P-33	0	0
S-35	2.4×10^{-14}	1.3×10^{-14}
K-42	0	0
Rb-86	0	0
I-125	5.9×10^{-17}	3.1×10^{-17}

DOSE ESTIMATES

Table 10.1 ADULTS

ISOTOPE	DFA (mrem/pCi)	D(mrem/yr) STACK	200(m)	300(m)
H-3	1.3×10^{-7}	4.3×10^{-2}	2.7×10^{-5}	1.5×10^{-5}
C-14	4.3×10^{-7}	7.6×10^{-2}	2.2×10^{-5}	1.2×10^{-5}
Na-22	1.3×10^{-5}	2.9×10^{-2}	8.4×10^{-6}	4.4×10^{-6}
P-32	6.3×10^{-6}	6.0×10^{-4}	1.6×10^{-7}	9.1×10^{-8}
Ni-63	1.8×10^{-6}	8.1×10^{-3}	2.4×10^{-6}	1.2×10^{-6}
Sr-90	7.6×10^{-4}	2.9×10^{1}	1.1×10^{-3}	5.5×10^{-4}
I-129	6.9×10^{-6}	2.3×10^{-5}	6.9×10^{-9}	3.6×10^{-9}
Pm-147	3.2×10^{-6}	1.4×10^{-2}	4.4×10^{-6}	4.4×10^{-6}
Sm-151	3.6×10^{-6}	1.5×10^{-1}	4.4×10^{-5}	2.4×10^{-5}

Table 10.2 TEEN

ISOTOPE	DFA (mrem/pCi)	D(mrem/yr) STACK *	200(m)	300(m)
H-3	1.1×10^{-7}	1.1×10^{-1}	2.0×10^{-5}	1.1×10^{-5}
C-14	5.7×10^{-7}	3.2×10^{-1}	2.7×10^{-5}	1.4×10^{-5}
Na-22	1.8×10^{-5}	1.3×10^{-1}	1.1×10^{-5}	5.5×10^{-6}
Sr-90	9.0×10^{-5}	1.1×10^{1}	1.1×10^{-4}	6.1×10^{-5}
I-129	9.8×10^{-6}	1.1×10^{-4}	9.0×10^{-9}	4.7×10^{-9}

*See Appendix H for explanation.

DOSE ESTIMATES

Table 10.3 CHILD

ISOTOPE	DFA (mrem/pCi)	STACK *	D(mrem/yr) 200(m)	300(m)
H-3	2.0×10^{-7}	1.5×10^{-1}	2.7×10^{-5}	1.4×10^{-5}
C-14	1.7×10^{-6}	6.9×10^{-1}	5.7×10^{-5}	3.1×10^{-5}
Na-22	4.4×10^{-5}	2.2×10^{-1}	1.9×10^{-5}	9.9×10^{-6}
Sr-90	2.7×10^{-4}	2.3×10^{1}	2.5×10^{-4}	1.3×10^{-4}
I-129	2.9×10^{-5}	2.2×10^{-4}	1.9×10^{-8}	9.7×10^{-9}

*See Appendix H for explanation

ASH ANALYSIS

Following each burn, the incinerator will be allowed to cool for at least two days. The health physics technician will then spray the ash with water, being careful not to wet the refractory, to reduce dust. He will wear protective clothing, including a dust mask. Presently the ashes are removed with a shovel and then the refractory is swept clean. We are considering using a vacuum to simplify the task.

All of the ash will be placed in 30 gallon steel drums, sealed and taken back to the warehouse on campus. There it will remain until an appropriate method of analysis is established; or it will be shipped if storage space becomes unavailable before it can be analyzed. Attempts have been made to analyze the ash by liquid scintillation, but the ash is insoluble, rendering counting unsuccessful.

Until we are licensed to burn radioactive waste, random samples of the non-radioactive waste ash will be analyzed by gamma spectroscopy to check for possible mis-reported waste types.

EFFLUENT MONITORING

Currently we have no continuous effluent monitoring sustem. Funds have been requested to move the incinerator approximately 25 (m) away from the building, install a hydraulic loader, and construct a sampling platform around the incinerator stack.

Air samples have been taken with a RADECO Model HD28/B air sampler at various points within the site boundary to determine the background activity. These will be analyzed by gamma spectroscopy and liquid scintillation as soon as possible. (The equipment is being used currently.)

Once we commence radioactive burns, air samples will be taken at various points, including the point where maximum ground level concentration should occur, and then analyzed by gamma spectroscopy and liquid scintillation.

Soil samples have been taken at various points within the site boundary. The samples are being analyzed by gamma spectroscopy to obtain natural background activity. (See Appendix J for the gamma spectroscopy procedure.) Soil samples will be taken again after radioactive burning commences.

To obtain further background activity information, wipe samples have been taken around the site boundary and will also be analyzed by gamma spectroscopy and liquid scintillation. The same type of samples will be taken and analyzed after radioactive burning commences.

Finally, a TLD analysis will also be done. TLD's will be placed in a protective container and distributed at various points within the boundary.

The equipment and procedure for this analysis has not yet been determined.

All of the results from the above mentioned tests will be available in an incineration journal which is currently being devised. The journal will also contain all data pertaining to each burn, including volume, weight, and activity; operating temperatures, and stack observations; ash removal and clean-up; and maintenance.

We will be glad to cooperate with any state agencies in further environmental monitoring.

STATE COMPLIANCE

Part of our licensing requirements is to comply with the Bureau of Air Quality Control and the local governments of the cities surrounding the incinerator.

Air Quality Control (AQC) required us to obtain an operating permit which included an EPA test method for vinyl chlorides. The details of the test are given in Appendix K. We passed the test and are awaiting the actual permit. The notification from AQC approving the permit is also contained in Appendix K.

The city governments of Mesa, Tempe and the Salt River Pima Reservation were notified of our plan to incinerate. So far there have been no questions regarding the incinerator from the above mentioned agencies. Only Tempe has responded to our letters with a letter of acknowledgement. Copies of the correspondence are in Appendix L.

PUBLIC RELATIONS

Richard Brown the ASU Radiation Protection Officer, has met with representatives of the trailer park adjacent to the incinerator.

One article concerning the incinerator has been published in the ASU State Press.

Appendix M contains correspondence with the trailer park and the newspaper article.

REFERENCES

1. Bureau of Radioligical Health, Radiological Health Handbook, U.S. Dept. of Health, Education, and Welfare, Maryland, 1970.

2. D. Bruce Turner, Workbook Of Atmospheric Dispersion Estimates, Environmental Protection Agency, North Carolina, 1970.

3. D. Bush, R.S. Hundal, "The Fate Of Radioactive Materials Burnt In An Industrial Institutional Incineration", Health Physics Journal, Pergamon Press, New York, May 1973, pg. 564-568.

4. ICRP, Report Of The Task Group On Reference Man, Pergamon Press, New York, 1975, pg. 346.

5. L.R. Cooley, M.R. McCampbell, J.D. Thompson, Current Practice Of Incineration Of Low-Level Institutional Radioactive Waste, U.S. Dept. of Energy - EG&G Idaho, National Technical Information Service, U.S., Feb. 1981.

6. M. Eisenbud, "The Status Of Radioactive Waste Management: Needs For Reassessment", Health Physics Journal, Pergamon Press, New York, April 1981, pgs. 429-432.

7. N.W. Crouch, J.E. Watson, Jr., "Radionuclide Emissions From Incineration Of Institutional Low-Level Radioactive Wastes", Health Physics Journal, Pergamon Press, New York, June 1982, pgs. 871-873.

8. Purdue University, Radioactive Waste Incineration; National Low-Level Radioactive Waste Management Program, National Technical Information Service, U.S., Nov. 1982.

9. R. Landolt, "Evaluation Of A Small Inexpensive Incinerator For Institutional Radioactive Waste", Health Physics Journal, Pergamon Press, New York, June 1983, pgs. 671-675.

10. U.S. NRC, Regulatory Guide 1.109; Calculation Of Annual Doses To Man From Routine Releases Of Reactor Effluents For The Purpose Of Evaluating Compliance With 10 CFR Part 50, Appendix I, March, 1976.

11. United States Nuclear Regulatory Commission, Rules And Regulations, Title 10, Chapter 1, Code of Federal Regulations, Part 20, Appendix B, Table II, Column 1, Aug. 1, 1980.

12. Roché-Farmer, Study Of Alternative Methods For The Management Of Liquid Scintillation Counting Wastes, U.S. NRC, Feb. 1980.

APPENDICES

APPENDIX A

NRC Incineration Guidelines For Medical/Academic Licensees

1. Submit the characteristics of the incinerator such as height of the stack, height of and distance to buildings in the surrounding areas, rated airflow of the incinerator in cubic feet per hour or similar units and its proximity to any air intake ducts.

2. State specifically the isotopes and the maximum amount of each isotope that you wish to incinerate per burn. For the combination of isotopes listed, submit calculations to demonstrate that the following conditions have been met:

   A. The gaseous effluent from the incinerator stack should not exceed the limits specified for air in Appendix B, Table II, 10 CFR Part 20 when averaged over a 24 hour period.

   B. In order to be in compliance with the ALARA philosophy stated in section 20.1(c), 10 CFR Part 20, the gaseous effluent from the incinerator stack should be a fraction (approximately 10%) of the limits specified for air in Appendix B, Table II, 10 CFR Part 20, when averaged over a period of one year.

If more than one isotope is involved, your calculations must follow the "sum of ratios" method in the "Note" at the end of the Appendix B, 10 CFR Part 20.

3. State the maximum number of burns to be performed in any one week and the maximum number of burns per year.

4. A. Describe your method for measuring or estimating the concentration of radioactive material remaining in the ash residue. Unless you present scientific evidence to the contrary, you must use the most conservative assumption.

   B. Submit your procedures for collection, handling and disposal of the ash residue, including radiation safety precautions to be observed.

5. Describe procedures to be followed to minimize exposure to personnel during all phases of the operation, including instruction given to personnel handling the combustibles and the ash.

6. Submit evidence (e.g., copies of outgoing and incoming letters) to show that all State and local jurisdictions have been notified of your plans to incinerate radioactive waste and have no objections to them.

APPENDIX B

ARIZONA STATE
UNIVERSITY TEMPE, ARIZONA 85281

UNIVERSITY RADIATION SAFETY OFFICE
c/o COLLEGE OF ENGINEERING (D-102) (602) 965-6140

Department of Energy
Grant #DE-FG07-81ID12228

COST ANALYSIS FOR INCINERATION

Increasing shipping costs and decreasing land availability for burial sites has prompted Arizona State University to consider the potential for incineration as a means to dispose of hazardous and low-level radioactive waste (LLRAW). Several factors must be considered before incineration becomes a common, effective means of disposal for LLRAW generators such as ASU. One very important factor is cost versus benefit.

In March of 1982, ASU was issued a grant from the Department of Energy to investigate the feasibility of LLRAW incineration in an existing pathological incinerator. The grant, totaling $19,994.00, provides for personnel, materials, supplies, travel, and special equipment needed for the project. See FIGURE 1 for a detailed breakdown of the grant.

The "existing incinerator" was purchased and installed through ASU along with the Lab Animal Care Facility in December of 1980. The approximate cost for the incinerator was $25,000. We, (Radiation Protection Office) started conducting experimantal burns of non-radioactive waste in August of 1981. Prior to that time, ASU shipped all of it's LLRAW to commercial burial sites in either Beatty, NV or Richland, WA. FIGURE 2 contains information pertinent to previous shipments.

FIGURE 1

Direct Labor		$ 5,500
Fringe Benefits (1% of D.L.)		55
Domestic Travel		2,138
Other Direct Costs:		
Materials and Supplies	$1,352	
Registration Fees for Meetings	355	1,707
Equipment		
1. Draeger Air Sampling System	$ 600	
(a) Hand pump		
(b) Tubes		
2. Staplex Filter System	1,150	
3. Eberline Portable Survey System	930	
(a) E-120 Portable survey meters (2)		
(b) HP-210 pancake probes (2)		
4. Ludlum Semi-portable Detection System	1,705	
(a) Model 44-6 GM probe		
(b) Model 43-5 Alpha scintillation probe		
(c) Beta scintillator		
(d) Alpha counter w/sample charger		
(e) Model 2000 scaler		
5. KURZ 541s Lo-Vol Flow Calibrator	725	
6. Polymeter Shift Long Pump	690	
Total Equipment		5,800
Total Direct Costs		$15,200
Indirect Costs (51% of Direct Costs excluding equipment)		4,794
Total Estimated Costs		$19,994

FIGURE 2

DATE SHIPPED	NO. DRUMS SHIPPED	NO. MONTHS WASTE COLLECTED	DRUMS/ MONTH	COST/DRUM FOR * SHIPPING	TOTAL COST/SHIPMENT	INCREASE IN COST/DRUM SINCE PREVIOUS SHIMPMENT
6/25/74	3	------	----	no records	no records	no records
1/15/75	7	7	1	no records	no records	no records
12/17/75	10	11	.9	25.00	250.00	----------
7/15/76	15	7	2.1	28.00	420.00	1.3 x
4/28/77	17	9	1.9	36.00	612.00	1.6 x
1/13/78	21	9	2.3	45.50	955.00	1.5 x
2/07/79	38	13	2.9	73.90	2802.10	1.9 x
6/23/80	57	16	3.6	106.67	6080.03	1.6 x
9/30/82	47 82 **	26	3.2	600.00	28200.00	5.6 x

* The Total Cost/Drum includes the replacement cost of $15.00 per drum. Each 55 gallon drum contains 7.5 cu. ft.

** Eighty-two drums is the amount of waste collected since the last shipment in 1980. The number of drums to be shipped this month, however, would only be 47. (The cost indicated represents 47 drums.) This is because out of the 82 drums collected 42% has been incinerated thus far. The 42% consisted mainly of $\leq$ .05mCi/g C-14 and/or H-3. (The amount, .05mCi/g, of C-14 and/or H-3 is that which may be disposed of without regard to its radioactivity specified in 10 CFR Part 20 as of March 11, 1981.)

At present there is only one person, a local private consultant, in the state of Arizona who will handle disposal of radioactive waste via shipping. His fee of $585.00 per 55 gallon drum includes packaging, labeling, handling, and all site fees.

The cost of shipping has risen 2400% since 1975. In the last two years alone, the jump has been an unbelievable 562%. There are approximately 54 radioactive materials license holders at ASU. Since 1968 there has been an average increase of 3.2 licensees per year. (See FIGURE 3) This increase in licensees obviously accounts for the .3 average increase in drums of waste collected per month. Taking these values into account, within the next two years (by Sept. of 1984) there will be approximately 92 drums of waste collected in addition to the 47 drums already in storage. The cost to ship 139 drums of waste would be $83,400, calculated at today's prices.

If licensed to do so, incineration of LLRAW at ASU would be a much more cost-effective method of disposal than shipping. The costs which apply to incineration are transportation of waste from campus to the incinerator, operation costs, and routine maintenance. We figured earlier that in two years there will be a total of 139 drums of waste collected, including the 47 drums already in storage. Disposal of these by incineration breaks down to six drums per month over the two year period.

The contents of each drum is divided into four plastic bags for easy handling and loading into the incinerator. The cost of bags used for the total amount of waste is $150.

The incinerator is four miles from campus. Waste is taken from the ASU warehouse to the incinerator via means of the office truck which gets approximately 17 miles/gal gas milage. Two days following a burn, the ashes are removed from the incinerator and disposed of as non-radioactive waste if no detectable levels of radiation remain. The cost of transportation to and from the incinerator for two years worth of trips is $120, ($5/month).

The six drums (24 bags) of waste can be incinerated at a rate of 1.5 drums (6 bags) per week. This is accomodated in one burn. A burn consists of a 30 minute warm-up time, six charges at 30 minute intervals, and a five hour burn-down time. The total fueling time per burn then is 8.5 hours. At four burns per month, the total fueling time is 34 hours per month. By taking into account the fueling time and incinerator specifications, Arizona Public Service Company assessed a cost of $190 per month for natural gas. In two years this amounts to $4560.

Monthly, routine maintenance service on the incinerator has been quoted at $4800 per year by Karber Air Conditioning. For two years the cost would be $9600.

The total cost to incinerate 139 drums of waste in two years is $14,430. This amount can be compared to $83,400 it would cost to ship. FIGURE 4 is a summary of this report.

FIGURE 3

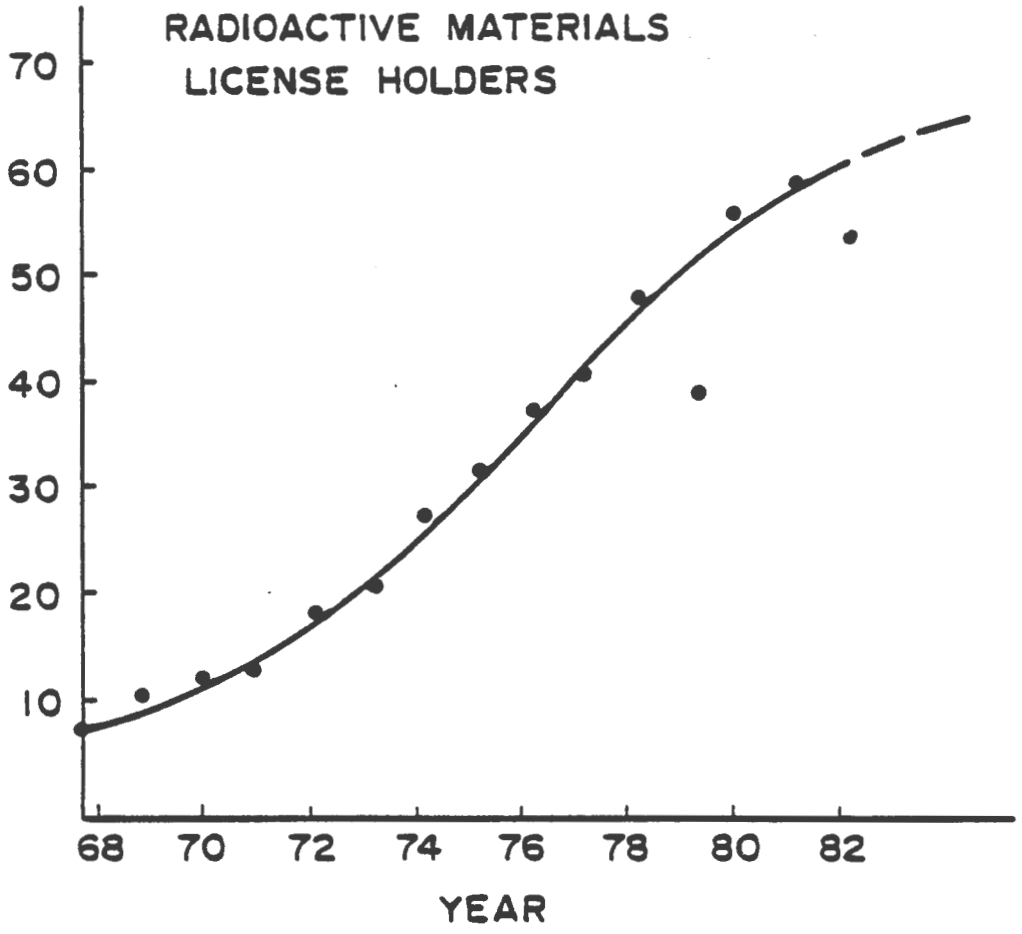

RADIOACTIVE MATERIALS
LICENSE HOLDERS
70
60
50
40
30
20
10
68
70
72
74
76
78
80
82
YEAR

FIGURE 4

Annual increase in licensees at ASU	3.2
Annual increase in drums of waste collected	3.6
Increase in cost of shipping since 1975	2400%
Increase in cost of shipping since last shipment (June 1980)	562%

Comparison:

	INCINERATION	SHIPPING
Costs:	plastic bags gasoline natural gas maintenance	packaging labeling shipping site fees
Total Cost (139 drums in 2 years):		
	$14430.00	$83400.00
Cost/Drum:	$ 103.80	$ 600.00
Cost/Cu. Ft.	$ 13.84	80.00

Initial cost for incinerator:
$25000.00

Initiatory incineration program (DOE grant):
$19994.00

$59424	$83,400.00

APPENDIX C
(1-4)

C-1

Health Physics Pergamon Press 1973. Vol. 24 (May), pp. 564–568. Printed in Northern Ireland

The Fate of Radioactive Materials Burnt in an Institutional Incinerator

(*Received* 27 *July* 1972; *in revised form* 9 *November* 1972)

Introduction

INCINERATORS are widely used in the treatment and disposal of radioactive wastes and their use appears likely to increase.[1,2] Incineration is a useful process in that considerable mass and volume reductions can be achieved,[3–5] and it is a convenient method of disposing of biological wastes such as animal carcases and bedding, although the use of a mascerator to convert the waste to liquid form is sometimes preferred.[6]

The fate of incinerated radioactive material depends on several factors including operating temperature, air volume and velocity, degree of combustion, chemical and physical form, and the radionuclides involved.[7,8] Radioactivity may be discharged to atmosphere in gaseous or particulate form, retained in the ash, or deposited on the interior of the incinerator, stack, or associated equipment.[4,9,10] Attention has been drawn to possible hazards from discharges to the atmosphere, ash handling and disposal, and incinerator maintenance.[4,6,8,9,11,12]

The I.A.E.A. has indicated how to calculate the maximum quantities of radioactivity that can be safely incinerated, taking into account hazards from stack discharges and from handling ashes,[8] and has given information on the likely behaviour of particular radionuclides. Similar information is available from other sources[2,6,9,13] and various authors[7,10,12] have reported results of experiments designed to study this problem.

At this University an incinerator is used in the disposal of radioactive waste, mainly animal carcases and bedding. The I.A.E.A.[8] method of calculation showed that for the quantities of radioactivity that we are authorized to burn, that the hazards from stack discharges would be quite insignificant. The situation with regard to the ash did not appear so satisfactory, in that the hazard to the incinerator operator and the matter of ash disposal would need careful control.

It was therefore decided to examine this problem in detail in order to accumulate the information necessary to draw up a safe operating scheme. Tests have been carried out using 27 different radionuclides, the primary object being to determine the variability of retention of activity in ash under our operating conditions. An account is given of the incinerator, the experimental methods, and the results of the retention studies, together with a summary of operational surveys carried out on and around the incinerator. The problems highlighted by these results are discussed.

The Incinerator

The incinerator used for these tests is an ordinary institutional gas fired model and is regularly used for the incineration of low level radioactive wastes mixed with non-active waste. The combusion chamber is lined with refractory brick and can accept a load of 0.5 m^3. Air is blown into the chamber, and air is also drawn in from the room in which the incinerator is situated. After leaving the combustion chamber, the smoke and gases pass into a gas fired afterburner, and then are discharged to atmosphere via a stack on the roof of the eight story building. No filtration or gas clean-up equipment is provided.

The combustion chamber operates at a temperature of about 800°C although this is subject to variation due to the nature of the load. The total flow from the stack is about 50 m^3/min and the exit temperature about 250°C.

The ash falls from the combustion chamber through a grate into a trough which can be withdrawn for emptying. The ash is manually transferred from the trough to a bin which is removed from the site by the local authority refuse department. All ash handling is carried out manually with the ash in a dry condition. Any ash spilt during transfer from trough to bin is cleaned up using a suction cleaner.

Experimental Methods

The object of these tests was to study the retention of activity in ash for various radionuclides, and to

look for any dependence on chemical and physical form.

GEYER *et al.*,[12] in a similar study, used relatively large quantities of activity and accumulated large amounts of ash of which only a small proportion was counted. Geyer found wide variations among different samples taken from the same bulk quantity of ash, and this method was not considered to be of high accuracy for determining activity in ash. For this reason a different approach was adopted in this study. Small samples containing low activity i.e. a few μCi or less, were used. The active material was contained in a small metal can which was placed in the incinerator with non-active waste, care being taken to ensure that the can remained upright. The top of the can was covered by a wire grille to allow combustion products to escape, but prevent non-active ash from entering. The can was always placed in the incinerator with non-active waste so that conditions would be as representative as possible of those normally met in routine incineration.

Before incineration, the activity of the sample was determined using standard beta or gamma counting equipment, and for the more bulky samples the mass and volume were noted. After incineration the activity was re-measured, and checks were made to ensure that the location of active material in the can was essentially the same as before incineration. For an initially bulky sample, the resulting ash was mixed with damp sawdust to make the mass and volume the same as before incineration, so that geometry and self absorption effects would be similar. In calculating the percentage of activity remaining in the ash, allowance was made for radioactive decay if significant.

Ash Retention Results

For most radionuclides, more than one sample has been incinerated, and in a few cases different physical and chemical forms have been used. The results obtained are summarized in Table 1. The chemical form data relates to the material as originally used e.g. as administered to rats.

The results show that under our conditions of incineration, different radionuclides behave quite differently as far as retention of activity in ash is concerned, with values ranging from almost 0 to 100%. Also for some radionuclides e.g. ^{86}Rb, wide variations occurred although conditions were nominally identical in all the tests. In those cases where the chemical and physical form of a radionuclide was varied e.g. ^{32}P, ^{35}S, ^{125}I, no marked difference was apparent provided complete combustion was achieved.

Other Studies and Results of Operational Surveys

The interior of the incinerator

The incinerator is normally used for the disposal of larger quantities of radioactive waste than used in the above tests, the average activity incinerated per week being about 100 μCi.

Measurements have been made to locate and identify activity in various parts of the incinerator. The lining of the combustion chamber has retained some activity, the level of which has varied but not exceeded 5×10^{-4} μCi/cm^2. At the top of the stack, the level has remained steady at about 3×10^{-6} μCi/cm^2. Because of these low levels, identification of the radionuclides has not been possible.

In the afterburner, levels of up to 2×10^{-4} μCi/cm^2 have been measured. Samples of the residue removed from this unit have had specific activities up to 2×10^{-3} μCi/g, and gamma emitting radionuclides that have been identified are ^{22}Na, ^{54}Mn, ^{60}Co, ^{65}Zn, ^{75}Se, ^{126}I and ^{137}Cs.

Air sampling

For some radionuclides, a very high proportion of activity remains in the ash, and this could present a hazard to the incinerator operator during the manual handling of ash. Air samples have been run in the work zone during ash handling after the incineration of fairly large amounts of radionuclides in this category. Typical levels of airborne activity are shown in Table 2 and these are compared with the most restrictive values of 40 hr week MPCa taken from *ICRP Publication 2*.[14]

It has been confirmed that stack discharges do not present an inhalation hazard. Iodine-125 is one of the most volatile and hazardous radionuclides that we incinerate. An air sample was run for 2 hr, using an activated charcoal filter, while 38 μCi of ^{125}I was incinerated. The measured concentration was 2×10^{-10} μCi/ml at a position in the plume only 1 m from the stack exit.

Outside the incinerator

Although slight activity has been detected in air samples run during ash removal, no significant contamination of the exterior of the incinerator or of the incinerator room has resulted, levels having always been less than 10^{-4} μCi/cm^2 provided any spilt ash has been cleaned up.

Surveys of the roof on which the incinerator stack is located have shown no detectable activity above background. Similar results have been found when monitoring inlet filters on nearby air intakes.

Table 1. Results of ash retention studies

Radionuclide	Number of samples	Chemical form	Physical form	Percentage of activity left in ash
^{14}C	2	Sodium carbonate in aqueous solution	Dried on metal planchets	0.04, 0.02
^{22}Na	2	Sodium hydroxide	Contaminated papers	99.0, 83.6
^{32}P	2	Orthophosphate in dilute hydrochloric acid	Dried on syringe needle	95.5, 100.0
	1		On filter paper	100.0
	1		In syringe body	96.6
	2		Dried on metal planchets	67.7, 99.9
^{35}S	3	Sodium sulphate in aqueous solution	Dried on metal planchets	9.6, 73.5, 91.2
	3	Potassium sulphate in aqueous solution		77.2, 63.5, 39.6
^{42}K	1	Potassium chloride in aqueous solution	On a filter paper	100.0
^{48}V	2	Dioxovanadium chloride in hydrochloric acid	On filter papers	96.2, 92.6
^{51}Cr	2	Sodium chromate in aqueous solution	On filter papers	83.5, 98.5
^{54}Mn	2	Manganous chloride in hydrochloric acid	On filter papers	91.2, 90.0
^{59}Fe	2	Ferric chloride in hydrochloric acid	On filter papers	78.4, 76.2
^{60}Co	2	Cobaltous chloride in aqueous solution	On filter papers and sawdust	99.1, 99.4
^{64}Cu	1	Cupric nitrate in nitric acid	On a filter paper	100.0
^{65}Zn	2	Zinc chloride in hydrochloric acid	On filter papers	29.1, 68.6
^{86}Rb	2	Rubidium chloride in aqueous solution	On filter papers	43.9, 100.0
^{95}Zr	2	Oxalate complex in oxalic acid	On filter papers	87.6, 100.0
^{99}Mo	2	Sodium molybdate solution	On filter papers	87.0, 100.0
^{110m}Ag	1	Silver	Metal foil	99.8
	2	Silver nitrate in nitric acid	On filter papers	94.4, 68.6
^{131}I	3	Sodium iodide in sodium hydroxide solution	On filter papers	0.5, 1.4, 0.1
	1	Aqueous solution of 5-Iodo-2-deoxyuridine	Sawdust bedding from rat cage	0.02
	2		Rat carcases	1.2, 1.7
^{132}Te	2	Sodium tellurite solution	On filter papers	62.4, 45.1
^{134}Cs	2	Caesium chloride in aqueous solution	On filter papers	83.0, 95.5
^{137}Cs	3	Caesium chloride in aqueous solution	In syringe needles and barrels	82.0, 100.0, 47.5
^{147}Pm	2	Promethium chloride in hydrochloric acid	On metal planchets	91.0, 94.5
$^{175/181}Hf$	3	Hafnium chloride in hydrochloric acid	On filter papers	87.6, 99.8, 90.7
^{182}Ta	2	Oxalatotantalate in oxalic acid	On filter papers	93.6, 81.0
^{198}Au	2	Tetrachloroaurate in hydrochloric acid	On filter papers	79.5, 72.0
^{203}Hg	2	Mercuric acetate in aqueous solution	On filter papers	0.09, 1.2
^{204}Tl	3	Thallous sulphate in sulphuric acid	On metal planchet	0.2, 0.7, 4.7

Table 2. Typical air sampling results during ash handling

Radionuclides incinerated	Quantity (μCi)	Measured air activity level (μCi/ml)	40 hr week MPCa (μCi/ml)
^{45}Ca	130	1.1×10^{-10}	3×10^{-6}
^{58}Co	4.5		5×10^{-6}
^{60}Co	2.5		9×10^{-9}
^{65}Zn and ^{22}Na mixed	210	7.2×10^{-11}	6×10^{-6} 9×10^{-9}
^{65}Zn and ^{22}Na mixed	300	3.5×10^{-10}	6×10^{-6} 9×10^{-9}
^{99}Tc	200	1.2×10^{-10}	6×10^{-6}

Discussion

The principal problem associated with the use of our incinerator is the disposal of ash and afterburner residue. This University has been authorized to dispose of solid radioactive waste to the local authority, provided the volume concentration of activity does not exceed 100 μCi/m^3, and that no single item is more active than 1 μCi. Provided complete combustion is achieved the latter condition should present no difficulty, but if for example the daily burning rate of non-volatile radionuclides is 100 μCi, then the activity-volume concentration of the ash could exceed the allowable level by an order of magnitude. Therefore incineration of such radionuclides must either be limited to about 10 μCi per day, or dilution of the ash with non-active waste must be ensured. In some countries, radioactive waste disposal is controlled by reference to a threshold specific activity for radioactive material of 2×10^{-3} μCi/g. In such cases, and again assuming the incineration of non-volatile radionuclides at a rate of 100 μCi/day, the specific activity of the ash would be about 1×10^{-2} μCi/g, requiring a 5-fold dilution prior to disposal.

The other problem concerning ash was the possible hazard to the incinerator operator, but as seen from Table 2, with careful handling of dry ash, up to a few hundred μCi/day of non-volatile radionuclides could be safely incinerated. The contamination levels inside and around the incinerator have been such as to present no problems.

As mentioned above, sometimes when more than one nominally identical sample of a particular radionuclide has been incinerated e.g. ^{86}Rb, there has been quite a variation in the results obtained. Counting statistics alone have contributed very little to this e.g. for the ^{86}Rb case, the standard deviation was about 0.25%. Other factors which might have caused such variations are slight geometry changes, loss of active ash despite the presence of the wire grille, variable amounts of radioactive impurities in samples and the normal variations of incineration conditions, particularly operating temperature.

In all the tests for which results are reported, combustion of the samples was complete, but when burning rat carcases containing ^{125}I the problem of incomplete combustion was met. Although the carcases appeared at first sight to have been properly burnt, it was found that the activity remaining was about 50% of that originally present. Closer examination showed that the carcases were not burnt all the way through, so they were re-incinerated and after complete combustion the results were as shown in Table 1.

Some comment is called for on the observed behaviour of ^{32}P, ^{35}S and ^{137}Cs. MAWSON[9] described these radionuclides as volatile, and ^{35}S is similarly classified by the I.A.E.A.,[6] but under our conditions quite a large percentage of these radionuclides has remained in the ash. In the case of ^{32}P, our findings are in reasonable agreement with those of GEYER.[12] Such variations in behaviour only serve to emphasize the need for careful examination of the situation wherever incinerators are used.

Finally, some comment should be made on the desirability of using such incinerators in the treatment and disposal of radioactive waste. A comparison of maximum permissible daily intakes by ingestion and inhalation, derived from data in *ICRP Publication 2*,[14] shows that for most of the radionuclides listed in Table 1, inhalation represents the greatest hazard. If therefore, in considering the disposal of animal carcases, one compares the radiation hazards to the operators of macerators and incinerators, then on fundamental grounds the incinerator is at a disadvantage. Added to this is the fact that due to the nature of the processes, an intake by an incinerator operator appears more likely than an intake by a macerator operator.

As far as the general public is concerned, incineration tends to release radioactivity into the environment rather sooner than would be the case if the waste was macerated and discharged as a liquid. This might be of some slight significance where short-lived radionuclides are concerned.

Despite these potential disadvantages, it is our opinion that the use of institutional incinerators for the treatment and disposal of radioactive wastes is acceptable provided that the quantity burnt per day is tightly controlled, and that the ash is handled carefully and diluted before disposal.

Acknowledgements—The authors wish to acknowledge the co-operation of Mr. D. HICKMAN-SMITH, Biochemistry Department for accommodating our

programme of special tests, and of various others for providing us with suitable samples.

D. Bush
R. S. Hundal

University Radiation Protection Service
University of Birmingham
Birmingham B15 2TT, England

References

1. J. A. Bonnel and G. C. Dale, *Health Phys.* **21**, 637 (1971).
2. I. Dougall and J. E. Newell, Proc. Symp. Dev. Mgmt. Low and Intermed. Radioact. Wastes., 275, I.A.E.A., Vienna (1970).
3. R. H. Burns, Proc. Scient. Conf. Disp. Radioact. Wastes, 413, I.A.E.A., Vienna (1960).
4. Safety Series No. 12. I.A.E.A., Vienna (1965).
5. Technical Report Series No. 106, I.A.E.A., Vienna (1970).
6. The Public Health Implications of the Widespread Use of Radioactive Materials and the Disposal of Radioactive Wastes to the Environment. W.H.O. Copenhagen (1969).
7. R. H. Burns, G. W. Clark, A. J. Smith and D. K. Dunkason, Symp. Prac. Treat. Low and Intermed. Lev. Radioact. Wastes, 639, I.A.E.A. Vienna (1966).
8. Safety Series No. 19, I.A.E.A. Vienna (1966).
9. C. A. Mawson, *Management of Radioactive Wastes*, D. Van Nostrand, Princetown, N. J. (1965).
10. J. Meissner, Symp. Prac. Treat. Low and Intermed. Lev. Radioact. Wastes, 117, I.A.E.A. Vienna (1966).
11. Safety Series No. 24, I.A.E.A. Vienna (1967).
12. J. C. Geyer, L. C. MacMurray, A. P. Talboys and H. W. Brown, Int. Conf. Peaceful Uses Atom. Energy, 9, 19, Geneva (1955).
13. A. W. Kenny, Symp. Prac. Treat. Low and Intermed. Lev. Radioact. Wastes, 43, I.A.E.A. Vienna (1966).
14. Recommendations of the ICRP, Report of Committee 2 on permissible dose for internal radiation. *ICRP Publication* 2, Pergamon Press, Oxford (1959).

Health Physics, Vol. 40 (April), pp. 429–437, 1981
Printed in the U.S.A.

0017-9078/81/040429-09$02.00/0
Pergamon Press Ltd.

C-2

THE STATUS OF RADIOACTIVE WASTE MANAGEMENT: NEEDS FOR REASSESSMENT

MERRIL EISENBUD
Institute of Environmental Medicine, New York University Medical Center, 550 First Avenue, New York, NY 10016

(*Received* 18 *April* 1980; *accepted* 4 *August* 1980)

Abstract—Three systems of radioactive waste management, land burial of wastes from biomedical laboratories, storage in minded cavities, and use of the oceans, are discussed briefly for the purpose of illustrating the need for re-examination of the basic approaches being taken at the present time. It is concluded that most of the low level wastes from biomedical institutions need not be shipped to burial grounds, but can be incinerated on site subject only to restrictions determined by the nonradioactive characteristics of the wastes. With respect to storage of high level wastes, it is suggested that studies of the mobilization rates of natural ore bodies may provide the best way of modeling the behavior of selected waste forms over long periods of time. The oceans, particularly the deep ocean sediments, should be more thoroughly investigated as a possible disposal option.

DISCUSSION

THE PURPOSE of this paper is to emphasize the need for continuing re-examination of the options available for disposal of both low level and high level radioactive wastes. Towards this end, three subjects are discussed: disposal of low level wastes from biomedical institutions, storage of high level wastes in mined cavities, and the use of the oceans.

Wastes from biomedical clinics and laboratories

During much of the past year almost all of the low level radioactive waste burial capacity in the U.S. has been closed. This had a particularly disruptive effect on the biomedical community because clinics, hospitals and laboratories generate substantial volumes of low level wastes but, unlike many industrial facilities, they have little reserve storage capacity.

It has been estimated that 2400 U.S. biomedical organizations shipped a total of about 2500 Ci of radioactive waste to burial grounds in 1978 (NUS77). Several relatively short-lived nuclides, such as ^{32}P, ^{99m}Tc, ^{131}I, ^{125}I and ^{35}S, contributed appreciably to the total. Because these nuclides have half-lives measured in days, the reported annual shipment must be corrected for decay. Assuming that the wastes are generated at a uniform rate throughout the year, and allowing for decay, the total accumulation at yearend would have totaled about 1300 Ci. Seventy-two percent of the radioactivity was due to two nuclides, tritium (720 Ci) and ^{14}C (221 Ci).

Tritium and ^{14}C not only account for two-thirds of the total radioactivity shipped to the burial sites, but contribute in a major way to the volume of waste produced. About 21,000 m^3 of wastes were produced in 1978, of which 43% (9200 m^3) were made up of liquid scintillation counting vials containing these nuclides. These quantities of tritium and ^{14}C are insignificant as a potential source of public exposure.

Both tritium and ^{14}C are produced in nature by the interaction of cosmic rays with the atmosphere and both have been produced copiously by explosions of nuclear weapons. The natural rate of ^{14}C production is about

38,000 Ci/yr, and because of its long half-life (5730 yr), the nuclide accumulates to such an extent that the global steady state inventory of naturally-produced ^{14}C is estimated to be about 315×10^6 Ci, which delivers a *per capita* dose of about 0.7 mrem/yr to the world's population (UN77). It is also known that by 1972 a total of about 5.8×10^6 Ci was injected into the atmosphere as a result of weapons testing. This one source was thus equivalent to more than 153 yr of natural ^{14}C production, and about 26,000 times the annual production of ^{14}C wastes by the biomedical community in the U.S.

If all ^{14}C used in biomedical laboratories in the U.S. were incinerated to $^{14}CO_2$, the steady state environmental inventory would eventually increase the dose from ^{14}C by less than 0.004 mrem/yr. However, this equilibrium would not be reached for about 25,000 yr of ^{14}C production at the 1978 rate, because of the long half-life of ^{14}C.

About 720 Ci ^3H was shipped as wastes by U.S. biomedical facilities in 1978, about 55% of their total radioactive waste production. This nuclide is also produced naturally by cosmic ray interactions, and the worldwide steady state inventory is estimated to be 34×10^6 Ci from an annual production rate of 1.9×10^6 Ci (UN77). The dose from naturally-occurring tritium is estimated to average 0.001 mrem/yr. Tritium released without restriction by biomedical facilities at the 1978 rate would gradually diffuse into the environmental hydrogen pool and would reach a steady state accumulation of about 13,000 Ci, the fractional increase in dose would be about 0.04% of the tritium background dose of 0.001 mrem/yr.

Tritium, like ^{14}C, was also produced copiously in tests of thermonuclear weapons, which resulted in injection of an estimated 4.5×10^9 Ci into the environment. This was more than 100 times the steady state inventory from natural sources. The nuclide is also produced by nuclear reactors, which discharge between 0.1 and 1 Ci/MWe/yr. A single 1000 MWe nuclear power plant can thus discharge more tritium to the environment than the total quantity of waste tritium produced by all the medical facilities and biomedical research laboratories in the U.S. It has been estimated that nuclear reactors throughout the world and associated fuel reprocessing will release about 10^6 Ci of tritium in 1980 (NCRP75).

Unrestricted release by incineration of the two long-lived nuclides, ^3H and ^{14}C, would thus add insignificantly to the quantities already present in the environment due mainly to production of the two nuclides by cosmic ray interactions with atmospheric gases. The data on the quantities of tritium and ^{14}C sent to burial grounds by biomedical facilities are applicable only to the U.S. However, if the quantities are multiplied tenfold, which would be more than sufficient to account for wastes generated by all countries, the global impact of the incinerated emissions would still be negligible.

The discussion thus far has considered only the global impact of the two nuclides after they have been dispersed in the atmosphere. There remains the problem of evaluating the possibility of exposure to individuals who live close to the incinerator and may therefore be exposed directly to its effluents. To estimate the possible magnitude of such exposure, it is assumed that a single large facility discharges 1% of the total quantity of radioactive wastes generated by the biomedical clinics and laboratories in the U.S. The wastes are incinerated, and the gaseous products are discharged at a uniform rate for 200 days/yr, 8 hr/day. The volume of exhaust gases discharged from the incinerator stack is assumed to be 1 $m^3 sec^{-1}$. It is further assumed that members of the general population must not be exposed to more than 10% of the limits recommended by the ICRP and the NCRP.

Tritium. The total quantity of waste tritium generated annually in the U.S. by biomedical facilities has been given as 720 Ci, of which the hypothetical institution releases 1%, at a rate $Q = 7.2$ Ci yr^{-1}, $= 1.25 \times 10^{-6}$ Ci sec^{-1}.

The ICRP/NCRP limit for public exposure to tritium in the atmosphere (MPCa), is 2×10^{-7} Ci m^{-3}. Since public exposure should be limited to 10% of MPCa in this case, the

average concentration at the nearest point of human occupancy should be no more than 2×10^{-8} Ci m^{-1}.

The ^{3}H concentration, C, at the point of discharge to the environment = (1.25×10^{-6} Ci sec^{-1})(1 m^{-3} sec) = 1.25×10^{-6} Ci m^{-1}. Thus, not surprisingly, the undiluted effluent would exceed our target level at the point of release to the atmosphere by a factor of 62. One then needs to know the rate at which the effluents would be diluted as a function of distance downwind of the stack, i.e. the distance at which the effluent will be diluted to 2×10^{-8} Ci m^{-3} (at ground level) under various meteorological conditions.

A convenient method of estimating dilution from a point source is by the index χ/Q, for a mean windspeed of 1 m sec^{-1} (2.2 m/h), where χ is the concentration (Ci m^{-3}) at any ground level point downwind of the stack. For the above case:

$$\frac{\chi}{Q} = \frac{2 \times 10^{-8} \text{ Ci m}^{-3}}{1.25 \times 10^{-6} \text{ Ci sec}^{-1}} = 1.6 \times 10^{-2} \text{ sec m}^{-3}.$$

The actual values of χ/Q will vary depending on the stack height and distance from the source. It can be shown from published values of χ/Q, as reproduced in Fig. 1, that, under all meteorological conditions, by the time the effluent is diffused to ground level it is diluted to below the 2×10^{-8} Ci m^{-3}. In fact, the dilution at ground level would actually be 100–1000 times greater than required even under the most adverse meteorological conditions for a release from a 100-m stack.

^{14}C. Following the same procedure as before, we find that the hypothetical institution discharges 2.2 Ci yr^{-1}, and the value of χ = 0.1 MPCa = 10^{-8} Ci m^{-3}. The ^{14}C will be released at a rate of 0.38×10^{-6} Ci sec^{-1}, at a concentration of $C = 0.38 \times 10^{-6}$ Ci m^{-3}, for which the required dilution factor is 38. The required value of χ/Q is 2.6×10^{-2}. Smaller values would result in proportionately lower values of χ, and thus a greater margin of safety. The maximum value of χ/Q in Fig. 1 (Hi62) is shown to orders of magnitude less than the required value.

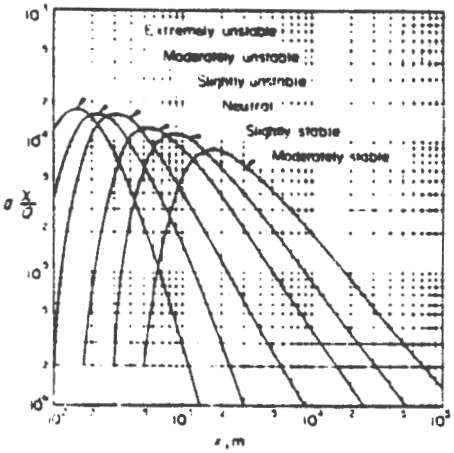


FIG. 1. Values of $\mu\chi/Q$ as a function of downwind distance for a source located at a height of 100 m (see text for units) (Hi62).

It becomes apparent from these calculations that ^{3}H and ^{14}C, which comprise the bulk of the radioactive wastes from the biomedical uses of radionuclides, can be incinerated with insignificant exposure to the public. The calculated dilutions are applicable to persons located at ground level, and it is possible that in some situations the limiting individuals may be located in apartments or offices located above ground level. Common sense restrictions as to the incinerator location would, in any case, be required to avoid the nuisance and hazard of exposure to effluents other than the ^{3}H or ^{14}C.

It should be noted, in addition, that these nuclides, for the most part, will have been used in scintillation counting systems in which they will be dissolved in organic solvents. Toluene is the solvent most frequently used for this purpose. Because of its toxicity and flammability, incineration not only provides a safe method of disposing of the radionuclides, but also a procedure by which the solvents can be oxidized to CO_2 and water. Alternatively, the scintillation vials could be shipped to a chemical waste treatment facility where the toluene could be recovered by distillation and where the remainder of the waste could be incinerated.

From the above discussion, it appears that biological and clinical laboratories could well be permitted to dispose of most of their radioactive wastes with no regulatory requirements other than those applicable to the wastes because of their chemical or physical characteristics. Instead, procedures established for the management of these wastes are of themselves a waste: they waste time, money and resources. The elaborate record keeping, the careful packaging, the shipment for long distances, and the burial practices themselves are an unnecessary ritual.

The reasoning applicable to ^{3}H and ^{14}C, which comprise such a major fraction of the radioactive wastes from these facilities, can be applied to other nuclides used in biomedical institutions. ^{32}P, ^{99m}Tc, ^{35}S, ^{125}I and ^{131}I are relatively short-lived, and are used routinely in only modest quantities. In most cases these nuclides could also be released harmlessly via incinerators or the sewers.

C-3

0017-9078/82/060871-03$03.00/0

Health Physics Vol. 42, No. 6 (June), pp. 871–873, 1982
Printed in the U.S.A.

Radionuclide Emissions From Incineration of Institutional Low-level Radioactive Wastes

(*Received* 30 *June* 1981; *accepted* 2 *September* 1981)

Introduction

INCINERATION IS an attractive alternative for disposal of institutional low-level radioactive waste. A properly operated incinerator is capable of a volume reduction of 80:1 and organic compounds are decomposed to CO_2 and H_2O. Since the radionuclides are unaffected, they are either deposited in the ash or on the walls of the incinerator or they are emitted in the effluent gases. This study was conducted to investigate the radionuclide emissions if institutional low-level radioactive wastes generated in North Carolina were incinerated.

A survey of state licensees was conducted in 1979 to determine the amount and characteristics of institutional radioactive waste generated in North Carolina (NC79). The results of the survey indicated that 90% of the waste was generated in the Research Triangle Area, with the remaining 10% generated throughout the state. The waste consisted of dry solids, liquids, scintillation vials and fluids, and animal carcasses. Approximately 85% of the waste was combustible and 15% was non-combustible which would require means of disposal other than incineration. The activities of the nuclides in combustible waste are shown in Table 1, with their halflives.

Method of Analysis

Incinerators have been licensed with the requirement that the annual average radionuclide concentrations in the effluent be less than 10% of the maximum permissible concentrations (MPC) (NRC79). This study evaluated annual average stack top concentrations and ground level concentration versus maximum permissible concentrations.

It was assumed that the short half-life nuclides, half-life ≤60d, were held for decay before incineration and that the wastes were incinerated at one facility. The operating characteristics for a typical 750 lb/hr incinerator were used in the calculations. For simplicity in calculations, 100% of the nuclides were assumed to be present in the effluent.

Table 1. Radionuclides in N.C. low-level institutional wastes (combustible)

NUCLIDE	ACTIVITY (Ci/yr)	HALF-LIFE
Hydrogen-3	134	12 yr
Carbon-14	4.4	5500 yr
Iodine-125	3.8	60 d
Sulfur-35	3.59	87 d
Calcium-45	0.04	160 d
Chromium-51	0.50	27 d
Phosphorous-32	3.0	14.5 d

The procedure for calculating the annual average stack concentrations was quite straight forward. The total volume of air moved through the incinerator during a period of one year was determined. The stack concentration was simply the activity in the waste to be burned divided by the air volume.

The Gaussian dispersion model was used to calculate annual average ground level concentrations assuming a continuous stack release. Calculations were performed using the workbook prepared by Turner (Tu70) which references procedures for dispersion estimates suggested by Pasquill (Pa61) and modified by Gifford (Gi61). The Gaussian equation for the annual average downwind ground level concentration, $\bar{\chi}$, is as follows: –

$$\bar{\chi}(x,\theta) = \sum_S \sum_N \frac{2.03Qf(\theta,S,N)}{\sigma_{zs}u_N x}\exp\left[-\tfrac{1}{2}\left(\frac{H_{ss}}{\sigma_{zs}}\right)^2\right]$$

where Q is the emission rate, $f(\theta, S, N)$ is the annual frequency that the wind is from direction, θ, for stability category, S, and wind speed class, N, σ_{zs} is the vertical dispersion coefficient evaluated at distance, x, for stability category, S, u_N is the average wind speed for wind speed class N, x is the distance from source and H_{ss} is the effective stack height for wind speed u_N and distance, x.

In order to use the Gaussian model, meteorological data were obtained from the National Oceanic and Atmospheric Administration (NOAA). Since a specific site for an incinerator has not been chosen, Raleigh–Durham airport data were used as an example for the purpose of this study. In actuality, meteorological data are site

specific and a study should be carried out in more detail with actual data for the specific site when, and if, it is chosen. The meteorological data utilized consisted of the frequency of occurrence for each wind direction (16 points) and wind speed class (6 classes) for each stability category (6 categories) for a 5 yr period (1/72–12/76).

The effective stack height was calculated using a U.S. Army handbook (USA80) which contained the Briggs' plume rise equations (Br75). The effective stack height ranged from approx. 20 to 90 m, depending upon the stability category, wind speed and distance from source. The Gaussian dispersion equation was solved for downwind distances from 100 to 3000 m in each of the 16 compass directions.

Results and Discussion

The total volume of air that could be exhausted from the incinerator was calculated to be 1.2×10^{14} ml/yr (at 2000°F temperature). Based on this volume and the nuclide activities considered for incineration, annual average stack top concentrations were calculated and are shown in Table 2. The sum of the % MPC values was about 700% which was significantly greater than the 10% value used as a licensing guide.

Using the Gaussian model, the annual average ground level concentrations were calculated and the maximum results are also shown in Table 2. The maximum ground level concentrations were located between 500 and 800 m from the incinerator. These ground level concentrations were smaller than the stack top concentration by a factor of approx. 5×10^{5}. The maximum ground level concentrations were shown to be small fractions of a percent of the respective MPC values. The sum of the % MPC values was only about 0.001%. (If the short half-life nuclides were not held for decay before incineration the sum of the % MPC values would be approx. 42,000% at the stack top and 0.09% at ground level.)

It is concluded that the incineration of institutional low-level radioactive waste generated in North Carolina is environmentally acceptable from the radiological standpoint. (Air emissions requirements must still be met.) The criterion under which most incinerators have been licensed is an annual average concentration of less than 10% of the MPC at the stack top. The results of the present study indicated that this criterion is too conservative.

It is recommended that atmospheric dispersion be considered when assessing radionuclide emissions from the incineration of low-level radioactive waste. Dispersion was included by the Nuclear

Table 2. Annual average stack concentrations and ground level concentrations

NUCLIDE	MPC (μCi/ml)	STACK CONC. (μCi/ml)	% MPC	GROUND CONC. (μCi/ml)	% MPC
H-3	2×10^{-7}	1.1×10^{-6}	570	2.3×10^{-12}	0.0012
C-14	1×10^{-7}	3.7×10^{-8}	37	7.5×10^{-14}	0.000075
S-35	9×10^{-9}	5.0×10^{-9}	55	1.0×10^{-14}	0.00011
Ca-45	1×10^{-9}	3.5×10^{-10}	35	7.1×10^{-16}	0.000071
		TOTAL:	700%	TOTAL:	0.001%

Regulatory Commission in its "Study of Alternate Methods for the Management of Liquid Scintillation Counting Wastes" (NRC80). The NRC's report states that "For dose calculational purposes in an unknown environment, we have assumed that a dilution factor (χ/Q) of 10^{-4} sec/m^3 is an appropriate upper bound at short (10–40 m) distances." The maximum annual average χ/Q value calculated in the present study was approx. 5×10^{-7} sec/m^3, a factor of 2000 lower than the upper bound value assumed by the NRC. Therefore, the results of this study emphasize the significance of using site specific data for dispersion calculations.

Acknowledgement—The authors wish to thank Donald L. Fox, Department of Environmental Sciences & Engineering, University of North Carolina, for his review and critique of this paper.

NELSON W. COUCH
JAMES E. WATSON, JR.*

Department of Environmental Sciences & Engineering
University of North Carolina
Chapel Hill, NC 27514

*Please direct reprint requests to Dr. Watson.

References

Br75 Briggs G. A., 1975, "Plume Rise Predictions", Paper presented at American Meteorological Society Workshop on Meteorology and Environment Assessment, Boston, MA., 29 Sept.–3 Oct., 1975.

Gi61 Gifford F. A., 1961, "Use of Routine Meteorological Observations for Estimating Atmospheric Dispersion", *Nucl. Safety*, 2(4), 47.

NC79 North Carolina *Ad-Hoc* Committee on ILLW, 1979, Survey of North Carolina Institutions, Revision: December 1979.

NRC79 Nuclear Regulatory Commission, 1979, "Information Required for Commission Approval of Treatment or Disposal by Incineration", Revised 3 October, 1979.

NRC80 Nuclear Regulatory Commission, 1980, "Study of Alternative Methods for the Management of Liquid Scintillation Counting Wastes", NUREG-0656.

Pa61 Pasquill F., 1961, "The Estimation of the Dispersion of Windborne Material", *Meteorol. Mag.* 90(1063), 33.

Tu70 Turner D. B., 1970, "Workbook of Atmospheric Dispersion Estimates", Environmental Protection Agency, Office of Air Programs Publication No. AP-26.

USA80 U.S. Army, DARCOM, 1980, "Handbook for Chemical Hazard Prediction", Handbook No. 385-2.1-80, p. G-1.

Printed in the U.S.A.

0017-9078/83/0000-0711-0$03.00/0
Pergamon Press Ltd.

C-4

C.13

Evaluation of a Small, Inexpensive Incinerator for Institutional Radioactive Waste*

(*Received* 20 *September* 1982; *accepted* 12 *October* 1982)

Introduction

CONCERN about the rapidly escalating costs of commercial low-level radioactive waste disposal is causing many institutions to utilize incinerators as an alternate disposal method (Co81). Of particular importance is the capability of incinerators to completely dispose of troublesome liquid scintillation solutions so copiously generated in biological research. Incinerators also provide a significant volume reduction factor for the disposal of animals whose carcasses are radioactive as a result of radiotracer studies. This research concerned the purchase of a small (100 lb/hr), inexpensive (less than $8000) pathological incinerator, and an evaluation of the feasibility of dedicating this type of incinerator entirely to the disposal of low-level radioactive waste.

The evaluation consisted of several phases. First, a modification of the fuel supply system which allowed liquid scintillation waste solutions to be mixed and burned with the incinerator fuel oil was designed and installed. Next, studies were performed on emissions from non-radioactive material which was representative of the radioactive waste scheduled to be processed in the incinerator. A third objective was related to a rather unique opportunity which presented itself during the initial evaluations of the incinerator. This research effort, within the Purdue University School of Veterinary Medicine, involved the use of radiolabelled microspheres in large research animals. The potential cost-savings afforded by incineration of these animals, as compared to burial at a low-level waste disposal site, were obvious. Consequently, a study was performed to estimate the amount of radioactivity released to the environment via the incinerator stack by analyzing the activity remaining in the ash of the animals. Another objective was to calculate the activity of various radionuclides which could be incinerated with this type of unit and have emissions remain within regulatory release limits. The final objective was to perform a cost-benefit analysis of the acquisition and use of this type of incinerator.

Equipment

The specifications of the incinerator are given in Table 1. The unit was installed in the Purdue University radioactive waste building located about 2 miles northwest of the main campus. The incinerator has two chambers, each consisting of an aluminized steel jacket lined with firebrick. The waste is supported by ceramic grates and incinerated from below by a burner in the primary chamber. The combustion products pass through a 2-ft long refractory-lined combustion chamber into a refractory lined secondary chamber where they are mixed with the flame of the secondary burner for complete combustion. The gases are then released to the atmosphere from a 7-m metal stack.

The fuel supply system was modified so that mixtures of fuel oil and liquid scintillation fluids could be used to fuel the incinerator. Figure 1 is a flow diagram of the converted fuel mixing system.

Table 1. Specifications of the Purdue University low-level radioactive waste incinerator

Model:	Shenandoah I-HW/ITC
Cost:	$7,083
Fuel:	No. 1 fuel oil; 5.5 gal/hr
Chamber:	16.5 ft^3; 400 lb Type IV
Burning Rate:	100 lb/hr
Dimensions:	4 x 7 x 24 ft

The conversion consisted of modifying the two fuel tanks to allow them to empty separately instead of in series. One tank is used to store fuel oil, and the other is used to store liquid scintillation fluids. The lines from the fuel storage tanks run separately through two fuel filters each, after which they are combined at a variable flow connection so that different fuel oil/liquid scintillation fluid mixtures can be used. After this point the oil/liquid scintillation fluid mixture flows into a storage/mixing tank from which it leaves through a single line. Just prior to the incinerator the line separates into two lines, each passing through a final filter and then leading to one of the burners. Because the burners use only about 10% of the fuel in the line, there are fuel lines leaving each burner which return the unused fuel to the storage/mixing tank.

Experimental

Non-radioactive emissions were studied using samples representative of the radioactive waste which would eventually be processed in the incinerator. These trials included a control burn with No. 1 fuel oil only (no trash) and two burns each of animal carcasses, laboratory trash and a fuel mixture of one part fuel oil and one part toluene. The carcass and the trash burns used No. 1 fuel oil only. For the two burns involving mixed fuel, the mixture was used to fuel the lower burner only. All burns were for 48 min. The sampling period was 24 min for the laboratory trash burns and 48 min for the other burns.

The sampling train, known as the EPA Method 5 procedure (Fe77), consisted of a probe, a 12.5-cm glass fiber filter, four bubblers, a vacuum pump, a dry gas meter and a flow meter. The first two bubblers were each filled with approx. 200 ml of 3% H_2O_2; the third bubbler was left empty and the fourth bubbler was filled with 200 g of silica gel. All four bubblers were cooled in an ice bath.

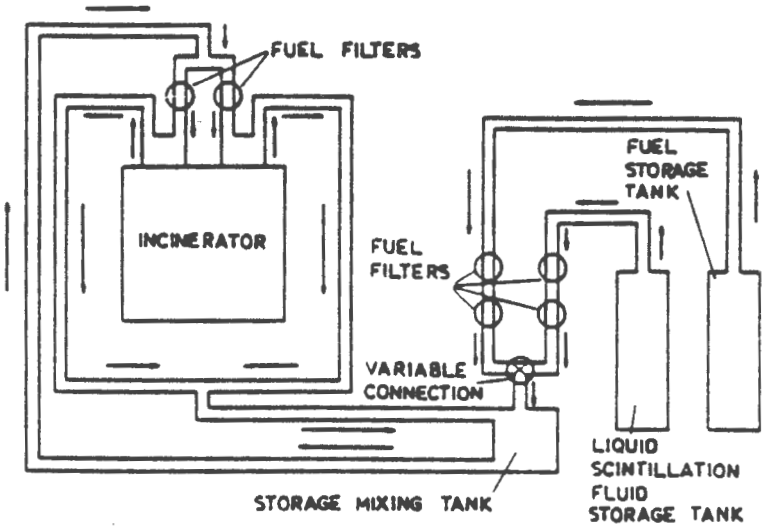


FIG. 1. Incinerator fuel supply system modified to allow use of liquid scintillation fluid as fuel.

It was determined (Fe77) that 20 traverse points of the stack would need to be sampled in order to properly characterize the effluent components. Particulates, NO_x, SO_x, HCl, H_2O, CO, CO_2 and unburned hydrocarbons were sampled and analyzed using standard procedures (Am77; Am71).

The need to incinerate large animals containing radiolabelled microspheres provided a unique opportunity to study possible environmental release from incineration of this type of waste. Eight animals containing plastic microspheres labelled with ^{46}Sc were weighed and incinerated individually. Each burn used a 15-min warm-up period for the secondary burner and no warm-up period for the primary burner. The animals were incinerated for 5 hr and the ash allowed to cool for at least 20 hr after which it was carefully removed and weighed. The total ash of each burn was placed in a 5-gal plastic jug which was then placed 1-m from a 3 × 3-in. NaI(Tl) crystal connected to a single channel analyzer. The counting efficiency of the system was determined by recounting one of the samples to which a known concentration of a ^{46}Sc standard solution has been distributed uniformly throughout the ash. All counting results were back-decayed to the time of incineration to determine the fraction of ^{46}Sc retained in the ash.

Results and Conclusions

Table 2 is a listing of the various emissions measured during the incineration of non-radioactive waste. No unburned hydrocarbons were detected. All emissions from all burns were below Indiana limits (In80) except for burn 4, a laboratory trash burn. That burn had particulate emissions of 0.73 lb/1000 lb gas which exceeded the Indiana limit of 0.5 lb/1000 lb gas. The elevated HCl emissions in the laboratory trash burns are believed to be from polyvinyl chloride plastics present in the trash. It should be mentioned that this particular incinerator is small enough to be exempt from all Federal non-radioactive emission regulations (En80).

Almost all of the ^{46}Sc from the labelled microspheres were found to be retained in the animal ash. The mean percentage retention and standard deviation for the eight burns was found to be 97.9 ± 7.6%. The mass reduction following incineration of the animals was approx. 25 : 1.

The NRC license obtained for this incinerator limited the gaseous effluent to the values given in Appendix B, Table 2, 10CFR20 for air (Co82). Based on these limits, calculations were made of the total activity per daily 5-hr burn that could be incinerated for selected radionuclides commonly found in institutional waste. These values, listed in

Table 2. Non-radioactive emissions from various incinerator loadings

Burn	Sample Type	Particulates (lb/1000 lb gas)	NO_x (ppm)	SO_x (lb/million BTU)	HCl (ppm)	CO (ppm)	CO_2 (%)	H_2O (%)
1	Fuel Oil	1.3×10^{-3}	ND*	0.27	17.6	30	2.8	4.86
2	Animals	8.8×10^{-3}	20	0.72	77.1	ND	3.5	6.63
3	Animals	7.9×10^{-3}	25	0.76	89.7	ND	3.5	7.15
4	Trash	7.3×10^{-1}	45	1.42	3,020	150	3.5	5.45
5	Toluene + fuel oil	1.2×10^{-3}	4.6	0.24	18.6	350	3.5	3.33
6	Trash	9.3×10^{-2}	25	0.59	647	120	3.5	6.10
7	Toluene + fuel oil	1.1×10^{-3}	13	0.23	9.1	175	3.0	3.6

*ND = nondetectable

Table 3, were calculated for single radionuclides using a stack flow rate of 8.6×10^6 ml/hr. The most restrictive soluble vs insoluble limits from 10CFR20 were used for the calculations and, in order to be conservative, the allowable averaging over a yearly period was not used. Because the area surrounding the building had unrestricted access, the values in Table 3 were calculated based on concentration limits imposed at the stack exit. Incinerators which have defined site boundaries could use atmospheric dispersion considerations to allow burning considerably larger amounts of the various radionuclides. Operation of the incinerator under the conditions described above was found to easily keep up with the rate of waste generated at Purdue with the exception of radioiodines which are stored for decay.

The cost-savings afforded by this type of incinerator are dramatic. As shown in Table 4 for the year 1982 the incinerator afforded an annual savings of greater than $140,000 when compared to the cost required if an incinerator had not been available. The method of cost comparison used did not include labor costs because it was estimated

Table 3. Calculated daily total radioactivity incinerator limits

Radionuclide	10CFR20 limit, μCi/ml	Daily (5h) limit, μCi
^{3}H (S)	2×10^{-7}	860
^{14}C (S)	1×10^{-7}	430
^{35}S (S)	9×10^{-9}	38.7
^{75}Se (I)	4×10^{-9}	17.2
^{59}Fe (I)	2×10^{-9}	8.6
^{137}Cs (I)	5×10^{-10}	2.2
^{125}I (S)	8×10^{-11}	0.34

Table 4. Cost analysis of disposal with and without the use of an incinerator for the year 1982

	Drums (55 gal)
Without Incineration	
Laboratory Trash	71
Animal Carcasses	480
Scintillation Fluids	20
Solvents	24
Total	595
With Incineration	
Ash, Metal and Glass Total	10
Net Savings	
585 drums @ $250 per drum =	$146,250

that labor costs would have been about the same with or without the incinerator.

In summary, the results of this study showed that a small, pathological incinerator dedicated to treatment of low-level radioactive wastes can give a very substantial volume reduction factor for institutional wastes with a concomitant high economic savings. The incinerator was capable of disposing of a high percentage of the radioactive waste generated at Purdue with a minimal release of non-radioactive emissions to the environment. In addition, a concurrent study showed that animals containing radiolabelled plastic microspheres, a rapidly growing medical research technique, can be incinerated with very little release of the radioactivity to the atmosphere.

Acknowledgment—The authors would like to thank Prof. R. B. Jacko for the use of equipment for the non-radioactive emissions sampling.

ROBERT R. LANDOLT
TERENCE P. BARTON
GORDON S. BORN
VICTORIA R. MORRIS
RICHARD J. VETTER
NEIL J. ZIMMERMAN

School of Health Sciences
Purdue University
West Lafayette, IN 47907

References

Am71 American Public Health Association, 1971, *Standard Methods for the Examination of Water and Wastewater*, 13th Edn (New York).

Am77 American Public Health Association, 1977, *Methods of Air Sampling and Analysis*, 2nd Edn (Washington, DC).

Co82 Code of Federal Regulations, Title 10, Part 20, Appendix B, Table II.

Co81 Cooley L. R., McCampbell M. R. and Thompson J. D., 1981, "Current Practice of Incineration of Low-level Institutional Radioactive Waste," U.S. Dept. of Energy Rep. EGG-2076 (Springfield, VA:NTIS).

En80 Environmental Protection Agency, Title 40, Code of Federal Regulations, Part 60.50, Subpart E, Standards for Performance of Incinerators.

Fe77 Federal Register, Vol. 42, No. 160, 1977.

In80 State of Indiana, Air Pollution Control Board, Title 325, Indiana Administrative Code, 1980.

APPENDIX D

Any consistent set of units may be used. The most common is:

$\mathcal{M}$ (g m^{-1}) or, for radioactivity (curies m^{-1})
Q (g sec^{-1}) or (curies sec^{-1})
u (m sec^{-1})
H, x, y, and z (m)

This equation is the same as equation (8.35) p. 293 of Sutton (1953) when σ's are substituted for Sutton's parameters through equations like (8.27) p. 286. For evaluations of the exponentials found in Eq. (3.1) and those that follow, see Appendix 3. χ is a mean over the same time interval as the time interval for which the σ's and u are representative. The values of both σ_y and σ_z are evaluated in terms of the downwind distance, x.

Eq. (3.1) is valid where diffusion in the direction of the plume travel can be neglected, that is, no diffusion in the x-direction.

This may be assumed if the release is continuous or if the duration of release is equal to or greater than the travel time (x/u) from the source to the location of interest.

For concentrations calculated at ground level, i.e., z = 0, (see problem 3) the equation simplifies to:

$$\chi\,(x,y,0;H) = \frac{Q}{\pi\,\sigma_y\,\sigma_z\,u}\exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] \qquad (3.2)$$

Where the concentration is to be calculated along the centerline of the plume (y = 0), (see problem 2) further simplification results:

$$\chi\,(x,0,0;H) = \frac{Q}{\pi\,\sigma_y\,\sigma_z\,u}\exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] \qquad (3.3)$$

For a ground-level source with no effective plume rise (H = 0), (see problem 1):

$$\chi\,(x,0,0;0) = \frac{Q}{\pi\,\sigma_y\,\sigma_z\,u} \qquad (3.4)$$

EFFECTS OF STABILITY

The values of σ_y and σ_z vary with the turbulent structure of the atmosphere, height above the surface, surface roughness, sampling time over which the concentration is to be estimated, wind speed, and distance from the source. For the parameter values given here, the sampling time is assumed to be about 10 minutes, the height to be the lowest several hundred meters of the atmosphere, and the surface to be relatively open country. The turbulent structure of the atmosphere and wind speed are considered in the stability classes presented, and the effect of distance from the source considered in the graphs determining the parameter values. Values for σ_y and σ_z are estimated from the stability of the atmosphere, which is in turn estimated from the wind speed at a height of about 10 meters and, during the day, the incoming solar radiation or, during the night, the cloud cover (Pasquill, 1961). Stability categories (in six classes) are given in Table 3-1. Class A is the most unstable, class F the most stable class considered here. Night refers to the period from 1 hour before sunset to 1 hour after sunrise. Note that the neutral class, D, can be assumed for overcast conditions during day or night, regardless of wind speed.

Table 3-1 KEY TO STABILITY CATEGORIES

Surface Wind Speed (at 10 m), m sec^{-1}	Day			Night	
	Incoming Solar Radiation			Thinly Overcast or ≥4/8 Low Cloud	≤3/8 Cloud
	Strong	Moderate	Slight		
< 2	A	A-B	B		
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
> 6	C	D	D	D	D

The neutral class, D, should be assumed for overcast conditions during day or night.

"Strong" incoming solar radiation corresponds to a solar altitude greater than 60° with clear skies; "slight" insolation corresponds to a solar altitude from 15° to 35° with clear skies. Table 170, Solar Altitude and Azimuth, in the Smithsonian Meteorological Tables (List, 1951) can be used in determining the solar altitude. Cloudiness will decrease incoming solar radiation and should be considered along with solar altitude in determining solar radiation. Incoming radiation that would be strong with clear skies can be expected to be reduced to moderate with broken (⅝ to ⅞ cloud cover) middle clouds and to slight with broken low clouds. An objective system of classifying stability from hourly meteorological observations based on the above method has been suggested (Turner, 1961).

These methods will give representative indications of stability over open country or rural areas, but are less reliable for urban areas. This difference is due primarily to the influence of the city's larger surface roughness and heat island effects upon the stability regime over urban areas. The greatest difference occurs on calm clear nights; on such nights conditions over rural areas are very stable, but over urban areas they are slightly unstable or near neutral to a height several times the average building height, with a stable layer above (Duckworth and Sandberg, 1954; DeMarrais, 1961).

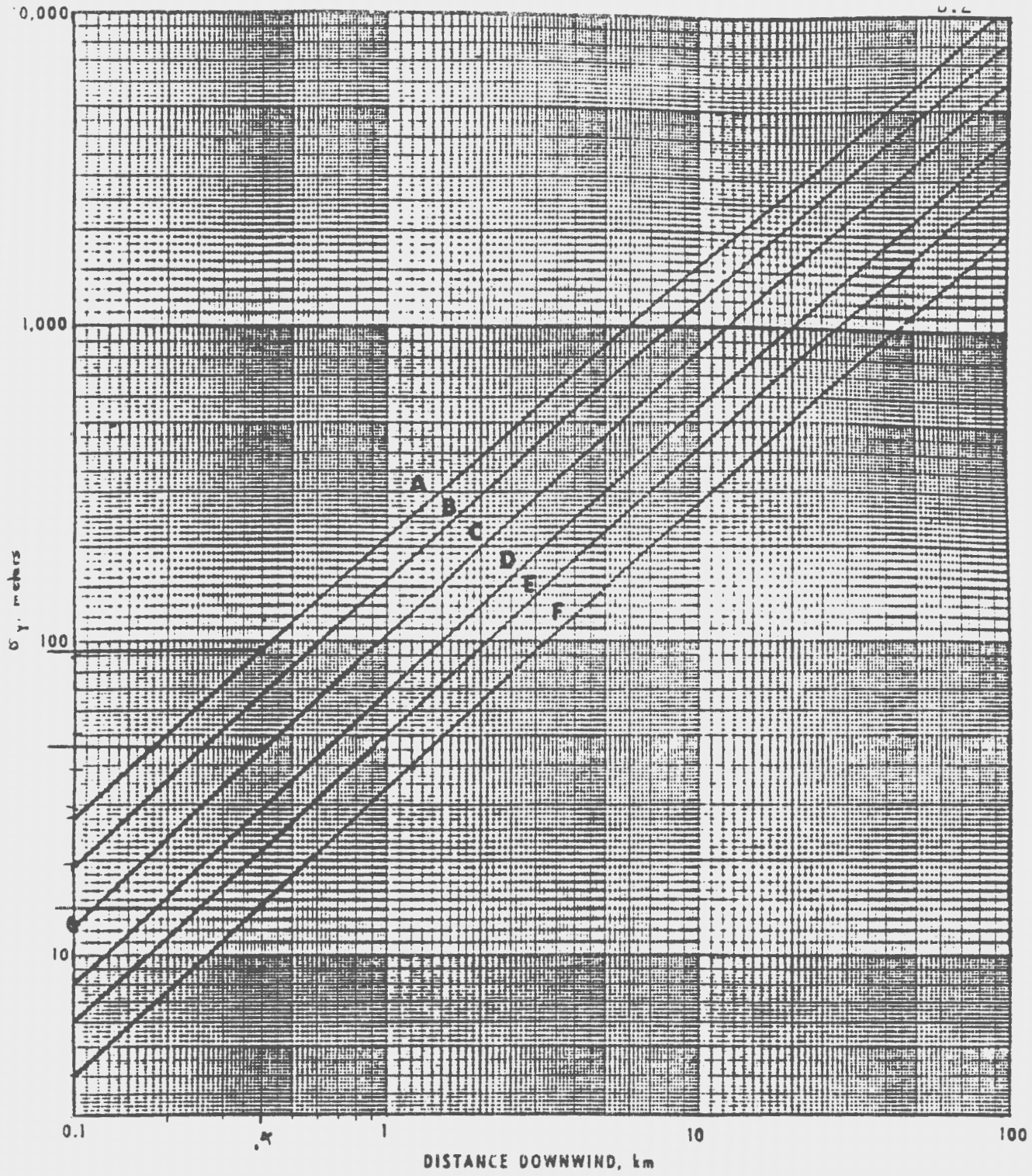


Figure 3-2. Horizontal dispersion coefficient as a function of downwind distance from the source.

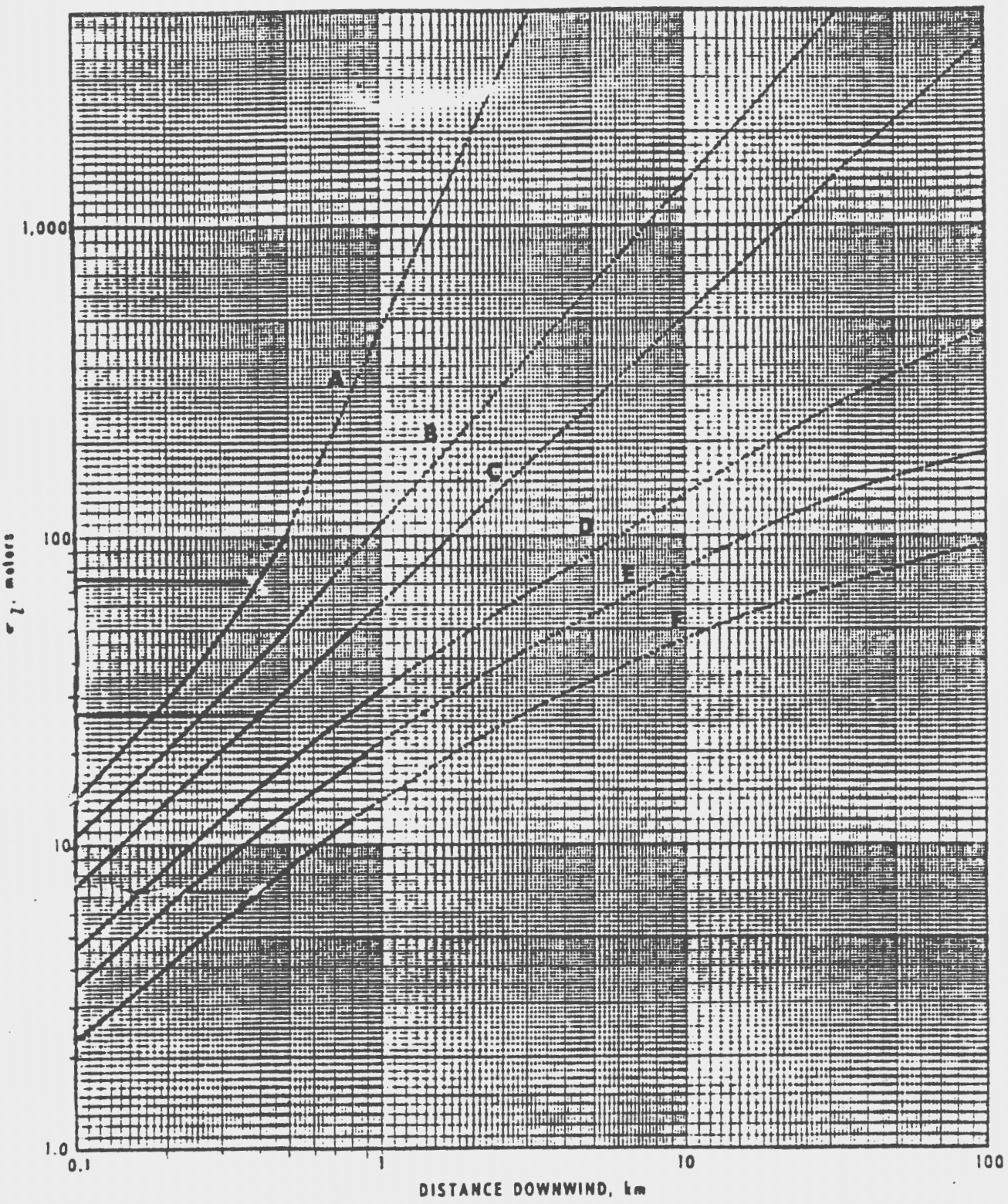


Figure 3-3. Vertical dispersion coefficient as a function of downwind distance from the source.

320-901 O - 68 - 2

From Table A-1 (Appendix 3) when exp $\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] = 0.345$, $y/\sigma_y = 1.46$

From Figure 3-2, for stability B and x = 600 m., σ_y = 92. Therefore y = (1.46) (92) = 134 meters. This is the distance of the 10^{-3} isopleth from the x-axis at a downwind distance of 600 meters.

This can also be determined from:

$$y = \left\{2 \ln^* \left[\frac{\chi(x,0,0;H)}{\chi(x,y,0;H)}\right]\right\}^{\frac{1}{2}} \sigma_y \qquad (3.8)$$

The position corresponding to the downwind distance and off-axis distance can then be plotted. After a number of points have been plotted, the concentration isopleth may be drawn (see problems 8 and 26). Figures 3-6 and 3-7 give ground-level isopleths of $\chi u/Q$ for various stabilities for sources at H = 0 and H = 100 meters. For example, to locate the 10^{-3} g m^{-3} isopleth resulting from a ground-level source of 20 g sec^{-1} under B stability conditions with wind speed 2 m sec^{-1}, one must first determine the corresponding value of $\chi u/Q$ since this is the quantity graphed in Figure 3-6. $\chi u/Q = 10^{-3} \times 2/20 = 10^{-4}$. Therefore the $\chi u/Q$ isopleth in Figure 3-6B having a value of 10^{-4} m^{-2} corresponds to a χ isopleth with a value of 10^{-3} g m^{-3}

AREAS WITHIN ISOPLETHS

Figure 3-8 gives areas within isopleths of ground-level concentration in terms of χ u/Q for a ground-level source for various stability categories (Gifford, 1962; Hilsmeier and Gifford, 1962). For the example just given, the area of the 10^{-3} g m^{-3} isopleth (10^{-4} m^{-2} χ u/Q isopleth) is about 5 x 10^{4} meter^2.

CALCULATION OF MAXIMUM GROUND-LEVEL CONCENTRATIONS

Figure 3-9 gives the distance to the point of maximum concentration, x_{max}, and the relative maximum concentration, $\chi u/Q_{max}$, as a function of effective height of emission and stability class (Martin, 1965). This figure was prepared from graphs of concentration versus distance, as in Figure 3-5. The maximum concentration can be determined by finding χ u/Q as a function of effective emission height and stability and multiplying by Q/u. In using Figure 3-9, the user must keep in mind that the dispersion at higher levels may differ considerably from that determined by the σ_y's and σ_z's used here. As noted, however, since σ_y generally decreases with height and u increases with height, the product u σ_y σ_z will not change appreciably. The greater the effective height, the more likely it is that the stability may not be the same from the ground to this height. With the longer travel distances such as the points of maximum concentrations for stable conditions (Types E or F), the stability may change before the plume travels the entire distance.

REVIEW OF ASSUMPTIONS

The preceding has been based on these assumptions, which should be clearly understood:

(i) Continuous emission from the source or emission times equal to or greater than travel times to the downwind position under consideration, so that diffusion in the direction of transport may be neglected.

(ii) The material diffused is a stable gas or aerosol (less than 20 microns diameter) which remains suspended in the air over long periods of time.

(iii) The equation of continuity:

$$Q = \int_0^{+\infty} \int_{-\infty}^{+\infty} \chi \, u \, dy \, dz \qquad (3.9)$$

is fulfilled, i.e., none of the material emitted is removed from the plume as it moves downwind and there is complete reflection at the ground.

(iv) The mean wind direction specifies the x-axis, and a mean wind speed representative of the diffusing layer is chosen.

(v) Except where specifically mentioned, the plume constituents are distributed normally in both the cross-wind and vertical directions.

(vi) The σ's given in Figures 3-2 and 3-3 represent time periods of about 10 minutes.

REFERENCES

DeMarrais, G. A., 1961: Vertical temperature difference observed over an urban area. Bull. Amer. Meteorol. Soc., *42*, 8, 548-554.

Duckworth, F. S., and J. S. Sandberg, 1954: The effect of cities upon horizontal and vertical temperature gradients. Bull. Amer. Meteorol. Soc., *35*, 5, 198-207.

Gifford, F. A., 1961: Use of routine meteorological observations for estimating atmospheric dispersion. Nuclear Safety, *2*, 4, 47-51.

Gifford, F. A., 1962: The area within ground-level dosage isopleths. Nuclear Safety, *4*, 2, 91-92.

*"ln" denotes natural logarithms, i.e., to the base e.

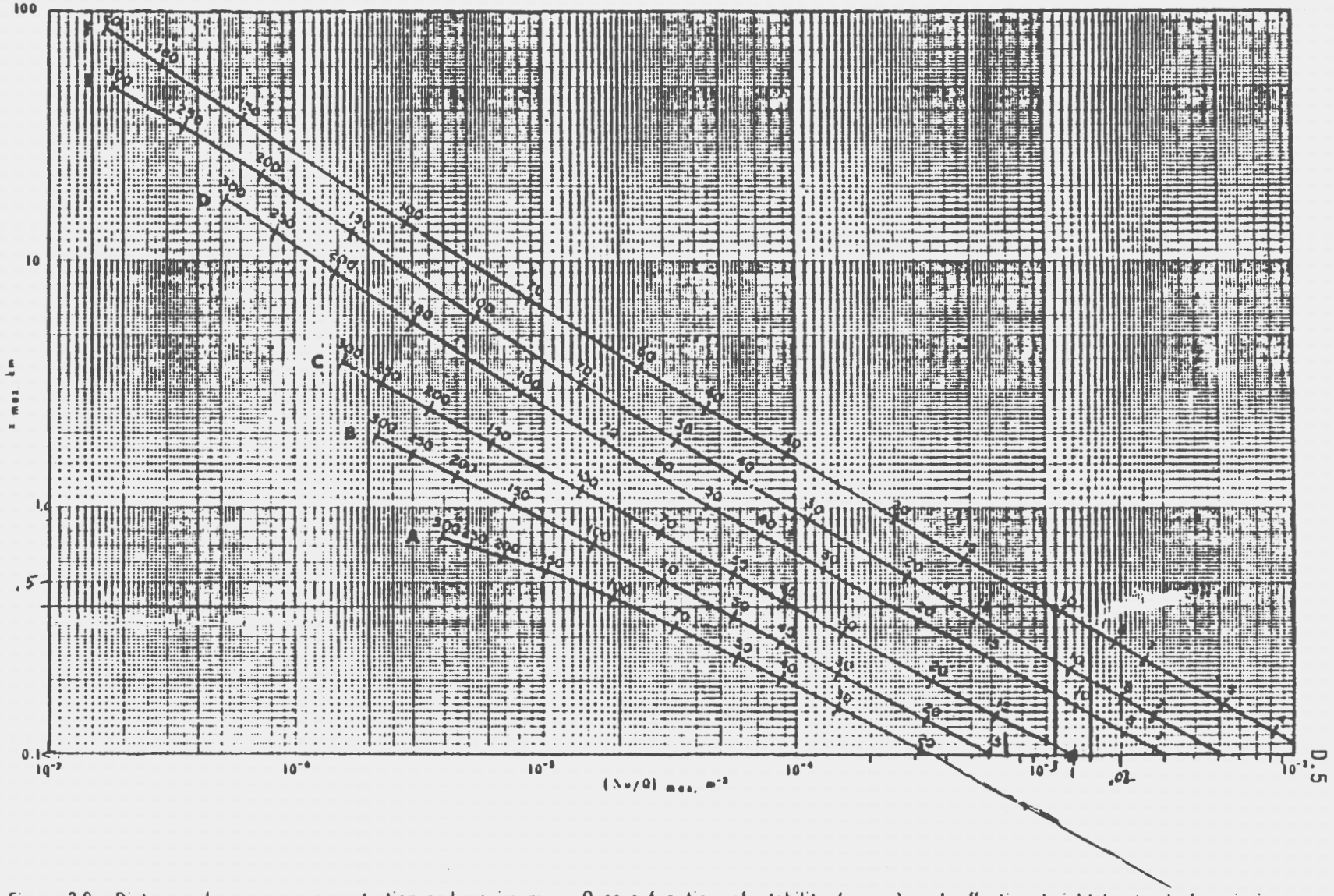


Figure 3-9. Distance of maximum concentration and maximum χu Q as a function of stability (curves) and effective height (meters) of emission (numbers).

Chapter 4 — EFFECTIVE HEIGHT OF EMISSION

GENERAL CONSIDERATIONS

In most problems one must estimate the effective stack height, H, at which the plume becomes essentially level. Rarely will this height correspond to the physical height of the stack, h. If the plume is caught in the turbulent wake of the stack or of buildings in the vicinity of the stack, the effluent will be mixed rapidly downward toward the ground (aerodynamic downwash). If the plume is emitted free of these turbulent zones, a number of emission factors and meteorological factors influence the rise of the plume. The emission factors are: velocity of the effluent at the top of the stack, v_s; temperature of the effluent at the top of the stack, T_s; and diameter of the stack opening, d. The meteorological factors influencing plume rise are wind speed, u; temperature of the air, T_a; shear of the wind speed with height, du/dz; and atmospheric stability. No theory on plume rise takes into account all of these variables; even if such a theory were available, measurements of all of the parameters would seldom be available. Most of the equations that have been formulated for computing the effective height of emission are semi-empirical. For a recent review of equations for effective height of emission see Moses, Strom, and Carson (1964).

Moses and Strom (1961), having compared actual and calculated plume heights by means of six plume rise equations, report "There is no one formula which is outstanding in all respects." The formulas of Davidson-Bryant (1949), Holland (1953), Bosanquet-Carey-Halton (1950), and Bosanquet (1957) all give generally satisfactory results in the test situations. The experiments conducted by Moses and Strom involved plume rise from a stack of less than 0.5 meter diameter, stack gas exit velocities less than 15 m sec^{-1}, and effluent temperature not more than 35°C higher than that of the ambient air.

The equation of Holland was developed with experimental data from larger sources than those of Moses and Strom (stack diameters from 1.7 to 4.3 meters and stack temperatures from 82 to 204°C); Holland's equation is used in the solution of the problems given in this workbook. This equation frequently underestimates the effective height of emission; therefore its use often provides a slight "safety" factor.

Holland's equation is:

$$\Delta H = \frac{v_s d}{u}\left(1.5 + 2.68 \times 10^{-3} p \frac{T_s - T_a}{T_s} d\right) \quad (4.1)$$

where:

ΔH = the rise of the plume above the stack, m

v_s = stack gas exit velocity, m sec^{-1}

d = the inside stack diameter, m

u = wind speed, m sec^{-1}

p = atmospheric pressure, mb

T_s = stack gas temperature, °K

T_a = air temperature, °K

and 2.68×10^{-3} is a constant having units of mb^{-1} m^{-1}.

Holland (1953) suggests that a value between 1.1 and 1.2 times the ΔH from the equation should be used for unstable conditions; a value between 0.8 and 0.9 times the ΔH from the equation should be used for stable conditions.

Since the plume rise from a stack occurs over some distance downwind, Eq. (4.1) should not be applied within the first few hundred meters of the stack.

EFFECTIVE HEIGHT OF EMISSION AND MAXIMUM CONCENTRATION

If the effective heights of emission were the same under all atmospheric conditions, the highest ground-level concentrations from a given source would occur with the lightest winds. Generally, however, emission conditions are such that the effective stack height is an inverse function of wind speed as indicated in Eq. (4.1). The maximum ground-level concentration occurs at some intermediate wind speed, at which a balance is reached between the dilution due to wind speed and the effect of height of emission. This critical wind speed will vary with stability. In order to determine the critical wind speed, the effective stack height as a function of wind speed should first be determined. The maximum concentration for each wind speed and stability can then be calculated from Figure 3-9 as a function of effective height of emission and stability. When the maximum concentration as a function of wind speed is plotted on log-log graph paper, curves can be drawn for each stability class; the critical wind speed corresponds to the point of highest maximum concentration on the curve (see problem 14).

ESTIMATES OF REQUIRED STACK HEIGHTS

Estimates of the stack height required to produce concentrations below a given value may be made through the use of Figure 3-9 by obtaining solutions for various wind speeds. Use of this figure considers maximum concentrations at any distance from the source.

In some situations high concentrations upon the property of the emitter are of little concern, but

APPENDIX E

Source:

DRAFT

ARIZONA DISPERSION CLIMATOLOGY

VOLUME II

Submitted to:

Bureau of Land Management

Phoenix, Arizona

BLM Project Officer: Dirk C. Herkhof

Contract Number: YA-553-CT1-1021

Prepared by:

Joseph A. Catalano and Thomas Chico

Aerocomp, Inc.

3303 Harbor Boulevard

Costa Mesa, California 92626

Anthony J. Brazel

Laboratory of Climatology

Arizona State University

Tempe, Arizona 85281

June 1982

TABLE 4.2-2. DIURNAL WIND SUMMARY FOR PHOENIX FOR THE PERIOD, 1955-64.

F = Frequency (all speeds)
M = Mean speed (knots)

MST	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL		MAX SPD
00	2.8	2.0	9.4	7.0	19.8	13.4	11.8	3.1	3.4	1.7	6.7	4.7	6.9	2.5	3.2	1.5		F	
	4.8	5.3	5.5	5.6	4.8	5.2	4.9	5.8	5.2	4.8	5.0	6.0	5.4	5.3	4.9	4.9	4.4	M	27
01	3.5	1.6	8.8	6.9	23.7	13.4	13.1	2.6	3.1	1.4	4.9	4.3	5.7	1.7	3.0	2.1		F	
	5.1	4.8	5.6	5.7	5.1	5.3	5.0	5.4	5.1	5.0	4.8	5.9	5.6	5.7	5.2	4.6	4.5	M	24
02	2.6	2.3	10.5	7.7	27.8	13.9	11.6	2.0	2.6	1.2	4.5	2.9	4.5	1.6	3.1	1.3		F	
	4.6	4.7	5.4	5.9	5.0	5.4	5.0	5.1	5.2	4.5	4.8	5.9	5.4	5.2	5.2	4.6	4.5	M	26
03	3.0	1.6	10.4	9.4	29.6	14.4	10.9	2.4	3.0	1.1	3.5	2.6	4.2	1.4	1.6	1.0		F	
	4.6	4.9	5.5	5.9	5.1	5.3	4.9	4.5	4.6	4.8	4.9	6.2	5.1	5.7	4.4	4.9	4.5	M	20
04	1.8	1.6	11.0	9.8	31.3	15.3	11.5	1.7	2.3	0.8	3.1	2.1	3.7	1.2	1.7	0.8		F	
	4.2	4.4	5.5	5.9	5.0	5.2	4.8	4.6	4.3	4.7	4.6	5.5	5.1	4.8	4.4	4.8	4.5	M	26
05	1.7	1.1	11.6	10.5	31.4	17.9	10.4	1.8	1.7	0.6	3.1	1.5	3.5	0.9	1.4	0.8		F	
	4.4	4.5	5.4	6.1	5.1	5.3	4.6	4.9	4.6	4.7	4.7	5.7	5.2	5.2	3.9	5.4	4.6	M	25
06	1.8	1.1	11.8	11.2	31.6	17.8	10.3	2.0	2.0	0.9	2.8	1.5	2.3	0.5	1.4	0.9		F	
	4.2	5.5	5.6	5.8	5.2	5.2	4.6	5.3	4.2	4.6	4.3	5.8	6.0	5.4	4.9	4.3	4.6	M	21
07	1.5	1.0	11.4	11.1	31.2	17.6	12.7	1.7	1.8	0.6	2.2	1.7	2.5	0.9	1.3	0.9		F	
	4.7	4.4	5.6	6.1	5.4	5.6	4.7	5.1	4.7	5.8	4.3	5.8	5.7	5.5	4.3	4.7	4.8	M	18
08	1.9	1.4	9.7	10.3	26.3	20.8	14.9	1.7	1.8	0.5	2.2	2.2	2.6	1.1	1.5	1.2		F	
	4.5	5.0	6.2	6.3	5.8	5.8	5.6	5.4	4.2	4.3	4.2	7.1	5.8	5.4	4.9	4.6	5.2	M	22
09	2.1	1.3	8.4	7.8	23.5	18.4	18.9	3.3	1.8	0.8	2.6	2.5	3.7	1.8	1.9	1.2		F	
	4.6	5.9	6.1	6.7	6.1	6.1	5.9	5.9	4.9	5.5	5.0	6.7	6.5	5.5	5.1	5.1	5.4	M	23
10	2.7	1.5	8.7	6.7	18.0	12.9	20.0	5.4	3.4	1.3	3.7	3.6	5.1	2.4	3.2	1.3		F	
	5.0	4.5	6.5	6.6	6.1	6.1	5.9	6.1	5.2	6.0	5.3	6.3	6.2	5.9	4.9	4.9	5.5	M	25
11	2.6	1.6	7.2	5.9	13.9	10.0	17.6	5.8	6.3	2.8	6.0	4.9	7.5	3.0	4.1	1.6		F	
	4.6	5.4	7.0	6.6	6.3	6.3	5.8	6.9	5.9	5.5	5.5	5.8	6.2	5.8	4.8	5.2	5.5	M	23
12	3.4	1.5	6.8	4.7	10.6	7.4	15.2	6.1	7.0	2.5	7.9	5.7	10.7	4.4	4.8	1.4		F	
	4.8	5.6	6.3	7.0	6.0	6.4	6.1	6.2	6.8	6.1	5.8	7.2	6.4	6.4	5.0	5.9	5.7	M	28
13	3.4	1.5	5.8	3.4	7.5	5.3	11.9	4.4	7.2	3.2	10.5	8.7	13.8	5.4	5.9	2.1		F	
	5.0	6.0	6.2	6.8	6.8	6.4	6.4	7.1	6.0	6.5	5.9	7.2	6.7	7.0	5.5	5.6	5.9	M	25
14	2.8	1.7	5.3	2.7	5.8	4.1	9.0	4.0	6.4	2.9	11.8	10.8	16.6	6.9	6.8	2.2		F	
	5.4	5.7	5.9	6.6	6.3	6.6	5.9	7.2	6.3	6.1	6.2	7.7	7.4	7.0	6.3	5.5	6.2	M	25
15	3.1	1.9	5.0	2.4	4.6	3.4	6.6	3.6	5.3	2.5	11.7	12.4	19.3	7.8	8.1	2.2		F	
	5.6	5.6	5.9	6.7	5.8	6.3	6.5	6.9	6.2	6.4	6.5	7.8	7.6	7.9	6.8	5.8	6.5	M	26
16	3.5	1.6	4.0	2.1	3.8	2.2	5.8	2.8	4.8	2.1	11.8	13.3	21.6	8.8	9.5	2.4		F	
	5.8	6.3	6.1	6.3	6.2	6.3	6.0	6.6	6.1	6.6	6.7	8.2	7.8	7.6	6.8	6.0	6.6	M	32
17	3.8	1.7	3.4	1.9	3.8	2.2	4.0	2.8	3.7	1.9	12.3	12.7	24.2	9.3	10.2	3.0		F	
	6.2	7.6	6.3	5.3	5.5	6.1	5.9	6.2	6.2	5.9	6.7	8.3	7.7	7.8	6.6	6.7	6.6	M	34
18	4.4	1.8	3.6	2.1	3.2	2.3	4.0	1.6	3.1	1.6	11.4	11.1	24.2	10.8	11.0	3.8		F	
	5.3	6.7	6.6	6.1	4.9	5.7	6.3	6.8	5.8	5.8	6.4	7.7	7.3	7.2	6.5	5.5	6.8	M	40
19	5.5	1.8	5.8	2.3	4.6	2.5	4.6	1.9	4.0	2.6	12.1	10.1	19.4	7.6	10.7	4.7		F	
	5.3	6.7	6.1	6.6	5.2	5.3	5.8	5.7	5.5	5.4	5.3	6.9	6.9	7.3	5.3	5.1	5.2	M	40
20	5.2	2.7	5.7	3.6	7.0	4.7	7.5	2.2	5.4	3.2	12.0	10.4	14.6	6.4	5.7	3.5		F	
	4.7	6.6	5.7	5.9	4.9	5.3	4.9	5.9	4.7	5.0	5.0	6.2	6.1	5.7	5.0	4.6	4.4	M	35
21	2.9	1.5	7.1	4.4	12.6	7.2	8.2	3.5	7.2	3.6	11.4	9.4	11.5	3.7	3.8	2.0		F	
	5.8	5.9	5.2	5.4	4.6	5.1	4.8	6.2	4.5	4.8	4.9	5.9	6.1	6.2	4.9	5.0	4.2	M	30
22	3.3	1.8	6.8	5.4	16.1	9.6	9.4	3.8	4.7	2.6	9.8	8.5	10.7	3.1	3.2	1.1		F	
	5.5	5.3	5.6	5.3	4.6	5.0	5.2	6.1	5.2	4.8	4.9	5.9	5.7	5.4	5.3	5.0	4.3	M	42
23	2.6	1.7	8.2	6.7	17.2	11.5	11.1	3.0	4.0	2.3	7.4	7.0	8.6	3.4	3.7	1.6		F	
	5.1	5.7	5.3	5.3	5.0	5.3	5.1	6.4	5.3	5.5	5.2	6.0	5.7	5.3	5.0	5.3	4.4	M	28
TOTAL	3.0	1.6	7.7	6.1	16.7	10.3	10.9	3.0	4.0	1.8	7.3	6.5	10.4	4.0	4.7	1.9		F	
	5.1	5.6	5.8	6.1	5.3	5.6	5.5	6.1	5.5	5.5	5.6	7.0	6.7	6.7	5.7	5.3	5.2	M	42

N NE E SE S SW W NW

APPENDIX F

CALCULATION OF EFFECTIVE STACK HEIGHT

$H_{release} = h_{stack} + \Delta H_{effluent}$

$\Delta H_{effluent} = V_s\, d/\bar{u}\, [1.5 + 2.68 \times 10^{-3}\, p((T_s - T_a)/T_s)\, d]$ *

*Workbook of Atmospheric Dispersion Estimates, by D. B. Turner, Environmental Science Services Adm., EPA, 1970, pg. 31.

where:
- V_s - stack gas exit velocity (m/s)
- d - inside stack diameter (m)
- $\bar{u}$ - mean windspeed (m/s)
- p - atmospheric pressure (mb)
- T_s - stack gas temp (°K)
- T_a - air temp (°K)
- 2.68×10^{-3} - constant ($mb^{-1}\, m^{-1}$)

FOR ASU INCINERATOR:

h_{stack} (total ht.) = 21(ft.)(.3048 m/ft) = 6.4 (m)

V_s = 7.68 (m/s)

d = 1.5(ft.)(.3048 m/ft) = .4572 (m)

$\bar{u}$ = 3.4 (m/s)

p = 760 mm Hg = 1013 (mb)

T_s = 1800°F = °K = (°F-32)5/9 + 273 = 1256°K

T_a = 90°F = 305°K

$\Delta H_{effluent} = (7.68)(.4572)/(3.4)[1.5 + 2.68 \times 10^{-3}(1013)((1256-305)/1256)(.4572)]$

$\Delta H_{effluent}$ = 2.5(m) = 8(ft)

$H_{release}$ = 6.4 + 2.5 = 8.9(m) = 27(ft)

APPENDIX G

APPENDIX C

MODELS FOR CALCULATING DOSES VIA ADDITIONAL PATHWAYS
FROM RADIOIODINES AND OTHER RADIONUCLIDES*
DISCHARGED TO THE ATMOSPHERE

1. Annual External Dose from Direct Exposure to Activity Deposited on the Ground Plane

The ground plane concentration of radionuclide i at the location (r,θ) with respect to the release point may be determined by

$$C_i^G(r,\theta) = \frac{1.1 \times 10^8 \cdot \delta_i(r,\theta)\, Q_i'}{\lambda_i} [1 - \exp(-\lambda_i t)] \qquad (C\text{-}1)$$

where

$C_i^G(r,\theta)$ is the ground plane concentration of the radionuclide i in the sector at angle θ at the distance r from the release point, in pCi/m^2;

Q_i' is the annual release rate of nuclide i to the atmosphere, in Ci/yr;

t is the time period over which the accumulation is evaluated, which is 15 years (mid-point of plant operating life). This is a simplified method of approximating the average deposition over the operating lifetime of the facility;

$\delta_i(r,\theta)$ is the annual average relative deposition of effluent species i at location (r,θ), considering depletion of the plume during transport, in m^{-2}; and

λ_i is the radiological decay constant for nuclide i, in yr^{-1}.

The annual dose from nuclide i resulting from direct exposure to the contaminated ground plant is then

$$D_{ij}^G(r,\theta) = 8760\, S_F C_i^G(r,\theta) DFG_{ij} \qquad (C\text{-}2)$$

where

$D_{ij}^G(r,\theta)$ is the annual dose to organ j from the ground plane concentration of nuclide i at the location (r,θ), in mrem/yr;

and other terms are as defined previously in Regulatory Position C.3.a of this guide.

The annual dose to organ j is therefore

$$D_j^G(r,\theta) = 8760\, S_F \sum_i C_i^G(r,\theta) DFG_{ij} \qquad (C\text{-}3)$$

Values for the open field ground plane dose conversion factors for the skin and total body are given in Tables A-3 to A-7. The annual dose to all other organs is taken to be equivalent to the total body dose.

*Does not include noble gases or their short-lived daughters; see Appendix B.

2. Annual Dose from Inhalation of Radionuclides in Air

The annual average airborne concentration of radionuclide i at the location (r,θ) with respect to the release point may be determined as

$$x_i(r,\theta) = 3.17 \times 10^4 Q_i' [x/Q']^D(r,\theta) \qquad \text{(C-4)}$$

where

Q_i' is the release rate of nuclide i to the atmosphere, in Ci/yr;

$x_i(r,\theta)$ is the annual average ground-level concentration of nuclide i in air in the sector at angle θ at distance r from the release point, in pCi/m^3;

$[x/Q']^D(r,\theta)$ is the annual average atmosphere dispersion factor, in sec/m^3 (see Regulatory Guide 1.111). This includes depletion (for radioiodines and particulates) and radioactive decay of the plume; and

3.17×10^4 is the product of the number of pCi/Ci and sec/yr.

The annual dose associated with inhalation of nuclide i at the airborne concentration $x_i(r,\theta)$ is then

$$D^A_{ija}(r,\theta) = x_i(r,\theta) R_a DFA_{ija} \qquad \text{(C-5)}$$

Values for DFA_{ija} are given in Tables C-1 to C-4, and all other symbols are as defined earlier in Regulatory Position C.3.b.

The annual dose to organ j in age group a from all nuclides in the effluent is:

$$D^A_{ja}(r,\theta) = R_a \sum_i x_i(r,\theta) DFA_{ija} \qquad \text{(C-6)}$$

3. Concentrations of Airborne Radionuclides in Foods

The concentration of radioactive material in vegetation results from deposition onto the plant foliage and from uptake of activity initially deposited on the ground. The model used for estimating the transfer of radionuclides from the atmosphere to food products is similar to the model developed for estimating the transfer of radionuclides from irrigation water given in Appendix A of this guide.

For all radioiodines and particulate radionuclides, except tritium and carbon-14, the concentration of nuclide i in and on vegetation at the location (r,θ) is estimated using

$$C^v_i(r,\theta) = d_i(r,\theta) \left[\frac{r[1 - \exp(-\lambda_{Ei} t_e)]}{Y_v \lambda_{Ei}} + \frac{B_{iv}[1 - \exp(-\lambda_i t_b)]}{P\lambda_i} \right] \exp(-\lambda_i t_h) \qquad \text{(C-7)}$$

See Regulatory Position C.1 of this guide for definitions of terms.

Carbon-14 is assumed to be in oxide form (CO and CO_2). The concentration of carbon-14 in vegetation is calculated by assuming that its ratio to the natural carbon in the vegetation is the same as the ratio of carbon-14 to natural carbon in the atmosphere surrounding the vegetation (see Refs. 1 and 2).

TABLE C-1

ADULT INHALATION DOSE FACTORS
(mrem/pCi inhaled)

NUCLIDE		BONE	LIVER	TOTAL BODY	THYROID	KIDNEY	LUNG	GI-LLI
1H	3	0.0	1.34E-07	1.34E-07	1.34E-07	1.34E-07	1.34E-07	1.34E-07
4BE	10	1.98E-04	3.06E-05	8.96E-06	0.0	0.0	2.23E-04	1.67E-05
6C	14	2.28E-06	4.27E-07	4.27E-07	4.27E-07	4.27E-07	4.27E-07	4.27E-07
7N	13	6.27E-09	6.27E-09	6.27E-09	6.27E-09	6.27E-09	6.27E-09	6.27E-09
9F	18	4.71E-07	0.0	5.20E-08	0.0	0.0	0.0	9.24E-09
11NA	22	1.30E-05	1.30E-05	1.30E-05	1.30E-05	1.30E-05	1.30E-05	1.30E-05
11NA	24	1.69E-06	1.69E-06	1.69E-06	1.69E-06	1.69E-06	1.69E-06	1.69E-06
15P	32	1.65E-04	9.65E-06	6.27E-06	0.0	0.0	0.0	1.08E-05
20CA	41	3.83E-05	0.0	4.13E-06	0.0	0.0	0.0	2.86E-07
21SC	46	5.51E-05	1.07E-04	3.11E-05	0.0	1.00E-04	0.0	3.23E-05
24CR	51	0.0	0.0	1.25E-08	7.44E-09	2.95E-09	1.80E-06	4.15E-07
25MN	54	0.0	4.95E-06	7.87E-07	0.0	1.23E-06	1.75E-04	9.67E-06
25MN	56	0.0	1.55E-10	2.29E-11	0.0	1.63E-10	1.18E-06	2.53E-06
26FE	55	7.62E-06	3.43E-05	9.01E-06	0.0	0.0	9.98E-05	7.54E-06
26FE	59	1.47E-06	3.47E-03	1.32E-06	0.0	0.0	1.27E-04	2.35E-05
27CO	57	0.0	9.65E-08	8.39E-08	0.0	0.0	4.62E-05	3.93E-06
27CO	58	0.0	1.98E-07	2.59E-07	0.0	0.0	1.16E-04	1.33E-05
27CO	60	0.0	1.44E-06	1.85E-06	0.0	0.0	7.47E-04	3.56E-05
28NI	59	4.06E-06	1.46E-06	6.77E-07	0.0	0.0	9.21E-06	6.11E-07
28NI	63	5.40E-05	3.92E-06	1.81E-06	0.0	0.0	2.23E-05	1.67E-06
28NI	65	1.92E-10	2.62E-11	1.14E-11	0.0	0.0	7.01E-07	1.54E-06
29CU	64	0.0	1.83E-10	7.69E-11	0.0	5.78E-10	9.49E-07	6.12E-06
30ZN	65	4.05E-06	1.29E-05	5.82E-06	0.0	8.62E-06	1.09E-04	6.68E-06
30ZN	69M	1.02E-09	2.45E-09	2.24E-10	0.0	1.48E-09	2.39E-06	1.71E-05
30ZN	69	4.23E-12	9.13E-12	5.65E-13	0.0	5.27E-12	1.15E-07	2.04E-09
34SE	79	0.0	3.83E-07	6.09E-08	0.0	5.69E-07	4.48E-05	3.33E-06
35BR	82	0.0	0.0	1.69E-06	0.0	0.0	0.0	1.30E-06
35BR	83	0.0	0.0	3.01E-08	0.0	0.0	0.0	2.90E-08
35BR	84	0.0	0.0	3.91E-08	0.0	0.0	0.0	2.05E-13
35BR	85	0.0	0.0	1.60E-09	0.0	0.0	0.0	0.0
37RB	86	0.0	1.69E-05	7.38E-06	0.0	0.0	0.0	2.08E-06
37RB	87	0.0	9.87E-06	3.21E-06	0.0	0.0	0.0	2.88E-07
37RB	88	0.0	4.85E-08	2.41E-08	0.0	0.0	0.0	8.18E-19
37RB	89	0.0	3.21E-08	2.12E-08	0.0	0.0	0.0	0.0
38SR	89	3.80E-05	0.0	1.09E-06	0.0	0.0	1.75E-04	4.37E-05
38SR	90	1.24E-02	0.0	7.62E-04	0.0	0.0	1.20E-03	9.02E-04
38SR	91	7.94E-09	0.0	3.49E-10	0.0	0.0	4.92E-06	2.59E-05
38SR	92	8.43E-10	0.0	3.64E-11	0.0	0.0	2.06E-06	5.38E-06
39Y	90	2.61E-07	0.0	7.01E-09	0.0	0.0	2.12E-05	6.32E-05
39Y	91M	3.26E-11	0.0	1.27E-12	0.0	0.0	2.41E-07	1.66E-10
39Y	91	5.78E-05	0.0	1.55E-06	0.0	0.0	2.13E-04	4.81E-05

Note: 0.0 means insufficient data or that the dose factor is <1.0E-20.

TABLE C-1 (Continued)

NUCLIDE		BONE	LIVER	TOTAL BODY	THYROID	KIDNEY	LUNG	GI-LLI
39Y	92	1.29E-09	0.0	3.77E-11	0.0	0.0	1.96E-06	9.19E-06
39Y	93	1.18E-08	0.0	3.26E-10	0.0	0.0	6.07E-06	5.27E-05
40ZR	93	5.22E-05	2.92E-06	1.37E-06	0.0	1.11E-05	2.13E-05	1.51E-06
40ZR	95	1.34E-05	6.30E-06	2.91E-06	0.0	6.77E-06	2.22E-04	1.88E-05
40ZR	97	1.21E-08	2.45E-09	1.13E-09	0.0	3.71E-09	9.85E-06	6.54E-05
41NB	93M	3.10E-05	1.01E-05	2.49E-06	0.0	1.16E-05	3.11E-05	2.38E-06
41NB	95	1.76E-06	9.77E-07	5.26E-07	0.0	9.67E-07	6.32E-05	1.30E-05
41NB	97	2.78E-11	7.03E-12	2.56E-12	0.0	8.18E-12	3.00E-07	3.02E-08
42MO	93	0.0	1.17E-06	3.17E-08	0.0	3.55E-07	5.11E-05	3.79E-06
42MO	99	0.0	1.51E-08	2.87E-09	0.0	3.64E-08	1.14E-05	3.10E-05
43TC	99M	0.0	3.64E-13	4.63E-12	0.0	5.52E-12	9.56E-08	5.20E-07
43TC	99	0.0	4.64E-08	1.37E-04	0.0	5.85E-07	1.01E-04	7.54E-06
43TC	101	0.0	7.52E-15	7.38E-14	0.0	1.35E-13	4.99E-08	0.0
44RU	103	1.91E-07	0.0	8.23E-08	0.0	7.29E-07	6.32E-05	1.38E-05
44RU	105	9.88E-11	0.0	3.89E-11	0.0	1.27E-10	1.38E-06	6.02E-06
44RU	106	8.64E-06	0.0	1.09E-06	0.0	1.67E-05	1.18E-03	1.14E-04
45RH	105	9.24E-10	6.73E-10	4.43E-10	0.0	2.86E-09	2.41E-06	1.09E-05
46PD	107	0.0	9.27E-08	5.87E-09	0.0	6.57E-07	9.48E-06	7.06E-07
46PD	109	0.0	4.63E-10	1.16E-10	0.0	2.35E-09	1.85E-06	1.52E-05
47AG	110M	1.35E-06	1.25E-06	7.43E-07	0.0	2.46E-06	5.80E-04	3.78E-05
47AG	111	4.25E-08	1.78E-08	8.87E-09	0.0	5.74E-08	2.34E-05	2.79E-05
48CD	113M	0.0	1.54E-04	4.97E-06	0.0	1.71E-04	2.08E-04	1.59E-05
48CD	115M	0.0	2.46E-05	7.99E-07	0.0	1.98E-05	1.76E-04	4.80E-05
50SN	123	3.02E-05	6.66E-07	9.82E-07	5.66E-07	0.0	2.88E-04	3.92E-05
50SN	125	1.16E-06	3.13E-08	7.03E-08	2.59E-05	0.0	7.42E-05	6.81E-05
50SN	126	1.58E-04	4.18E-06	8.00E-06	1.23E-06	0.0	1.17E-03	1.59E-05
51SB	124	3.90E-06	7.36E-08	1.55E-06	9.44E-09	0.0	3.10E-04	5.08E-05
51SB	125	8.26E-06	8.91E-08	1.66E-06	7.34E-09	0.0	2.75E-04	1.26E-05
51SB	126	4.50E-07	9.13E-09	1.62E-07	2.75E-09	0.0	9.58E-05	6.01E-05
51SB	127	3.30E-08	7.22E-10	1.27E-08	3.97E-10	0.0	2.05E-05	3.77E-05
52TE	125M	4.27E-07	1.98E-07	5.84E-08	1.31E-07	1.55E-06	3.92E-05	8.83E-06
52TE	127M	1.58E-06	7.02E-07	1.96E-07	4.11E-07	5.72E-06	1.20E-04	1.87E-05
52TE	127	1.75E-10	9.03E-11	3.87E-11	1.32E-10	6.37E-10	8.15E-07	7.17E-06
52TE	129M	1.22E-06	5.84E-07	1.98E-07	4.30E-07	4.57E-06	1.45E-04	4.79E-05
52TE	129	6.22E-12	2.99E-12	1.55E-12	4.87E-12	2.34E-11	2.42E-07	1.96E-08
52TE	131M	8.74E-09	5.45E-09	3.63E-09	6.88E-09	3.86E-08	1.82E-05	6.95E-05
52TE	131	1.39E-12	7.44E-13	4.49E-13	1.17E-12	5.46E-12	1.74E-07	2.44E-09
52TE	132	3.25E-07	2.69E-08	2.02E-08	2.37E-08	1.82E-07	3.60E-05	6.37E-05
52TE	133M	7.24E-12	5.60E-12	7.14E-12	6.27E-12	3.74E-11	5.51E-07	3.45E-09
52TE	134	3.84E-12	3.22E-12	1.57E-12	3.44E-12	2.18E-11	4.34E-07	3.69E-09
53I	129	2.48E-06	2.11E-06	6.91E-06	5.55E-05	4.54E-06	0.0	2.22E-07
53I	130	5.75E-07	1.68E-06	6.61E-07	2.18E-04	2.61E-06	0.0	9.61E-07
53I	131	3.15E-06	4.47E-06	2.56E-06	1.49E-03	7.67E-06	0.0	7.85E-07
53I	132	1.45E-07	4.07E-07	1.45E-07	5.48E-05	6.49E-07	0.0	5.08E-08

TABLE C-1 (Continued)

NUCLIDE		BONE	LIVER	TOTAL BODY	THYROID	KIDNEY	LUNG	GI-LLI
53I	133	1.08E-06	1.86E-06	5.67E-07	3.66E-04	3.25E-06	0.0	1.09E-06
53I	134	8.06E-08	2.16E-07	7.70E-08	2.87E-05	3.44E-07	0.0	1.26E-10
53I	135	3.36E-07	8.74E-07	3.22E-07	1.17E-04	1.39E-06	0.0	6.56E-07
55CS	134M	1.60E-08	3.20E-08	1.72E-08	0.0	1.83E-08	2.94E-09	7.92E-09
55CS	134	4.67E-05	1.06E-04	9.11E-05	0.0	3.60E-05	1.22E-05	1.30E-06
55CS	135	1.46E-05	1.29E-05	6.00E-06	0.0	5.11E-06	1.57E-06	2.11E-07
55CS	136	4.89E-06	1.83E-05	1.39E-05	0.0	1.07E-05	1.50E-06	1.46E-06
55CS	137	5.98E-05	7.77E-05	5.36E-05	0.0	2.78E-05	9.41E-06	1.05E-06
55CS	138	4.14E-08	7.77E-08	4.06E-08	0.0	6.01E-08	6.07E-09	2.33E-13
55CS	139	2.56E-08	5.63E-08	1.39E-08	0.0	3.05E-08	2.84E-09	0.0
56BA	139	1.17E-10	8.32E-14	3.42E-12	0.0	7.78E-14	4.70E-07	1.12E-07
56BA	140	4.88E-06	6.13E-09	3.21E-07	0.0	2.09E-09	1.59E-04	2.73E-05
56BA	141	1.25E-11	9.41E-15	4.20E-13	0.0	8.75E-15	2.42E-07	1.45E-17
56BA	142	3.29E-12	3.38E-15	2.07E-13	0.0	2.96E-15	1.49E-07	0.0
57LA	140	4.30E-08	2.17E-08	5.73E-09	0.0	0.0	1.70E-05	5.73E-05
57LA	141	5.34E-10	1.66E-10	2.71E-11	0.0	0.0	1.35E-06	7.31E-06
57LA	142	8.54E-11	3.88E-11	9.65E-12	0.0	0.0	7.92E-07	2.64E-07
58CE	141	2.49E-06	1.69E-06	1.91E-07	0.0	7.83E-07	4.52E-05	1.50E-05
58CE	143	2.33E-08	1.72E-08	1.91E-09	0.0	7.60E-09	9.98E-06	2.83E-05
58CE	144	4.29E-04	1.79E-04	2.30E-05	0.0	1.06E-04	9.73E-04	1.02E-04
59PR	143	1.17E-06	4.69E-07	5.79E-08	0.0	2.70E-07	3.51E-05	2.50E-05
59PR	144	3.76E-12	1.56E-12	1.91E-13	0.0	8.81E-13	1.27E-07	2.69E-18
60ND	147	6.59E-07	7.62E-07	8.56E-08	0.0	4.45E-07	2.76E-05	2.16E-05
61PM	147	8.37E-05	7.87E-06	3.18E-06	0.0	1.49E-05	6.61E-05	5.54E-06
61PM	148M	9.82E-06	2.54E-06	1.94E-06	0.0	3.45E-06	2.14E-04	4.18E-05
61PM	148	3.84E-07	6.37E-08	3.20E-08	0.0	1.20E-07	3.91E-05	5.80E-05
61PM	149	3.44E-08	8.87E-09	1.99E-09	0.0	9.19E-09	7.22E-06	2.50E-05
61PM	151	8.50E-09	1.42E-09	7.21E-10	0.0	2.55E-09	3.94E-06	2.00E-05
62SM	151	8.59E-05	1.48E-05	3.55E-06	0.0	1.66E-05	4.46E-05	3.25E-06
62SM	153	1.70E-08	1.42E-08	1.04E-09	0.0	4.59E-09	4.15E-06	1.58E-05
63EU	152	2.34E-04	5.40E-05	4.76E-05	0.0	3.35E-04	3.43E-04	1.59E-05
63EU	154	7.40E-04	9.10E-05	6.48E-05	0.0	4.36E-04	5.85E-04	3.40E-05
63EU	155	1.01E-04	1.43E-05	9.21E-06	0.0	6.59E-05	9.47E-05	5.95E-06
63EU	156	1.93E-06	1.48E-06	2.40E-07	0.0	9.95E-07	8.57E-05	4.50E-05
65TB	160	2.21E-05	0.0	2.75E-06	0.0	9.10E-06	1.92E-04	2.68E-05
67HO	166M	3.37E-04	1.05E-04	8.00E-05	0.0	1.57E-04	3.98E-04	1.59E-05
74W	181	6.23E-09	2.03E-09	2.17E-10	0.0	0.0	1.72E-06	2.53E-07
74W	185	1.95E-07	6.47E-08	6.81E-09	0.0	0.0	5.57E-05	1.07E-05
74W	187	1.06E-09	8.85E-10	3.10E-10	0.0	0.0	3.63E-06	1.94E-05
82PB	210	2.64E-02	6.72E-03	8.37E-04	0.0	2.12E-02	2.63E-02	3.65E-05
83BI	210	0.0	1.59E-06	1.32E-07	0.0	1.92E-05	1.11E-03	2.95E-05
84PO	210	3.97E-04	8.60E-04	9.58E-05	0.0	2.95E-03	3.14E-02	4.19E-05

TABLE C-2

TEENAGER INHALATION DOSE FACTORS
(mrem/pCi inhaled)

NUCLIDE		BONE	LIVER	TOTAL BODY	THYROID	KIDNEY	LUNG	GI-LLI
1H	3	0.0	1.06E-07	1.06E-07	1.06E-07		1.06E-07	1.06E-07
6C	14	5.66E-07	5.66E-07	5.66E-07	5.66E-07		5.66E-07	5.66E-07
11NA	22	1.76E-05	1.76E-05	1.76E-05	1.76E-05		1.76E-05	1.44E-06
27CO	58	0.0	2.20E-08	2.93E-08	0.0		1.71E-04	1.19E-05
27CO	60	0.0	1.55E-07	2.06E-07	0.0		1.07E-03	2.94E-05
38SR	89	4.84E-06	0.0	1.39E-07	0.0	(USE	3.13E-04	4.42E-05
38SR	90	1.48E-03	0.0	9.04E-05	0.0		2.07E-03	9.05E-05
39Y	90	1.41E-08	0.0	3.79E-10	0.0		0.0	6.79E-05
39Y	91	6.72E-06	0.0	1.80E-07	0.0	ADULT	3.57E-04	4.67E-05
40ZR	95	1.36E-06	4.54E-07	3.17E-07	0.0		3.20E-04	1.66E-05
41NB	95	1.70E-07	1.03E-07	5.78E-08	0.0		5.96E-05	1.10E-05
44RU	103	2.04E-08	0.0	9.15E-09	0.0	DOSE	9.39E-05	1.18E-05
44RU	106	1.05E-06	0.0	1.32E-07	0.0		2.05E-03	1.16E-04
50SN	123	3.89E-06	7.68E-08	1.15E-07	6.15E-08		4.89E-04	3.91E-05
52TE	125M	5.09E-08	2.32E-08	6.91E-09	1.46E-08	FACTOR)	6.70E-05	8.85E-06
52TE	127	1.62E-11	7.30E-12	4.02E-12	1.34E-11		1.33E-06	1.01E-05
52TE	129M	1.49E-07	7.05E-08	2.40E-08	4.88E-08		2.54E-04	4.80E-05
52TE	132	3.75E-09	3.00E-09	2.29E-09	2.58E-09		5.67E-05	6.81E-05
53I	129	3.53E-06	2.98E-06	9.81E-06	7.32E-03		0.0	2.16E-07
53I	131	4.21E-06	5.90E-06	3.52E-06	1.74E-03		0.0	7.45E-07
53I	133	1.54E-06	2.58E-06	7.93E-07	4.79E-04		0.0	1.25E-06
55CS	134	6.04E-05	1.38E-04	6.80E-05	0.0		1.80E-05	1.12E-06
55CS	137	8.02E-05	1.03E-04	3.79E-05	0.0		1.47E-05	9.60E-07
56BA	140	6.62E-07	6.06E-10	4.27E-08	0.0		2.53E-04	2.65E-06
57LA	140	1.79E-09	4.72E-10	1.67E-10	0.0		2.70E-05	5.81E-05
58CE	141	2.84E-07	1.90E-07	2.18E-08	0.0		7.29E-05	1.42E-05
58CE	144	5.24E-05	2.17E-05	2.80E-06	0.0		1.72E-03	1.05E-04
63EU	154	9.95E-05	1.02E-05	8.07E-06	0.0		9.29E-04	3.41E-05
92U	232	6.14E-03	0.0	4.37E-04	0.0		3.84E-01	4.16E-05
92U	234	1.25E-03	0.0	7.72E-05	0.0		9.00E-02	3.81E-05
94PU	238	3.22E-01	4.43E-02	7.98E-03	0.0		3.14E-01	4.52E-05
94PU	239	3.67E-01	5.00E-02	9.06E-03	0.0		2.98E-01	4.13E-05
94PU	240	3.66E-01	5.04E-02	9.13E-03	0.0		3.01E-01	4.13E-05
94PU	241	1.29E-04	1.84E-05	3.24E-06	0.0		1.92E-04	7.94E-08
95AM	241	1.20E-01	4.11E-02	7.79E-03	0.0		1.01E-01	4.44E-05
96CM	242	1.35E-03	1.40E-03	8.97E-05	0.0		6.47E-02	4.83E-05
96CM	244	6.99E-02	2.99E-02	4.16E-03	0.0		1.05E-01	4.60E-05

Note: 0.0 means insufficient data or that the dose factor is <1.0E-20.

TABLE C-3

CHILD INHALATION DOSE FACTORS
(mrem/pCi inhaled)

NUCLIDE		BONE	LIVER	TOTAL BODY	THYROID	KIDNEY	LUNG	GI-LLI
1H	3	0.0	2.03E-07	2.03E-07	2.03E-07		2.03E-07	2.03E-07
6C	14	1.69E-06	1.69E-06	1.69E-06	1.69E-06		1.69E-06	1.69E-06
11NA	22	4.42E-05	4.42E-05	4.42E-05	4.42E-05		4.42E-05	1.28E-06
27CO	58	0.0	4.11E-08	7.23E-08	0.0		3.04E-04	9.78E-06
27CO	60	0.0	2.90E-07	5.07E-07	0.0	(USE	1.87E-03	2.53E-05
38SR	89	1.45E-05	0.0	4.16E-07	0.0		6.06E-04	4.56E-05
38SR	90	4.43E-03	0.0	2.70E-04	0.0		4.00E-03	9.31E-05
39Y	90	9.87E-08	0.0	2.65E-09	0.0		7.26E-05	7.43E-05
39Y	91	2.01E-05	0.0	5.36E-07	0.0	ADULT	6.90E-04	4.82E-05
40ZR	95	3.81E-06	8.86E-07	8.05E-07	0.0		5.72E-04	1.55E-05
41NB	95	4.60E-07	1.96E-07	1.44E-07	0.0	DOSE	1.58E-04	8.96E-06
44RU	103	5.84E-08	0.0	2.36E-08	0.0		1.71E-04	1.14E-05
44RU	106	3.12E-06	0.0	3.88E-07	0.0		3.93E-03	1.18E-04
50SN	123	1.04E-05	1.74E-07	3.43E-07	1.84E-07	FACTOR)	9.46E-04	4.03E-05
52TE	125M	1.52E-07	5.25E-08	2.06E-08	4.35E-08		1.30E-04	9.13E-06
52TE	127	4.83E-11	1.65E-11	1.20E-11	4.01E-11		2.58E-06	1.58E-05
52TE	129M	4.44E-07	1.58E-07	7.03E-08	1.46E-07		4.87E-04	4.93E-05
52TE	132	1.08E-08	6.08E-09	5.91E-09	7.24E-09		1.03E-04	6.52E-05
53I	129	1.05E-05	6.40E-06	2.86E-05	2.14E-02		0.0	2.15E-07
53I	131	1.23E-05	1.25E-05	9.47E-06	8.16E-03		0.0	7.17E-07
53I	133	4.53E-06	5.53E-06	2.17E-06	1.36E-03		0.0	1.50E-06
55CS	134	1.68E-04	2.69E-04	6.02E-05	0.0		3.21E-05	1.02E-06
55CS	137	2.34E-04	2.16E-04	3.38E-05	0.0		2.71E-05	9.22E-07
56BA	140	1.93E-06	1.26E-09	1.14E-07	0.0		4.69E-04	2.68E-06
57LA	140	5.20E-09	9.63E-10	4.34E-10	0.0		4.92E-05	6.14E-05
58CE	141	8.47E-07	4.24E-07	6.30E-08	0.0		1.39E-04	1.47E-05
58CE	144	1.57E-04	4.91E-05	8.37E-06	0.0		3.32E-03	1.08E-04
63EU	154	2.87E-04	2.12E-05	2.09E-05	0.0		1.67E-03	3.51E-05
92U	232	1.83E-02	0.0	1.31E-03	0.0		7.43E-01	4.28E-05
92U	238	3.73E-03	0.0	2.31E-04	0.0		1.74E-01	3.92E-05
94PU	238	9.62E-01	1.00E-01	2.38E-02	0.0		5.47E-01	4.65E-05
94PU	239	1.10E 00	1.13E-01	2.71E-02	0.0		5.56E-01	4.24E-05
94PU	240	1.09E 00	1.14E-01	2.73E-02	0.0		5.61E-01	4.24E-05
94PU	241	3.84E-04	4.16E-05	9.73E-06	0.0		3.61E-04	8.16E-08
95AM	241	3.57E-01	9.31E-02	2.33E-02	0.0		1.95E-01	4.57E-05
96CM	242	4.05E-03	3.17E-03	2.68E-04	0.0		1.25E-01	4.98E-05
96CM	244	2.09E-01	6.77E-02	1.24E-02	0.0		2.02E-01	4.73E-05

Note: 0.0 means insufficient data or that the dose factor is <1.0E-20.

APPENDIX H

Minute volume for Reference Man

	Adult man	Adult woman	Child (10 y)	Infant (1 y)	Newborn
Resting (l/min)	7.5	6.0	4.8	1.5	0.5
Light activity (l/min)	20.0	19.0	13.0	4.2	1.5

Liters of air breathed for Reference Man

	Adult man	Adult woman	Child (10 y)	Infant (1 y)	Newborn
8 h working "light activity"	9,600†	9,100‡	6,240§	2,500‖ (10 h)	90¶ (1 h)
8 h nonoccupational activity	9,600†	9,100‡	6,240§		
8 h resting	3,600†	2,900‡	2,300§	1,300‖ (14 h)	690¶ (23 h)
Total	2.3×10^4	2.1×10^4	1.5×10^4	0.38×10^4	0.08×10^4
% of total air breathed at work	42	43			

For the dose calculations at 200 and 300(m), the 24 hour total intake was used.

The adult dose at the stack is calculated for occupational exposures of 40 hours per week, 50 weeks per year.

However, dose estimates for teen and child at the stack using a 24 hour intake are also included to determine the dose to the animals on the site.

Adult women values from the above table were used for our teen calculations.

(Above table from Reference 4).

APPENDIX I

Maximum permissible body burdens and maximum permissible concentrations of radionuclides in air and in water for occupational exposure

Radionuclide and type of decay		Organ of reference (critical organ in boldface)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations			
				For 40 hour week		For 168 hour week**	
				$(MPC)_w$ $\mu c/cc$	$(MPC)_a$ $\mu c/cc$	$(MPC)_w$ $\mu c/cc$	$(MPC)_a$ $\mu c/cc$
$_1H^3$(HTO or H_2O)(β^-)	(Sol)	**Body Tissue**	10^3	0.1	5×10^{-6}	0.03	2×10^{-6}
		Total Body	2×10^3	0.2	8×10^{-6}	0.05	3×10^{-6}
(H_2)	(Immersion)	**Skin**	----	----	2×10^{-3}	----	4×10^{-4}
$_6C^{14}(CO_2)$(β^-)	(Sol)	**Fat**	300	0.02	4×10^{-6}	8×10^{-5}	10^{-6}
		Total Body	400	0.03	5×10^{-6}	0.01	2×10^{-6}
		Bone	400	0.04	6×10^{-6}	0.01	2×10^{-6}
	(Immersion)	**Total Body**	----	----	5×10^{-6}	----	10^{-6}
$_{15}P^{32}$ (β^-)	(Sol)	**Bone**	6	5×10^{-4}	7×10^{-6}	2×10^{-4}	2×10^{-6}
		Total Body	30	3×10^{-5}	4×10^{-7}	9×10^{-4}	10^{-7}
		GI (LLI)	----	3×10^{-5}	6×10^{-7}	9×10^{-4}	2×10^{-7}
		Liver	50	5×10^{-5}	6×10^{-7}	2×10^{-5}	2×10^{-7}
		Brain	300	0.02	3×10^{-6}	8×10^{-5}	10^{-6}
	(Insol)	**Lung**	----	----	8×10^{-6}	----	3×10^{-6}
		GI (LLI)	----	7×10^{-4}	10^{-7}	2×10^{-4}	4×10^{-8}
$_{20}Ca^{45}$ (β^-)	(Sol)	**Bone**	30	3×10^{-4}	3×10^{-6}	9×10^{-4}	10^{-6}
		Total Body	200	2×10^{-5}	3×10^{-7}	7×10^{-4}	9×10^{-8}
		GI (LLI)	----	0.01	3×10^{-6}	4×10^{-3}	10^{-6}
	(Insol)	**Lung**	----	----	10^{-7}	----	4×10^{-8}
		GI (LLI)	----	5×10^{-5}	9×10^{-7}	2×10^{-5}	3×10^{-7}
$_{24}Cr^{51}$ (ϵ, γ)	(Sol)	**GI (LLI)**	----	0.05	10^{-6}	0.02	4×10^{-6}
		Total Body	800	0.6	10^{-4}	0.2	4×10^{-6}
		Lung	10^3	1	2×10^{-5}	0.4	8×10^{-6}
		Prostate	2×10^3	2	3×10^{-5}	0.5	10^{-5}
		Thyroid	4×10^3	3	6×10^{-5}	1	2×10^{-5}
		Kidney	8×10^3	6	10^{-4}	2	4×10^{-5}
	(Insol)	**Lung**	----	----	2×10^{-4}	----	8×10^{-7}
		GI (LLI)	----	0.05	8×10^{-6}	0.02	3×10^{-6}
$_{27}Co^{60}$ (β^-, γ)	(Sol)	**GI (LLI)**	----	10^{-5}	3×10^{-7}	5×10^{-4}	10^{-7}
		Total Body	10	4×10^{-5}	4×10^{-7}	10^{-3}	10^{-7}
		Pancreas	70	0.02	2×10^{-6}	7×10^{-3}	6×10^{-7}
		Liver	90	0.03	10^{-6}	9×10^{-3}	5×10^{-7}
		Spleen	200	0.05	4×10^{-6}	0.02	2×10^{-6}
		Kidney	200	0.07	6×10^{-6}	0.03	2×10^{-6}
	(Insol)	**Lung**	----	----	9×10^{-6}	----	3×10^{-8}
		GI (LLI)	----	10^{-5}	2×10^{-7}	3×10^{-4}	6×10^{-8}
$_{30}Zn^{65}$(β^+, ϵ, γ)	(Sol)	**Total Body**	60	3×10^{-5}	10^{-7}	10^{-3}	4×10^{-8}
		Prostate	70	4×10^{-5}	10^{-7}	10^{-3}	4×10^{-8}
		Liver	80	4×10^{-5}	10^{-7}	10^{-3}	5×10^{-8}
		Kidney	100	6×10^{-5}	2×10^{-7}	2×10^{-3}	7×10^{-8}
		GI (LLI)	----	6×10^{-5}	10^{-6}	2×10^{-3}	4×10^{-7}
		Pancreas	200	7×10^{-5}	3×10^{-7}	3×10^{-3}	9×10^{-8}
		Muscle	200	0.01	4×10^{-7}	4×10^{-3}	10^{-7}
		Ovary	300	0.01	5×10^{-7}	4×10^{-3}	2×10^{-7}
		Testis	400	0.02	6×10^{-7}	6×10^{-3}	2×10^{-7}
		Bone	700	0.04	10^{-6}	0.01	4×10^{-7}
	(Insol)	**Lung**	----	----	6×10^{-6}	----	2×10^{-8}
		GI (LLI)	----	5×10^{-5}	9×10^{-7}	2×10^{-3}	3×10^{-7}
$_{33}As^{76}$ (β^-, γ)	(Sol)	**GI (LLI)**	----	6×10^{-6}	10^{-7}	2×10^{-4}	4×10^{-8}
		Total Body	20	0.4	5×10^{-6}	0.1	2×10^{-6}
		Kidney	20	0.6	8×10^{-6}	0.2	3×10^{-6}
		Liver	40	1	10^{-5}	0.4	5×10^{-6}
	(Insol)	**GI (LLI)**	----	6×10^{-6}	10^{-7}	2×10^{-4}	3×10^{-8}
		Lung	----	----	6×10^{-7}	----	2×10^{-7}

*The abbreviations GI, S, SI, ULI, and LLI refer to gastrointestinal tract, stomach, small intestines, upper large intestine, and lower large intestine, respectively.

**It will be noted that the MPC values for the 168-hour week are not always precisely the same multiples of the MPC for the 40-hour week. Part of this is caused by rounding off the calculated values to one digit, but in some instances it is due to technical differences discussed in the ICRP report. Because of the uncertainties present in much of the biological data and because of individual variations, the differences are not considered significant. The MPC values for the 40-hour week are to be considered as basis for occupational exposure, and the values for the 168-hour week are basis for continuous exposure as in the case of the population at large.

Maximum permissible body burdens and maximum permissible concentrations of radionuclides in air and in water for occupational exposure—Continued

Radionuclide and type of decay		Organ of reference (critical organ in boldface)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations			
				For 40 hour week		For 168 hour week**	
				$(MPC)_w$ $\mu c/cc$	$(MPC)_a$ $\mu c/cc$	$(MPC)_w$ $\mu c/cc$	$(MPC)_a$ $\mu c/cc$
$_{38}Sr^{89}$ (β^-)	(Sol)	**Bone**	4	3×10^{-4}	3×10^{-8}	10^{-4}	10^{-8}
		GI (LLI)		10^{-3}	3×10^{-7}	4×10^{-4}	9×10^{-8}
		Total Body	40	2×10^{-3}	2×10^{-7}	7×10^{-4}	6×10^{-8}
	(Insol)	**Lung**			4×10^{-6}		10^{-6}
		GI (LLI)		8×10^{-4}	10^{-7}	3×10^{-4}	5×10^{-8}
$_{38}Sr^{90}$ (β^-)	(Sol)	**Bone**	2	4×10^{-6}	3×10^{-10}	10^{-6}	10^{-10}
		Total Body	20	10^{-3}	9×10^{-10}	4×10^{-6}	3×10^{-10}
		GI (LLI)		10^{-3}	3×10^{-7}	5×10^{-4}	10^{-7}
	(Insol)	**Lung**			5×10^{-6}		2×10^{-9}
		GI (LLI)		10^{-3}	2×10^{-7}	4×10^{-4}	6×10^{-8}
$_{40}Zr^{95}$ (β^-, γ, e^-)	(Sol)	GI (LLI)		2×10^{-3}	4×10^{-7}	6×10^{-4}	10^{-7}
		Total Body	20	3	10^{-7}	1	4×10^{-8}
		Bone	30	4	2×10^{-7}	2	6×10^{-8}
		Kidney	30	4	2×10^{-7}	2	6×10^{-8}
		Liver	40	6	3×10^{-7}	2	9×10^{-8}
		Spleen	40	7	3×10^{-7}	2	10^{-7}
	(Insol)	**Lung**			3×10^{-6}		10^{-6}
		GI (LLI)		2×10^{-3}	3×10^{-7}	6×10^{-4}	10^{-7}
$_{41}Nb^{95}$ (β^-, γ)	(Sol)	GI (LLI)		3×10^{-3}	6×10^{-7}	10^{-3}	2×10^{-7}
		Total Body	40	10	5×10^{-7}	4	2×10^{-7}
		Liver	60	20	7×10^{-7}	6	3×10^{-7}
		Kidney	60	20	8×10^{-7}	6	3×10^{-7}
		Bone	80	20	9×10^{-7}	7	3×10^{-7}
		Spleen	80	20	10^{-6}	7	3×10^{-7}
	(Insol)	**Lung**			10^{-7}		3×10^{-8}
		GI (LLI)		3×10^{-3}	5×10^{-7}	10^{-3}	2×10^{-7}
$_{44}Ru^{106}$ (β^-, γ)	(Sol)	GI (LLI)		4×10^{-4}	8×10^{-8}	10^{-4}	3×10^{-8}
		Kidney	3	0.01	10^{-7}	4×10^{-3}	5×10^{-8}
		Bone	10	0.04	5×10^{-7}	0.01	2×10^{-7}
		Total Body	10	0.06	7×10^{-7}	0.02	3×10^{-7}
	(Insol)	**Lung**			6×10^{-6}		2×10^{-8}
		GI (LLI)		3×10^{-4}	6×10^{-6}	10^{-4}	2×10^{-8}
$_{53}I^{131}$ (β^-,γ,e^-)	(Sol)	**Thyroid**	0.7	6×10^{-8}	9×10^{-9}	2×10^{-8}	3×10^{-9}
		Total Body	50	5×10^{-3}	8×10^{-7}	2×10^{-3}	3×10^{-7}
		GI (LLI)		0.03	7×10^{-6}	0.01	2×10^{-6}
	(Insol)	GI (LLI)		2×10^{-3}	3×10^{-7}	6×10^{-4}	10^{-7}
		Lung			3×10^{-7}		10^{-7}
$_{55}Cs^{137}$ (β^-, γ, e^-)	(Sol)	Total Body	30	4×10^{-4}	6×10^{-8}	2×10^{-4}	2×10^{-8}
		Liver	40	5×10^{-4}	8×10^{-8}	2×10^{-4}	3×10^{-8}
		Spleen	50	6×10^{-4}	9×10^{-8}	2×10^{-4}	3×10^{-8}
		Muscle	50	7×10^{-4}	10^{-7}	2×10^{-4}	4×10^{-8}
		Bone	100	10^{-3}	2×10^{-7}	5×10^{-4}	7×10^{-8}
		Kidney	100	10^{-3}	2×10^{-7}	5×10^{-4}	8×10^{-8}
		Lung	300	5×10^{-3}	6×10^{-7}	2×10^{-3}	2×10^{-7}
		GI (SI)		0.02	5×10^{-6}	8×10^{-3}	2×10^{-6}
	(Insol)	**Lung**			10^{-6}		5×10^{-9}
		GI (LLI)		10^{-3}	2×10^{-7}	4×10^{-4}	8×10^{-8}
$_{58}Ce^{144}$ (α, β^-, γ)	(Sol)	GI (LLI)		3×10^{-4}	8×10^{-8}	10^{-4}	3×10^{-8}
		Bone	5	0.2	10^{-6}	0.08	3×10^{-9}
		Liver	6	0.3	10^{-6}	0.1	4×10^{-8}
		Kidney	10	0.5	2×10^{-6}	0.2	7×10^{-9}
		Total Body	20	0.7	3×10^{-6}	0.3	10^{-8}
	(Insol)	**Lung**			6×10^{-9}		2×10^{-9}
		GI (LLI)		3×10^{-4}	6×10^{-8}	10^{-4}	2×10^{-8}
$_{61}Pm^{147}$(α, β^-)	(Sol)	GI (LLI)		6×10^{-3}	10^{-6}	2×10^{-3}	5×10^{-7}
		Bone	60	1	6×10^{-8}	0.5	2×10^{-8}
		Kidney	200	4	2×10^{-7}	2	7×10^{-8}
		Total Body	300	7	3×10^{-7}	2	10^{-7}
		Liver	300	8	4×10^{-7}	3	10^{-7}
	(Insol)	**Lung**			10^{-7}		3×10^{-8}
		GI (LLI)		6×10^{-3}	10^{-6}	2×10^{-3}	4×10^{-7}

Maximum permissible body burdens and maximum permissible concentrations for radionuclides in air and in water for occupational exposure—Continued

Radionuclide and type of decay		Organ of reference (critical organ in boldface)	Maximum permissible burden in total body μc	Maximum permissible concentrations			
				For 40 hour week		For 168 hour week**	
				$(MPC)_w$ $\mu c/cc$	$(MPC)_a$ $\mu c/cc$	$(MPC)_w$ $\mu c/cc$	$(MPC)_a$ $\mu c/cc$
$_{73}Ta^{182}$ (β^-, γ)		GI (LLI)		10^{-5}	3×10^{-7}	4×10^{-4}	9×10^{-6}
		Liver	7	0.9	4×10^{-6}	0.3	10^{-4}
	(Sol)	Kidney	20	2	8×10^{-6}	0.7	3×10^{-5}
		Total Body	20	2	9×10^{-6}	0.7	3×10^{-5}
		Spleen	30	4	10^{-7}	1	5×10^{-5}
		Bone	50	6	3×10^{-7}	2	9×10^{-5}
	(Insol)	Lung			2×10^{-6}		7×10^{-6}
		GI (LLI)		10^{-5}	2×10^{-7}	4×10^{-4}	7×10^{-6}
$_{77}Ir^{192}$ (β^-, γ)		GI (LLI)		10^{-5}	3×10^{-7}	4×10^{-4}	9×10^{-6}
		Kidney	6	4×10^{-3}	10^{-7}	10^{-3}	4×10^{-6}
	(Sol)	Spleen	7	4×10^{-3}	10^{-7}	10^{-3}	5×10^{-6}
		Liver	8	5×10^{-3}	2×10^{-7}	2×10^{-3}	6×10^{-6}
		Total Body	20	0.01	4×10^{-7}	4×10^{-3}	10^{-7}
	(Insol)	Lung			3×10^{-6}		9×10^{-6}
		GI (LLI)		10^{-5}	2×10^{-7}	4×10^{-4}	6×10^{-6}
$_{79}Au^{198}$ (β^-, γ)		GI (LLI)		2×10^{-5}	3×10^{-7}	5×10^{-4}	10^{-7}
		Kidney	20	0.07	3×10^{-6}	0.02	9×10^{-7}
	(Sol)	Total Body	30	0.1	4×10^{-6}	0.04	2×10^{-6}
		Spleen	60	0.2	8×10^{-6}	0.07	3×10^{-6}
		Liver	80	0.3	10^{-5}	0.1	4×10^{-6}
	(Insol)	GI (LLI)		10^{-5}	2×10^{-7}	5×10^{-4}	8×10^{-6}
		Lung			6×10^{-7}		2×10^{-7}
$_{86}Rn^{222}$†(α, β, γ)		Lung			3×10^{-6}		10^{-6}
$_{88}Ra^{226}$ (α, β^-, γ)		Bone	0.1	4×10^{-7} *	3×10^{-11}	10^{-7}	10^{-11}
	(Sol)	Total Body	0.2	6×10^{-7}	5×10^{-11}	2×10^{-7}	2×10^{-11}
		GI (LLI)		10^{-5}	3×10^{-7}	5×10^{-4}	10^{-7}
	(Insol)	Lung			5×10^{-11}		2×10^{-11}
		GI (LLI)		9×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-6}
$_{92}U^{238}$ (α, β^-, γ)		GI (LLI)		8×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-6}
		Kidney	0.03	0.01	5×10^{-10}	4×10^{-3}	2×10^{-10}
	(Sol)	Bone	0.06	0.01	6×10^{-10}	5×10^{-3}	2×10^{-10}
		Total Body	0.4	0.04	2×10^{-9}	0.01	6×10^{-10}
	(Insol)	Lung			10^{-10}		4×10^{-11}
		GI (LLI)		8×10^{-4}	10^{-7}	3×10^{-4}	5×10^{-6}
$_{92}U^{235}$ (α, γ, β^-)		GI (LLI)		10^{-5}	2×10^{-7}	4×10^{-4}	8×10^{-6}
		Kidney	5×10^{-5}	2×10^{-5}	7×10^{-11}	6×10^{-4}	3×10^{-11}
	(Sol)	Bone	0.06	0.01	6×10^{-10}	5×10^{-3}	2×10^{-10}
		Total Body	0.5	0.04	2×10^{-9}	0.01	6×10^{-10}
	(Insol)	Lung			10^{-10}		5×10^{-11}
		GI (LLI)		10^{-5}	2×10^{-7}	4×10^{-4}	6×10^{-6}
$_{94}Pu^{239}$ (α, γ)		Bone	0.04	10^{-4}	2×10^{-12}	5×10^{-3}	6×10^{-12}
		Liver	0.4	5×10^{-4}	7×10^{-12}	2×10^{-3}	2×10^{-12}
	(Sol)	Kidney	0.5	7×10^{-4}	9×10^{-12}	2×10^{-3}	3×10^{-12}
		GI (LLI)		8×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-6}
		Total Body	0.4	10^{-5}	10^{-11}	3×10^{-4}	5×10^{-12}
	(Insol)	Lung			4×10^{-11}		10^{-11}
		GI (LLI)		8×10^{-4}	2×10^{-7}	3×10^{-4}	5×10^{-6}

†The daughter isotopes of Rn^{222} and Rn^{220} are assumed present to the extent they occur in undiltered air. For all other isotopes the daughter elements are not considered as part of the intake and if present must be considered on the basis of the rules for mixtures.

Maximum permissible concentration of unidentified radionuclides in water, $(MPCU)_w$ values[a], for continuous occupational exposure

Limitations	$\mu c/cm^3$ of water[a,b]
If no one of the radionuclides Sr^{89}, I^{130}, I^{132}, I^{131}, Pb^{210}, Po^{210}, At^{211}, Ra^{223}, Ra^{224}, Ra^{226}, Ra^{228}, Ac^{227}, Th^{230}, Pa^{231}, Th^{232}, and Th-nat is present, then the $(MPCU)_w$ is	3×10^{-6}
If no one of the radionuclides Sr^{90}, I^{129}, Pb^{210}, Po^{210}, Ra^{223}, Ra^{224}, Ra^{226}, Pa^{231}, and Th-nat is present, then the $(MPCU)_w$ is	2×10^{-5}
If no one of the radionuclides Sr^{90}, I^{129}, Pb^{210}, Ra^{223}, and Ra^{224} is present, then the $(MPCU)_w$ is	7×10^{-5}
If neither Ra^{223} nor Ra^{224} is present, then the $(MPCU)_w$ is	10^{-4}
If no analysis of the water is made, then the $(MPCU)_w$ is	10^{-7}

[a]Each $(MPCU)_w$ value is the smallest value of $(MPC)_w$ in table 1 for radionuclides other than those listed opposite the value. Thus these $(MPCU)_w$ values are permissible levels for continuous occupational exposure (168 hr/wk) for any radionuclide or mixture of radionuclides where the indicated isotopes are not present (i.e., where the concentration of the radionuclide in water is small compared with the $(MPC)_w$ value for this radionuclide). The $(MPCU)_w$ may be much smaller than the more exact maximum permissible concentration of the material, but the determination of this $(MPC)_w$ requires identification of the radionuclides present and the concentration of each.

[b]Use one-tenth of these values for interim application in the neighborhood of a controlled exposure area.

Maximum permissible concentration of unidentified radionuclides in air, $(MPCU)_a$ values[a], for continuous occupational exposure

Limitations	$\mu c/cm^3$ of air[a,b]
If there are no α-emitting radionuclides and if no one of the β-emitting radionuclides Sr^{89}, I^{129}, Pb^{210}, Ac^{227}, Ra^{228}, Pa^{230}, Pu^{241}, and Bk^{249} is present, then the $(MPCU)_a$ is	10^{-9}
If there are no α-emitting radionuclides and if no one of the β-emitting radionuclides Pb^{210}, Ac^{227}, Ra^{228}, and Pu^{241} is present, then the $(MPCU)_a$ is	10^{-10}
If there are no α-emitting radionuclides and if the β-emitting radionuclide Ac^{227} is not present, then the $(MPCU)_a$ is	10^{-11}
If no one of the radionuclides Ac^{227}, Th^{230}, Pa^{231}, Th^{232}, Th-nat, Pu^{238}, Pu^{239}, Pu^{240}, Pu^{242}, and Cf^{249} is present, then the $(MPCU)_a$ is	10^{-12}
If no one of the radionuclides Pa^{231}, Th-nat, Pu^{238}, Pu^{239}, Pu^{242}, and Cf^{249} is present, then the $(MPCU)_a$ is	7×10^{-13}
If no analysis of the air is made, then the $(MPCU)_a$ is	4×10^{-13}

[a]Each $(MPCU)_a$ value is the smallest value of $(MPC)_a$ in table 1 for radionuclides other than those listed opposite the value. Thus these $(MPCU)_a$ values are permissible levels for continuous occupational exposure (168 hr/wk) for any radionuclide or mixture of radionuclides where the indicated isotopes are not present (i.e., where the concentration of the radionuclide in air is small compared with the $(MPC)_a$ value for this radionuclide). The $(MPCU)_a$ value may be much smaller than the more exact maximum permissible concentration of the material, but the determination of this $(MPC)_a$ requires identification of the radionuclides present and the concentration of each.

[b]Use one-tenth of these values for interim application in the neighborhood of a controlled exposure area.

[a]These radionuclides were selected from National Bureau of Standards Handbook 69 (for sale by U. S. Government Printing Office, Washington 25, D. C.). This publication lists (for all radionuclides) the recommendations of the National Committee on Radiation Protection and Measurements for Maximum Permissible Body Burdens and Maximum Permissible Concentrations in Air and Water for Occupational Exposure. The handbook should be consulted for MPC and MPBB values of other nuclides or for information on derivation and limitations of these values.

APPENDIX J

Explanation of Radioactivity Data Sheet

The Data sheet presents the results of a Gamma Spectroscopic Analysis of a given sample. The equipment used is a Multichannel Analyzer in conjunction with either a Sodium Iodide or Germanium Lithium Detector. The detector itself is located inside a shield consisting of an eight inch lead casing.

The one liter sample is placed in a Marinelli Beaker (for reprocible detection geometry) and counted for at least 100,000 seconds.

The detector efficiencies given on the Data sheet were found using a plot of efficiency versus energy for the detector of interest. The plot was obtained using a Marinelli Beaker configuration calibration source traceable to the National Bureau of Standards, containing at least five nuclides with energies ranging from 0.122 MeV Co-57 to 1.33 MeV Co-60.

The Area data given for each nuclide is found by:

Area = integral under photopeak - scatter continuum - laboratory background

The laboratory background is obtained using the same Gamma Spectroscopy equipment, counting for a length of time equivalent to that of the sample count time.

The Activity and Minimum Detectable Activity of the sample are determined for each nuclide present according to the following relation:

$$\text{Activity(Bq/gm)} = \frac{\text{Area}}{(\text{Frequency})(\text{Efficiency})(\text{Count time})(\text{Sample Mass})}$$

$$\text{MDA(Bq/gm)} = \frac{3}{(\text{Efficiency})(\text{Sample Mass})} \frac{\text{Laboratory Background}}{(\text{Count time})}$$

The Minimum Detectable Activity formula corresponds to 99.7% confidence level in the accuracy of the data, as stipulated by the National Bureau of Standards.

Note that the Frequency is sometimes called the Abundance and is characteristic of each nuclide.

Combined Peaks arise from the lack of high enough system resolution to differentiate between nuclides having photopeaks relatively close to one another. Therefore, they may be identified by their energy but an activity for each nuclide cannot be determined.

Also note that the first eight nuclides listed in the Data table exist naturally from the decay of the long-lived Uranium-238 and Thorium-232. The other nuclides listed are some of the gamma emitting isotopes that the Radiation Protection Office might be burning in the incinerator. All gamma emitting nuclides will be included in the analysis.

J.3

RADIOACTIVITY DATA SHEET

Nuclide	Energy(MeV)	Frequency(%)	Detector Efficiency (%) NaI (Tl)	GeLi	Area (Counts)	Activity Ci/gm	Activity Bq/gm	MDA Ci/gm	MDA Bq/gm
Th-234	0.063	3.5	4.85						
Ra-226	0.186	4	4.45						
Pb-214	0.295	19	4.1						
	0.352	36	3.95						
Bi-214	0.609	47	3.3						
	1.120	17	2.3						
	1.764	17	1.46						
Pb-212	0.239	47	4.28						
Ac-228	0.340	15	4.0						
	0.908	25	2.68						
	0.960	20	2.58						
Tl-208	0.511	23	3.51						
	0.583	86	3.36						
	0.860	12	2.75						
	2.614	100	0.8						
K-40	1.460	11	1.8						
K-42	0.310	0.2	4.1						
	1.520	18	1.7						
Rb-86	1.08	8.8	2.4						
Na-22	1.275	100	2.1						

System: _____ Count Time: _____

Detector: _____ Date: _____

Sample: _____ Processed by: _____

Sample Mass: _____ Approved by: _____

Combined Peaks:

Nuclides	Energy (MeV)	Area (Counts)

APPENDIX K

PURCHASE REQUISITION
(for off-campus purchases)
ARIZONA STATE UNIVERSITY

Shaded area to be completed by the Purchasing Dept. only

SERVICE REQUESTED	ACCOUNT NUMBER	ACCOUNT NAME	DATE OF REQ.	REQUISITION NO.
[X] Purchase Order: [ ] Check	400344	RESEARCH SERVICES	6-28-83	465676

DELIVER TO (NAME)	RECEIVING REPORT AND P.O. COPY TO (NAME)	DIRECT INQUIRIES TO (NAME)
Jody/Richard Brown	Jody Stewart	Richard Brown

BUILDING	ROOM	DEPARTMENT	PHONE
McAllister Office Complex	130-B	Radiation PRotection Office	965-6140/6190

SUGGESTED VENDORS (Suggestions are encouraged)

NAME	ADDRESS	CITY, STATE, ZIP
ARIZONA DEPARTMENT OF HEALTH SERVICES	1740 W. Adams Street	Phoenix, AZ 85007
State Health Building		

ATTN: Carl H. Billings, P.E.

SELECTED VENDORS (Final selection will be made by the Purchasing Department)

VENDOR CODE	VENDOR NUMBER	VENDOR NAME
A		
B		
C		

OBJECT CODE	QUANTITY	UNIT	DESCRIPTION (Give full description. Include catalog no. of widely known supply house when possible.)	UNIT PRICE (Estimate if exact price not known)	AMOUNT
7412.0-00			$100.00 for Operating Permit for	100.00	100.00
			Consumat Waste Disposal System		

Authorized funds are available in the account and the merchandise or service requested is for bona fide business purpose(s) of the Account charged.

APPROVAL INITIALS (as needed)

TOTAL 100.00

AUTHORIZED ACCOUNT SIGNATURE	DATE	CODING	ACCOUNTANT	FORMS CONTROL	OTHER
H.B. Hunnicutt					

APPROVAL SIGNATURES (as needed)

FOR THE COMPTROLLER	DATE	FOR THE VICE-PRESIDENT	DATE

100829-1 4/80

K.2

ARIZONA STATE UNIVERSITY
PURCHASING DEPARTMENT

DATE	P.O. (CHECK) NO.
7-5-83	619868

ORIGINATED BY	DEPARTMENT
Stewart	Engr Rad Prot Office

RECEIVING REPORT: Detach and return this Report to the Business Office, Accounts Payable, within 48 hours of receipt of this Order. No back orders will be shipped. If you did not receive full order, please re-order on new purchase requisition.

I certify that the item(s) described on this Order were received by me, that the quantities were carefully counted and that the condition was satisfactory except as otherwise noted.

DATE RECEIVED	SIGNATURE

SHIP WITHIN	QUOTATION	ABU REQ. NO.	ACCOUNT NO.	OBJECT CODE	VENDOR NO.	BUYER (NAME) ✱	(NO.)	USE
		465676	400344	7412-000	217896	Kral	09	

QUANTITY	UNIT	DESCRIPTION	UNIT PRICE	AMOUNT
1	ea	Operating permit for Consumat Waste Disposal System Permit #0291-84	100.00	100 00

*Contact this Buyer at (602) 965-3271 if there are any questions.

ESTIMATED TOTAL 100 00

DELIVERY INSTRUCTIONS

☐ Ship to: Arizona State University
University Warehouse
Attn: Brown
MOC 1308
Tempe, AZ 85287
Carton labels must include the above information as well as the P. O. No.)

☐ Mail to:
Arizona State University
Tempe, AZ 85287

☐ Will be picked up by

101402-2 4/83

PREPAID PURCHASE ORDER 619868

DATE OF ORDER
7-5-83

VENDOR NAME AND ADDRESS

AZ Dept of Health Services
State health Building
1740 W. Adams
Phoenix, Arizona
ATT: Carl H. Billings P.E.

ES:RH:3982

K-7

ARIZONA DEPARTMENT OF HEALTH SERVICES

Division of Environmental Health Services

Carla

BRUCE BABBITT, Governor
Donald B. Mathis, Acting Director

John Selvaggi

MAY 27 1983

Arizona State University
Laboratory Animal Care Facility
Annex - 1st and Price Road
Tempe, Arizona 85257
ATTN: George Bjotvedt, VMD, Acting Director

Operating Permit No. 0291-84 for Consumat Waste Disposal System
Permit Fee: $100.00

Gentlemen:

Your operating permit for the referenced facility has been granted by the Department of Health Services subject to payment of the fee above.

Please make check payable to the Arizona Department of Health Services and remit to the Controller, Division of Administration, Department of Health Services (Attention: Bureau of Air Quality Control). Upon receipt of your check, the permit will be forwarded to you.

You are advised that an operating permit is a legally enforceable document. If your facility fails to comply with the provisions contained in its operating permit, you will be subject to enforcement action and could incur criminal fines of up to one thousand dollars a day under Section 36-1720, Arizona Revised Statutes.

If you have any questions, please do not hesitate to contact the Engineering Services Section of the Bureau of Air Quality Control at (602) 255-1144.

Sincerely,

Carl H. Billings

Carl H. Billings, P.E., Manager
Engineering Services Section
Bureau of Air Quality Control

ARIZONA STATE
UNIVERSITY TEMPE, ARIZONA 85287

UNIVERSITY RADIATION PROTECTION
MCALLISTER OFFICE COMPLEX 130-B (602) 965-6140/6190

February 16, 1983

Arizona Dept. of Health Services
Bureau Of Air Quality Control
Compliance Section
1740 W. Adams Street
Phoenix, AZ 85007

Gentlemen:

SUBJECT: Vinyl Chloride Emissions Test: Operating Permit Request

The following is a report of the vinyl chloride (VC) emissions test (Method 106) conducted January 18, 1983 at the ASU Lab Animal Care Facility pathological incinerator at Price Road and 1st Street in Tempe. The test was performed as requested by the ADHS to demonstrate compliance with the applicable air quality standards prescribed by the State of Arizona ARRA Rules and Regulations, Titles 9 and 12.

Two previous VC tests did not meet specifications. Recommendations (see Appendix A) by Mr. Dennis Siivola, AQCB representative, were initiated in this third test. Considering our limitations, we have complied with the test methods and procedures specified in the Code of Federal Regulations as closely as deemed possible. Our pollutant emissions test results are well below federal limits.

If you have any problems or questions concerning this report, please contact our office. Thank you very much for your consideration.

Sincerely,

Richard F. Brown
Radiation Protection Officer

RFB/jls

CONTENTS

I. GENERAL

A. Background Information

May 20, 1981 ASU submitted an application for an amendment to its Radioactive Materials License, #7-37, to the Arizona Radiation Regulatory Agency (ARRA) which would allow disposal of hazardous and low-level radioactive waste by incineration in a commercially available, (Type 4 waste) pathological incinerator. Before the ARRA can issue the amendment, all other necessary permits for the operation of the incinerator must be obtained.

At a meeting in July 1981, Richard Brown, ASU RPO, was advised by a representative from the Air Quality Control Board (AQCB) that stack emissions would have to be tested for vinyl chloride due to the type of waste being incinerated.

An application for installation and operating permits was submitted to ADHS on 8-6-81. (See Appendix B).

B. Waste Types

Type 4 waste may consist of up to 85% moisture and 5% incombustible solids, with a heating value of 1000 Btu per pound fired.
The materials currently being incinerated include:

-Animal remains (carcasses, organs and excreta)
-Dry waste; contaminated disposable lab equipment (gloves, syringes, spill paper, etc.) contained in plastic bags or cardboard drums
-Liquid scintillation fluid (toluene) contained in 22mL plastic and glass vials (approximately 10 ml/vial)
-Toluene-saturated wood shavings contained in 3.8L plastic jars

With regard to radioactivity, the materials noted above contain a maximum of .05μCi per gram of H-3 and C-14. These isotopes may be disposed of without regard to their radioactivity (10 CFR 20.306, effective March 11, 1981).

The requested amendment would allow the incinerator of radioactive materials with atomic numbers 1-82. The stack effluent will not exceed the limits specified in the State of Arizona ARRA Rules and Regulations, R12-1-407(B).

C. Incinerator Specifications

CONSUMAT model #C-75P (dual chamber)
Serial #P-4380
175 lb/hr capacity
Type 4 waste

Stack: 22" O.D., refractory stack x 2' 9" long
22" O.D. 90° elbow refractory lined
22" O.D. refractory lined tee with 16" barometric damper

Lower chamber:
12 guage H.R. steel lined with 1" mineral wool insulation and 3" high strength 2600°F cast refractory
Two WC-5 - 250,000 Btu/hr burners with orifice 5/16.

Upper Chamber:
12 gauge lined with 1-1/2 mineral wool insulation and 4-1/2" insulation 2800°F cast refractory.
One WC-6 - 700,000 Btu/hr with orifice 7/16.

Controls (semi automatic):

1. Burner flame safety - Honeywell #C7008A1018 flame rod sensor.
2. Burner timers - 5 hr type, Paragon #536-045-0
3. Gas valves - ASCO type 8040B4 1", 8262C2 1/8" 8040B3 3/4"
4. Transformers - Dongan cat. #A06-SA6 primary voltage 115/120, secondary voltage 6000, 60 cycle (one required per burner).
5. Temp. controllers (one per chamber) - Honeywell Minipak controller R7380 - 0-2000°F for type "K" thermocouple

Forced air supply: (upper and lower chamber)
-Dayton blower #2C820
-500 CFM at 1" W.C. motor 1/2 HP
-3450 RPM, NEMA 48 frame

See Appendix C for diagram and general description.

D. Operation

When our amendment is obtained, the incinerator will be in operation once a week to accomodate the amount of waste collected. The amount of waste burned each week will be approximately 1.5 drums, (55 gal.; 7.5cu. ft. each). A burn consists of a 30 minute warm-up period, three charges at 30 minute intervals, and a five hour burn down time. Each charge consists of approximately 1/2 drum, (3.75 cu. ft.). This is done manually by two persons. The feed rate has been determined by trial and error.

ASU requested funds for an automatic hydraulic ram loader for the incinerator, but has not received the money yet.

II. VINYL CHLORIDE TEST

A. Apparatus

Pitot tube:	type S; C_p = .84 K_p = 84.49 (from 40 CFR 60 APP A5.1)
	.9 cm O.D. metal tubing with quartz lining
	P_a and P_b = 1.1 cm.
Inclined manometer:	.01" H_2O (1.3 mm H_2O) division horizontal scale
	1J to 10" H_2O vertical scale
Sample lines:	6.5mm O.D. Teflon tubing
Tedlar bag:	48.5L (16"x16") capacity; 4mL thick
Rigid box with lid:	2 quick connect valves 16" square box (67L) covered with black plastic
Pump:	leak free, 2L min. capacity
Charcoal filter tube	
Flow meter:	.1 to 12L scale
Gas chromatograph:	(see G.C. Analysis section of this report)

B. Data

The sample was drawn by Carla Greenup (student research aid) and Ron Daggett (ASU Health Physics Technician). Mr. Dennis Siivola was the AQCB compliance section representative.

Test date:	1-18-83 Tuesday
Barometric pressure at site:	29.92 inHg
Weather:	≈10% cloud cover, 60°F
Began sampling:	4:23 p.m.
flow rate	.5L per minute
waste loaded:	400 LS vials, 1 jar saturated wood chips
LC temp.:	1500°F
UC temp.:	1800°F
2nd Load	4:28 p.m.
contents:	2 bags dry waste
flow rate:	1L per minute

3rd Load	4:36 p.m.
contents:	3 bags dry waste, 200 LS vials
flow rate:	1.7L per minute
4th Load	4:44 p.m.
contents:	4 bags dry waste, 100 vials
flow rate:	1.7L per minute
5th Load	5:00 p.m.
contents:	3 bags dry waste, 200 vials
flow rate:	1.7L per minute
Ended Sampling:	5:16 p.m.
Total time:	53 minutes

Manometer readings:

upper port .05" H_2O

lower port .05" H_2O

$\Delta p = \leq .01"\ H_2O$

C. Gas Chromatograph Analysis (Robert Crouch, ASU Chemistry Dept.)

1. Apparatus: A microprocessor controlled integrating Hewlett-Packard Model 5830A gas chromatograph with flame ionization detector (F110) was used to analyze the samples. The chromatographic column was Poropols Q (equivalent to Chromosorb 102). Sample introduction to the GC was accomplished with a gas tight 2.5 ml syringe.

2. Reagents: A 101 ppm (±2%) vinyl chloride standard in nitrogen was purchased from Scott Specialty Gases, San Bernadino, CA. A 10 ppm standard (± 3 ppm) was prepared immediately prior to injection by tenfold dilution of the standard with air using the calibrated injection syringe. Typically, 0.25 ml vinyl chloride standard was diluted to 2.5 ml and injected immediately.

3. Procedure: The chromatographic conditions were as follows. Initial temperature 100°C, time at initial temperature 0.5 minute, rate 30°C per minute, final temperature 140°C, time at final temperature 3.00 minutes. The temperature program used was found to give improved peak resolution over isothermal operation.

In order to analyze a given stack sample for vinyl chloride, first the 100 ppm and 10 ppm standards were chromatographed. This established the retention time and F110 response. Using the program above, vinyl chloride had a retention time of 2.67 ± 0.09 minutes (average of 10 runs) and a response of $6.33 \pm 1.92 \times 10^8$ area counts per ml (average of 8 runs) of vinyl chloride at laboratory temperature and pressure. The limit of detection was estimated to be 0.08 ppm assuming linear detector response.

4. Results: Analysis of stack samples by the method described showed no peak that matched the retention time of vinyl chloride. This shows that vinyl chloride, if present, is at a concentration of less than 0.08 ppm.

As further confirmation of this conclusion, 2.0 ml of stack gas was spiked with 0.5 ml of 100 ppm standard vinyl chloride. This yielded an analysis peak for vinyl chloride that amounted to 10.57 ppm and was completely isolated from all other peaks in the sample. This shows that, within the limits of error for this procedure, no vinyl chloride is present in the stack gas samples analyzed.

5. Print-out: Page 7 & 8 contain computer print-out.

IV. OTHER TESTS

A. Particulates

The incinerator has been rated at a particulate output of .03 grains per dry standard cubic foot by the manufacturer.

B. Drager Tube Analysis

A gas analysis of H_2O vapor, CO_2, CO, and toluene was conducted with the Dräger Gas Detector. (See Appendix E for description and diagram).

The results of the analysis are listed below:

Gas	Range	Reading
H_2O vapor	.1-40 mg/liter	$\geq$ 40 mg/liter
CO_2	1-20% volume	2.5% volume
CO	10-300 ppm	$<$ 10 ppm (none detected)
Toluene	5-400 ppm	$<$ 5 ppm (none detected)

C. Stack Velocity

Using the formula specified in 40 CFR 60 APP A 5.2, we were able to calculate a rough estimate for the stack gas velocity. Because we did not perform Test Methods 1-6 of 40 CFR 61, the estimate is based on several assumptions.*

$$V_{sg} = K_p \text{ (ft./sec.) } C_p \sqrt{\Delta p(\text{inH}_2\text{O})} \sqrt{T(^\circ\text{R})/M_s(\text{lb/lb-mole})P_s(\text{inHg})}$$

V_{sg} ≡ stack gas velocity (ft/sec)

K_p ≡ pitot tube coefficient in units of (ft./sec.)(lb/lb-mole)(inHg)/(°R)(inH_2O)

C_p ≡ pitot tube constant (dimensionless)

Δp ≡ change between pitot tube port readings

T ≡ average stack gas temperature

M_s ≡ stack gas molecular wt. (wet basis)

P_s ≡ barometric pressure at test site

The values we used are:

K_p = 84.49 ft/sec (given in CFR for standard S-type pitot tube)

C_p = .84 (given in CFR for standard S-type pitot tube)

* Δp = .01 inH_2O (this value is the smallest detectable change for our manometer; there was no detectable change in the manometer readings)

T = 2260 °R (temperature of upper chamber)

* M_s = 29.0 lb/lb-mole (this is the given value for dry basis molecular wt. of air)

P_s = 29.92 inHg (recorded value from ASU weather data)

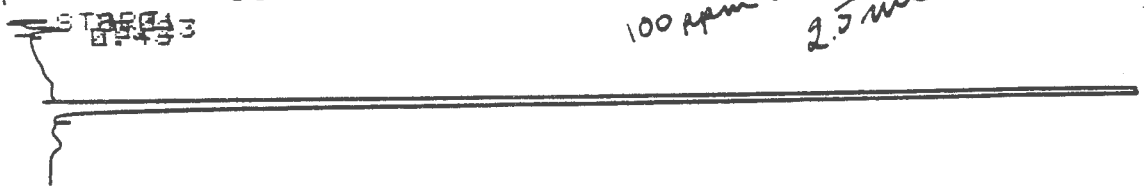
$$V_{sg} = (84.49)(.84)\sqrt{.01}\sqrt{2260/(29)(29.92)}$$

V_{sg} = 11.45 ft/sec

1/19/83
K.11

34
34
36
35

100 ppm VC std
2.5 ml

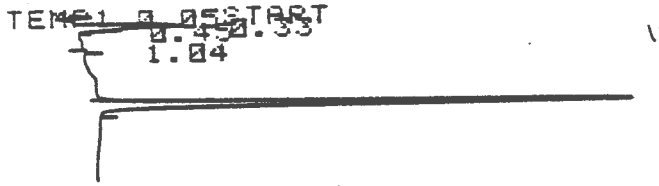


hp 5830A
AREA %

RT	AREA	AREA %
0.01	87	0.072
0.23	996	0.819
0.43	54	0.044
2.59	120500	99.065

XF: 1.0000 E+ 0

100 ppm diluted to 10 ppm VC std
2.5 ml



hp 5830A
AREA %

RT	AREA	AREA %
0.05	138	0.743
0.33	3247	17.477
0.45	324	1.744
2.62	14870	80.037

XF: 1.0000 E+ 0

2.5 ml Stock sample

hp 5830A
AREA %

RT	AREA	AREA %
0.03	86	0.220
0.28	1570	4.019
0.33	2908	7.444
0.74	21540	55.139
1.57	51	0.131
1.75	5265	13.478
1.94	691	1.769
2.41	2180	5.580
3.39	4423	11.322
4.72	351	0.899

XF: 1.0000 E+ 0

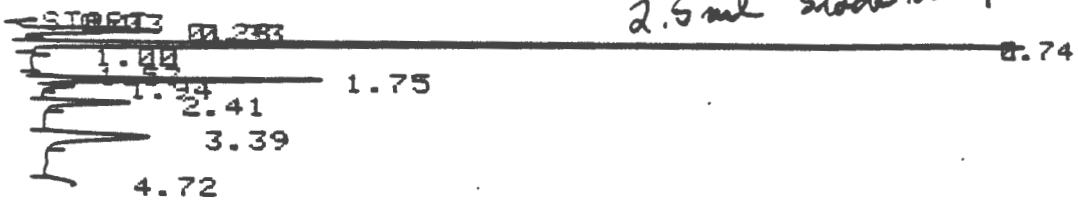
2.5 ml Stock spiked with VC

hp 5830A
AREA %

RT	AREA	AREA %
0.05	138	0.743
0.33	3247	17.477
0.45	324	1.744
2.62	14870	80.037

XF: 1.0000 E+ 0

2.5 ml Stock sample

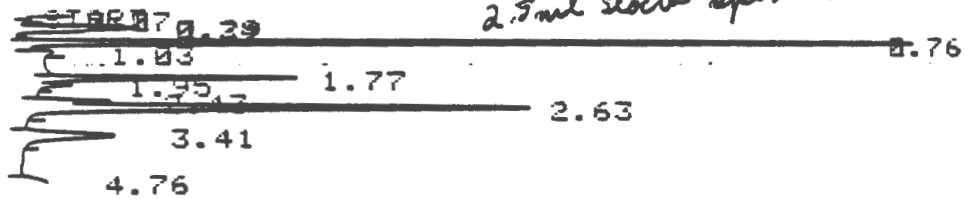


hp 5830A
AREA %

RT	AREA	AREA %
0.03	86	0.220
0.28	1570	4.019
0.33	2908	7.444
0.74	21540	55.139
1.57	51	0.131
1.75	5265	13.478
1.94	691	1.769
2.41	2180	5.580
3.39	4423	11.322
4.72	351	0.899

XF: 1.0000 E+ 0

2.5 ml Stock spiked with VC



11/9/83

hp 5830A
AREA %

RT	AREA	AREA %
0.29	1229	2.539
0.34	2509	5.184
0.76	18950	39.153
1.03	468	0.967
1.77	4724	9.760
1.95	629	1.300
2.43	1795	3.709
2.63	14160	29.256
3.41	3840	7.934
4.76	96	0.198

XF: 1.0000 E+ 0

APPENDIX A

CS:DRS:2616

ARIZONA DEPARTMENT OF HEALTH SERVICES

Division of Environmental Health Services

BRUCE BABBITT, Governor
JAMES E. SARN, M.D., M.P.H., Director

November 10, 1982

Mr. Dick Brown, Radiation Officer
Radiation Protection Office
College of Engineering
Arizona State University
Tempe, Arizona 85287

RE: Animal Care Facility Incinerator
Effluent Test

Dear Mr. Brown:

Enclosed is a copy of Field Activity Report Number CS:DRS:2606 which pertains to the sampling of the Consumat Systems, Inc. incinerator at the ASU Animal Care Facility. Mr. Robert Hollis and I wish to express our appreciation for the hospitality and cooperation of yourself and the test team members, Carla Greenup and Ron Daggett.

We look forward to working with you on the follow up tests.

Sincerely,

Dennis R. Siivola,
Compliance Section
Bureau of Air Quality Control

DRS:pt

Enclosure

,A DEPARTMENT OF HEALTH SERVICES
ION OF ENVIRONMENTAL HEALTH SERVICES
EAU OF AIR QUALITY CONTROL

K.15

FIELD ACTIVITY REPORT NUMBER CS:ORS:2606

Date October 21, 1982 Time

SOURCE NAME ARIZONA STATE UNIVERSITY, Animal Care Facility

LOCATION OF SOURCE Price Road and 1st Street

COUNTY Maricopa

TYPE OF SOURCE Incinerator PERMIT NUMBER (if applicable) applied

REPRESENTATIVE CONTACTED Dick Brown TITLE ASU Radiation Officer

REASON FOR INSPECTION - ☐ Permit ☐ Routine ☐ Hearing ☐ Complaint ☒ Special test emissions

FINDINGS

Arizona State University operates an incinerator at the Animal Care Facility. The substances that compose the incinerator feed include glass, vinyl chloride isotope traces in toluene, paper, wood, and animal carcasses. The method of charging the furnace is by manual handling the feed material which results in a discontinuous feed rate. The Consumat Systems, Inc. incinerator has a lower chamber at 1800°F, and an afterburner at 1400°F. The fans and burners turn off during loading while the door is open. When the furnace is charged the stack opacity goes to about 60% for fifteen seconds then tapers down to zero %.

The stack was being sampled for vinyl chloride emissions by Method 106, "Determination of Vinyl Chloride From Stationary Sources." Cecil Brewer and Jon Daggett, ASU students, performed the testing. The probe was stainless steel with a glass liner. The sampling was done for 30 minutes. When the probe was removed from the stack, the liner had sagged from the heat. The glass liner apparently was not quartz.

The following material was loaded into the incinerator during the test:

1: 40 pound dog carcass.

800: 1 oz. bottles having vinyl caps containing toluene with radioactive isotopes.

3: plastic bags containing wood shavings saturated with toluene containing radioactive isotopes.

NOTICE OF VIOLATION ISSUED? ☐ YES ☒ NO If yes, Notice of Violation Number

BUREAU REPRESENTATIVE Dennis R. Siivola DRS. REPORT DATE November 5, 1982

COPIES TO: X Engineering Services ___ Compliance ___ SRO
___ Technical Services ___ Monitoring ___ NRO

DHS/ AQC 301 (3-77)

3: 4 gallon size cardboard cartons with paper items that were used in conjunction with the isotope tracer work.

A few detector tube grab samples were taken during the test at the top of the stack on the upwind side. The detector tubes extended about five inches into the stack.

The sealed plexiglass box containing the integrated bag gas sample was transported to the ASU Chemistry Department Laboratory for analysis by Dr. Mike Parsons.

The Hewlett Packard gas chromatograph was out of service due to repairs on the analyzer's printed circuit boards. The test will need to be repeated at such time that the probe liner has been replaced and the gas chromatograph is able to process the integrated bag sample within the time limitations established by Method No. 106, i.e. within 24 to 72 hours. There are plans sometime in the future when funds are available to move the incinerator 20 feet and install a hydraulic ram feed. This will eliminate the hazard of manual loading and allow continuous feed. A sampling platform will be added after the move to facilitate testing.

RECOMMENDATIONS

The system should be tested for vinyl chloride emissions when the hydraulic ram feed system is operable. Also the requirement of maintaining a daily log describing the type and amount of material loaded should be made a permit condition. Quarterly reporting of the log's entries should be required as a permit condition too.

CS:DRS:2716

ARIZONA DEPARTMENT OF HEALTH SERVICES

Division of Environmental Health Services

January 12, 1983

Mr. Dick Brown, Radiation Officer
Radiation Protection Office
College of Engineering
Arizona State University
Tempe, Arizona 85287

RE: Animal Care Facility Incinerator Effluent Test

Dear Mr. Brown:

Enclosed is a copy of Field Activity Report Number CS:DRS:2668, which covers the observations made of the Method 106 test on December 3, 1982. Please note the Recommendation. It should be understood that vinyl chloride is a highly reactive substance. Using a sample bag constructed of potentially reactive material such as the black rubber bladder used in the previous test could cause the test results to be lower than actual. Test Method 106 requires utilization of a tedlar sample bag. The procedures detailed in Method 106, "Determination of Vinyl Chloride from Stationery Sources," must be followed.

To give you an understanding of how the permit application is processed, the following is a general description of the sequence in issuing an operating permit. When the test report is submitted to the Bureau of Air Quality Control Compliance Section, it will be checked for errors and compliance with the emission standard of 10 ppm. The Review of the Compliance Test Report will be forwarded to the Bureau Engineering Services Section (ESS) and the source. The permit application is technically evaluated with the use of the Technical Review and Evaluation of Application for Operating Permit form. A final permit draft is sent to the Compliance Section Manager for evaluation. The draft is returned to ESS for typing and signatures. The fee letter is sent out and upon receipt of the fee the operating permit is issued.

We look forward to the completion of testing and hope things go well.

Sincerely,

Dennis R. Siivola
Compliance Section
Bureau of Air Quality Control

DRS:pt
Enclosure

ARIZONA DEPARTMENT OF HEALTH SERVICES
DIVISION OF ENVIRONMENTAL HEALTH SERVICES
BUREAU OF AIR QUALITY CONTROL

K.18

FIELD ACTIVITY REPORT NUMBER CS:DRS:2668

Date 12/3/82 Time

SOURCE NAME ARIZONA STATE UNIVERSITY, Animal Care Facility

LOCATION OF SOURCE Price Road and 1st Street, Tempe

COUNTY Maricopa

TYPE OF SOURCE Incinerator PERMIT NUMBER (if applicable) applied for

REPRESENTATIVE CONTACTED Dick Brown TITLE Radiation Protection Officer

REASON FOR INSPECTION - ☐ Permit ☐ Routine ☐ Hearing ☐ Complaint ☒ Special Test emissions

OBSERVATIONS

This source was tested on October 21, 1982. The sample from the first test was not analyzed within the 24 to 74 hour requirement of Method 106, "Determination of Vinyl Chloride from Stationary Sources." The delay was caused by unscheduled but necessary repairs of the gas chromatograph. The test was rescheduled.

Today's test was performed during the incineration of 200 one ounce glass bottles having poly vinyl chloride caps. Each bottle contained toluene with radioactive isotopes. The upper incineration chamber operated at 2200° F and the lower incineration chamber operated at 1350° F. The opacity of the stack emissions was approximately 70% after loading the viles into the incinerator. The opacity decreased to less than 5% after five minutes.

After sampling, the sealed plexiglass box containing the sample bag was transported to the ASU Chemistry Lab where Mr. Robert Crouch performed the analysis. The gas chromatograph's data handler printed out the results. The retention time in the sample analysis most closely resembling that of the 10.1 ppm vinyl chloride standard had an area count that equated to 0.44 ppm. The standard for this source is 10.0 ppm.

The repaired probe was in excellent condition after the test. There was no distortion of the glass liner. The light colored elastic sample bag of the previous test was

NOTICE OF VIOLATION ISSUED? ☐ YES ☒ NO If yes, Notice of Violation Number

BUREAU REPRESENTATIVE Dennis R. Siivola DRS REPORT DATE 12/14/82

COPIES TO: X Engineering Services ___ Compliance ___ SRO X source
___ Technical Services ___ Monitoring ___ NRO

DHS/ AQC-001 (3-77)

replaced with a black bag. It could not be established that the black bag is constructed of tedlar material. Another test will be performed when a tedlar bag can be obtained and used for the test. A copy of the gas chromatograph's data handler printout is attached.

RECOMMENDATIONS

This system's emissions should be retested when the proper sample bags can be used.

2.55 .1594 23.417

SCAPE

TEMP1 2 5 0 ...

K.20

TEMP1	150	250
TIME1	0.5	
RATE	30.00	
TEMP2	140	
TIME2	3.0	
INJ TEMP	250	250
FID TEMP	275	275
OVEN MAX	270	

CHT SPD	0.50
ATTN 2↑	6
FID SGNL	A
SLP SENS	0.10
AREA REJ	50
FLOW A	35
FLOW B	31
OPTN	0

START STOP29

HP 5830A

AREA %

ESCAPE

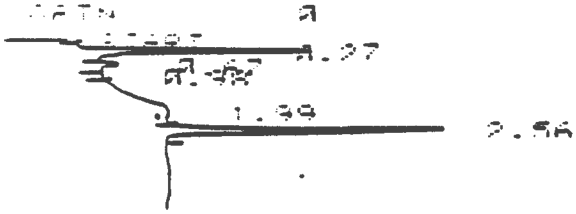
TEMP1 1 0 0 0

TEMP1 100 100

TEMP1	100	100
TIME1	0.5	
RATE	30.00	
TEMP2	140	
TIME2	3.0	
INJ TEMP	250	250
FID TEMP	275	276
OVEN MAX	270	

CHT SPD	0.50
ATTN 2↑	6
FID SGNL	A
SLP SENS	0.10
AREA REJ	50
FLOW A	35
FLOW B	35
OPTN	0

START



Vinyl chloride standard 100 ppm diluted to 10 ppm
821503 1040 hrs RLC-5
RLC

HP 5830A

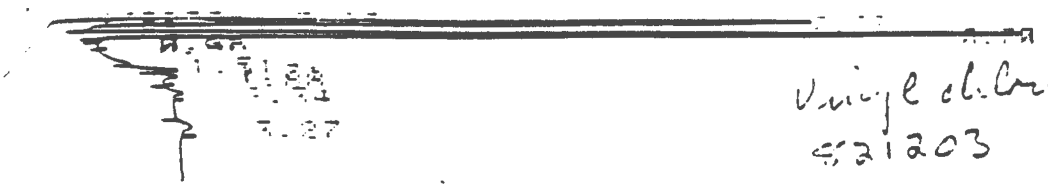
AREA %

RT	AREA	AREA %
0.27	10190	33.598
0.67	1728	5.698
0.98	209	0.689
1.99	3592	11.844
2.56	14610	48.172

XF: 1.0000 E+ 0

6.84×10^{-4} ppm/area count

Vinyl chloride Sample 531203 1205hrs KLC-5



hp 5830A
AREA %

RT	AREA	AREA %
0.25	3574	4.349
0.33	32860	39.988
0.70	40940	49.821
0.86	367	0.447
0.97	202	0.246
1.71	1442	1.755
1.88	1117	1.359
2.34	643	0.782
3.27	1029	1.252

RF: 1.0000 E+ 0

TEMP1	100	101
TIME1	0.5	
RATE	30.00	
TEMP2	140	
TIME2	3.0	
INJ TEMP	250	250
FID TEMP	275	275
OVEN MAX	270	
CHT SPD	0.50	
ATTN 2↑	6	
FID SGNL	A	
SLP SENS	0.10	
AREA REJ	50	
FLOW A	35	
FLOW B	35	
OPTN	0	

Recovery tied to VC = 2.44 ppm

program used

APPENDIX B

ARIZONA STATE
UNIVERSITY TEMPE, ARIZONA 85287
DEPARTMENT OF PLANNING AND CONSTRUCTION

August 14, 1981

Arizona Department of Health Services
Division of Environmental Health Services
Bureau of Air Quality Control
1740 West Adams Street
Phoenix, Arizona 85007

Subject: Application for Installation and Operation of Incinerator

Gentlemen:

Enclosed you will find the application and information as requested by both the Bureau of Air Quality Control and Bureau of Waste Control. Complete information is being provided to both offices in order to avoid confusion, as the units will be used to dispose of both pathological waste and low level radio active waste material.

Two different individuals are responsible for the two different operations. Questions about the pathological waste operation should be directed to Dr. George Bjotvedt (965-4380). Questions about the low level radio active waste material should be directed to Richard Brown (965-6140).

Sincerely yours,

Paul E. McClellan, P.E.
Director, Planning & Construction

By: Al Mages
Project Manager

PEM:AM:jk

Enclosures

FROM: Dr. George Bjotvedt, Animal Care Program

K.24

GUIDELINES FOR PATHOLOGICAL WASTE INCINERATORS

I. Design Criteria

A. Need for Facility

1. Waste sources will be from the various experimental animal resources at ASU.

2. Waste quantities will amount to a hundred (45 kilo) pounds per week for a ten month period.

3. Waste type will be a hundred percent pathological.

D. Facility Design

1. Incoming Wastes Storage Area

a. See Section II, paragraph 1. a - d.

b. Under veterinary supervision.

c. Under veterinary supervision.

II. Operations Criteria

1. Incoming Wastes Storage Areas

a. Animal remains will be contained in a water repellant paper bag container held in deep freezer situated on the second floor Life Science building ASU Campus and necropsy room in building at Price and University.

b. Animal remains will be held for one week prior to disposal.

c. Animal remains to be transported in a panel truck which may be sanitized.

d. Animal containers are disposable.

2. Incinerator

a. On the job-training with one person assigned as operator.

b. Loading to be under veterinary supervision.

c. A padlocks have been placed on imput and ash door to to prevent introduction of waste when unit it is inoperative.

d. Operation manual followed for incinerator procedures.

3. Ash and Residuals Storage Area

   See Incoming Wastes Storage Areas. Also, ash amount should approximate two percent of waste material.

4. Vector Control Plan

   Not a problem under veterinary supervision.

5. Access Control and Security Plan

   a. Unit has locked panel cover over control and firing instructions.

   b. University personnel reside on property as well as chain-link fence encloses property.

6. Site maintenance is a responsibility of the Laboratory Animal Care Program.

7. Contingency plan for waste disposal in event of a incinerator shut-down would revolve around transporting remains to the Phoenix disposal site.

8. A fire extinguisher will be located nearby as well as fire control plan would come under university rules and regulations.

9. Radiation Safety Officer will maintain incinerator records in Administrative Office of the Central Laboratory Animal Facility.

ARIZONA DEPARTMENT OF HEALTH SERVICES
DIVISION OF ENVIRONMENTAL HEALTH SERVICES ■ BUREAU OF AIR QUALITY CONTROL
1740 West Adams Street ■ Phoenix, AZ 85007 ■ Phone: (602)255-1144

K.26

APPLICATION FOR INSTALLATION PERMIT

(As required by Title 36, Chapter 3, Article 1, Section 36-1707.01 C., Arizona Revised Statutes and Section R9-3-301, Chapter 3, Article 3, Arizona Administrative Rules and Regulations)

1. PERMIT TO BE ISSUED TO (Business License Name of Organization that is to Receive Permit) Laboratory Animal Care Facility
   Arizona State University
2. NAME (OR NAMES) OF OWNER, PRINCIPALS, OR STATUTORY AGENTS DOING BUSINESS AS THE ABOVE ORGANIZATION
   Jack G. Penick, Vice President for Business Affairs
3. MAILING ADDRESS Tempe, Arizona 85257
4. EQUIPMENT LOCATION Laboratory Animal Care Facility, ASU Annex, 1st Street & Price Rd., Tempe
5. TYPE OF ORGANIZATION - ☐ Corporation ☐ Partnership ☐ Individual Owner ☒ Government Agency
6. PERMIT APPLICATION REASON -
   ☒ Begin Installation of New Equipment ☐ Transfer Existing Equipment
   ☐ Modify Existing Equipment ☐ Change of Location of Ownership
7. PERMIT TYPE - ☐ Class A (Major Source) ☐ Class B (Pollution Control Equipment) ☒ Class C (Minor Source)
8. CLASSIFY AREA IN WHICH EQUIPMENT IS LOCATED:
   Particulate - ☐ Unclassifiable ☒ Non-attainment ☐ Attainment, Class _____
   Sulfur Dioxide - ☐ Unclassifiable ☐ Non-attainment ☒ Attainment Class II
   Carbon Monoxide - ☐ Unclassifiable ☒ Non-attainment ☐ Attainment
   Oxidants - ☐ Unclassifiable ☒ Non-attainment ☐ Attainment
9. GENERAL NATURE OF BUSINESS Pathological Crematorium
10. EQUIPMENT DESCRIPTION Consumat Waste Disposal System Model C75P Capacity 175#/Hr
    Serial No. 4380 Type 4 Waste
11. IF THIS EQUIPMENT HAD A PREVIOUS WRITTEN PERMIT, STATE NAME OF CORPORATION, COMPANY OR INDIVIDUAL OWNER THAT OPERATED THIS EQUIPMENT AND STATE PREVIOUS BUREAU OF AIR QUALITY CONTROL PERMIT NUMBER.
    NAME None PERMIT NUMBER _____
12. IF THE ORGANIZATION IS ACQUIRING AIR POLLUTION CONTROL DEVICE(S) AND WISHES TO APPLY FOR CERTIFICATION OF THE DEVICE(S) IN ACCORDANCE WITH SECTION 43-123.02.C., ARIZONA REVISED STATUTES, CHECK HERE ☐
13. SIGNATURE OF RESPONSIBLE MEMBER OF ORGANIZATION [signature]
    OFFICIAL TITLE OF SIGNER Acting Director, Laboratory Animal Care Program
14. TYPED OR PRINTED NAME OF SIGNER GEORGE BJOTVEDT, VMD
    DATE August 6, 1981 TELEPHONE NUMBER 965-4385

ARIZONA DEPARTMENT OF HEALTH SERVICES
Bureau of Air Quality Control - Division of Environmental Health Services
1740 West Adams Street - Phoenix, AZ 85007 Phone: (602)255-1144

APPLICATION FOR OPERATING PERMIT

(As required by Title 36, Chapter 14, Article 1, Section 36-1707 01. C., Arizona Revised Statutes)

ermit to be issued to (Business License Name of Organization that is to Receive Permit) Laboratory Animal Care Facility
ARIZONA STATE UNIVERSITY

2. Name (or names) of Owner, Principals, or statutory agents doing business as the above organization
Jack G. Penick, Vice President for Business Affairs

3 Mailing Address Tempe, Arizona 85257

4 Equipment Location Laboratory Animal Care Facility, A.S.U. Annex, 1st St. & Price Rd., Tempe

5. Type of Organization - ☐ Corporation ☐ Partnership ☐ Individual Owner ☒ Government Agency

6. Permit Application Reason - ☒ Begin Operation of New Equipment ☐ Continue Operation of Existing Equipment
☐ Transfer (change of location or ownership)

7. General Nature of Business

Pathological Crematorium

8. Equipment Description

Consumat Waste Disposal System Model C75P Capacity 175#/Hr
Serial No. 4380 Type 4 Waste

9. If this equipment had a previous written permit, state name of corporation, company or individual owner that operated this equipment and state previous Bureau of Air Quality Control Permit Number.

Name N/A Permit Number

10. If the organization is acquiring air pollution control device(s) and wishes to apply for certification of the device(s) in accordance with Section 43-123.02, C., Arizona Revised Statutes, check here ☐

11. Signature of Responsible Member of Organization

Official Title of Signer Acting Director, Laboratory Animal Care Program

12. Typed or Printed Name of Signer GEORGE BJOTVEDT, VMD

Date 8-6-81 Telephone number 965-4385

ARIZONA DEPARTMENT OF HEALTH SERVICES

Division of Environmental Health Services
REF: TS 0310

BRUCE E. BABBITT, Governor
JAMES E. SARN, M.D., M.P.H., Director

November 10, 1981

Paul E. McClellan, P.E.
Director
Department of Planning and Construction
Arizona State University
Tempe, Arizona 85281

Dear Mr. McClellan:

Upon review of the application for the installation and operation of an incinerator at Arizona State University, this bureau has the following questions and comments:

a. What is the construction schedule for the proposed incinerator, and when is initial operation planned?

b. The pathological waste incineration plan indicates that "on the job training" of the operator will be utilized. Will an individual trained in incineration techniques provide this training?

c. Will the temperature monitor/control be utilized to automatically stop the waste feed (or indicate that it should be stopped) if the proposed incinerator is overloaded?

d. How will the feed rate be controlled?

e. Upon completion of incineration, the waste must be visually checked to insure complete combustion.

f. The "scintillation cocktail" portion of the low level radioactive waste contains toluene, a listed hazardous waste which is ignitable with a flashpoint of 40°F. The incinerator's operating manual says, "Do not attempt to destroy explosives or highly volatile or hazardous materials". Therefore, the incineration of toluene would appear to contradict the manufacturer's operating specifications. In addition, the operator's manual does not address the incineration of low level radioactive waste.

g. Due to the fact that the proposed ASU animal care center-incinerator complex will be located in an area zoned for one family residences, and will be adjacent to a trailer park, this bureau recommends that the City of Tempe zoning board be contacted and informed of the nature of the waste proposed to be incinerated.

K.29

h. The Bureau's hazardous waste regulations exempt "... any radioactive waste material whose storage, transportation, treatment, and disposal is regulated by the Arizona Atomic Energy Commission..." (In July 1980, the AAEC was renamed the Arizona Radiation Regulatory Agency). Please have the ARRA forward a letter to the Bureau of Waste Control stating which of the above concerns have been specifically examined and found acceptable from the aspect of health and the environment.

i. If any ash is buried on site, an approval by this bureau to operate a landfill will be needed.

If you have any questions, please feel free to contact this bureau. The lead contact person for this type of operation is Bill Hudson at 255-1166. Your cooperation in this matter is appreciated.

Sincerely,

Alan L. Roesler

Alan L. Roesler, R.G., Manager
Technical Support Section
Bureau of Waste Control

ALR:mc

cc: Steve Parker, Bureau of Air Quality Control
Daryl Warren, Arizona Radiation Regulatory Commission

ARIZONA STATE
UNIVERSITY

TEMPE, ARIZONA 85281

UNIVERSITY RADIATION SAFETY OFFICE
COLLEGE OF ENGINEERING (ECG-102) (602) 965-3140

REF: RS 0310

November 17, 1981

Bill Hudson
Technical Support Section
Bureau of Waste Control
AZ Dept. of Health Services
1740 W. Adams
Phoenix, AZ 85007

Dear Mr. Hudson:

This letter is in reply to the questions raised by your office regarding the installation and operation of an incinerator at Arizona State Universities Laboratory Animal Care Facility. These replies follow the outline of your letter dated November 10.

a) Incinerator has already been installed. We are presently testing its operation with approval of the Bureau of Air Quality Control.

b) Regarding training of operator personnel, after installation of the incinerator a representative from Consumat held a day-long incinerator dry-out and discussed operation procedures for the incinerator with the Director of the Lab Animal Care Facility and the Radiation Safety Officer, additionally two representatives from the Radiation Safety Office attended a workshop at North Carolina State University on the incineration of low level radioactive waste. Included in this workshop were several sessions on general incinerator operation. We used the term "on the job training" to indicate that modifications in our operating procedures will be necessary based on the incinerator and the type of waste being disposed of.

c) The temperature monitor/control is a standard feature of the incinerator. It's function is to maintain temperature of upper and lower chambers at set points. The only indication of overloading which can be inferred from it would be if the temperature control consistently is at the level of the temperature set point which would indicate a high level of high BTU content waste, not necessarily a system overload.

d) Since the incinerator is hand-fed the only reasonable method for ensuring proper feed rate is to develop an operational feed rate by trial and error methods.

e) Toluene has been incinerated by several universities and research institutes using systems similar or identical to our own with no adverse effects on the incinerator or its operation. Toluene can, in fact, serve as an aid in incineration due to its high BTU content when loaded along with low BTU content waste such as pathological waste or other waste with a high moisture content. No separate provisions need be made for low level radioactive waste. Such waste as generated at Arizona State University may be classified as Type 4 waste.

f) Although Arizona State University is a state agency and as such is not subject to municipal zoning ordinances we are willing to seek out the advice of the City of Tempe in our operation. Regarding the trailer park adjacent to the site, representatives of the Radiation Safety Office spoke to a meeting of park residents and found them to be supportive of the project as long as they were kept informed of the progress after incineration had begun.

g) Applications have been submitted to the Arizona Radiation Regulatory Agency regarding a license amendment which would permit this form of disposal. Upon approval of this amendment copies of such approval will be forwarded to your office.

h) Any information regarding an application for on-site or other burial by Arizona State University would be appreciated.

If there are any further questions regarding this operation please contact this office.

Thank you for your consideration.

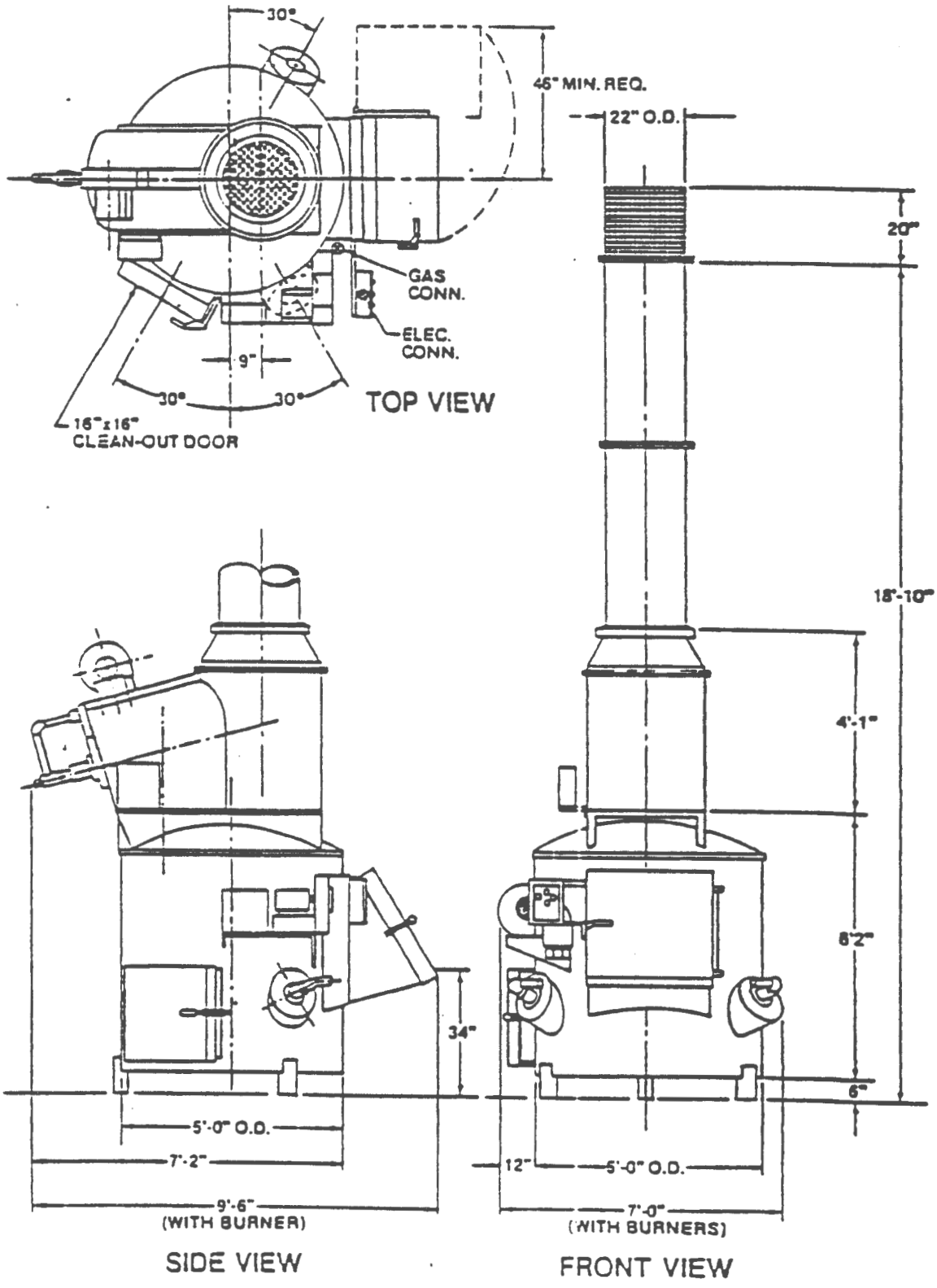
Sincerely,

Herbert J. Miller Jr.
Director Physical Plant

HJM/jls

APPENDIX C

MODEL C-75P


30°
46" MIN. REQ.
22" O.D.
20"
GAS CONN.
ELEC. CONN.
9"
30°
30°
TOP VIEW
16"x16" CLEAN-OUT DOOR
18'-10"
4'-1"
8'2"
6"
34"
5'-0" O.D.
7'-2"
9'-6" (WITH BURNER)
SIDE VIEW
12"
5'-0" O.D.
7'-0" (WITH BURNERS)
FRONT VIEW

1.0 GENERAL DESCRIPTION

The CONSUMATO incinerator is a compact, factory assembled incinerator that employs IIA (Incinerator Institute of America) recommended velocity profiles in a novel arrangement, that meets or exceeds all EPA (Environmental Protection Agency) standards for particulate matter and noxious gas emissions, when maintained and operated in a responsible manner.

The grateless lower chamber, or distillation chamber, volatilizes, or partially oxidizes the waste. In the upper chamber, the gases that are generated in the lower chamber are fully combusted. As a result, the CONSUMATO incinerator can consume from Type 0 to Type 6 wastes, when properly set up for each, without emitting smoke, odor or fly ash. This is accomplished without the use of water scrubbers or electrostatic precipitators.

APPENDIX D

method 5 ml of concentrated H_2SO_4 and 2 ml of concentrated HNO_3 are added to the 0.2 grams of sample. 5 ml of saturated $KMnO_4$ solution are added and the bottle is covered with a piece of aluminum foil. The samples are autoclaved at 121°C and 2.1 kg/cm² (ca. 15 psig) for 15 minutes. Cool, make up to a volume of 100 ml with distilled water, and add 6 ml of sodium chloride-hydroxylamine sulfate solution to reduce the excess permanganate. Purge the dead air space and continue as described in paragraph 4.4.1 of this method.

5. *Calibration.* 5.1 Measure the peak height of the unknown from the chart and read the mercury value from the standard curve.

5.2 Calculate the mercury concentration in the sample by the formula:

μg Hg/gm = μg Hg in the aliquot/wt. of the aliquot in g

5.3 Report mercury concentrations as follows: Below 0.1 μg/g; between 0.1 and 1 μg/g, to the nearest 0.01 μg/g; between 1 and 10 μg/g, to nearest 0.1 μg; above 10 μg/g, to nearest μg.

6. *Precision and accuracy.* 6.1 According to the provisional method in reference number 5, the following standard deviations on replicate sediment samples have been recorded at the indicated levels: 0.29 μg/g ± 0.02 and 0.82 μg/g ± 0.03. Recovery of mercury at these levels, added as methyl mercuric chloride, was 97 and 94%, respectively.

7. *References.*

1. Bishop, J. N. "Mercury in Sediments," Ontario Water Resources Comm., Toronto, Ontario, Canada, 1971.

2. Salma, M. Private communication, EPA Cal/Nev Basin Office, Alameda, California.

3. Hatch, W.R., and Ott, W. L. "Determination of Sub-Microgram Quantities of Mercury by Atomic Absorption Spectrophotometry," Anal. Chem. 40, 2085 (1968).

4. Bradenberger, H. and Bader, H. "The Determination of Nanogram Levels of Mercury in Solution by a Flameless Atomic Absorption Technique," Atomic Absorption Newsletter 6, 101 (1967).

5. Analytical Quality Control Laboratory (AQCL), Environmental Protection Agency, Cincinnati, Ohio, "Mercury in Sediment (Cold Vapor Technique)," Provisional Method, April 1972.

6. Kopp, J. F., Longbottom, M. C. and Lobring, L. B. "Cold Vapor Method for Determining Mercury," Journal AWWA, 64, 1 (1972), pp. 20–25.

7. "Manual of Methods for Chemical Analysis of Water and Wastes," Environmental Protection Agency, EPA-625/2-74-003, pp. 118–138.

Method 106—Determination of Vinyl Chloride From Stationary Sources

[Method 106 revised by 47 FR 39170, September 7, 1982]

Introduction

Performance of this method should not be attempted by persons unfamiliar with the operation of a gas chromatograph (GC) nor by those who are unfamiliar with source sampling, because knowledge beyond the scope of this presentation is required. Care must be exercised to prevent exposure of sampling personnel to vinyl chloride, a carcinogen.

1. Applicability and Principle

1.1 Applicability. The method is applicable to the measurement of vinyl chloride in stack gases from ethylene dichloride, vinyl chloride, and polyvinyl chloride manufacturing processes. The method does not measure vinyl chloride contained in particulate matter.

1.2 Principle. An integrated bag sample of stack gas containing vinyl chloride (chloroethene) is subjected to GC analysis using a flame ionization detector (FID).

2. Range and Sensitivity

This method is designed for the 0.1 to 50 ppm range. However, common GC instruments are capable of detecting 0.02 ppm vinyl chloride. With proper calibration, the upper limit may be extended as needed.

3. Interferences

The chromatographic columns and the corresponding operating parameters herein described normally provide an adequate resolution of vinyl chloride; however, resolution interferences may be encountered on some sources. Therefore, the chromatograph operator shall select the column and operating parameters best suited to his particular analysis requirements, subject to the approval of the Administrator. Approval is automatic, provided that the tester produces confirming data through an adequate supplemental analytical technique, such as analysis with a different column or GC/mass spectroscopy, and has the data available for review by the Administrator.

4. Apparatus

4.1 Sampling (see Figure 106-1). The sampling train consists of the following components:

4.1.1 Probe. Stainless steel, Pyrex glass, or Teflon tubing (as stack temperature permits) equipped with a glass wool plug to remove particulate matter.

4.1.2 Sample Lines. Teflon, 6.4-mm outside diameter, of sufficient length to connect probe to bag. Use a new unused piece for each series of bag samples that constitutes an emission test, and discard upon completion of the test.

4.1.3 Quick Connects. Stainless steel, male (2) and female (2), with ball checks (one pair without), located as shown in Figure 106-1.

4.1.4 Tedlar Bags. 50- to 100-liter capacity, to contain sample. Aluminized Mylar bags may be used if the samples are analyzed within 24 hours of collection.

4.1.5 Bag Containers. Rigid leak-proof containers for sample bags, with covering to protect contents from sunlight.

4.1.6 Needle Valve. To adjust sample flow rates.

4.1.7 Pump. Leak-free, with minimum of 2-liter/min capacity.

4.1.8 Charcoal Tube. To prevent admission of vinyl chloride and other organics to the atmosphere in the vicinity of samplers.

4.1.9 Flowmeter. For observing sampling flow rate; capable of measuring a flow range from 0.10 to 1.00 liter/min.

4.1.10 Connecting Tubing. Teflon, 6.4-mm outside diameter, to assemble sampling train (Figure 106-1).

4.1.11 Tubing Fittings and Connectors. Teflon or stainless steel, to assemble sampling train.

4.2 Sample Recovery. Teflon tubing, 6.4-mm outside diameter, to connect bag to GC sample loop for sample recovery. Use a new unused piece for each series of bag samples that constitutes an emission test, and discard upon conclusion of analysis of those bags.

4.3 Analysis. The following equipment is required:

4.3.1 Gas Chromatograph. With FID, potentiometric strip chart recorder and 1.0- to 5.0-ml heated sampling loop in automatic sample valve. The chromatographic system shall be capable of producing a response to 0.1 ppm vinyl chloride that is at least as great as the average noise level. (Response is measured from the average value of the base line to the maximum of the wave form, while standard operating conditions are in use.)

4.3.2 Chromatographic Columns. Columns as listed below. The analyst may use other columns provided that the precision and accuracy of the analysis of vinyl chloride standards are not impaired and he has available for review information confirming that there is adequate resolution of the vinyl chloride peak. (Adequate resolution is defined as an area overlap of not more than 10 percent of the vinyl chloride peak by an interferent peak. Calculation of area overlap is explained in Appendix C, Procedure 1: "Determination of Adequate Chromatographic Peak Resolution.")

4.3.2.1 Column A. Stainless steel, 2.0 m by 3.2 mm, containing 80/100-mesh Chromosorb 102.

4.3.2.2 Column B. Stainless steel, 2.0 m by 3.2 mm, containing 20 percent GE SF-96 on 60/80-mesh Chromosorb P AW; or stainless steel, 1.0 m by 3.2 mm containing 80/100-mesh Porapak T. Column B is required as a secondary column if acetaldehyde is present. If used, column B is placed after column A. The combined columns should be operated at 120° C.

4.3.3 Flowmeters (2). Rotameter type, 100-ml/min capacity, with flow control valves.

4.3.4 Gas Regulators. For required gas cylinders.

4.3.5 Thermometer. Accurate to 1° C, to measure temperature of heated sample loop at time of sample injection.

4.3.6 Barometer. Accurate to 5 mm Hg, to measure atmospheric pressure around GC during sample analysis.

4.3.7 Pump. Leak-free, with minimum of 100-ml/min capacity.

4.3.8 Recorder. Strip chart type, optionally equipped with either disc or electronic integrator.

4.3.9 Planimeter. Optional, in place of disc or electronic integrator on recorder, to measure chromatograph peak areas.

4.4 Calibration. Sections 4.4.2 through 4.4.4 are for the optional procedure in Section 7.1.

4.4.1 Tubing. Teflon, 6.4-mm outside diameter, separate pieces marked for each calibration concentration.

4.4.2 Tedlar Bags. Sixteen-inch-square size, with valve; separate bag marked for each calibration concentration.

4.4.3 Syringes. 0.5-ml and 50-μl, gas tight.

individually calibrated to dispense gaseous vinyl chloride.

4.4.4 Dry Gas Meter, with Temperature and Pressure Gauges. Singer model DTM-115 with 802 index, or equivalent, to meter nitrogen in preparation of standard gas mixtures, calibrated at the flow rate used to prepare standards.

5. Reagents

Use only reagents that are of chromatograph grade.

5.1 Analysis. The following are required for analysis.

5.1.1 Helium or Nitrogen. Zero grade, for chromatographic carrier gas.

5.1.2 Hydrogen. Zero grade.

5.1.3 Oxygen or Air. Zero grade, as required by the detector.

5.2 Calibration. Use one of the following options: either 5.2.1 and 5.2.2, or 5.2.3.

5.2.1 Vinyl Chloride. Pure vinyl chloride gas certified by the manufacturer to contain a minimum of 99.9 percent vinyl chloride, for use in the preparation of standard gas mixtures in Section 7.1. If the gas manufacturer maintains a bulk cylinder supply of 99.9+ percent vinyl chloride, the certification analysis may have been performed on this supply rather than on each gas cylinder prepared from this bulk supply. The date of gas cylinder preparation and the certified analysis must have been affixed to the cylinder before shipment from the gas manufacturer to the buyer.

5.2.2 Nitrogen. Zero grade, for preparation of standard gas mixtures as described in Section 7.1.

5.2.3 Cylinder Standards (3). Gas mixture standards (50-, 10-, and 5-ppm vinyl chloride in nitrogen cylinders). The tester may use cylinder standards to directly prepare a chromatograph calibration curve as described in Section 7.2.2, if the following conditions are met: (a) The manufacturer certifies the gas composition with an accuracy of ±3 percent or better (see Section 5.2.3.1). (b) The manufacturer recommends a maximum shelf life over which the gas concentration does not change by greater than ±5 percent from the certified value. (c) The manufacturer affixes the date of gas cylinder preparation, certified vinyl chloride concentration, and recommended maximum shelf life to the cylinder before shipment to the buyer.

5.2.3.1 Cylinder Standards Certification. The manufacturer shall certify the concentration of vinyl chloride in nitrogen in each cylinder by (a) directly analyzing each cylinder and (b) calibrating his analytical procedure on the day of cylinder analysis. To calibrate his analytical procedure, the manufacturer shall use, as a minimum, a three-point calibration curve. It is recommended that the manufacturer maintain (1) a high-concentration calibration standard (between 50 and 100 ppm) to prepare his calibration curve by an appropriate dilution technique and (2) a low-concentration calibration standard (between 5 and 10 ppm) to verify the dilution technique used. If the difference between the apparent concentration read from the calibration curve and the true concentration assigned to the low-concentration calibration standard exceeds 5 percent of the true concentration, the manufacturer shall determine the source of error and correct it, then repeat the three-point calibration.

5.2.3.2 Verification of Manufacturer's Calibration Standards. Before using a standard, the manufacturer shall verify each calibration standard (a) by comparing it to gas mixtures prepared (with 99 mole percent vinyl chloride) in accordance with the procedure described in Section 7.1 or (b) calibrating it against vinyl chloride cylinder Standard Reference Materials (SRM's) prepared by the National Bureau of Standards, if such SRM's are available. The agreement between the initially determined concentration value and the verification concentration value must be within ±5 percent. The manufacturer must reverify all calibration standards on a time interval consistent with the shelf life of the cylinder standards sold.

5.2.4 Audit Cylinder Standards (2). Gas mixture standards with concentrations known only to the person supervising the analysis of samples. The audit cylinder standards shall be identically prepared as those in Section 5.2.3 (vinyl chloride in nitrogen cylinders). The concentrations of the audit cylinder should be: one low-concentration cylinder in the range of 5 to 20 ppm vinyl chloride and one high-concentration cylinder in the range of 20 to 50 ppm. When available, the tester may obtain audit cylinders by contacting: Environmental Protection Agency, Environmental Monitoring Systems Laboratory, Quality Assurance Division (MD-77), Research Triangle Park, North Carolina 27711. Audit cylinders obtained from a commercial gas manufacturer may be used provided: (a) the gas manufacturer certifies the audit cylinder as described in Section 5.2.3.1, and (b) the gas manufacturer obtains an independent analysis of the audit cylinders to verify this analysis. Independent analysis is defined here to mean analysis performed by an individual different than the individual who performs the gas manufacturer's analysis, while using calibration standards and analysis equipment different from those used for the gas manufacturer's analysis. Verification is complete and acceptable when the independent analysis concentration is within ±5 percent of the gas manufacturer's concentration.

6. Procedure

6.1 Sampling. Assemble the sample train as shown in Figure 106-1. A bag leak check should have been performed previously according to Section 7.3.2. Join the quick connects as illustrated, and determine that all connection between the bag and the probe are tight. Place the end of the probe at the centroid of the stack and start the pump with the needle valve adjusted to yield a flow that will fill over 50 percent of bag volume in the specific sample period. After allowing sufficient time to purge the line several times, change the vacuum line from the container to the bag and evacuate the bag until the rotameter indicates no flow. Then reposition the sample and vacuum lines and begin the actual sampling, keeping the rate proportional to the stack velocity. At all times, direct the gas exiting the rotameter away from sampling personnel. At the end of the sample period, shut off the pump, disconnect the sample line from the bag, and disconnect the vacuum line from the bag container. Protect the bag container from sunlight.

6.2 Sample Storage. Keep the sample bags out of direct sunlight. When at all possible, analysis is to be performed within 24 hours, but in no case in excess of 72 hours of sample collection. Aluminized Mylar bag samples must be analyzed within 24 hours.

6.3 Sample Recovery. With a new piece of Teflon tubing identified for that bag, connect a bag inlet valve to the gas chromatograph sample valve. Switch the valve to receive gas from the bag through the sample loop. Arrange the equipment so the sample gas passes from the sample valve to 100-ml/min rotameter with flow control valve followed by a charcoal tube and a 1-in. H_2O pressure gauge. The tester may maintain the sample flow either by a vacuum pump or container pressurization if the collection bag remains in the rigid container. After sample loop purging is ceased, allow the pressure gauge to return to zero before activating the gas sampling valve.

6.4 Analysis. Set the column temperature to 100° C and the detector temperature to 150° C. When optimum hydrogen and oxygen flow rates have been determined, verify and maintain these flow rates during all chromatography operations. Using zero helium or nitrogen as the carrier gas, establish a flow rate in the range consistent with the manufacturer's requirements for satisfactory detector operation. A flow rate of approximately 40 ml/min should produce adequate separations. Observe the base line periodically and determine that the noise level has stabilized and that base line drift has ceased. Purge the sample loop for 30 seconds at the rate of 100 ml/min, shut off flow, allow the sample loop pressure to reach atmospheric pressure as indicated by the H_2O manometer, then activate the sample valve. Record the injection time (the position of the pen on the chart at the time of sample injection), sample number, sample loop temperature, column temperature, carrier gas flow rate, chart speed, and attenuator setting. Record the barometeric pressure. From the chart, note the peak having the retention time corresponding to vinyl chloride as determined in Section 7.2.1. Measure the vinyl chloride peak area, A_m, by use of a disc integrator, electronic integrator, or a planimeter. Measure and record the peak heights, H_m. Record A_m and retention time. Repeat the injection at least two times or until two consecutive values for the total area of the vinyl chloride peak do not vary more than 5 percent. Use the average value for these two total areas to compute the bag concentration.

Compare the ratio of H_m to A_m for the vinyl chloride sample with the same ratio for the standard peak that is closest in height. If these ratios differ by more than 10 percent, the vinyl chloride peak may not be pure (possibly acetaldehyde is present) and the secondary column should be employed (see Section 4.3.2.2).

6.5 Determination of Bag Water Vapor Content. Measure the ambient temperature

and barometric pressure near the bag. From a water saturation vapor pressure table, determine and record the water vapor content of the bag as a decimal figure. (Assume the relative humidity to be 100 percent unless a lesser value is known.)

7 Preparation of Standard Gas Mixtures, Calibration, and Quality Assurance

7.1 Preparation of Vinyl Chloride Standard Gas Mixtures. (Optional Procedure—delete if cylinder standards are used.) Evacuate a 16-inch square Tedlar bag that has passed a leak check (described in Section 7.3.2) and meter in 5.0 liters of nitrogen. While the bag is filling, use the 0.5-ml syringe to inject 250 µl of 99.9 + percent vinyl chloride gas through the wall of the bag. Upon withdrawing the syringe, immediately cover the resulting hole with a piece of adhesive tape. The bag now contains a vinyl chloride concentration of 50 ppm. In a like manner use the 50 µl syringe to prepare gas mixtures having 10- and 5-ppm vinyl chloride concentrations. Place each bag on a smooth surface and alternately depress opposite sides of the bag 50 times to further mix the gases. These gas mixture standards may be used for 10 days from the date of preparation, after which time new gas mixtures must be prepared. (Caution: Contamination may be a problem when a bag is reused if the new gas mixture standard is a lower concentration than the previous gas mixture standard.)

7.2 Calibration.

7.2.1 Determination of Vinyl Chloride Retention Time. (This section can be performed simultaneously with Section 7.2.2.) Establish chromatograph conditions identical with those in Section 6.4 above. Determine proper attenuator position. Flush the sampling loop with zero helium or nitrogen and activate the sample valve. Record the injection time, sample loop temperature, column temperature, carrier gas flow rate, chart speed, and attenuator setting. Record peaks and detector responses that occur in the absence of vinyl chloride. Maintain conditions with the equipment plumbing arranged identically to Section 6.3, and flush the sample loop for 30 seconds at the rate of 100 ml/min with one of the vinyl chloride calibration mixtures. Then activate the sample valve. Record the injection time. Select the peak that corresponds to vinyl chloride. Measure the distance on the chart from the injection time to the time at which the peak maximum occurs. This quantity divided by the chart speed is defined as the retention time. Since other organics may be present in the sample, positive identification of the vinyl chloride peak must be made.

7.2.2 Preparation of Chromatograph Calibration Curve. Make a GC measurement of each gas mixture standard (described in Section 5.2.3 or 7.1) using conditions identical with those listed in Sections 6.3 and 6.4. Flush the sampling loop for 30 seconds at the rate of 100 ml/min with one of the standard mixtures, and activate the sample valve. Record the concentration of vinyl chloride injected (C_c), attenuator setting, chart speed, peak area, sample loop temperature, column temperature, carrier gas flow rate, and retention time. Record the barometric pressure. Calculate A_m, the peak area multiplied by the attenuator setting. Repeat until two consecutive injection areas are within 5 percent, then plot the average of these two values versus C_c. When the other standard gas mixtures have been similarly analyzed and plotted, draw a straight line through the points derived by the least squares method. Perform calibration daily, or before and after the analysis of each emission test set of bag samples, whichever is more frequent. For each group of sample analyses, use the average of the two calibration curves which bracket that group to determine the respective sample concentrations. If the two calibration curves differ by more than 5 percent from their mean value, then report the final results by both calibration curves.

7.3 Quality Assurance.

7.3.1 Analysis Audit. Immediately after the preparation of the calibration curve and prior to the sample analyses, perform the analysis audit described in Appendix C, Procedure 2: "Procedure for Field Auditing GC Analysis."

7.3.2 Bag Leak Checks. Checking of bags for leaks is required after bag use and strongly recommended before bag use. After each use, connect a water manometer and pressurize the bag to 5 to 10 cm H_2O (2 to 4 in. H_2O). Allow to stand for 10 min. Any displacement in the water manometer indicates a leak. Also, check the rigid container for leaks in this manner. (Note: An alternative leak check method is to pressurize the bag to 5 to 10 cm H_2O and allow it to stand overnight. A deflated bag indicates a leak.) For each sample bag in its rigid container, place a rotameter in line between the bag and the pump inlet. Evacuate the bag. Failure of the rotameter to register zero flow when the bag appears to be empty indicates a leak.

8. *Calculations.*

8.1 Determine the sample peak area, A_m, as follows:

$$A_c = A_m A_f \qquad \text{Eq. 106-1}$$

Where:

A_m = Measured peak area.

A_f = Attenuation factor.

8.2 Vinyl Chloride Concentrations. From the calibration curves described in Section 7.2.2, determine the average concentration value of vinyl chloride, C_c, that corresponds to A_c, the sample peak area. Calculate the concentration of vinyl chloride in the bag, C_b, as follows:

$$C_b = \frac{C_c P_r T_f}{P_f T_r (1 - B_{wb})} \qquad \text{Eq. 106-2}$$

Where:

P_r = Reference pressure, the laboratory pressure recorded during calibration, mm Hg.

T_r = Sample loop temperature on the absolute scale at the time of analysis, °K.

P_f = Laboratory pressure at time of analysis, mm Hg.

T_f = Reference temperature, the sample loop temperature recorded during calibration, °K.

B_{wb} = Water vapor content of the bag sample, as analyzed.

9. *Bibliography.*

1. Brown D.W., E.W. Lay, and M.H. Stephenson. Vinyl Chloride Monitoring Near the B. F. Goodrich Chemical Company in Louisville, KY. Region IV, U.S. Environmental Protection Agency, Surveillance and Analysis Division, Athens, GA. June 24, 1974.

2. G.D. Clayton and Associates. Evaluation of a Collection and Analytical Procedure for Vinyl Chloride in Air. U.S. Environmental Protection Agency, Research Triangle Park, N.C. EPA Contract No. 68-02-1408, Task Order No. 2, EPA Report No. 75-VCL-1. December 13, 1974.

3. Midwest Research Institute. Standardization of Stationary Source Emission Method for Vinyl Chloride. U.S. Environmental Protection Agency, Research Triangle Park, N.C. Publication No. EPA-600/4-77-028. May 1977.

4. Schenl, C. and M.C. Sharp. Collaborative Testing of EPA Method 106 (Vinyl Chloride) that Will Provide for a Standardized Stationary Source Emission Measurement Method. U.S. Environmental Protection Agency, Research Triangle Park, N.C. Publication No. EPA 600/4-78-058. October 1978.

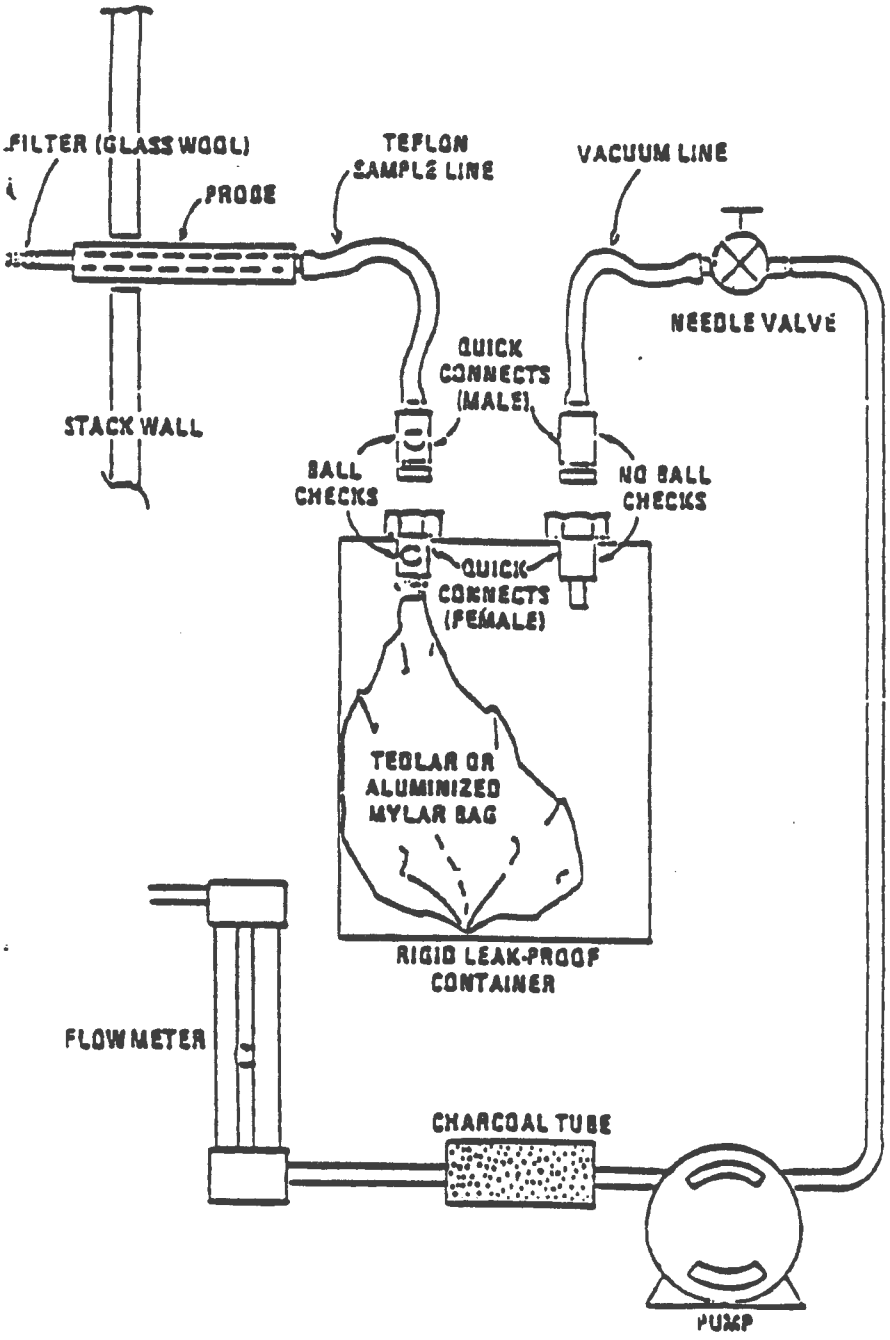


Figure 106-1. Integrated-bag sampling train. (Mention of trade names or specific products does not constitute endorsement by the Environmental Protection Agency.)

APPENDIX E

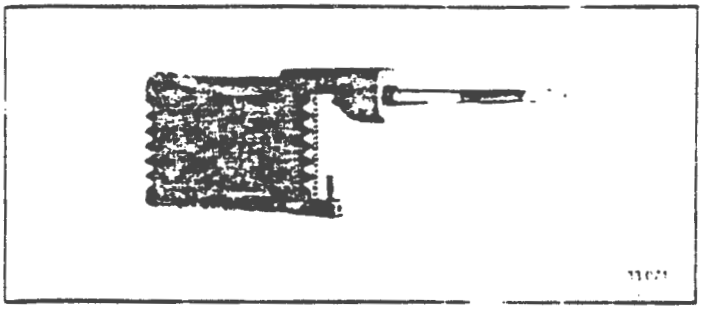


Fig. 1 DRAGER Gas Detector, consisting of the gas detector pump and DRAGER Tube

The detector tube method is an officially approved analysis method. The most important of the international regulations and standards on the properties of detector tubes are listed below:

- Regulations for certification of gas detector tubes in the USA.
- Council of Europe Resolution on Detector Tubes.
- Performance Standard for Detector Tubes, issued by the International Union of Pure & Applied Chemistry.
- Detector Tube Standard, issued by The British Standards Institution.

APPENDIX L

ARIZONA STATE
UNIVERSITY TEMPE, ARIZONA 85281

UNIVERSITY RADIATION SAFETY OFFICE
c/o COLLEGE OF ENGINEERING (D-102) (602) 965-6140

July 20, 1982

NOTE Original Copies sent to:

The Honorable Don Strauch
Mayor of Mesa

The Honorable Harry E. Mitchell
Mayor of Tempe

The Honorable Herschel Andrews
Salt River Pima Tribal President

This letter is to advise you of the intentions of ASU to incinerate "Low-Level Radioactive Waste" (LLRAW) at the pathological incinerator located on ASU property near Price Rd. and First Ave. in Tempe.

I have been given the responsibility of coordinating this project. The proceeding papagraphs contain a brief explanation and some background information concerning this project. I welcome any comments and questions you may have and would enjoy meeting with you and any interested governmental parties to discuss the issue.

We first began the project about one year ago by burning representative non-radioactive waste of the same nature as the LLRAW generated by various ASU laboratories. This was done to monitor stack effluent and determine whether or not the results were within Air Quality Control Board (AQCB) limitations. We expect to complete the initial testing and receive AQCB approval within the next two weeks.

We submitted a request to Arizona Radiation Regulatory Agency (ARRA) in May of 1981 for an amendment to our Radiation Material License which would allow us to dispose of LLRAW by incineration. The ARRA cannot act officially on our request until we receive approval from the AQCB. However, they (ARRA) have been following the project closely inasmuchas ASU is the first in Arizona to request such authorization.

You may rest assured that we are going to meet all standards of the AQCB and ARRA and will make every possible effort to set our own standards at least a magnitude below those prescribed.

Again, let me extend my invitation for you to meet with me and discuss any questions or comments you may have.

Very sincerely yours,

Richard F. Brown

Richard F. Brown
Radiation Protection Officer

ARIZONA STATE
UNIVERSITY TEMPE, ARIZONA 85287

UNIVERSITY RADIATION PROTECTION
MCALLISTER OFFICE COMPLEX 130-B (602) 965-6140/6190

March 15, 1983

Reference: RAD PROT OFF
ltr dtd 7-20-82

The Honorable Harry E. Mitchell
Mayor of Tempe
P.O. Box 5002
Tempe, Arizona 85281

Copies also sent to:
1) The Honorable Don Stranch (Mayor of Mesa)
2) The Honorable Herschel Andrews (Salt River Rima Tribal President)

Dear Mayor Mitchell:

I informed your offices on July 20th, 1982 of ASU's proposal to incinerate Low Level Radioactive Waste (LLRAW) in the existing incinerator located on ASU property near Price Road and First Avenue, Tempe, AZ.

At a meeting with the Arizona Radiation Regulatory Agency (ARRA) on March 11, 1983 I was advised that an acknowledgement of the above notification, by you, in writting, be forwarded to my office to comply with ARRA Rules and Regulations. Please feel free to contact me regarding any comments or questions you may have regarding this matter.

Most Sincerely,

Richard F. Brown
Radiation Protection Officer

Enclosure:
ASU ltr of 7-20-82

Copy:
ARRA
Chair, RPC

Salt River
PIMA-MARICOPA INDIAN COMMUNITY
ROUTE 1, BOX 216 / SCOTTSDALE, ARIZONA 85256 / PHONE [redacted] 941-7277

IN REPLY REFER TO: Administration

August 16, 1983

Mr. Richard F. Brown
Radiation Protection Office
Arizona State University
McAllister Office Complex 130-B
Tempe, Arizona 85287

Dear Mr. Brown:

Reference your letter to Mr. Andrews, dated August 9, 1983 regarding your intention to incinerate Low Level Radioactive Waste.

Please be advised that we have no objection and I regret we did not respond to your earlier request.

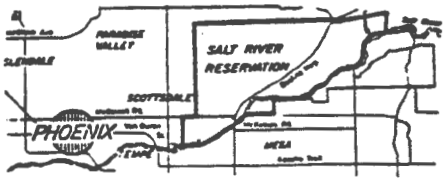
Sincerely yours,

Gerald Anton,
SRPMIC President

sj

Copy:
Dr. Rhoads
Dr. Hammett
ARRA - Blanton (2)
DoE (5)

SALT RIVER INDIAN RESERVATION



APPENDIX M

ARIZONA STATE
UNIVERSITY — TEMPE, ARIZONA 85281

UNIVERSITY RADIATION SAFETY OFFICE
c/o COLLEGE OF ENGINEERING (D-102) (602) 965-6140

March 4, 1982

Mr. Doyl B. Stemen
2340 E. University Dr. #42
Tempe, AZ 85281

Dear Mr. Stemen:

Last April I attended a meeting of your Association of Home Owners. The purpose of this response on my part was to explain the proposed use of ASU's animal incinerator for the incineration of very low level Radioactive Material (RAM).

To bring you up to date on our progress I am pleased to report that our project is proceeding in a smooth and progressive manner. We have not as of yet incinerated any RAM however, we have had several burns of materials which were representative of the RAM. These burns were conducted to ascertain the contents of the effluent from the smoke stack and the ashes. To date these data meet all requirements for the Air Quality Control Board. We expect to have final approval from Air Quality Control (AQC) shortly. Following the approval authorization from AQC we will then proceed with our action to gain approval from the Arizona Radiation Regulatory Agency (ARRA) for the incineration of RAM. When we obtain approval from ARRA, I will be visiting your area to collect air samples, install radiation monitoring devices and, if you desire, meet with your organization again.

The ARRA has requested that I obtain from you, as President of the Home Owners Association, a short letter verifying that my staff and I did in fact meet with your group on 4-13-81.and presented our proposal then opened the meeting to a question and answer session. Please address your letter to me. I will send copies to ARRA and others as necessary.

I appreciate your interest and cooperation in this matter and if I may be of further help or if you have specific questions please feel free to call or write me.

Sincerely,

Richard F. Brown
Radiation Protection Officer

Doyle B. Stemen, Pres.
Tempe Cascade Mobile Homeowners'Assoc.
2340 E. University Dr. #42
Tempe, Az. 85281
March 29, 1982

Arizona State University
Radiation Safty Office
Attention Officer Richard F. Brown
Tempe, Az. 85281

Dear Mr. Brown:

I enjoyed your short visit recently, bringing our Association up to date on the proposed use of A.S.U's animal incinerator for very low level radioactive material (RAM).

We were very well satisfied with the meeting on Apr. 13, 1981 which you and your staff presented at a public meeting in our club house.

The question and answer period was very informative and well handled. From our discussion recently, I personally feel we should have radiation monitoring devices placed in our park just to put every one at ease.

Thanks for your fine cooperation and willingness to answer questions of concern to many of us.

With Kindest Regards, I am
Sincerely yours,

Doyle B. Stemen

P.S. We may, after you start your program of burning low level radioactive material, have you meet with our park organization again.

Scott Miller

Facility near ASU to burn waste

M.3

ASU STATE PRESS Tues. 1/20/81

By Julie Mann

Radioactive wastes produced at ASU will be burned in a new Central Animal Care Facility incinerator located one mile east of the University, the ASU radiation safety officer said Monday.

Richard Brown said the incinerator will handle low-level radioactive wastes one month after the facility opens. The facility, located at University and Price, will begin operating in six to seven weeks.

"The amount of emissions from the stack will be well within the limits set by the government and the state of Arizona for discharge into the atmosphere," Brown said. "The ash residue will be buried according to state and federal regulations at a yet-to-be-designated site."

The process will occur under "very strict controls" and will be supervised by the Arizona Regulatory Commission, he said.

"There will be no hazard to anyone," Brown added.

However, Dr. Ed Monty, director of the University Animal Laboratory Program, said the animal care facility is being studied for several possible uses and that Brown now has "no permission to use it (the incinerator) for disposal of radioactive material."

If it is proven that the process is safe, disposal of radioacive materials at the facility is a possibility, Monty said.

But Brown said by converting the incinerator he is "acting upon written approval of state, federal personnel and the administration through the director of grants and contracts."

Monty said the incinerator originally was designed to destroy lab animals and animal products and would have to be modified to accomodate radioactive wastes.

"Those animals exposed to radiation will not be put in the incinerator if they have over a certain level of radioactive contamination," Monty said. "(If the incinerator is converted) the only things incinerated would be materials that are below the level controlled by state and federal regulations."

ASU has been disposing its radioactive wastes at a site in Richland, Wash., but as of July 1, 1981, the Washington dump site will no longer accept radioactive wastes from outside the state.

Brown said changes in the incinerator are necessary, and although there is "little modification to be done to it for dry wastes," liquid radioactive waste disposal will require more extensive modifications.

Only low-level radioactive wastes will be burned in the incinerator, he said. If there is any high-level radioactive waste, which would be "rare and uncommon," ASU would need to acquire a special dispensation to ship the high-level radioactive material to Washington or Nevada for disposal, he said.

Because of the high cost of handling the waste, the incinerator is needed to reduce the radioactive material to a size that is easier to dispose of, Brown said.

The incinerator shrinks the material by burning it into ash and diluting it into the atomosphere, Brown said.

"You can't destroy radioactive material," he added.

Contaminated radioactive materials such as protective clothing, containers and absorbent paper are currently being stored on campus in a "well-marked" warehouse (which meets state specifications for storage of radioactive material) before they are packaged and driven to Washington for burial, Brown said.

"We're overly cautious here and include an awful lot of bulk and volume in our disposals with a small amount of radioactive material," he said. "In eight months, we accumulated and shipped off approximately 150 millicures (of radiation) in 50 to 60 55-gallon drums."

Fifty people are licensed by ASU through the Arizona Regulatory Commission to experiment with radioactive material in research and teaching, Brown said.

"I issue my own licenses through the University to individuals," he said.

More than 50 percent of the work done with radiation is done through life sciences. Other departments that use radiation include physical sciences, engineering, agriculture and home economics, Brown said.

Dale Partridge, University safety officer, said non-radioactive toxic wastes from ASU laboratories are disposed of on a monthly basis in southern Nevada.

He said there is no legal waste disposal site in Arizona.

Disposed wastes include flammables, caustics, poison, corrosives and high-oxidizing and reactive chemicals, Partridge said.

Arizona State University
Laboratory Animal Care Facility
"CONSUMATE" Incinerator Model C-75P

INCINERATOR DATA SHEET
"CONSUMATE" Incinerator Model C-75P

Please complete this form and load forms for every burn. This form must be completed in its entirety as stipulated by the operating permit for the incinerator.

Burn #_____ Date_____ Time Start-up_____

Prepared by:_____ Radioactive _____%

Non-Radioactive_____%

Weather Data: Temp._____°F; Wind Speed_____mph; Direction_____ From

Weather information may be obtained by calling 261-4000 or 261-6000.

Cloud Cover_____%; Baro Pressure_____ in. Hg.

Start-up time_____ Shut-down time_____

FOLLOW-UP DATA:

Total Weight Burned_____lbs. Total Activity Burned_____uCi

(lb x 0.454 = kg) _____kilo grams

Breakdown of Activity (totals):

Date Incinerator Cleaned_____

Ashes From Burns Nos._____

Cleaned by_____

Ash Disposal Method_____

_____

Isotope	Activity

Total Weight of Ashes_____lbs.

Approximate Volume of Ashes:

_____ cu. ft.

Total No. Loads_____

SAMPLING: Please list below all sample methods pertaining to this burn. Also attach the complete details and results of each test.

INCINERATION DATA SHEET

Burn #_____ Date_____ Page_____

Load #_____ UC Temp.(before load)_____°F LC Temp._____°F Time_____

Contents:

- •Dry Waste_____lbs.
- •Mixed-in bags(vials,glassware) _____lbs.
- •Animals_____lbs. (Radioactive-Non Radioactive)
- •Animal Bedding_____lbs.
- •LS Vials_____lbs.
  - plastic # of vials_____
  - glass # of vials_____
- •Absorbed Liquid_____lbs.
- •Other_____

Radioactivity: Total Wt._____lbs.; _____cu. ft.

Isotope	Activity
Total	

Stack Observations: (please check condition & note length of time where applicable)

clear_____

black smoke_____

flame_____

white smoke_____

Comments:_____

UC Temp. (after load)_____°F LC Temp._____°F

Burn #_____ Date_____ Page_____

Load #_____ UC Temp.(before load)_____°F LC Temp._____°F Time_____

Contents:

- •Dry Waste_____lbs.
- Mixed-in bags(vials,glassware) _____lbs.
- •Animals_____lbs. (Radioactive-non Radioactive)
- •Animal Bedding_____lbs.
- •LS Vials_____lbs.
  - plastic # of vials_____
  - glass # of vials _____
- •Absorbed Liquid_____lbs.
- •Other_____

Radioactivity: Total Wt._____lbs.; _____cu. ft.

Isotope	Activity
Total	

Stack Observations: (please check condition & note length of time where applicable)

Clear_____

black smoke_____

flame_____

white smoke_____

Comments:_____

UC Temp. (after load)_____°F LC Temp._____°F

ARRA-1
July 1980

ARIZONA RADIATION REGULATORY AGENCY

APPLICATION FOR RADIOACTIVE MATERIAL LICENSE

INSTRUCTIONS – Complete all items whether this is an initial application or an application for renewal of a license. Use supplemental sheets where necessary. Mail in duplicate to: Arizona Radiation Regulatory Agency, 925 South 52nd Street, Suite 2, Tempe, Arizona 85281. Upon approval of this application, the applicant will receive a Radioactive Material License, issued in accordance with the requirements contained in the Arizona Radiation Regulatory Agency Regulations for the Control of Ionizing Radiation. Medical applicants: use form ARRA-2 in lieu of this form.

1. *(a)* NAME AND STREET ADDRESS OF APPLICANT. (Institution, firm, hospital, person, etc. Include Zip Code.)

Arizona State University
Tempe, AZ 85287
Radiation Protection Office
McAllister Office Complex 130-B

(b) STREET ADDRESS(ES) AT WHICH RADIOACTIVE MATERIAL WILL BE USED. (If different from 1 *(a)*. Include Zip Code.)

Same as (a)

2. DEPARTMENT TO USE RADIOACTIVE MATERIAL.

Radiation Protection Office

3. THIS IS AN APPLICATION FOR: (Check appropriate item)

a. ☐ New License
b. ☒ Amendment to License No. 7-37
c. ☐ Renewal of License No. _____

4. INDIVIDUAL USER(S). (Name and title of individual(s) who will use or directly supervise use of radioactive materials. Give training and experience in Items 8 and 9.)

Richard F. Brown
Radiation Protection Officer

5. RADIATION PROTECTION OFFICER. (Name of person designated as radiation protection officer if other than individual user. Attach resume of his training and experience as in Items 8 and 9.)

Same as #4

Telephone No.: Area Code (602) 965-6140/6190

6. *(a)* RADIOACTIVE MATERIAL. (Elements and mass numbers of each.)

Atomic Numbers 3 thru 83 inclusive
(Refer to original application plus amendments)

(b) CHEMICAL AND/OR PHYSICAL FORM AND MAXIMUM QUANTITY OF EACH CHEMICAL AND/OR PHYSICAL FORM THAT YOU WILL POSSESS AT ANY ONE TIME. (If sealed source(s), also state name of manufacturer, model number, number of sources and maximum activity per source.)

Any form — Total activity not to exceed four (4) Ci.

7. DESCRIBE PURPOSE FOR WHICH RADIOACTIVE MATERIAL WILL BE USED.

Waste disposal of Low Level Radioactive Material by incineration.

(Continued on reverse side)

ARRA-1 (Continued)

8. TRAINING OF EACH INDIVIDUAL NAMED IN ITEM 4 (Use supplemental sheets if necessary).

TYPE OF TRAINING	WHERE TRAINED	DURATION OF TRAINING	ON THE JOB (Circle answer)	FORMAL COURSE (Circle answer)
Principles and practices of radiation protection	Refer to original application		Yes No	Yes No
Radioactivity measurement standardization and monitoring techniques and instruments	"		Yes No	Yes No
Mathematics and calculations basic to the use and measurement of radioactivity	"		Yes No	Yes No
Biological effects of radiation	"		Yes No	Yes No

9. EXPERIENCE WITH RADIATION (Actual use of radioisotopes or equivalent experience).

ISOTOPE	MAXIMUM AMOUNT	WHERE EXPERIENCE WAS GAINED	DURATION OF EXPERIENCE	TYPE OF USE
Refer to original application (27 years experience in US Navy, Washington University and ASU).				

10. RADIATION DETECTION INSTRUMENTS (Use supplemental sheets if necessary).

TYPE OF INSTRUMENTS (Include make and model number of each)	NUMBER AVAILABLE	RADIATION DETECTED	SENSITIVITY RANGE (mR/hr)	WINDOW THICKNESS (mg/cm²)	USE (Monitoring, Surveying, Measuring)
Refer to original application					

11. METHOD, FREQUENCY, AND STANDARDS USED IN CALIBRATING INSTRUMENTS LISTED ABOVE.

Refer to original application

12. FILM BADGES, DOSIMETERS, AND BIO-ASSAY PROCEDURES USED (For film badges, specify method of calibrating and processing, or name of supplier).

R.S. Landauer, Jr. and Co.

INFORMATION TO BE SUBMITTED ON ADDITIONAL SHEETS

13. FACILITIES AND EQUIPMENT. Describe laboratory facilities and remote handling equipment, storage containers, shielding, fume hoods, etc. Explanatory sketch of facility is attached (Circle answer). Yes No

14. RADIATION PROTECTION PROGRAM. Describe the radiation protection program including control measures. If application covers sealed sources, submit leak testing procedures where applicable, name, training, and experience of person to perform leak tests and arrangements for performing initial radiation survey, servicing, maintenance and repair of the source.

15. WASTE DISPOSAL. If a commercial waste disposal service is employed, specify name of company. Otherwise, submit detailed description of methods which will be used for disposing of radioactive wastes and estimates of the type and amount of activity involved.

CERTIFICATE

16. THE APPLICANT, AND ANY OFFICIAL EXECUTING THIS CERTIFICATE ON BEHALF OF THE APPLICANT NAMED IN ITEM 1, CERTIFY THAT THIS APPLICATION IS PREPARED IN CONFORMITY WITH THE ARIZONA RADIATION REGULATORY AGENCY REGULATIONS FOR THE CONTROL OF IONIZING RADIATION, AND THAT ALL INFORMATION CONTAINED HEREIN, INCLUDING ANY SUPPLEMENTS ATTACHED HERETO, IS TRUE AND CORRECT TO THE BEST OF OUR KNOWLEDGE AND BELIEF.

Richard F. Brown

Richard F. Brown
Applicant named in Item 1

Date 8-9-83

By: Ronald H. Alvarado
Ronald H. Alvarado
Chair, Radiation Protection Committee
Title of certifying official authorized to act on behalf of the applicant

(I T)

ARRA-3 (Cont.)
July, 1980

ARIZONA RADIATION REGULATORY AGENCY

RADIOACTIVE MATERIAL LICENSE

SUPPLEMENTARY SHEET

License Number 7-37

Amendment #40

Appendix H

Arizona State University
Radiation Protection Office
McAllister Office Complex 130-B
Tempe, Arizona 85287

In accordance with application dated August 9, 1983, signed by Richard F. Brown, Radiation Safety Officer, and Ronald H. Alvarado, Chairman, Radiation Protection Committee, License #7-37 is hereby amended as follows.

Condition #12 is amended to read:

12. A. Radioactive material shall be used by, or under the supervision of, individuals designated by the University Radioisotope Committee, Dr. Ronald H. Alvarado, Chairman.

B. Radioactive material may be disposed of by incineration pursuant to Condition #23 of this license only by, or under the supervision and in the physical presence of, Richard Brown, Radiation Safety Officer.

A new Condition #23 is added to read:

23. A. Pursuant to A.C.R.R. R12-1-420, R12-1-407 and R12-1-417, the licensee is authorized to dispose of radioactive material by incineration provided the gaseous effluent from the incincerator does not exceed 10 percent of the limit specified for air in Appendix A, Table 2 of A.C.R.R. Title 12, Chapter 1, Article 4. Ash residues may be disposed of as ordinary waste provided appropriate surveys pursuant to R12-1-409 are made to determine that the radiation levels from the ash are not distinguishable from background.

B. The licensee is authorized to incinerate only waste generated at Arizona State University, and containing only those isotopes identified as categories 1 through 5, Table 1, page 4 of the report by the licensee dated July 1983.

C. The licensee is authorized to hold radioactive material with a physical half-life of less than 65 days for decay in storage prior to disposal by incineration.

D. The licensee is authorized to hold radioactive material with a physical half-life of 65 days or greater, but less than 90 days, for a period not to exceed six half-lives prior to disposal by incineration.

E. The licensee shall survey ash residue with a low-level survey meter prior to removal of the ash residue from the incinerator.

ARIZONA RADIATION REGULATORY AGENCY

RADIOACTIVE MATERIAL LICENSE

SUPPLEMENTARY SHEET

License Number 7-37

Amendment #40

F. Incineration of waste material containing radioactive material, and, the removal of ash residue from incinerated waste material containing radioactive material, shall be conducted by, or under the supervision and in the physical presence of, Richard Brown, R.S.O.

G. The licensee shall maintain specific records showing at least the date and time of each burn, the isotopes and quantities incinerated, results of surveys, disposal of ash and any other information as needed to demonstrate compliance with this condition.

Condition #22 is amended to read:

22. Except as specifically provided otherwise by this license, the licensee shall possess and use radioactive material described in Items 6, 7 and 8 of this license in accordance with statements, representations and procedures contained in:

1) Application dated June 16, 1980, signed by Richard F. Brown;
2) Letter dated June 16, 1980, signed by John W. McKlveen;
3) Letter dated June 19, 1980, signed by John W. McKlveen;
4) Letter dated September 3, 1980, signed by Richard F. Brown;
5) Letter with attachments dated December 17, 1982, signed by Richard F. Brown and Ronald H. Alvarado, Ph.D.;
6) Letter with attachments dated February 9, 1983, signed by Richard F. Brown;
7) Letter with attached report, dated July 18, 1983, signed by Karla Greenup and Richard F. Brown;
8) Application dated August 9, 1983, signed by Richard F. Brown and Ronald H. Alvarado.

The Agency's regulations shall govern the licensee's statements, applications or letters, unless the statements are more restrictive than the regulations.

Charles F. Tedford

Charles F. Tedford, Director

DATE ISSUED:
February 10, 1984

jr

ARIZONA STATE
UNIVERSITY TEMPE, ARIZONA 85287

DEPARTMENT OF ZOOLOGY
September 13, 1983

Mr. Charles Tedford, Director
Arizona Radiation Regulatory Agency
925 S. 52nd Street
Suite 2
Tempe, AZ 85281

Dear Mr. Tedford:

This letter is to advise you that the administration of Arizona State University approves of the proposed use of the "pathological incinerator" located on 1st Street and Price Road in Tempe for incineration of low level radioactive waste. This approval is based upon recommendation of the ASU Radiation Protection Committee with the concurrence of the Office of Research and Development (Dr. H.B. Hunnicutt) and the Office of the Vice President for Academic Affairs (Dr. J. Kinsinger). The ASU Radiation Protection Officer (Mr. R.F. Brown) is authorized to carry out this project upon approval of our pending amendment to license number 7-37.

Thank you for consideration.

Sincerely,

Jack B. Kinsinger

Jack B. Kinsinger, Ph.D.
Vice President for Academic Affairs

H B Hunnicutt

Harold B. Hunnicutt, EDD
Assistant Vice President for Research

R. H. Alvarado

R. H. Alvarado, Chair
Radiation Protection Committee

dp

(70)

SAFETY PRACTICES INVOLVING LAB ANIMAL CARE FACILITY INCINERATOR

The most important consideration in the operation of an incinerator is safety, particularly the safety of machine operators and maintenance workers. Improper safety procedures can result in injury, loss of time, money and life.

Procedures must be defined for the following four major safety areas:

1) Protection of the machine operator at the point of operation.
2) Protection from unexpected machine movements during operation.
3) Protection of maintenance personnel from unexpected machine movements during maintenance.
4) Protection from unauthorized usage.

Protection of machine operator will involve the following:

1) Ash removal door will be locked during use and remain locked until ash has cooled to ash removal temperature.
2) When loading operator(s) will be equipped with gloves and face protection, operator will open charging door slightly and hold allowing incinerator to depressurize before charging. After charging, door will remain secured for a minimum of five minutes between charges.
3) Ash removal procedure will be as follows:
    a) Allow ash sufficient time to cool.
    b) If radioactive waste is involved outside of ash removal door must be surveyed prior to opening.
    c) Wet down ash to minimize airborne particulates.
    d) Remove ash to fiberboard containers.

Before maintenance is performed:

1) Turn power switch to "Power off"
2) Set temperature controllers to 0°F for both upper and lower burners, preventing accidental ignition.
3) Secure any valves or controllers involved in maintenance.

Protection from unauthorized usage involves:

1) Placing locks on control panel, charging door and ash removal door.
2) Setting temperature controller for both burners to 0°F when not in use.