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POTENTIAL AIRBORNE RELEASE
OF SURFACE CONTAMINATION DURING
A RANGE FIRE IN THE B-C
CONTROLLED AREA

**Battelle**

Pacific Northwest Laboratories
Richland, Washington 99352

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POTENTIAL AIRBORNE RELEASE OF SURFACE CONTAMINATION DURING A RANGE FIRE IN THE B-C CONTROLLED AREA

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DECEMBER , 1973

BATTELLE
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ABSTRACT

The potential for ^{137}Cs to become airborne when contaminated materials are burned in a range fire was investigated. Contaminated soil, rabbit feces, and detritus were involved in a gasoline fire and the fractional release of ^{137}Cs measured. In bench-scale experiments the fraction airborne from detritus was 2.7×10^{-6} . Release from contaminated soil alone in a gasoline fire was not detectable. In engineering-scale experiments in a wind tunnel fractional releases of 0.04 and 0.1 percent occurred during burning of detritus. Radioactive particles in ashes remaining were re-entrained to the extent of 0.6 percent by a wind of 2.5 mph and up to 8 percent in a wind of 20 mph. Particles airborne had an aerodynamic equivalent diameter of 2 μm .

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POTENTIAL AIRBORNE RELEASE OF SURFACE CONTAMINATION DURING A RANGE FIRE IN THE B-C CONTROLLED AREA

INTRODUCTION

As a result of burrowing animals, radioactive elements (predominantly ^{137}Cs and ^{90}Sr) have been distributed over an area designated the B-C Controlled Area. [1] The Controlled Area has been divided into three zones according to the estimated levels of activity present. Preliminary estimates indicate that 10 to 25 curies is likely present as surface contamination. The contamination is present as animal excrement and material contacted by excrement or fluids. Some uptake by the flora is possible.

Various alternative procedures for decontaminating the Controlled Area are under consideration. In the interim, the contamination is relatively stabilized except for two potential processes which can make control difficult -- weathering of animal droppings and range fires. This study was undertaken to investigate the potential for radioactive material becoming airborne during range fires.

OBJECTIVE

The objective of this study was to measure the fractional airborne release of radioactive contaminants found on the surface of the B-C Controlled Area under conditions simulating those encountered in a range fire in that area.

SUMMARY

Eleven bench-scale and five engineering-scale experiments were performed to measure the fractional airborne release of ^{137}Cs during a fire promoted by gasoline and involving contaminated materials in the B-C Controlled Area. Six types of materials -- soil, animal droppings, detritus*, sagebrush, tumble weeds, and cheat grass -- were collected from Zone 1 in the Controlled Area.

*Detritus is a combination of decayed vegetation and other litter accumulated on the ground.

Measurable amounts of activity were found only in the first three types of material. Specimens of these materials were burned on gasoline-soaked sand held in a 100 milliliter beaker. The material entrained in the air drawn up and around the burning material was collected. A measurable amount of activity was collected in one of the eleven experiments. This was one in which contaminated detritus was used as the source material. The fraction airborne under these conditions was 2.7×10^{-6} .

The five engineering-scale experiments were conducted in the wind tunnel in the Radioactive Aerosol Release Test Facility. The source material was placed in a holder which was embedded in soil held in the 23-inch diameter \times 6-inch deep burner tray. The soil was inundated with a gallon of gasoline. The gasoline was ignited and air drawn across the burning mass at 2.5 or 20 mph. The material airborne was collected by glass fiber filters backed with caustic scrubbers. At 2.5 mph, the fire burned from 52 to 65 minutes. The fire lasted 18 minutes at 20 mph. Cascade impactor samples were taken to determine the size distribution. Entrainment of the activity from the residues following the fire was measured in the same manner. The radioactive material remaining at the source, redistributed down the wind tunnel, and deposited on the wall and floor of the wind tunnel was also measured. Recoveries of the activity used in the source ranged from 61.5 to 101 percent and are adequate considering the differences in counting configurations used to measure the activities in various samples.

No measurable activity was detected in the first two experiments in which the primary source was contaminated soil. These results reinforce the findings of the bench-scale test which indicate very low fractional releases from the soil. No measurable activity was entrained during the 1-hour period immediately following the fire.

Contaminated organic surface detritus (primarily animal droppings) was burned with fractional releases of 4×10^{-4} and 10^{-3} measured at 2.5 mph and 20 mph. At 2.5 mph, the activity appears to be involved with particles 0.5 to 2.2 μm Aerodynamic Equivalent Diameter (A.E.D.).

Larger amounts of activity were entrained from the residues in a 24-hour period immediately after the fire. As much as 6.3×10^{-3} was entrained using an air velocity of 2.5 mph during that period. The particle size of the material airborne at both 2.5 and 20 mph was 2 μm aerodynamic equivalent diameter.

From 1 to 4 percent of the activity used in the source was entrained at 20 mph.

Some of the active material present in the residue was moved along the tunnel floor when air flow was 20 mph. From 4 to 8 percent of the activity was recovered in the soil and ashes found in the wind tunnel and vessel. For the objective of this study, this fraction is not regarded as "airborne".

EXPERIMENTAL

Various mechanisms can be postulated as a means of initiating a range fire on prairie land -- lighted cigarettes, loss of control during burning of other vegetation, lightning, etc. A realistic initiating event resulting in a fire most likely to release material was taken to be a gasoline fire resulting from loss of control of a motor vehicle. Experiments performed in other studies involving large scale, outdoor gasoline fires indicated that the gasoline soaks into sand soil.^[2] Any gasoline remaining on the surface burns rapidly as in a standing pool fire -- the quantity of gasoline involved depends upon the porosity of the surface and the length of time between release and ignition. Since fires are vapor-phase reactions, the flame front is some distance above the surface and surface temperatures are not extreme until the latter stages of burning.

Thus, experiments were designed to measure the fractional airborne release of radioactive isotopes from various contaminated materials collected from the surface of the B-C Controlled Area under conditions simulating the steady burning stage of a gasoline fire. A variety of materials was collected from Zone 1 in the B-C Controlled Area (the most highly contaminated area). Previous analysis of the isotopes present indicate that the radioactive contaminants are primarily ^{137}Cs and ^{90}Sr . Since ^{137}Cs is a gamma emitter and can be measured without destroying the material, ^{137}Cs was used to represent both contaminants. Cesium and its compounds are generally more volatile than strontium and corresponding strontium compounds.

Bench-Scale Experiments

Preliminary experiments were performed in the laboratory under nominal flow conditions to ascertain the fractional release to be anticipated in the engineering scale simulation.

Specimens from B-C Controlled Area, Zone 1

The ^{137}Cs content of the specimens collected was measured (see Table I). The activity levels varied from not detectable ($< 2 \times 10^{-7} \mu\text{Ci}$) to $3.28 \mu\text{Ci}$. Useable activity levels were found for three types of materials -- soil, rabbit droppings and organic detritus -- and these materials were selected for use in the study. Some highly contaminated, relatively fresh rabbit droppings collected during the initial subsequent collections were found to contain primarily ^{90}Sr at levels equal to or greater than the highest ^{137}Cs content observed.

Apparatus and Procedure

Small quantities of contaminated material were burned in a gasoline fire using nominal flow conditions and the fractional airborne released measured. Amounts of the three types of materials listed in Table I were placed on gasoline soaked sand held in a 100 ml beaker (see Figures 1a and 1b). A 100 mesh stainless steel screen separated the sand and specimen. The beaker was placed under the 10-inch diameter bell opening of the 3.5-inch by 10-inch long stainless steel chimney and the material ignited. Air at a rate of 2 cfm was drawn through the apparatus producing a nominal velocity of approximately 4 fpm at the opening. Nominal air velocity through the chimney was 30 fpm.

Particles airborne were collected on a 4-inch diameter glass fiber filter sealing the end of the chimney. A 1/4 to 1/2 inch thick mat of glass fiber was used as a pre-filter to prevent clogging of the filter by the copious quantities of smoke generated by the experiments (see Figure 2). Any materials adhering to the chimney were removed by washing with acetone, distilled water and dilute nitric acid and swabbing. Air leaving the filter was passed through a caustic scrubber to capture cesium vapors.

The fires lasted from 28 to 38 minutes with the exception of a single experiment. All the flammable materials tested were consumed during the experiments. In some experiments the residue from animal droppings retained the shape of the materials but disintegrated into a fine powder upon handling.

 ^{137}Cs Content Measurements

The ^{137}Cs content of the various specimens and samples from the lab-

TABLE I

SPECIMENS COLLECTED FROM SURFACE OF B-C CONTROLLED AREA
FOR USE IN LABORATORY STUDY

<u>Sample Number</u>	<u>Description</u>	<u>Weight Grams</u>	<u>¹³⁷Cs μCi</u>
1	Soil	22.34	0.142
2	Soil	21.09	0.182
3	Soil	28.886	0.006
4	Soil	26.953	0.0035
5	Rabbit Droppings	3.699	0.043
6	Rabbit Droppings	3.547	0.0011
7	Soil	18.444	0.50
8	Soil	10.725	3.28
9	Rabbit Droppings	3.765	0.048
10	Organic Debris (detritus)	2.543	0.075
11	Organic Debris (detritus)	1.522	0.038
12	Rabbit Droppings	4.786	1.80
13	Organic Debris (detritus)	9.711	1.10
14	Organic Debris (detritus)	3.111	0.090
15	Organic Debris (detritus)	6.067	4.5×10^{-5}
16	Rabbit Droppings	--	--
17	Rabbit Droppings	--	--
18	Organic Debris (detritus)	7.831	2.9
19	Organic Debris (detritus)	3.883	n.d.
20	Organic Debris (detritus)	20.721	n.d.
21	Sagebrush Foliage	9.721	2.0×10^{-5}
22	Sagebrush Foliage	9.747	3.6×10^{-5}
23	Sagebrush Foliage	30.977	--
24	Sagebrush Foliage	10.471	3.5×10^{-5}
25	Tumbleweed	3.068	4.1×10^{-5}
26	Sagebrush Foliage	12.106	1.7×10^{-5}
27	Cheat grass	2.338	4.6×10^{-5}
28	Rabbit Droppings	3.817	3.2×10^{-4}
29	Rabbit Droppings	3.960	2.4×10^{-4}
30	Rabbit Droppings	3.611	3.2×10^{-4}
31	Rabbit Droppings	4.26	5×10^{-4}
32	Rabbit Droppings	3.526	*
33	Rabbit Droppings	4.388	*
34	Rabbit Droppings	4.059	4.8×10^{-4}
35	Rabbit Droppings	3.926	2.8×10^{-4}

n.d. -- non-detectable

* Only measurable contaminant was ⁹⁰Sr

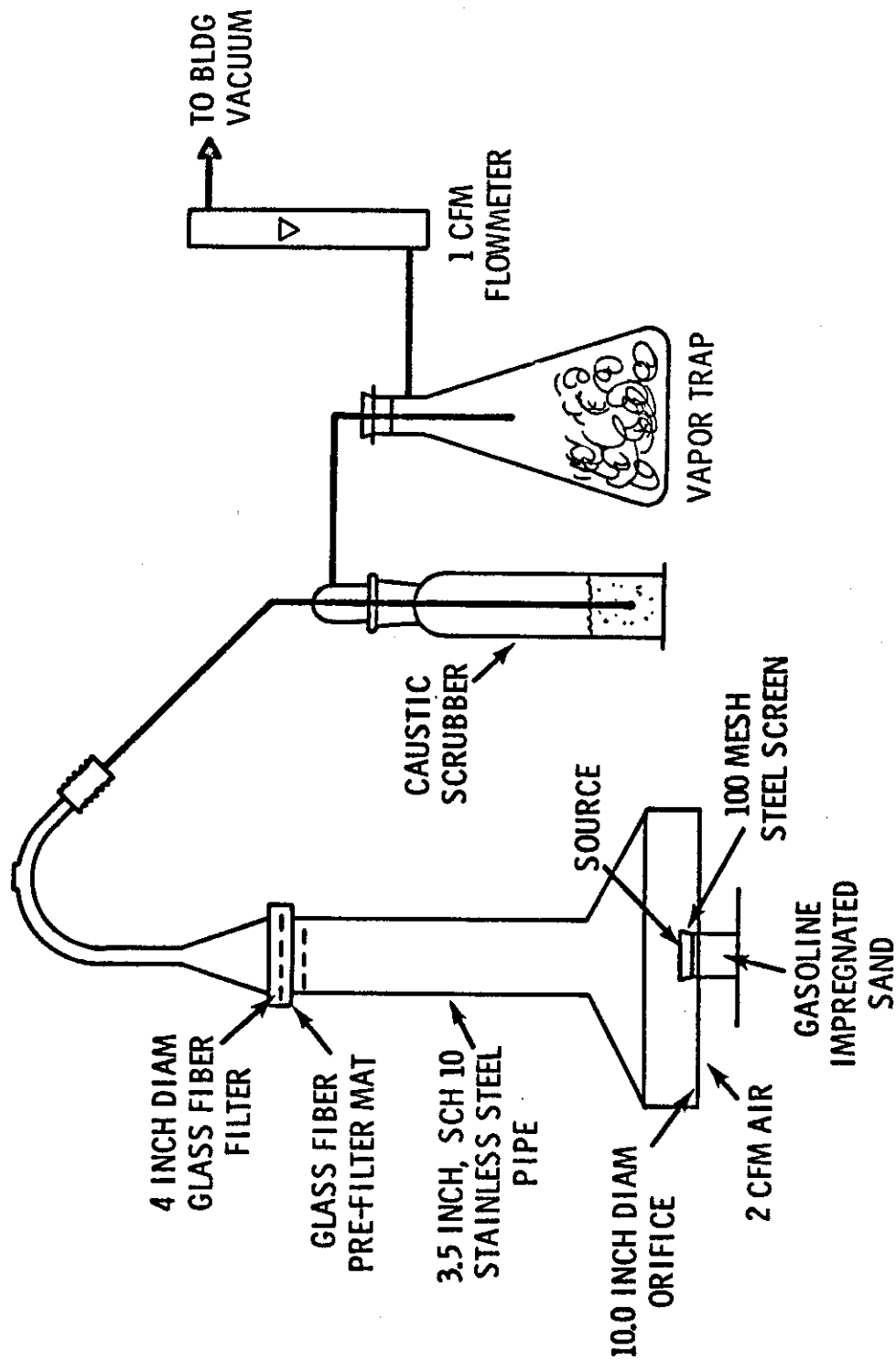


FIGURE 1a

DIAGRAM -- LABORATORY APPARATUS TO MEASURE FRACTIONAL AIRBORNE RELEASE DURING THE BURNING OF CONTAMINATED MATERIALS COLLECTED FROM THE B-C CONTROLLED AREA

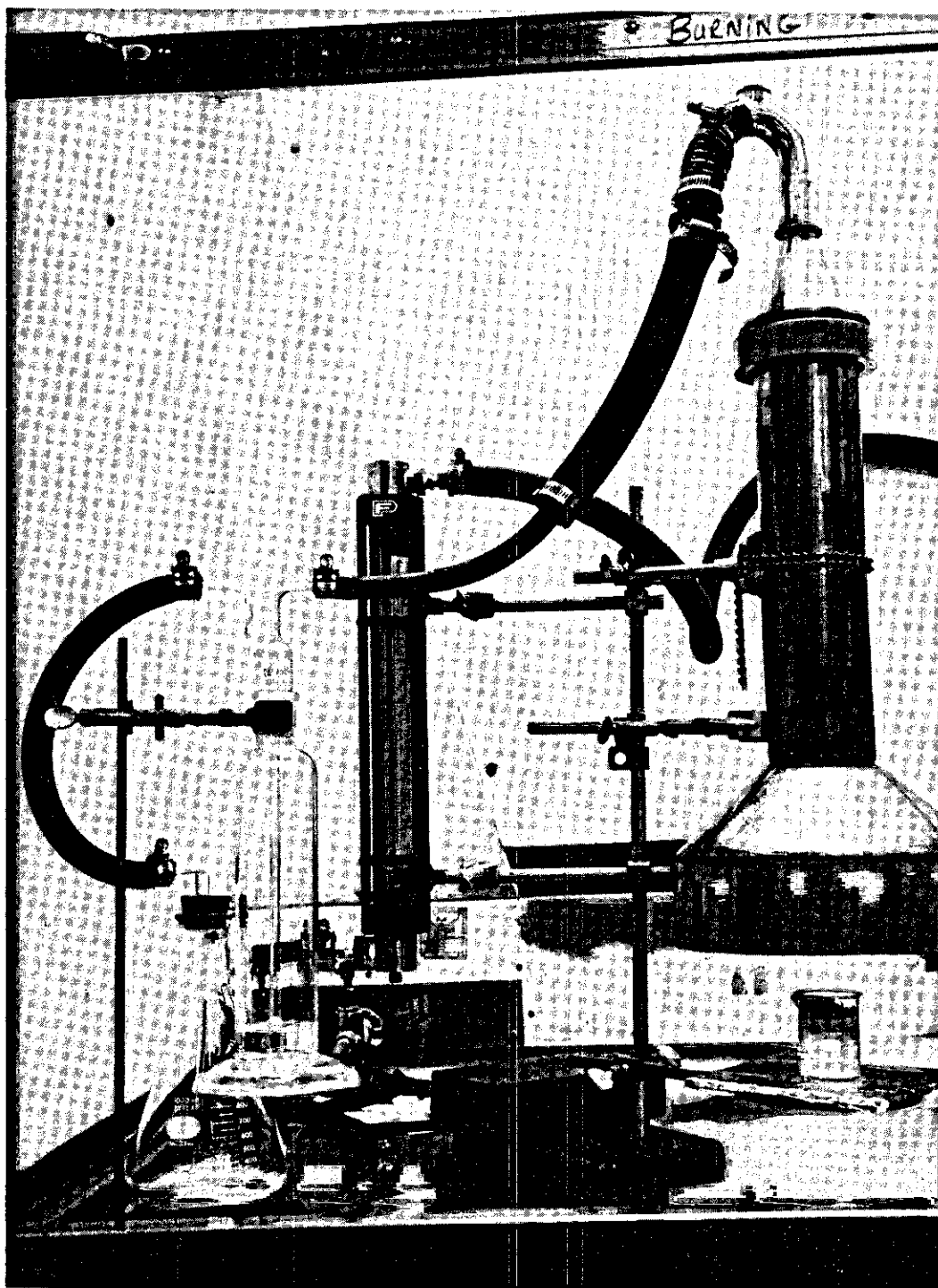


FIGURE 1b

PHOTO — LABORATORY APPARATUS TO MEASURE
FRACTIONAL AIRBORNE RELEASE

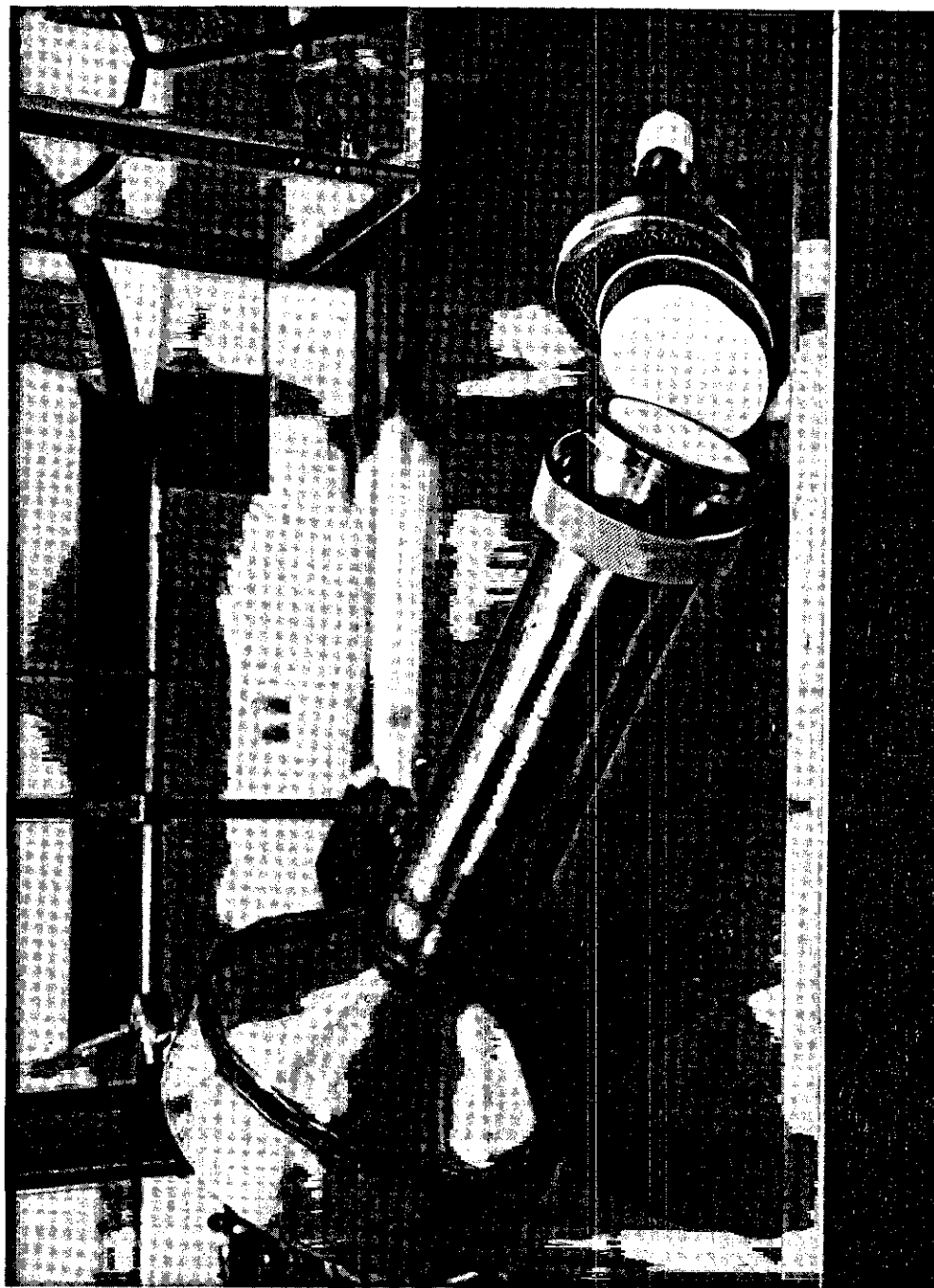


FIGURE 2
**GLASS FIBER PRE-FILTER AND FILTER IN HOLDER AT END OF 3.5 INCH
DIAMETER x 10 INCH LONG STAINLESS STEEL CHIMNEY**

oratory experiments were determined by the Automatic Radioactivity Inventory System (ARIS) operated by the Chemical Technology Laboratory, ARHCO. ARIS is a package counter utilizing 3 Ge(Li) and NaI(Tl) detectors to quantitatively and qualitatively measure penetrating radiation from low atomic number media. [3,4] All specimens and samples from these experiments were packaged in 25 ml vials -- the most sensitive configuration. The ARIS limits of detection for a 1 hour analysis is 8×10^{-12} Ci ^{137}Cs per liter (2×10^{-13} Ci for a 25 ml sample).

Results

Very little of the ^{137}Cs contamination present in the soil, animal droppings and organic detritus was made airborne under the conditions imposed. Results are shown in Table II. With analysis of 11 of 12 filter samples, only 1 (an organic debris specimen) had a measurable quantity of activity. All seven measurements on bubbler samples were below detection limits. Recoveries of activities initially measured in the source ranged from 5 to 123 percent. The low value is suspect but unfortunately cannot be confirmed since the specimen was consumed in the experiment. Excluding the single low results, the recovered range from 69 to 123 percent -- a reasonable range considering the change in counting configurations between initial and final samples.

Engineering-Scale Experiments

Five experiments involving contaminated soil and animal droppings were performed in the Radioactive Aerosol Release Test Facility in the 242-B Building. These experiments were performed to measure the fractional airborne release of the contaminants under more rigorous conditions. The facility is shown in Figure 3, and its operations described in reference [2]. In the first 2 experiments at low wind speeds, the activity was predominantly involved with the soil and entrainment of radioactive material from the residue was measured for one hour. No measurable amounts of activity were found except in the residue. In subsequent experiments only animal droppings with greater levels of activity were used. Higher wind speeds and long sampling periods were employed.

Specimens Collected from the B-C Controlled Area

A separate group of specimens (only contaminated soil and animal droppings) containing a higher level of activity were collected for the experi-

TABLE II
FRACTIONAL AIRBORNE RELEASE OF ^{137}Cs DURING A GASOLINE FIRE INVOLVING CONTAMINATED
MATERIALS COLLECTED FROM B-C CONTROLLED ZONE FOR LABORATORY EXPERIMENTS -- SUMMARY SHEET

Material	Weight Grams	^{137}Cs Activity in Aliquot, μCi			$\% \text{ } ^{137}\text{Cs}$ Recovered	$\% \text{ } ^{137}\text{Cs}$ Airborne
		Source	Residue	Filter	Bubbler	
Soil	22.34	0.142	0.136	*	--	*
Soil	28.89	0.006		*	--	*
Soil	26.95	0.0035	0.0043	*	*	*
Soil	10.73	3.28	3.31	*	*	*
Rabbit Droppings	3.77	0.048	2.3×10^{-4}	*	*	*
Organic Debris (detritus)	1.52	0.038	0.031	*	--	*
Rabbit Droppings	4.79	1.80	1.60	*	*	*
Organic Debris (detritus)	3.11	0.090	0.064	--	--	--
Organic Debris (detritus)	7.83	2.90	2.0	2.7×10^{-4}	*	0.0093
Rabbit Droppings	3.12	3.2×10^{-4}	*	*	*	*
Rabbit Droppings	4.26	5×10^{-4}	*	*	*	*

* not detectable

** Percent ^{137}Cs measured in source.

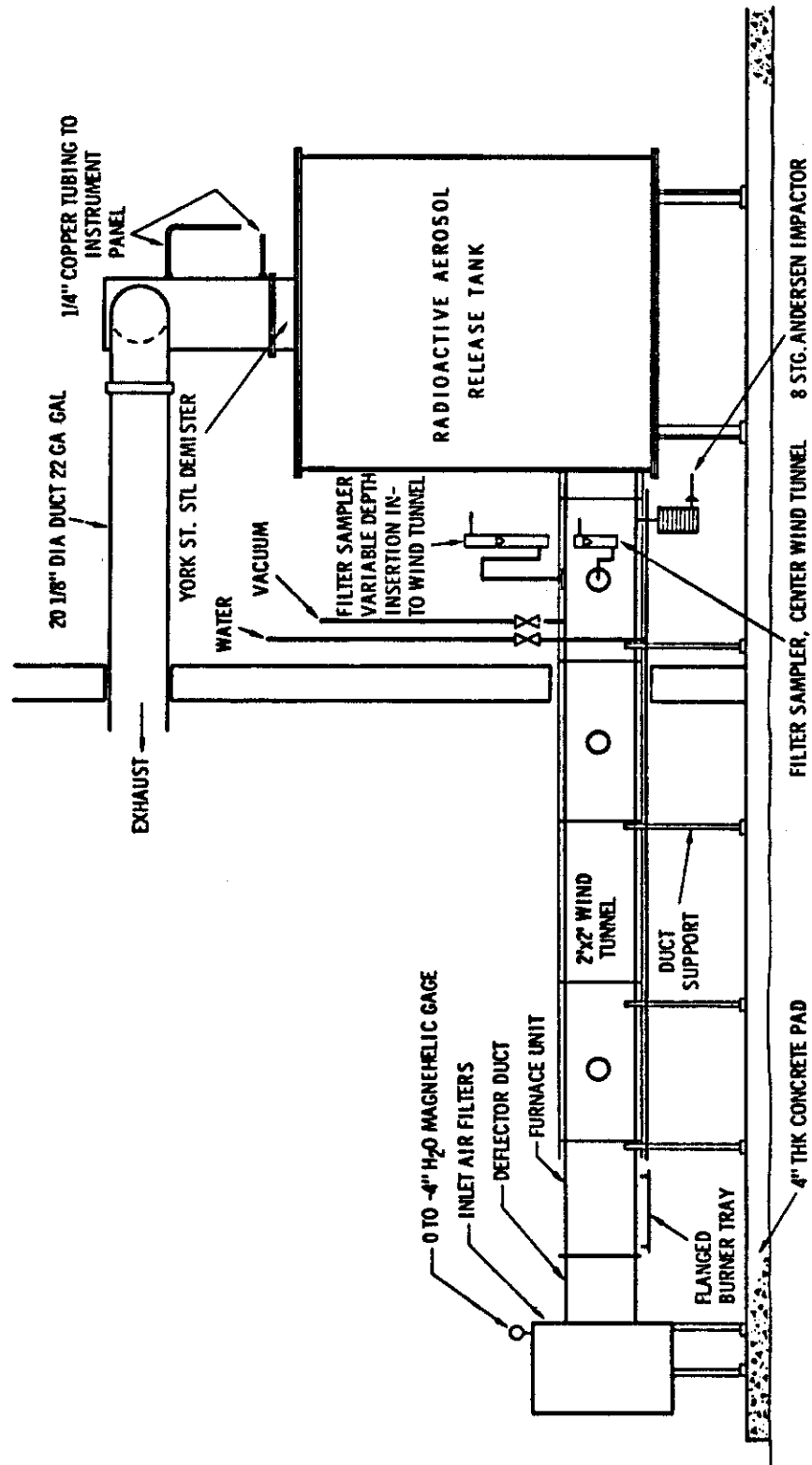


FIGURE 3

DRAWING — RADIOACTIVE AEROSOL RELEASE TEST FACILITY
242-B BUILDING

ments in the R.A.R.T.F. The specimens are listed in Table III along with the weight of the sample and measured ^{137}Cs content. The ^{137}Cs value listed for specimens of soil are in μCi per gram. The ^{137}Cs in the source was obtained by multiplying by the weight of contaminated soil used in the source by the concentration. Some of the animal dropping specimens had to be divided in order to be counted on the NaI(Tl) counter. Some individual pellets were too radioactive to be counted on the NaI(Tl) counter and were counted on a Ge(Li) diode counter. Some highly active, fresh (moist and plump as opposed to small and dry) animal droppings were found to contain significant but not quantified amounts of ^{90}Sr and no measurable quantities of ^{137}Cs . For most experiments, several aliquots were combined to accumulate sufficient activity.

Apparatus and Procedures

All experiments were conducted in the wind tunnel (see Figure 4) in the 242-B Building. The contaminated specimens were placed on the downwind side of a soil-filled, 23-inch diameter by 6-inch deep, burner tray (see Figure 5). The contaminated material was contained in a 6-inch diameter by 1/2 inch deep ring whose bottom was sealed with a 100-mesh stainless steel screen. The tray was lifted into the flanged opening in the furnace section of the wind tunnel (see Figures 6a and 6b), inundated with a gallon of gasoline via a 1/2 inch stainless steel tube (see Figure 7) entering through the top of the furnace section, and the gasoline ignited. Air was drawn across the burning materials at a speed of 2.5 or 20 mph.

Particulate material airborne was measured by samplers at 3 locations. Airborne material at the top and center of the duct was drawn through 2-inch diameter glass fiber filters at a rate of 1 cfm. A 1/2 inch stainless steel probe whose orifice was positioned into the flow approximately 2 inches from the floor of the duct extracted samples for an 8-stage Andersen cascade impactor. Air passing through all three samplers was passed through caustic scrubbers to trap Cs vapors before passing through variable air flowmeters used to monitor flow. The arrangement is shown in Figure 8. Airborne material adhering to the walls and swept down the duct was sampled by aluminum foil strips attached to the wall and floor of the duct (see Figure 7).

TABLE III

CONTAMINATED SPECIMENS COLLECTED FROM B-C CONTROLLED AREA
USED IN ENGINEERING SCALE EXPERIMENTS

<u>Sample Number</u>	<u>Total Wt. (grams)</u>	<u>Material</u>	<u>Wt. Aliquot (grams)</u>	<u>^{137}Cs (μCi)</u>
S-1	510.5	Soil	32.5	$4.28 \times 10^{-3}*$
S-2	539	Soil	33.2	$5.0 \times 10^{-3}*$
S-3	562	Soil	32.4	$4.8 \times 10^{-3}*$
S-4	528.1	Soil	33.0	$4.94 \times 10^{-3}*$
RD-1A	11.6	Animal Droppings		6.29×10^{-4}
RD-1B	13.3	"		3.3×10^{-3}
RD-1C	14.1	"		4.17×10^{-3}
RD-1D	117.7	"		
RD-1E	12.078	"		8.08×10^{-4}
RD-1F	12.414	"		3.79×10^{-4}
RD-1G	14.430	"		3.43×10^{-4}
RD-1H	12.443	"		3.12×10^{-4}
RD-1I	14.256	"		4.19×10^{-3}
RD-2	12.403	"		4.02×10^{-4}
RD-3	16.243	"		7.41×10^{-4}
RD-4	14.222	"		1.15×10^{-3}
RD-5	14.03	"		1.84×10^{-4}
RD-6	11.125	"		Too active to count
RD-7A	14.66	"		0.227
RD-7B		"		6.67×10^{-3}
RD-8A	15.845	"		0.0117
RD-8B		"		0.288
RD-9A	15.05	"		6.66×10^{-3}
RD-9B		"		3.02×10^{-3}
RD-10	12.873	"		Too active to count
RD-11	15.52	"		3.97×10^{-3}
RD-12	14.758	"		1.22×10^{-3}
RD-13A	20.68	"		0.0296
RD-13B		"		0.0149
RD-13C		"		0.143
RD-13D		"		5.27×10^{-3}
RD-13E		"		0.0121
RD-13F		"		8.29×10^{-3}
RD-14	3.769	"		4.01
RD-15A	1.564	"		12.2
RD-15B	0.674	"		9.83
RD-15C	1.584	"		10.1
RD-16A	9.27	"		0.56
RD-16B		"		1.87

* μCi per gram

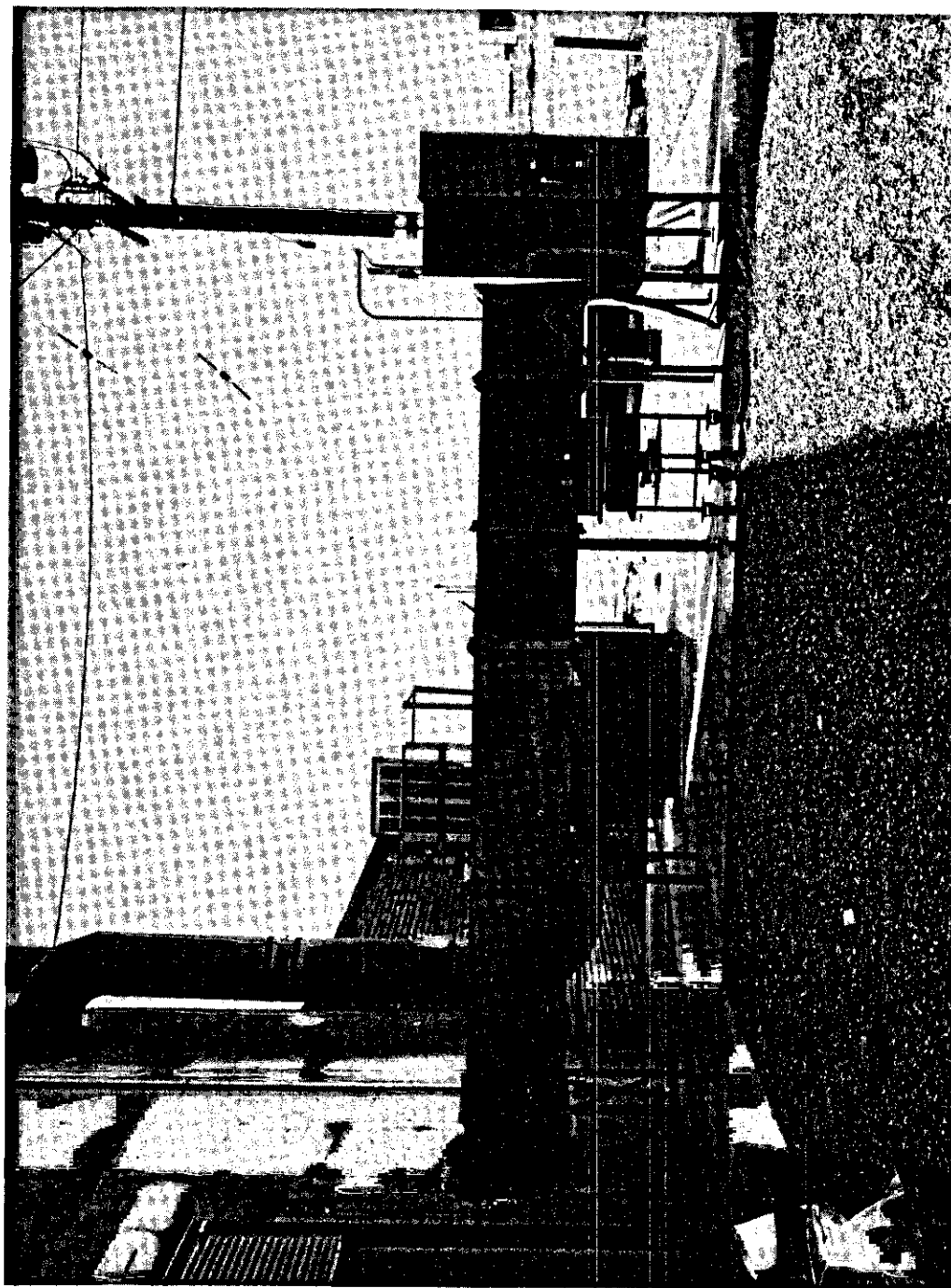


FIGURE 4
PHOTO -- WIND TUNNEL RADIOACTIVE AEROSOL RELEASE TEST FACILITY

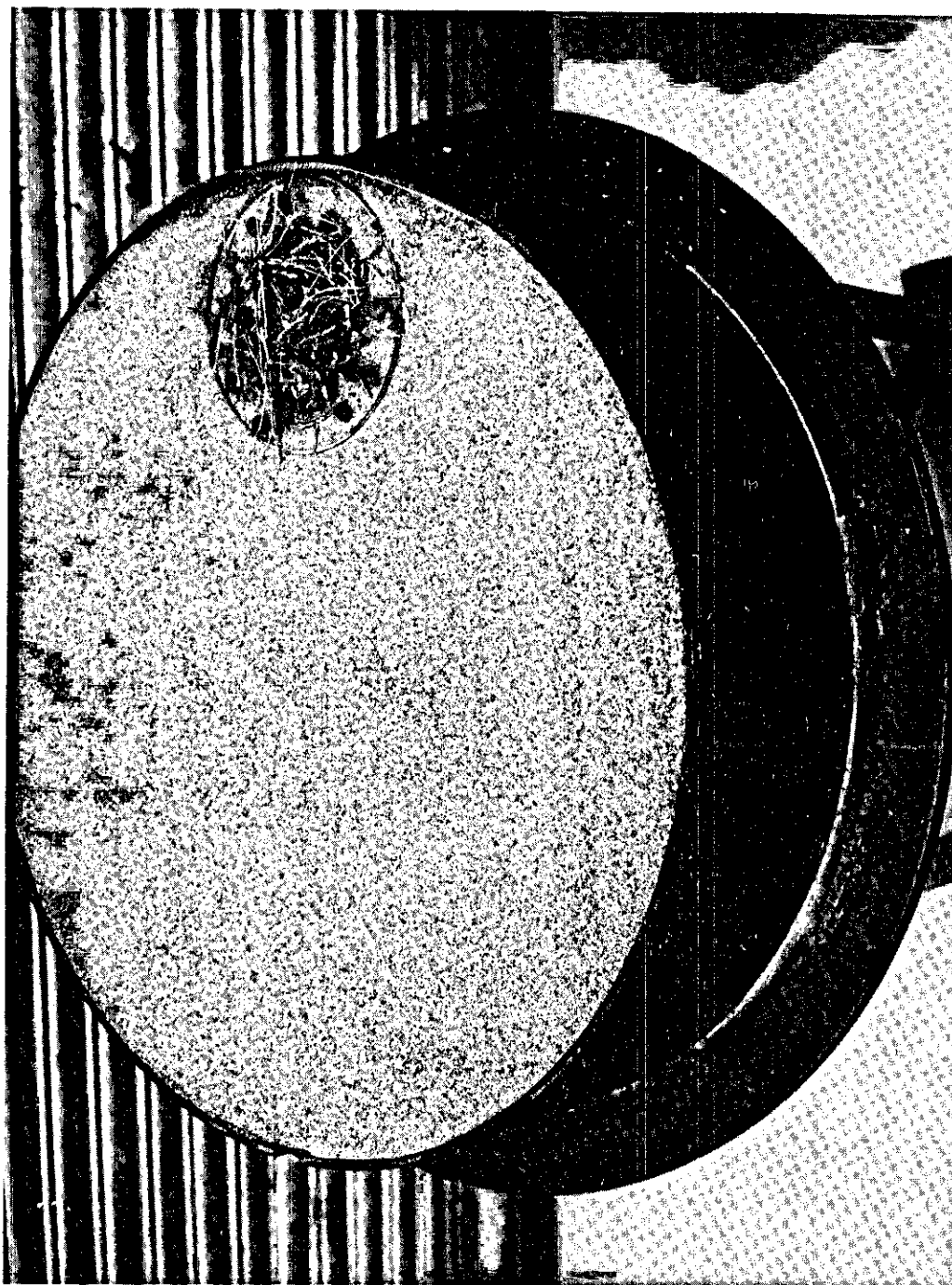


FIGURE 5

BURNER TRAY ARRANGEMENT USED IN ENGINEERING SCALE TESTS TO MEASURE FRACTIONAL AIRBORNE RELEASE DURING BURNING OF CONTAMINATED MATERIAL FROM B-C CONTROLLED AREA

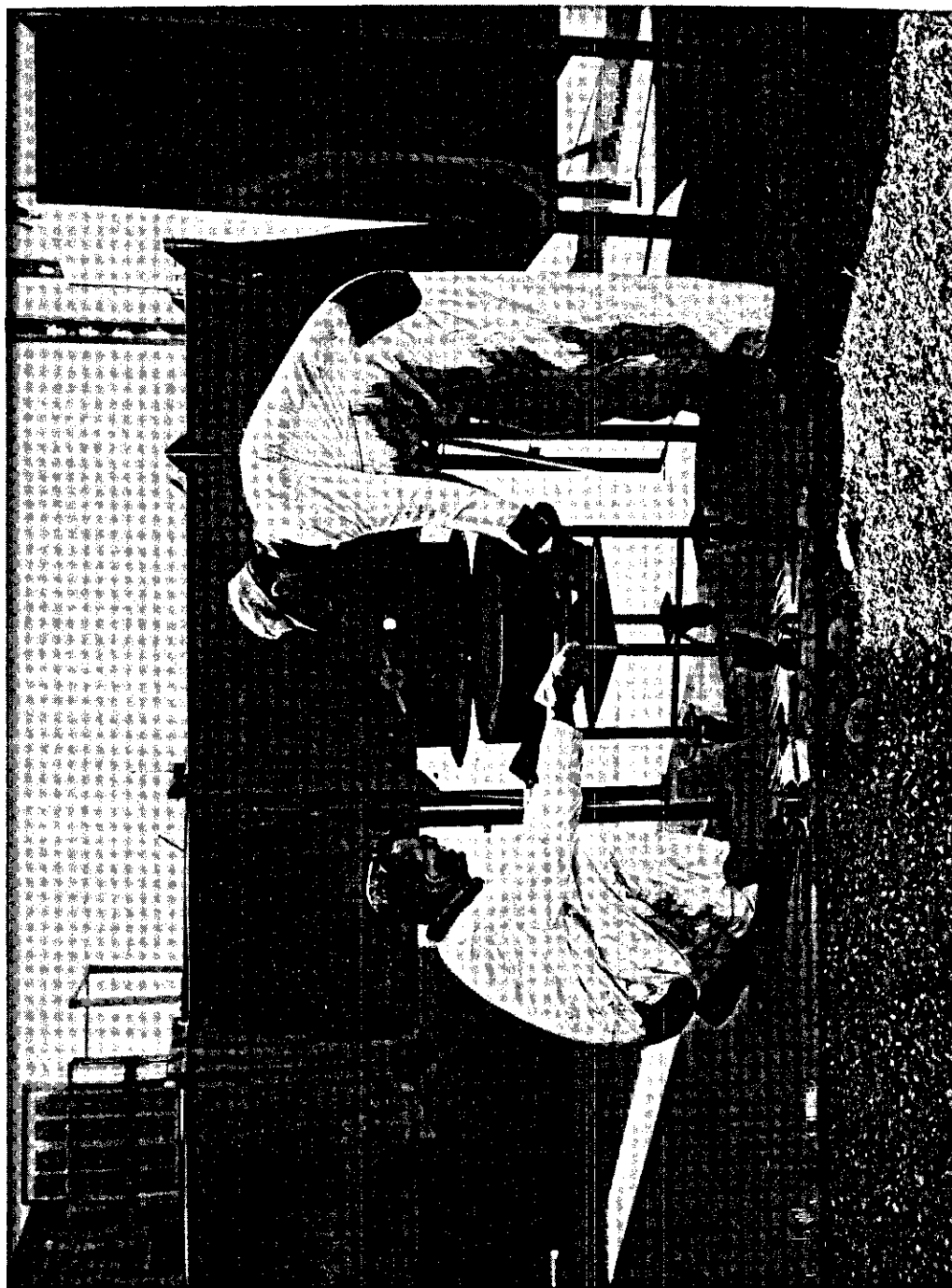


FIGURE 6a
PHOTO -- POSITIONING BURNER TRAY UNDER FLANGED OPENING IN FURNACE
SECTION OF WIND TUNNEL R.A.R.T.F.

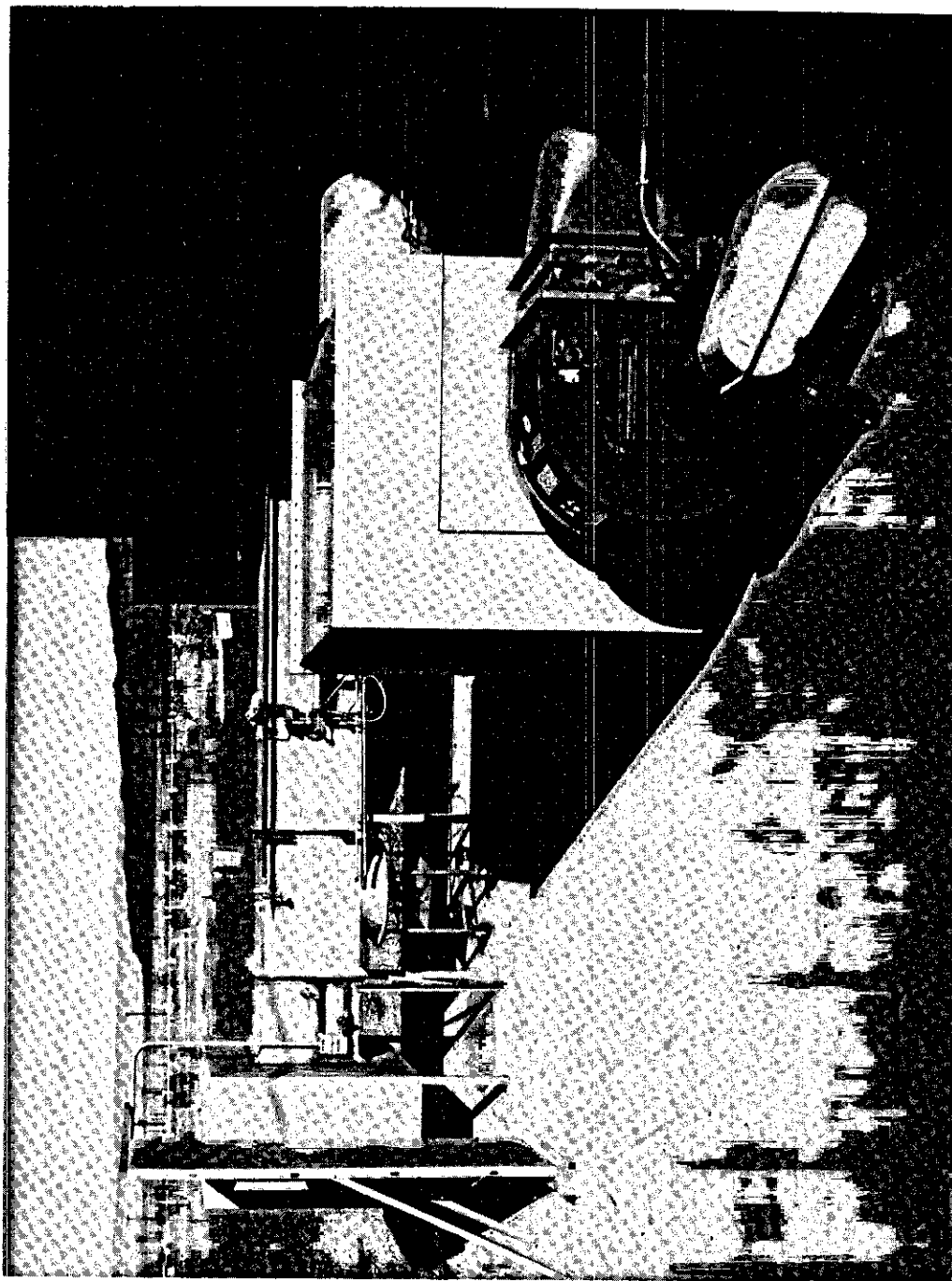


FIGURE 6b
PHOTO — BURNER TRAY IN POSITION IN FURNACE SECTION OF
WIND TUNNEL, R.A.R.T.F.

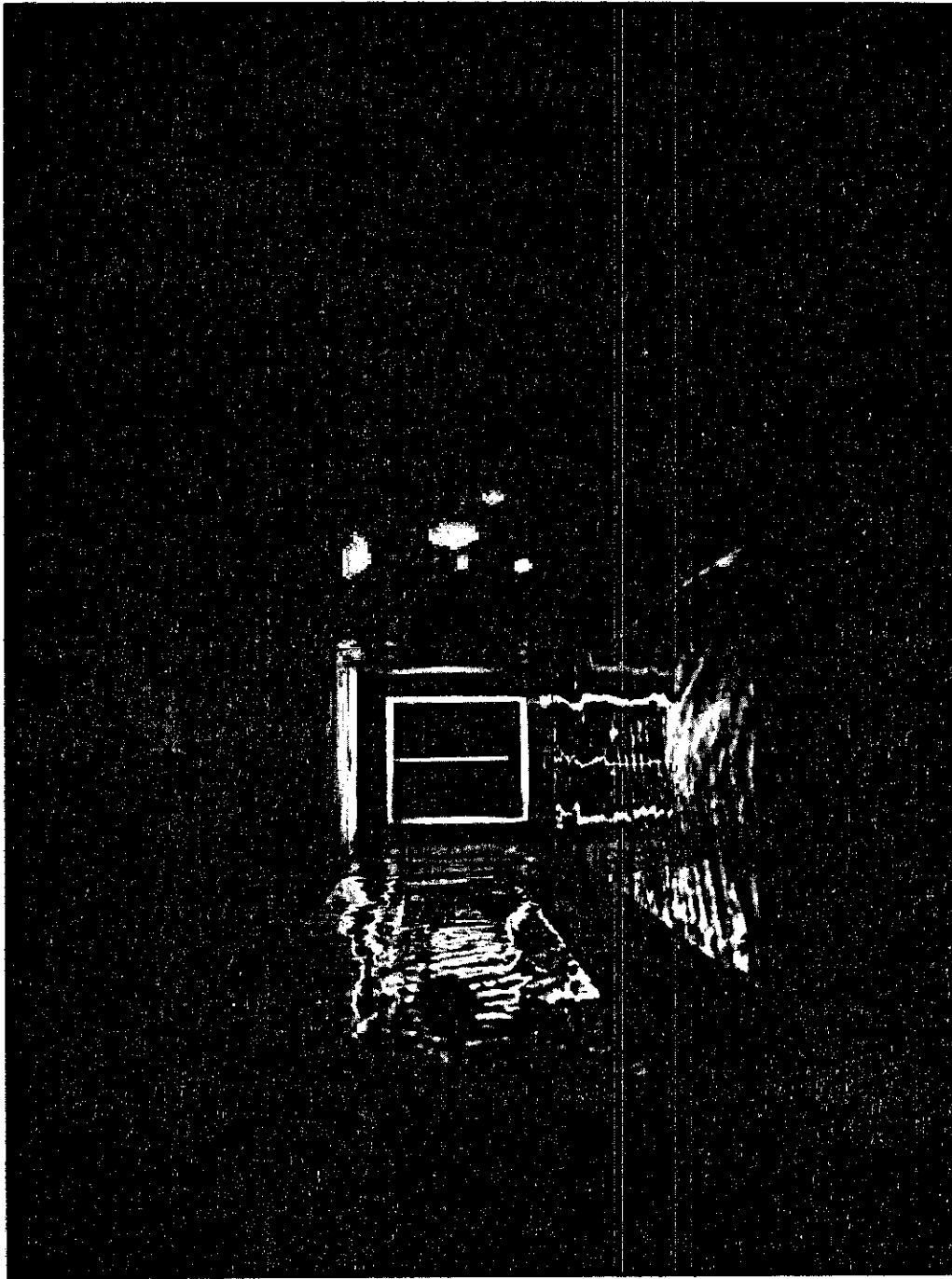


FIGURE 7

PHOTO -- UPSTREAM VIEW OF INTERIOR OF WIND TUNNEL. NOTE FILTER HOLDERS IN FOREGROUND, ALUMINUM FOIL ON WALL & FLOOR, AND GASOLINE ENTRY TUBE OVER OPENING

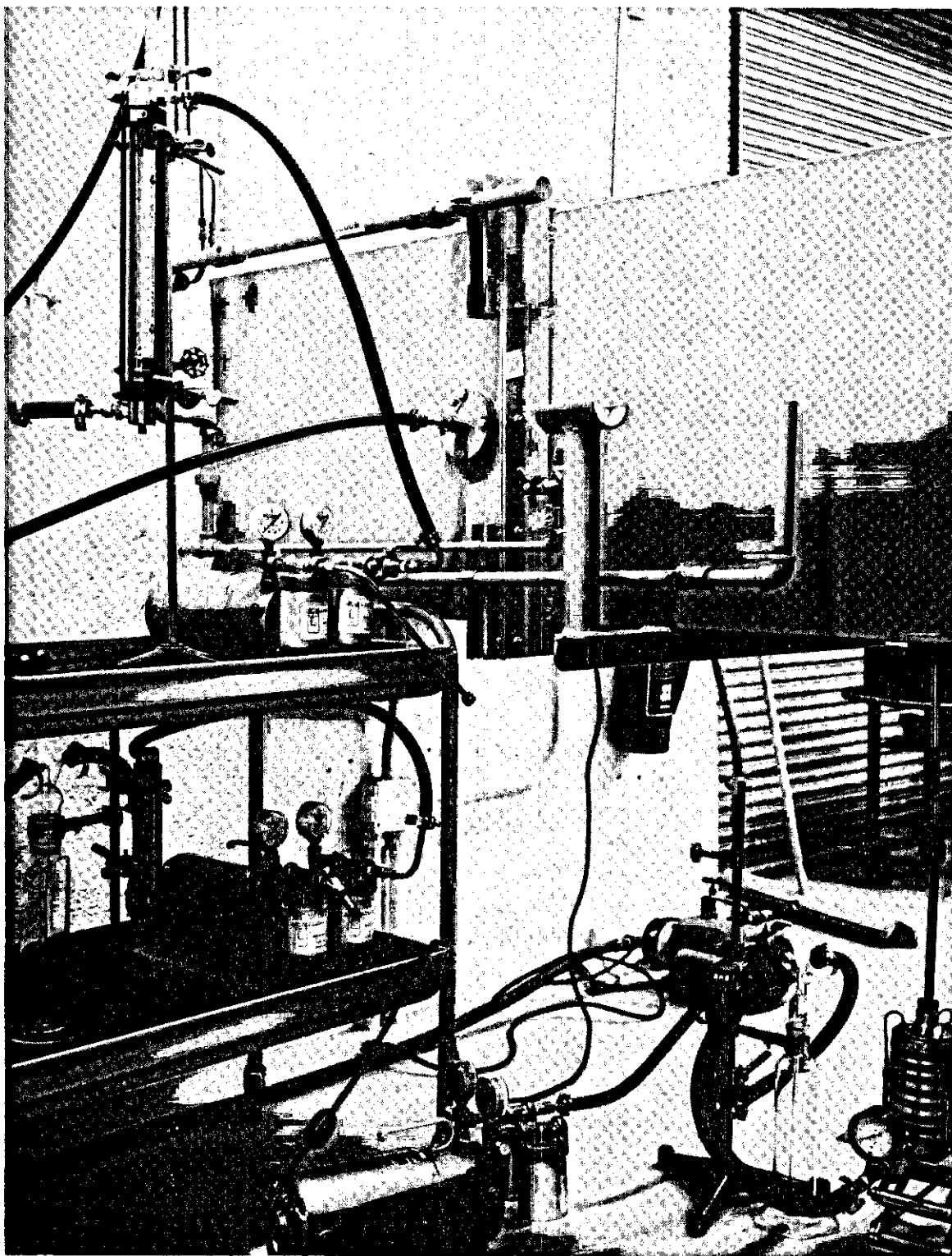


FIGURE 8

PHOTO -- SAMPLING TRAINS AND CASCADE IMPACTOR USED IN
ENGINEERING SCALE STUDY

In experiment No. 6, high volume filter and cascade impactor samples were taken due to the low activity detected in earlier experiments. Samples were extracted via 1-inch diameter probes near the top for the impactor and at the center for the filter. The arrangement is shown in Figures 9a and 9b. Sampling rates were 20 cfm for the cascade impactor and 35 cfm for the 8 in. \times 10 in. glass fiber filter.

At the completion of the burning cycle, the samplers were changed and airflow reinstituted for measurement of fractional airborne release from the residue. The burning cycle ranged from 52 to 65 minutes using an air velocity of 2.5 mph and 18 minutes for the single experiment at 20 mph. Entrainment of activity from the residue was monitored for 1 hour in the first 2 experiments then increased to 24 hours for the last 3 experiments, due to the absence of measurable activity.

^{137}Cs Measurements

Upon completion of each experiment, all samplers were appropriately packaged and the ^{137}Cs content measured by comparative gamma spectrometry or by counting a Ge(Li) diode. Filter, cascade impactor collection stages, or aluminum foil samples were counted on a NaI(Tl) crystal-multichannel analyzer system and the counting rates compared to standard ^{137}Cs spikes in blank samples of like material. Filter, caustic solution from the bubblers, and cascade impactor collection stages (strippable plastic coating on stainless steel planchets shown in Figure 10) were counted in a well counter. The limits of detection for the 10-minute counting period is 20 dpm. Residue and other samples containing high levels of activity were counted using Ge(Li) diode-multichannel analyzer combinations.

Results

The results and pertinent conditions for the five experiments performed in the R.A.R.T.F. are tabulated in Table IV. Measurable quantities of ^{137}Cs were found only on filter samples and impactors during the last 2 experiments (No. 5 and 6) during the burning cycle for the 24-hour periods for entrainment from the residue. Small but measurable amounts of ^{137}Cs were detected on the floor and walls after the last three experiments. Significant quantities of ^{137}Cs activity in the residue were found on the

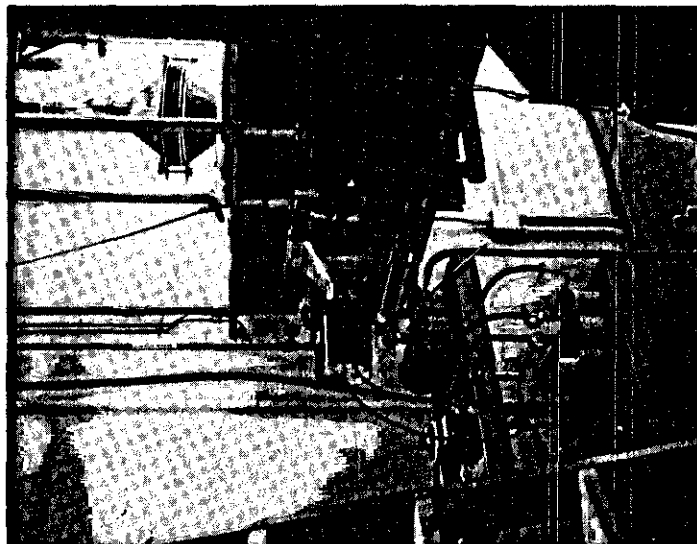


FIGURE 9b

HIGH VOLUME 8 IN. x 10 IN. GLASS FIBER
FILTER SAMPLER USED IN
EXPERIMENT NO. 6

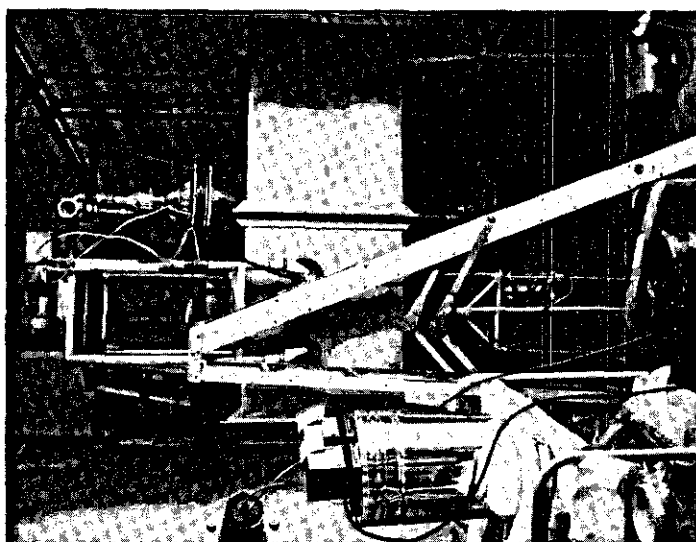


FIGURE 9a

HIGH VOLUME CASCADE IMPACTORS USED IN
EXPERIMENT NO. 6

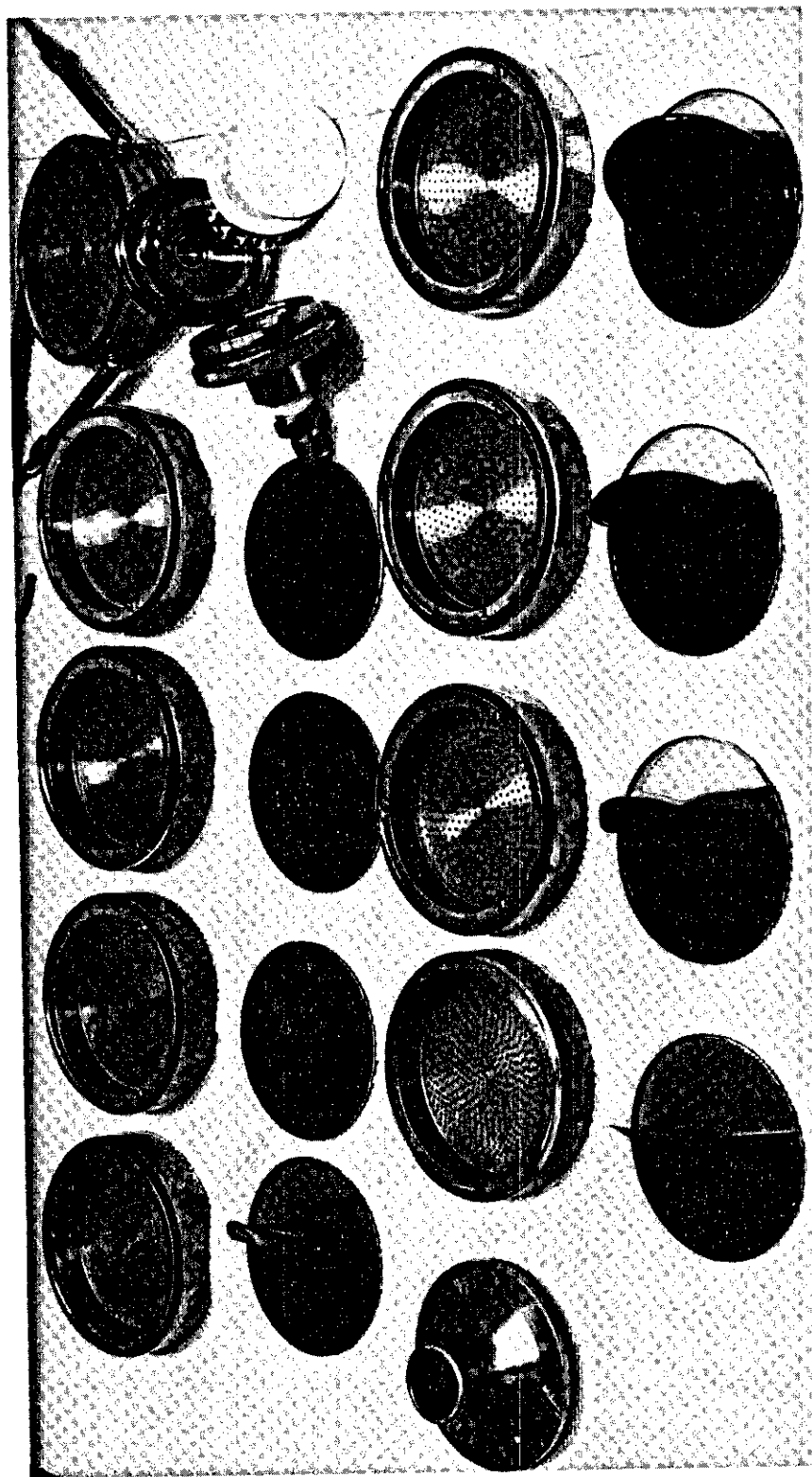


FIGURE 10
6-STAGE ANDERSEN IMPACTOR AND COATED IMPACTOR PLATES USED IN
ENGINEERING SCALE EXPERIMENTS

TABLE IV

FRACTIONAL AIRBORNE RELEASE OF ^{137}Cs DURING A GASOLINE FIRE INVOLVING CONTAMINATED MATERIALS
COLLECTED FROM THE B-C CONTROLLED AREA, ENGINEERING SCALE EXPERIMENTS -- SUMMARY SHEET

Date	5/9/73	5/14/73	6/4/73	6/19/73	6/27/73
Experiment Number	2	3	4	5	6
o SOURCE					
Wt. Contaminated Soil, g	302.5	286.5	--	--	--
$\mu\text{Ci } ^{137}\text{Cs}$ in Soil	1.34	1.60	--	--	--
Wt. contaminated animal droppings, g	25.7	25.4	0.674	1.564	0.674
$\mu\text{Ci } ^{137}\text{Cs}$ in animal droppings	0.081	0.067	4.22	12.2	9.83
Total $\mu\text{Ci } ^{137}\text{Cs}$ in Source	1.42	1.68	4.22	12.2	9.83
o BURNING CYCLE -- One gallon of gasoline					
Air speed, mph	2.5	2.5	2.5	2.5	20
Duration of Cycle, minutes	52	54	52	65	18
Percent source airborne	<0.4	<0.27	0.11	0.041(-0.52)	0.091-0.13
Activity Median Diameter, μm	n.d.	n.d.	n.d.	n.d.	2.8
o ENTRAINMENT FROM RESIDUE					
Air speed, mph	2.5	2.5	20	2.5	20
Duration, hours	1	1	24	24	24
Percent source airborne	<0.4	<0.27	0.6-1.0	0.151(-0.63)	1.4-4.9
Activity median diameter, μm	n.d.	n.d.	n.d.	2	2
o RECOVERY OF ACTIVITY USED IN SOURCE					
Airborne during burning cycle, %	<0.4	<0.27	<0.11	0.04	0.1
Entrained from residue, %	<0.4	<0.27	1.0	0.63	3.7
On floor, %	<0.01	<0.01	0.0042	0.0026	0.04
On walls, %	<0.01	<0.01	0.0018	<0.00015	0.0044
In residue burner tray, %	101	82.1	81.4	84.5	52.8
In residue, duct, %	--	--	0.44	--	1.3
In residue, R.A.R.T., %	--	--	6.9	--	2.4
Percent activity used in source recovered	101	82.1	90.0	87.4	61.5

n.d. -- not detectable

floor of the wind tunnel and R.A.R.T. after the two experiments using a 20 mph wind speed. From 61.5 to 101 percent of the ^{137}Cs activity used in the source was recovered in the various samples taken during the experiment. Considering the changes in counter geometry due to the variation in activity levels and physical forms between the specimens used to measure the ^{137}Cs in the source and recovered, the recoveries are satisfactory.

CONCLUSIONS AND RECOMMENDATIONS

Based on the current study, very little of the activity present on the surface of the B-C Controlled Area would be airborne during a range fire. The quantity is dependent upon the fractional airborne release from the various types of material and the distribution of the total activity involved in each type of material. Measurements of the ^{137}Cs content of various specimens in the Controlled Area indicate that the activity is primarily found in three materials -- soil, animal droppings, and organic detritus. The relative abundance of ^{137}Cs in these kinds of material is not known to the author; hence, the potential for each media being of lesser or greater importance cannot be stated. Nevertheless, the fractional airborne release from any of the materials used in these studies is so low that the total quantity airborne during a gasoline-promoted fire should be low. The fractional release of ^{137}Cs from contaminated soil was not detectable in the bench-scale experiments and indicates a fractional airborne release of less than 2×10^{-6} under static conditions. Using a wind speed of 2.5 mph in the R.A.R.T.F. wind tunnel, we collected no measurable amounts of ^{137}Cs in samples taken of airborne material, and material deposited in the floor and walls of the wind tunnel. Measurement of the activity in the residue after the experiment indicates that any loss was from organic debris rather than from activity in the soil.

Small, but measurable quantities of ^{137}Cs were made airborne during the burning of organic surface detritus (animal droppings and dead vegetation) under all conditions tested. Under static conditions in laboratory experiments, a fractional release of 2.7×10^{-6} was detected in 1 of 7 experiments using this material. Fractional release in the R.A.R.T.F. wind tunnel at wind speeds of 2.5 and 20 mph were 4×10^{-4} and 1×10^{-3} respectively.

Considerably greater quantities could be mobilized from the residues re-

maintaining after the fire. As much as 6.3×10^{-3} of the activity was found airborne in a 24-hour period at a wind speed of 2.5 mph from the residue remaining after a gasoline fire involving contaminated surface debris. Very little additional activity was detected on the wall and floor of the R.a.R.T.F. wind tunnel following the experiment, nor were contaminated materials (soil and ashes) found in the wind tunnel and vessels as in the experiments at higher wind speeds. The levels of activity at the top and centerline of the wind tunnel were in good agreement. The activity level near the floor of the duct (calculated by summing the activity in each stage of the cascade impactor) indicates a level factor of 5 or greater. The activity mean diameter (A.M.D.) at this level was 2 μ m aerodynamic equivalent diameter (A.E.D.) and is probably more coarse than the particle distribution at the centerline of the wind tunnel. Approximately 85 percent of the activity airborne was associated with particles less than 10 μ m A.E.D.

At a wind speed of 20 mph, a release fraction as great as 0.04 was measured on a single sample. Again, higher levels were measured near the floor of the duct. Measurable quantities of contaminated soil and ash were found in the wind tunnel (0.44 and 1.3 percent) and in the vessel (6.9 and 2.4 percent). Thus it appears that a considerable amount (from 4 to 8 percent) of the radioactive residues in contaminated organic surface debris can be redistributed immediately after a fire. The effects of age were not determined. The A.M.D. of the material airborne was 2 μ m A.E.D. with approximately 85 percent of the activity involved with particles less than 10 μ m A.E.D.

Thus, it appears that less than 0.1 percent of the radioactive material in the B-C Controlled Area would be made airborne during a range fire at wind speeds less than 20 mph. The exact quantity will depend upon the distribution of activity between soil and organic material. The A.M.D. at 20 mph was 2.8 μ m A.E.D. As much as 4 percent could be made airborne in a 24-hour period immediately following the fire with an additional 10 percent being redistributed downwind. The A.M.D. of the material was 2 μ m A.E.D. How rapidly the residue from the fire becomes attached to the soil, the effects of moisture and weathering and how far such material would travel across rough surfaces (soil) still needs to be evaluated.

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