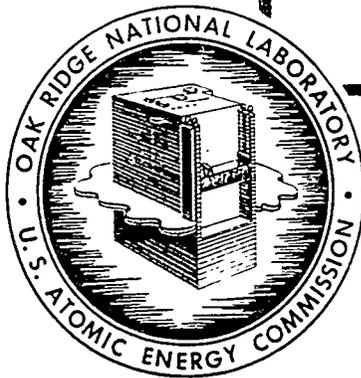
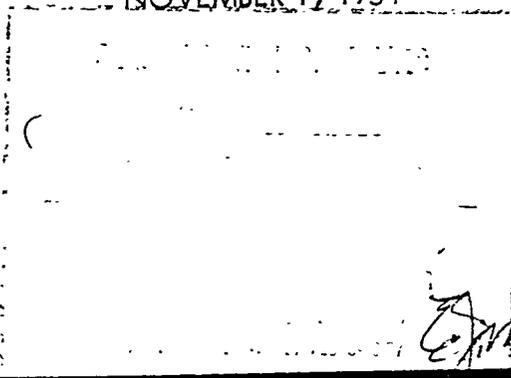


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A STUDY OF THE CONTRIBUTION OF THE
RALA PROCESS TO ATMOSPHERIC
CONTAMINATION AT ORNL

NOVEMBER 1, 1954



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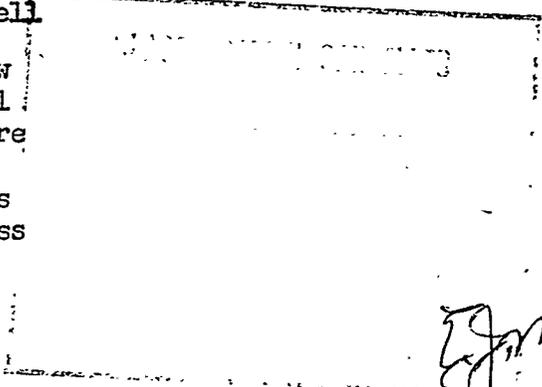
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HEALTH PHYSICS DIVISION

A STUDY OF THE CONTRIBUTION OF THE RALA
PROCESS TO ATMOSPHERIC CONTAMINATION AT ORNL

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November 1, 1954

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CONTENTS

	<u>Page</u>
ABSTRACT.....	1
INTRODUCTION.....	2
RALA PROCESS WASTE DISPOSAL SYSTEM.....	6
AIR SAMPLING.....	6
ASSAY OF SAMPLES.....	9
RESULTS.....	13
DISCUSSION.....	25
CONCLUSIONS.....	31
RECOMMENDATIONS.....	33
ACKNOWLEDGMENTS.....	34
APPENDIX I.....	35
APPENDIX II.....	39
APPENDIX III.....	44

ABSTRACT

Data on the particulate contamination of the atmosphere at the Oak Ridge National Laboratory were correlated with laboratory processes and reactor operations for the period from March, 1949 to June 1954. A significant correlation was found to exist between one of the chemical separations processes, RaLa, and peaks of particulate activity on the Laboratory area.

The RaLa process was monitored during two complete cycles of operation. The contribution of the process to the general atmospheric contamination of the Laboratory area was determined. The activity was identified and its release to the atmosphere was investigated.

It was concluded that the major portion of the contaminated RaLa effluent released to the 3039 stack does not fall out or diffuse in the immediate environs, and hence, the stack is not the primary means by which RaLa contributes to atmospheric contamination. A serious offender was found to be an underground liquid waste storage tank, W-9, in the south tank farm. This tank is used to store RaLa wastes and is vented to the atmosphere. Atmospheric contamination in the immediate vicinity of this vent was observed to reach values as high as 2×10^{-5} $\mu\text{c}/\text{cc}$, beta activity, averaged over a 24 hour period.

INTRODUCTION

Since March 1949, complete records have been kept of the airborne radioparticulate contamination on the X-10 Laboratory site. These data are taken and the records maintained by the Survey Monitoring Section of the Health Physics Division.

The data from a group of 10 continuous air monitors (CAM), located about the Laboratory site, were reduced to the histogram shown in Figure 1.

The yearly averages are as follows:

Particles/1000 ft ³	<u>1949</u>	<u>1950</u>	<u>1951</u>	<u>1952</u>	<u>1953</u>
	0.16	0.55	0.56	3.35	2.14

The upward trend through 1952 is attributed to the greater amounts of activities handled and the new processes placed in operation. The apparent decrease in 1953 may be attributable to the unusually high average for 1952 caused by the high peak on the week of February 25. This high average for the one week increased the yearly average of 1952 by more than 30%.

An attempt to correlate ORNL processes and reactor operations with peaks of particle activity revealed that a significant correlation did exist between certain processes and high particle count on the Laboratory area.

The RaLa process, was found to be associated with peaks of particulate activity. The vertical arrows shown in Figure 1 represent RaLa runs and it may be seen that every run made during the five year

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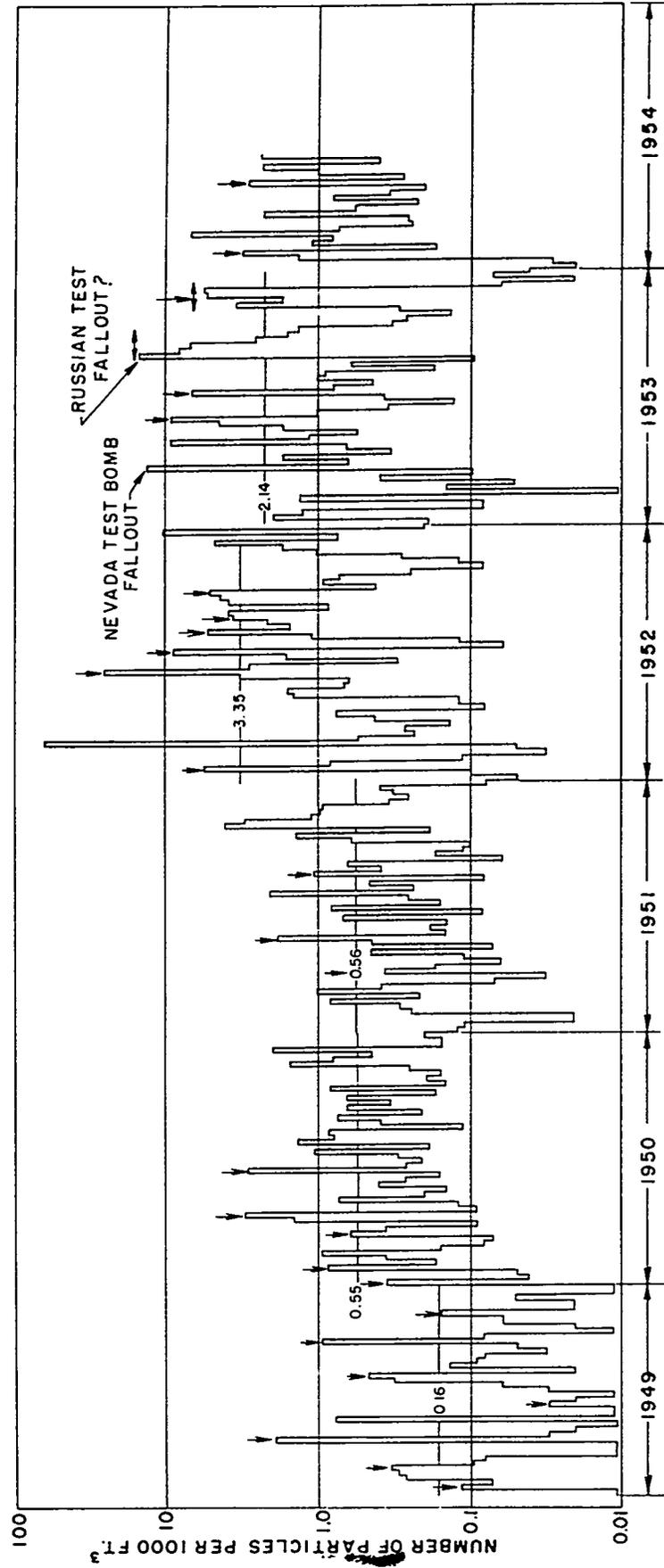


FIG. 1 - AIRBORNE RADIOPARTICULATES AT ORNL
AVERAGE OF TEN MONITORS
1949 - JUNE 1954 BY WEEKS

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-4-

period coincides with a peak of the particle count. The RaLa process cannot be held accountable for all the incidents of high particle count, but more of the peaks may be attributed to this process than to any other. This, together with the fact that RaLa was shown during the 1948-49 "particle problem"¹ to be a profuse source of particulates, was considered sufficient evidence to warrant this investigation, even though measures were subsequently taken to reduce the air contamination due to RaLa.

The immediate objectives of this investigation were as follows:

- (1) To determine if the RaLa process was still a major contributor to ORNL air contamination.
- (2) To determine the sources of the air contamination emanating from the RaLa process.
- (3) To determine the physical and chemical properties of the radioactive air contaminants.
- (4) To compare the active particle concentration obtained with the standard CAMS to the concentration obtained by millipore filter sampling techniques.
- (5) To investigate the applicability of a flow ionization chamber to continuous monitoring of RaLa stack gases.
- (6) To recommend measures for reduction of the air contamination.

¹Cheka, J. S., and H. J. McAlduff - Particle problem progress reports, ORNL 146, 172, 211 and 319, and "Particulate Air Contamination at ORNL", ORNL 283.

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The air contamination from two RaLa runs was investigated. The first run, No. 52, covered the period May 23, 1953 to June 4, 1953. The second run, No. 54, covered the period November 5, 1953 to November 25, 1953.

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RALA PROCESS WASTE DISPOSAL SYSTEM

The process off-gas and the cell ventilation air from the RaLa process are cleaned separately and then discharged to the atmosphere through a common 250 foot stack. Figure 2 shows a diagrammatic sketch of the waste gas cleaning equipment and the points at which samples were taken. The gases evolved from the RaLa process vessels are scrubbed with a caustic scrubber, routed to the Cottrell precipitator, a filter bank, and then forced up the stack by a blower.

The cell ventilation air is passed through a roughing filter and a finishing filter before being exhausted to the stack. The roughing filter is made up of layers of American Air Filter F.G. 25 and F.G. 50, while the finishing filter is CWS type 6 paper.

The liquid wastes from the process are jettied to an underground tank, W9, in the south tank farm for storage.

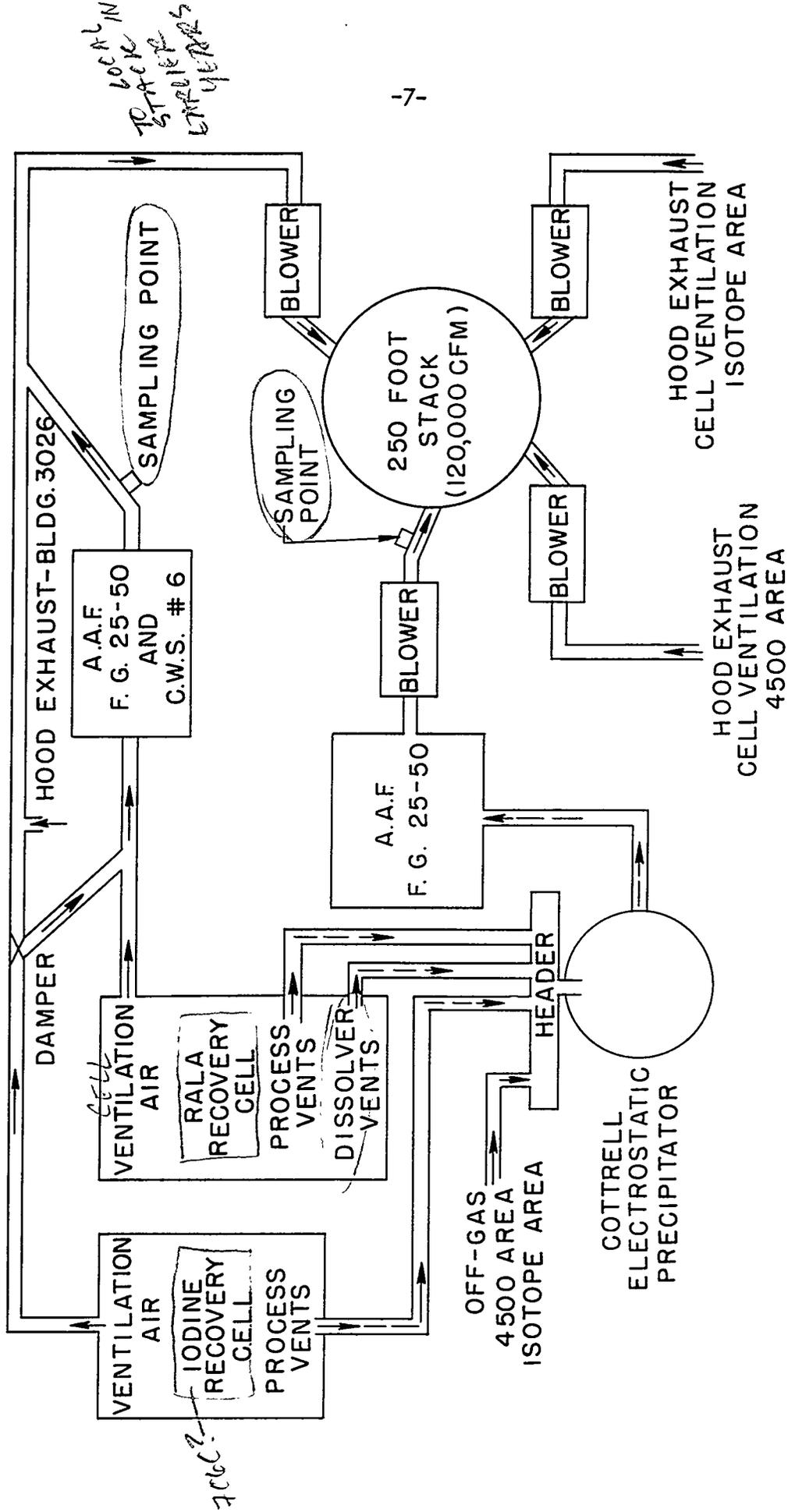
AIR SAMPLING

Location of Sampling Points

The air sampling locations were as follows:

- (1) Off-gas duct (Figure 2);
- (2) cell ventilation duct (Figure 2);
- (3) stack, at the 50 foot level;
- (4) inside of process building on second level;
- (5) about 18 inches from the vent of the process liquid waste storage tank;
- (6) at 10 standard air sampling locations about the Laboratory area (Figure 3).

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*LOCAL IN
 TO STACK
 STAIRS
 ENTRANCE
 YARDS*

FIG. 2
 DIAGRAMATIC SKETCH OF CENTRAL WASTE GAS COLLECTION SYSTEM

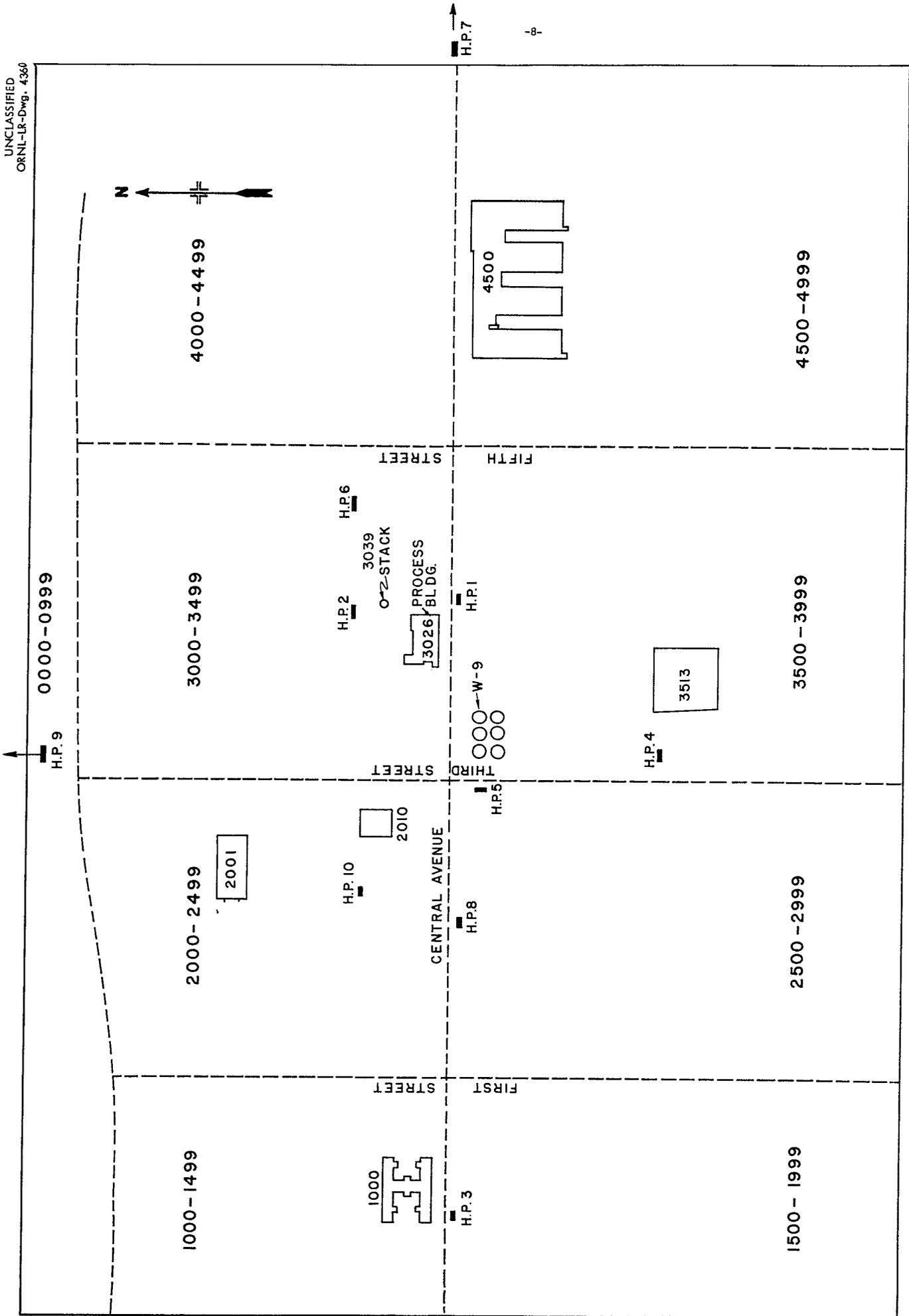


FIG. 3. LOCATION OF CONSTANT AIR MONITORS (HP 1-10), PROCESS BUILDING, STACK, AND W-9 TANK.

Equipment and Procedures

Millipore (molecular membrane) filters were used, where feasible, to sample the air for particulate matter. These filters have been shown to be better than 99.99% efficient in filtering aerosols of 0.3 μ mass median diameter.² Cascade impactors were used also for sampling particulate contamination.

The 10 continuous air monitors (CAM) which are used routinely in determining the airborne radioparticulate contamination in the Laboratory area were utilized during this investigation to provide comparative data. These monitors are equipped with Hollingsworth and Vose Number 70 (H & V 70) filter paper, through which air is drawn continuously. A continuous flow ionization chamber was used as a stack monitor (Appendix I).

Since it was known from previous work that iodine was present in the process effluent, gas sampling bubblers were also used. The bubbler solution was prepared by dissolving 50 grams of sodium thiosulfate and 5 grams of sodium hydroxide in one liter of water. Twenty to thirty milliliters of this solution used in each bubbler. A rough test of a bubbler for removal of inert iodine vapor at the flow rate used in RaLa sampling indicated that the removal efficiency was better than 99.8%. The removal efficiency for iodine particulates would be much lower.

Samples were taken both continuously and intermittently for

² Lauterbach, K. E., et al., "Efficiency Studies of the Electrostatic Precipitator" UR-287, October 15, 1953.

various lengths of time and flow rates, as shown in Tables I and II. In the first run, #52, flow rates were adjusted to approximate those of isokinetic air sampling.

ASSAY OF SAMPLES

Samples were counted using an end window Geiger tube, window thickness 2-3 mg/cm². Decay and adsorption measurements were made. In the case of the bubbler samples, suitable aliquots were pipetted from the bubbler solution and evaporated to dryness for counting.

Gross autoradiograms were obtained to determine the number of radioactive particles in a given sample. Eastman Blue Brand X-ray film was used for this work with a sheet of 0.4 mil rubber hydrochloride between the sample and the emulsion. The spots on the film was counted with a stereoscopic microscope at a magnification of approximately 20X.

Certain cascade impactor and millipore filter samples were exposed to strippable film and an effort was made to examine the individual radioactive particles after locating them by means of the autoradiogram. The strippable film used was Eastman, autographic permeable base film, type NTB, with an emulsion thickness of approximately 10 μ . The emulsion was placed directly in contact with the samples and exposed for periods of from three days to two weeks. The emulsion was developed while still in contact with the sample, and, when dried, was examined under a microscope for tracks and particle analysis.

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TABLE I

RUN #52

Sampling Location	Type of Sample			
	Millipore Filter	Bubbler	Cascade Impactor	CAM (H.V. 70)
Off-gas Duct	Intermittent during entire run 1 to 100 minutes 14 liters/minute 34 samples		Intermittent ending May 29 1 to 70 minutes 14 liters/minute 12 samples	
Cell Ventilation Duct	Intermittent ending May 29 5 to 300 minutes 16 liters/minute 14 samples		Intermittent during entire run 60 to 290 minutes 12 liters/minute 10 samples	
Fifty Foot Level of Stack	Intermittent during entire run 5 to 100 minutes 30 liters/minute 41 samples		Intermittent ending May 26 12 to 320 minutes 15 liters/minute 4 samples	
Inside Process Building	Continuous beginning June 1 13 to 965 minutes 30 liters/minute 12 samples			
Laboratory Area	Continuous during entire run 150 to 1140 minutes 30 liters/minute 25 at each of two locations 29 at each of two locations			Continuous during entire run 8 to 24 hours 5 cubic feet/minute

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TABLE II

RUN #54

Sampling Location	Type of Sample			
	Millipore Filter	Bubbler	Cascade Impactor	CAM (H. V. 70)
Off-gas Duct	In series with int. bubbler Nov. 11-Nov. 15 6 to 24 hours 1 liter/minute 6 samples	Intermittent in series with M.F. and continuous during entire run 6 to 25 hours 1 liter/minute 3l cont. samples	<i>duration?</i>	
Cell Ventilation Duct		Continuous during entire run 6 to 25 hours 1 liter/minute 3l samples		
Fifty Foot Level of Stack	Cont. in series with cont. bubbler beginning Nov. 11 7 to 25 hours 1 liter/minute 14 samples	Continuous during entire run 6 to 25 hours 1 liter/minute 3l samples		
Inside Process Building	Continuous during entire run 6 to 25 hours 17½ liters/minute 3l samples	Continuous during entire run 6 to 25 hours 1 liter/minute 3l samples	Continuous during entire run 6 to 25 hours 13½ liters/minute 3l samples	
Laboratory Area				Continuous during entire run - 24 hours 5 ft ³ /min.
Near Waste Tank Vent	Continuous during entire run 6 to 25 hours 32 liters/minute 3l samples	Continuous during entire run 6 to 25 hours 1 liter/minute 3l samples		

Radiochemical analyses were made of some of the millipore filter and bubbler samples. The solution in the bubbler samples was analyzed directly; the millipore filters were dissolved in nitric acid prior to analysis.

RESULTS

Table III shows the highest, lowest and average air activities obtained during the second run at the various sampling locations and the type of sample and length of sampling period for which the values were obtained.

Off-Gas Duct

In the first run (No. 52) the cascade impactor was found to be unsuitable due to condensation of water from the hot, wet gas in the duct. Twenty of the 34 millipore filter samples taken gave absorption curves indicating that the activity present was iodine 131. Such a typical absorption curve is shown in Figure 4. The other fourteen absorption curves showed the presence of mixed fission products. Figure 5 is typical of this group. These results were confirmed by the gamma ray scintillation spectrometer. In addition, a radiochemical analysis of four of the samples showed that 86% of the gross beta activity was iodine 131. Figure 6 shows a typical autoradiogram of one of the 20 millipore filter samples which were found to contain iodine 131. The appearance of the autoradiogram indicated that the iodine was probably present in a gaseous

TABLE III

AIR ACTIVITY IN SECOND RUN #54

Sampling Location	Type of Sample						H & V No. 70 Filter
	Millipore Filter		Bubbler		Cascade Impactor		
	Activity (uc/cc)	Sampling Period (hours)	Activity (uc/cc)	Sampling Period (hours)	Activity (uc/cc)	Sampling Period (hours)	
Off-gas Duct	Highest		1.8×10^{-4}	6			
	Average		3.2×10^{-5}				
	Lowest		1.6×10^{-6}	14			
Cell Ventilation Duct	Highest		1.3×10^{-6}	4			
	Average		1.6×10^{-7}				
	Lowest		1.8×10^{-8}	7			
Fifty Foot Level of Stack	Highest		1.9×10^{-6}	11			
	Average		3.4×10^{-7}				
	Lowest		1.8×10^{-8}	24			
Process Building	Highest	1.5×10^{-8}	1.3×10^{-8}	23	2.9×10^{-8}	23	
	Average	8.2×10^{-10}	1.7×10^{-9}		1.8×10^{-9}		
	Lowest	2.0×10^{-12}	2.0×10^{-11}	6	2.9×10^{-12}	9	
Waste Tank	Highest	2.1×10^{-5}	1.3×10^{-6}	24	2.1×10^{-7}	7	
	Average	1.8×10^{-6}	2.1×10^{-7}		2.2×10^{-8}	10	
	Lowest	2.6×10^{-9} *		12			
CAM Outlying Stations	Highest						7.4×10^{-11}
	Average						2.0×10^{-11}
	Lowest						1.3×10^{-12}

* After the first wastes were jettied to the tank.

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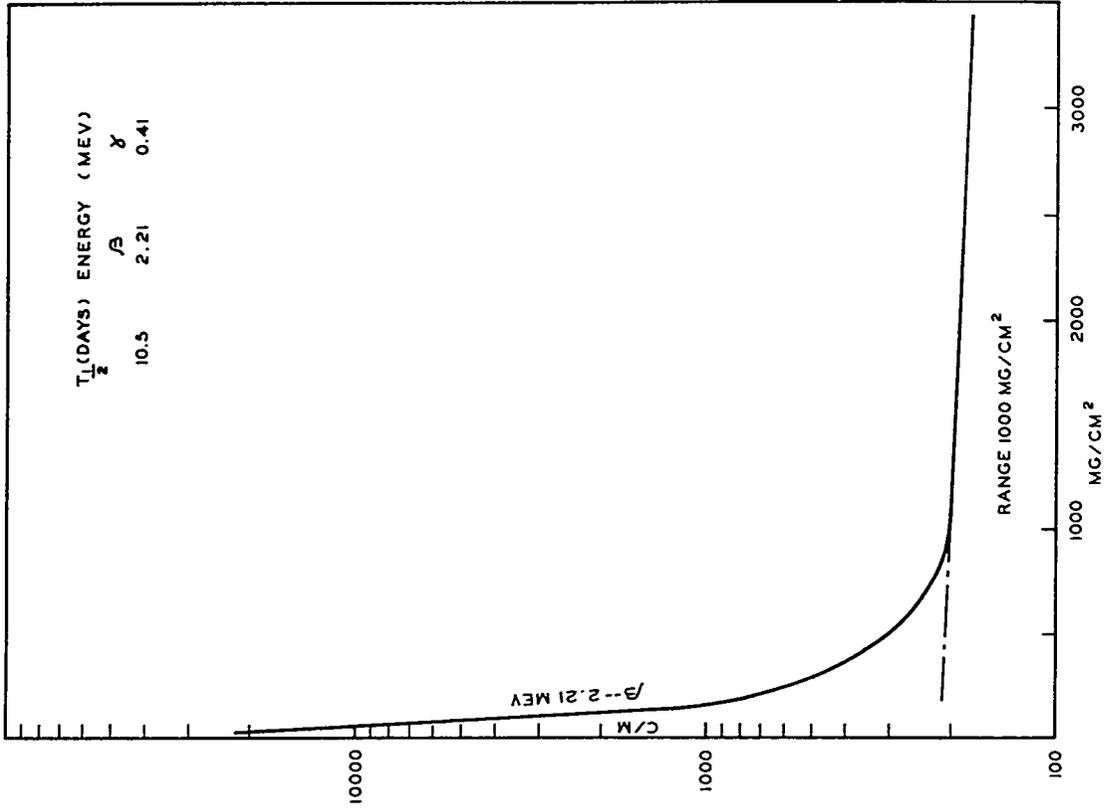


FIG. 5. ALUMINUM ABSORPTION CURVE
OF SAMPLE OGMF #7.

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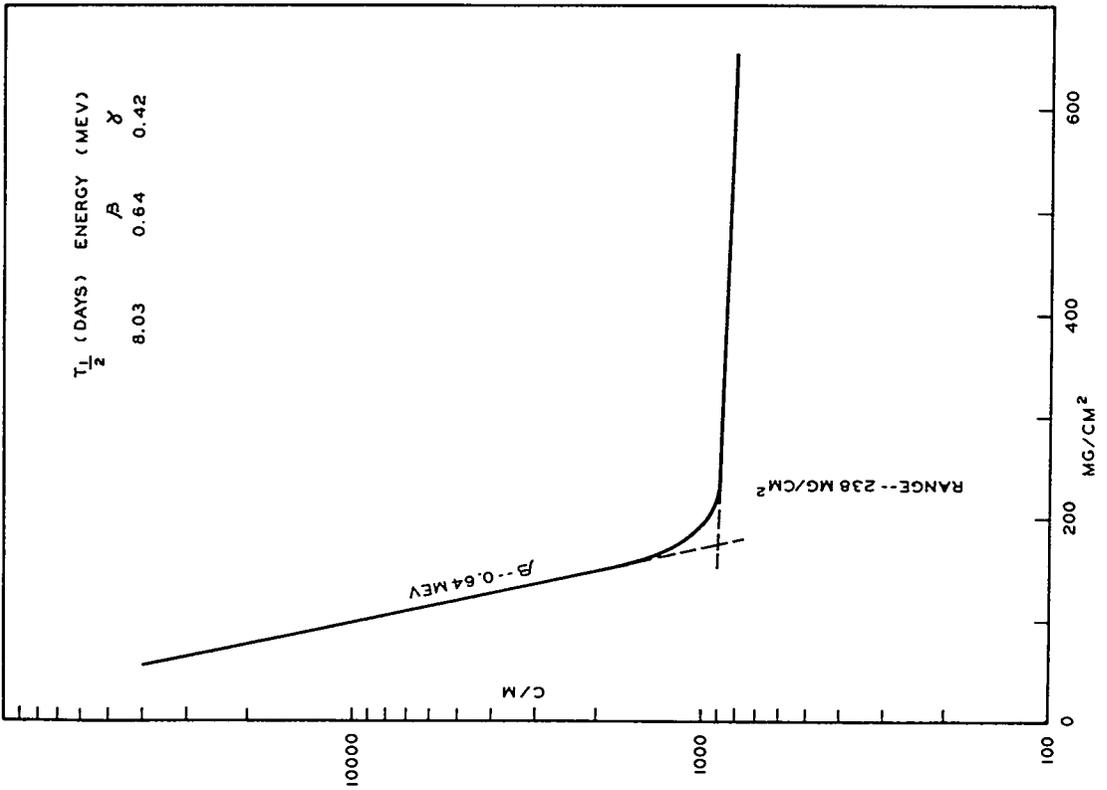


FIG. 4. ALUMINUM ABSORPTION CURVE
OF SAMPLE OGMF #8.

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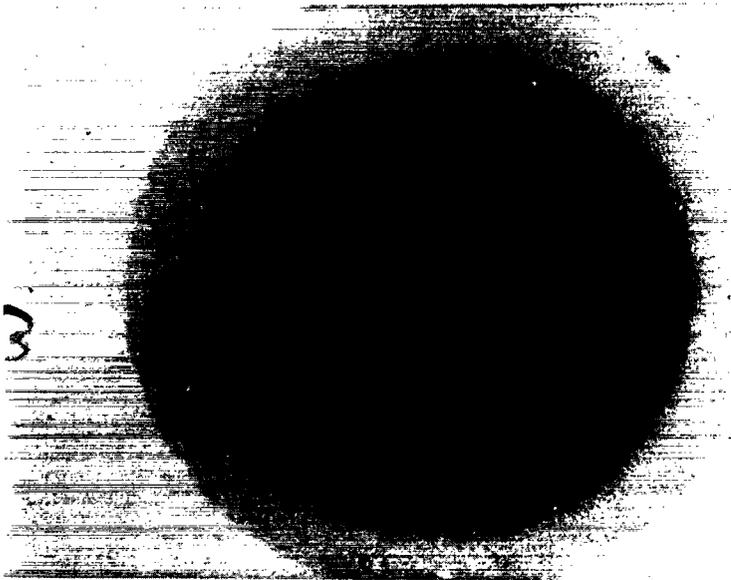


FIG. 6. AUTORADIOGRAM OF OGMF #13. FIG. 7. AUTORADIOGRAM OF CVMF #6

or very fine particulate form. Samples which showed the presence of particles contained trace amounts of barium, strontium, and rare earths, in addition to iodine. Samples which contained no discernable particles contained only iodine.

Since the results of the first run showed that iodine was the major contributor to the activity in the off-gas line in the second run, experiments were made to determine the relative portion of gaseous to particulate activity (Appendix II). The results showed that the particulate activity ranged from 7 to 28% of the total activity. A radiochemical analysis of the bubblers and millipore filters indicated that from 79 to 126% of the gross beta activity was due to iodine. This identified the major portion of the activity as gaseous iodine.

The total amount of iodine activity in the off-gas line was determined by continuous bubbler sampling over the period of the second run. Radiochemical analyses of all samples showed that 89% to 107% of the gross beta activity was due to iodine. Decay and absorption studies on three samples indicated the iodine isotope to be iodine 131. This confirms the results obtained in the first run.

The total amount of activity collected in the 31 continuous off-gas bubbler samples was approximately $900 \mu\text{c}^3$. Since the flow in the off-gas line was estimated to be about $600 \text{ ft}^3/\text{minute}$, this indicates that a total of about 15 curies of gaseous iodine 131 was released to the stack by the off-gas line during the period of the run.

³ The activity at the time of counting was extrapolated back to the time of sampling, assuming the activity was 100% iodine 131.

Cell Ventilation

In the first run, NTB strippable film autoradiograms of the cascade impactor samples showed a few clusters of developed silver grains, but not enough particles could be identified and measured to be of any significance. An autoradiogram of one of the more active millipore filter samples is shown in Figure 7. (The ink marks in the autoradiogram were used as an aid in counting particles). A comparison of Figure 7 with Figure 6 shows that the proportion of particulate activity to gaseous activity is much higher in the cell ventilation line than in the off-gas line. The sample shown in Figure 7 contained 800 particles, collected in one hour. This gives a particle concentration of approximately 24,000 particles per 1000 ft³ of cell ventilation air. Absorption and gamma scintillation spectrometer studies showed the sample activity to be mixed fission products. Another cell ventilation sample was both autoradiogrammed and radiochemically analyzed. The autoradiogram showed no particles, and the analysis showed that 93% of the gross beta activity was iodine. Absorption and decay studies were made on a total of five samples. Two of the samples proved to be iodine 131; the other three contained mixed fission products.

In the second run, continuous bubblers were used on the cell ventilation line in the same manner as on the off-gas line to determine the total amount of gaseous iodine released to the stack by this line. Radiochemical analyses of all samples showed that 86 to 103% of the gross

beta activity was due to iodine. The total amount of activity collected in the 3l cell ventilation bubbler samples was $4.5 \mu\text{c}^3$. Assuming an air flow of $7700 \text{ ft}^3/\text{minute}$ in the cell ventilation line, it was calculated that about one curie of gaseous iodine 131 was released to the stack during the period of the run.

Stack

Cascade impactor samples taken in the first run were similar to the cell ventilation air samples and revealed little information. Absorption and decay studies on ten millipore filter samples and radiochemical analyses on two samples all indicated, as would be expected, that the preponderance of the activity was iodine 131. Figure 8 is a typical absorption curve. Results obtained from autoradiograms of the stack millipore filter samples indicated that the particle contamination occurred in short bursts. The autoradiogram shown in Figure 9 is typical of the stack samples, although some showed a small number of particulates against a diffuse background.

In the second run radiochemical analyses on all the continuous bubbler samples showed that iodine content was from 91 to 113% of gross beta activity. A total of $9.6 \mu\text{c}^4$ of activity was collected in the stack bubblers, Table IV. Based on a stack flow of $120,000 \text{ ft}^3/\text{minute}$ this indicates that approximately 33 curies of gaseous iodine 131 were released by the stack during the period of this run.

⁴ Activity was determined at two intervals several days apart. On this basis, the activities were extrapolated back to the time of collection. Half-lives obtained in this way varied from 6.1 days to 9.8 days with an average for the 3l samples of 7.5 days.

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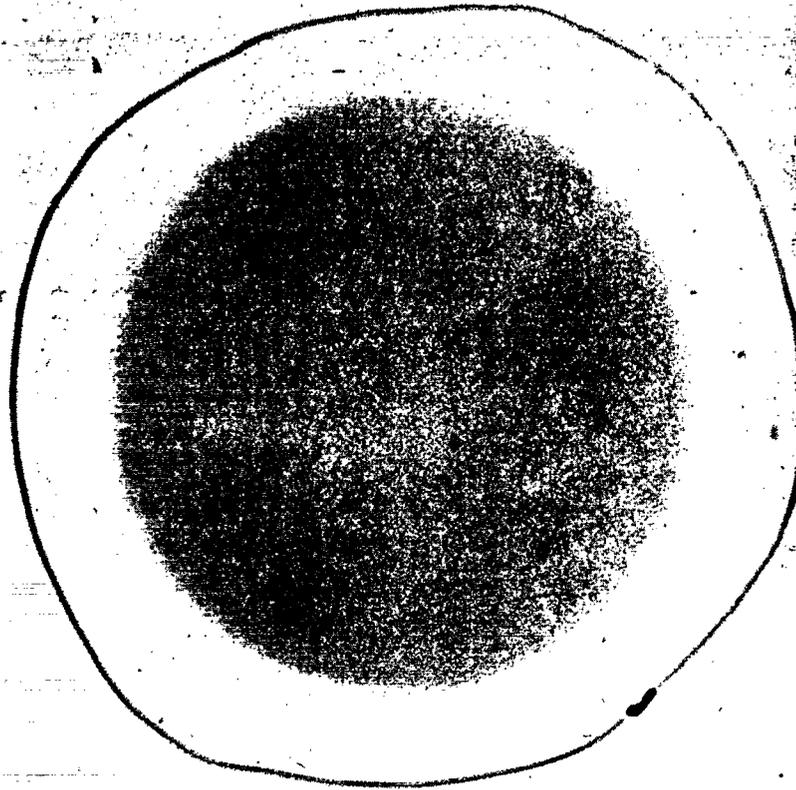


FIG. 9. AUTORADIOGRAM OF SSMF 12.

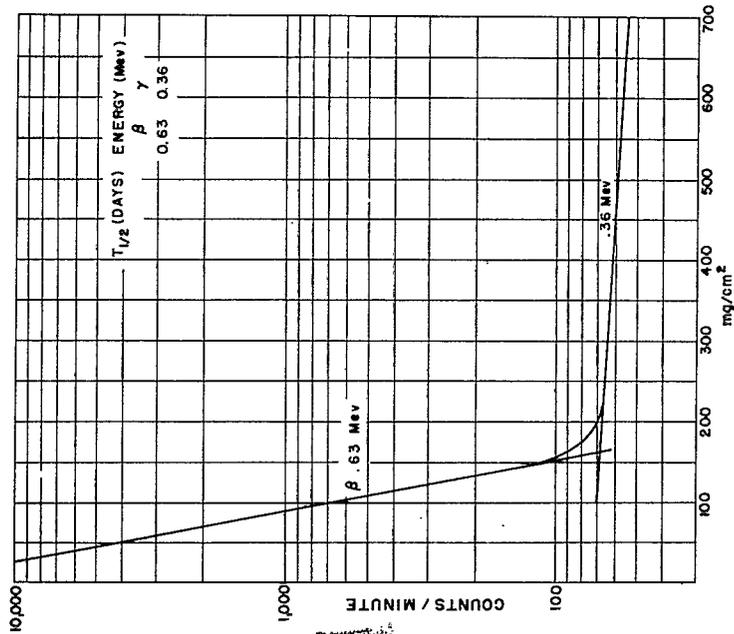


FIG. 8. ALUMINUM ABSORPTION CURVE
OF SSMF-16.

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Disassembly began 11/5 of 2015

TABLE IV

STACK BUBBLER SAMPLES

SAMPLING AND COUNTING DATA

RUN #54

Sample Number	ON		OFF		Sampling Time (min.)	Volume Sampled (liters)	Activity		
	Date	Time	Date	Time			$10^5 d/m^3$	$10^{-7} \mu c/cc$	
SB- 1	11-5-53	1535	11-6-53	0025	530	530	3.4	2.88	
2	11-6-53	0025		0910	525	525	12.8	11.0	
3		0912		1510	358	358	11.0	13.8	
4		1510	11-7-53	0030	560	560	20.2	16.3	
5	11-7-53	0035		0847	562	562	5.2	4.14	
6		0850		1645	475	475	10.4	9.85	
7		1645		2348	423	423	6.0	6.40	
8		2349	11-8-53	0845	536	536	16.5	13.9	
9	11-8-53	0900		1625	445	445	9.7	9.83	
10		1625		2345	440	440	3.6	3.69	
11		2350	11-9-53	1320	810	810	3.0	1.67	
12	11-9-53	1320		2230	550	550	3.9	3.20	
13		2230	11-10-53	0855	625	625	2.1	1.53	
14	11-10-53	0855		1535	400	400	4.0	4.51	
15		1535		2315	460	460	2.6	2.57	
16		2316	11-11-53	1110	714	714	7.4	4.68	
17	11-11-53	1112		2228	676	676	28.0	18.7	
18		2234	11-12-53	1015	641	641	2.9	2.02	
19	11-12-53	1021	11-13-53	0950	1409	1409	16.0	5.09	
20	11-13-53	0950	11-14-53	0910	1400	1400	3.4	1.08	
21	11-14-53	0918	11-15-53	0913	1435	1435	5.0	1.58	
22	11-15-53	0921	11-16-53	1005	1484	1484	3.0	0.90	
23	11-16-53	1005	11-17-53	1010	1445	1445	2.4	0.77	
24	11-17-53	1017	11-18-53	0950	1413	1413	2.2	0.72	
25	11-18-53	0954	11-19-53	1035	1481	1481	3.4	1.04	
26	11-19-53	1040	11-20-53	0938	1378	1378	8.3	2.70	
27	11-20-53	0940	11-21-53	0840	1380	1380	7.3	2.39	
28	11-21-53	0840	11-22-53	0852	1452	1452	4.8	1.49	
29	11-22-53	0854	11-23-53	1015	1521	1521	1.6	0.49	
30	11-23-53	1015	11-24-53	0940	1405	1405	1.6	0.49	
31	11-24-53	0940	11-25-53	0915	1415	1415	0.61	0.18	
Total						28,348	212.3	3.4	

Total gaseous I¹³¹ activity collected at 1 l/min.: 9.6 uc.
Total gaseous I¹³¹ discharged by stack (120,000 ft³/min.): 33 curies.

*See Footnote 4.

S [redacted]

Total 28 348 min

Table V shows data on millipore filter samples which were used in series with and following the bubbler. As the tables show, the activity measured on the filters was only 3 to 10% of that measured in the corresponding bubbler samples, confirming that the activity was present largely in the gaseous state. As would be expected, decay studies on 8 of the filters and absorption studies on 5 of the same filters indicated that a large proportion of the activity on the filters was iodine 131. Autoradiograms showed mostly diffuse background with a few discernable particles.

Results obtained with a flow ion chamber are given in Appendix I.

Process Building

Autoradiograms of eight millipore filter samples taken during the last three days of the first run showed an average of 418 active particles per 1000 ft³.

Autoradiograms of 26 of the 31 samples taken during the entire second run showed an average of 177 particles per 1000 ft³. The maximum value obtained for an 8 hour period was 2600 particles per 1000 ft³. These figures exclude the most active sample, which gave a heavy diffuse blackening of the film and prevented the resolution of individual particles. Decay studies on five samples and absorption studies on two of these samples indicated a mixture of beta activities. Decay and absorption studies on two cascade impactor samples confirmed this. Autoradiograms of the cascade impactor slides again gave little information, due primarily to the large amount of inert particulate matter present. Due to the low

TABLE V

STACK MILLIPORE FILTERS

SAMPLING AND COUNTING DATA

RUN #54

Sample Number**	ON		OFF		Sampling Time (min.)	Volume Sampled (liters)	Counting Date	10^4 d/m**	10^{-9} uc/cc
	Date	Time	Date	Time					
SMF-18	11-11-53	2234	11-12-53	1015	641	641	11-13-53	0.85	5.95
19	11-12-53	1021	11-13-53	0950	1409	1409	11-16-53	6.76	21.60
20	11-13-53	0950	11-14-53	0910	Ruptured				
21	11-14-53	0918	11-15-53	0913	1435	1435		2.67	8.39
22	11-15-53	0921	11-16-53	1005	1484	1484		1.77	5.35
23	11-16-53	1005	11-17-53	1010	1445	1445	11-18-53	0.82	2.57
24	11-17-53	1017	11-18-53	0950	1413	1413		0.96	3.06
25	11-18-53	0954	11-19-53	1035	1481	1481	11-19-53	2.83	8.60
26	11-19-53	1040	11-20-53	0938	1378	1378	11-23-53	5.85	19.15
27	11-20-53	0940	11-21-53	0840	1380	1380		6.18	20.20
28	11-21-53	0840	11-22-53	0832	1452	1452		3.05	9.46
29	11-22-53	0854	11-23-53	1015	1521	1521		1.63	4.82
30	11-23-53	1015	11-24-53	0940	1405	1405	11-24-53	1.08	3.47
31	11-24-53	0940	11-25-53	0915	1415	1415	11-25-53	0.20	0.63

* No filter was used with the first seventeen bubbler samples.
 *** Corrected to collection time on basis of all activity being I131.

Handwritten notes:
 28318 m...
 82713-9
 120000
 28318 m...
 H.B. =

flow rate through the bubblers, insufficient activity was collected to permit absorption, decay or radiochemical analyses.

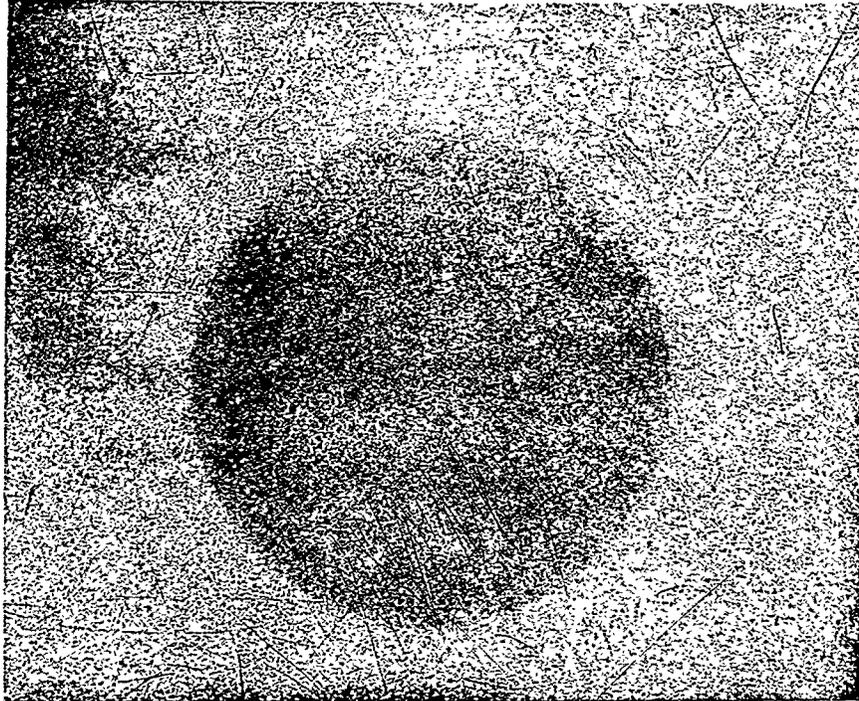
Process Liquid Waste Storage Tank (W-9)

In the second run, autoradiograms of eight of the thirty-one millipore filters showed heavy diffuse blackening which prevented resolution of individual particles. Typical autoradiograms are shown in Figure 10. Decay studies of the six filter samples which were taken before the first wastes were jetted to the tank show half-lives greater than 136 days. Absorption studies of the same samples indicated that a large portion of the contamination consisted of isotopes having maximum beta ray energies of 0.35 Mev and 3 Mev. Decay studies of 7 additional filter samples taken during various parts of the run indicated initial half-lives of from 8 1/2 to 22 days with half-lives of 21 1/2 to 58 days approximately one month after collection. Absorption studies of these samples showed mixtures of beta energies with some as high as 3 Mev.

Results of radiochemical analyses are shown in Tables VI & VII. Decay and absorption studies were made on some of the elements separated during the radiochemical analyses. The barium isotope present was largely barium 140; zirconium, Zr⁹⁵, strontium, Sr⁸⁹, and tellurium, Te¹²⁹. The first 18 bubbler samples were checked for alpha activity. No activity above background was detectable.

From Table III it may be seen that the average activity obtained from bubbler data was only about 10% of that obtained from millipore filter data, indicating that the major portion of the activity escaping the W-9 tank was in particulate form.

FIG. 10.



AUTORADIOGRAM OF W9MF 4
ONE HOUR EXPOSURE
11-10-53



AUTORADIOGRAM OF W9MF 10
24 HOUR EXPOSURE
12-9-53 to 12-10-53

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TABLE VI
WASTE TANK MILLIPORE FILTER SAMPLES

RADIOCHEMICAL DATA

RUN #54

Sample Number	Date of Analysis	Percent of Gross Beta*												
		TRF**	Ru	Sr	Ba	Zr	Nb	Te	I	Np	Cs			
W9MF- 4	11-23-53	54***	6	24	0.5	2	1.5	50	2	12				
7	11-17-53	20	4	8	0.5	9	1	50	13	13	2.5			
8	11-12-53	45	2	39	1	6	0.5		2.5	17.5				
12	11-12-53	48	4	8	2.5	7	0.5		6	7				
13	11-12-53	58	4.5	12.5	2	7	0.5		7	17				
14	11-12-53	55	4	13	2	7	0.5		17	1				
15	11-12-53	54	4	12.5	2	7	0.5		1	1				
18	11-20-53	64	2.5	9	1.5	10	1	3.5	3.5	1				
19	11-20-53	65	2.5	10	2.5	10	1	2.5	2.5	1				
23	11-20-53	44	0.05	16	36	0.27	0.02	0.02	0.02	0.05				
24	11-20-53	56	2	18.5	11	6	1	1	10	10				
26	11-30-53	41	3.5	11	17.5	2.5	1.5	13	2	2				
27	11-30-53	64	3	12	3.5	12.5	1	2.5	2	1.5				
28	11-30-53	64	3	13	0.5	10.5	1	5.5	1.5	1.5				
29	11-30-53	60	1.5	19		4	1	4	5	5				
30	11-30-53	48	1	18.5	17.5	3	0.5	2	0.5	0.5				

* At time of analysis

** Total Rare Earths

*** Cerium 20%, Others 34%

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TABLE VII

WASTE TANK BUBBLER SAMPLES

RADIOCHEMICAL DATA

RUN #54

Sample Group	Analysis Date	Percent of Gross Beta*								
		Ru	I	Te	TRE	Sr	Zr	Nb	Ba	
W9B 1-5	11-18-53		17							
6-10	11-18-53	4	12	16	15	41				
11-15	11-18-53	5	32	13	20	26				
16-20	11-18-53	3	6							
21-25	11-30-53	0.5	1	2	43	21	1	0.5	31	
26-31	11-30-53	4	6	9	38	17	3	2	21	

* At time of analysis

Laboratory Air Sampling Stations

During the first run, 25 millipore samples were taken at each of 4 continuous air monitor stations (HP-3, 4, 7, 9 shown in Figure 3). These were collected concurrently with the regular CAM samples taken on H and V Number 70 paper so as to permit correlation of the data from the two types of samplers. Particulate data obtained from autoradiograms on both types of samples are shown in Table VII. In general, the activity was too low for identification of the elements present but the three samples measured had half-lives of 18 to 20 days. In Figure 11 is a plot of the particulates and activity per 1000 ft³ of air sampled by the 10 continuous air monitors beginning three days before the start of the second run and ending four days after the end of the run.

DISCUSSION

Since samples of the stack gas showed that over 90% of the activity was collected by bubblers in the bubbler-millipore filter sampling combination, most of the collected activity was gaseous, rather than particulate. The average activity in the stack, as shown by the samplers, was 3.4×10^{-7} $\mu\text{c}/\text{cc}$ (Table IV). As previously stated, this activity was largely iodine 131. However, the flow ionization chamber gave results of a different order of magnitude, Appendix I. The flow ionization chamber has been calibrated only for sulfur 35; however, it is estimated that the calibration should hold to within a factor of 5, at least, for any isotope likely to be present in the stack. As shown in Appendix I, the flow ionization chamber

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TABLE VIII

COMPARISON OF NUMBER OF RADIPARTICULATES COLLECTED

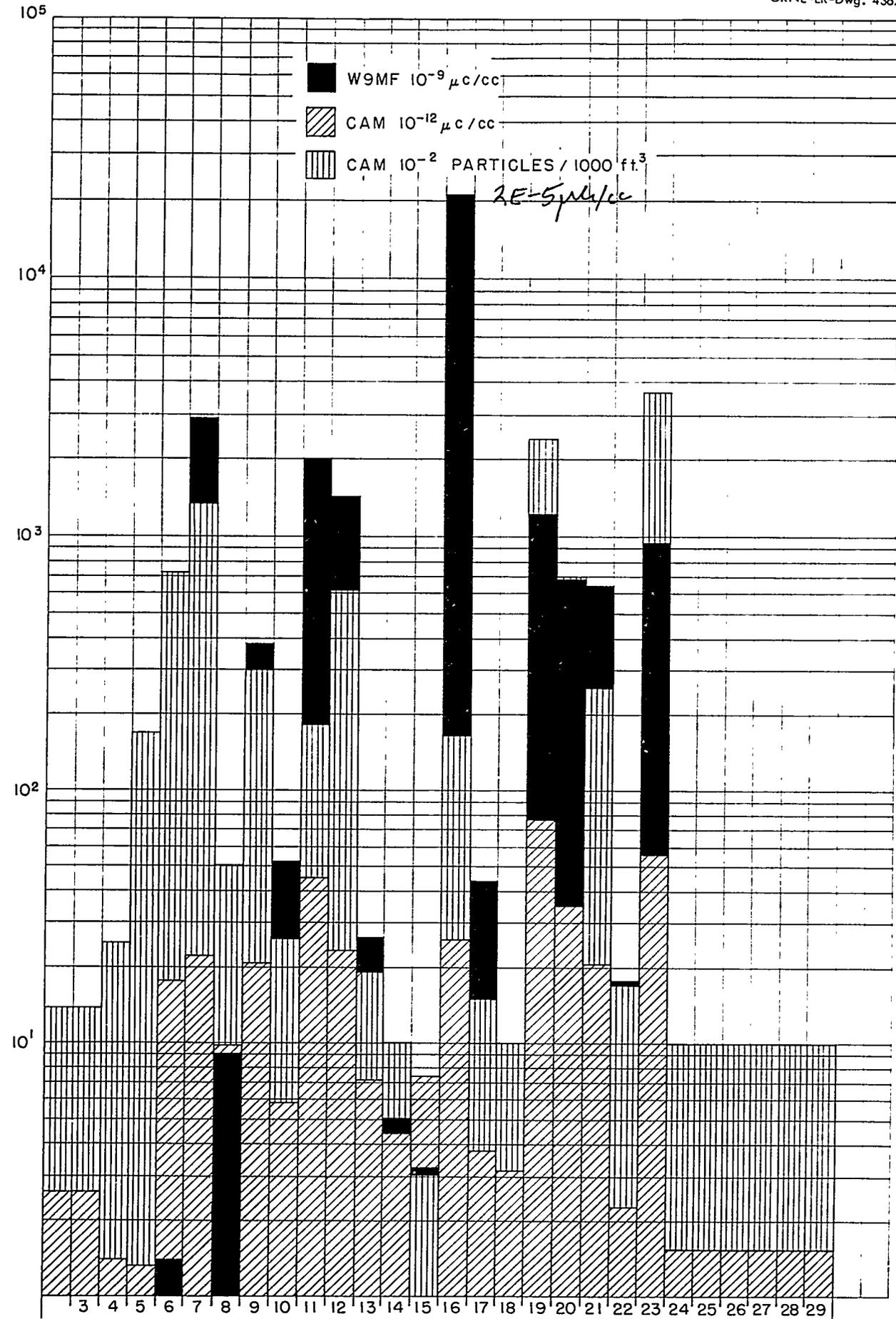
BY CONTINUOUS AIR MONITORS (C.A.M.) AND MILLIPORE

FILTER SAMPLES (M. F.)

PARTICLES/1000 ft³

RUN #52

Sampling Period	Location H. P. No.	C.A.M.		M.F.	
		Filter-H. V. No. 70 Air Flow-5 cfm		Filter-Millipore Type AA Air Flow-30 l/m	
1 0235-1718 5/24	3	29.4		20.9	
	4	2.7		36.3	
	7	22.2		40.1	
	9	16.2		233.1	
2 1718-0222 5/24-5/25	3	16.5		6.8	
	4	12.7		17.5	
	7	15.5		20.7	
	9	6.8		14.1	
3 0222-0605 5/25	3	3.7		0.0	
	4	4.6		10.8	
	7	3.4		27.2	
	9	3.4		0.0	
4 0605-1413 5/25-5/29	3	8.0		35.8	
	4	15.0		38.9	
	7	12.6		52.5	
	9	3.9		33.5	
5 1413-1008 5/29-6/1	3	5.5		57.6	
	4	6.8		33.8	
	7	9.1			
	9	9.5			



0900
11-2-53

CORRELATION OF WASTE TANK DATA
AND CONTINUOUS AIR MONITOR DATA

0900
11-30-53

Fig. 11

indicated an average concentration of about 10^{-3} $\mu\text{c}/\text{cc}$ in the stack line. The very high activity shown by the ionization chamber must have been due to krypton and xenon, since all other elements would have been collected by the bubbler or millipore filter. This view seems reasonable, since it is not to be expected that large quantities of the non-volatile fission product elements would escape the RaLa reacting vessel, and iodine and bromine are removed by a caustic scrubber.

The presence of about 10^{-3} $\mu\text{c}/\text{cc}$ of krypton and xenon in the stack, as well as 3.4×10^{-7} $\mu\text{c}/\text{cc}$ of collectable activity, mainly iodine 131, is not considered to be a serious hazard. The minimum ground level dilution factor⁵ which would be expected from the RaLa stack is approximately 1000. This corresponds to a maximum ground concentration, for the period of the run, of about 10^{-6} $\mu\text{c}/\text{cc}$ of xenon and krypton and about 3×10^{-10} $\mu\text{c}/\text{cc}$ of iodine. These values are less than maximum permissible concentration values given in Handbook 52.⁶ However, during part of the run, the concentration of krypton and xenon in the stack was much higher than the average value (Appendix I). This means, for short periods of time, that the MPC for krypton and xenon may have been exceeded at ground level.

Since the off-gas line and cell ventilation line are discharged to the atmosphere through a common stack, the sum of the collectable

⁵ Calculated from the maximum ground concentration curves prepared from Sutton's equation by the Oak Ridge Branch of the U. S. Weather Bureau.

⁶ Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentration in Air and Water, Handbook 52, U.S. Dept. of Commerce, NBS, March 20, 1953.

activity discharged by the two lines should equal the total collectable activity discharged by the stack. Results of the off-gas sampling indicated 15 curies discharged to the stack in the second RaLa run; cell ventilation line data showed one curie discharged to the stack. However, the stack sampling data showed 33 curies, mainly iodine 131, discharged to the atmosphere. This discrepancy was very likely due to an under-estimation of the flow in the off-gas duct.

The flow ionization chamber was found to be valuable for indicating the presence of krypton and xenon. The instrument seems well adapted for detecting, instantaneously, short bursts of activity in the stack, and will also detect relatively low activities (about 10^{-6} to 10^{-7} $\mu\text{c}/\text{cc}$). Both gases and particulates are detected. Little or no trouble was experienced due to contamination of the ionization chamber.

Correlation between process operations and numbers of particles found in cell ventilation, off-gas, and stack samples as indicated by autoradiograms showed jetting and sparging⁷ to be the two most consistent particle producing processes.

The particle concentration in the process building during the first run was found to be more than 3 times that of the stack effluent during the 30 hour period of simultaneous sampling. This does not necessarily mean that the process building contributes more to the general atmospheric particulate

⁷ Jetting is the name applied to the transfer from one vessel to another by the use of air or steam under pressure. Sparging is the process of agitating a solution by an air or steam jet.

contamination than the stack since the stack effluent is discharged to the atmosphere at the rate of approximately 120,000 ft³/min. In the process building during the second run, the maximum mixed fission product activity, averaged over a period of 23 hours, reached a value 1.5 times the maximum permissible concentration.⁸ The average in the building for the entire run was approximately one tenth of MPC.

In general, the millipore filter samples showed more particles than the simultaneous CAM samples, (H & V No. 70 filter paper). The difference in particle count between the two types of samples is most likely due to two things; the nature of the filters, and the particle counting technique. Particles collected on millipore filters remain very close to the surface and hence will be in closer contact with the emulsion and produce much sharper spots than particles collected on H & V No. 70 filters. Also the millipore filter autoradiograms were examined under a low power microscope while the CAM filters were counted with the unaided eye.

No correlation was found between the stack activity and the response of the CAMS on the Laboratory area in either run. However, a good correlation was found between the emission of activity from W-9 tank and the CAM data. This is shown in Figure 11. There were 9 days during which the activity near the vent in the W-9 tank was greater than 10⁻⁷ μ c/cc and in each case both the airborne activity and particle

⁸ The MPC used was 10⁻⁸ μ c/cc as given for unknown mixtures of beta-gamma activity: "Recommended Operating Levels for the Control of Personnel Exposure", ORNL, January 1, 1954.

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-31-

count as indicated by the average of the ten CAMS was high (10^{-11} $\mu\text{c}/\text{cc}$ and 1 particle/1000 ft^3). During this period there were only two days when the particle count on the CAMS was high while the activity at W-9 was low. On only one day out of the 18 did the CAM activity and particle count fail to rise and fall in unison with the activity emanating from the waste tank, and waste tank activity was always much higher than CAM activity. This indicates that the W-9 tank was the major, though not the only, source of Laboratory area atmospheric contamination during this RaLa run.

CONCLUSIONS

1. In spite of corrective measures taken in 1949 and 1950 to reduce air contamination from the RaLa process, this process was found to be the major contributor to Laboratory area contamination during the November 1953 run ("second run" of this report).
2. (a) The process liquid waste storage tank, and not the process stack, was the major source of air contamination from the RaLa process during this period.
(b) The RaLa jetting and sparging operations were the most consistent particle producing processes.
(c) The particle concentration in the process building during the first run was found to be higher than the particle concentration in the stack effluent. However, during the second run, the average mixed fission product activity was less than the MPC value.

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3. (a) The activity level of krypton and xenon discharged by the stack was about 10^{-3} $\mu\text{c}/\text{cc}$, averaged over the entire second run, corresponding to a total emission of about 10^5 curies. In addition, about 30 curies of other isotopes, mainly gaseous iodine 131, were discharged. However, it was calculated that the discharge of this activity did not result in an average ground concentration exceeding the MPC for those isotopes.

(b) Mixed fission product activity near the vent in the liquid waste storage tank was about 2×10^{-6} $\mu\text{c}/\text{cc}$, averaged over the entire second run. Most of this activity was in the form of particulates.
4. The present continuous air monitoring method used at the Laboratory does not detect all particles present, as shown by the higher particle counts obtained with millipore filters.
5. The flow ionization chamber is valuable for the detection of krypton and xenon, and is well adapted for monitoring where krypton and xenon may be present.

RECOMMENDATIONS

It was recommended that a filter be installed on the process liquid waste storage tank, and that tests be made to determine the reduction in air contamination. This was done, and the results are contained in the memorandum in Appendix III.

ACKNOWLEDGMENTS

The U. S. Weather Bureau, ORO, under the direction of R. F. Myers cooperated wholeheartedly in this study. Especially were they helpful in the collection and correlation of data with weather conditions at time of sampling.

Continuous Air Monitor data was supplied by the Area Monitoring Group under the direction of H. H. Abee.

Decay, adsorption and gamma ray spectrograph studies on the first run were made by E. C. Long and co-workers of the Y-12 Health Physics Department. Autoradiograms were made by the Autoradiography Section of the same department.

APPENDIX I

Heated Flow Ionization Chamber as a Stack Monitor

At the present time, gaseous effluent from the ORNL graphite reactor is continuously monitored for argon 41 by a flow ionization chamber. There is no continuous monitor installed on the RaLa process stack. Since a continuous type monitor is highly desirable, the applicability of a flow ionization chamber previously developed⁹ was investigated.

The stack effluent was monitored by passing an aliquot at 32 liters per minute through 2 one liter ionization chambers in series. The first chamber served as an ion trap. The ion current of the second chamber was read by a vibrating reed electrometer and recorded on a strip chart recorder. The electrometer head, containing high value resistors, was placed in a closed box partially filled with Drierite to minimize humidity effects. Provision was made for taking background readings on the second chamber by drawing filtered air through the chamber. Both chambers were operated at a potential of 300 volts. A heating mantle was placed over the second chamber so that the top and sides of the chamber were operated at an elevated temperature, approximately 100°C .

The vibrating reed electrometer used to measure the ionization current was set so that full scale deflection (100 divisions) of the recorder corresponded to an ion current of approximately 10^{-10} amperes.

⁹ R. L. Quinn, August 1, 1951.
"A Flow Type Ionization Chamber for Measurement of Activity in Low Energy Beta Emitting Gases", ORNL Y-791.

The recorded data began at approximately 1700 on November 7, 1953 and continued through 1000 on November 25, 1953 with the loss of approximately 43 hours data during this interval.

A total of 19 background readings was taken varying from a minimum of one recorder scale division (10^{-12} amp.) to a maximum of 4 divisions with the average being less than 2 divisions. Recorder readings were averaged over half-hour intervals, background readings subtracted, and the data plotted in Figure 12. These average readings varied from zero to greater than 100 recorder scale divisions. The average recorder reading (after subtraction of background) for the 386 hours of data was approximately 6×10^{-12} amp. If the isotope present had been sulfur 35, this corresponds to an activity level of 10^{-3} $\mu\text{c}/\text{cc}$ in the stack.¹⁰

There were four peaks of activity which built up sharply and dropped off exponentially with a half-time of $1\frac{1}{2}$ to 2 hours. A background reading was taken during one of these peaks which proved that this exponential fall-off was real and not due to decay of contamination on the chamber walls.

The data obtained with the heated flow-type ionization chamber indicates that it is satisfactory for indicating the general level of activity in the isotope area stack during a RaLa run. Contamination of the chamber walls was not found to be a major problem, though it is not

¹⁰ Thomas, J. W., and R. L. Quinn, "Calibration of a Flow-Type Ionization Chamber with Radioactive Sulfur Dioxide", Y-793, August 20, 1951.

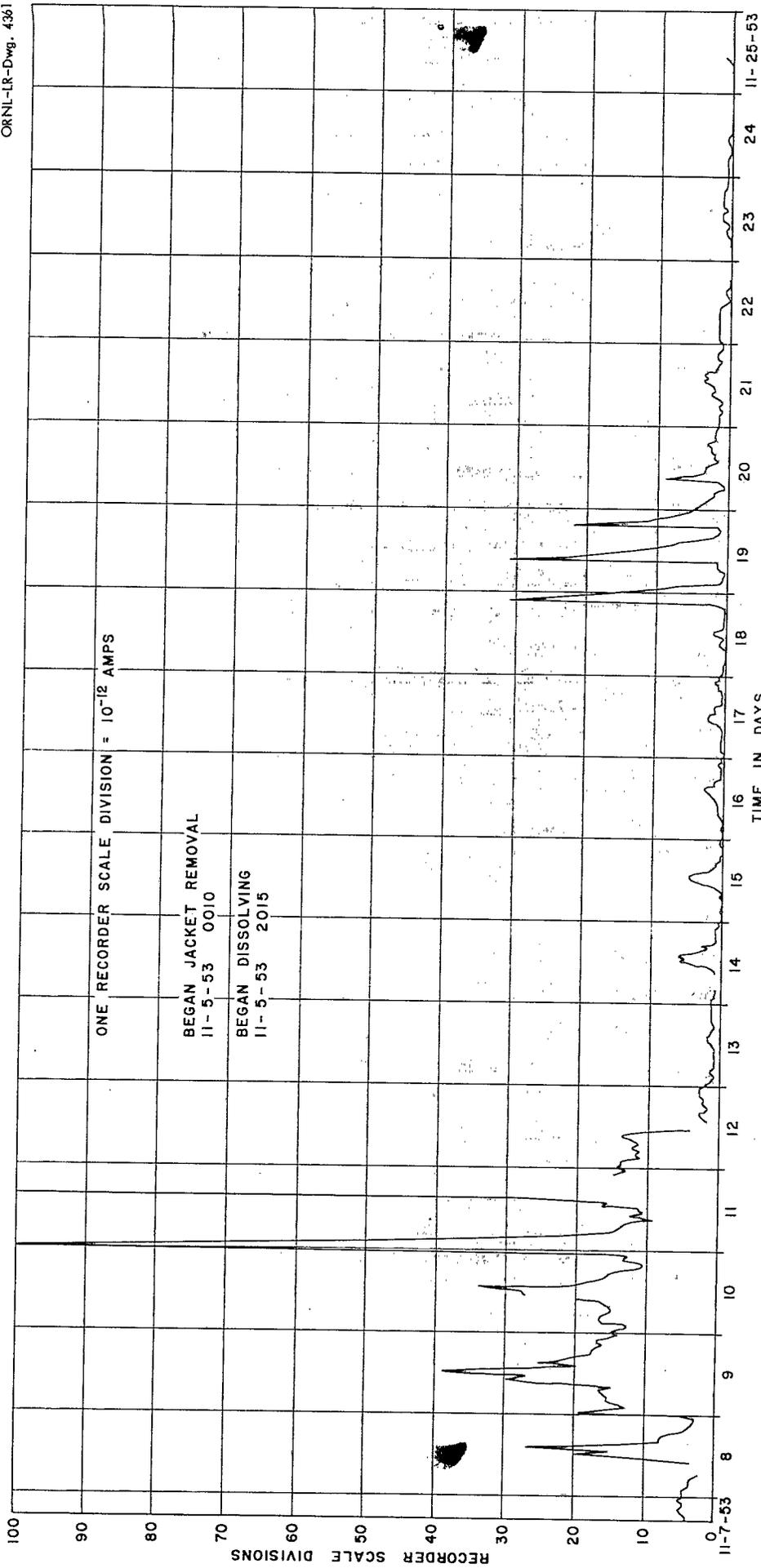


FIGURE 12. STACK ACTIVITY AS INDICATED BY FLOW-TYPE IONIZATION CHAMBER

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-11-

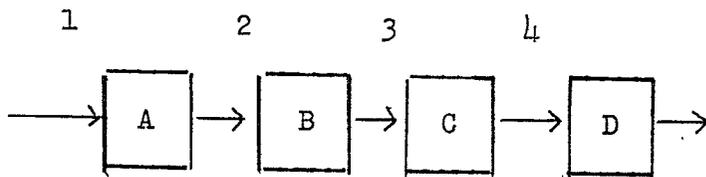
known to what extent heating of the walls helped reduce the contamination.

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APPENDIX II

Determination of the Relative Proportions of Gaseous and Particulate Iodine

Expressions may be derived which give the efficiencies of a bubbler for particulates and gases and the relative amounts of each present in a gas stream with 3 identical bubblers connected in series with a millipore filter as a fourth stage. The derivation is given below:



A, B, and C denote the bubblers and the activity collected in the corresponding bubblers.

D denotes the millipore filter and the activity collected on the filter.

1, 2, 3, and 4 denote the activity transmitted from one stage to the next.

P denotes total particulate activity.

G denotes total gaseous activity.

a denotes fractional efficiency of bubblers for particles.

b denotes fractional efficiency of bubblers for gases.

g denotes fractional efficiency of millipore filter for gases.

f denotes fractional efficiency of millipore filter for particles.

Considering first the particulate activity:

<u>Point</u>	<u>Holdup</u>	<u>Transmittance</u>
1		P
A	aP	
2		P(1 - a)
B	aP(1 - a)	
3		P(1 - a) ²
C	aP(1 - a) ²	
4		P(1 - a) ³
D	fP(1 - a) ³	

An identical analysis will hold for gases, and the activity collected in a given collector will be the sum of the gaseous and particulate activities.

Therefore:

$$A = aP + bG$$

$$B = aP(1 - a) + bG(1 - b)$$

$$C = aP(1 - a)^2 + bG(1 - b)^2$$

$$D = fP(1 - a)^3 + gG(1 - b)^3$$

Since the bubblers are better than 99% efficient for gaseous iodine at the flow rate used in sampling (approximately one liter per minute) and the efficiency for particulates would be expected to be much less, the assumption is made that $(1 - b)^2 \ll (1 - a)^2$ and the $(1 - b)^2$ and $(1 - b)^3$ terms are dropped. Since the millipore filter has been shown to be better

than 99.99% efficient for an aerosol of 0.3 u mass median diameter,
f is taken as unity.

This then gives:

$$\begin{aligned} A &= aP + bG \\ B &= aP(1 - a) + bG(1 - b) \\ C &= aP(1 - a)^2 \\ D &= P(1 - a)^3 \end{aligned}$$

The above equations are then solved and give:

$$\begin{aligned} a &= \frac{C}{C + D} \\ P &= \frac{(C + D)^3}{D^2} \\ b &= \frac{Pa^2 - A + B}{Pa - A} \\ G &= \frac{A - aP}{b} \end{aligned}$$

1
G should also equal
(A + B + C + D) - P

With 3 bubblers in series without a fourth stage, the particulate efficiency and relative amounts of particulates and gases may be determined if the first bubbler is assumed 100% efficient for gases. The equations then become:

$$\begin{aligned} A &= aP + G \\ B &= aP(1 - a) \\ C &= aP(1 - a)^2 \end{aligned}$$

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Giving:

$$a = \frac{B - C}{B}$$
$$P = \frac{B^3}{C(B - C)}$$

2

The above equations are strictly valid only when the particles present are all of the same size; however, it is believed that this analysis will give a fair approximation for the mixed particle sizes which were actually present.

The results of the series of experiments is given in Figure 13. It is believed that the results of experiment 1 are in error due to mechanical carry-over of the absorbing solution.

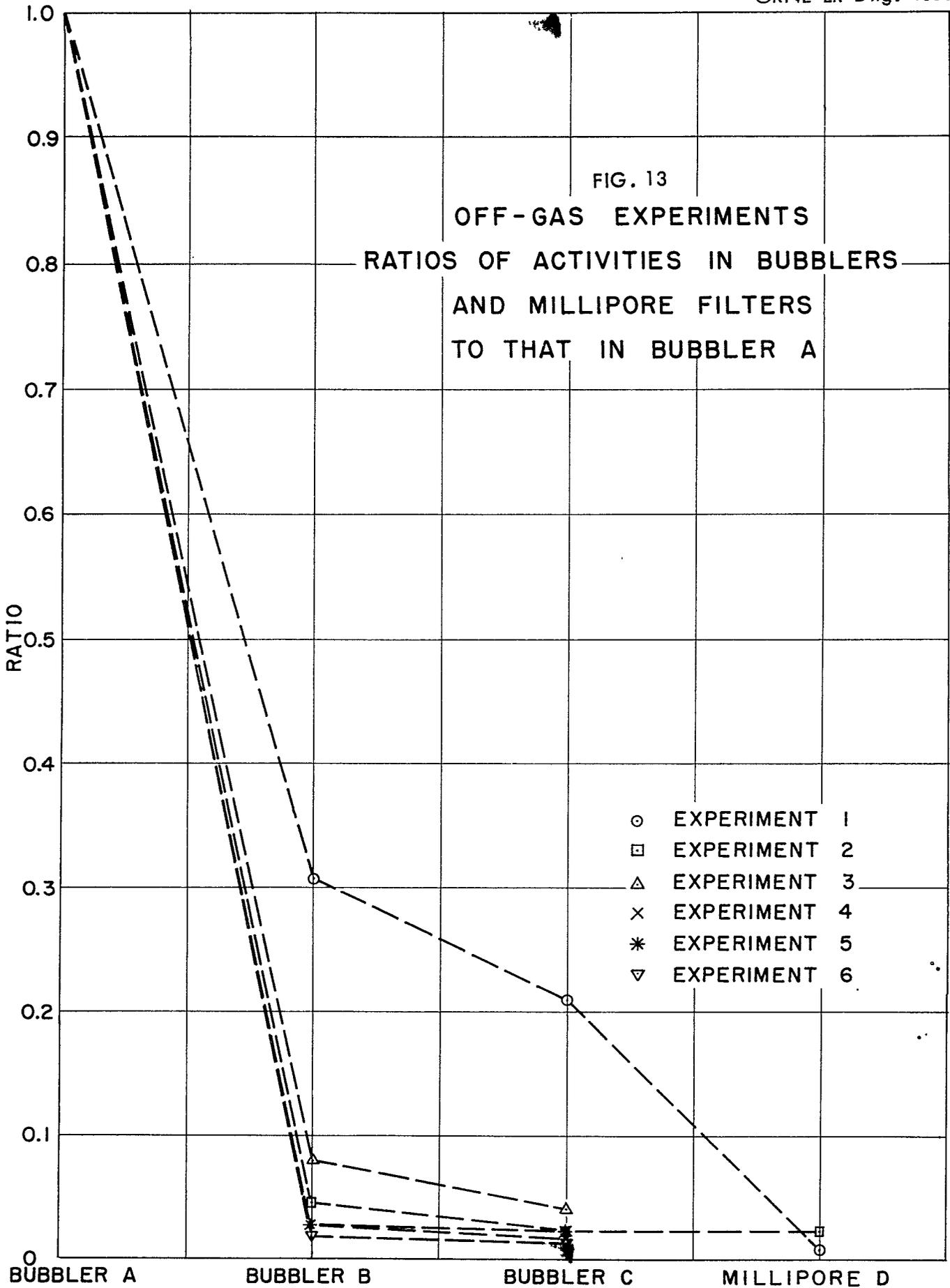
Using equations 1, the measured activities in the bubblers and millipore filter (A, B, C, and D) in the second experimental off-gas sample yield 51% as the average efficiency of the bubblers for the particulates present in the off-gas during the collection of this sample and 17% as the percentage of total activity due to these particulates. Bubbler efficiency for the gases present during the collection period was 100% as calculated from the data.

Using the assumption that the bubblers are 100% efficient for the gases present (Equations 2), particulate efficiency of the bubblers and particulate percentage of total activity were calculated from the last four off-gas experimental samples. Calculated efficiencies ranged from 18 to 50% and particulate percentages of total activity ranged from 7 to 28%.

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FIG. 13

OFF-GAS EXPERIMENTS
RATIOS OF ACTIVITIES IN BUBBLERS
AND MILLIPORE FILTERS
TO THAT IN BUBBLER A



APPENDIX III

To: J. C. Hart-A. D. Warden
From: H. H. Abee

September 13, 1954

Study of Air Activity at W-9 Tank During RaLa Run #57

Just prior to RaLa Run #57, the Area Monitoring and General Surveys Section set up air sampling equipment at W-9 tank in order to measure the air activity escaping through a fiberglass filter placed in the tank vent during the run.

Previous work by Bradshaw and Cottrell during the RaLa Run #54 indicated that W-9 tank was a contributing factor to the air activity measured during the run. Hence, it was recommended that a fiberglass filter be placed in the vent of W-9 tank.

Equipment

The equipment consisted of the following:

1. Fiberglass filter - six layers of fiberglass (FG-50) sandwiched between stainless wire mesh on either side of a stainless cylindrical case. The filter design followed recommendations by Cottrell and Thomas.
2. PDS type pump.
3. Millipore filter sampler.
4. Bubbler sampler - contained 25 ml of Sodium Thiosulfate.
5. Ring stand and clamps.

Equipment Arrangement

The fiberglass filter was placed in the vent of W-9 tank and the edges sealed with a non-hardening mastic. Other openings into the tank were also sealed except for a small clearance around the rod of the liquid level

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-48-

indicator protruding from the tank.

The millipore filter sampler and the bubbler sampler were connected in parallel to the pump, attached to the ring stand and placed approximately 18 inches from the tank vent.

Procedure

Sampling was started on July 16, 1954. Filters and bubblers were changed on a 24 hour schedule during the run except for the first day. The flow rate through the bubbler was adjusted to 1 liter per minute, the remainder of the air flow pulled by the pump going through the millipore filter. This varied from 15 liters/min for the first four days to approximately 30 liters/min for the remaining six days. The difference in flow rate resulted from a change in pumps after the fourth day.

Filters on the ten outside constant air monitors (CAM) were changed each day at approximately the same time as the W-9 samples for the purpose of correlating plant wide air activity with local conditions.

All filters were counted for gross beta activity and the average air activity in $\mu\text{c}/\text{cc}$ determined for a given sampling period.

Autoradiograms were made of all filters to determine the number of radioactive particles collected. Spots appearing on the films were counted and the average number of particles/1000 ft^3 , calculated.

Tabulation and Analysis of Data

Table I presents the data obtained from the millipore filter samples taken at W-9 tank.

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TABLE I

W-9 WASTE TANK MILLIPORE SAMPLES

Sample Number	From	To	Sample Activity 10 ⁻⁴ μ c	Sampling Time Hours	Air Flow l/min	Average Conc. 10 ⁻¹¹ μ c/cc	Number Particles	Particles Per 1000 ft ³
MF-1	7-16-54	7-17-54	.77	17.5	15	.5	59	106
MF-2	7-17-54	7-18-54	6.57	24	15	3.0	185	242
MF-3*	7-18-54	7-19-54	47000	24	15	21850.0	373-	490

MF-4	7-19-54	7-20-54	72.4	24	15	33.5	1	1.3
MF-5*	7-20-54	7-21-54	144	24	29.2	34.2	97	65.3
MF-6	7-21-54	7-22-54	8.96	24	29.8	2.1	72	47.5
MF-7*	7-22-54	7-23-54	13.9	24	29.8	3.2	240	158
MF-8	7-23-54	7-26-54	288	72	29.8	22.4	25	5.5

Samples changed at approximately 9:00 a.m. each day.

* Wastes jetted from RaLa to W-9 tank during this period.

*** Rod of liquid level indicator sealed off for remainder of run.

For the ten day period studied during RaLa Run #57, the average air concentration at W-9 tank was found to be 2.74×10^{-8} $\mu\text{c}/\text{cc}$ with the maximum daily average concentration reaching 2.18×10^{-7} $\mu\text{c}/\text{cc}$. A comparison of this data with that obtained by Bradshaw and Cottrell during RaLa Run #54 with no filter in W-9 tank vent indicates a reduction, on the order of 100, in air activity near W-9 tank.

It should be noted that after sample MF-3 was taken, the clearance around the rod of the liquid level indicator was sealed off with mastic. The amount of the air activity was reduced during and following jettings to such an extent that indications are, had this been done at the start of the study, the results would have shown a reduction of air activity on the order of 10^4 times that measured by Bradshaw and Cottrell.

Table II gives the correlation of the W-9 filter data and the CAM data.

The correlation of the data is not good. In general, however, when the millipore data went up or down, the CAM did likewise. The 24 hour period ending July 18, 1954 and the 24 hour period ending July 19, 1954 are the exceptions.

Table III compares average plant wide particulate activity during RaLa Runs for the past two years with that of Run #57.

It may be of interest to note that this was the only run during which the average particle count fell below 1 particle/1000 ft^3 of air sampled.

The bubbler samplers did not collect sufficient activity during the period of sampling to be of significance.

TABLE II

CORRELATION OF WASTE TANK DATA AND CAM DATA

DATE		CAM*	W-9	CAM*	W-9
From	To	Particles Per 1000 ft ³	Particles Per 1000 ft ³	10 ⁻¹³ µc/cc	10 ⁻¹¹ µc/cc
7-16-54	7-17-54	1.25	106.0	7.8	.5
7-17-54	7-18-54	.42	242.0	25.9	3.0
7-18-54	7-19-54	.68	490.0	18.2	21850
7-19-54	7-20-54	.28	1.3	16.4	33.5
7-20-54	7-21-54	.78	65.3	18.0	34.2
7-21-54	7-22-54	.14	47.5	5.5	2.1
7-22-54	7-23-54	1.40	158.0	10.4	3.2
7-23-54	7-26-54	.78	5.5	13.0	22.4
Average		.71	139.4	14.4	2744

*Average of all ten Constant Air Monitors.

TABLE III

PAST RALA RUN PARTICULATE ACTIVITY

Year	Run Number	CAM Particles Per 1000 ft ³
1952	46	5.57
	47	27.26
	48	8.92
	49	5.27
	50	3.66
	51	5.06
1953	52	8.24
	53	6.60
	54	5.18
1954	55	5.31
	56	3.37
	57	3.04
		.71

Conclusions

The information obtained from the study during this one RaLa Run seems to indicate that the installation of the fiber glass filter in W-9 tank vent was effective in reducing air contamination from this source. The trend of the data obtained would seem to be justifiable grounds for a similar study during a future RaLa Run for confirmation of results. If results are confirmed, installation of similar filters in other tank vents where sparging and jetting are frequent should be recommended.

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